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THE EVOLUTION OF DISASTER-RESPONSE CAPABILITIES: THE CASE OF TOYOTA[1]

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Abstract

This Chapter takes an in-depth look at Toyota's current disaster-response capabilities and how they have evolved in the face of numerous natural and man-made disasters in the company's supply chain in Japan over the past forty years. The chapter also contains excerpts from interviews with three individuals who have first-hand experience managing the front line of Toyota's disaster responses. This chapter clearly reveals the principles that guide Toyota in dealing with disasters and the company's view that the individual skills and organizational capabilities that are built up through normal *kaizen* activities and just-in-time production are also highly effective in facilitating disaster responses.

Keywords

Kaizen capability, Evolutionary capability, Kanban, Nihonzaka tunnel fire, Kobe earthquake, Kumamoto earthquake, Aisin Kyushu, Takeyama foundry, Judgements, decisions and actions, Operations management development division, Disaster response center, Production control division, Expertise, Toyota last, Taiichi Ohno, Multi-skilled, Piping, Nagoya flood, Specialist team, Recovery of the damaged plant, Toyota's principle, Genbutsu, Leadership, Standard procedures, Pull system, Excessive division of labor, Job rotation, Judgments/decisions/actions, Judge, decide and act, Human networks, Manual tools, Long bars, Anchor bolt, Routing, Plant engineering, Communities, Manual tools and techniques, Confirmation of employees' safety, Overspecialization, Order to leave the building, Skills, Great Hanshin Awaji earthquake, Human-community-production priority, Tacit knowledge, Explicit knowledge, Continuous improvements, Priority, Initial triage, Nankai trough (megathrust) earthquakes

1. TOYOTA'S CAPABILITIES AND RESILIENCE

1.1. Introduction - Can Manufacturing Capabilities Enhance Disaster-Resilience?

This and the following chapters will analyze a Japanese firm that has repeatedly demonstrated its great capabilities and leadership in recovering from various disasters and restoring damaged supply chains—the Toyota Motor Corporation and its group.

Toyota is also famed for having distinctive manufacturing and supply chain capabilities, known as the Toyota Production System (TPS), which emphasizes good flows of value added to customers, as well as their continuous improvement and evolution (Schonburger 1982, Monden 1983, Ohno 1988, Womack et al. 1990, Fujimoto 1999, Shimokawa and Fujimoto 2009). We therefore conjecture that a firm with strong manufacturing capabilities for competitiveness may also have significant capabilities in terms of supply chain resilience and robustness.

We will examine this hypothesis mainly through interviews with three key Toyota employees, who actually led rescue, recovery and restoration activities for suppliers hit by disasters. Special attention will be paid to Toyota's Operations Management Development Division/Department (OMDD; *Seisan Chousa Bu/Shitsu*), which has been providing TPS continuous improvement and education at Toyota and its suppliers since 1970 (Fujimoto 1999)[2]. We interviewed former OMDD managers (often called TPS *Shusa*) in charge of the recovery activities after the 1995 Kobe Great Earthquake, 2011 Tohoku Great Earthquake, 2016 Kumamoto Earthquake, as well as other earthquakes, fires and floods in the past few decades.

Rather than analyzing their comments from a theoretical point of view, we will present them by keeping as close as possible to what was actually said. Their stories are convincing enough for us to come to two main conclusions, e.g., that capability building is the most important measure to enhance the anti-disaster robustness of supply chains, and that capabilities for the continuous improvement (*kaizen*) of industrial sites (*genba*) are compatible with capabilities for quick and accurate preparations and actions to counter major supply chain disruptions.

1.2. Toyota's Manufacturing, Kaizen and Evolutionary Capabilities

Before discussing Toyota's actions and capabilities in times of supply chain disasters, let us first outline its capabilities in terms of competitiveness.

As for the revealed competitive performance, the main stylized facts concerning the post-War world automobile industry can be summarized as follows.

First, a group of Japanese firms and genba demonstrated significantly higher levels of productive performance in the world auto industry during the period 1970s-2010s (Womack et al. 1990, Clark and Fujimoto 1991, Holweg and Pil 2005). Second, high-performance Japanese manufacturers, like Toyota, improved their performance in relation to productivity and manufacturing quality faster and more consistently than other firms prior to the 1980s. Third, these high levels of performance and continuous improvements stemmed from overall manufacturing capabilities rather than from individual technologies or practices, such as robots and kanban techniques. Fourth, the Toyota-style system was not created at once, but it gradually and cumulatively evolved over time, mainly between the 1940s and 1980s (Cusumano 1985, Fujimoto 1999, Shimokawa and Fujimoto 2009).

[2] This unit for TPS kaizen and education was first set up in 1970 as Operations Management Development Department (*Seisan Chousa Shitsu*) by Mr. Taiichi Ohno. Its name changed to Operations Management Development Division (*Seisan Chousa Bu*), and then back to Operations Management Development Department (*Seisan Chousa Shitsu*) in 2011. Yet, the functions of *Seisan Chousa Shitsu* and *Seisan Chousa Bu* are basically the same, so we will use the name OMDD for both of these two organizational units interchangeably in this book.

As a result, while many Japanese electronics and digital industries lost international competitiveness after the 1990s (e.g., during the post-Cold-War period), the Japanese automobile manufacturers still have about 30% of the global market share, and Toyota remains one of the world's largest automakers.

Today, the manufacturing system at Toyota is recognized as an organizational capability (e.g., a system of organizational routines that contribute to competitive performance) in manufacturing. As indicated by the Toyota Group's kaizen consultants, it consists of around 400 manufacturing routines, all of which collectively improve and maintain fast, efficient and precise flows of value added (design information, according to this book's interpretation) to the customers. While the details of such capabilities are discussed elsewhere, a brief summary of key features is presented here (Fujimoto 1999). We classify the firm's capabilities into three layers: (i) ordinary *manufacturing capability*, as a set of routines to maintain a "good flow" of design information to the customers; (ii) *kaizen capability*, as a set of routines to continuously improve that flow; (iii) *evolutionary capability*, as dynamic capability-building capability for the evolution of routines, whatever they may be, including both deliberate and emergent processes (Mintzberg and Waters 1985).

Toyota's *ordinary manufacturing capability* includes such routines as Just-in-Time (including *kanban*), *jidoka* (automation with human intervention), small-lot or piece-by-piece production, standard operating procedures developed by work group leaders, multi-skilling (operators carrying out inspections, minor maintenance, and so on), multi-process operators (*takoteimochi*), *poka-yoke* (simple physical devices for preventing defects), visualization of problems (*mieruka*), building-in-quality, self-inspection, continual monitoring of value-adding time ratios, and so on.

The company's *kaizen capability*, regarded also as an organization's routinized ability for continuous learning, is based on standardized practices of finding and solving problems. Such kaizen activities may be carried out by workers, work groups/teams and their leaders, shop engineers (*kojo gijutsu-in*) and other plant/process/equipment engineering specialists, individually or collectively. Such kaizen activities used to be seen as a collection of small incremental process innovations developed within each work group. However, recent field studies of some Toyota plants (Iwao 2017) have revealed that kaizen is actually a mixture of process (and product, if necessary) improvements of different proportions and that shop floor engineers play the role of linking pins between the work teams and the headquarters engineers, so that kaizen activities may help cope with both small and big process changes. Whether Toyota's kaizen capability can deal with not only small but also large-scale changes, including recovery from major supply chain disruptions, is an important point in the context of the present book. We will discuss it later in this chapter.

Toyota's *evolutionary capability* is what makes it truly unique, setting it apart from most other manufacturing firms, but this feature is not easily observed in the everyday workings of companies. It refers to a firm's distinctive ability to create a set of effective (e.g., ex-post, rational) long-term organizational routines faster and earlier than its competitors. Generally speaking, however, the evolution of an artificial system can occur along multiple paths that include rational decision making, leaders' visionary initiatives, organizational actions forced by historical imperatives, as well as pure chance, and it is impossible to identify in advance which paths will emerge. The result of such evolutionary paths can be "expected success," "unexpected failure," "unexpected success," or even "unexpected success caused by previous unexpected failure," but the actual outcome produced cannot be predicted. A firm's evolutionary capability, therefore, denotes its ability to build additional capabilities *anyway*, whichever the paths taken and whatever the consequences may be (Fujimoto 1999). And one of the entirely unexpected events that firms and genba will inevitably experience is the next large-scale disaster.

Toyota has often been described by the media and researchers as a company that seldom makes big mistakes, thanks to visionary leaders, deliberate planning and capability building that turn out to be mostly successful. In a sense, it is indeed true that the firm's distinctive competence resides in its ability to find and solve many small problems to continuously improve its competitiveness.

Nonetheless, like many other companies, Toyota has also made mistakes and suffered failures in the past. What is remarkable, though, is the fact that, after almost every failure, it has managed to recover by mustering additional capability building, not only to solve past problems but also to enhance its overall competitiveness. This is indeed a manifestation of its evolutionary capability building.

We can analyze Toyota's resilience and preparedness vis-à-vis major disasters through the above framework of kaizen capability and evolutionary capability. That is, if this company has distinctive strengths not only in continuously improving its manufacturing competitiveness (e.g., kaizen capability) but also in enhancing its capabilities after unexpected disasters (e.g., evolutionary capability), we may infer that these two aspects share some common traits in terms of values, mentalities, practices and organizational cultures behind them. We will investigate the above hypothesis later in this and the next chapter by using our interview records.

1.3. A Brief History of Toyota Facing Major Disasters

Keeping in mind Toyota's evolutionary capability, or organizational ability to learn from past disasters in preparation for the future, let us now move on to a brief history of how Toyota has faced and coped with some major natural and man-made disasters causing disruptions to its supply chain. We will first focus only on certain epoch-making ones.

Toyota's parts supply disruptions can be classified according to whether the site of the disaster was a supply route or a supplier's production site, whether only one or many sites were damaged, and so on. Yet, in most cases, the suspension of Toyota's assembly lines lasted for just a few days.

1.3.1. 1979 Nihonzaka Tunnel Fire

The first major catastrophe that seriously affected Toyota's supply chain was a man-made disaster rather than a natural one, e.g., the fire that occurred inside the (outbound) Nihonzaka Tunnel along the Tokyo–Nagoya Expressway on July 11, 1979. The tunnel was closed to traffic for about one week. Complete restoration of the tunnel was finished 60 days later, on September 9. Since Toyota's assembly plants (not including consignment production plants) were concentrated around Toyota City at that time, the supply of parts from 65 companies east of the tunnel was severed, causing the temporary shutdown of the Motomachi and Takaoka Plants. However, the latter resumed regular operations on the evening of July 12. Resumption was relatively rapid because the suppliers' production lines were not damaged.

1.3.2. 1995 Great Hanshin Awaji Earthquake (Kobe Earthquake)

The Great Hanshin Awaji Earthquake on the morning of January 17, 1995, was a large-scale local earthquake (moment magnitude scale: 7.3) almost directly underneath the city of Kobe, in Hyogo Prefecture. Although a tsunami did not occur, over 600,000 houses collapsed or suffered damage, over 7,000 were burned down, and the death toll was over 6,000. The economic damage to homes, factories and infrastructures reached about 10 trillion yen (roughly 100 billion USD).

A relatively small number of the damaged plants belonged to Toyota's parts supply chain, located mostly in the central part of Japan (Aichi Prefecture), but some were indeed affected. The

earthquake caused suspension of operations at Sumitomo Electric Industries' Itami Works (brake parts) and Fujitsu Ten's Kobe Plant (car audio), as well as at their suppliers' plants located near the city of Kobe. Because of this, 29 Toyota assembly plants and their consignment production companies stopped operations on January 19 (Thursday) and 20 (Friday). However, normal operations were resumed on the following Monday, January 23. The Ikeda (Osaka) assembly plant of Daihatsu, a Toyota Group automobile manufacturer, was also affected, but supply chain damage was not severe and it restarted operations the following day, January 18.

By working together with the affected suppliers, Toyota's recovery assistance teams significantly contributed to the above quick restoration, which will be described later in this chapter. The strategy of dispatching recovery assistance teams to damaged plants was also adopted in subsequent major disasters.

1.3.3. 1997 Aisin Seiki Fire and Recovery in Alternative Sites

On February 1, 1997, a fire broke out at the Kariya No. 1 Plant of Aisin Seiki, one of Toyota group's major automotive parts suppliers, causing the destruction of its brake parts production line. Since Toyota depended on this plant for the supply of 80%–90% of its brake components, such as proportioning valves, operations at 22 of Toyota's 30 domestic assembly lines were suspended for three days. Normal operations were resumed on February 7 with reduced production volumes. Long-term suspension of production at the Kariya plant was unavoidable, since the production line was entirely burned down, and restoration was completed only at the end of April. However, many small manufacturing firms, with suitable machining capacities and located in the same region, voluntarily responded to the Aisin crisis by offering substitutive production of a fraction of the necessary parts, one after the other. Their contribution led to full resumption of parts supply and assembly plant operations within a week—much sooner than expected (see Nishiguchi and Beaudet 1998, reprinted as Chapter 5 of this book).

1.3.4. 2007 Chuetsu Offshore Earthquake

Two major earthquakes occurred in Niigata Prefecture along the coast of the Sea of Japan: the Chuetsu Earthquake in 2004 (magnitude scale 6.8) and the Chuetsu Offshore Earthquake in 2007 (magnitude scale 6.8). The Chuetsu Offshore Earthquake, on July 16, 2007, caused production stoppages at all of Toyota Group's domestic assembly plants for three days from the evening of July 19. Indeed, all of Japan's automobile manufacturers (12 companies) depended on the supply of piston rings (approx. 50% domestic share) and other parts from Riken's Kashiwazaki Plant in Niigata Prefecture. Toyota dispatched about 500 of its workers (out of 650 people in total, including support from other companies) to the disaster site to assist in resuming production at Riken's plant (see Chapter 4 of this book). Production was restarted at Kashiwazaki on Monday, July 23, and Toyota resumed normal operations on the same day. All other domestic car assembly plants were once again operational by July 25.

1.3.5. 2011 Great East Japan Earthquake

On March 11, 2011, one of the largest earthquakes in the world's modern history (magnitude scale 9.0) hit the North-Eastern part of Japan (Tohoku district). A tsunami wiped out communities and industrial facilities across over 500 km^2 of coastal areas and the accident at Fukushima's No.1 Nuclear Power Plant caused a wide evacuation area to become inaccessible. These events were described in Chapter 1.

Toyota was building and expanding its assembly plants in the Tohoku district, ironically for the purpose of dispersing its supply chains geographically, thus protecting itself from major earthquakes that seemed imminent in the central part of Japan, where most of its plants and suppliers operated. Toyota's own plants in Tohoku were inland and consequently avoided major destruction, but about 600 first-tier and lower-tier suppliers belonging to Toyota's supplier networks were located in the affected area.

Toyota's rescue and recovery teams reached or contacted many of the affected firms and plants relatively quickly. Yet, the problem was that, since the damaged area was unprecedentedly wide this time, it proved extremely difficult to identify all of them, particularly the smaller, low-tier suppliers. Even a month after the earthquake, a Toyota manager responsible for this task stated: "We know that over 500 of our suppliers were affected by the earthquake, but we still don't know exactly how many." The number was in fact about 600, as mentioned above. Two months later, the company had already narrowed down the number of the suppliers needing recovery assistance to less than ten, but the problem of invisibility of lower-tier suppliers was still unsolved.

In reaction to this, Toyota created a comprehensive supply chain database for the first time, collecting basic data about almost all the over 10,000 factories and firms in its supply chains, including their names, locations, products, customers and normal transportation routes.

1.3.6. 2016 Kumamoto Earthquake

Kumamoto Prefecture is located on the island of Kyushu, in the Western part of Japan, which is known for its relatively few earthquakes. On April 14 and 16, 2016, two large dislocation earthquakes (moment magnitude scale: 6.2 and 7.3), as well as several strong pre-shocks and after-shocks, occurred in Kumamoto. The death toll of 50 was mainly due to the collapse of buildings and nearly 200,000 people were evacuated from their homes. Damage was rather severe but limited to certain areas, unlike in the 2011 Great East Japan Earthquake.

One of the assembly plants of the production consignment subsidiary Toyota Kyushu was located in neighboring Fukuoka Prefecture, but it was luckily intact. However, Aisin, one of Toyota's major suppliers, had a plant (Aisin Kyushu) in the affected area, and the latter facility was heavily damaged. So Aisin had no choice but to borrow some space in the plants of its suppliers and customers to start temporary substitutive production of door parts, seats and other. Equipment and dies were quickly moved out of the damaged buildings, while half of Aisin Kyushu's 700 employees were also dispatched to the locations of substitutive production. The local communities were concerned that the plant may eventually be closed down, but Aisin Kyushu's president, Mr. Takahashi, stated that it would be restored right there and production would soon resume. With help from Aisin and other related companies, the situation was almost back to normal in October.

Another Toyota Group supplier affected by this earthquake was the Takeyama foundry. Less than 30 minutes after the first big shock, Mr. Hirano, vice president and plant manager of Takeyama, sent the following e-mail to Toyota: "I have never experienced such a big earthquake in my life. I'm alive, but we need to repair our plant to restart production."

Mr. Hirano organized and directed the recovery team and, by using Toyota-style kaizen capabilities and the critical path method, the plant was reopened in the afternoon of April 15, about 17 hours after the first shock. However, a second, bigger shock hit Takeyama on April 16 and severely destroyed the plant equipment. Mr. Hirano sent a second e-mail to Toyota, asking for help. The following day, Toyota's recovery assistance team of 17 engineers and technicians arrived at Takeyama and a new joint recovery team was set up. Their recovery works were conducted in an

overlapped way, from the roof to the electrical system to the mechanical system and so on. By April 28, the Takeyama plant had regained its regular production levels.

Toyota Group's initial actions to help their damaged suppliers, like Takeyama, were much faster than, for example, in the case of the 2011 Earthquake, partly because the number of affected suppliers was smaller and partly because Toyota already had the aforementioned comprehensive supplier database, which made its supply chains much more visible than in 2011.

2. INTERVIEWS WITH TOYOTA'S MANAGERS IN CHARGE OF SUPPLY CHAIN RECOVERY

2.1. Some Cases of Rescue and Recovery

In order to shed light on the typical judgements, decisions and actions of Toyota's leaders in charge of supply chain recovery, on October 28, 2016 in Toyota City, we performed a three-hour interview with Mr. A, a former manager (TPS *Shusa*) of Toyota's Operations Management Development Division. After retirement from Toyota, Mr. A was still active as a TPS consultant to other firms and factories. We will present three stories, one from 1991 and two from 1995, in which Mr. A helped Toyota's suppliers C, S and F recover from disasters. At the time of the disasters, Mr. A was in the position of providing TPS kaizen consultations to suppliers such as these in normal times. The record below, taken from the 3-hour-long interview, closely follows the order in which topics were addressed during the meeting. We think that the orderly nature of these narratives can be ascribed partly to Mr. A's excellent memory and partly to the fact that there seems to exist a standard way of thinking and acting when facing problems like these at Toyota, whether they are daily kaizen activities or unexpected supply chain disruptions.

2.1.1. 1991 Nagoya Flood - Supplier C (Mr. A)

In September 1991, heavy rains hit the city of Nagoya and the plant of Supplier C, a manufacturer of springs, was flooded. Mr. A led the recovery activities.

"On September 19, after finishing my work at a Toyota plant, I heard that all of Toyota's assembly lines would stop that night. So I went to the Disaster Response Center of Production Control Division and they said that the night shift that day and the day shift the following morning would be suspended due to a flood at Supplier C's plant, which was located next to a river.

I wondered if electrician had already been sent to C's site, because I knew from past experience that electric items get damaged and back-up motors and other electrical equipment are needed in times of flooding. I had experience working at an old Toyota plant that had been built in 1936. When there were heavy rains, sometimes water would leak from the ceiling onto our equipment and create big problems.

But the staff there did not know this and asked me why. So I told them 'If flooding happens, send in electricians.' Mr. U of the Production Control Division heard this and said 'Then you should go there now.' So I went to Supplier C that evening.

By the time I reached C's plant in Nagoya at around 6:30pm, the water had receded but not completely. At peak time it had actually come up to above the knee. I looked at the topography and understood that this was the only plant that had been damaged in the flooding. I asked C's president, who was already there, 'Please, tell me how many motors (of the production equipment) were submerged.' But no one from company C could answer, and someone said 'Maybe less than 20.'

So I said, ‘OK, we will need 15 people to cope with 20 motors. How many electricians do you have here at C now? I will ask Toyota to immediately send the rest.’ They said ‘None of them have arrived yet, but we think we can handle this, so we don’t need to bother you by making you send your rescue team.’ I replied, ‘No, this is a problem not only for your company but for the entire automobile industry.’ Indeed, this plant supplied various other automakers, although Toyota’s share was the largest. This plant made springs used in vehicles and, if production was not quickly restored, many automakers would also have to shut down their assembly lines. So I went ahead and asked Toyota to quickly dispatch 15 people who knew about electrical equipment.

Then I asked them to take me to the plant. It was completely dark and only flashlights could be used but I determined, upon first inspection, that at least 70 or maybe 100 motors were submerged and 30-40 or more control panels had been damaged by the water. So I called Toyota again and said, ‘Sorry, I said 15 people, but now I have seen the genba and found that we need at least 100 electricians. So, please, send 85 more.’

But somehow there was a misunderstanding and one Toyota plant alone sent 85 people. In total, 185 people soon arrived from Toyota. Sending back 85 workers is awkward, so the whole team of 185 began working on recovering this plant’s production. In fact, it turned out that there were 300 motors that had been under water.

After Toyota’s team came, we set up the assistance center in a corner of the plant and organized some units under it, each of which was in charge of a Toyota plant that received springs from this plant. The head of Supplier C’s maintenance department had arrived at the plant by then, so I asked him to take charge of the assistance center, explained the organizational design, and urged him to work with us and talk to us whenever problems occurred. We also made sure that people leaving the site would hand their tasks over to others and that those who finished their jobs would move on to help others.

Each member of Toyota’s assistance team had different types of expertise. For example, some of the machines in C’s plant were made in Germany and the circuit board drawings for their control panels contained markings that were seldom used in Japan, including at Toyota. But we can usually find people with the appropriate skills through discussion and communication among team members. In this case, I happened to know that such a man had come to help, so I explained, ‘There is a man here called X from Toyota’s plant Y. Find him and tell him to come here, and then ask him about these German drawings. He will know everything about them.’ In this way, we can tell who knows what from our many conversations within and across the teams.

Toyota’s Production Control Division had to decide whether to reopen its assembly lines from the night shift of Friday September 20 (the day after then flooding). That decision would, of course, affect all of Toyota’s suppliers. News came that they had decided not to reopen, so the target was to make Supplier C’s production lines and Toyota’s assembly lines reopen by Monday September 23, as we had no operations on Saturday and Sunday anyway.

During such disaster recovery activities, Toyota’ principle is to go to the damaged locations first, but to fix the production lines for Toyota last. So we fix other customers’ lines first. If the lines for Toyota are about to be recovered earlier than others, then we work on the other lines to help them reopen first, and then come back to our lines. This principle has remained unchanged for a long time, since the big flood caused by the 1959 Isewan Typhoon. We heard about such episodes over and over again from our seniors in the OMDD, originally headed by Mr. Taiichi Ohno, the creator of TPS. So it is our unchanging principle to fix the suppliers’ Toyota-dedicated production lines last.

At Supplier C, we fixed the lines dedicated to other automakers, the mixed production lines, and then the lines dedicated to Toyota. If it looked like recovery of the Toyota lines would finish first,

we would go and help with work on the other lines to ensure that Toyota's line would be the last to recover. After the reopening of C's production lines on Saturday and Sunday, production went smoothly and no shortages occurred at Toyota's assembly plants when they reopened on Monday. Lines of other automakers were also able to run at regular production levels on Monday, September 23.

Since we were at C's plant anyway, we did some kaizen activities to improve their up-time ratios, which in turn reduced overtime and increased throughput."

2.1.2. 1995 Great Hanshin Awaji Earthquake - Supplier S (Mr. A)

On the early morning of January 17, 1995, a huge earthquake almost entirely destroyed Kobe and other nearby cities. That day, Mr. A happened to be visiting a location near Kobe and he unexpectedly became the leader of the advance team helping the recovery of the affected suppliers. He stayed in the area for four days, mostly to carry out diagnosis for the main team reporting to Toyota and initial actions for two suppliers, S and F. Supplier S was a large, independent supplier of various components and its damaged plant mainly produced automobile brake parts and sinter metal parts. Mr. A stayed at Supplier S until January 18.

"On January 17, 1995, my original plan was to visit Daihatsu, a Toyota Group automaker located in Osaka, and then go to Kobe to visit supplier F. So I went from Toyota City to Osaka on January 16 and met up with the head of Daihatsu's Operations Management Development Division (OMDD) in Osaka the evening before the earthquake. The Great Hanshin Awaji Earthquake hit Kobe and other cities at 5:45 am on January 17. My hotel was intact, so we went to Daihatsu's Ikeda plant, which is close to Kobe, at around 10:00 am and found that the plant had been severely damaged by the earthquake. Public and ordinary telephones were almost unusable and there were not many cell phones at that time, but we discovered that the dedicated line between Daihatsu and Toyota was still open.

I called Toyota's Disaster Response Center in Production Control Division to check in. The head of the Production Control Division, Mr. U, picked up the phone and asked me, 'Where are you now?' I explained that I had come to visit Daihatsu and there had been a big earthquake. Then Mr. U said, 'I'm glad you're there. We have been having a hard time getting information from Osaka and Kobe. Since Toyota's help team is already on its way to Daihatsu, why don't you go and see the situation at companies and suppliers near Daihatsu?'

I asked Daihatsu for a car and a driver and at around 2:00-3:00 pm went to check on nearby companies and suppliers. Some were clearly going to be able to recover without too much difficulty, but I found that Supplier S's plant was severely damaged.

I met a senior managing director of Supplier S and asked him to show me the plant. He said that the only components that S was supplying to Toyota from that area were brake parts. They were initially reluctant to show me all three brake-parts plants, but I insisted and they agreed. Most of the production equipment had either been shifted off its base or had fallen over. It was going to be a big recovery job, so I said, 'Now I will call Toyota and ask them to dispatch a recovery assistance team to you, OK?' I also knew that we could ask Daihatsu to use its dormitory as Toyota team's sleeping quarters, so I told the people from S that they did not need to worry about finding accommodation for us.

Based on my observation of the damaged plants, I told them, 'It will take three days to move the machine tools back to the production lines and fix them, but we will be able to start trial production then and I believe the product quality will be OK.' The managing director was surprised, 'Three days? No way. It usually takes three months to build this type of production line. Even if

Toyota can dispatch enough outstanding people to help us, it will take three weeks. Absolutely no less.' So I said, 'OK, OK, we'll manage. Don't worry.' But I asked him to give the buses transporting Toyota's recovery assistance teams free access to the plant and to write a collective entry permission form for all the names on the list sent to S in advance, to speed up the recovery activities. If they did this, I assured them that it would take a maximum of three or four days to start production trials. It turned out that, with Toyota's help, they managed it in less than three days. This is Toyota's speed of making changes at normal times as well.

I then went back to Daihatsu at around 5:00 pm and reported to Toyota's head office that some suppliers were okay but Supplier S needed help. I requested that the recovery assistance team be dispatched to S. I informed Toyota of my estimates regarding the number of people to be sent and their expertise, as well as the necessary tools, materials, types and sizes of pipes, and so on. Since S's plant buildings could not be accessed by heavy equipment and did not have beams, which meant that we could not use chain blocks to lift heavy equipment, I also asked them to bring hydraulic jacks and 2-meter long bars from Toyota. I can usually give such instructions without taking notes, because experience has taught me to memorize these features.

Since S is an independent supplier, other automakers also came to offer their help. Apparently they were told that a special team from Toyota had arrived, a team that trains daily to be ready for emergency recovery efforts. In fact, the team that had come was made up of regular people from a mixture of different plants and divisions. Such people had had their skills honed by dealing quickly and effectively with the unexpected situations that occur in plants every day.

People from other companies tend to say, 'I'm a pipe fitter or electrician, or I'm here to move heavy equipment.' At Toyota, we are multi-skilled during recovery efforts too. Even when something does not fall within a person's specialization, the person will do the job if he is able to do so. For example, a piping specialist will take the screws off a control panel without waiting for an electrician. In this way we all cooperate in getting the job done.

Toyota's team members will discuss the night before, in this case at the Daihatsu dormitory where the recovery team was staying, how to proceed the next day, such as who does what and where at the site being recovered. Then, upon arrival at the plant in the morning, everyone knows where to go and can immediately start recovery activities simultaneously. In this way, there is no need to stand around and decide things after reaching the plant. Other firms' teams tend to decide to do their work sequentially, like piping first and electrical work next. So, while the piping work is going on, the other team members have to remain idle.

Nevertheless, our principle is consistently the same: 'recovery of the production lines for Toyota should be the last activity that we complete.' So, if other firms' recovery teams come in, we stay away from their lines but, if we are about to finish our recovery work ahead of them, we help them finish first."

2.1.3. 1995 Great Hanshin Awaji Earthquake - Supplier F (Mr. A)

On Wednesday, January 18, Mr. A was told by Toyota's head office to go to another large manufacturer of car audio components, Supplier F. The plant was severely damaged and operations ended up having to be stopped for four days. Mr. A stayed at Supplier F until January 20. He concentrated mainly on verification of employees' safety, provision of food, water, relief supplies and accommodation, as well as preparation for the arrival of Toyota's recovery team.

"The day after the earthquake, January 18, my plan was to go to Supplier S with Toyota's recovery assistance team and work with them. But I was instructed by Toyota's head office to go to Supplier F instead, a manufacturer of car audio equipment near Kobe's most damaged area. Not very

much information had come in from that supplier, but it seemed that some major problems had arisen there. So, together with another member of OMDD, who had arrived with the recovery assistance team from Toyota, we left for Supplier F using two vehicles lent to us by Daihatsu, along with two drivers.

It took a long time to get there, since many roads were impassable. We arrived at 7:30 pm and with the power outage it was completely dark. It was now a day and a half after the earthquake. When we arrived, there were only two people in the plant, a security guard and a general affairs manager. They said that the surrounding area had been so damaged that only about ten out of the plant's 2400 employees had been able to make it to the site at that point, including Supplier F's president.

After looking around the plant, I concluded that the situation was serious and Toyota would need to dispatch a recovery assistance team. The first issue that I had to consider was finding food and accommodation for the incoming team. There were no suitable sleeping areas inside the plant, but I found a corner of F's head office that could be used for that purpose.

Electricity came only to the head office, not to the plant, and the water supply was entirely stopped. Almost all of the production equipment had fallen over. Solder had flown out of the pots and completely solidified. I reported to Toyota's head office that this was not a situation in which Supplier F could immediately restart operations. So Toyota decided to stop operations at all of its vehicle assembly lines from the night shift of January 19. I also told the head office to send food and sleeping bags and explained that the food was not just for our team but also for F's employees helping in the recovery.

We needed close communication between Toyota's Disaster Response Center and Supplier F's center, but the telephone lines were down. So I also asked for a few wireless phones, which were very big back in 1995 and could be used only by continuously charging their batteries.

This was a completely different situation from the 1991 Nagoya Flooding (Supplier C). The areas around the plant were virtually destroyed and many of its employees had to take care of their families first. Disruption of the transportation network prevented those living in distant places from coming to the plant. There was virtually no information about who and exactly how many of the plant's employees were okay. As a first measure to collect this information, a notebook was put up at the gate to gather data on who had made it to the plant.

Companies generally have quick-response teams, emergency procedures, and written rules about confirming that employees and their families are safe, checking who comes to the security gate, designating the head of the disaster response team and so on, but such plans seldom work as expected when an actual disaster happens. In this case, Supplier F's designated head of the response team was not present and no one was confirming the employees' safety. Even those who managed to come to the plant were deeply concerned about their families and neighbors, which sometimes prevents them from making accurate decisions and taking quick action. In chaotic post-disaster situations, such as this one, it is often best if the recovery assistance teams coming in from the outside work together with the people at the site to be useful.

So I suggested that F's workers who managed to reach the plant use whatever means they could, including spending all day if necessary, to try and make phone calls, to check on the condition of other workers and their families. The areas surrounding the plant were severely damaged, so I proposed chartering busses for those who were farther away who could come but had trouble getting to the plant due to impassable roads. This worked and little by little the number of employees who could make it to the plant increased.

Moreover, we had to make sure that there would be enough food for the employees arriving at the plant, as the food supply situation in the surrounding areas was not good. Relief provisions were

coming in from all over Japan, but they seemed to remain piled up in schoolyards, while the prefecture and city bureaucrats were apparently discussing how to distribute them equally among the residents. To me this was a waste of time. I wanted to simply allow whoever came to take as much as they need, while quickly and frequently replenishing our stocks.

Therefore, I contacted Toyota's head office and told them to send as many provisions as possible. But it would have taken Toyota's trucks 20 hours to travel the 300 km to Supplier F due to traffic jams. So I wondered if we could use Toyota's helicopters to bring in the supplies in regular 50-minute trips. We eventually found a place nearby that could be used as a temporary helipad, so stock replenishment started to run smoothly. We made it clear that water and relief provisions should be distributed not only to the employees of F but also to people in the neighboring communities. People from F were initially trying to distribute the provisions equally, but I suggested allowing everyone to take as much as they wanted, since the helicopters were delivering fresh supplies.

As for drinking water, the tanks of potable water at the head office were starting to run low, so I asked Toyota's Disaster Response Center to dispatch 10 water tank trucks. When they arrived at F, I made sure that they would remain in the Kobe area for a while and keep providing water to the nearby communities as well as to F by hauling water from a place in Kobe where they could fill up. Regarding water for flushing toilets, fortunately the sewage system was working. We happened to find out that an underground tunnel in the plant had been filled with water from the canal during the earthquake, so we asked the employees to take buckets of that water and use it for flushing.

Here follow some comments by Mr. H, former Senior Technical Executive of Toyota, OMDD Manager and a senior of Mr. A, regarding the latter's contribution during the 1995 Kobe Earthquake.

"The lesson we learned from the two huge earthquakes, the 1995 Great Hanshin Awaji Earthquake and the 2011 Great East Japan Earthquake, is that, at all costs, we have to let the people who can make judgments go immediately to the affected genba. By observing the genba directly, they can assess whether the damaged process is approachable, the safety of the employees, human and physical damage to the surrounding communities, as well as damage to equipment, buildings and infrastructures, including electricity, water and gas systems. In the aftermath of the 1995 Earthquake, Mr. A did this job very well. For example, he told us that heavy machines could not be used at the genba, so we would have to bring one hundred 2-meter long bars and hydraulic jacks to move things, and this advice helped us a lot."

2.1.4. 1995 Great Hanshin Awaji Earthquake - Suppliers O and S (Mr. H)

When Mr. A completed his job with the advance team and left Kobe, Mr. H (introduced above) and Mr. Asakura came from Toyota to Kobe and started to lead Toyota's recovery assistance operations for the damaged suppliers in the Kobe area. Below are his interview notes concerning Supplier O, which is Supplier F's metal parts subcontractor. He also refers to the operation to retrieve dies at Supplier S.

"I entered Kobe's disaster area early in the morning of January 19, 1995. It took us 20 hours to get there by car from Toyota's headquarters. We saw heaps of rubble and people crying, which reminded us that, in cases of major disasters such as this one, we must take care of local communities, including workers, before focusing on production recovery. If we hadn't gone to the actual place where the disaster happened and seen the devastation for ourselves, it might have been easy to just think about restoring production and ignore the surrounding community.

When the earthquake hit Supplier S, for example, the plant was in operation and its managing director, who lived nearby, immediately came and issued an order that all employees should go home

at once, although his house had been completely destroyed. We need someone who can make such critical decisions. Looking after the communities is mainly the work of the public sector, but, when one of our recovery assistance teams reaches the gates of a damaged plant, our first priority is to help the local people, who have lost their homes and have no food or shelter.

Supplier S had about 1,500 dies for sintering in its automated warehouse, which had half collapsed in the earthquake. Without them, its sintering production line would have to stop for half a year, so we discussed how to retrieve them. People at S said it would be crazy to walk into such a damaged building and Toyota's executives also urged us to stop, as it was too dangerous. But I decided to go ahead anyway, proceeding with great caution and leading the operation in person from inside the building. However, when I approached the warehouse with Toyota's team, I saw that S's managing director, Mr. Fu, was already inside, leading the die retrieval operation. So I told our specialist team (from San-Ei Kogyo Co., Ltd.) to stand by and move in quickly to rescue them if an accident looked imminent.

In the end, the dies were retrieved safely in one day but we had a hard time identifying which die was which, since serial numbers are engraved on the initial dies but not on replacement dies. We worked all day and into the night to solve the puzzle and reproduce the original series of 1,500 dies ready for use.

Later, when we arrived at Supplier O, our second-tier supplier and a subcontractor of Supplier F, its president was standing in front of the gate and did not let us in, probably fearing that we might take away their stamping dies for substitutive production. I asked him if the employees were safe, and he said he did not know. So I said, 'Why are you standing here without confirming your employees' safety?' I told my team to carry in all the provisions that we had brought for them and said to him, 'Give these to your employees. We won't take away your dies. We came to recover your production lines here.' The president then understood our intentions and with tears in his eyes politely let us in.

We always have to give top priority to the recovery of the damaged plant, as opposed to hasty substitutive production. When Toyota's recovery team arrives at a damaged site of a small company, its people, this president for instance, might be afraid that we have come to take away their dies. One of my bosses told me that the dies still had to be moved to another location near Toyota's plants, so that Toyota would not have to stop its production lines, but I insisted that the dies belonged neither to us nor to F and that we would fix them here.

The earthquake had created a large crack on the floor of O's plant, so I asked that a concrete mixer truck be dispatched from Aichi Prefecture where Toyota's head office is located. We filled in the crack, but then aftershocks came and it opened up again. It is important to work hard to keep on taking care of such problems.

Supplier O's dies were stored in an automated warehouse, which is quite wise in normal times, but when a disaster happens automatic stackers often get broken. So the workers have to remove the dies manually, one after the other, by climbing up to the top and moving them down. Working from below is too dangerous because anything can fall from the broken racks at any time."

2.2. Toyota's Principles and Way of Thinking

This section lists Toyota's principles, practices and ways of thinking at times of disasters, based on interviews with Mr. H, former Senior Technical Executive of Toyota and OMDD Manager, who already provided some comments above, and Mr. N, former head of OMDD at Toyota. The interviews took place on October 28, 2016, at Toyota's Headquarters in Toyota City.

2.2.1. Capability and Leadership

- The capabilities needed for recovering from disasters are the same as the capabilities for problem solving and *kaizen* (continuous improvements). (Mr. H)
- Companies need to develop human resources who can make the right judgments based on *genba* (real place) and *genbutsu* (real things) and take on strong leadership roles regardless of the harshness of the situations that they face. Such leaders can be trained through daily problem solving or kaizen in manufacturing genba. (Mr. H)
- Having manuals and standard procedures for recovering from disasters is important, but they have to be as simple as possible. How can you read a detailed manual at a disaster site? (Mr. H)

2.2.2. Toyota's Principles about Priorities

- We have experienced many serious disasters in the past, learned from them and discussed how to respond to them in the form of a Business Continuity Plan (BCP). What is unchanged, however, is our order of priority: first, human life; second, recovery of the communities; and third, recovery of production. (Mr. N)
- As BCP awareness prevailed in Toyota, our principles about what to prioritize—human life, community and then production—also became prevalent in our company. In other words, we provide rescue and help to the communities around the damaged plants. What is important is to have a sharp sense of priority. (Mr. H)
- When a supplier's plant is damaged by a disaster, Toyota gives top priority to the recovery of the damaged plant itself. If this is too difficult, priority is given to an alternative plant of the same supplier. If this also proves too difficult, finally we might consider switching to other suppliers as a last resort. (Mr. H)
- The mindset that production recovery or supply recovery should be given the highest priority did exist to a degree at Toyota's headquarters in the past, but now consensus on this order of priority—human-community-production—is well established at Toyota. (Mr. N)

2.2.3. Flows, Not Buffers

- When Toyota stops its production lines after a disaster, the mass media criticize this as a weakness of Toyota's buffer-less system. Then, when we achieve a quick recovery, they praise us saying the Toyota Way is great. Even if we had plenty of buffer inventories, much of it might become destroyed in a disaster. If we shorten lead times through the Toyota Production System, we can quickly reopen our lines and resume production even if all the product inventories were somehow destroyed. The key is simplifying the flow and establishing a pull system so that we can tell which item to produce first when supply chains are disrupted. (Mr. H)
- No matter how much inventory you have, a disaster can destroy all of it in an instant. In order to be able to quickly replenish inventory, is important to develop capabilities for small lot production at suppliers. We need capabilities for quick recovery of disrupted lines and for making production lead times shorter. (Mr. H)
- Supply chain management will become increasingly important. Even when we have two first-tier suppliers of a certain part, there may be only one second-tier supplier. A supplier database was created after the 2011 Tohoku Earthquake but then we discovered, after the 2016

Kumamoto Earthquake, that we had only one supplier of certain metal parts. We need to improve this system. (Mr. H)

- We need to understand our supply chains more accurately and shorten them. Also, if we can halve our fixed costs for equipment, we can have two lines in separate locations without any cost penalties. (Mr. H).

2.2.4. Human Resource Development

- Excessive division of labor can turn into a source of weakness, because skills become dispersed and specialized employees tend to do only what fits within their narrow skill set. We need to develop human resources who can act on what is really happening at actual sites (*genba-genbutsu*). We should continue active job rotation of our people, involving the Operations Management Development Division (OMDD; *Seisan Chousa Bu*) as well. Mr. Koda, who did an excellent job in the aftermath of the 2011 Earthquake (see Chapter 9), had gone through two years of training at OMDD. (Mr. H)
- What is important in BCM/BCP is human resources development. We need people who can provide quick and accurate judgments/decisions/actions in times of disaster and we can train them through daily problem solving. Kaizen is a series of small but frequent problem-solving activities and those who can do this consistently will develop the ability to instantly react to big changes, like disasters. Doing overhauls of production equipment by ourselves instead of outsourcing it to specialists is a good example of such training. (Mr. H)
- After the 1995 Kobe Earthquake, we documented our experience. Yet, what proved useful in subsequent disasters were not the documents themselves but those who had participated in the documentation process—people who could judge, decide and act quickly without seeing any documents. We certainly need rules and standards and organizations, but what is most important is having capable people at the core of the process. (Mr. H)

2.2.5. Human Networks

- We usually send an advance team first and then a main recovery team, but the interval between the two is becoming shorter, because Toyota now has a clearer picture of who is good at what. We have a list of potential team members with special skills in production technologies, maintenance and so on. So, for instance, we can easily identify the people in a certain plant who can use long bars for moving heavy equipment. Our company's mindset has become such that, if the recovery team asks that a specific person be dispatched to a damaged site, almost no manager above that person will say no. Actually, after the Kumamoto earthquake, one of our managers was reluctant to dispatch a key person on his line and said, 'Without Mr. T our line would stop,' so I replied, 'Don't worry, your assembly line will stop anyway if you don't send Mr. T!' We are still fighting against the "my line first" mentality. (Mr. N)
- Once our skilled team members reach a damaged site, they get back to us saying, 'Send Mr. X from Plant A' and, when X arrives, he says, 'If we can get Mr. Y, then we can fix this machine together.' This network of people who know from memory who can do what works very well. Formal organization charts do not. (Mr. H)
- There is a firm called San-Ei Kogyo Co., Ltd in Aichi Prefecture, to which Toyota has been subcontracting tasks like moving, installing, maintaining and dismantling its heavy production equipment, especially cutting and stamping machines and lines. This has been

going on for so many years, almost since the beginning of our company. San-Ei's tasks require the use heavy machines, which are indispensable in recovery missions, and we would not have been able to provide recovery assistance in past disasters without their help. So it would be useful to take stock of their skills in terms of who can do what and of our production equipment shops that handle heavy equipment. Additionally, we need to strengthen our training in the use of traditional manual tools, such as jacks, chain blocks, long bars and rollers, because heavy machines cannot always be used in damaged plants. (Mr. H)

2.2.6. Physical Robustness

- Some say that we should use anchor bolts to fix the production equipment to the floor as an anti-earthquake measure, but others say that this hampers flexible line layout changes. We need to discuss the issue further. We used to do anchor bolt placing, and the Naka plant of Renesas started to do it again after the 2011 Earthquake. We think that we do indeed need anchor bolts, even though they must be pulled out every time equipment is moved. Our production equipment has become smaller and lighter, and we call this 'simple-slim'. These compact machines are easier to anchor because they have greater rigidity (e.g., stiffness). We are also doing seismic strengthening of our buildings. In the case of Renesas's Naka Plant, the equipment fell down but the building withstood the impact of the disaster. (Mr. H.)

2.2.7. Recovery or Substitution

- About 600 suppliers and plants in the Tohoku district were affected by the 2011 Great East Japan Earthquake, but we could dispatch our recovery teams to only about 200 of them. In many cases, both the buildings and the equipment were almost intact and we did not need to go to those sites. On the contrary, some other plants had tragically been washed away by the tsunami, so all we could do was find other plants for substitutive production. (Mr. N)
- Our stance is to move in quickly to help our suppliers. Our task is either to recover the damaged plants and equipment or to switch to substitutive production in other plants of the same supplier. But even when we opt for substitutive production, we always try to achieve both recovery and substitution simultaneously and start receiving shipments from the plant that reopened first. When both plants are ready, we buy parts from both for a certain period. (Mr. N).

2.2.8. Concentration and Dependence – The Case of the Kumamoto Earthquake

- Before the 2016 Kumamoto Earthquake, we did not know that there was such a high concentration of parts suppliers in that particular area. We were then informed that, as part of its BCP, one of our major first-tier suppliers, supplier A, had decided to disperse its plants and suppliers, since they were concentrated in the central part of Japan, which is a region that is said to be prone to major earthquakes. They chose Kumamoto Prefecture in Western Japan, which was known as less earthquake-prone, although there is a big volcano there. Deeming it a safe location, Supplier A moved all its production lines for some parts to Kumamoto, as opposed to splitting them between two areas. Unfortunately, it was this very place that got hit by the 2016 Earthquake. The damaged lines were rather simple lines for assembling door-closing mechanisms, so substitutive lines were set up at a nearby warehouse while the damaged plant buildings underwent restoration. (Mr. N).

2.2.9. Supply Chain Database

- After the 2011 Earthquake, Toyota established a comprehensive supplier database, so now we can do mapping of the affected suppliers much faster at times of big disasters. When a catastrophe occurs, the people in Toyota's Purchasing Division and OMDD will get together, share information about the damage that has occurred and predict recovery lead times for the affected suppliers and parts. All the necessary information can be easily visualized (*mieruka*), such as the location of each supplier, what it produces, the damage that it suffered, as well as its recoverability and production substitutability. (Mr. N).
- When Toyota teams reach second-, third-, and lower-tier suppliers after a disaster, they often say, 'Why have you come here? We have no business transactions with you.' First-tier suppliers sometimes do not tell their second-tier suppliers where their parts eventually end up. So, we have to explain that their products are actually used in Toyota models before we ask them to let us into their plant. This initial rejection is a very good lesson for those people with the arrogant assumption that they can do anything if they say that they are from Toyota. (Mr. N)

2.2.10. Truck Routing Instructions

- Major earthquakes destroy both factories and roads. So, when the recovered or substitutive plants restart parts production and shipments, we have to provide instructions on which traffic routes to choose. After the 2016 Kumamoto Earthquake, we used our portal, P-LISS, to identify which roads were cut off and which were undamaged. We were thus able to give the suppliers routing instructions by means of colored maps displayed on their vehicles' navigation monitors, indicating open routes in green, disrupted routes in orange and uncertain routes in yellow. In the past, we were not able to give suppliers real-time routing information in emergency situations, but now transportation of parts supplies has become much more reliable thanks to this improved system. (Mr. N)

2.2.11. Parts Inventory Checking at Suppliers

- When the 2016 Kumamoto Earthquake hit, our system was not collecting suppliers' inventory information. Toyota monitors the level of in-transit inventories between a first-tier supplier and its plants through the JIT *kanban* system, but we knew nothing about the affected suppliers' own inventory levels. We had to physically go to all the genba in the damaged region to gather this information, so we needed a large team, including people from the Purchasing Division, Operations Management Development Department (OMDD), and specialists borrowed from our plants. No matter the situation, what is important is to gather real-time, accurate information on the conditions of both suppliers and roads. After the 2011 Earthquake, for example, our purchasing people were able to contact some of our suppliers by phone using their established communication channels. However, it is natural for suppliers to generally be reluctant to give bad news. The contact at the supplier might have said 'I think we will be OK', and our purchasing staff would have reported to our managers that the supplier in question was going to recover pretty quickly. But when we actually got to the genba, there were cases where the plant had been completely destroyed. How can we make accurate judgments on important matters without seeing the genba? Now, our purchasing people always go to visit our suppliers' sites when a disaster strikes. (Mr. N)

2.2.12. Members of the Advance Team

- The advance teams sent to disrupted suppliers should include staff from OMDD, as well as Purchasing, Telecommunications (IT), and Plant Engineering (PE). We, the operations people, can assess the production situation on the spot, but we do not know much about buildings. The PE people can provide diagnosis and rapid recovery of buildings and they can assess, together with the supplier, whether the plant buildings can be used as they are or whether they require repairs. Additionally, they can gather the necessary materials and resources for quick restoration. The telecommunications specialists are also very helpful in this regard. Based on our experience during the 2011 Great East Japan Earthquake, we now make sure that the advance team sent to a damaged supplier includes people not only from Operations and Purchasing but also from Telecommunications and Plant Engineering. There are now no supermen like Mr. H. who can cover everything, including assessing the state of buildings. So we have to do it as a team. Too much division of labor has produced a situation where there no longer are any such people. (Mr. N)

2.2.13. If a Disaster Hits Toyota Directly

- We have accumulated a great deal of experience and knowledge about helping suppliers recover from disasters, but we have yet to deal with a major disaster hitting the heart of Toyota's production and supply chains in and around Toyota City. We do not have direct experience with such a case. (Mr. H)
- If this happens in the future, we will have to recover our own plants while helping damaged suppliers at the same time. (Mr. N)
- In such a case, we will receive support from the recovery teams of our group companies in Kyushu (Western Japan), Tohoku (North-Eastern Japan) and other areas. It will be a challenge to coordinate such a recovery effort, but we have established an organization to handle such a situation and are training for it. (Mr. H)

2.2.14. Preparations for Future Disasters

- We have to make sure that our anti-disaster or disaster-mitigation preparations are making progress. We still have much to do. We have to teach our operators how to stop the machines in case of big earthquakes. Vertical piping stretching down from the ceiling of plants is still common, but in the 1995 Earthquake this caused many problems, since it easily comes loose and swings. We have to make the piping safer. Also, are the evacuation routes open? Are any cabinets, lockers or vending machines blocking the way? If the electricity is cut off and the emergency lights do not work, the plants are in complete darkness, so evacuation routes should be marked with fluorescent paint. (Mr. H)
- In wide-area disasters, like the 1995 and 2011 earthquakes, public rescue teams must focus not on the damaged production lines but on the affected communities first. So, companies must take into account the possibility that heavy machinery may not be able to reach the damaged sites. That is why we need to be familiar with manual tools and techniques, such as jacks, chain blocks, long bars and rollers for moving heavy equipment. We need training and licenses to be able to work with such things. (Mr. H)
- Confirmation of employees' safety still takes too long. Digital systems may not always work in times of crisis. Basic methods are simple and fast. Sometimes they are the most reliable too. For example, you can train people to pay attention to who is immediately before and after

them when escaping from a building. Once people get outside, they can check to make sure the person before and after them also made it out. (Mr. H)

- It is also very important to make preparations to avoid fires during earthquakes. Where is the load center located? Who is in charge of periodical functional checks on the emergency shutoff of the gas system? Rather than outsourcing this task, the employees should know how to do it themselves. Overspecialization is the enemy of careless explosions and fires. Are workers well prepared for effective emergency fire-fighting? I was impressed to see that in American plants all the fire extinguishers are stored by the entrance. When I went home to Japan, I saw a fire extinguisher on the floor near some painting equipment. I said to the worker, "C'mon, who's going to be able to come over here to get the fire extinguisher in the middle of a blazing fire?" (Mr. H)
- Who issues the order to leave the building when a disaster hits a plant? Who confirms that the employees got home safely? There is probably a manual detailing who is in charge, but the person may not be there at that time. If a disaster occurs during the night shift, a group leader on the shop floor must clearly be given the authority to issue the order to go home. (Mr. H).
- Are you well prepared for quick recovery of equipment and lines? Can you recover the dies? Do all the dies bear a serial number? Using automated warehouses, especially for storing heavy dies, is not recommended. Are equipment and devices that are difficult to recover if submerged, such as chip mounters and liquid chemical pumps, located high up, for instance on the second floor? The issues are different from plant to plant, but simulations and preparations should be carried out well in advance of actual disasters, because what is not recognized as a problem in normal times often becomes the cause of major problems in the aftermath of disasters. (Mr. H)

2.2.15. Different Measures in Different Situations

- Technologies and businesses are advancing and every disaster is different from the previous one. So, we have to be flexible in choosing the best methods to help the affected suppliers. For example, supplying PET bottles of drinking water by helicopter may be faster than dispatching water tank trucks these days. Convenience stores have extensive networks in Japan now, so their *bento* (packed lunches) may be more convenient than setting up emergency cooking centers. We have cell phones and the Internet as well. But these advanced technologies and systems may not always work, so we also need to possess skills in traditional manual techniques. (Mr. H)
- While the 1995 Kobe and 2011 Tohoku Earthquakes were wide-area disasters, causing destruction of numerous buildings and roads, the damage from the 2016 Kumamoto Earthquake was highly concentrated in certain areas. When we arrived at one supplier to give them recovery assistance, the convenience store next to the building was already open. After the 2011 Tohoku Earthquake, we found no food in shops in entire districts. So, the situation was completely different. Plenty of provisions were sent from our group companies all over Japan, including Tohoku, but there were not enough places where to store them. So we decided to concentrate storage at one site near Toyota's headquarters in Aichi Prefecture and another site near Toyota Kyushu and supply the evacuation centers in Kumamoto with frequent small batches of only what was really needed. (Mr. H)

2.2.16. Implications Regarding Knowledge, Learning and Problem Solving

The above are the main points that emerged from our interviews with Mr. A, Mr. H and Mr. N. They all have experience in leading recovery activities after major disasters, either on the spot, e.g., at the facilities of damaged suppliers, or from the head office, as managers or as heads of Toyota's Operation Management Development Division/Department (*Seisan Chousa Bu/Shitsu*), which is in charge of TPS kaizen (improvement) and education not only in Toyota and its group companies but also for its main suppliers in normal times.

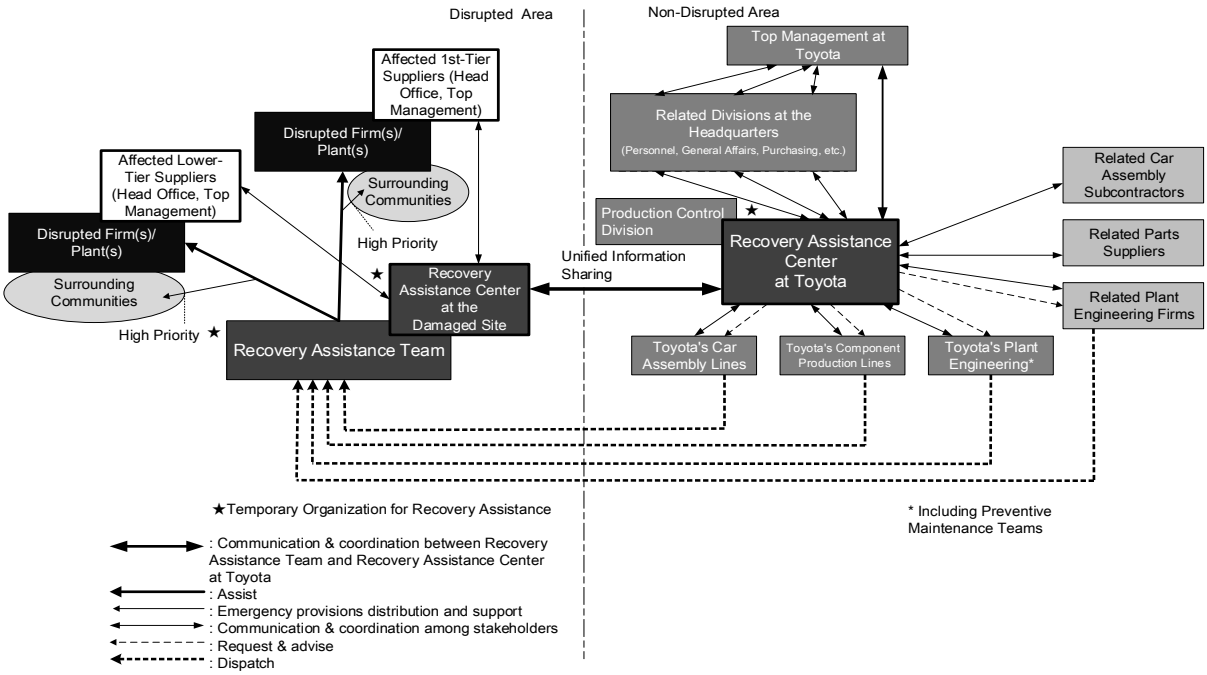
We will not summarize the content of the above interviews, but rather offer some comments on the knowledge structure behind them.

First, the stories about actual disaster recovery experiences, recounted in the first part mostly by Mr. A, are remarkably consistent with the description of practices and principles adopted at Toyota (or, at least, at the OMDD), provided by Mr. H and Mr. N, despite the fact that they refer to separate places and different times. This indicates that the principles and practices are not just talked about but also implemented in the actual settings of genba.

Second, it should be noted that the cases illustrated in the first part are about the 1991 Nagoya Flooding and the 1995 Great Hanshin Awaji Earthquake, which implies significant continuity and consistency in Toyota's anti-disaster principles and practices between the 1990s and the 2010s. Although their disaster-response capabilities seem to have been constantly enhanced through cumulative organizational learning, their core values, such as the human-community-production priority rule and the emphasis on genba-based judgment-decision-action, have remained unchanged for a long time.

Third, the fact that, in their interviews, the three former OMDD leaders provided such a large amount of oral information regarding this topic (note here that this chapter presents a compressed summary of what was said that day) indicates that the anti-disaster knowledge at Toyota—or at least at the OMDD—has been fully internalized and shared among key members in charge of supply chain robustness/resilience. In other words, the application of the Nonaka/Takeuchi model of knowledge creation (Nonaka and Takeuchi 1995) and of the SECI cycle (Socialization, Externalization, Combination and Internalization) appears to have worked extremely well, particularly in terms of internalization (explicit to tacit knowledge) and socialization (tacit to tacit knowledge), which results in sharing both explicit knowledge (e.g., standard procedures and rules) and tacit knowledge (e.g., judgment capabilities) among the members of the organization.

Fourth, the fact that the leaders of the OMDD in charge of TPS-style continuous improvements (kaizen) have been taking leading roles in post-disaster supply chain recovery is consistent with Toyota's belief that those who can make smaller but more frequent problem-solving activities at genba can accumulate the skills and knowledge needed to deal with large-scale but infrequent problems, or major supply chain disruptions caused by big disasters (Hiiragi 2013). In the context of innovation management theories, the above belief and evidence regarding continuity between small- and large-scale problem solving may be an intriguing counterargument against the well-known proposition that those who implement effective incremental innovations (involving smaller and frequent problem-solving cycles) are not good at developing radical innovations (focusing on bigger and infrequent problems). Radical innovations and large-scale restoration are clearly different, but they both entail problem-solving cycles in H. Simon's sense (Simon 1969, Clark and Fujimoto 1991).



Source: Created by the authors based on discussion with Mr. A.
Figure 1. Disaster Recovery Organization at Toyota.

Figure 1 is a summary of Toyota's disaster recovery system in the case of 1995 Hanshin Awaji Great Earthquake, illustrated by Mr. A whom we interviewed in this chapter. Its basic structure is unchanged since then. In times of disaster recovery, Toyota uses this temporary organizational structure to support the timely recovery of a disrupted site(s). A central issue is keeping information accurate and up-to-date by the careful sharing of information between personnel at the disrupted site(s) and those assisting the recovery operation at Toyota. In this way, Toyota is able to advise and quickly dispatch resources that meet the on-site needs.

CONCLUSION

This chapter described and analyzed Toyota's efforts and ways of thinking concerning supply chain robustness and resilience. To conclude, let us discuss some implications of our findings in relation to a few key topics addressed in the present book.

Rapid Recovery of Supply Chains

As shown in this chapter, Toyota has experienced various types of supply chain crises, but its assembly line stoppages have so far been limited to one or a few days, regardless of whether the disruptions happened at supply points (e.g., production lines) or along supply routes (e.g., a tunnel accident), whether the disasters involved a single site (e.g., fire at a plant) or many sites (e.g., Tohoku Earthquake), whether the damage was minor or severe, whether dependence on the affected suppliers was heavy or not, whether the visibility of the damaged suppliers was high or not, whether the strategy chosen was recovery on the spot or production at substitutive locations, whether there were abundant buffer inventories or not, and so on. This means that Toyota's recovery teams flexibly chose different measures in different situations, although their key principles and values remained unchanged, as explained above. Hence, the initial on-the-spot judgments by the advance teams are

vital, and this is why Toyota's managers in charge of disaster response emphasize the importance of developing leaders who can ensure quick and right judgment/decision/action in any situation.

Recovery on the Spot

This chapter also indicted that, among the various approaches to speeding up supply chain recovery, Toyota gives top priority to rapid on-the-spot recovery of the damaged equipment and lines, as well as continuous capability building for it. Note that rapid supply chain recovery and rapid production line recovery are not always the same. There are other methods for enhancing supply chain robustness, such as obtaining parts from back-up production lines (including overseas plants) that produce identical parts, using other existing lines for substitutive production after having transferred the design information to them (e.g., virtual dualization), moving the whole production line to a safer place, etc.. The choice will depend upon Toyota's initial triage of the affected suppliers—which might require no help as their genba are intact, or might have suffered damage but have good chances of fast recovery, or are completely destroyed with no hope of quick recovery, so that substitution is inevitable. If Toyota deems it likely that the damaged production lines will be recovered fast enough, its principle is to help the affected supplier achieve this, even when substitutive production is also considered and preparations are being made for it. This principle of "recovery on the spot first" seems to influence the suppliers' motivation and trust vis-à-vis their customer companies, which, in turn, affects supply chain competitiveness in normal times. In other words, if Toyota and other customer firms were recognized as quick switchers to substitutive production in the aftermath of disasters, their suppliers' trust would decrease, leading to reduced investments in physical and human resources specific to that supply chain.

Recovery through Substitutive Production

Although top priority is given to recovery on the spot, Toyota considers the possibility of substitutive production and prepares for it whenever there is a chance that the damaged line may not be recovered fast enough. It is worth underlining that, when a disaster strikes, the goal is to reopen the whole supply chain as early as possible and recovery of a damaged production line is just one of various means to achieve it.

However, Toyota seems to be keenly aware that it has to take care of the communities surrounding the suppliers' plants and that these communities usually rely on the supplier's stable employment practice, particularly when they are located outside big cities. Thus, even when Toyota chooses substitutive production, it always tries to opt for another plant or location of the same supplier, so that the workers from the damaged plant have greater chances of working at the substitutive production sites.

Hence, Toyota's choices in times of disaster are strongly influenced by its consideration of trust and motivations on the part of its suppliers and surrounding communities in times of normal competition.

Buffers or Capabilities

Our interview notes confirmed that Toyota's managers at the OMDD, who are in charge of both supply chain competitiveness (e.g., TPS) and robustness/resilience (e.g., recovery assistance), never refer to the necessity of adding buffer inventories. Of course, inventories are not ignored, as having appropriate levels is essential for TPS, but they are considered only after all efforts have been made to achieve rapid supply chain recovery.

For example, recognizing that it was the only manufacturer of a certain critical component, one of Toyota's suppliers damaged by the Kumamoto Earthquake decided to increase its inventories in preparation for future disasters, but it did so only after concentrating all efforts on resuming its parts supply as soon as possible. It is obvious that this supplier's appropriate level of inventories is directly influenced by its estimated recovery lead times in case of future disasters. Thus, the principle of "capability first, buffers next" is applied in this case as well.

When Toyota's assembly lines stop after a disaster, the media tend to immediately point out the limits of Toyota's famous Just-in-Time system, but this has not altered Toyota's focus on building quick recovery capabilities.

Continuous Improvements of Robustness and Resilience

Our analysis and interviews also revealed that Toyota is trying to continuously build capabilities for anti-disaster robustness and resilience by learning from past disasters and retaining routines that have proven effective. It may be concluded that the company possesses evolutionary capabilities not only for competitiveness but also for robustness (Fujimoto 1999).

As for suppliers' visibility, in the aftermath of the 2011 Tohoku Earthquake, Toyota learned that, despite its strong capabilities, quick supply chain recovery cannot be achieved unless certain small and lower-tier supplier of critical parts or processes are promptly identified. This is the issue of suppliers' invisibility and, as discussed elsewhere in this volume, Toyota has recently implemented a large database that includes not only its first-tier suppliers but also most lower-tier suppliers. It is thus possible to instantly locate which company supplies which parts to which customers through which routes— a fact that represents a significant evolution of Toyota's anti-disaster capabilities in the 2010s.

Overall, our investigation about Toyota's counter-disaster activities, practices and principles, illustrated in this chapter, seems to be generally consistent with the capability-building framework of supply chain competitiveness and robustness put forward in this book.

As mentioned in the interviews, one situation that Toyota has not yet experienced is a major disaster such as the so-called "Nankai Trough (Megathrust) Earthquakes" striking Aichi Prefecture and Toyota City directly. Scientists estimate that the probability of this happening in the next 30 years is 70% and the magnitude of the event might be as big as that of the 2011 Great East Japan Earthquake. Toyota's next challenge will be to further build capabilities in preparation for this occurrence, alleviate the ensuing damage as much as possible and achieve the recovery of its own plants as well as of its suppliers' genba in a reasonably short time.

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