Case Study
The Toyota Group and the Aisin Fire

The Japanese model of long-term collaborative partnerships between firms and their suppliers has attracted much attention from business researchers and practitioners. Several U.S. and European automakers have attempted to establish similar partnerships of their own, seeking to reduce their supplier base and cultivate relationships with their best suppliers. As a result, the early involvement of suppliers in product-development and cost-reduction efforts is becoming standard practice in the automotive industry and beyond.

A recent crisis involving Toyota and its supplier network suggests, however, that the Japanese model — or at least the Toyota model — involves more than a set of long-term relationships between a firm and a few select suppliers. As the Toyota group's collaborative response to the sudden destruction of a key supplier's plant suggests, the relationships among a firm's suppliers are equally important. More generally, a complex mix of institutions permits self-organization during times of crisis with little need for a leader's direct control. These strong relationships among many firms along with the steady but largely invisible control of a leader promote flexible and coordinated responses to crises. In addition, they foster long-term competitiveness through decentral-
A fire at one of Aisin Seiki’s plants threatened to halt Toyota-group operations for weeks.

ized, groupwide efforts to solve day-to-day problems and improve performance.

On February 1, 1997, a fire at one of Aisin Seiki’s plants threatened to halt Toyota-group operations for weeks. Aisin Seiki, one of Toyota’s most trusted suppliers, was the sole source for proportioning valves (for P-valves, in the industry parlance), a small but crucial brake-related part used in all Toyota vehicles.1 Because of Toyota’s and Aisin’s dedication to the principles of just-in-time (JIT) production, only two or three days’ worth of stock was on hand. A shutdown of Toyota-group plants (including those of several hundred suppliers) seemed unavoidable.

The timing could not have been worse. Toyota plants were operating at full capacity with levels of overtime and use of temporary workers unheard of in years, in anticipation of a last-minute boom in automobile sales prior to the 2 percent consumption sales-tax increase slated for April 1. Every day lost meant potentially huge and irretrievable losses in sales and profits for Toyota and related firms.2

Yet, remarkably, disaster was averted, and assembly plants were reopened after only two days of shutdown. The recovery was accomplished through an immediate and largely self-organized effort by firms, mostly from within but also from outside the Toyota group, to set up alternative production sites outside of Aisin. Within days, firms with little experience with P-valves were manufacturing and delivering the parts to Aisin, where they were assembled and inspected before being sent to Toyota’s and other clients’ assembly plants. The collaborative effort, which involved more than 200 firms (of which approximately sixty-two took direct responsibility for P-valve production), was orchestrated with very limited direct control from Toyota and with no haggling over technical proprietary rights or financial compensation.

The Toyota group demonstrated its cohesion and resiliency at a time when many observers were discussing the weakening of traditional ties among group members. Based on data collected through in-depth interviews with key players in the incident, we describe what took place during the Aisin Seiki crisis and how individual firms came together to orchestrate the recovery effort. We believe that the episode holds lessons for businesses adopting the Japanese model of long-term supplier partnerships as well as for businesses moving away from that model. Of course, competition for future contracts and the pressure to maintain their reputations motivated the suppliers to cooperate with each other. Nevertheless, we argue, it was the various capabilities developed through institutionalized problem-solving activities within the Toyota group that ensured the effectiveness and speed of the suppliers’ collaborative effort. For businesses of many kinds, the capabilities developed through committed partnerships can enhance competitiveness, driving participants to respond effectively to emergencies and to pursue continuous improvement on a daily basis.

### The Aisin Seiki Crisis

At 4:18 a.m. on Saturday, February 1, 1997, a fire erupted in Aisin’s Kariya plant number one. By 8:52 a.m., the lines dedicated to P-valves and to other brake-related parts (clutch master cylinders and tandem master cylinders) were almost completely destroyed, along with special-purpose machinery and drills that could take months to reorder. The near destruction of the P-valve lines was potentially disastrous for Toyota; nearly all of its vehicles used Aisin P-valves manufactured exclusively at the Kariya plant, which turned out 32,500 P-valves a day for Toyota and other Toyota-group assemblers such as Hino and Daihatsu as well as for Mitsubishi, Suzuki, and Isuzu.

Used in all vehicles, P-valves control pressure on rear brakes to help prevent skidding. About the size of a pack of cigarettes, the part is mass-produced using dedicated transfer lines, which keeps costs down and ensures high productivity and reliability. Although structurally simple and inexpensive, costing only between ¥770 and ¥1,100 apiece, P-valves require complex, high-precision machining to ensure the reliability and durability essential to the safety of any brake system.

That Aisin was the sole supplier of this small but critical part was surprising to many in Japan. To reduce the risk of the very kind of disruption it was now confronting, Toyota had increased parallel sourcing.
Its relationship with Aisin was distinctive, however: Aisin was one of Toyota's closest suppliers in sales, personnel, and financial linkages; its outstanding cost, quality, and delivery performance record made it difficult to replace.\textsuperscript{7}

Toyota suddenly found itself in crisis. As a result of JIT operations, only one day's worth of P-valves were in immediate stock. Predictably, on Monday, February 4, when assembly lines were still running, Toyota announced the following day's shutdown of twenty of its thirty assembly lines (including those of Toyota's contract assemblers); from Tuesday, February 5, to Wednesday, February 6, practically all of Toyota's and most of its related firms' plants were closed, bringing to halt almost the entire Toyota group.\textsuperscript{8} As a result, hundreds of tiered suppliers who would have to wait for the reopening of their clients' plants to resume deliveries were also affected, as were local electricity, gas, and transportation companies, such as the fragility of JIT; a surprise event can paralyze entire networks and even industries.\textsuperscript{9}

**How could alternative P-valve production sites be organized and the delivery of the required 32,500 P-valves a day be resumed so quickly?**

Indeed, Toyota was facing one of the worst crises in its history.\textsuperscript{10} But on Tuesday, February 5, only three days after the fire, the first alternative volume P-valves (as opposed to prototype P-valves that had been delivered one day earlier) were rolling off temporary lines hastily set up by an Aisin supplier, Kotsu Sanyo, marking the beginning of the recovery process. As a result of this and many other firms' efforts, by Thursday, February 7, Toyota's Tahara and Hino Hamura plants were reopened, followed by the other car assembly plants affected the next day on a single-shift basis. By Monday, February 11, a little more than one week after the fire, all Toyota-group assembly plants were back to normal with production volumes of 13,000 to 14,000 vehicles per day. After another week, the plants were in full operation at the previously planned production volumes of 15,500 vehicles per day. At that time, the proportion of P-valves produced by Aisin itself was less than 10 percent of the total amount necessary; it gradually increased, however, reaching 60 percent by March 14 and almost 100 percent by the end of March. The bulk of the P-valve production was taking place at approximately sixty-two firms, including Kotsu Sanyo, which gave full priority to the restoration of P-valve production and often worked double shifts through weekends.

In total, the fire cost Aisin ¥7.8 billion and Toyota about ¥70,000 vehicles and ¥1.6 billion in revenues.\textsuperscript{11} Although Toyota officials claim to have recouped most of the lost vehicle production through increased overtime and holiday shifts, losses in the range of ¥20 billion to ¥30 billion were unavoidable, mainly because the creation of alternative P-valve sites was costly.\textsuperscript{12} In the end, however, Toyota and Aisin could only be grateful that group members achieved a rapid and effective recovery and averted what could have been a much more devastating incident.

**The Recovery Effort**

How could alternative P-valve production sites be organized and the delivery of the required 32,500 P-valves a day be resumed so quickly? We describe the roles played in the recovery by six firms, which we visited during our field research: Toyota, Aisin Seiki, Denso, Taiho Kogyo, Kayaba Industry, and Kotsu Sanyo. While these firms differ in size, areas of specialization, position in the value chain, and financial linkages to Toyota, they share several characteristics: a commitment to, and capabilities for, JIT production and the ability to solve problems at their source.

From the beginning, it was clear that until Aisin could rebuild its previous capacity, outside help would be indispensable. It was decided then that firms from both inside and outside the Toyota group would be asked to set up alternative P-valve production sites as soon as possible, with Aisin providing technical assistance, design drawings, jigs (e.g., specialized drills), machine tools, and raw materials (e.g., cast iron) salvaged from the fire.\textsuperscript{13} Aisin was to immediately begin setting up alternative production sites in its other plants as well.

Sixty-two firms responded to Aisin's call and immediately began preparations to manufacture P-valves. Responding firms included twenty-two of Aisin's own suppliers (e.g., Kotsu Sanyo); Toyota itself; thirty-six of Toyota's regular suppliers (e.g., Toyota keihatsu firms such as Denso and Taiho Kogyo, independent

---

*Shan Management Review*  
Fall 1986  
Nishimura - Boudet

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
suppliers such as Kayaba Industry and Akebono Brake Industry, and firms belonging to other keiretsu such as Sumitomo Electric Industries); and four non-regular suppliers (e.g., Nabco).

Aisin asked machinery makers in Japan and beyond to gather every available machine on hand, including exhibition models taken from showrooms and equipment already promised to other clients.

Along with these firms were about 150 others, including seventy machine-tool makers that were involved indirectly in the recovery process, since machinery, drills, fixtures, and gauges had to be found to replace the ones destroyed in the fire. Aisin asked machinery makers in Japan and beyond to gather every available machine on hand, including exhibition models taken from showrooms and equipment already promised to other clients. For the sake of fast recovery, both regular and nonregular suppliers of machinery to Aisin were called on. The cooperation of these suppliers was crucial to the success of the recovery effort; undoubtedly, many were hoping to increase sales to Toyota in the future.

Firms were asked to machine the needed parts using Aisin’s design drawings and forged blocks and to deliver them to Aisin. Then Aisin would be responsible for final assembly, quality control, and delivery to Toyota and other customers. A few firms such as Nabco, Sumitomo Electric Industries, and Akebono Brake Industry already produced P-valves of different types, but most had no experience with this particular part. One firm, the sewing-machine manufacturer Brother Industries, had never made car parts.10 Although the technology and skills involved in manufacturing P-valves are relatively simple, their numerous and complex orifices require highly precise machining. Without the dedicated equipment used by Aisin (which was largely destroyed in the fire), P-valve production would be slow and arduous.

The situation was discouraging: the suppliers recruited lacked sufficient tools, were mostly unfamiliar with P-valve production, and were inexperienced in responding to crises of this magnitude. The problem-solving capabilities developed through long-term collaboration and the flexible deployment of resources enabled the firms to overcome these obstacles and ensured a rapid recovery of P-valve production and of Toyota’s assembly plants.

Preparations
The first step involved the establishment at 5:30 a.m. on Saturday, February 1 (while the P-valve lines were still on fire), of an “emergency response unit” at Aisin to centralize and coordinate efforts to deal with the crisis in an orderly and organized manner. At 6:30 a.m., the unit was reorganized and divided into four teams, dealing respectively with production (for example, the setting up of alternative production sites), materials handling (for example, the delivery of materials to those sites), liaison with customers (for example, Toyota, which was immediately contacted), and general affairs (e.g., negotiations with Aisin’s union). The unit’s first meeting was held at noon; twenty-seven meetings subsequently took place until February 21. The second step involved contacting potential collaborators and deciding who would do what, since many kinds of P-valves were needed (there are more than 100 main types of P-valves) and available equipment and capacity differed from firm to firm. After consulting its clients on which P-valves should be given priority, Aisin started as early as Sunday, February 2 (the day after the fire), to fax design drawings to various firms that had already voluntarily offered their help (e.g., Taiho Kogyo, which had contacted Aisin on hearing about the fire on the radio) or had agreed to the request of Aisin or its clients (for example, Kayaba, which was asked for help on the day of the fire by Mitsubishi Motors and the next day by Toyota and Aisin).

In many respects, of course, the firms that “voluntarily” offered their help were forced to cooperate with Aisin and Toyota. Failure to do so might have jeopardized future business relations with Toyota-group firms; moreover, because of JIT, most suppliers were losing millions of yen every day that Toyota plants remained shut down. Still, cooperation worked both ways. For example, Toyota chose not to put pressure on Aisin to give priority to its own models to the detriment of Aisin’s other clients, such as Mitsubishi, even though it could have easily done so given Aisin’s financial and commercial dependence on Toyota. Pressuring Aisin would have yielded Toyota short-term gains, but in the long run, the parties concerned would
remember such actions and possibly retaliate in
some fashion.

After reviewing the faxed design drawings, its equip-
ment availability, and its pertinent technical capabili-
ties, each firm had to notify Aisin of its decision
on whether to participate in the recovery effort. The
process was not easy because most of the firms
had never produced P-valves and knew little about the
technical implications of P-valve production. Moreover,
the design drawings they received lacked necessary
technical details for first-timers and needed to be
decoded into something more readily understandable.

To make matters worse, P-valve produc-
tion had to be organized without Aisin’s
special-purpose machines and drills.

To make matters worse, P-valve production had to be
organized without Aisin’s special-purpose machines
and drills because these were seriously damaged in
the fire. As noted earlier, P-valves require highly pre-
cise machining, and to manufacture more than 30,000
of them a day requires highly customized jigs, drills,
and transfer machines. Instead, firms would have
to rely on general-purpose machines such as machin-
ing centers to manufacture P-valves, which most
firms already possessed. This method would mean
much higher labor content and lower productivity
than usual.

Compounding the problem, Aisin’s know-how was
largely restricted to the special-purpose transfer
machines, making it difficult for Aisin to instruct firms
on how to manufacture P-valves by other means.
Furthermore, although a few drills were salvaged from
the fire, there were only enough to allocate one drill
per firm, which slowed down production because
the drill had to be used with extra caution to avoid
breaking. Moreover, not one but many different drills
were needed, and the scarce ones received from
Aisin were not a perfect match for machining centers.

Yet another problem was the difficulty in controlling
quality without Aisin’s special-purpose gauges. To
ensure the reliability and durability of the brake sys-
tem, quality control is very strict, involving at least
seven inspection steps per piece. Even though Aisin
was to double-check every incoming P-valve, firms
had to conduct some form of quality control before
delivery, using general-purpose gauges.

Finally, in the first few days of the crisis, Aisin was in
a state of chaos and was difficult to contact. Indeed,
so confused were conditions at Aisin that during the
evening of the first day of the fire, Taiho Kogyo’s
director of production control was wrongly informed
that master cylinders, not P-valves, were the main
problem for Aisin. Within days, Aisin installed 250
additional fixed phones and 300 mobile phones in an
attempt to accommodate skyrocketing inquiries. The
magnitude of incoming calls, however, overwhelmed
Aisin’s capacity to respond.

Because Aisin lacked sufficient resources to provide
direct assistance to every firm at once, collaborating
drills firms had to figure out by themselves how to pro-
gram their machining centers for P-valve production
and find or make appropriate drills. For example,
Denso scrambled for drills from all over Japan and
even sourced some special ones from a U.S. maker
arranged for by Denso’s Tennessee plant. Although
Aisin supported these efforts as much as it could by
setting up a “drill center” to coordinate drill purchas-
es and by organizing meetings to discuss technical
problems and solutions, firms had to rely largely on
their own capabilities to begin P-valve production.

For all these reasons, many firms declined to help at
all, judging their equipment and capabilities insuffi-
cient to manufacture P-valves. But many accepted,
including Denso, Taiho, Kayaba, and Toyota, which
agreed to manufacture between two and five types of
P-valves each. These and other firms then immediate-
ly started preparations for P-valve production.

At this point, significant differences in the firms’
approaches to P-valve production emerged. Denso
gave full priority to in-house P-valve production, and
some of Denso’s other processes were temporarily
outsourced to make room for P-valves. In all, about
forty machining centers were made available at
Denso for P-valve production. Taiho met with thirty
of its suppliers the day after the fire to plan an appro-
priate division of labor, eventually involving eleven
suppliers in the effort, with Taiho itself taking charge
of the final processes. Fifty machining centers were
made available at two of the firm’s three local plants.

Toyota set up temporary production sites in its
Honsha plant, entrusting P-valve production to the
The collaborating firms established their own "emergency response units" to coordinate P-valve production activities.

At this stage, the collaborating firms established their own "emergency response units" to coordinate P-valve production activities. A challenge for many firms was to ensure close collaboration among usually remotely related units. Kayaba set up a special team, under the direction of Kayaba's director of production engineering, to centralize control and coordinate activities with the suppliers concerned; the team was composed of sixteen employees from the quality assurance, production engineering, and purchasing departments. Three salespeople were also dispatched to Asin to obtain real-time information and feedback. At Toyota, the production control department was put in charge of coordinating in-house P-valve production and direct assistance to Asin.

Production Begins
The next step involved each firm completing its first prototype to send to Asin for approval before volume production. It was a tiny second-tier supplier, Korsu Sango, that first delivered its prototype on Monday, February 3, only two days after the fire. Denso, the largest and most famous supplier in Toyota's group, was the second to deliver a prototype on the early morning of February 5, followed by Toyota and Taiho Kogyo later that day. Kayaba's first prototype was ready on February 6, delivered from the sixteen-employee supplier, followed by those from the 110-employee and the six-employee suppliers on February 7 and February 8, respectively.

The operational speed of the firms reflected their familiarity with Asin or with brake-related parts and their technical capabilities with machining centers and prototype making. In all cases, however, work was complicated by such difficulties as the lack of details in Asin's design drawings, appropriate equipment, and direct assistance from Asin. As a result, in making many of the production decisions, firms had to experiment and exercise judgment, which explains the variety of methods used to manufacture P-valves. Taiho used two drills; Toyota used only one for a similar task. At Kayaba, two of the three suppliers, including the six-employee firm, ended up making their own drills.

Once the prototypes were approved, each firm moved to volume production. Korsu Sango began volume production on February 4. Denso started volume production on the evening of February 5, with production volumes of 1,000 units a day (raised to 2,200 on February 11 under pressure from Toyota). Taiho started volume production the next day, beginning with low batches of about fifty units and gradually moving toward volume of 2,000 units a day. Kayaba started on February 7 with a daily production volume of 520 units. Toyota began volume production on February 6.

Solving Technical Problems
The next step involved solving the technical problems that emerged during volume production. Since Asin was unfamiliar with P-valve production by machining centers, it was unable to provide solutions on its own. A testimony to the firm's impressive technical capabilities, Denso assumed an important role, with its engineers quickly solving one problem after another. Denso's solutions were then disseminated to other participating firms during special problem-solving meetings organized by Asin. Denso also modified Asin's design drawings and process instructions to make them more appropriate for machining centers, which Asin passed on to other firms.

These problem-solving capabilities are the hallmark of firms ingrained with the principles of the Toyota Production System (TPS), or lean production. The capacity to disseminate solutions quickly is also characteristic of Toyota-group firms; they regularly do benchmarking studies and set up problem-solving study groups in Toyota's supplier association, the Kyohokai, or as part of jishuken (voluntary study...
group) activities, usually in the presence, and sometimes under the supervision, of consultants sent free of charge by Toyota. These efforts, along with the meetings of company presidents, the training programs and internships held for lower-tiered suppliers’ employees, and the constant flow of employees among firms, permit rapid horizontal and vertical diffusion of best practices.

Despite these efforts to disseminate the newly found best practices and to standardize P-valve production, the diversity in practices persisted as some firms preferred to stick to their own methods. For example, Taiho declined five out of six design modifications proposed by Aisin because they created discrepancy problems with Taiho’s existing equipment.

Once the major technical problems were solved, the firms devoted their efforts to raising productivity and increasing volume through kanzan activities. Again, years of training in TPS principles ensured that the appropriate capabilities and routines were already in place. At Toyota, for example, cycle time was reduced from more than two minutes to one minute, twenty seconds, within a few weeks, by minimizing changeover times through the presetting of the machining centers (P-valve production was still relatively slow because of limits to increasing productivity in the absence of Aisin’s special-purpose transfer machines). The results of these efforts were then recorded on video to be stocked as “organizational memory” should the need to manufacture P-valves emerge again.

Flexible employee deployment and procedures, which are also associated with Toyota and many other Japanese firms, were evident throughout the effort.

The ability of Toyota and the other firms to move quickly toward shortening set-up times and to resume full JIT production demonstrates how deeply ingrained the TPS is in these firms. For example, at Taiho, which used kaihatsu to make P-valves and delivered them to Aisin in eight batches per day, managers stressed that this was the only way they knew how to do it.

Flexible employee deployment and procedures, which

The flow of employees also occurred among firms. For example, at least 300 Toyota employees from production control, maintenance, production engineering, purchasing, quality control, and materials handling could be seen at Aisin at any time during the first three weeks, helping Aisin set up more permanent P-valve assembly lines, among other tasks; other automakers sent about forty people to Aisin. Toyota employees (in particular from the maintenance department) were also sent to Denso to assist in the P-valve production process, staying until they observed that everything was in order; they also visited the machine-tool makers to help them repair Aisin’s damaged transfer machines, an effort that was completed by mid-March. Within the Aisin group, various flows of personnel also took place, for example, from Aisin suppliers to Aisin (about 250 people). In total, more than 500 employees from Aisin’s customers and suppliers as well as Toyota-group firms were on site at Aisin during the peak days of the crisis.

As these examples demonstrate, the P-valve recovery effort involved more than just individual initiatives to set up temporary production sites and increase productivity. The flow of employees within and among firms, the meetings organized to discuss and disseminate solutions to technical problems, and the group-level coordination efforts exerted by Aisin’s “emergency response unit” and Toyota’s production control department all contributed to a successful outcome that was more than just the sum of individual efforts. These capabilities for groupwide coordination and organizational learning were revealed once again sev-
eral months after the incident, when Aisin Seiki published a booklet on how to organize the rapid recovery of production following a disaster such as a factory fire. Based on lessons learned during the crisis, the booklet was distributed to 500 firms, including all those that had joined the recovery effort and all remaining Kyohokai members. The gesture was a way of thanking the firms for their support and ensuring that mistakes would not be repeated. The lessons from the Aisin incident were thus recorded as organizational memory for all cooperating firms to use should the need ever arise.

**Settling Compensation**

P-valve production continued until March 10 for Denso, until March 6 for Taiho (with one small-volume item lasting until the end of March), until April 10 for Kayaba, until mid-March for Kojutsu, and until March 15 for Toyota. Considerable expenses were incurred during the recovery process, including labor costs (which were particularly high because of the lack of specialized machinery and experience in P-valve production and because much of the work included overtime) and machinery and tooling costs.

Firms including Denso and Kayaba had begun production of P-valves without making any explicit agreements with Toyota or Aisin on eventual compensation for their expenses. There was neither time nor reason to do so. Eventually it was agreed that Aisin would fully reimburse all firms for the expenses incurred in P-valve production, including labor costs. For example, Denso would be compensated by Aisin for the more than ¥300 million in labor, equipment, special-purpose oil, and other costs. The arrangement addressed only direct expenses, however. More important were the losses in output during the closure of assembly plants incurred by Toyota and all the suppliers involved.

Toyota settled the issue in a surprising manner: it announced that all its first-tier suppliers would receive a payment equivalent to 1 percent of their respective sales to Toyota from January to March 1997. This amounted to overall payments of more than ¥15 billion, with Denso, for example, to receive ¥1.5 billion. Many of the firms viewed the offer as a reward for cooperation rather than as compensation.

Toyota’s decision was then replicated throughout the network, as most of the first-tier suppliers announced in turn that they would pass on most of these payments to their own (second-tier) suppliers, and some of these then announced their intention to compensate their own (third-tier) suppliers in the same manner.

**Lessons from the Toyota Group**

What lessons can be drawn from the Toyota group’s organized effort to recover from the Aisin fire? While the incident underscores the risk of single sourcing in a JIT setting, the chances of such an event recurring are low. Furthermore, apart from natural disasters or fires, there is usually little need for coordinated responses of the magnitude we have described here, (Strikes pose different problems because the setting up of alternative sites at other firms would be viewed as interference and would generally be unacceptable to trade unions). More significant for our purposes are the implications of the recovery effort for everyday situations.

We believe that this episode demonstrates the benefits of clustered firm networks of the kind that Toyota and its partners have constructed. The Aisin incident reveals the capacity of these networks not only for self-organized, flexible responses to a crisis but also for routine problem solving that leads to incremental improvements in firm and group performance. In other words, the capabilities that made possible the reopening of Toyota-group plants in a few days instead of months are the same ones that have made Toyota and its suppliers among the most competitive in Japan and the world under normal circumstances.

A variety of institutionalized practices foster these capabilities. For example, JIT has the effect of immediately revealing bottlenecks, forcing workers and managers to continuously strive to detect and rapidly solve emerging problems. During the recovery effort, JIT made it easier to locate bottlenecks and improve the productivity of the emergency P-valve production sites. In a JIT environment, workers and managers gradually acquire capabilities for effective and pragmatic problem solving, enhancing their ability over time to deal with emerging problems. As the Aisin episode reveals, these capabilities are shared not only by Toyota and its group of first-tier suppliers (for example, Denso and Kayaba) but also by many second-tier suppliers.

These mechanisms also work at the interfirm level and help foster groupwide problem-solving capabili-
In this case, Toyota "pulled the cord" and stopped the entire value chain, from raw materials providers to assembly plants, forcing everyone to deal immediately with the problem.

ties. Because orders from Toyota would be severely curtailed until P-valve production could be restored, it was impossible for firms such as Denso or even Kayaba to ignore Toyota's and Aisin's troubles. Just as Toyota encourages its assembly-line operators to stop the line whenever a serious problem arises to promote rapid problem-solving at the source, so, in this case, Toyota "pulled the cord" and stopped the entire value chain, from raw materials providers to assembly plants, forcing everyone to deal immediately with the problem. The Aisin incident revealed the extent of Toyota-group firms' capabilities for dealing effectively with such problems, which were the product of years of working in an environment where interfirn coordination and collaboration were crucial to keeping operations running smoothly.

Given the increased competition within Japanese keiretsu, it is likely that Toyota suppliers cooperated to the extent they did in the hopes of being rewarded by increased business opportunities in the future. We believe that such incentives to cooperate were insufficient, however; the necessary capabilities to cooperate effectively had to be in place as well.

Many outside observers believed that the Aisin incident revealed the vulnerability of JIT environments, arguing at the time that any unexpected problem quickly leads to the breakdown of the system. Yet neither Toyota nor any other firm that we interviewed was considering abandoning JIT. With each vehicle containing more than 50,000 parts, it is just too costly to keep security buffers for each component; indeed, any production system is vulnerable to unexpected crises such as a plant fire.

Although crises are impossible to predict, the capabilities required to overcome them effectively and rapidly can be developed in advance. The constraints imposed by JIT ensure that firms gradually make the necessary preparations, since even routine problems can become "mini-crisis" whose resolution leads to new learning experiences. In other words, because of its inherent fragility, firms value JIT for the role it plays in fostering problem-solving and continuous improvement capabilities, at the individual firm and overall group levels and for both routine and major problems.

Several practices institutionalized within the Toyota group support the firms in their quest to develop these capabilities: information and know-how sharing in the Kyohokai and jishiken, regular transfers of employees among group firms, and other practices involving face-to-face contact. These practices facilitate organizational learning, encourage teamwork, and foster a set of common "codes" and understandings among group members regarding technology, management, and the "rules of the game." Thus they provide the basis for coordination and ease of communication during times of crisis and routine alike, as tacit agreements and understandings ensure that information is transmitted without having to explain everything.

Although the mutual dependence imposed by JIT, the competition for future contracts, and peer pressure to conform to group norms would seem to compel cooperative behavior, in reality, cooperation comes "naturally" in a network where firms have deep and intimate knowledge of each other. Trust was manifested throughout the recovery effort, as firms simply assumed that compensation for their efforts would be forthcoming and fair and that other firms would not take advantage of the situation to steal proprietary secrets or new contracts. Incidents such as the Aisin fire further strengthen these sentiments, as trust and reciprocity are deepened each time a crisis occurs.

Cooperation is also promoted by Toyota, as the recognized leader, it controls the general direction of the group. Toyota's financial resources and control over the design process make it the natural leader, but in the long run, it is Toyota's performance record that ensures that suppliers follow its suggestions and initiatives. Firms know that it pays to follow this particular leader, as suggested by Toyota suppliers' consistently above-average profits. Moreover, suppliers accept the constant pressure to improve performance because various practices ensure that firms are not left alone to develop capabilities and that Toyota does not demand anything that it could not do itself. Toyota's demands (e.g., cost-reduction targets) are
based on rational calculations and indisputable evidence that Toyota is invariably able to offer.

Toyota's leadership is undisputed and omnipresent, but at the same time, it is largely decentralized and often invisible. Rather than giving direct and detailed orders to its group firms, Toyota disseminates general approaches, or "recipes," giving firms the tools to self-organize in times of crisis and deal autonomously with emerging problems. These tools are disseminated to first-tier suppliers, which are then responsible for disseminating them to their own network of second- and third-tier suppliers. In this way, similar patterns of behavior are replicated throughout the network without any explicit orders from Toyota (as exemplified by the replication of Toyota's 1 percent compensatory bonus policy throughout the group).

An advantage of this approach is that responses may be differentiated and flexibly adapted to each firm's particular situation, as the "recipe" leaves considerable room for discretion.

One might wonder, then, why all firms do not adopt Toyota's group practices, if the benefits are so great. The answer is that emulating Toyota's model is not easy; it is the product of decades of investments in supplier capabilities and in trust and commitment. Even in Japan, many firms are unable to replicate either the structure or the performance of the Toyota group. Nevertheless, we believe that the Toyota model offers an excellent goal for firms to strive toward. Through earnest and persistent efforts to build supplier capabilities and promote horizontal knowledge sharing among suppliers, firms can reap substantial gains in long-term competitive performance. These efforts should be the next step for the many firms that have already begun the work of restructuring supplier relations in the direction of the partnership model. Moreover, Japanese firms currently under pressure to rationalize their supply base and adopt more market-oriented supplier management practices could also learn from Toyota. Its approach toward supply chain management gives it both flexibility and continuous cost reductions and has proved to be effective even in the current domestic recession.

References

The authors wish to thank Yacht Asahima, Michael A. Cosmato, Takahiro Fujimoto, Ken Kusunoki, Jens Langier-Hellman, Tomo Arai, Annick U.S. Eleanor Wintner, and Min Xue for their valuable comments, as well as the Japan Automotive Manufacturers' Association, the Japan Auto Parts Industries' Association, the Institute for International Economic Studies, the International Motor Vehicle Program at the Massachusetts Institute of Technology, the Sasaki Institute Foundation, the Ministry of Education, Science, Sports, and Culture for the support received for our research. The above mentioned people and institutions are not responsible for any mistakes we might have made.

6. Although in Japanese, the company's name is pronounced "Aisin Seiki," we use the registered English name "Aisin Seiki" in this article. Sales to Toyota currently account for 65 percent of Aisin's total sales.
7. Another interpretation might suggest that the crisis occurred at a relatively good time, that is, when Toyota profits were at their third-highest level ever due to booming sales in Japan, the recent depreciation of the yen, and cost-saving efforts in product development and other areas that saved Toyota nearly $2.5 billion. See: B. Brenner, J. Armstrong, K. Kervin, and K. Naughton, "Toyota's Crusade," Business Week, 7 April 1997, pp. 44-50.
8. In this article, the term "Toyota group" refers to Toyota's network of core suppliers, including affiliates (e.g., Aisin Seiki), independent suppliers, and affiliated vehicle assembly and售后 in the Toyota group.
9. In the Toyota group, this includes fourteen of its closest affiliates, three of its suppliers. All "Toyota group affili- ates and many of Toyota's important suppliers belonging to the automaker's supplier association, the Kyokoukai (245 members) for more details, see: M. Sako, "Suppliers' Associations in the Japanese Automotive Industry: Collective Action for Technology Diffusion," Cambridge Journal of Economics, volume 20, November 1996, pp. 657-671. Within this association is a core group of about sixty firms that account for 80 percent of Toyota's total parts purchasing costs.
10. Interviews were conducted on March 24, 25, and 26, 1997, with managers of Toyota Motor Company, Aisin Seiki Co., Ltd., Koito Sangyo, Ltd., Tatsuno Kogyo Co., Ltd., Kyoritsu Industry Co., Ltd., and Denso Corporation (formerly, Nippon Denso Co., Ltd.).
16. Although a particular model's parts may be sourced to a single supplier, slightly different versions are often sourced to a competing supplier, enabling the assembler to compare each firm's performance and promote long-term competition between the suppliers. Single sourcing is usually adopted by smaller assemblers in Japan.
17. Like Denso Corp, Aisin Seiki was originally a department within Toyota prior to 1949. In 1949, it spin off as a subsidiary. In 1969, it present, it owns about 80 percent of Aisin shares, and several of Aisin's executives are original Toyota managers, including Aisin's current president, Isamu Kato (son of Toyota's founder, Toyota Fujio), Toyota's former president and current chairman).
informal linkages are not sufficient to explain Toyota's high reliance on Asm. The supplier's high performance and reliability must also be considered.

- 11. Toyota vehicles are assembled not only in Toyota's own assembly plants but also in plants of its related firms such as Toyota Auto Body, Aregio Co., Toyota Automatic Loom Works, Central Motors, Gifu Auto Body, Hino Motors, and Daihatsu Motor Co. On Tuesday, February 4, only Daihatsu's weeds plant was kept open. Mitsubishi, which also used Asm P-valves and had only about two days' worth of stock, had to close some assembly lines on February 5. Toyota and Suzuki were not affected, however, because they were able to prioritize production schedules for models not using Asm P-valves and because they had five days' and three to four days' worth of P-valves in stock, respectively.

- 12. The Ministry of International Trade and Industry's estimates of the loss in output during February 1997 caused by the fire were 8.3 percent for the entire transportation equipment industry and 1 percent for all metal-related industries.

- 13. As a consequence of the Kobe earthquake in January 1996, production was halted for several days, but not for as long as in the aftermath of the fire. Most production was halted for one day, with some factories restarting as early as two days after the earthquake. No temporary production sites were established for the affected suppliers, and most of the affected Toyota suppliers, such as Sanyo Electric Co., and Fujitsu-Temco, actually suffered further damage than they had before the earthquake. The major difference was that Toyota and its suppliers were much more prepared for the earthquake than they were for the fire.

- 14. To help Toyota's three vendors, it is estimated that Toyota is helping to assist them with their vendors' own facilities.


- 16. Toyota (65,000 employees) is the world's third-largest automaker, and Japan's largest firm in terms of sales. Both Asm Seiko (11,000 employees) and Denso (45,500 employees) are part of what Toyota defines as the Toyota group. Asm and Denso sell, respectively, 65 percent and 50 percent of their output to Toyota and are, respectively, 20 percent and 23 percent owned by Toyota. Like many Toyota suppliers, their clients include every Japanese automaker as well as many other automakers in the world. In addition, Asm specializes in brake-related parts (its subsidiary, Warner-Aisin, in transmissions), Denso specializes in diesel and electronic power systems, and they are the world's fourth-largest automotive parts supplier. Taiyo Kogyo (435 employees), although not nominally part of the Toyota group, sells 74 percent of its output to group firms (53 percent to Toyota itself), and 50 percent owned by Toyota, and has many former Toyota managers occupying key positions, including Tetsuro Tanaka (chairman), Denso has only one Toyota executive. Its main products are engine bearings, aluminum die-cast products, and dies.

Koyaba is considered to be an independent supplier in Japan's automobile industry, with both Toyota and Nissan owning approximately the same number of its shares: 45.5 percent and 43 percent, respectively. Its clientele is diversified, with Toyota accounting for about 25 percent of sales and Mitsubishi and Nissan accounting for 16 percent and 12 percent, respectively. Koyaba specializes in shock absorbers and hydraulic equipment and has 47 percent of Japan's market share for shock absorbers. Koyaba successfully bid for 320 employees to join Toyota's new factory in northern Kyushu.

- 17. Main P-valve production was to be out sourced in this way. Existing capacity to produce clutch master and tandem master cylinders in-house was deemed sufficient; these parts were not manufactured at Asm's Kiiya plant, whereas P-valves were. Only two firms were needed to assist Toyota with the production of the clutch master and tandem master cylinders.


- 19. Koyaba successfully bid for 320 employees to join Toyota's new factory in northern Kyushu. Its president, Kenji Asada, states that the rapid recovery seen in the company's sales last year was due to the unexpected lack of supplier problems caused by the fire.

- 20. Koyaba's president, Kenji Asada, states that the rapid recovery seen in the company's sales last year was due to the unexpected lack of supplier problems caused by the fire. The company's sales last year were 1.2 times higher than in the pre-fire period.

- 21. The book, "The Miracle of Toyota," by James Womack and Diederik Hoekstra, is a comprehensive guide to Toyota's management system and the lessons learned from the experiences of Toyota and its suppliers during the recovery effort.

- 22. Toyota and its suppliers estimated that the recovery period would take about a year. However, production was back to normal within three months.

- 23. Koyaba is considered to be an independent supplier in Japan's automobile industry, with both Toyota and Nissan owning approximately the same number of its shares: 45.5 percent and 43 percent, respectively. Its clientele is diversified, with Toyota accounting for about 25 percent of sales and Mitsubishi and Nissan accounting for 16 percent and 12 percent, respectively. Koyaba specializes in shock absorbers and hydraulic equipment and has 47 percent of Japan's market share for shock absorbers. Koyaba successfully bid for 320 employees to join Toyota's new factory in northern Kyushu. Its president, Kenji Asada, states that the rapid recovery seen in the company's sales last year was due to the unexpected lack of supplier problems caused by the fire. The company's sales last year were 1.2 times higher than in the pre-fire period.

- 24. Suggestions proposed for alleviating the risk of interruptions caused by such disasters included (1) reducing the variety of parts, among other reasons because reducing the variety of parts complicates the setting up of alternative production sites after the fire; (2) reorganizing production facilities; (3) increasing education efforts toward fire and accident prevention, and (4) increasing parallel sourcing. Regarding P-valves, however, unconfirmed reports suggest that Toyota will probably continue to rely almost exclusively on Asm for P-valves, indicating a reluctance to forgo the many benefits of single sourcing, e.g., possible availability of important cost reductions through exploitation of scale economies, simplification of parts procurement and quality-control activities, and building of trusted relationships with a reduced number of suppliers.

- 25. The examples of 320 to 330 employees at Koyaba bringing the first to complete a P-valve after the fire or of Koyaba's six-month prototype specialist that made its debut for P-valve use in February 1997.


- 28. It is noted that P-valves are relatively mature products and that Asm's technology was not particularly advanced or of a proprietary kind.
