BRIEF CASES

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AIC Netbooks: Optimizing Product Assembly

November 15, 2008, was a cold night in Shenzhen, China. Inside the factory of electronics firm AIC, Inc., Production Manager Elias Chen watched completed QuiN 816 netbooks rolling toward the end of the conveyor belt, where the final assembly line worker placed each unit onto the rack for the shock test and the final burn-in test by quality assurance. After a frantic start-up phase in August 2008 and three months of frequently recalibrated production runs, the line was operating more smoothly. However, Chen knew that the Taipei office wanted to further improve performance at the Shenzhen plant. It was time to review the netbook assembly operations and identify ways to optimize the line.

Company Background

Advanced Integrated Circuitry, Inc.—later renamed AIC Systems—was founded in Taichung, Taiwan, in 1992 as a producer of printed circuit boards, focusing on motherboards and graphics cards for the personal computer industry. Initially, AIC Systems competed for business as a low-cost manufacturer in the industrial zone of Xitun, focusing on the PCI bus chipset that launched with the Intel Pentium CPU in 1993. The company supplied branded manufacturers of desktop and laptop computers such as Dell, Hewlett-Packard, and Compaq. While AIC Systems total volume was lower than Taiwanese rivals Elitegroup Computer Systems, ASUS, and MSI, the company's relentless focus on cost management allowed it to be a competitive source.

By the early 2000s, AIC Systems had evolved into what the industry considered an original design manufacturer (ODM). As an ODM, the company took an active role in innovating and designing each new generation of components. By doing in-house design and development work, the company was able to foster more exclusive, longer-term relationships with its customers. AIC Systems also protected its position as a low-cost supplier by opening its Kaizhi plant outside Shenzhen in early 2001 when the Taiwanese government relaxed restrictions on investments in mainland China. The company was among the first of the Taiwanese firms to shift all of its production volume to China. Management's aggressiveness in transitioning away from Taiwan-based manufacturing enabled the

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HBS Professor Steven C. Wheelwright and writer Sunru Yong prepared this case solely as a basis for class discussion and not as an endorsement, a source of primary data, or an illustration of effective or ineffective management. This case, though based on real events, is fictionalized, and any resemblance to actual persons or entities is coincidental. There are occasional references to actual companies in the narration.

operations team to quickly move down the learning curve and take advantage of the lower labor costs.

In fall 2007, AIC Systems embarked on a new strategy: diversifying its product portfolio to include consumer electronics, with a particular focus on mobile technology. Anne Lin, chief strategy officer, explained the decision:

> In the technology world, most hardware has become a commodity, and this will continue to be a space with relatively thin profit margins. We have a solid position as a manufacturer of circuit boards, but we will continue to find ourselves beholden to our end-customers with established brands—Dell, HP, Sony, and so on. As middle-class demand for mobile technology grows in the Asia-Pacific markets, we have the opportunity to serve their needs directly and build a new proprietary consumer brand. This will be a multi-year investment, but we believe we are well-positioned with our technological and manufacturing capabilities.

Mobile technology took several forms, including ultra-portable laptops called netbooks; traditional laptops; and mobile phones laden with variable arrays of computer-like functions. (See **Exhibit 1**, which compares types of mobile technology.) The success of the Eee, created by ASUS Tek Computer of Taiwan, made the netbook an attractive platform for AIC Systems' first foray into consumer electronics. It appeared to be a fast-growing market where another Taiwanese firm had already taken the lead, and it presented an opportunity for the company to leverage its cost base and its capabilities in PC components.

History of the Netbook

Prior to 2007, "ultraportable" laptop computers were available but commanded steep premiums, retailing at $2,000 or more. No manufacturer had successfully introduced an inexpensive, lightweight computer. This changed with the efforts of a non-profit, One Laptop Per Child (OLPC), to build a cheap laptop for classroom use in developing countries. In close partnership with a Taiwanese firm, OLPC aimed to produce a $100 laptop and received support funding from the likes of AMD, eBay, Google, Red Hat, and others. The organization failed to hit the $100 price target, but its initiative had an indirect effect on the entire PC industry. The publicity generated by OLPC led other companies to explore their own versions of a low-priced, ultraportable computer. Intel introduced the unsuccessful Classmate PC that cost too much and lacked a keyboard, while VIA launched the Nanobook but struggled to overcome production challenges, a high retail price, and software bugs.

Ultimately, it was Taiwan manufacturer ASUS that proved a viable market existed—not in serving students in the developing world, but rather in selling to middle-class consumers in western Europe and the United States. The ASUS Eee came with a 7-inch screen, an Intel Celeron ULV Dothan processor, 4 gigabytes of solid-state flash memory, and weighed just 2 pounds. The necessary trade-off in functionality to achieve better portability and affordability was no hindrance to sales. Indeed, for many consumers, it served as a second laptop used primarily for email and surfing the Web while on the go. The retail price of $399 made it a popular choice for consumers looking for an affordable, ultra-portable, web-enabled computer. Launched in fall 2007, the ASUS Eee sold 350,000 units in just four months.

Over the next few months, every major PC manufacturer launched a similar device or announced plans to do so. In June 2008, Intel launched another ultramobile platform with its new Atom processor that combined high performance with low voltage requirements. In addition, Microsoft extended the life of its Windows XP Home edition operating system specifically to serve netbook devices. Industry analysts estimated that the total industry unit volume for 2008 could top 15 million (see **Exhibit 2** for sales estimates and projections for 2007–2008).

Development of the QuiN Netbook

AIC Systems began development of the QuiN (short for "quick net") in March 2008, and Elias Chen was charged with bringing a netbook to market by the third quarter of the year. An early, critical decision that Chen had to make was the selection of the processor. He challenged James Ashey, the chief industrial engineer, to avoid developing a "me-too" product. Ashey explained the key consideration:

> ASUS was very successful using the mobile Intel Dothan processor in the Eee netbook. We knew we could do the same. However, we also knew that Intel was close to introducing another processor, which turned out to be the Atom. We wanted to be among the first to introduce an Atom-based netbook, but this meant waiting until it became available, then quickly designing the motherboard and production process for it.

Although waiting for the Intel Atom processor made their task more difficult, Ashey was confident that they could adhere to the timeline set by the Taipei corporate office. Following the mid-year introduction of the Atom 230 with an accompanying Mini-ITX motherboard, Ashey and his team quickly designed an improved motherboard. The engineering team dubbed the board "Koda," a portmanteau that recognized the production facility ("Kaizhi") and paid homage to Yoda, the Star Wars character that was small, green, and powerful—just like the Koda. The Koda board offered solid capacitors, a BIOS that allowed overclocking, and a lower-profile heat sink that allowed for a thinner netbook. The Atom processor was soldered in, and it featured Intel GMA950 integrated graphics, 5.1 channel audio, and a Realtek LAN. The rest of the QuiN 816 netbook consisted of parts that AIC Systems sourced externally, including the LCD screen, the clamshell consisting of the base and cover assemblies, the solid-state hard drive, the built-in webcam, and the touchpad (see **Exhibit 5** for a glossary on these components).

Netbook Assembly Line

While Ashey and his team completed the development of the Koda board and moved the Kaizhi plant into production, Chen focused on establishing the assembly line process for the QuiN 816 netbook itself. Working closely with Will Lapin, his process engineer, he designed a 16-meter assembly line that would be staffed by 10 operators (see the line's functions in **Exhibit 3**). With four of these lines set up, Chen and Lapin designed the operation of each line to produce 700 netbooks per nine-hour shift (including one hour for lunch and breaks), with two shifts per day, six days per week. Chen described their goals with the assembly line:

> The major criterion is to have enough capacity to meet peak monthly demand. It is hard to know exactly what this will be because the product is new and AIC Systems is new to the consumer market. However, our marketing team has projected our volume needs, and it's our job to make sure we can deliver. We also need to be flexible and design a line that can adjust as the market forces us to develop new specifications and products.

The Kaizhi plant had a dedicated warehouse for incoming materials, and the outsourced parts and subcomponents for the QuiN were directed from there to the production floor. For the four assembly lines, two dedicated material handlers ensured that each line had an adequate supply. Along one side of each 16-meter conveyor were gravity-feed shelves that served each station with required parts.

The conveyor belt itself was separated into 1.6-meter intervals by white stripes, and each interval contained one netbook unit. Thus at any moment, each conveyor had 10 netbooks in process. The line workers sat in rolling chairs in 10 stations along one side of the conveyor, with each one responsible for specific tasks in assembling the netbooks. The first operator laid out the key components and scanned the serial numbers. The second worker was responsible for installing the webcam, the third worker installed the LCD display into the cover assembly, the fourth worker installed the Kota motherboard, and so on. Most steps of the assembly process involved a number of simple operations performed by hand and with electric screwdrivers. While no single operation was difficult, the assembly process demanded dexterity, efficiency, and speed, with no wasted movements.

Lapin divided the tasks so that each operator had responsibility to select and count screws required for assembly operations at the next station. The screws were placed into small foam trays directly on the conveyor. He explained the rationale:

> By giving each person responsibility to help the next station, we build a double-check into the process. It decreases the likelihood that an operator forgets a screw in the installation, since the exact number she needs to use is there in the tray. It also helps our workers recognize that they have ownership over all steps of the assembly, not simply what they do at their own stations. This leads to higher-quality products.

Chen and Lapin also encouraged a *kaizen* approach to netbook assembly.[1] Line workers were asked to identify specific actions to improve processes, and *kaizen* meetings were organized to discuss how to implement changes. If the company implemented a worker's idea, he or she received a financial bonus. Chen described the benefits:

> It is easy in an assembly line environment in which people do only what they are asked – no more, no less. Through *kaizen*, we let our people know that we are listening, and that we will act upon and reward good ideas. One good example was a change in the way we load bins of new parts and discard of empty bins, which made the process significantly quicker.

Each assembly line had a supervisor who sat at the head of the conveyor belt. The supervisor had responsibility to ensure smooth production, helping line workers troubleshoot problems. In the first months, Lapin had also assigned two dedicated "floaters" to each line – one for stations 2 through 6, and another for stations 7 through 10. These were highly skilled workers who had been cross-trained for all assembly steps and moved between stations when workers fell behind or required breaks. Because they could help cover for less-efficient workers, Lapin believed they played an important role in ensuring that output was maintained without sacrificing quality.

After the netbooks were assembled, they were placed on racks for transport to quality assurance on another floor. Each solid-state hard drive came loaded with a simple diagnostic test to confirm that the circuitry was operational and led the operator through tests of the keyboard, touch pad, and webcam. Each netbook unit then went through a "burn-in" test that operated the hardware at an elevated temperature for 24 hours. Units that passed the burn-in test were packaged and palletized for shipment.

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[1] *Kaizen* is a Japanese word that means "change for the better." Companies encouraged employees to proactively identify ways to improve the way jobs were performed and processes were designed. By holding regular assessment meetings and incenting employees, *kaizen* was a way for organizations to pursue continuous improvement.

Challenges to the Operation

The first few months of full-scale production of the QuiN 816 had been frantic. The assembly line design required refinement, and initial orders had been unpredictable. For example, a Korean mobile telecom company ran a promotion offering a free QuiN netbook to anyone signing up for a two-year data plan; the program had generated significant publicity, but also created an unexpected spike in production demands. These spikes had to be managed with two shifts because Chief Strategy Officer Anne Lin was unwilling to invest in hiring and training the workers and supervisors required for a permanent third shift. Lapin observed:

> The early orders we received were what you might call "lumpy"—we would see very little demand, then receive an unexpected order for several thousand units on short notice. Since we had to work with two shifts, this forced us to run 10- or 12-hour shifts, which is not sustainable. In addition, we had the usual growing pains associated with getting a new assembly line fully operational, and even with two "floaters" per line, we were barely keeping up. This made for some sleepless nights for Elias and me.

By November 2008, the QuiN assembly lines were running more smoothly, each producing a netbook every 50 seconds. A few issues remained, including some non-standard operations that had crept into the assembly process. For example, the webcam cable required additional adhesive to be secured into the cover assembly frame; this had not been part of the original assembly line design. Occasionally, unsanctioned buffer inventories were also accumulated between stations. While the *kaizen* meetings were helpful, Chen still found that his supervisors were often engaged in "firefighting," addressing an immediate problem without fixing the root cause. He suspected that the pressure to maintain output levels was leading them to look for quick fixes, rather than being willing to temporarily halt production to find a more permanent solution.

Overall, Elias Chen was satisfied with the way Ashey and Lapin's teams had developed the QuiN 816, ramped up production, and successfully brought it to market. Nevertheless, the Taipei corporate office was putting pressure on him to improve on current performance and find ways to boost gross margins. An internal task force studying the rising labor costs in the Shenzhen area was evaluating the Kaizhi plant and had asked Chen whether the "floater" line workers would be needed on a permanent basis (see **Exhibit 4** for breakdown of the QuiN netbook unit costs). Anne Lin commented:

> The netbook market is proving to be a tough competitive environment, and we are proud to have built some momentum as a new player. Compared to some other companies, our quality has been consistently good. However, the Kaizhi plant has not yet moved very far down the experience curve. The first three months are behind us, and now it's time to take the next step with the operations. This is particularly important because in the next month or two, we expect demand to increase to over 130,000 units a month—we need to know if we can keep up without just squeaking by, or whether we need to invest in another line.

It was time to review the QuiN 816 operations and identify ways to improve the productivity of existing capacity.

Exhibit 1 Comparison of Mobile Devices, 2008

	Laptop	**Smartphone / PDA**	**Netbook**
Screen Dimensions	12″ – 17″	2.5″ – 3.5″	8″ – 10″
Weight	3.5 – 7 lbs	4 – 5 oz	2 – 3 lbs
Processor	Intel Core 2 Duo 1.2 – 2.26 GHz	Intel XScale, Samsung RISC ARM, et al.	Intel Atom 1.6 GHz
Memory	2 – 8 GB RAM 80 – 320 GB Hard Drive	1 – 16 GB	512 MB – 1 GB RAM 4 – 20 GB SSD Hard Drive
Operating System	Windows Vista	Multiple	Windows XP Home
Leading Brands	Acer Dell HP Lenovo Toshiba	Apple Blackberry Nokia Palm Sony	Acer ASUS Dell HP MSI
Price Range	$900 – $2000	$200 – $600	$400 - $600

Exhibit 2 Netbook Sales, 2007–2008

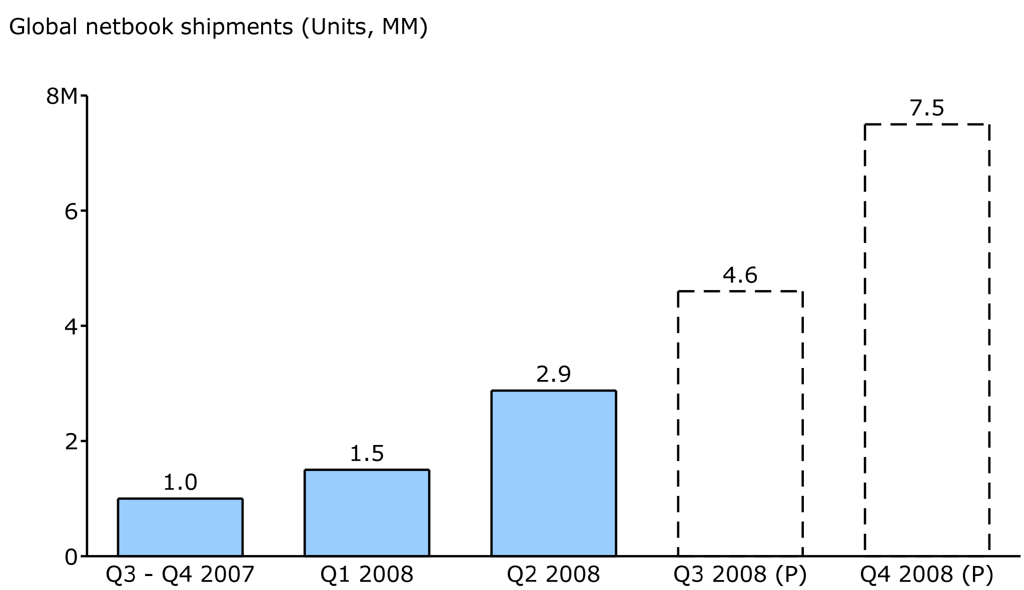

Exhibit 3 Kaizhi Plant Assembly Line for the QuiN 816 Netbook

Station	Operation #	Description of Operation	Planned Time (in seconds)	Planned Workers per Station	Actual Time (measured October 15)	Actual Workers per Station
1	1	Lay out principal components on conveyor	10	1	10	1
	2	Examine parts for visible defects (scratches, dents)	12		12	
	3	Scan serial number barcodes	12		12	
	4	Peel adhesive backing from cover assembly	6		6	
2	5	Attach webcam cable and secure to frame of cover assembly	15	1	23	1.2
	6	Insert webcam into cover assembly	20		21	
	7	Put screws for station 3 in tray on conveyor	5		6	
3	8	Connect LCD cable to display	12	1	12	1.2
	9	Install LCD display panel in cover assembly and secure with screws	22		22	
	10	Put screws for station 4 in tray on conveyor	5		5	
4	11	Install Kota motherboard onto base assembly	17	1	20	1.2
	12	Secure Kota motherboard with 6 screws	18		19	
	13	Put screws for station 5 in tray on conveyor	5		6	
5	14	Install and screw in solid-state hard disk drive	19	1	19	1.2
	15	Connect hard drive cable to motherboard	11		11	
	16	Place insulator sheet on hard drive	4		4	
	17	Put screws for station 6 in tray on conveyor	5		5	
6	18	Screw in microphone to base assembly	16	1	21	1.2
	19	Connect microphone to motherboard	11		14	
	20	Install support frame on base assembly	8		9	
	21	Put screws for station 7 in tray on conveyor	5		6	
7	22	Install speaker holders and speakers	16	1	22	1.25
	23	Secure speaker assembly with screws	10		11	
	24	Connect speaker cables to sound card	9		10	
	25	Put screws for station 8 in tray on conveyor	5		6	
8	26	Connect backup battery and clock battery	9	1	9	1.25
	27	Check voltage of clock battery and backup battery	13		13	
	28	Install wireless card to motherboard	10		10	
	29	Put screws for station 9 in tray on conveyor	5		5	
9	30	Install touchpad and screw onto base assembly	5	1	6	1.25
	31	Install keyboard support plate on base assembly	8		9	
	32	Screw in support plate	13		15	
	33	Install keyboard onto base assembly	10		12	
	34	Put screws for station 10 in tray on conveyor	5		6	
10	35	Turn machine over and put screws into base assembly	8	1	9	1.25
	36	Tighten screws to secure base assembly	12		13	
	37	Install connector protective flap to base assembly and cover assembly	8		10	
	38	Install battery pack and cover	8		9	
	39	Place assembled laptop on rack for transport to QA	4		5	

	Planned	Actual
Total Assembly Line Workers per Line	10	12
Material Handlers per Line	0.5	0.5
Supervisors per Line	1	1

Exhibit 4 Unit Cost Breakdown of AIC QuiN 816 Netbook

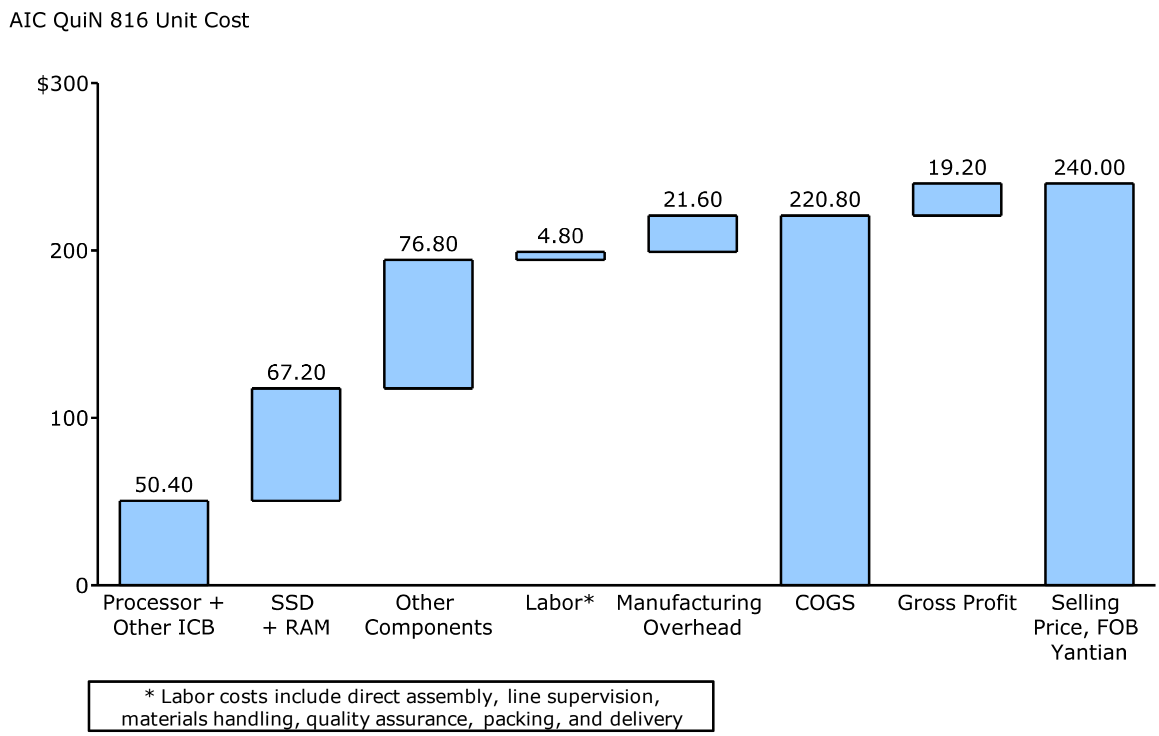

Exhibit 5 Glossary of Netbook Components

BIOS with overclocking: BIOS (basic input/output system) is software built into a personal computer (also known as firmware) that helps load the operating system (e.g., Windows) and initialize and identify system devices such as the keyboard, hard drive, and video graphics card. Overclocking is a means of running components at a higher clock rate (more cycles per second) than the standard specification, which may be done by vendors to improve profit margins by selling a higher-performing product.

Heat sink: A heat sink in a personal computer dissipates the heat generated by the processor by conducting it away, typically toward a fan. This is necessary to protect the processor and is a particular challenge in laptops and netbooks due to the limited space.

LAN: A LAN (local area network) card provides wireless internet access for computers.

Solid capacitors: Capacitors store and discharge electricity as needed. Solid capacitors on a motherboard provide greater durability and higher tolerance for a wide range of temperatures.

Solid-state hard drive: A hard drive that uses microchips in non-volatile memory chips and contains no moving parts, unlike a traditional hard disk drive, which is an electromechanical device with spinning disks and a movable read/write head. A solid-state drive is faster and less susceptible to physical shock.