Quality control and productivity improvement

Evolution of MONOZUKURI

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ATAC (Advanced Technologist Activation Center)

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Know-how of MONOZUKURI at Japanese Manufacture

- The symbolizing manufacturing company of Japan is Toyota. The philosophy and system of car manufacturing spread world-wide, and has been applied in many companies.
- Toyota is founded in 1937, and now is producing over 10 million cars in every year.
- Toyota has 51 factories in 28 countries and has 360 thousand employees in the world.
- Automobile industries consist of pyramid structure, and totally 5.5 million people are working and accounts for all industrial 20% in Japan.
- The export of the car accounts for 15 trillion yen, 20% of the whole Japanese export.

Automobile industry produces huge employment

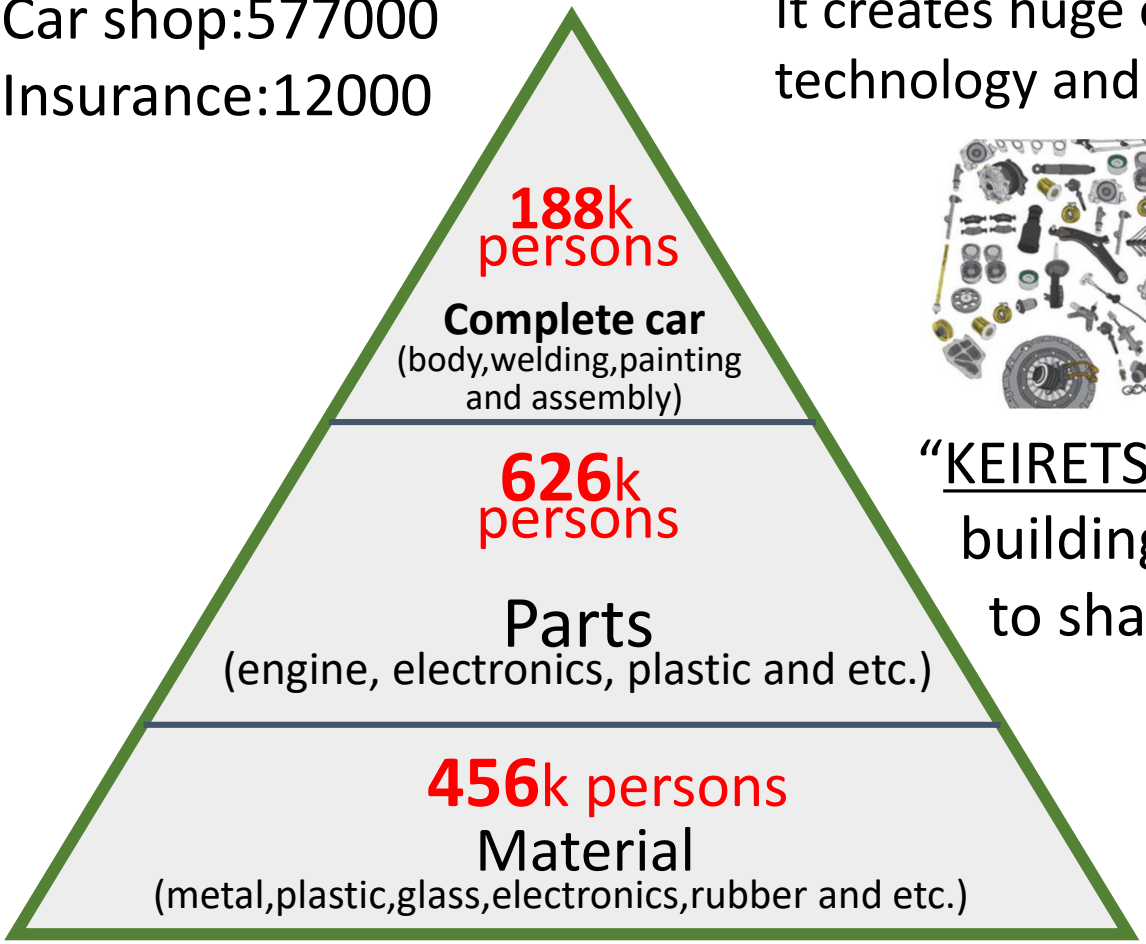
Allied service

Gas station:336000

Maintenance:264000

Car shop:577000

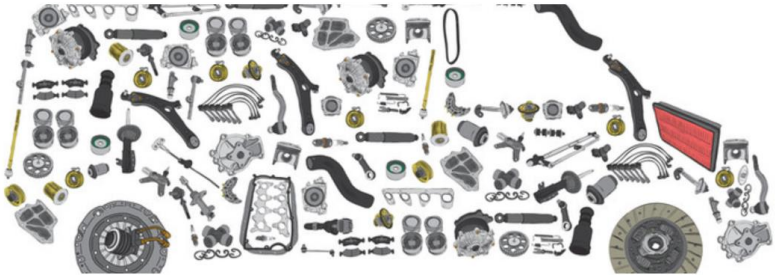
Insurance:12000



Total 5.5M persons,10 percent in Japan.

Car is assembled by 30,000 pcs of parts, and related industry are many.

It creates huge employment and their technology and skill are enhanced.



"KEIRETSU" means a company group building business and capital ties to share stocks each other.

- In today's lecture, I ‘d explain Toyota production system(TPS) at first, and technology of industrial robots which greatly contributed to car manufacturing.
- Massachusetts Institute of Technology(MIT) analyzed Toyota production system from the 1980s, and led the result to the global standards as “Lean Production System”.(LPS).
- TPS is the production system which evolved for a long term and it is still evolving every day.
- TPS is practiced in many car factories, and improvement was put on, even what kind of type of industry who has production spot can proof the effect.
- Honda operates a cell production system in 2016.
  It is the world first innovative system for car production.(page 19)
- The auto industry introduces IoT proactively, because effects of IoT accord with TPS well.

Peculiarity of manufacturing company in Japan

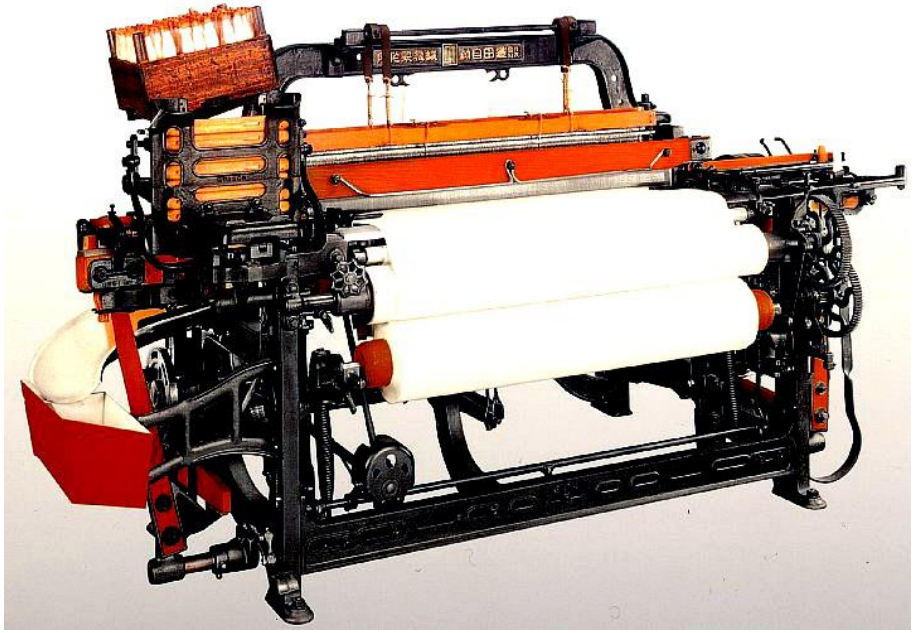
- High loyalty to the company by lifetime employment.
- Japanese think that companies belong to not only shareholders but also business partners, employees and region.
- Enterprise union system cooperates with the company at the time of the recession.
- A lot of small and medium enterprise（SME) which have high technology support a big manufacturing company.
- The production spot functionalizes PDCA* in Japan. Plan and Check are work of the managements in Europe and USA.
- The European and USA company aims at the quarterly profit, but Japanese company aims at the long-term growth.
- When production decreases, Japanese company protect employees by work-sharing, whereas Europe and USA companies lay off workers.

PDCA*:plan, do, check and action

History of Japanese automobile industry

- At the beginning of the 20th century Henry Ford introduced the mass production system by the belt conveyor.
  Henry Ford succeeded on the cost cut and doubled wage of workers, and created the automobile market.
- Toyota was founded in 1937.
  Toyota studied belt conveyor system in the auto industry of USA before World War II, and built Toyota Production system(TPS).
  TPS eliminated waste thoroughly and accomplished superb competitiveness, and Japanese other car makers followed TPS.
- In the 1970s Japanese makers expanded the export by high quality, the correspondence to regulation of exhaust gas, good fuel consumption and low price.
- The market expansion of the Japanese car caused trade friction, and car production in foreign countries spread from the 1980s.
- MIT analyzed factory of Toyota and proved superior productivity compared with GM factory.

The origin of TPS is Autonomy and Visual management



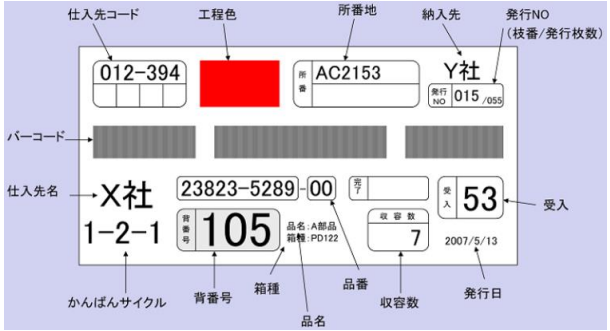
- Originally Toyota was a loom maker and invented automatic loom which built in a function to detect error and stop automatically in 1924.
- The detected trouble of each loom was shown in signboard, so a few workers could manage many machines.
- Beforehand error of loom made a large quantity of defectives and thanks to the automatic loom productivity has been improved drastically.

Peculiarity of Toyota production system

- The competitiveness of a product is a design, performance, quality, cost, delivery date.
- Longer lead time in common car means it has waste time in factory and high cost, poor quality.
- On the other hand, it is necessary to achieve small volume production in great varieties to cope with customer preference. Then problems become clear to do limited production of diversified products in short lead time.
- Lead time is time from an order to the receipt of money.
- Because the lead time is cost itself, so the shortening of lead time has same meaning as cost reduction.

- The basic spirit of Toyota is exclusion of thorough waste which prevent the shortening of lead time.
- So to get rid of any kind of MUDA(waste) is most effective measure to enhance productivity.
- TPS defines 7 kind of MUDA, and “just in time system” and autonomy are systemized to decrease seven kinds of MUDA.
- Currently this philosophy and approach are widely applied not only production but business and office work.
- It is required the shop floor to cope with an order quickly.
- In order to achieve small volume production in great varieties, lead time should be minimized as possible.
- Conventionally the previous process produce parts based on planned schedule and send it to the next process.

- If a trouble occurs at next process, produced parts accumulate as in-process inventory in every minute. These in-process inventory should be minimized.
- In Toyota production system a later process goes to take over a part necessary for a process in front. The previous process produces the parts to replenish. This system is called as pull production.
- To apply this pull production it is indispensable to shorten the lead time of each section.
- Toyota thought out “KANBAN” to realize this “Just in Time” system. “KANBAN” system supplies parts in time, and produce to replenish it as preventing overproduction.



Get rid of waste of the production

Waste(Muda) should be minimized to keep lead time and cost cut.
Analyze seven kind of waste(Muda) in production line.

(1) Waste of overproduction

→produce only needed number of next stage.

(2) Waste of time on hand (waiting)

→Worker can do different jobs by training.

(3) Waste in transportation

→Optimize layout of production line.

(4) Waste of processing itself

→Reconsider the work is necessary or not.

(5) Waste of stock on hand (inventory)

→produce only required number.

(6) Waste of movement

→make jig or tool to minimize movement.

(7) Waste of making defective products and repair.

→prevent defective in each process.

Key words of Toyota Production System

Kaizen : Continuous Improvement
Jidoka : Automation with human intelligence
Mieruka : Visual management
Andon : Signboard
Genchi, Genbutsu :Go and see for yourself
Heijunka : Leveled Production
Just-in-Time
Kanban : Index Card
Muda : Waste
Mura : Unevenness
Muri : Overburden
POKAYOKE : System to avoid human error

Belt conveyor system	TPS
Don't let a worker ask a question.	Let a worker ask "why".
The work manual should observe it.	The work manual should be updated.
Manage the spot with number and index.	Manage the spot with field and products.
Each spot can isolate and manage them.	Process connected and cannot isolate it.

Small volume production in great varieties

- Toyota produces cars in different specifications, such as type, color and options, in same working time. This is called “Heijunka” (Leveled Production).
- To accomplish “leveled production”, TPS apply skilled measures. TPS settles minimum lot size, and shorten the switching time of production in press, painting and assembly process as “Kaizen”.
- For small volume production in great varieties, Toyota educates and disciplines employees as versatile workers. Additionally, Toyota is implementing IoT* to support small volume production in great varieties.
- Nissan calls “Nissan Production WAY”(NPW) it is called as synchronized production, and the system is same as TPS basically.
- Honda operates a cell production system in Thailand from 2016. (page 19)

*Internet of Things

The quality is improved while building it up

- The inspection doesn't produce added value, and defective causes loss of time and money.
- In TPS quality is improved while building it up. It means all workers inspect at each stage of work. If abnormality occurs, workers stop a process without a hesitation, it is shown in visual board and prevent same trouble.
- For small volume production in great varieties, possible measures are embed in development stage such as "POKAYOKE", and IoT system.
- A strength of the manufacturing industry in Japan is based on tacit knowledge.

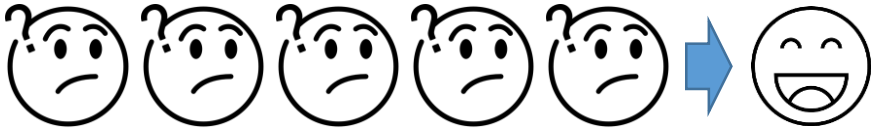
Quality problem solution in TPS

When a reason of problem doesn't become clear judging from an eye, TPS recommends to repeats "why" for five times.

After repeat five times "why" then can find the True cause hiding over there of the problem.

For example, If a machine breaks down, repeat five times of "why" and pursue a true cause.

1. Why the machine breaks down?
   ⇒An operation lever doesn't move smoothly.
2. Why the lever doesn't move smoothly?
   ⇒A bearing part of the lever was stuck.
3. Why the bearing part was stuck?
   ⇒Lubrication was not done.
4. Why did you not oil it?
   ⇒Lubrication did not enter the periodic inspection item.
5. Why did not enter the periodic inspection item?
   ⇒Staff did not understand the structure of the bearing part.



Performance, quality and cost depend on the first design

- Decide a target cost of material and man-hour cost in advance.
  It is difficult to cut down cost after drawings completed.
- The production cost is not from a design drawing,
  and target cost is fixed from the demand of the market.
- Minimize the total parts number.
  If decrease parts number 5%, then total cost decrease 10%.
- Normalize parts and modules as possible.
  It brings scale merits and stable procurement.
- Concentrate the installation of parts on one direction
  and design it in the structure that it is easy to automate.
  Simplify the assemble help visual check and “POKAYOKE”.
- The concurrent engineering to push forward design development
  and a production design at the same time is a necessary condition.
- Carry out a design revue by a development step many times
  and all companies cooperate and give completeness.

“POKAYOKE” defend human error

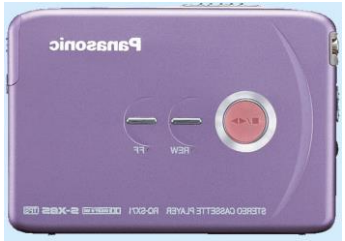
- For small volume production in great varieties, various kind of parts are mounted selectively in each car.
- To avoid human error, “POKAYOKE” should be embed.
- Discriminate parts by color, shape etc.
- Use digital picking system
- Use RF-ID (radio frequency identifier)
- Use image recognition by camera
- Install fool proof system
- Install fail safe system

Honda innovates Assembly Revolution Cell system in Thailand

- In 2016 Honda operates a cell production system in Thailand. It is the world first innovative system for car production.
- One car body and parts are loaded on ARC unit, and 4 skilled workers are in charge of plural processes of one car.
- A tablet terminal instructs order of parts mounting and quality control points by image and a sound to prevent human mistake.
- A new system supplies appropriate parts according to the specification to the assembling worker.

Production system of Audio and Video in Panasonic

- In the field of household appliance, price competition is severe, and there is a 5% profit limit opinion from old days.
- Panasonic had a top market share of VHS video in 1980s.
- Panasonic video factory produced main parts for cost reduction. Factory had press, molding and spring-coiling machines. They purchased a steel sheet as a coil, a resin pellet as molding materials, steel wire for spring and so on.



- Next to VHS Video, Panasonic produced DVD, but China makers produced in cheaper price in 2000s.
- In audio field Apple invented iPod and consigned it to **EMS***.
- Now EMS produce most of cell-phones and audio products.
- Additionally LSI is made in **foundry** such as TSMC.

*EMS : Electronics Manufacturing Service

Destroy a Japanese car with a hammer

- Japan-USA trade friction took place in 1980s.
- Japanese small car had excellent quality, low fuel consumption and price competitiveness.
  But USA thought it was dumping.
- Toyota decided to produce cars where the demand exists.
  It brought huge employment in oversea countries.
  Also offshore production can evade a currency risk.

Toyota decided offshore production in 1980s.

Subjects and measures

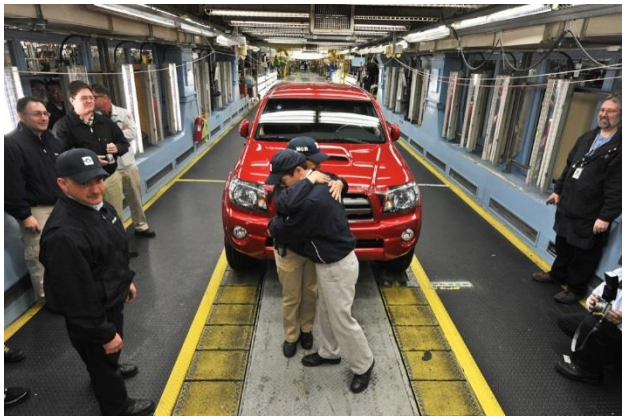
- How to keep same productivity and quality in offshore factories. TPS is consolidated through long term experience in Japan.
- There is a tacit relationship of mutual trust between the management and employees in Japanese traditional company.
- How to transfer whole skill and technic to offshore workers.
- Toyota introduced plenty of FA machines and robots. Machines and robots can produce same quality.
- Job training of offshore workers in TOYOTA factory.

Effect and end results

- Toyota let offshore production succeed in sequence without deteriorating with quality and created much employment.
- At the time of Lehman shock 30 thousand employees were redundant at Toyota, but did not downsize personnel by work-sharing.

The symbolizing factory is NUMMI in California Fremont

NUMMI (New United Motor Manufacturing, Inc.)



- 1982
  - GM closed California Fremont factory
  - The productivity was the worst, and workers absence rate was high.
- 1984
  - Reopened the factory as NUMMI (Toyota & GM)
  - NUMMI employed many workers laid off again.
  - The role of staff member changed to support from instructions.
  - Let them do autonomous management in a small group.
  - accept the production stop by the judgment of workers
- 1985
  - Productivity and quality are improved to double and come first in all GM factories.

Comparison report of productivity by J.P.Womack , et al..

Fremont

company	GM	Toyota	GM/Toyota
Factory name	Framingham	Takaoka(Japan)	NUMMI
Assembly time(h)	31	18	19
Defects/100 cars	135	45	45
Space/car/sq.ft	8.1	4.8	7.8
Parts stock time	2 weeks	2 hours	2 days

Research in 1987. NUMMI (New United Motor Manufacturing, Inc.)

IMVP(International Motor Vehicle Program)

- IMVP has been organized in 1989 in Massachusetts Institute of Technology(MIT) and investigating automobile Industries in world wide .
- Later many universities joined in this project and continued research over 20 years including Asian automobile factories.

- The rationale of the Toyota Production System(TPS) don't have many meanings and consist of words on Japanese-style mentality not to be able to express.
- TPS is a production technology, and based on steady improvement activity. It is called "KAIZEN".
- TPS is spot technique, and acquired by experience practically at factory spot. It is called "GENBA, GENBUTSU".
- MIT investigated TPS and re-systematized the result as "LEAN Production System(LPS)" in 1980s.
- The LPS doesn't intend to produce a standardized product in large quantities. LPS makes it enable to produce an appropriate amount and many kinds products by team formation of workers and automatic machines. As a result, facilities investment, space and stock might be reduced half, and the development time shorten.

- The basis of the TPS is thorough exclusion of waste and rationality of how to make car.
- The TPS is established focusing on two ways of thinking. That is, factory produce cars without stagnation, a machine stops promptly if abnormality occurs and does not make a defectives. Each process produces only the necessary amount.
- The car maker makes a sales forecast and the production schedule for 3 months and announce parts makers it unofficially .
- The parts are delivered 16 times a day. Less than 3 hours are demanded from the last decision to the delivery.

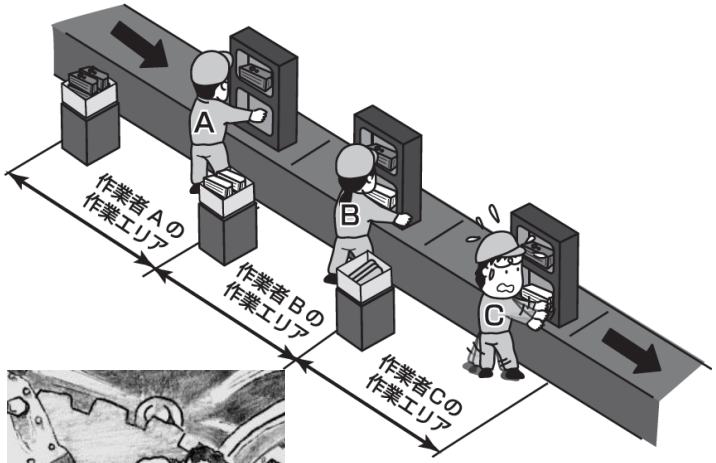
Source:Website of DAIFUKU

Ford Model T made in 1908

Comparison of mass production system

Belt conveyor roller (Ford system)

- adopted in car production mainly
- stable quantity
- stress of workers are big
- defectiveness is easy to occur
- standardize all parts
- change complicated work to simple works

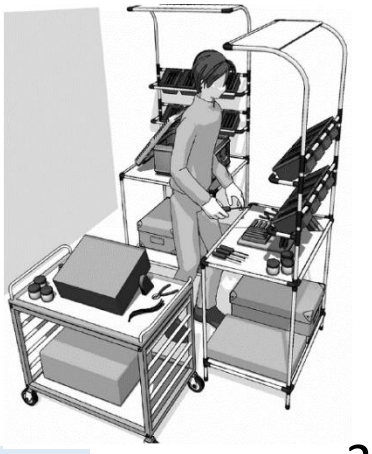


Free flow belt conveyor

- adopted in electrical appliances mainly
- Amount of production is fixed by the slowest process
- little stress of workers
- stable quality
- a product stops once, it is easy to implement robots

Cell production system

- adopted in PC, printer etc.
- Assembly Revolution Cell system of Honda.



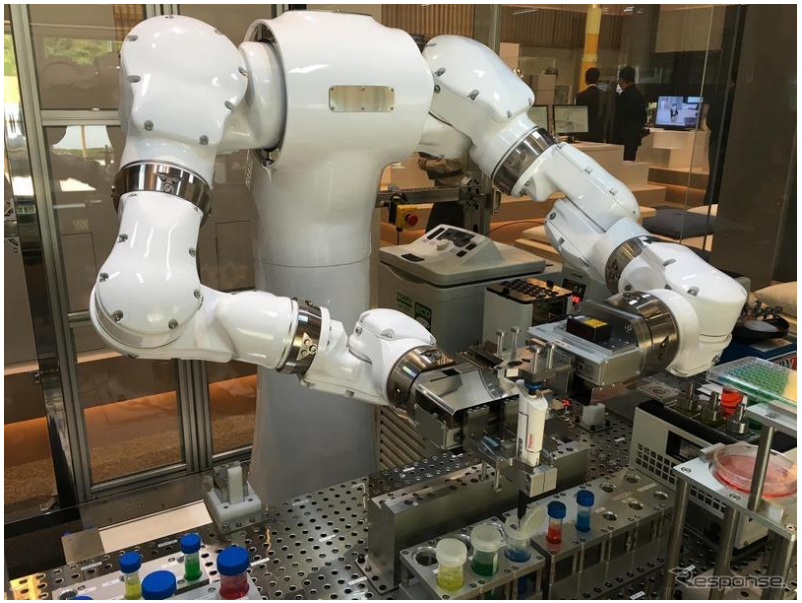
Comparison of worker, specialized machine and robot

	Invest-ment	Power/speed	Continuo-us operation	Disper-sion	flexbility	space	Severe inviron-ment	hygienic
worker	◎	△	×	△	◎	◎	×	△
specialized machine	△	◎	◎	◎	△	△	◎	◎
robot	○	○	◎	◎	◎	◎	◎	◎

- Robot is effective for painting, welding, work at the dangerous and high places.
- Robot is suitable for the spot in disfavor with hygiene and the dust including a food factory and the semiconductor factory.
- In order to maximize the introduction effect of the robot, peripheral devices, an anteroposterior process and workers placement should be redesigned.
- Henceforth, technology development to let a robot act for the technique of expert workers is necessary.

Progress of industrial robots

- 100,000 industrial robots are shipped in Japan in one year, and 70% or more are exported.



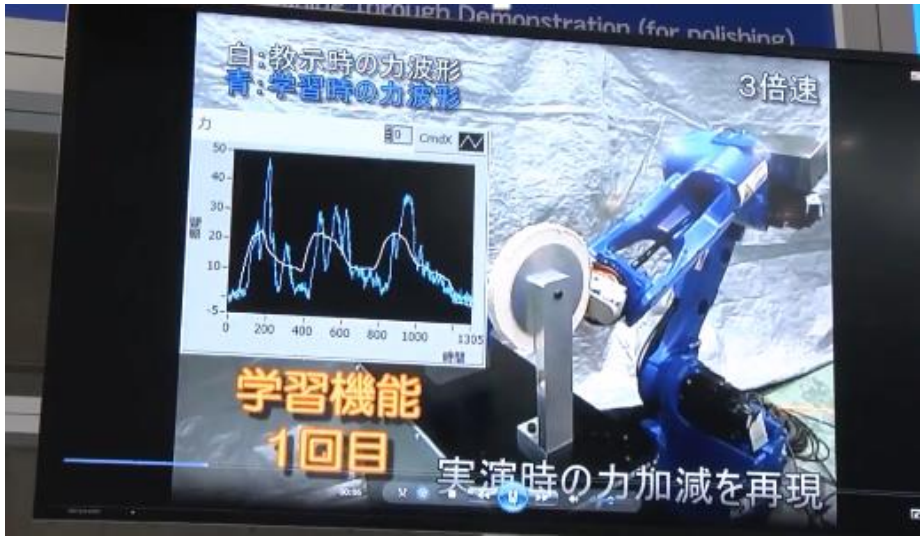
Dual arm robot works with a person

Fence-less robot

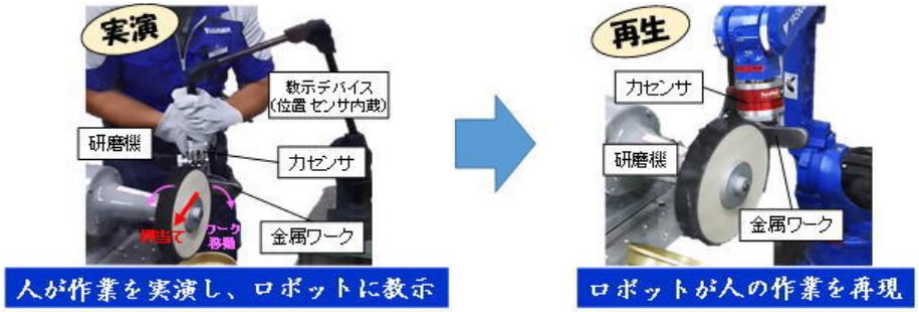
- The general robot is good at the reproduction of the position posture, but is weak in the reproduction of delicate power.
- The industrial robot works by a procedure which is called " teach and playback" basically.

- In 2017 Yasukawa developed a demonstration instruction function. A robot can instruct even expert work such as the abrasion easily.
- The demonstration instruction function measures position posture and the power of hand and fingers work with a sensor and converts measurement data into the operation of the robot automatically.

AI* robot can work as same as expert.



AI* technology are implemented in the latest robots, and can work same as experts.

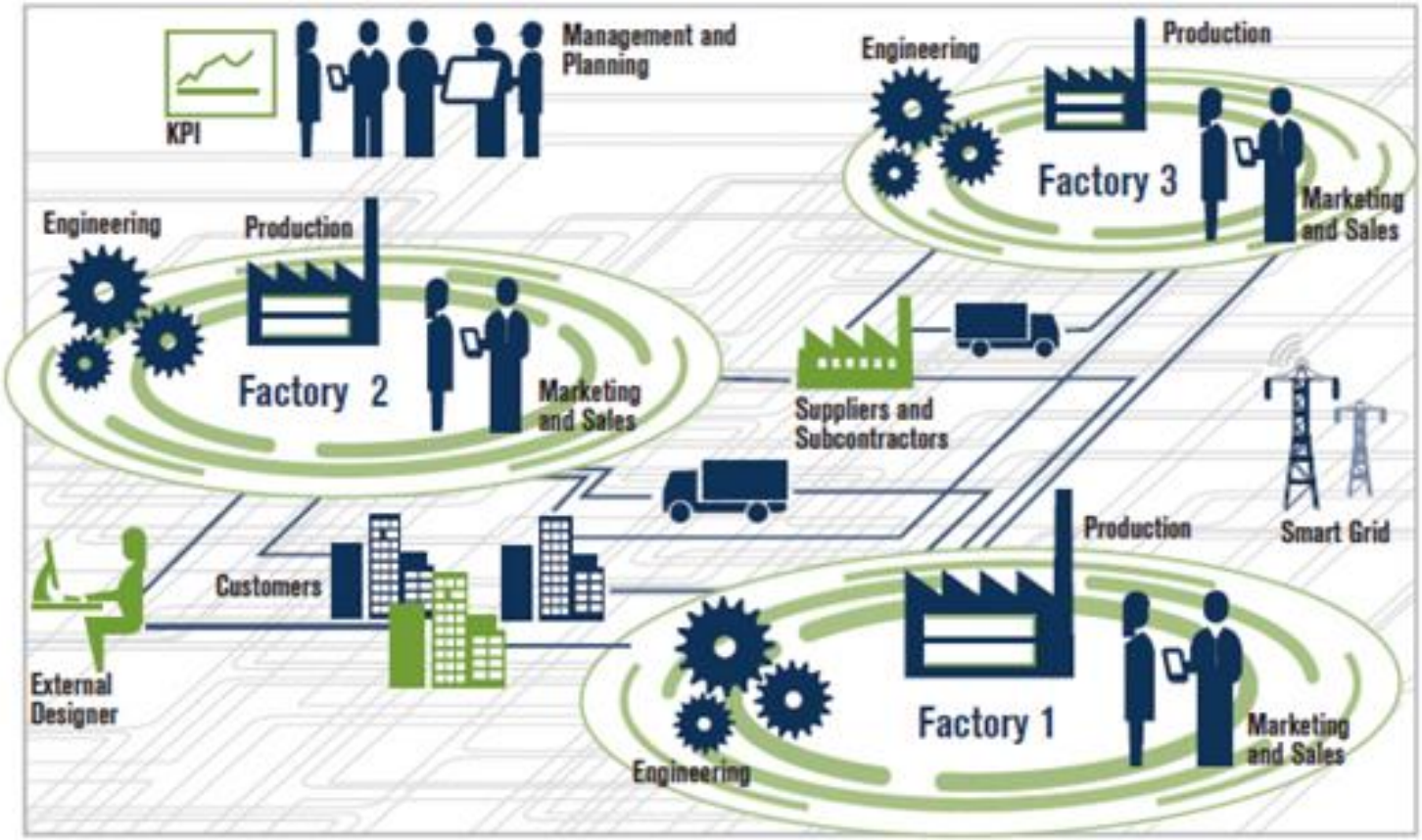


AI*: Artificial Intelligence

Introduction IoT into machine tools and factory

- Production efficiency is expected to increase by evolution of FA machines and industry robots.
- In addition, data from sensors which is connected in machines, and inspection instruments are analyzed by AI, and will contribute to increase the productivity.
- Large corporation has many affiliated companies, and the data of operational condition brings positive effect to improve total efficiency of group business.
- In Germany, proposing industry 4.0, Mercedes started the use of IoT at an early stage.
  Mercedes attach sensors to every apparatus of the factory and analyze the data. As a practical result Mercedes realized to decrease waste time in the production process.
  Furthermore the data predict the need of maintenance before fault occurrence.

Industry 4.0 and IoT



Industry 4.0 started in Germany from 2011.
Bosch, Siemens wrestle as the fourth Industrial Revolution.
The action same as industry 4.0 advances in each country such as "Made in China 2025"(China), "Industrial Internet"(USA) and "Society 5.0"(Japan).

Screw torque management by IoT

- Hitachi got an order of 866 trains from British railway.
- Several thousand of screws used in one train should be controlled by torque wrenches connected to IoT.
- The data of torque wrenches are transfer by radio to PC and recorded for trace in any time.
- Because there are few experienced workers of the railroad carriage assembling in UK, IoT can equalize same quality as Japanese factory.

torque wrenches connected to IoT

Fig.1

Appendix

Number of the world car production top 20 in 2018

(k units)

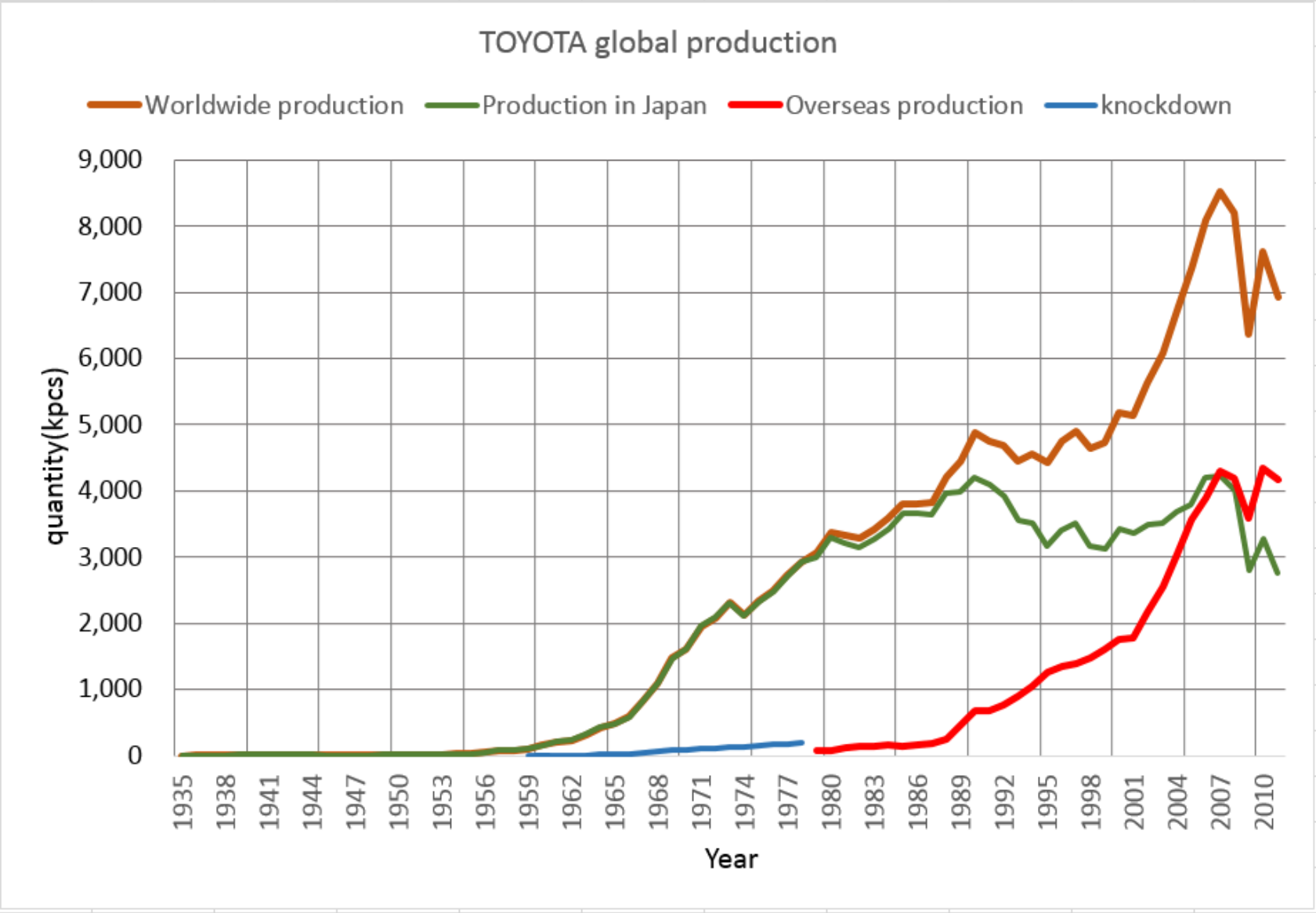
1	China	27,809 ↘	11	Thailand	2,168
2	USA	11,315 ↘	12	Canada	2,021
3	Japan	9,729 ↗	13	Russian	1,768
4	India	5,174 ↘	14	United Kingdom	1,604
5	Germany	5,120 ↗	15	Turky	1,550
6	Mexico	4,100 ↗	16	Czech Republic	1,345
7	Korea Rep.	4,029 ↘	17	Indonesia	1,344
8	Brazil	2,880 ↗	18	Iran	1,096
9	Spain	2,820 ↘	19	Slovak Republic	1,090
10	France	2,270 ↗	20	Italy	1,060

World car output in 2018 was 95,634,593 units,
and prediction in 2020 is over 100 M units

source:OICA（International Organization of Motor Vehicle Manufacturers ）

Fig.2

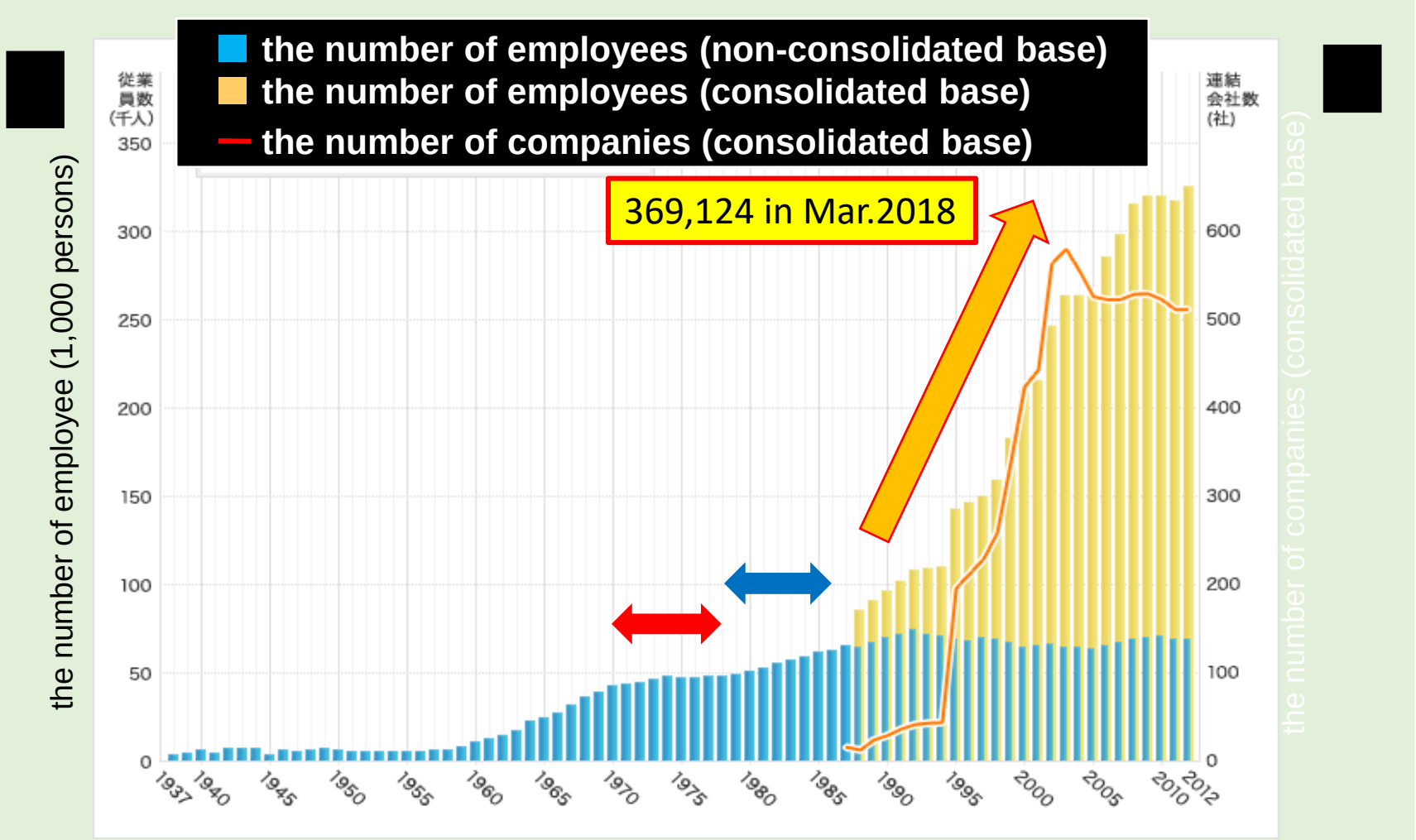
Toyota's offshore production history



Data Source : http://www.toyota-global.com/company/history_of_toyota/

Fig.3

Numbers of global employees history

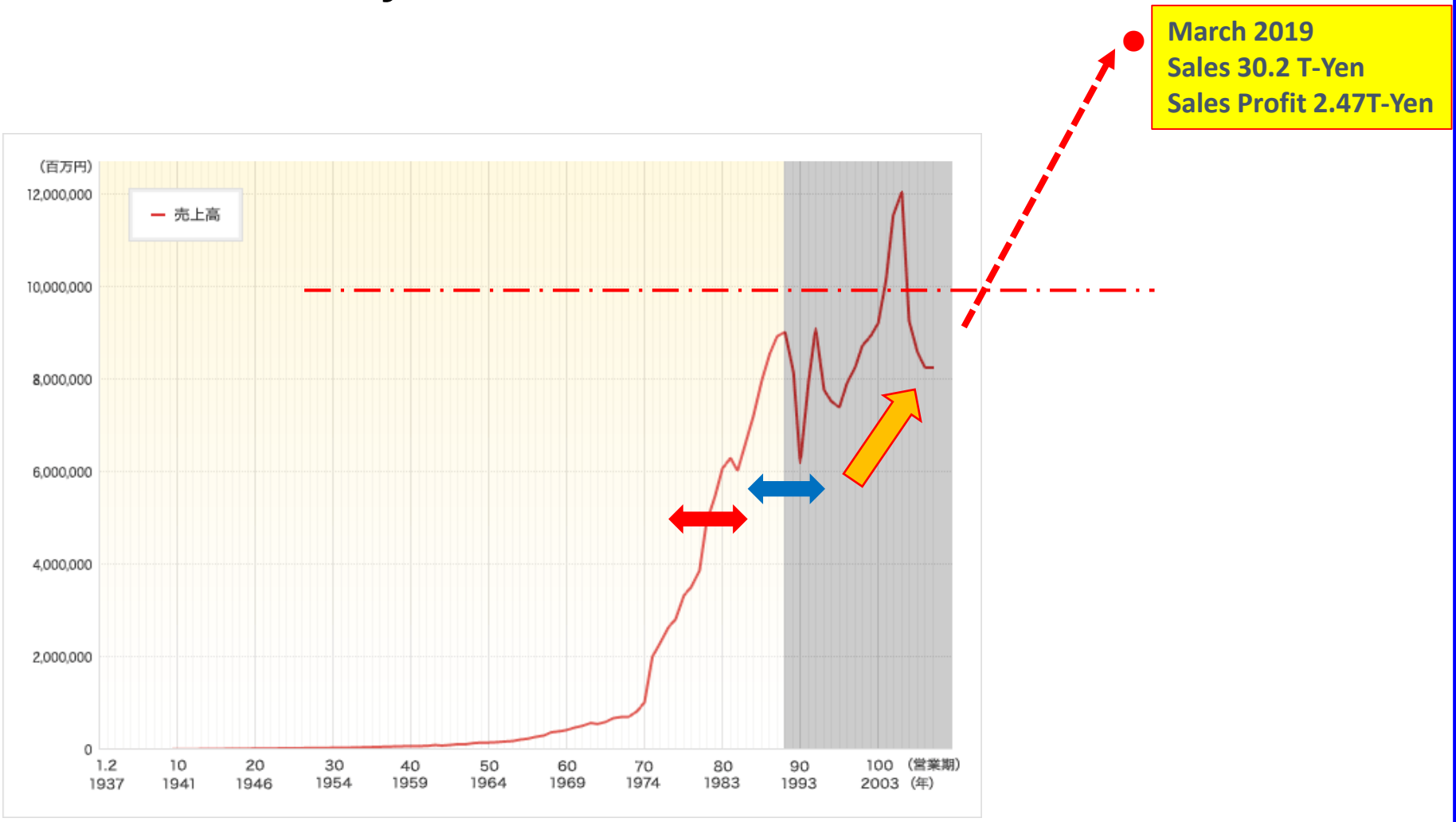


In the 1970s, Toyota innovated robots aggressively.
In 1980s Toyota promoted diversification of operations.
After 1990, the number of employees is increasing rapidly.

Data Source: Toyota website of 75 years history

Fig.4

Toyota's global sales history



In the 1970s, Toyota innovated robots aggressively.
In 1980s Toyota promoted diversification of operations.
After 1990, the number of employees is increasing rapidly.

Data Source: Toyota website of 75 years history

Fig.5

New United Motor Manufacturing, Inc. (NUMMI) was an automobile manufacturing company in Fremont, California, jointly owned by General Motors and Toyota that opened in 1984 and closed in 2010.

The NUMMI plant in Fremont, California

1st car produced in NUMMI(1884)

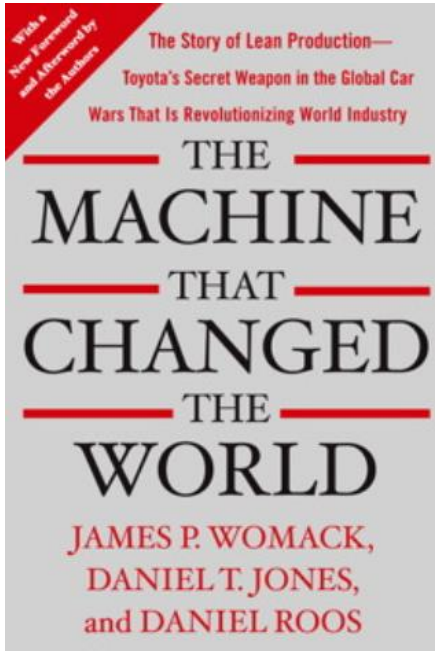
Job training of NUMMI workers in TOYOTA(1884)

NUMMI is producing EV car with Tesla from 2010.

Fig.6

”The Machine that Changed the World ”

James P. Womack, Daniel T.Jones and Daniel Roos 1987



This report write productivity of Japanese automobile factory is 2 times better than USA factory.
In addition quality is 3 times better than USA.

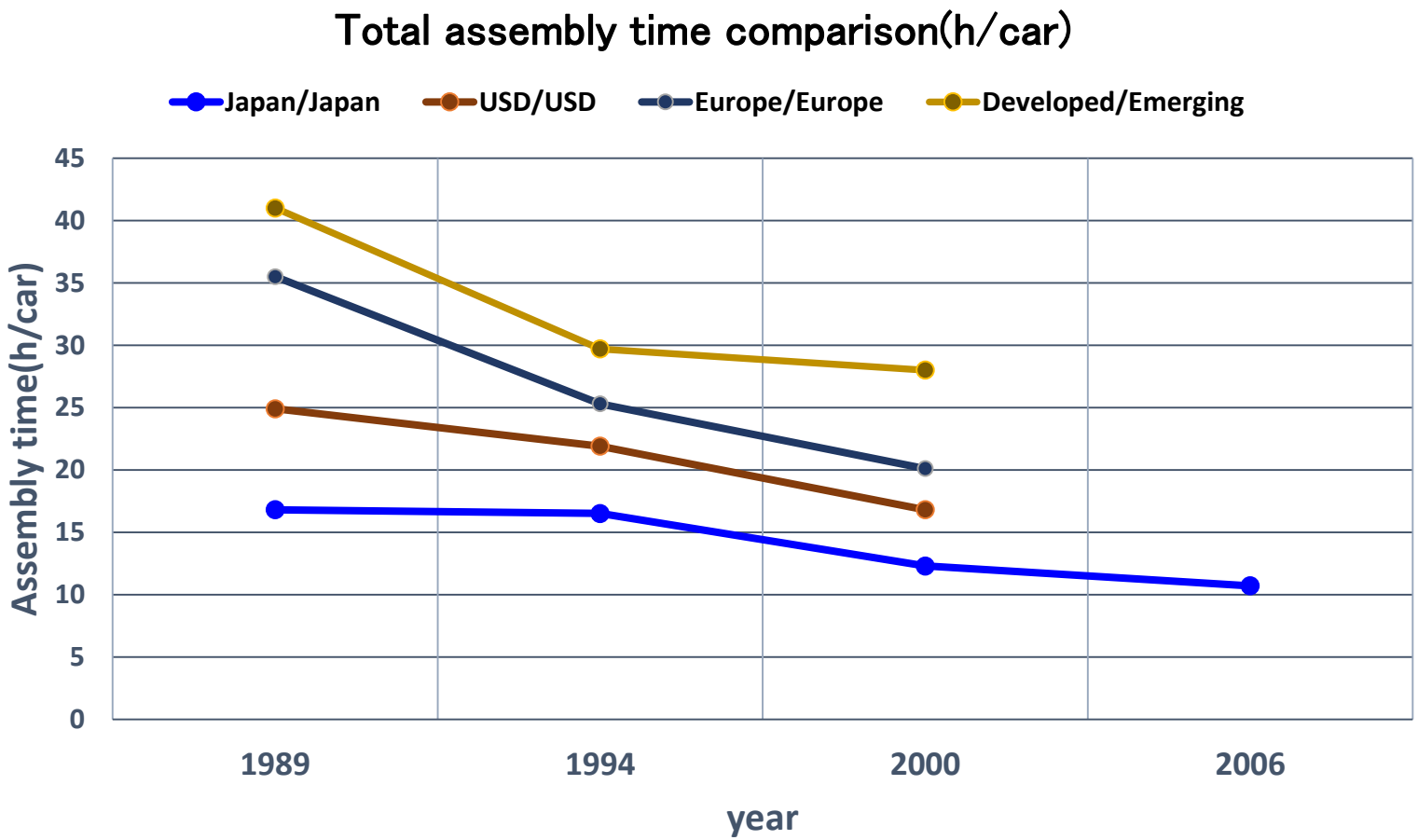
The tale of the superior performance of Toyota over its mass-producing competitors was first brought to widespread Western attention by “The Machine that Changed the World”.
The success of this book was claimed to trigger much attention into finding.

A better way to organize and manage customer relations, the supply chain, product development, and production operations.
The book documented the history of management thinking in the automotive sector from the early craft manufacturers, to the mass production techniques exemplified by Ford/GM, before telling the story of the TPS’s creation (1950) and that of Toyota’s thought leader Taiichi Ohno*.

*VP of Toyota

Fig.7

IMVP(International Motor Vehicle Program) report

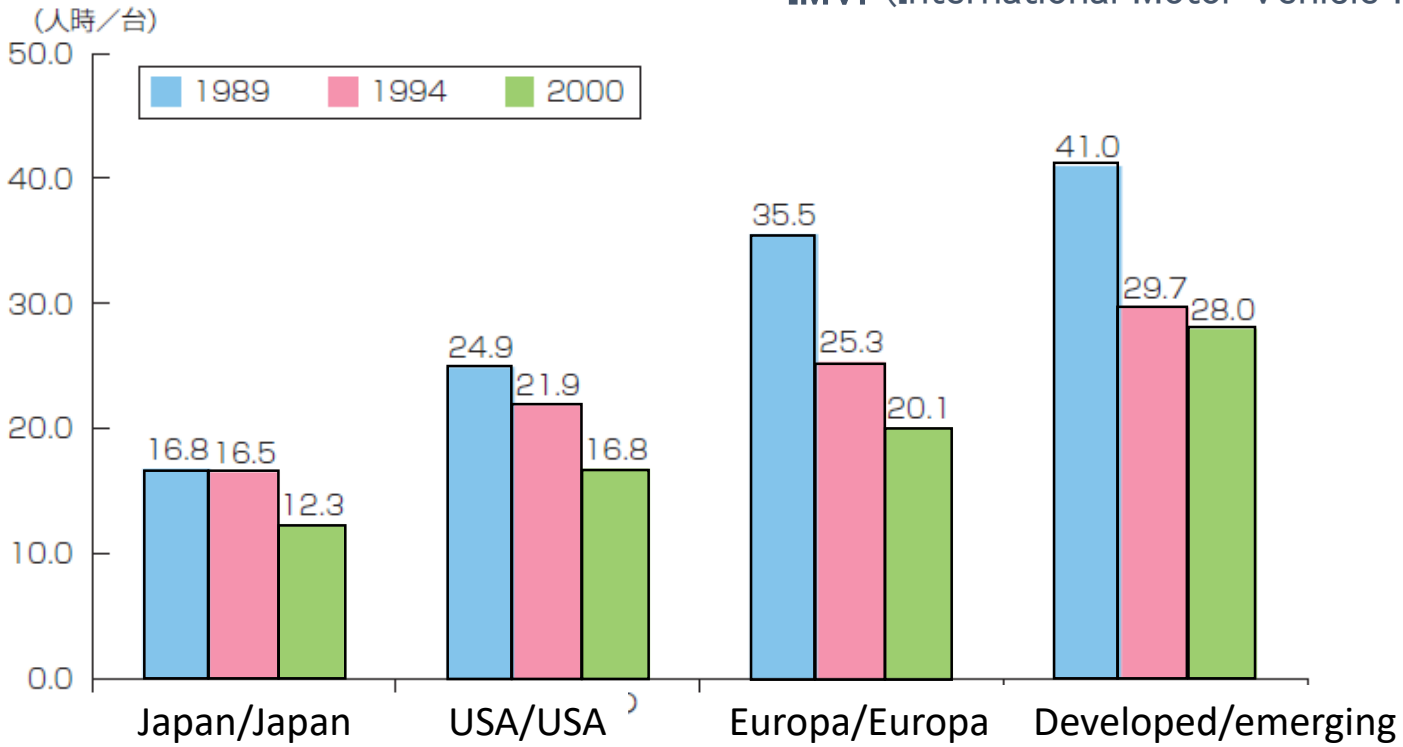


IMVP was the study organization which MIT established.
IMVP investigated about world car factories more than 20 years.

Fig.8

Analysis result in round 1 to round 3 by IMVP

IMVP(International Motor Vehicle Program)



Measures to improve productivity based on IMVP report.

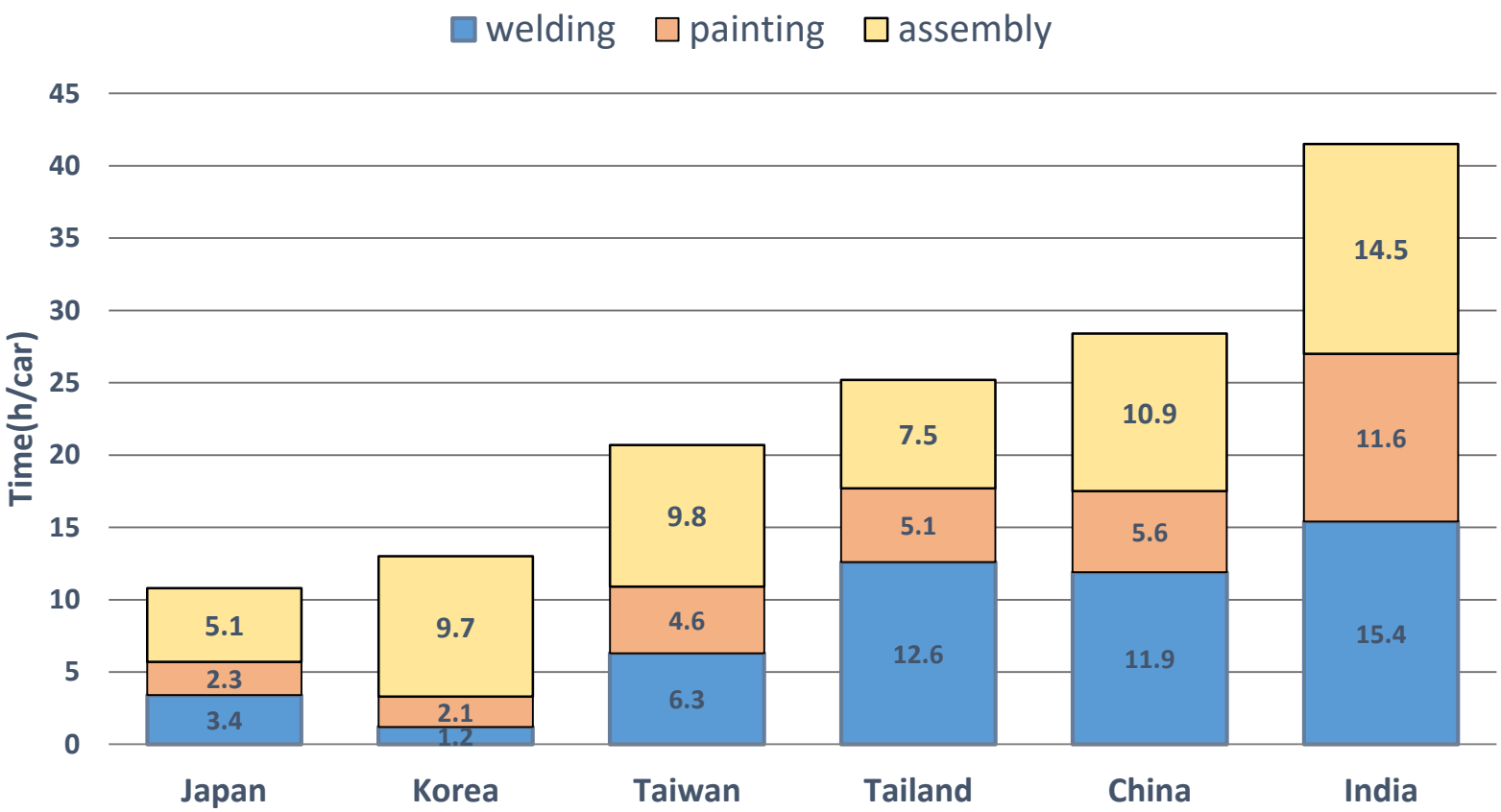
(1) Investment to FA and robots.

(2) Take a seasonal laborer and discipline them as versatile workers.

(3) Increase a rate of subcontract and make a production process simplify and shorten.

Fig.9

Comparison of total assembly time(h/car) in 2006

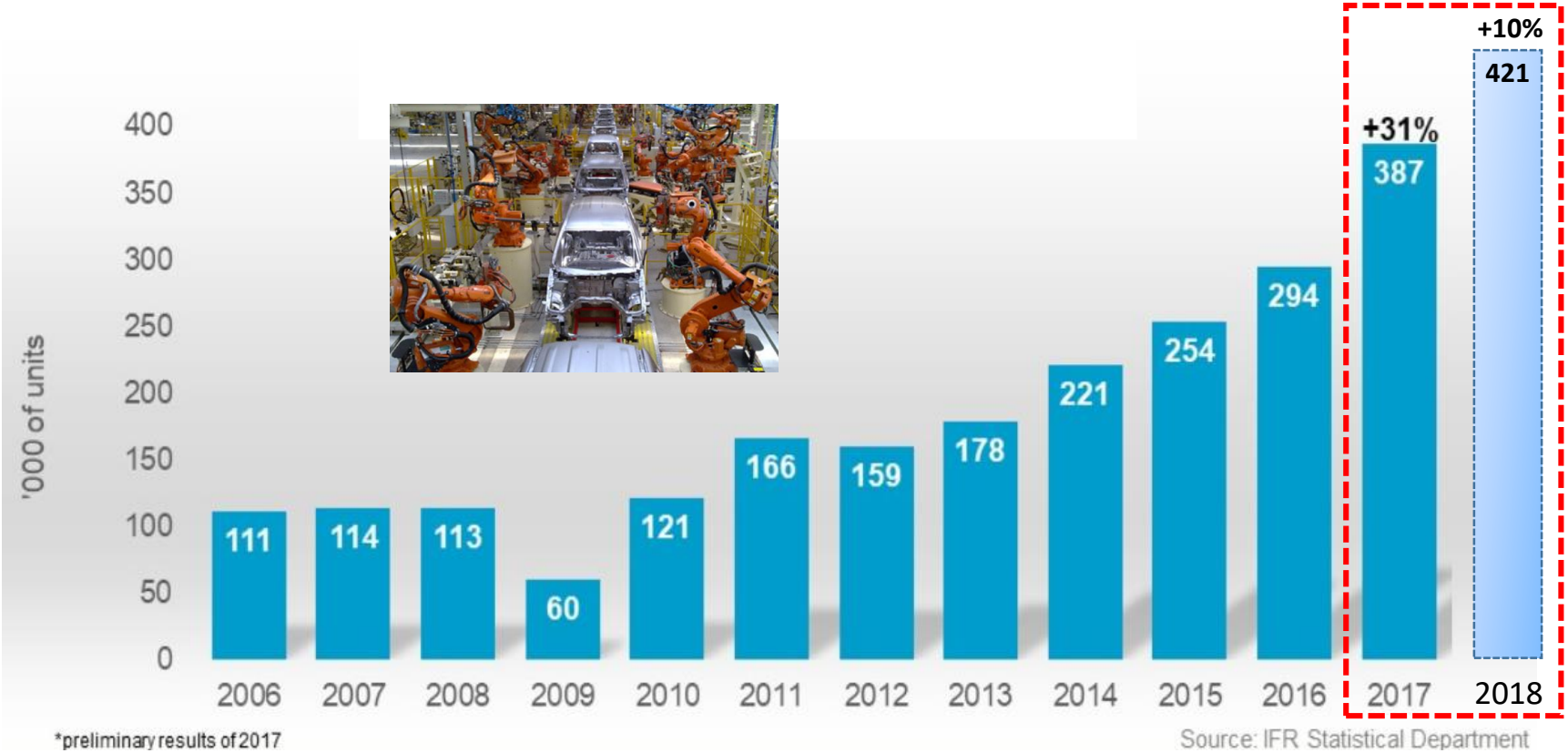


In round 4, IMVP measured average time to make a car in factories in Asia. They are 10 factories of Japan, 3 factories in Korea, 3 factories in Taiwan, 6 factories in Thailand, 5 factories in China, 3 factories in India.

IMVP(International Motor Vehicle Program)

Fig.10

Worldwide shipment of industrial robots



Global sales of industrial robots reached the new record of 421k units in 2018. That is an increase of 9 % compared to the previous year (2017: 387 kunits). China saw the largest growth in demand for industrial robots, up 58%. Sales in the USA increased by 6% - in Germany by 8% compared to the previous year.

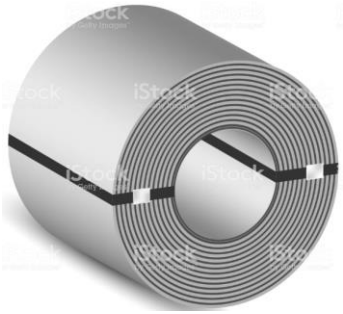
Fig.11

Makers and expertise of industrial robots

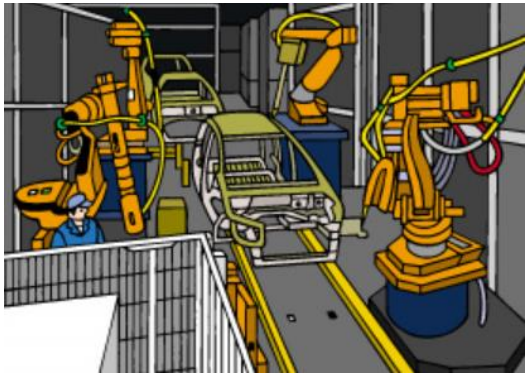
Maker		Welding	Painting	Carrier	Multifunction
Fanuc	Japan	○	○		
Yasukawa	Japan	○	○	○	
ABB	Swiss	○	○		
KUKA	China	○	○		
Kawasaki	Japan	○	○	○	
Fujikoshi	Japan	○		○	
Comau	Italy	○			
Staubli	Swiss				○
Epson	Japan				○
Mitsubishi	Japan				○
UNIVERSAL ROBOTS	Denmark				○

Fig.12

The ratio of material used for a car



steel plate
40%

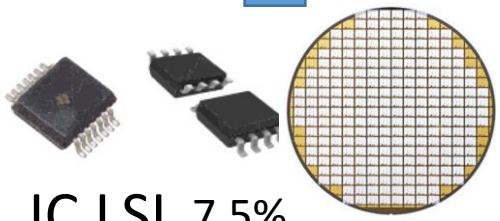


robot
70%

38%

synthetic rubber
80%

glass 10%



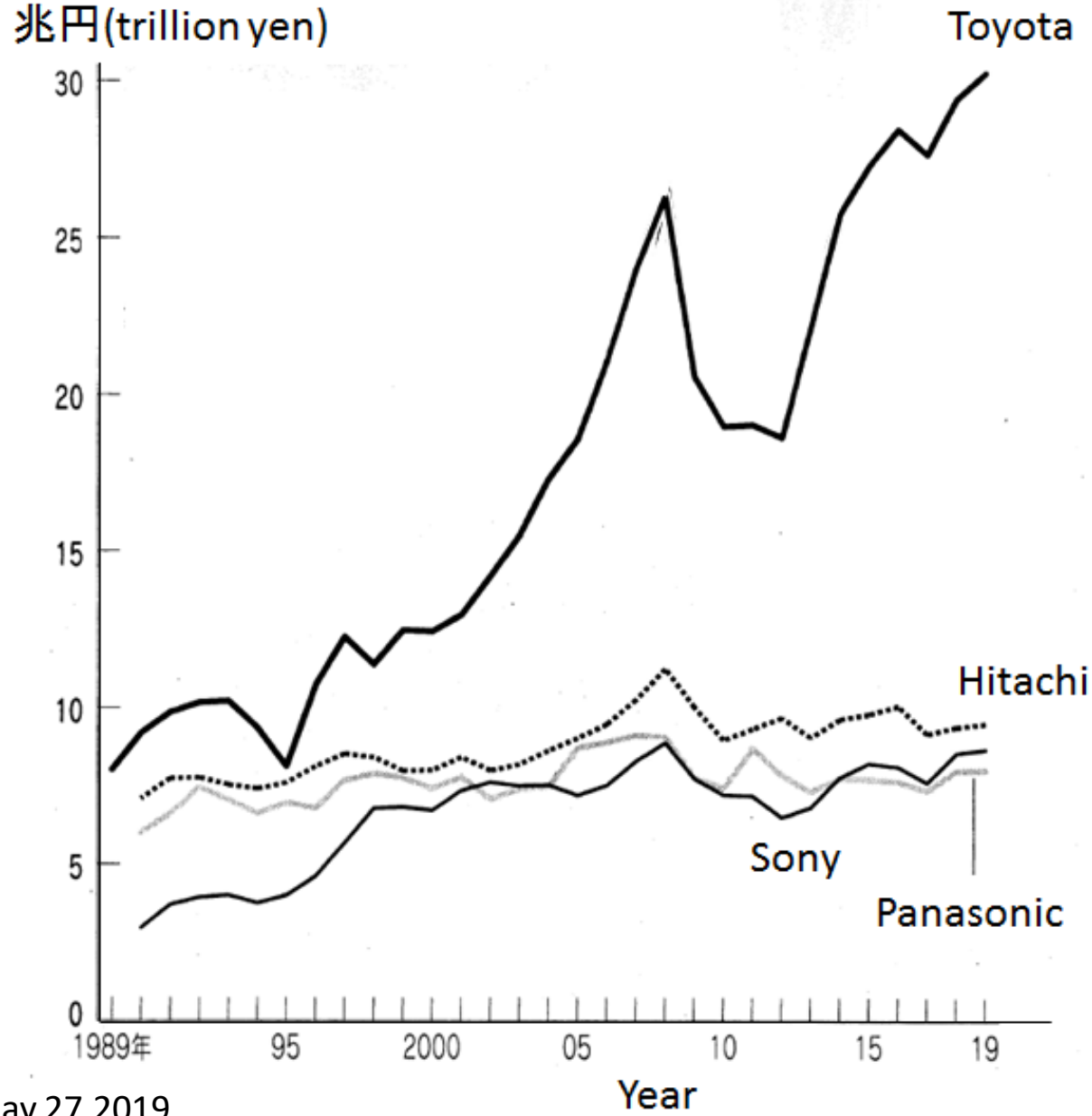
IC,LSI 7.5%

motor 40%

The numerical value of the indication is estimated by K.Sakai.

Fig.13

Comparison of consolidated sales of Toyota, Hitachi, Sony and Panasonic



source : Nikkei May.27.2019

Fig.14

Overseas companies which introduces TPS

DELL computer

DELL established BTO system for personal computers.

Amazon

Use the words of GENBA, KAIZEN.

Huawei

The production engineering by TPS contributes to the high cost competitiveness of Huawei.
The latest model is produced in-house for continuous improvement of the production engineering.

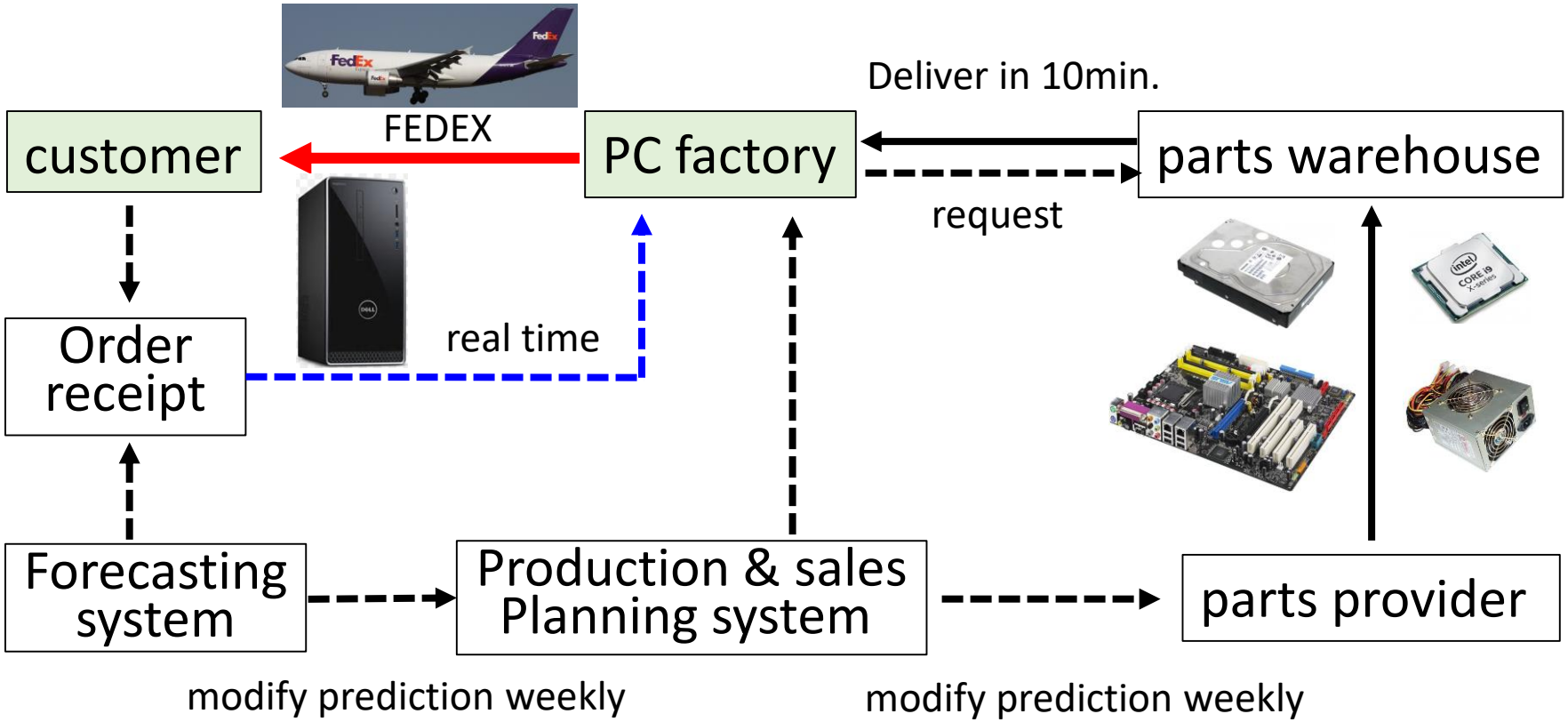
Google

Google intends to adopt TPS philosophy in order to improve the productivity of shop floor instead of the management by MBA holders.

Fig.15

BTO system of DELL computer

DELL was established in 1984 and learned Toyota system.



- DELL has four venders for each parts.
- Parts vendor has warehouse near DELL factory.
- DELL pay for parts provider after PC shipment.

Fig.16

Our Company Our Culture Capabilites ANDROID Business System Careers

NEWS

GM Recognizes Android Industries for Performance, Quality, and Innovation

April 26th, 2018

Android Industries is a <u>just-in-time assembly</u> integrator, responsible for global supply chain management and the assembly of complex modular vehicle systems. Since 1988, Android has shipped more than 400 million modules to its customers' vehicle assembly plants. Also, Android continues to refine its expertise in the design / build of tooling and equipment; this know-how originated in 1974 and today's solutions are engineered to meet the unique needs of each vehicle program.

Fig.17

Regulation of the gasoline engine car

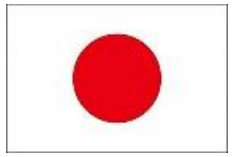
U.K. France	prohibit the sale of the engine car by 2040
U.S.A.	California and 10 states study to prohibit the sale of the engine car.
Australia	Under study to build reserved roads for EV cars.
China	Under study to prohibit the sale of the engine car from 2019
Netherlands	prohibit the sale of the engine car by 2025
Germany	prohibit the sale of the engine car by 2040
Sweden	prohibit the sale of the engine car by 2030
India	prohibit the sale of the engine car by 2030

Fig.18

The environmental regulation about CO_2 emissions

- EU aims for reducing the CO_2 emission 37.5% in comparison with 2021 in 2030.

- Japan aims for reducing the CO_2 emission 30% in comparison with 2020 in 2030.



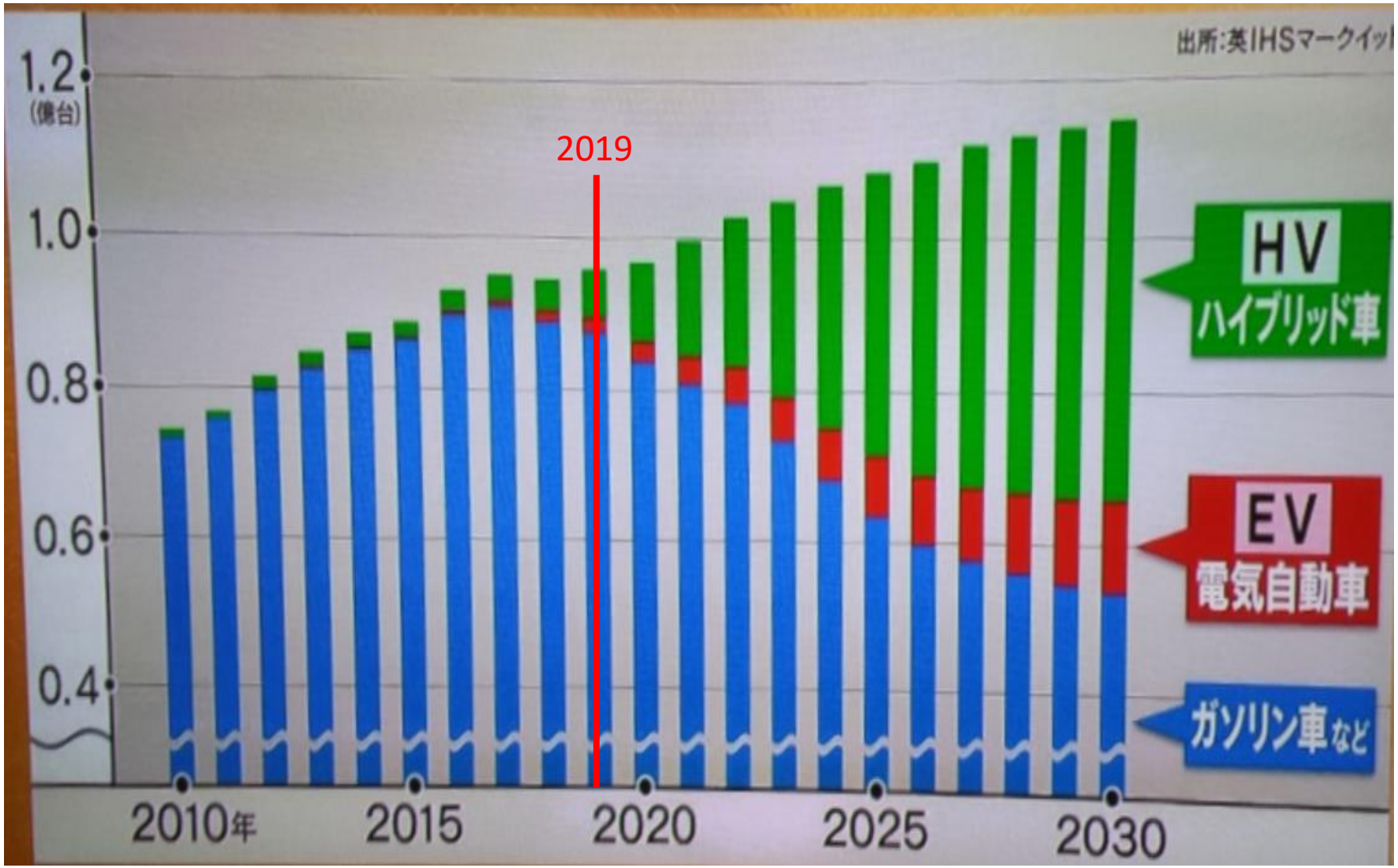
- China obliges it to assuming the ratio of the EV cars for all car makers should produce 10% from 2019, and 12% from 2020 of whole as NEV regulation.

- USA aims for reducing the CO_2 emission 30% in comparison with 2017 in 2025 by Obama. Trump asked reconsider.

NEV : New Energy Vehicle

Fig.19

Estimates of configuration ratio of HV, EV and gasoline cars



source: IHS Markit Automotive(UK)

Fig.20

Number of EV cars and capacity of battery in 2018

Number of EV production

	company	K units
1	BYD(China)	247
2	Tesla(USA)	245
3	北京汽車集団(China)	158
4	BMW (Germany)	143
5	VW(Germany)	100
6	上海汽車集団(China)	97
7	Nissan(Japan)	97
8	奇瑞汽車(China)	91
9	浙江吉利控股集団(China)	79
10	安徽江淮汽車集団(China)	64
	Total of top 10	1,321

Capacity of battery for EV

	company	GWh
1	CATL(China)	23.5
2	Panasonic(Japan)	23.3
3	BYD(China)	11.6
4	LG Chemical (Korea)	7.5
5	AESC(China)	3.7
6	Samsung SDI(Korea)	3.5
7	国軒高科(China)	3.0
8	天津力神(China)	2.1
9	字能科技(China)	2.0
10	比克電池(China)	1.8
	Total of top 10	82.0

SOURCE: Nikkei research, 中国・深JII市起点諮詢調査(2018)

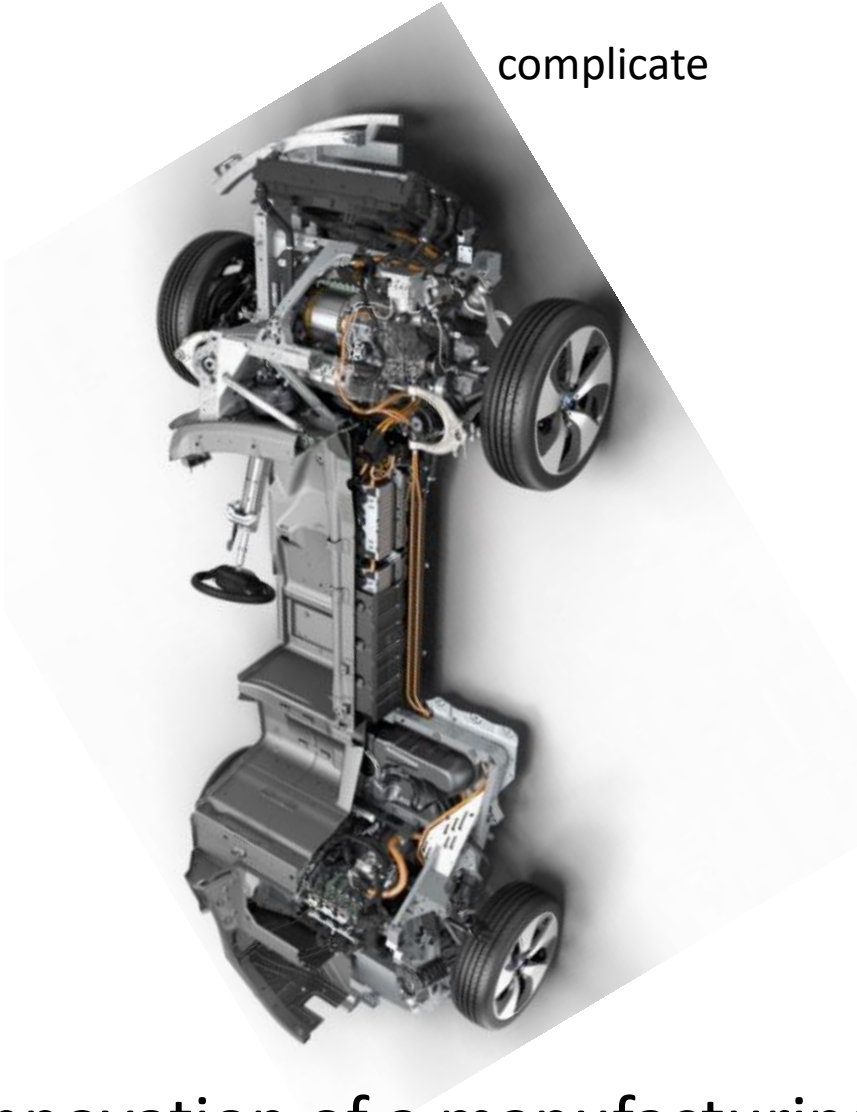
Fig.21

Comparison of automobile chassis

Engine(Toyota)

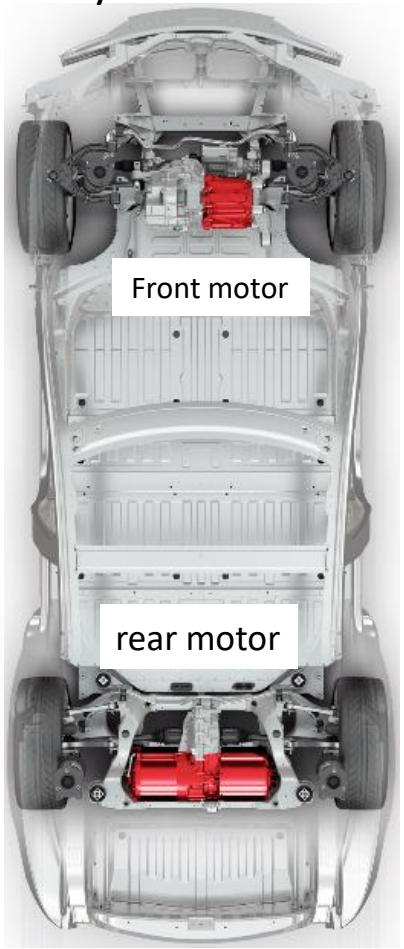
HV(BMW i8)

complicate



EV(Tesla model-S)

easy to assemble



EV performs innovation of a manufacturing technology and industrial structure from the root.

Thank you for your kind attention.

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