

**SELF-ORGANIZATION AND CLUSTERED CONTROL
IN THE TOYOTA GROUP: LESSONS FROM THE AISIN FIRE**

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International Motor Vehicle Program**

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Lessons from the Aisin Fire**

Toshihiro Nishiguchi and Alexandre Beaudet

ABSTRACT

Japanese supplier management practices have in past years attracted much attention in the US and Europe. Several aspects of these practices still remain relatively neglected, however, such as collaborative relationships between suppliers themselves. In this paper we argue that a recent incident involving Toyota and its supplier network reveals the importance of these relationships and their implications for firm competitiveness. We describe how Toyota suppliers effectively and rapidly organized a group-wide effort to restore production of a key brake-related part, whose supply was suddenly interrupted as a result of a fire at a supplier's plant. We conclude that this remarkable group-wide effort was a function of shared capabilities within Toyota's supplier network. These capabilities lead to effective responses to major crises like this one, and in normal times to decentralized and group-wide problem-solving permitting continuous improvements in firm and group performance, under the omnipresent yet largely invisible leadership of Toyota.

The Japanese model of long-term collaborative supplier partnerships has attracted much attention in recent years from business researchers and practitioners. Several American and European automakers have attempted to emulate this model, seeking to drastically reduce their supplier base and build collaborative relationships with their best suppliers (Dyer, 1996a; Helper and Sako, 1995; Nishiguchi, 1994). As a result, early implication of suppliers in product development and promotion of joint cost reduction efforts are rapidly becoming standard practices in the automotive industry and beyond, along with other practices associated with Japanese manufacturing (Womack and Jones, 1996).

A recent incident involving Toyota and its supplier network suggests, however, that the Japanese model –or at least the Toyota model– involves more than just a collection of long-term *bilateral* relationships with a few select suppliers. Indeed, the nature of the Toyota group's response to the sudden destruction of a key supplier's plant suggests that *multilateral* relationships among suppliers are as important, and more generally that a complex mix of institutions permits *self-organization* (Ulrich and Probst, 1984) in times of crisis with very little direct control by Toyota, the group's undisputed but often invisible leader. This decentralized but omnipresent control permits flexible as well as coordinated responses to emergent crises like the one to be described here, but also foster long-term competitiveness through decentralized group-wide efforts to solve problems and improve overall performance and flexibility.

The incident in question occurred on February 1, 1997, when a fire at one of Aisin Seiki's plants threatened to pull the entire Toyota group to a halt for several weeks. This is because Aisin Seiki,¹ a major parts manufacturer and one of Toyota's most trusted suppliers, was the sole source for proportioning valves (henceforth P-valves, to use the industry parlance), a small but crucial brake-related part used in all Toyota vehicles. Because of both Toyota's and Aisin's dedication to the principles of Just-in-Time (JIT) production, there was only 2 or 3 days' worth of stocks at hand, and shutdown of Toyota group plants (including those of several hundred suppliers) appeared unavoidable.

The timing for such a crisis was particularly awkward, because at the time 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% consumption sales-tax increase slated for April 1.

¹ Although in Japanese the company's name is in fact pronounced "Aishin Seiki," the registered English name "Aisin Seiki" is adopted in this article. Sales to Toyota currently account for 65% of Aisin's total sales.

Every day lost in production therefore meant potentially huge and irretrievable losses in sales and profits for Toyota and related firms.²

However, as a result of an intense collaboration effort involving firms mostly from within but also from outside the Toyota group, disaster was averted and assembly plants were reopened after only two days of complete shutdown. This was accomplished by means of an immediate and largely self-organized effort to set up alternative production sites outside of Aisin. Within days, firms with generally no previous experience with P-valves were manufacturing and delivering them to Aisin, where they were assembled and inspected before being sent to Toyota's and other clients' assembly plants. This remarkable collaboration effort involving over 200 firms (of which approximately 70 took direct responsibility for P-valve production) was orchestrated with very little direct control from Toyota, and without any haggling over issues of technical proprietary rights or financial compensation.

The Toyota group once again showed its cohesion and resiliency, at a time when many were speaking of the weakening of traditional business relationships among group members. Competition for future contracts and pressure to maintain one's reputation virtually forced firms to cooperate with each other, but, as we argue later, it was various capabilities developed through institutionalized problem-solving activities within the Toyota group that ensured the effectiveness and rapidity of the collaboration effort.

In this article we show how such a self-organizing response could emerge out of the chaos in the aftermath of the fire, based on unique data collected through in-depth interviews with several key players in the incident.³ We believe that this incident has important implications and lessons to offer regarding interfirm relations and competitiveness. These implications should interest not only those firms currently restructuring their relationships with suppliers toward the "Japanese" model, but also those moving *away* from it, as many Japanese firms under economic and political pressures appear to be moving toward more market-based sourcing strategies.

In what follows we describe how the Aisin Seiki crisis occurred, how the recovery effort was orchestrated, and how individual firms responded in a diverse, self-organizing manner. After touching upon compensation issues, we then conclude that

² Another interpretation might suggest that the crisis occurred at a relatively *good* time, i.e., when Toyota profits are at their third highest level ever due to booming sales in Japan, the recent depreciation of the yen, as well as cost saving efforts in product development and other areas which have saved Toyota nearly \$2.5 billion (*Business Week*, April 7, 1997, pp. 44-50).

³ Interviews were conducted on March 24, 25, and 26, 1997, with managers of Toyota Motor Corporation, Aisin Seiki Co., Ltd., Koritsu Sangyo Ltd., Taiho Kogyo Co., Ltd., Kayaba Industry Co., Ltd., and Denso Corporation (formerly, Nippondenso Co., Ltd.).

the remarkable group-wide recovery from the Aisin fire incident is a function of shared capabilities within Toyota's supplier network, driving participants to both daily continuous improvements and effective response to larger contingencies.⁴

The Aisin Seiki Crisis

The incident started at 4:18 AM Saturday, February 1, 1997, when a fire erupted in Aisin's Kariya plant number 1. By 8:52 AM the lines dedicated to P-valves and two 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 sudden destruction of the P-valve lines was particularly damaging for Toyota because nearly all of its vehicles use Aisin P-valves manufactured exclusively in this plant, which turns 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 1,400 yen a piece, P-valves require complex high-precision machining in order to assure the reliability and durability essential to the safety of any brake system.

The fact that Aisin was the sole supplier of this small, critical part was surprising to many in Japan, as Toyota has in past years increased multiple sourcing precisely to reduce the risk of such interruptions.⁵ The case of Aisin is particular, however, as it is one of Toyota's closest suppliers in terms of sales, personnel, and financial linkages, and because its outstanding record in terms of cost, quality, and delivery performance makes it extremely difficult to replace.⁶

⁴ Because the "Japanese" model of assembler-supplier relationships is already well documented, we do not detail them in this article; interested readers might benefit from consulting Dyer and Ouchi (1993); Nishiguchi (1994); and Womack, Jones, and Roos (1990).

⁵ Single sourcing is in fact less common in Japan than usually thought, as "parallel sourcing" is used by many Japanese automakers (Richardson, 1993). 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 relative performance and promote long-term competition between the suppliers. Single sourcing is usually adopted by smaller assemblers in Japan.

⁶ Like Denso Corp., Aisin Seiki was originally a department within Toyota before it was hived off as a subsidiary in 1949. Toyota presently owns approximately 20% of Aisin shares, and several of Aisin's executives were originally Toyota managers, including Aisin's current president Toyoda Kanshiro (the son of Toyoda Eiji, Toyota's former president and current honorary chairman). But these formal and informal linkages are not sufficient to explain Toyota's high reliance on Aisin. The supplier's high

In any case, Toyota suddenly found itself facing an imminent crisis because as a result of JIT operations there were only about two days' worth of P-valves in stock at hand. Predictably, the following Monday, February 3 Toyota announced the shutdown of 20 out of its 30 assembly lines (including those of Toyota's contract assemblers), and from Tuesday, February 4 to Wednesday, February 5 practically all Toyota's and related firms' plants were closed, forcing practically the entire Toyota group to a halt.⁷ As a consequence, hundreds of tiered suppliers who would have to wait for the reopening of their client's plants to resume deliveries were also seriously affected, as were local electricity, gas, and transportation companies. Such is the fragility of JIT: An unforeseen event such as this one can bring entire networks and even industries to a screeching halt.⁸

Toyota was in effect facing one of the worst crises of its history.⁹ However, on Tuesday, February 4, only three days after the fire, the first "alternative" P-valves were rolling off the temporary lines hastily set up by an Aisin supplier, Koritsu Sangyo, marking the beginning of the recovery process that we describe below. As a result of this and many other firms' efforts, by Thursday, February 6 Toyota's Tahara and Hino's Hamura plants were reopened, followed by the other affected car assembly plants the next day on a single shift basis. By Monday, February 10, a little over one week after the plant fire, all Toyota group assembly plants were back to normal with production volumes of 13,000 to 14,000 vehicles per day, and after another week they 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% of the

performance and reliability must also be considered.

⁷ Toyota vehicles are assembled not only in Toyota's own assembly plants, but also in plants of Toyota *keiretsu* firms such as Toyota Auto Body, Araco, Kanto Auto Works, Toyoda Automatic Loom Works, Central Motors, Gifu Auto Body, Hino Motors, and Daihatsu Motor Co. On Tuesday, February 4, only Daihatsu's Ikeda plant was kept open. Mitsubishi, which also used Aisin P-valves and had only about two days' worth of stocks, also had to close some assembly lines on February 5. Isuzu and Suzuki were not affected, however, as they were able to prioritize production schedules for models not using Aisin P-valves, and because they had 5 days and 3-4 days of P-valves in stock, respectively.

⁸ The Ministry of International Trade and Industry (MITI)'s estimates of the loss in output during the month of February 1997 caused by the incident were 8.3% for the entire transportation equipment industry and 1% for all metal-related industries.

⁹ As a consequence of the Kobe earthquake in January 1995 production was curtailed for several days, but not as severely as this time. Most production equipment (i.e., jigs and fixtures, machine tools, transfer machines) of the affected Toyota supplier plants (Sumitomo Electric and Fujitsu-Ten) were salvaged intact or repaired quickly, resulting in only minor disruptions for Toyota's assembly plants and only for a few models. In contrast, Aisin P-valves are used in practically every Toyota model and their assembly lines were completely burned down with three transfer machines seriously damaged. In the former incident no temporary production sites outside the affected suppliers were set up, as Toyota assisted them at the suppliers' own facilities.

total amount necessary, although it gradually increased, reaching 60% by March 14 and close to 100% by the end of March. The bulk of P-valve production was occurring at approximately 70 firms including Koritsu Sangyo, 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 yen (*Nikkei Weekly*, May 19, 1997) and Toyota about 70,000 vehicles and 160 billion yen in revenues. Although Toyota officials claim to have recouped most of the lost vehicle production through increased overtime and holiday shifts (*Wall Street Journal*, May 8, 1997), losses in the range of 20 to 30 billion yen are unavoidable, in particular because the setting-up of alternative P-valve sites was costly. In the end, however, Toyota and Aisin could only be grateful that group members helped 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 resumed in such a short period? We document below the recovery process in some detail because it represents a good case of self-organization. We describe in particular the respective roles of 6 firms visited during our field research: Toyota, Aisin Seiki, Denso, Taiho Kogyo, Kayaba Industry, and Koritsu Sangyo. These firms differ in terms of size, specialization, position in the value chain, and financial linkages to Toyota, but share a common set of characteristics including commitment and capabilities for JIT production and problem-solving at the source.¹⁰

¹⁰ Toyota (69,000 employees) is the world's third largest automaker and Japan's largest firm in terms of sales. Both Aisin Seiki (11,100 employees) and Denso (56,500 employees) are part of what Toyota itself defines as the Toyota Group (which comprises 14 firms including major suppliers such as Denso and automakers such as Hino and Daihatsu). Aisin and Denso sell, respectively, 65% and 50% of their output to Toyota, (a proportion that has been on the gradual decline in past years) and are, respectively, 20% and 23% owned by Toyota. Like all Toyota suppliers nowadays, their clients include every Japanese automaker as well as many other automakers in the world. While Aisin specializes in brake related parts (and its subsidiary, Warner-Aisin, in transmissions), Denso specializes in electric and electronic auto components and is now the world's fourth largest automotive parts supplier. Taiho Kogyo (1,350 employees), although not nominally part of the Toyota Group, sells 74% of its output to Group firms (59% to Toyota itself), is 58% owned by Toyota, and has many former Toyota managers occupying key positions, including Taiho's chairman (in contrast, Denso has only one Toyota-bred executive). Its main products are engine bearings, aluminum die-cast products, and dies. Kayaba is considered to be an "independent" supplier in the Japanese auto industry, with both Toyota and Nissan owning approximately the same number of its shares (8.5% and 8.1%, respectively). Its clientele is relatively diversified, with Toyota accounting for about 25% of sales, and Mitsubishi and Nissan accounting for 16% and 12%, respectively. Kayaba specializes in shock absorbers and hydraulic equipment, and has 47% of Japanese and 22% of world market share for shock absorbers. Koritsu Sangyo (320 employees) is a second-tier supplier highly dedicated to Aisin Seiki. It specializes in transmission related parts.

The P-valve recovery effort involved not only Aisin but many other firms as well, because from the very beginning it was crystal clear that outside help would be indispensable until Aisin could rebuild its previous capacity. 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.¹¹ Aisin was to immediately begin setting up alternative production sites in its other plants as well.

Using often very different approaches, sixty-two firms responded to Aisin's call and immediately began preparations to manufacture P-valves, including 22 of Aisin's own suppliers (e.g., Koritsu Sangyo); Toyota itself; 36 of Toyota's regular suppliers¹² (e.g., Toyota *keiretsu* firms such as Denso and Taiho Kogyo, independent suppliers such as Kayaba Industry and Akebono Brake Industry, as well as firms belonging to other *keiretsu* such as Sumitomo Electric Industries); and 4 nonregular suppliers (e.g., Nabco).

Along with these firms were about 150 other firms including 70 machine tool makers that were involved indirectly in the recovery process, as machinery, drills, fixtures, and gages had to be found to replace the ones destroyed in the fire. Machinery makers in Japan and beyond were asked to gather every available machine at hand, including exhibition models taken from show rooms and equipment already promised to other clients. While complicating procedures, for fast recovery both regular and nonregular suppliers of machinery to Aisin were called upon. Their pragmatic cooperation during the incident was crucial to the success of the recovery effort. In doing so many of these firms were no doubt hoping to increase sales to Toyota in the future, which would remember those who helped during this crucial moment.

Firms were asked to machine the needed parts using Aisin's design drawings and forged blocks, and 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 previous experience with this particular part. One firm, sewing-machine manufacturer Brother Industries, had never

¹¹ Mainly P-valve production was to be outsourced in this way as existing capacity to produce clutch master and tandem master cylinders in-house was deemed sufficient; these parts were not manufactured solely at Aisin's Kariya plant whereas P-valves were. Only 5 firms were needed to assist Aisin with the production of these clutch master and tandem master cylinders.

¹² In other words, members of the *Kyohokai*, Toyota's supplier association (see Sako [1996] for more details).

even made car parts (*Wall Street Journal*, May 8, 1997). Although the technology and skills involved in manufacturing P-valves are relatively simple (e.g., relative to transmissions), 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 therefore be slow and arduous.

This lack of sufficient tools and of experience in P-valve production along with inexperience in dealing with such an incident might have appeared discouraging to many, but pragmatic problem-solving capabilities and flexible deployment of resources compensated for these lacunas and ensured a rapid recovery of P-valve production and of Toyota's assembly plants.

Preparations

The first step involved the setting up at 5:30 AM 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 imminent crisis in a orderly and organized manner. At 6:30 AM the unit was reorganized and divided into 4 teams, dealing respectively with production (e.g., the setting-up of alternative production sites), materials handling (e.g., the delivery of materials to these sites), liaison with customers (e.g., Toyota, which was immediately contacted), and general affairs (e.g., negotiations with Aisin's union). The unit's first meeting was held at noon, and subsequently held 27 times until February 21.

The second step involved contacting potential collaborators and deciding who would do what, because many kinds of P-valves were needed (there are over 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 produced in priority, Aisin started as early as Sunday, February 2 (the day after the fire) to fax design drawings to various firms which had already voluntarily offered their help (e.g., Taiho Kogyo, which contacted Aisin after hearing about the fire on the radio) or those that had accepted to do so at the request of Aisin or its clients (e.g., Kayaba, which was asked for help on the day of the fire by Mitsubishi Motors, and the next day by Toyota and Aisin).

It should be noted that those firms who "voluntarily" offered their help were in many ways *forced* to cooperate with Aisin and Toyota. Failure to do so might have jeopardized future business relations with Toyota group firms, and, because of JIT, most suppliers were losing millions of yen every day Toyota plants remained shut down.

Cooperation worked both ways, however. For example, Toyota chose not to put pressure on Aisin to prioritize its own models to the detriment of other clients (e.g.,

Mitsubishi), despite the fact that it could have easily done so given Aisin's financial and commercial dependence on Toyota. Doing so would have given Toyota some short-term gains, but in the long run such actions would be remembered by the parties concerned and usually retaliated in some fashion.

After reviewing the faxed design drawings, their equipment availability, and pertinent technical capabilities, each firm had to notify Aisin of its decision regarding potential collaboration in the recovery effort. This process was not easy as most 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 production had to be organized without the special-purpose machines and drills used by Aisin as they were seriously damaged in the fire. As stated, P-valves require highly precise machining, and to manufacture over 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 machining centers to manufacture P-valves, which most firms already possessed. This would mean a lot more labor content and much lower productivity than usual. The problem then was that Aisin's know-how was largely specific to the special-purpose transfer machines, making it difficult for Aisin to instruct firms on how to manufacture P-valves by other means. Also, although a few drills were salvaged from the fire there was 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 are usually 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 gages. In order to assure the reliability and durability of the brake system, quality control is very strict, involving at least 70 inspection steps per piece. Even though Aisin was to double-check every incoming P-valve, some form of quality control by firms had to be conducted before delivery, using general-purpose gages.

To top it all off, in the first few days of the crisis Aisin was in a state of chaos and was very difficult to contact.¹³ As Aisin had nowhere near sufficient resources to

¹³ The confusion at Aisin was such 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, simply

provide direct assistance to every firm at once, collaborating firms had to figure out by themselves how to program their machining centers for P-valve production as well as find or make appropriate drills. For example, Denso scrambled drills from all over Japan and even sourced some special ones from an American 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 purchases of drills and by organizing meetings where technical problems were discussed and their solutions disseminated, 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 insufficient to manufacture P-valves. But many accepted, including Denso, Taiho, Kayaba, and Toyota, which agreed to manufacture between 2 and 5 types of P-valves each. These and other firms then immediately started preparations for P-valve production.

At this point significant differences in each firm's approach to P-valve production emerged. For Denso full priority was given to in-house P-valve production, and some of Denso's other processes were temporarily outsourced to make room for P-valves. This was judged preferable to outsourcing P-valves because of the difficulties mentioned above. In all, about 40 machining centers were made available at Denso for P-valve production.

Taiho first met with 30 of its suppliers the day after the fire to plan an appropriate division of labor, eventually involving 11 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 division responsible for experimental prototype production and machinery maintenance, whose engineers and operators possess considerable know-how on setting up machines for new models and preparing the transition to volume production.

In contrast, Kayaba's approach involved outsourcing P-valves to three of its suppliers, with no actual P-valve production occurring in any of its own factories. Three prototype specialists were chosen, the largest with 110 employees and the others with only 16 and 6 employees, respectively (this last one composed of the president, two craftsmen, and three female part-time employees). Originally about 10 suppliers had been contacted, of which three were chosen on the basis of equipment availability

overwhelmed Aisin's capacity to respond.

and technical capabilities.

At this stage collaborating firms established their own "emergency response units" to coordinate activities related to P-valve production. A major problem for many firms was to assure close collaboration among usually remotely related units. At Kayaba, for example, a special team was set up to centralize control and coordinate activities with the suppliers concerned, under direction of Kayaba's director of production engineering and composed of 16 employees from the quality assurance, production engineering and purchasing departments. Three sales people were also dispatched to Aisin in order to get real-time information and feedback. At Toyota the production control department was put in charge of coordinating in-house P-valve production as well as direct assistance to Aisin.

Production Begins

The next step involved each firm completing its first prototype to be sent to Aisin for approval. As noted earlier, it was a tiny second-tier supplier, Koritsu Sangyo, that first did it as early as Monday, February 3, only three days after the fire.¹⁴ 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 16-employee supplier, followed by those from the 110-employee and the 6-employee suppliers on February 7 and February 8, respectively.

The operational speed of each firm reflected their familiarity with Aisin or with brake-related parts, and their technical capabilities regarding machining centers and prototype making.¹⁵ In all cases, however, work was complicated by the difficulties mentioned earlier, i.e., the lack of details in Aisin's design drawings and the absence of appropriate equipment or of any direct assistance from Aisin. Many decisions on

¹⁴ Koritsu Sangyo is perhaps an exceptional case. Its president currently presides Aisin's supplier association (93 member firms) and is one of Aisin's best performing suppliers, having won several awards for quality. It is highly dedicated to Aisin (the supplier's president wished he had 30 hours per day instead of just 24 to help Aisin during this incident), the result of decades of continuous and stable relationships involving not only business transactions but also know-how exchange and capability upgrading activities. For example, under the *wakamekai* program junior executives of second-tier suppliers like Koritsu Sangyo are dispatched to Aisin for training on a long-term basis. Through such long standing collaboration emerged not only high levels of loyalty and dedication, but also a shared language and tacit understanding regarding organization and technology. There was therefore no need for extensive and detailed explanations from Aisin for Koritsu Sangyo to begin preparations for P-valve production.

¹⁵ It should also be noted that Kayaba is geographically the farthest from Aisin (in Okazaki City), in contrast to Denso which is located in the same city as Aisin (Kariya City).

production therefore had to be made on collaborating firms' own judgments in an experimental manner. This explains the diversity of methods to manufacture P-valves; for instance, Taiho used two drills where Toyota used only one. At Kayaba, two of the three suppliers, including the 6-employee firm, ended up in making their own drills.

Once the prototypes were approved, each firm moved to volume production. Koritsu Sangyo began volume production on February 4. Denso started volume production on the evening of February 5, with production volumes of 1,600 units per day (raised to 2,200 a day after February 10 under pressure from Toyota). Taiho started volume production the next day, starting with low batches of about 50 units and gradually moving toward volumes of 2,000 units per day. Kayaba started on February 7 with a daily production volume of 520 units.

Solving Bottlenecks

The next step involved solving the various technical problems and bottlenecks that emerged during volume production. As stated already, many of these were foreign to Aisin which was unfamiliar with P-valve production by machining center. A testimony to the firm's impressive technical capabilities, Denso played an important role here, as the firm's engineers were quick to solve one bottleneck after another. These solutions were then disseminated to other firms participating in the recovery process during special problem-solving meetings organized by Aisin. Denso also modified Aisin's design drawings and process instructions to make them more appropriate for machining centers, which were passed onto other firms via Aisin.

Such capabilities for problem-solving are the hallmark of firms ingrained with the principles of the Toyota Production System (TPS) or lean production. The capacity to quickly diffuse solutions is also characteristic of Toyota group firms, who regularly hold benchmarking studies and set up problem-solving study groups (*jishuken*), usually in the presence and sometimes supervision of consultants sent free of charge by Toyota. These practices, along with the monthly meetings of company presidents, the numerous training programs and internships held for lower tiered suppliers' employees, and the constant flow of personnel between firms, permit rapid horizontal and vertical diffusion of best-practices.

Despite these efforts to disseminate the newly found best-practices and standardize P-valve production, diversity of practices persisted as some firms preferred to stick to their own methods. For example, Taiho declined 5 out of 6 design modifications proposed by Aisin because these created discrepancy problems with

Taiho's existing equipment.

Having solved major bottlenecks, efforts were next put into raising productivity and increasing volumes through *kaizen* activities. Again, years of training in TPS principles made sure that the appropriate capabilities and routines were already in place for this end. At Toyota, for example, cycle time was reduced from more than 2 minutes to 1 minute 20 seconds within a few weeks, by minimizing changeover times through pre-setting of the machining centers (P-valve production was still relatively slow, as there were limits to increasing productivity in the absence of Aisin's special-purpose transfer machines). The results of these various efforts were then recorded on video to be stocked as "organizational memory," should the need to manufacture P-valves emerge again.

That Toyota and others quickly moved toward shortening of set up times and even resumed full JIT production suggests how ingrained the TPS is in these firms. For example, at Taiho, which used *kanban* to make P-valves and delivered them to Aisin in 8 batches per day, managers stressed that this was simply the only way they knew how to do it.

The flexibility of personnel deployment and of procedures that is also associated with Toyota and with many other Japanese firms was observed throughout the effort as well, perhaps more so than is customary. At Aisin, with the cooperation of the union, the majority of employees were mobilized for the recovery effort, which involved, for example, white-collar staff from advertising and accounting departments helping with plant operations. At Toyota, the situation often dictated that managers and employees make decisions and take action on the spot without necessarily following normal procedures or obtaining permission from superiors or bookkeepers. They were after all thrown into highly unusual circumstances in which the usual departmental divisions had to be overcome, and many bureaucratic procedures relaxed (e.g., regarding orders for machinery and materials without proper invoices, or changing shifts of workers without prescribed prior notice).

This flow of personnel also occurred between firms. For example, at least 300 Toyota personnel 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, among other things to help Aisin set up more permanent P-valve assembly lines, and about 40 people were sent to Aisin from other automakers as well. Toyota personnel was also sent to Denso to assist in the P-valve production process (in particular from the maintenance department), staying until they observed

everything was in order, and to machine-tool makers, to assist them in the repair of Aisin's damaged transfer machines (which was complete by mid-March). Within the Aisin group various flows of personnel also took place, e.g., from Aisin suppliers to Aisin (about 250 people).

In other words, the P-valve recovery effort involved more than just individual initiatives to set up temporary production sites and increase their productivity. The flow of personnel within and between firms, the various meetings organized to discuss and disseminate solutions to technical bottlenecks, and the various group-level coordination efforts exerted by Aisin's "emergency response unit" and by Toyota's production control department, all contributed to a striking outcome that was more than just the sum of individual efforts.

Compensation Issues

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, and until March 15 for Toyota. Considerable expenses were accumulated in this 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.¹⁶

A striking feature of this incident is that firms such as Denso and Kayaba began production of P-valves without any explicit agreements with Toyota or Aisin on eventual compensation for these 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 will be compensated by Aisin for the more than 300 million yen in labor costs, equipment, special-purpose oil, and so on. This arrangement concerned only the *direct* expenses, however. More important were the losses incurred by Toyota and all the affected suppliers in terms of lost output during the closure of assembly plants.

Toyota settled this issue in a surprising manner: It announced that all of its first-tier suppliers would receive a payment equivalent to 1% of their respective sales to Toyota from January to March 1997. This amounted to overall payments of over 15

¹⁶ Overall, hundreds of Denso employees were daily involved in P-valve production, working double shifts and even during weekends for the first two weeks. At Taiho about 70 people were directly involved in the emergency production effort, including 55 people fully dedicated to P-valve production. At Toyota, 25 employees were directly involved in in-house P-valve production while hundreds more were sent to Aisin and other firms to assist them in the recovery effort.

billion yen, with Denso for example to receive 1.5 billion yen. This offer was seen by many as a *reward* for cooperation rather than compensation.¹⁷

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 in the same manner their own (third-tier) suppliers.

Conclusions and Implications

What lessons can be drawn from the Aisin incident and the Toyota group's organized effort to overcome it? There are implications regarding the risk of single sourcing in the context of JIT, but these interest us less because the chances of such incidents actually recurring are usually low, and the aim of this article is to discuss more general implications applicable even in normal situations.¹⁸ Apart from natural disasters or fires, there is usually little need for coordinated responses of the magnitude of the one described earlier. (Strikes pose very different problems, because setting up of alternative sites at other firms would be viewed as interference and generally be unacceptable to trade unions).

We believe that more general lessons can indeed be drawn from this episode, concerning in particular the benefits of *clustered firm networks* of the kind Toyota and its partners have constructed. The Aisin incident reveals the remarkable capabilities of these networks not only for self-organized, flexible responses to a major crisis of this magnitude, but also for routine problem-solving that lead to incremental improvements in firm and group performance. In other words, we argue that the capabilities that made possible the reopening of Toyota 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 usual circumstances.

¹⁷ It should be noted, however, that Toyota could afford such payments at this juncture of time because profits are higher than expected, in particular as a result of the continued depreciation of the yen. This compensation scheme can also be interpreted as having the objective of spreading these unexpected gains from the lower yen and thus averting criticisms that Toyota is monopolizing them.

¹⁸ Suggestions that were proposed to alleviate the risk of interruptions caused by such disasters include: (1) reducing variety of parts; among other reasons because excessive variety of P-valves (i.e., over 100 main types) complicated the setting up of alternative production sites after the fire; (2) dispersing production facilities; (3) increasing education efforts toward fire and accident prevention; and finally (4) more multiple sourcing. Regarding P-valves, however, unconfirmed reports suggest that Toyota will most probably continue to rely almost exclusively on Aisin for P-valves. This indicates a reluctance to pass away the many benefits of single sourcing, i.e., possibility of important cost reductions through exploitation of scale economies; simplification of parts procurement and quality control activities, and building of trust relationships with a reduced number of suppliers.

These capabilities are fostered by a variety of institutionalized practices. A key practice in this regard is JIT, which has the effect of immediately revealing technical bottlenecks, forcing workers and managers to continuously strive to detect and rapidly solve emergent problems. Note that this was observed even during this incident, as JIT made it easier to pinpoint bottlenecks and improve productivity of the emergency P-valve production sites. In such an environment, capabilities for effective and pragmatic problem-solving are gradually accumulated, leading to always improved capabilities to deal with emergent problems. As was revealed in this incident, these capabilities are shared not only by Toyota and its group of first-tier suppliers (e.g., Denso and Kayaba) but also by many second-tier suppliers¹⁹.

These mechanisms also work at the interfirm level and help foster *group-wide* problem-solving capabilities. Because until P-valve production could be restored orders from Toyota would be severely curtailed, it was impossible for firms such as Denso or even Kayaba to ignore Toyota's and Aisin's pains. Just as Toyota assembly line operators are encouraged to stop the line whenever a serious problem arises in order to promote rapid problem-solving at the source, in this case Toyota "pulled the cord" and stopped the entire value chain, from raw material providers to assembly plants, forcing everyone to deal immediately with the problem. The Aisin incident revealed the extent of Toyota group firms' capabilities for effectively dealing with such problems, the product of years of working in an environment where interfirm coordination and collaboration are crucial to keep operations running smoothly.

In these times of increased competition within Japanese *keiretsu*, it is likely that Toyota suppliers cooperated to the extent they did hoping to be rewarded by increased business opportunities in the future. We believe that such *incentives* to cooperate were not sufficient, however, the necessary *capabilities* to effectively cooperate had to be there as well.

It is interesting to note in this regard that the initial reaction of many outside observers was in fact to attribute the extent of the Aisin crisis to JIT itself, in which any unexpected problem (in this case, a fire at a supplier's plant) quickly leads to the complete breakdown of the system. In other words, they believed that the Aisin incident revealed the *fragility* of JIT. Despite the damages caused by such incidents, however, neither Toyota nor any other firm that we interviewed was considering abandoning JIT. With over 30,000 parts in a vehicle it is just too costly to keep security

¹⁹ The examples of 320-employee Koritsu Sangyo being the first to complete a P-valve after the fire or of Kayaba's 6-employee prototype specialist that made its own drills for P-valve use are telling in this regard.

buffers for each component, and any production system is vulnerable to unexpected crises such as a plant fire.

However, although such crises are impossible to predict, the required capabilities to effectively and rapidly overcome them can be developed in advance. The constraints imposed by JIT ensure that this is done, gradually and incrementally, as even routine problems can become “mini-crises” whose resolution leads to new learning experiences. In other words, we believe that JIT *because* of its inherent fragility is valued for the role it plays in fostering capabilities for problem-solving and continuous improvement, both at the individual firm and overall group levels, and for both routine and major problems.

Firms are supported in their quest to develop these capabilities by ways of several practices institutionalized within the Toyota group, such as the *jishuken* mentioned above, regular transfers of personnel between group firms, and many other practices involving tremendous amounts of face-to-face contacts. These practices facilitate *group-wide* organizational learning and help foster a strong sense of common fate and mutual familiarity among group members, along with a set of common “codes” and understandings regarding technology, management, and the “rules of the game” (e.g., regarding JIT). This provides the basis for the kind of coordination and ease of communication observed in this incident and in more normal times as well, as tacit agreements and understandings ensure that information is transmitted without having to explain everything (Nonaka, 1991; Nonaka and Takeuchi, 1995).

Although the mutual dependence imposed by JIT, the competition for future contracts, along with peer pressures to conform to group norms leave little room for anything *but* cooperative behavior, in reality cooperation comes “naturally” in a community where firms have such deep and intimate knowledge of each other. This was manifested throughout the recovery effort, as firms basically assumed that compensation for their efforts would be forthcoming and fair, and that other firms could be trusted not to take advantage of the situation to steal proprietary secrets or new contracts.²⁰ Incidents such as the Aisin fire further strengthen these sentiments, as trust and reciprocity are exchanged and accumulated each time a major crisis occurs.²¹

Cooperation is also enforced by Toyota’s presence, which as the recognized

²⁰ It should also be pointed out that P-valves are relatively mature products and that Aisin’s technology in this regard was not particularly advanced or of a proprietary kind.

²¹ For example, the automaker Daihatsu, in gratitude for help received after the Kobe earthquake, collaborated in the recovery effort by immediately sending equipment engineers to help Aisin set up new assembly lines at its Handa plant.

leader controls the general direction of the group. Toyota's abundant financial resources and control over the overall design process make it the natural leader, but in the long run it is a proven record in terms of performance that ensures that its suggestions and initiatives are followed (Nishiguchi and Anderson, 1994). Firms know that it pays to follow this particular leader, as suggested by Toyota suppliers' consistently above average profits (Dyer, 1996b). Moreover, the constant pressure to improve performance is accepted by firms because as stated various practices ensure that firms are not left alone to develop capabilities, and Toyota does not demand anything that itself could not do. Its 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 give direct and detailed orders to its group firms, Toyota disseminates general approaches or "recipes" (e.g., problem-solving at the source, visual control), giving firms the tools to self-organize in times of crisis and autonomously deal with emergent problems. These tools are first diffused to the first-tier suppliers, who are then responsible for their diffusion 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% compensatory bonus policy throughout the group). An advantage of this 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 group practices, if their benefits are in fact so substantial. The answer is that imitating Toyota's model of supplier relations and overall enterprise group system is not easy, as it is the product of decades of investments in supplier capabilities as well as in trust and commitment. Even in Japan many firms are unable to replicate either the structure or performance of the Toyota group. We believe nevertheless that the Toyota model of supplier relations offers an excellent *target* for firms to aim at. Through earnest and persistent efforts to build supplier capabilities and promote horizontal knowledge sharing among suppliers, we believe that substantial gains in terms of competitive performance and long-run flexibility can indeed be found. This should be the next step for the many firms who have already made big efforts to restructure supplier relations in direction of the partnership model.

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