

# Disaster Management and JIT of Automobile Supply Chain

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## Abstract

The 2011 Tohoku Earthquake was huge damage to Japan, especially, along the coasts of Miyagi, Iwate, and Fukushima. There was catastrophic damage by tsunami created by this earthquake. Japan frequently has been affected by strong earthquake before Tohoku Earthquake. Much has been emphasized about the impacts of human and physical visible damages since disasters struck and there are a lot of studies about disaster in terms of seismology, meteorology, geology, structural mechanics, etc. But, the invisible damages, such as supply chain network, production system has been obstructed, not revealed. In spite of our experiences in huge disasters, we haven't tried to unveil these invisible damages. In fact, the automobile industries also suffered a great loss due to this disaster. Supplies of assemblies/products from Japan had stopped, and interrupted other production activities in the world.

In order to unveil invisible damages, this paper describes the affects to the supply chain network, production system in Japanese automobile manufacturers by two disasters - the 2011 Tohoku Earthquake and the 2007 Niigata Chuetsu-offshore Earthquake-. In addition, to unveil fundamental issues of their damages, there are the research questions; "Why did automobile manufacturers immediately decide all assembly plants' shutdown", "What's the difference of the impacts by disaster and depression" and, "Is the limitation of the JIT really exists, or not".

**Keywords** : Disaster, JIT, Supply Chain, Japanese Automobile Manufacturers

## 1. Introduction

Automobile manufacturers on the top of hierarchy of Automobile industry assemble cars. First Tier suppliers supply major components such as body, engine, and transmission, to automobile manufacturers. The Second Tier suppliers furnish the sub-assembly/components that the First Tier suppliers require. Similarly, lower level suppliers supply higher level suppliers. If only one component is unavailable, then the production process is interrupted.

Around 2008, there was the worldwide depression caused by the subprime mortgage crisis of Lehman Brothers in the US, and in 2011, there was the Tohoku Earthquake. These crisis and disaster affected the Japanese automobile industry. The demand for automobiles also rapidly dropped due to the subprime mortgage crisis, and then, the supply of automobiles was further delayed by the Earthquake. Especially, in the situation of globalized and centralized suppliers in the lower tiers; if these suppliers were affected by a disaster, the production at supplier's plant

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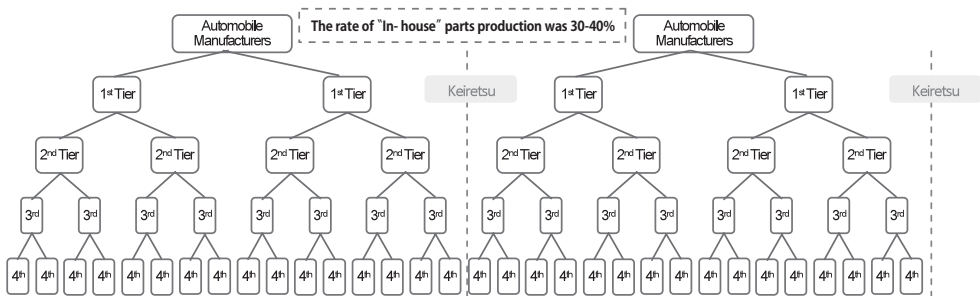
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stop, then almost every automobile manufacturer will be affected by it.

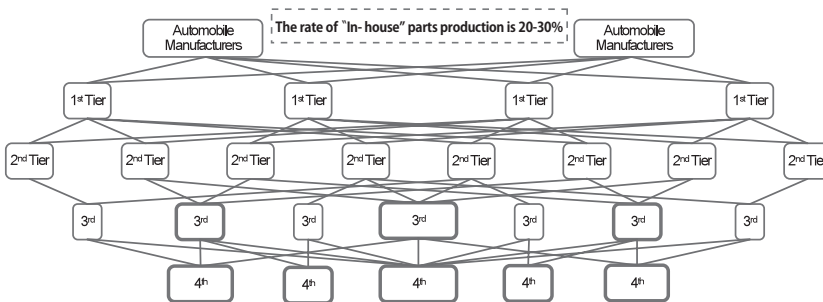
## 2. Supply Chain Network of Japanese Automobile Industry

The Japanese automobile supply chain network is very complex. The Japanese automobile supplier network is called “keiretsu”. This “keiretsu” structure of assembler-supplier relationship historically enabled Japanese automobile manufacturers to remain lean and flexible while enjoying a level of control over supply akin to that of vertical integration (Ahmadjian and Lincoln 2000). The Japanese automobile industry was like a pyramid, (as shown in Figure 1a), divided into three or any more tiers of suppliers, centred around the seven main assembly groups or single assemblers - Toyota-Daihatsu-Hino, Nissan-Subaru-Nissan Diesel, Honda, Mazda, Mitsubishi, Isuzu, and Suzuki (Shimokawa 1994). The Japanese supplier network had a hierarchical structure, with each major car manufacturer at the top of the hierarchy. In the 1980s, the in-house production ratio of Japanese car manufacturers was comparatively lower than those of US and European car manufacturers (Konno 2005). In Japan, only about 30-40 percent of parts was ‘in-house’. In North America and Europe up until the early 1980s, the rate of ‘in-house’ parts production was 60 percent to 70 percent (Shimokawa 1994).

However, in the 1990s, the Japanese automobile industry faced several crises, such as the



(a) Pyramidal Structure



(b) Diamond Structure  
(Barrel Structure)

Figure 1: Supply Chain Network of Automobile Industry

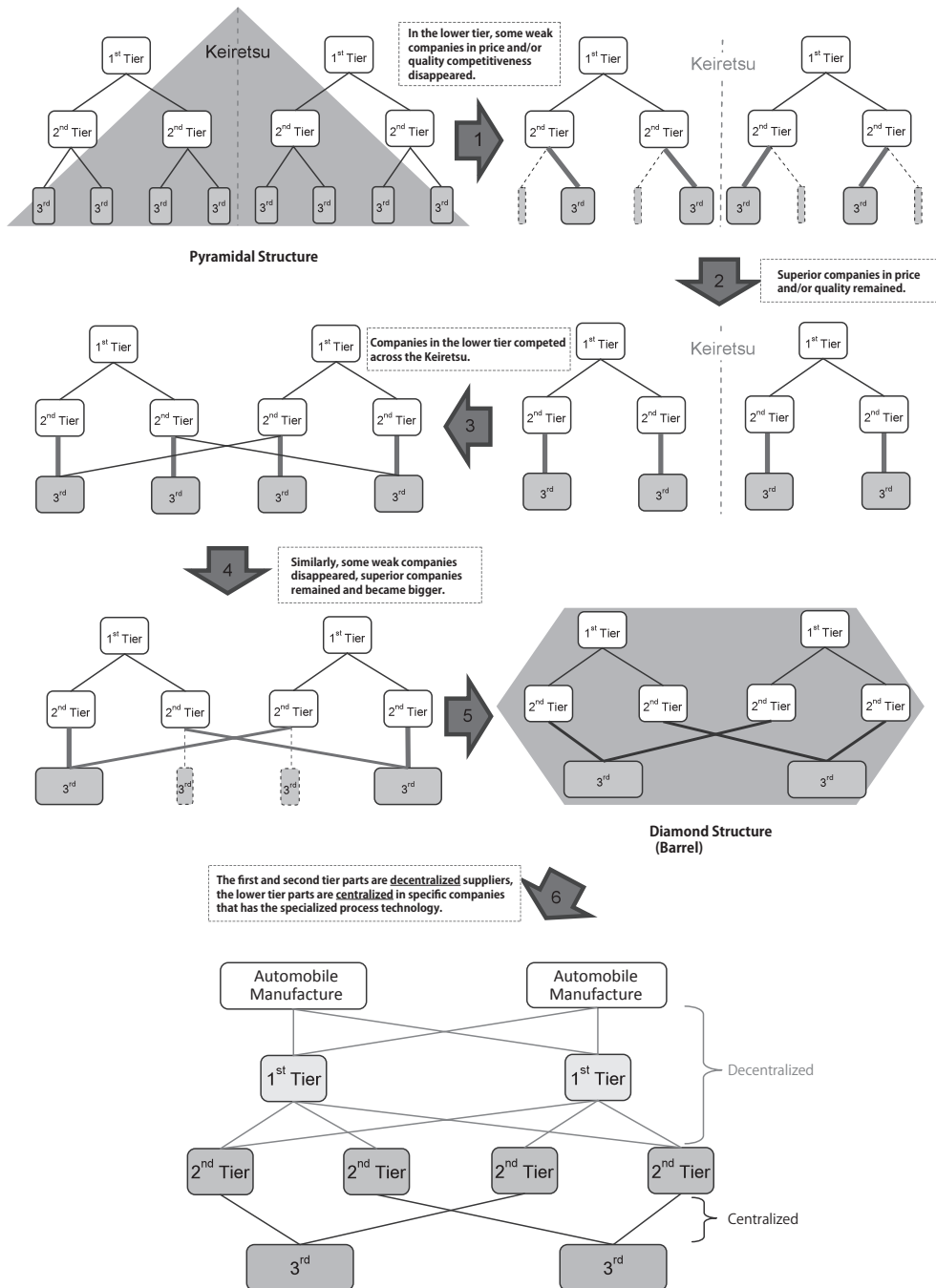
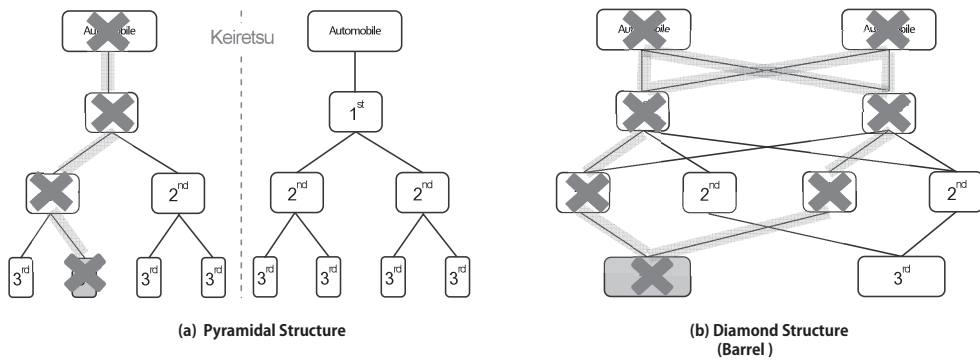


Figure 2: The Changes of Supply Chain Network of Automobile Industry

collapse of 'bubble' economy, the yen's appreciation (1990:140 yen, 1995:79 yen to the dollar), the 1995 Kobe Earthquake, and the increase of the consumption tax (from 3 percent to 5 percent; 1997). Due to the impact of these crises, the Japanese automobile industry accelerated shifting of production to overseas site, moving toward optimal parts, and promotion of the establishment



**Figure 3:** The Damages of Supply Chain Network by Disaster

of a global supply network. In fact, there are some Japanese companies which supply parts to not only assemblers inside the keiretsu group but also outside the group, as shown Figure 1b. Moreover, some of the major parts manufacturers supply the entire Japanese automobile manufacturers. In fact, a lot of suppliers in the lower tier provide own products across the keiretsu. The first and second tier parts (functional components) are decentralized amongst several suppliers, the lower tier parts (simple components) are centralized in one company that uses specialized process technology (Fujimoto 2011). This is the “diamond structure” or “barrel structure” of supply chain of Japanese automobile industry. Figure 2 shows the changes of this structure.

In pyramidal structure case, as shown Figure 3a, if disaster suffers in the lower supplier’s plant, although automobile assembly plants not damage, they were interrupted. Because of the supply of components from the suppliers in the lower tiers stopped. The impact of automobile industry affected in the “keiretsu” group. On the other hand, in diamond structure case, in this situation of centralized suppliers in the lower tiers, as shown Figure 3b; the production at suppliers’ plant stop, then almost every automobile manufacturer are affected by it.

In 2007, about four years before the 2011 Tohoku earthquake, there was a strong earthquake in Niigata. This earthquake isn’t known well, but Riken’s Kashiwazaki Plant in Niigata had huge damage by this earthquake, affecting the operations of all of Japan’s automobile manufacturers.

For the following chapter, I will attempt to clarify the effects that the lack of a small component in automobile affected to entire Japanese automobile industry.

### 3. Riken’s Kashiwazaki Plant (2007 Niigata Chuetsu-offshore Earthquake)

#### 3.1 Riken’s Overview

The Riken Corporation’s major products are piston ring of engine parts and seal ring of transmission parts, as shown Table 1. There are, depending on Riken’s parts, different companies that Riken supplies parts. In the case of Mazda, directly procure piston rings from Riken, transmission parts are supplied from Riken to Jatco (transmission manufacture in Nissan keiretsu),

**Table 1: Overview of the Riken Corporation**

Capital		¥8,573,597,000 (as of March 2011, all of Riken Corporation)
Number of Employees		1,627 (as of March 2011, all of Riken Corporation)
Major Products		Piston Ring <ul style="list-style-type: none"> <li>• Engine parts</li> <li>• Approx. 50% of domestic market share</li> </ul> Seal Ring <ul style="list-style-type: none"> <li>• Transmission parts</li> <li>• Approx. 70% of domestic market share</li> </ul>
Major Customers	Automobile and other Vehicle Manufacturers	Honda, Suzuki, Toyota, Nissan, Fuji Heavy Industries. Ltd, Mitsubishi, Mazda, Daihatsu, Mitsubishi Fuso Truck and Bus, Nissan Diesel, Hino, Isuzu, Yamaha, Kawasaki Heavy Industries. Ltd, Ford, BMW, VW/Audi, OPEL, FIAT, Renault, Porsche, Jaguar, Hyundai, Kia
	Distributors and Sales Agents for Automobile Parts	Eiwa, Empire, Auto Parts Uematsu, Global Tsusho, Chicago Product, Sumisho Machinery Trade, Daisho Trading, TMT Trading, Toko Trading, Parts International, Heian Boeki, Meiji Sangyo, Motorix International
	Automotive Parts Manufacturers	Aisin AW, Jatco, Musashi Seimitsu Industries, Calsonic Kansei, KYB, Nissan Kogyo, Yamaha Marine, BrotherPrecisionIndustry, Valeo, Aisin Seiki, Waga Precision, ZF

Source: Corporate Information of Riken

after then supplied to Mazda. Power steering's parts are supplied from KYB (Kayaba Co., Ltd.), and then supplied to Mazda. Riken produces them in Riken's Kashiwazaki Plant. In 2007, this Plant had huge damage from the Niigata Chuetsu-offshore Earthquake. The seismic center of this earthquake was close to the Riken's Kashiwazaki plant. The Riken's Kashiwazaki Plants had suspended operations for one week after this earthquake, then, the Japanese automobile manufacturers also interrupted operation.

### 3.2 Riken's Piston Rings

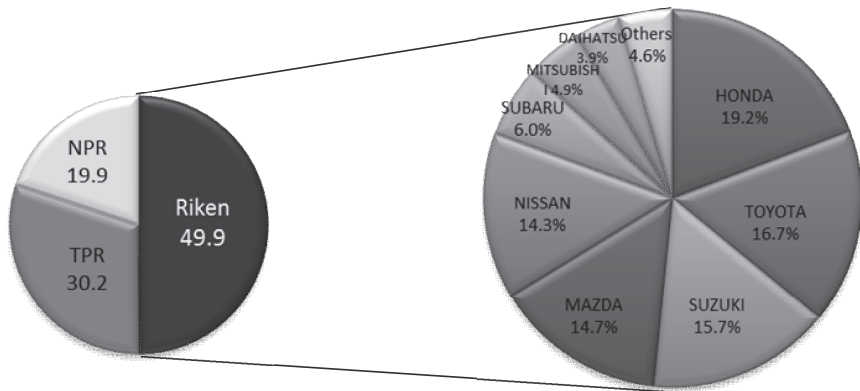
The Riken's Kashiwazaki Plant products approximately 50 percent of the piston rings that used by the entire automobile industry in Japan (the world market share was approximately 20 percent). There are only three companies of piston ring in Japan, thus, piston ring market is an oligopoly. In this market, Riken supplies the most piston rings to all automobile manufacturers, as shown Chart 1. Since all automobile manufacturers depended on the supply of piston rings and other components from Riken's Kashiwazaki Plant, all plants of automobile manufacturers suspended production.

### 3.3 Chronological Events at Riken's Kashiwazaki Plant (Operations)

Following the occurrence of the earthquake on 16 July 2007, all the production lines had stopped at Riken's Kashiwazaki Plant. Fortunately, 16 July was holiday. Although, Riken's Kashiwazaki Plant was off duty, several employees were injured while working on equipment maintenance at Riken's facilities. As to the equipment, there occurred some slide slip, some pieces

of the equipment got lopsided or toppled over. Some of products that were finished or in process, molds, jigs and tools, and measuring instruments fell to the floor. Riken’s machine’s losses were 100 million yen, inventory’s losses were 200 million yen, and it took recovery cost 1,200 million yen (consolidated).

The automobile manufacturers voluntarily provided assistance with engineering and repair immediately after earthquake and helped Riken restart much more quickly than it would have been able to on its own. They helped clean up and repair the damage to manufacturing equipment and the loss of building contents. Total number of assistances was approximately 9,000 from about 25 automobile manufacturers and automobile parts manufacturers. That is to say,



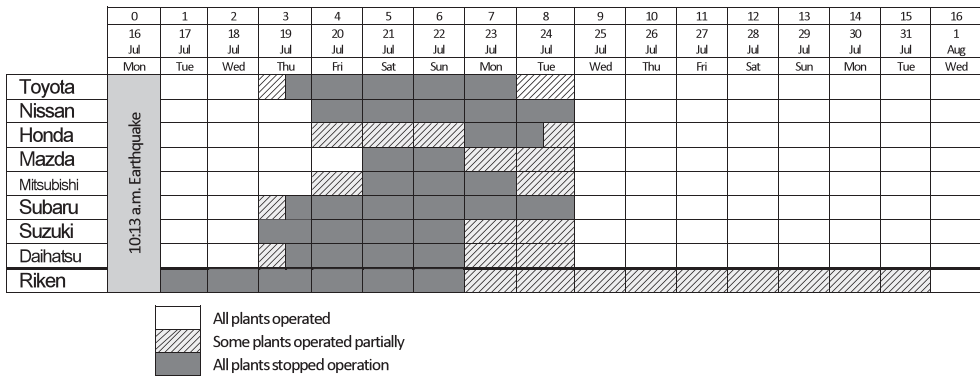
Source: Daniel E. *Supply Chain Disruption Risk and Recovery: Temporary Diversification and Its Limits*, 2011

**Chart 1:** Monthly Supplies and Purchases of Piston Rings in Japan, in 2005

**Table 2: Recovery at Riken’s Kashiwazaki Plant**

Date	Days Later	Events	Operations
16 July 2007	0	The 2007 Chuetsu Offshore Earthquake struck at 10:13 a.m. All the production lines at Riken’s Kashiwazaki plant had stopped. Toyota sent Riken about 20 employees to assess the situation of the damages.	0%
17 July - 2007	1	6 companies voluntarily provided 41 assistances to Riken’s Kashiwazaki Plant.	0%
18 July 2007	2	Mazda sent Riken 8 employees.	0%
19 July - 2007	3	There were 700 skilled volunteers from automobile manufacturers and parts manufacturers. ( Toyota:200 employees, Mazda: 13 maintenance engineers)	0%
22 July 2007	6	Riken started trial operation.	0%
23 July 2007	7	Riken resumed productions of major products (piston rings, seal rings, and camshafts) at 10 a.m. Part of the lines didn’t resume yet. 25 companies provided 830 assistances 23-24 July.	Almost 100%
1 August 2007	16	Riken announced Riken’s complete recovery.	100%

Source: Press Release of Riken and articles of Nihon Keizai Shinbun (Japan’s most prestigious economic newspaper)



Source: Press Releases of each automobile manufacturers and articles of Nihon Keizai Shinbun

Figure 4: Operations of Major 8 Automobile Manufacturers in Japan

Automobile/parts manufacturers provide five times as many assistances as Riken’s employees. Table 2 shows the chronological events at Riken’s Kashiwazaki Plant. On 23 July which one week after the earthquake, Riken’s Kashiwazaki Plant resumed operations.

### 3.4 The Riken’s Affects to Japanese Automobile Manufacturers

Riken has specialized in design and technologies of piston rings and other automobile components, so that other suppliers don’t imitate it easily. All major automobile manufacturers in Japan depend on Riken’s piston rings and other parts. In addition to specialization, “Just-in-Time” that aimed to reduce the inventory level of components at automobile manufacturers and the upper tail suppliers, had stopped productions of automobiles in Japan. Figure 4 shows the operations by automobile manufacturers after 2007 Niigata Chuetsu-offshore Earthquake. Although Toyota, Subaru, Suzuki, and Daihatsu had suspended operations from 19 July, Mazda went on operating. Because plants of Mazda are in the far distance from Riken’s Kashiwazaki Plant, so that there was a time lag of the delivery. This is similar to Honda’s mini-vehicle production line in Kumamoto Plant.

## 4. Renesas Electronics Corporation’s Naka Plant (2011 Tohoku Earthquake)

### 4.1 Renesas Electronics Corporation’s Overview

The major products of Renesas Electronics Corporation (REC) are Microcontroller, System LSIs/System on Chip (SoC) Devices, and Analog & Power Devices, as shown Table 3. In 2011, REC had huge damage from the Tohoku Earthquake. Especially, REC’s Naka Plant had suspended operations for 82 days after earthquake. REC’s Naka Plant produced a little less than 20 percent of REC’s Microcontroller Units (MCUs) and System LSIs/SoC Solutions, and a little less than 10 percent of REC’s Analog & Power Devices.

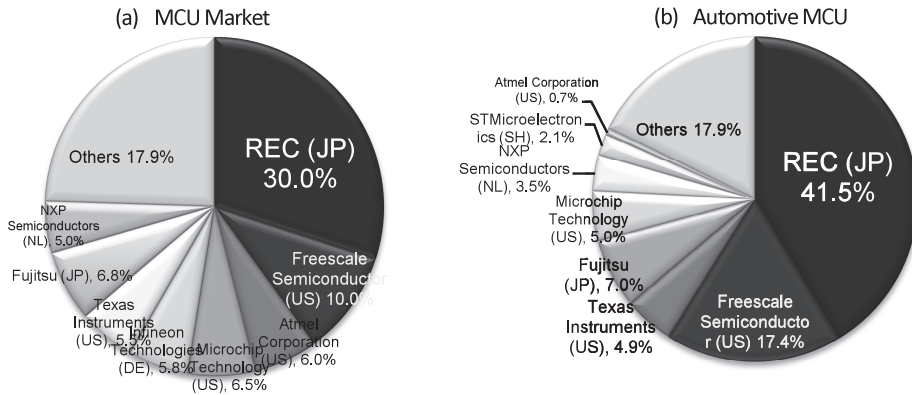
### 4.2 REC’s Microcontroller

REC is the world’s largest manufacturers of MCU with market share. Chart 2a shows the worldwide MCU market share in 2010 from the Databeans Estimate. In 2010, before the Tohoku

**Table 3: Overview of Renesas Electronics Corporation (as of April 2012)**

Capital	¥ 153.2 billion
Number of Employees	44,000(Consolidated)
Major Product	Microcontroller System LSIs/SoC Devices. Analog & Power Devices.
Group Companies	In Japan <ul style="list-style-type: none"> <li>• 1 Sales Companies.</li> <li>• 14 Manufacturing and Engineering Service Companies.</li> <li>• 7 Design and Application Technologies Companies.</li> <li>• 2 Business Corporations and Others.</li> </ul> Overseas <ul style="list-style-type: none"> <li>• 11 Sales Companies.</li> <li>• 8 Manufacturing and Engineering Service Companies.</li> <li>• 4 Design and Application Technologies Companies.</li> <li>• 6 Business Corporations and Others.</li> </ul>

Source: Corporate Outline of REC's



Source: Databeans Estimates, Company Reports

Note: Amount of the MCU revenue was 14.8 billion dollar in 2010

Amount of the automotive MCU revenue was 5.36 billion dollar in 2010

**Chart 2: Worldwide MCU Market Share by Suppliers in 2010**

Earthquake, the MCU market share of REC was 30.0 percent, the MCU revenue of REC was 4,441 million dollar. According to other market research companies, REC's MCU market share was 29 percent (Gartner), 27.3 percent (IHS iSuppli) in 2010.

In 2010, the automotive MCU market (5,358 million dollar) was 36.2 percent of the total MCU market (14,800 million dollar). Chart 2b shows the worldwide automotive MCU market share in 2010 from the Databeans Estimate. The automotive MCU market share of REC was 41.5 percent, the automotive MCU revenue of REC was 2,221 million dollar.

### 4.3 Chronological Events of REC's Naka Plant (Operations)

The impact of the earthquake on 11 March 2011 caused eight REC's plants (include Naka Plant) out of twenty two of REC's plants in Japan to immediately shut down production. These



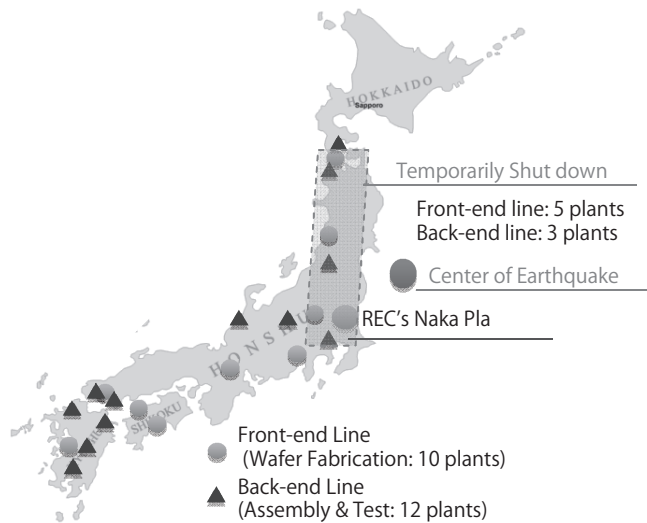


Figure 5: Locations of REC's Plants

Table 4: Chronological Events at REC's Naka Plant

Date	After days	Events
11 March 2011	0	The 2011 Tohoku Earthquake struck at 2:46 p.m. 7 (include Naka Plant) out of 22 of REC's plants in Japan have temporarily shut down production. REC's production volume felt to approximately 50%.
13-14 March 2011	2-3	8 REC's offices/sites in Japan had been impacted from the blackout measure by Tokyo Electric Power Company, These offices/sites shut down operation production.
21 March 2011	10	REC estimated that Naka Plant will resume part of production on 1 September.
28 March 2011	17	REC announced that Naka Plant will resume part of production on 15 July.
22 April 2011	42	REC announced that Naka Plant will resume part of production on 15 June.
23 April 2011	43	Naka Plant started test production at the 200-mm wafer fabrication line.
25 April 2011	45	Naka Plant started test production at the 300-mm wafer fabrication line.
11 May 2011	61	REC published that Naka Plant will resume 200-mm wafer fabrication line of production at Naka Plant on 1 June, 300-mm line of production on 6 June.
1 June 2011	82	200-mm wafer fabrication line started mass production.
6 June 2011	87	System LSI (300-mm) wafer fabrication line started mass production.
10 June 2011	91	REC announced that timing on when the supply(shipment) capacity will return to that of pre-earthquake levels in the end of September.
June 2011		REC's production volume recovered to approximately 85%.
Mid-September 2011		The supply(shipment) capacity returned to that more than pre-earthquake.

Source: Press Release of REC and articles of Nihon Keizai Shinbun

plants were five semiconductor wafer plants and three assembly plants, as shown Figure 5. Due to plant's shutdown, production volume of the whole REC's 200-mm wafer fabrication fell to 50 percent after this earthquake.

Table 4 shows the chronological events at REC's Naka Plant. REC's Naka Plant was the worst affected in all REC's plants. Although, just after the Tohoku Earthquake, initial predictions estimated that Naka plant would resume production in September 2011, in fact, production at Naka Plant restarted on 1 June 2011. The supply/shipment capacity returned that of pre-earthquake levels in the middle of September 2011, six months after the 2011 Tohoku Earthquake. Total number of assistances was approximately 80,000, and there were maximum 2,500 assistances per day. This number was many more than 1,900 employees of REC's Naka Plant (including its relation corporations).

#### 4.4 The 2011 Tohoku Earthquake's Affects to Automobile Manufacturers

REC is a major manufacturer of MCUs which Japanese companies holding a large share worldwide. The effect on customer companies' supply chain was very large. In fact, the Japanese Automobile manufacturers had been hit hard by shortages of MCUs and other components, causing REC's plants and other lower tiers had shutdown. Most automobile manufacturers was few direct damage to plants by the earthquake, but Nissan's Iwaki plant had with aftershocks still heavily impacted the region, its recovery took longer than the other plants. Toyota suspended production at all plants for about two weeks between from 14 March to 26 March. Following this, the domestic automobile productions of Toyota in March 2011 was recorded as 129,491 units. Compared with the 347,281 units total recorded for the same month of the previous year, this is a decrease of 217,790 unit or 37.3 percent. It was the 38 days after the Tohoku Earthquake that all Toyota's plants resumed operation. Similarly, others took about a month to resume all plant's operation.

Table 5 shows the reductions in production by the Tohoku Earthquake. Automobile production of the whole Japanese automobile manufacturers in March 2011 was recorded as 403,937 units. Compared with the 945,220 units total recorded for the same month of the previous year, this is a decrease of 541,283 unit or 42.7 percent. It's also 5.3 times as many as the reductions in the 2007 Niigata Chuetsu-offshore Earthquake and over 38 times of the 1995 Kobe Earthquake.

**Table 5: Reductions in Productions by the Earthquake**

Earthquake	Reduction	Productions
The 1995 Kobe Earthquake	14,021 (January 1995)	January 1994: 772,858 January 1995: 758,837
The 2007 Niigata Chuetsu-offshore Earthquake	101,636 (July 2007)	July 2006: 977,856 July 2007: 876,220
The 2011 Tohoku Earthquake	541,283 (March 2011)	March 2010: 945,220 March 2009: 403,937

Source: Active Matrix Database System of JAMA

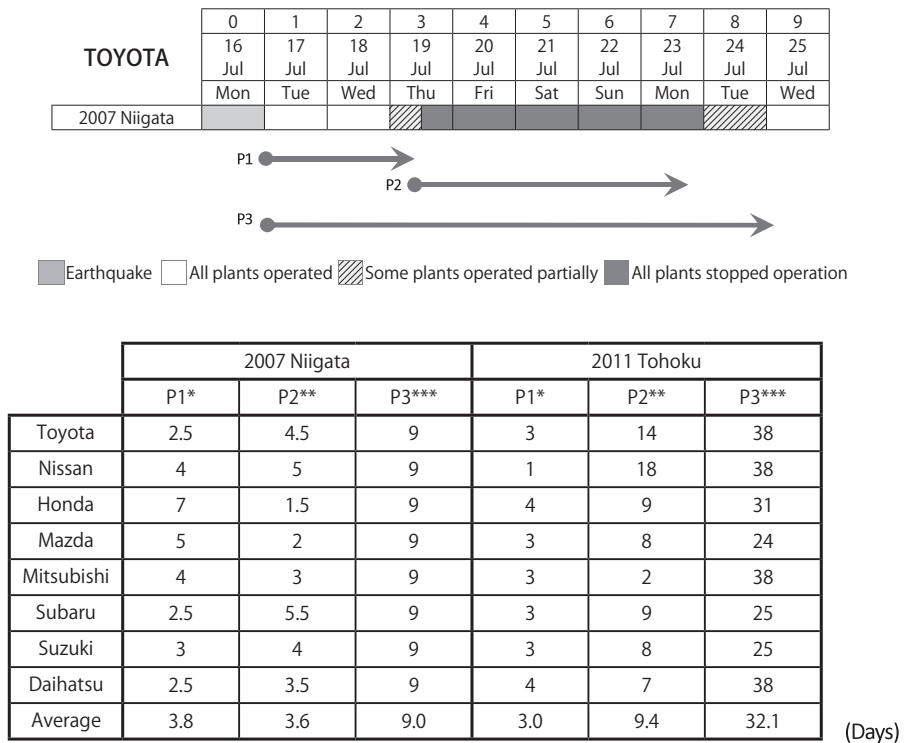
## 5. Summary of Earthquake Effects on Production

### 5.1 Earthquake's Effects to Automobile Manufacturers

#### 5.1.1 The Effect to Automobile Manufacturers' Operation

After both earthquakes, Japanese automobile manufacturers decided/executed the disruption of all assembly plants early. In case of Toyota, on the evening of the 19 July, 2.5 days after the 2007 Niigata Chuetsu-offshore Earthquake, all Toyota's plants started to suspend operation. Similarly, after the 2011 Tohoku Earthquake, all plants started to suspend operation 3 days later. The average number of days of the major eight automobile manufacturers was 3.6 (in 2007), and 3.0 (in 2011), as shown P1 in Figure 6.

Considering the huge scales of these earthquakes and damages by them, their decision of the shutdowns and the resumption of operations were speedy and appropriately. The reason why Japanese automobile manufacturers decided/executed the disruption so early after both earthquakes, there were related to the Toyota Production System (TPS) that a widely accepted production system. TPS was established based on two concepts - "jidoka" and "Just in Time (JIT)". "jidoka" means that when a problem occurs, the equipment stops immediately, preventing defective products from being produced. For this reason, there were not wrong decisions for Japanese automobile manufacturers to stop production lines/plant by both disasters. The second



\* P1: The number of days from the day on which the earthquake stroke until the day on which all assembly plants stopped operation.  
 \*\* P2: The period of days in which all assembly plants stopped operation  
 \*\*\* P3: The number of days from the day on which the earthquake stroke until the day on which all assembly plants resumed operation.

Figure 6: Comparison of Automobile Manufacturer's Recovery Time

is the concept of JIT, in which each process produces only what is needed, when it is need, and in the amount needed. “Just in Time” made eliminating unnecessary inventories in process. To keep inventories to acceptably low level achieve not only cost reduction but fast recovery. It is important for disaster-struck plans to recover quickly from the destructive effects of seismic disaster.

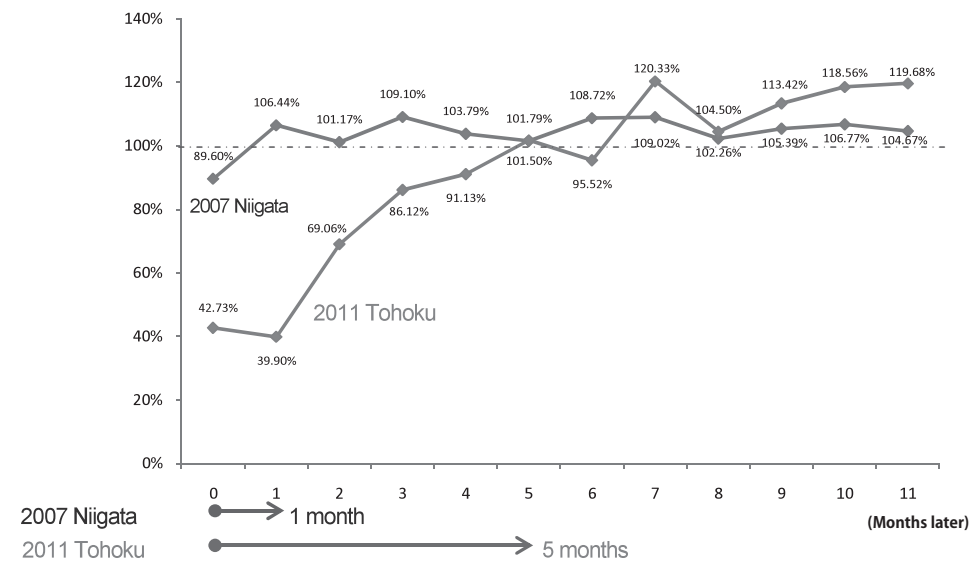
### 5.1.2 Speed of the Recovery

As shown P3 in Figure 6, in the case of Toyota, on 25 July, 9 days after the 2007 Niigata Chuetsu-offshore Earthquake, all Toyota’s plants resumed operation. Similarly, after the 2011 Tohoku Earthquake, all plants resumed operation 38 days later. The average number of recovery days of the major eight automobile manufacturers was 9.0 in the 2007 earthquake, and 32.1 in the 2011 earthquake. Like this, it took over a month to resume the operation of all plants in the 2011 Tohoku Earthquake.

This delay effects to the recovery speed of production. Chart 3 shows the rate of the domestic production of all automobile manufacturers for one year after the earthquake. Although the whole Japanese automobile manufactures had recovered their production after a month of the 2007 Niigata Chuetsu-offshore Earthquake, it took five months until the production of them returned to normal production after the 2011 Tohoku Earthquake.

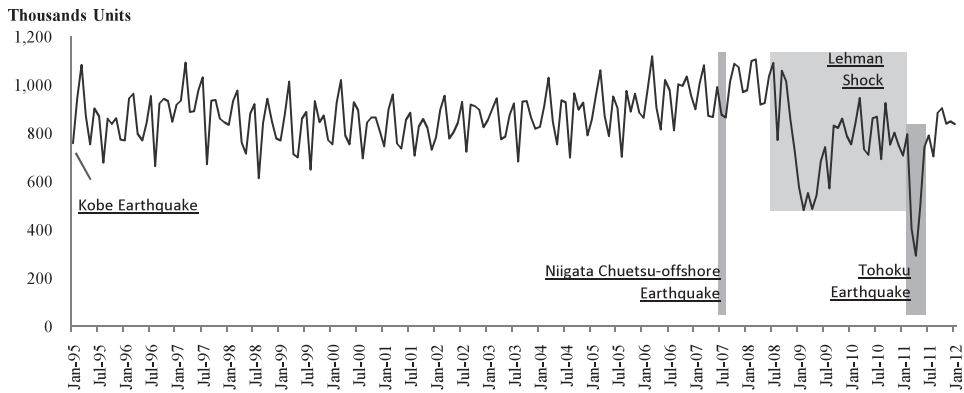
## 5.2 Chronological Changes of the Domestic Product in Japan

Chapter 9 shows the changes of the domestic automobile products in Japan from January 1995 through March 2012. It appears two things from this chapter. First, the disaster’s impacts to Japanese automobile manufacturers’ production were not more than the depression’s impacts.



Source: Active Matrix Database System of JAMA  
 Note: The previous year’s result indexed at 100

Chart 3: The changes (%) of the Domestic Automobile Products



Source: Active Matrix Database System of JAMA

**Chart 4:** The changes (Units) of the Domestic Automobile Products from Jan 1995 through Jan 2011

Second, the recovery speeds of Japanese automobile manufacturer's production at disasters were quicker rather than the depressions. Especially, in the Tohoku Earthquake, there was huge damage not only to the Japanese automobile industry but also to the whole economy in Japan. Japanese automobile manufacturers also rapidly decreased their products by interrupting of the assembly plants. Despite of them, the recovery speed after this earthquake was quicker than that of the depression such as the Lehman Shock.

### 5.3 Disaster and JIT

As shown Table 6, in the case of JIT, the inventory level/cost of the assembly plants of automobile manufacturers is lower, the transportation cost is higher. Because the lead times of the transportation are shorter and more frequent. Due to the fewer inventories, the adaptability of environments such as depression and crisis is higher than non JIT.

After both Earthquakes, there were not a few articles that insisted of the limitations of JIT in newspaper, journal, and public reports. But their arguments focused on that the lower inventory caused to the shutdown of plants after a disaster. As was mentioned Section 5.1, there were not wrong decisions for Japanese automobile manufacturers to immediately stop their production plants by both disasters. It was very important to recovery production quickly. Because of the Japanese automobile manufacturers knew it, they voluntarily provided a lot of assistances to the damaged plants of the lower tier companies do to recover plants quickly. As shown Table 11, in JIT case, the recovery speeds are quick, excluding large scale disasters such as the Tohoku Earthquake. This is reason that the loss on disposal of inventories at the damaged plants reduces. If damaged plants have a lot of inventories, the loss on disposal of inventories increase, they need more time to recover. Therefore, it is impossible to say definitely that the limitation of JIT exists in the situation of disasters.

As for the risk mitigation strategy to deal with large scale disruptions of supply chain

Table 6: Comparisons of JIT and Non JIT

Normal	Inventory Level / Cost	Transportation L.T. / Cost	Environment Adaptability
JIT	Low / Low	Short / High	High
Non JIT	High / High	Long / Low	Low

Abnormal (Depression)	Storage Time	Inventory Cost	Inventory Risk
JIT	Constant (Short)	Constant (Low)	Constant (Low)
Non JIT	Longer	Higher	Higher

Abnormal (Disaster)	Shutdown of Plants	Loss on disposal of Inventories	Recovery Speed of Plants
JIT	Damaged Plants: Immediately Other Plants: Earlier	Damaged Plants: Low Other Plants: Non	Damaged Plants: Quick Other Plants: Quick
Non JIT	Damaged Plants: Immediately Other Plants: Later / Avoid	Damaged Plants: High Other Plants: Non	Damaged Plants: Slow Other Plants: Slow

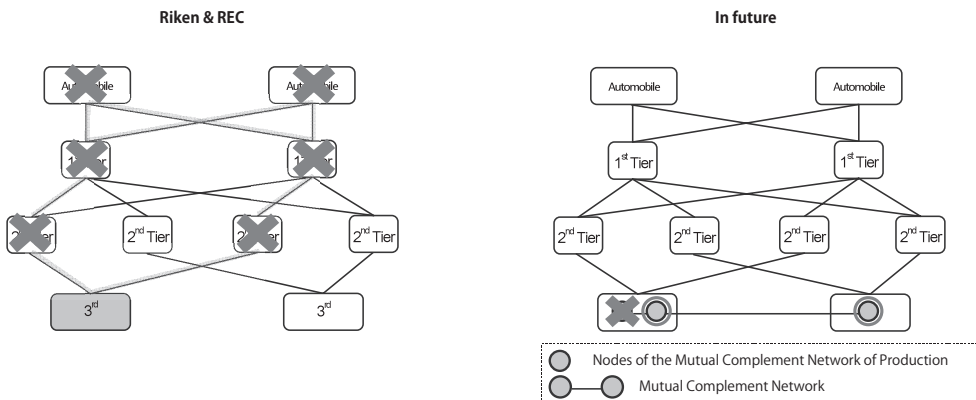


Figure 7: Mutual Complement Network

network, make provisions to move to alternative sites for production, if they are unable to produce component by a disaster, as shown Figure 7. In Riken and REC cases, in spite of the damaged plants disrupted for a long time, they were not able to immediately produce equivalent components in other plants. This reasons that both corporations created the higher technical skill and the strength of price competitiveness in a plant, come to hold a relatively large world market share of some particular automobile components

## 6. Conclusion

This paper has revealed the invisible damages by focusing on the effects to the supply chain

network, production system in Japanese automobile manufacturers by these disasters. As for recovery speed from disasters, JIT operated to advantage to the Japanese automobile industry. In addition, fundamental issues of their damages were unveiled.

As for TPS, there were not wrong decisions for Japanese automobile manufacturers to stop production lines/plants by both disasters. The comparison of disaster and depression in terms of the decreasing speed/volume of supply and the recovery speed. It is impossible to say definitely that the limitation of the JIT exists.

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