Defining New Business Models for the Mobile Device Supply Chain

by

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Bachelor of Science in Electrical Engineering
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Submitted to the MIT Sloan School of Management and the Electrical Engineering and Computer Science Division in Partial Fulfillment of the Requirements for the Degrees of

Master of Business Administration
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In conjunction with the Leaders for Global Operations Program at the
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Abstract

Mobile device companies typically manage supply and pricing for components that are used in production by their Vertical Integrators (VIs). By controlling the component pricing and supply chain, mobile device companies are able to increase their pricing and supply chain leverage over smaller component suppliers. Maintaining this leverage is crucial in ensuring that mobile device companies can mass-produce high quality products at efficient costs. However these advantages require that companies incur additional operational expenses associated with supply chain management. To reduce costs and improve lead times, OEM companies should consider having 1st Tier suppliers directly manage 2nd Tier suppliers.

This project will investigate VI capabilities to manage quality, design, and cost across the entire range of hardware used in Nokia phones. Alternatively, we will also identify specific program and commodity areas which may benefit from having a more integrated supply chain.

We will also investigate how Nokia can reduce supply chain management costs to meet future business needs related to cash flow.[1] By analyzing Nokia's historical supply chain performance, we will develop a model to quantify Nokia's "level of control" over its supply chain . We define this "level of control" in terms of the Operational Expenses and Investment which Nokia incurs in managing its supply chain. With this model, we will assess how future business constraints will affect Nokia's supply chain control. By evaluating key parameters which influence supply chain control, we can recommend how Nokia can allocate control across its supply chain. Finally, we will apply this model to recommend how Nokia should outsource supply chain management responsibility.

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[1] "Fitch Downgrades Nokia," Wall Street Journal, April 24, 2012

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I would like to thank Professor Vincent Chan for his advice on building an analytical description of Nokia's supply chain performance.

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1 Introduction

1.1 Background

Nokia manages its supply chain and manufacturing operations by focusing on four criteria: Product Technology, Quality, Cost, and Supply (TQSC).

- Product Technology defines the product's hardware capabilities: advanced displays, processors, cameras, etc.
- Quality is an indication of the customer's satisfaction with overall product performance.
- Cost describes the material, manufacturing, and supply chain expenses associated with producing the final product.
- Supply is defined by Nokia's ability to maintain availability of components used in production. Preventing supply chain disruptions caused by material shortages is one of Nokia's key supply chain management goals.

Nokia actively manages its supply chain in order to achieve its goals for TQSC. To do so, Nokia manages its overall supply chain consisting of component suppliers, vertical integrators, and Nokia's own factories. Nokia factories make the final assembly of phones based on partial assemblies provided by the Vertical Integrator (VI). Vertical Integrators include contract manufacturers such as Foxconn.[2] Component suppliers provide the basic pieces that go into phones, such as speakers, electronic chips, and mechanical parts. A portion of these components are shipped to the VI for partial assembly. A portion of these subassemblies are then shipped to Nokia factories for final assembly. (See Figure 1 for an example supply chain showing Nokia's suppliers and VIs.)

[2] *Wireless Handset EMS/ODM Struggle Despite Market Comeback*, iSuppli Global Manufacturing and Design Analysis, Jan. 2010

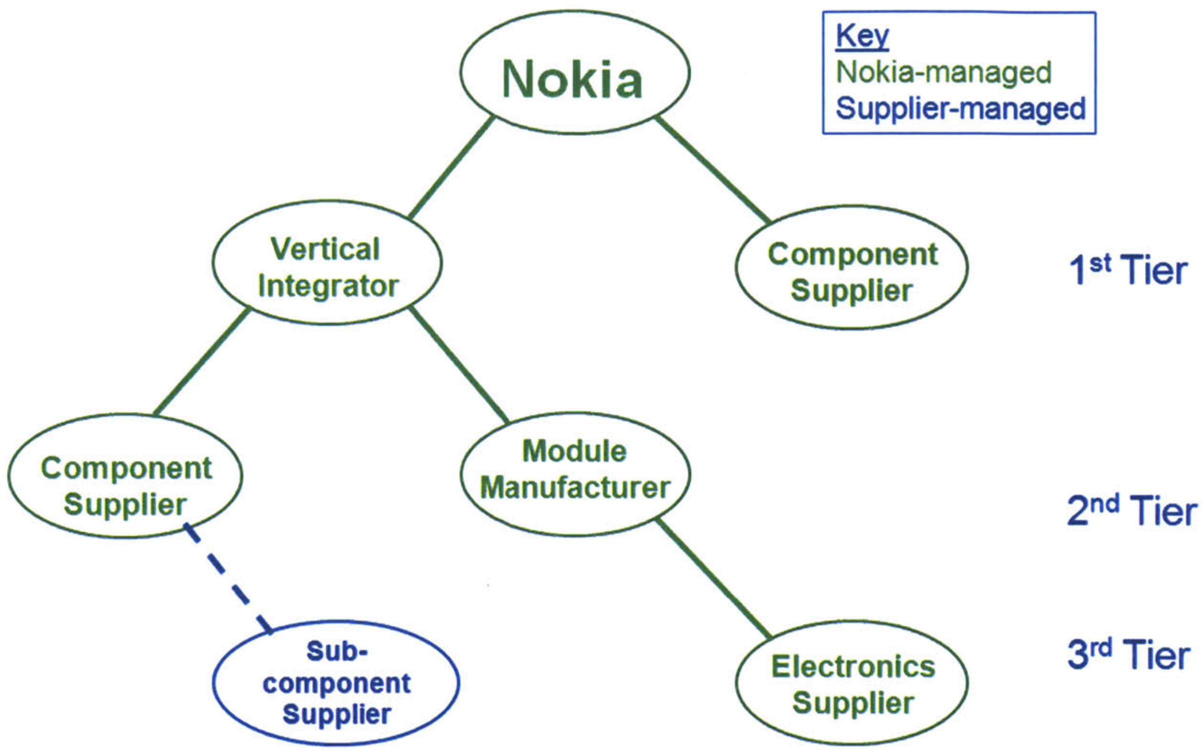

Figure 1: Nokia's management of 1st, 2nd, and 3rd tier suppliers.

1.2 Nokia's Purchasing Model (AVAP)

In order to achieve purchasing economies of scale, Nokia negotiates component prices directly with suppliers. By maintaining a direct link to component suppliers, Nokia has the option to control when and how component orders are delivered. This is especially important during material shortages, when a supplier must decide which of its customers will receive the first shipment.

Considering Nokia's large purchasing economies, it is possible that some of Nokia's Vertical Integrators have smaller purchasing economies of scale. To address this weakness, Nokia can negotiate prices and capacity directly with component suppliers. Nokia then has the option to provide the VI with its negotiated agreement. Such an arrangement may stipulate that the VI can purchase a certain quantity of components at a specific price from the component supplier. The VI is then able to order directly from the component supplier on behalf of Nokia. The purchased components are used specifically to produce Nokia products. This model is called Assigned Vendor Assigned Price (AVAP).

1.3 Problem Statement

Under AVAP, the VI receives sensitive pricing information. If the VI purchases the same component on behalf of another customer, then the VI may benefit from knowing Nokia's negotiated price for that component. It is conceivable that Nokia is helping its competitors lower their purchasing costs using information Nokia reveals to its VIs.

Commodity components are usually produced on a mass scale for companies across several industries. In some cases, VIs may be able to manage these commodity components at a relatively low cost. As technology improves, more components become commoditized, making it easier for the VI to manage those components .

1.4 Key Considerations

This thesis studies the entire supply chain needed to produce the latest and most cutting-edge mobile devices. We will focus on the companies who design and sell mobile devices—including familiar brands such as Nokia, Apple, Samsung, and Motorola. We will also compare major Vertical Integrators and Original Design Manufacturers (ODMs), such as Foxconn and Compal Electronics. Key questions which we will explore include:

1. How must Nokia adapt its supply chain model to face future business goals and needs?
2. If the Nokia sources directly from suppliers, can it reduce costs and improve supply availability over the long-term?
3. If Nokia reduces its future Supply Chain OpEx and Investment, how will this affect Nokia's future supply chain control and purchasing power?

1.5 Purpose of Study

The goal of this study is to describe the costs and benefits of different operational business models and show how these models are relevant to Nokia. We will understand the costs and benefits by observing how current and pastoperational business models have affected production cost, quality, and supply. We will study these performance factors across major commodity areas,. By identifying how business model performance varies across different commodity areas, we can recommend a business model to achieve future supply chain goals. In making a recommendation, we will also discuss future investment costs required to execute new business models. Finally, we will analyze Nokia's suppliers' capabilities and development areas required by future business models.

1.6 Approach

First, we will identify metrics to understand cost, quality, and supply performance on past programs. Second, we will compare these past performance metrics to current performance measures. Then, we will identify the costs and benefits observed in applying these new business models. Finally, we will recommend a set of business models for future programs, based on Nokia's ability to invest in and scale new production.

2 Background & Context

Note: Information in this section is drawn from industry research reports, not from Nokia internal information.

2.1 Nokia Corporation

Nokia is the world's largest manufacturer of mobile phones, with a market share of 23% in the second quarter of 2011. It is based in Finland and employs over 132,000 employees across 120 countries, with major operations in Finland, China, and the US. In 2010, Nokia achieved annual revenue of over €42 billion and operating profit of €2 billion. In the third quarter of 2011, Nokia recorded sales of €9 billion with a loss of €71 million. These figures place Nokia at #143 in the 2011 Fortune Global 500 list.

2.1.1 Nokia's Product Development

Product development requires coordination between major groups within Nokia, including Sales, R&D, Sourcing, and Logistics. Early on in the product development cycle, Nokia Sales and Marketing will identify phone features which consumers will want in the future. Some features depend on as yet non-existent software and hardware technologies. To deliver these features, Nokia will begin to develop relationships with software developers and component suppliers.

R&D begins by defining the phone concept and design, including the hardware and software architecture required to run the future phone. Since on-time phone delivery depends on the available technology of Nokia's suppliers, R&D will coordinate with Sourcing to select suppliers who will produce the phone later on. This process requires trading off various phone designs based on functionality, cost, time, and ease of production.

While the phone design is being finalized, Sourcing will set up the supply chain necessary to begin full production. Hardware suppliers are selected and component prices and delivery schedules are negotiated. Suppliers set up their manufacturing lines and prepare themselves for new manufacturing processes. Meanwhile, Sourcing representatives validate suppliers' processes according to a set of requirements. If those requirements are not met, Sourcing will provide corrective actions to help the supplier improve their process. All this preparation is done to ensure that sufficient supplies of the new phone can quickly reach consumers.

Phones assembled from dozens of components create new challenges even after Sourcing has set up the supply chain. These challenges force Nokia to continually redesign its supply chain. To prepare for these cases, the Sourcing and Logistics groups work together to actively monitor material inventories, production schedules, quality defects, and competitor forces affecting the global supply chain. Constant supply chain improvements ensure the cost-efficient production required to compete in the cutthroat mobile device industry.

In summary, Nokia adds value to the consumer by orchestrating a complex process involving Sales, R&D, and Supply Chain disciplines. While there are many phone manufacturers, few can provide an integrated hardware and software solution on a large scale to satisfy millions of consumers worldwide.

2.1.2 Nokia's Supply Chain Organization

As of mid-2011, Nokia's Markets division heads the supply chain, sales channel, brand and marketing functions of the company. The supply chain organization is further divided between Sourcing and Logistics groups. Sourcing is responsible for long-term supply chain planning, including supplier relationships, selecting new designs, and operations development. Logistics manages day-to-day supply chain and production issues, including monitoring inventory, quality, and in-house production.

<table>
<tr><th colspan="5">NOKIA CORPORATION</th></tr>
<tr><td colspan="3">MARKETS</td><td>Mobile Phones</td><td>Mobile Solutions</td></tr>
<tr><td>Supply Chain</td><td>Sales</td><td>Marketing</td><td></td><td></td></tr>
</table>

2.1.3 Nokia's Sourcing Organization

Nokia Sourcing group is organized by the major elements sourced for phone production, including software and hardware. Semiconductors such as electronic chips have a dedicating sourcing group to meet unique industry challenges. These three sourcing groups are supported in a matrix organization by four other groups, as seen in the table below. This thesis deals primarily with Operations Development for the Hardware & ODM Sourcing organization (as highlighted below).

SOURCING			
Mobile Phones Sourcing	Software, Content, & Services Sourcing	Semiconductor Sourcing	*Hardware & Original Design Manufacturing Sourcing*
Smart Devices Sourcing			
Quality			
Operations Development			

The Hardware & ODM organization is the largest sourcing group, and is responsible for many major components required for phone production.

In addition to sourcing groups for each commodity, there are also dedicated Sourcing representatives for each product program, who are responsible for quality and supply issues specific to one program. This program-specific sourcing team operates at the intersection of Nokia's R&D and Sourcing groups, supporting Design for Manufacturability goals.

2.1.4 Nokia's Supply Chain - Informal Advantages

How has Nokia maintained its top position in the global mobile industry? A more fitting question may be: How has being the largest mobile device maker helped Nokia maintain its top position?

Nokia sold 453 million mobile phones in 2010, with a market share of 32.6%. Being the #1 mobile device maker gives Nokia unmatched purchasing and production economies of scale. Lower prices enable Nokia to choose the best combination of low-cost and high-quality components for its phones. This supply chain advantage continues to help Nokia dominate the developing world market, including India and Africa.

With its huge buying power, Nokia's supply chain directives are accommodated more easily by suppliers, who see Nokia as an important customer. This in turns provides Nokia with economies of scale to efficiently manage its suppliers.

2.1.5 Nokia's Supply Chain - Formal Structure

Because of Nokia's production scale, it is able to operate in-house manufacturing facilities throughout the world, located in Finland, Brazil, China (Beijing and Dongguan), Hungary, India, Mexico, and South Korea. According to iSuppli, Nokia prefers to retain final assembly in-house for quality control and logistics coordination. It outsources much of its mobile phones' modules and sub-assemblies to its Vertical Integrator partners.[3] This structure results in Vertical Integrators and other suppliers performing the lower "value-added" steps in phone production.

According to iSuppli, in 2009, Nokia maintained 92.1% of final production in-house while outsourcing 7.9% of its final production. Note: this does not imply that mobile device production is concentrated in-house. Many time-consuming manufacturing processes are performed by Vertical Integrator partners before Nokia takes over final assembly. The figure below shows Nokia's mobile device manufacturing partners and share splits in 2009.

[3] *Wireless Handset EMS/ODM Struggle Despite Market Comeback*, iSuppli Global Manufacturing and Design Analysis, Jan. 2010

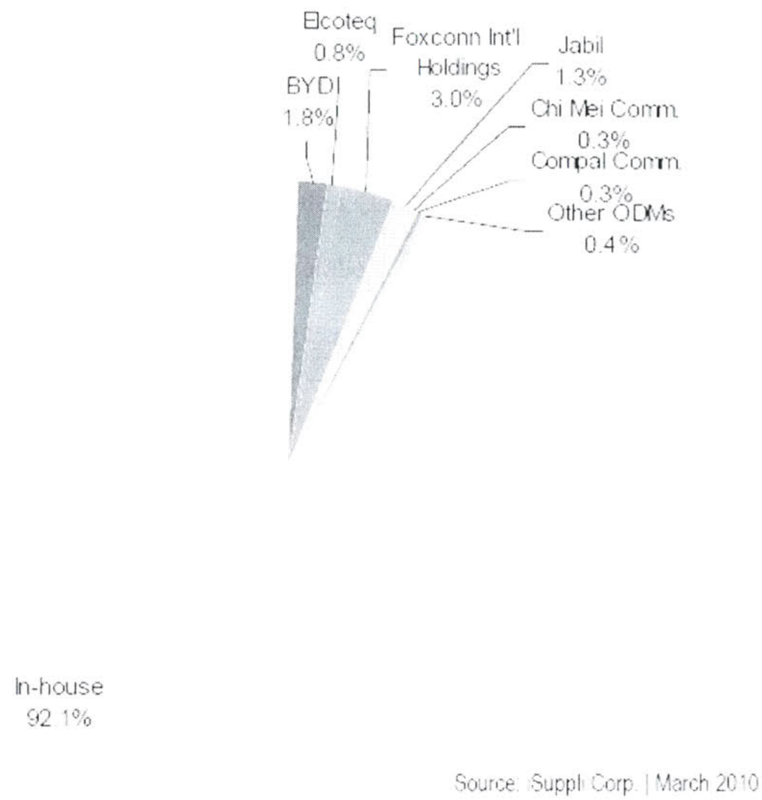

Figure 2: Nokia's Proportion of In-House vs Outsourced Production

The large proportion of in-house production reflects the 2008 economic downturn and contraction in the mobile device market. To maintain a healthy level of in-house production, Nokia moved manufacturing back to its own factories. Thus, at the beginning of 2009, Nokia announced that it would gradually decrease (or cease) the use of contract manufacturers in certain areas including Printed Circuit Board (PCB) and final assembly (source: iSuppli).

iSuppli estimates that with Nokia's strategic pullback from outsourced programs, all of Nokia's contract manufacturing partners—except for BYD—saw their shares with Nokia decline in 2009. BYD, however, saw its share with Nokia double in the same period. This increase was due to Nokia's effort to lessen its reliance on Foxconn. By developing alternative vertical integrator partners, Nokia sought to reduce risk and maintain buying power over its supplier base.

In addition to Vertical Integrators, who specialize in providing manufacturing services, there is a special class of solution provider called Original Design Manufacturers. ODMs also provide design expertise and can assist companies in developing new phones. Many ODMs combine manufacturing and design services to offer a more complete (and perhaps more expensive) solution. Among Nokia's partners, Foxconn and Compal Communications are notable ODMs *(source: iSuppli).*

2.2 Survey of the Mobile Device Industry

2011 experienced a shift in the mobile device competitive landscape, as Nokia dropped from the #1 place in smartphone market share. Growth at Samsung and HTC was driven by huge demand for Android phones, as Android eclipsed Apple's iOS as the dominant smart device platform with 47% market share (vs. 29% for Apple's iOS). The table below shows global smartphone sales and market share numbers for the period between July and September, 2011.

Top Five Smartphone Vendors, Shipments, and Market Share Q3 2011 (Units in Millions)

Vendor	3Q11 Unit Shipments	3Q11 Market Share	3Q10 Unit Shipments	3Q10 Market Share	Year-over-year Change
Samsung	23.6	20.0%	7.3	8.8%	223.3%
Apple	17.1	14.5%	14.1	17.0%	21.3%
Nokia	16.8	14.2%	26.5	32.0%	-36.6%
HTC	12.7	10.8%	5.9	7.1%	115.3%
Research In Motion	11.8	10.0%	12.4	15.0%	-4.8%
Others	36.1	30.6%	16.6	20.0%	117.5%
Total	118.1	100.0%	82.8	100.0%	42.6%

Figure 3: Global Smartphone Vendor Market Share (source: IDC)

The Others category include firms such as Motorola, Sony Ericsson, and LG, each with market share less than 5%. The Others category notably includes no-brand "grey-market" phones which are popular in emerging markets. These no-name brands are known for quickly producing cheap copies of famous brand phones, making them popular alternatives in India, Africa, and rural China. These small competitors exert downward pressure on Nokia's and Samsung's product offerings in emerging markets. Price competition is so acute that other major OEMs often lack the economies of scale and supply chain efficiency to compete in these markets.

2.2.1 In-house vs. Outsourced Design

Companies can outsource the development of their phones to Original Design Manufacturers (ODMs). ODMs provide a full suite of services for making a new phone, including: concept planning, external design, component selection, software and hardware integration, etc. Flextronics and Foxconn have actively developed and promoted their ODM capabilities.

OEMs such as Motorola and Sony Ericsson rely most heavily on ODMs. On the other hand, bigger players such as Nokia, Samsung, Apple, and LG prefer to retain design activities in house. As a result, iSuppli estimates that currently 80% of global mobile devices shipped are designed in-house by OEMs.

2.3 Key Competitors in the Mobile Device Industry

2.3.1 Samsung

Samsung sold just over 300 million phones for the first eleven months in 2011, putting it just under Nokia's total sales of 303.6 million phones over the same period. In comparison, Samsung sold 280 million phones in 2010 and 235 million phones in 2009. Such high growth rates have caused Samsung to increasingly rely on manufacturers such as Foxconn. In 2010, Samsung kept 100% of final assembly work in-house, while engaging Foxconn for PCB assemblies and sub-assemblies. The company still conducts primary R&D and production activities in-house.

Samsung operate production sites across the world to reduce costs, maintain competitiveness, and simplify logistics. Up until 2008, most production was kept in Korea due to high profitability and fears of technology leaks. However, in the last five years, Samsung has significantly expanded production capacity outside of Korea, especially in low cost countries such as China, India, and Vietnam. As of 2010, the proportion of overseas production has grown to over 80%. Nevertheless, Samsung is likely to maintain its 50 million units / year production in Korea for several reasons. The Korea plant can better manage trade secrets on leading and high-end products. Furthermore, Samsung seeks to minimize potential political and public protests following its continued production offshoring.

Roughly 50% of the components in a typical Samsung phone come from Korean suppliers. However, Korean companies are relatively weak suppliers of baseband chips, RF modules, and power amplifiers, so Samsung relies on other companies for these components.

Samsung's strategy emphasizes Korean suppliers for three main reasons: trust, ease of control and bargaining power, and the ability to respond faster to Samsung's requests. This shows that Samsung leverages informal supply chain advantages to maintain its competitiveness.

In expanding production into low-cost countries, Samsung has developed a network of Korean suppliers around its major factory in Huizhou, China. Its Vietnam factory also relies on some suppliers in Huizhou, while Samsung continues to ramp up suppliers around its Vietnam site. Samsung's India facility is at an earlier stage, but is expected to ramp up along similar lines.

The Vietnam and Brazilian facilities help Samsung improve its competitive position in these markets, partly by reducing import duties for phones manufactured and sold in these countries. In some facilities, Samsung has the additional advantage of producing flat panel TVs and other Samsung products. This allows Samsung to quickly scale production at new sites and also shift production volumes depending on changes in demand.

We believe that strong demand has enabled Samsung to localize its material supply chain across most of its major production sites. To support sudden demand, Samsung will also gradually engage contract manufacturers for more advanced production. For example, by partnering with Foxconn for its LCD-TV ODM programs, Samsung shows that it is open to outsourcing further work, especially in board-level assembly and sub-assembly production.

2.3.2 Apple

Apple sold 72.3 million iPhones in 2011, making it the #2 smartphone vendor. The large number is all the more surprising because Apple has by far the fewest models and SKUs among all the top OEMs.

Apple is an asset-light company, focusing on research and development while outsourcing manufacturing and fulfillment of its products. Components and assembly are sourced to low-cost, high-speed suppliers. Apple outsources its entire product manufacturing to contract manufacturers. Before 2011, Apple relied exclusively on Hon Hai, the parent company of Foxconn, as its contract manufacturer across many product categories. Hon Hai also served as a strategic mechanical part supplier. Since 2011, Apple has diversified its contract manufacturer portfolio to include Pegatron, for production of CDMA phones.

To protect its proprietary design, Apple is highly involved in material procurement and does not allow contract manufacturers much flexibility in quoting and selecting suppliers. For mechanical parts, Apple takes full ownership of the sourcing process: contract negotiation, engineering changes, vendor approval, etc.

Because Apple retains tight control of its supply chain, it chooses to (and is required to) minimize the amount of variation in its devices. One iPhone model is released per year and variations are limited to different memory capacities. By limiting product variation, Apple can achieve high volumes and insist on custom designs instead of off the shelf parts. This practice frustrates many of Apple's suppliers, who find themselves unable to use extra inventory for other platforms.

Apple maintains synchronized communication throughout its supply chain, allowing the company to respond quickly to changes in demand. Its supply chain strategy is best described as a highly synchronized, interdependent network of global external suppliers and partners. This allows Apple to provide anticipated sales volume figures to help component suppliers plan production. Next, Apple's Electronic Manufacturing Service providers (i.e. contract manufacturers such as Foxconn and Pegatron) receive components which they use to assemble, package, and ship the final iPhone.

The above strategy allows Apple to minimize inventories throughout its supply chain. Apple stores provide another key differentiator allowing Apple to make accurate demand forecasts. These stores provide an up-to-date picture of sales volumes and customer returns. Furthermore, all new iPhone users must register their devices through iTunes. This allows Apple to track new purchases made through retailer and wireless service provider channels.

Apple is famous for cutting large deals with suppliers by prepaying for future shipments. In some cases, Apple will invest in building the production capabilities which its suppliers will need. As of 2011, Apple can still approach these transactions more confidently than other OEMs because it can rely on a devoted customer base eager to buy the next iPhone.

2.3.3 Motorola

In the mid-1990s, Motorola and Nokia roughly split the market for mobile phones. In 2011, Motorola was the eighth largest OEM, with 5% of the market. After witnessing continued market share decline, Motorola undertook a series of structural changes to its supply chain beginning in 2005. Because these changes failed, it is instructive to study Motorola's supply chain strategy.

Before 2007, Motorola maintained the most decentralized R&D structure of all major OEMs. High overhead and potential labor duplication made this model unsustainable as Motorola's sales continued to decline. The firm moved quickly to scale down R&D operations in France, Singapore, China, and the

United Kingdom. This allowed Motorola to outsource its product design to ODMs (Original Design Manufacturers).

Motorola gained some initial success with its outsourcing strategy. The industry-wide downturn in 2008 drove most other OEMs to shift production in-house. ODMs facing excess capacity were eager to strike deals with Motorola. As a result, Motorola began to outsource the majority of its final production. Of course, Motorola's supply chain executives realized they needed to maintain purchasing power. Therefore, they prevented their ODMs from quoting and selecting suppliers. Instead, Motorola took full ownership of contract negotiations and component purchases. These efforts did not help Motorola regain market share. The company currently focuses on mid-range to high-end Android devices, which provide Motorola with better profit margins compared to lower-end products.

2.4 Briefing on Ecosystems: Android, Apple, and Windows

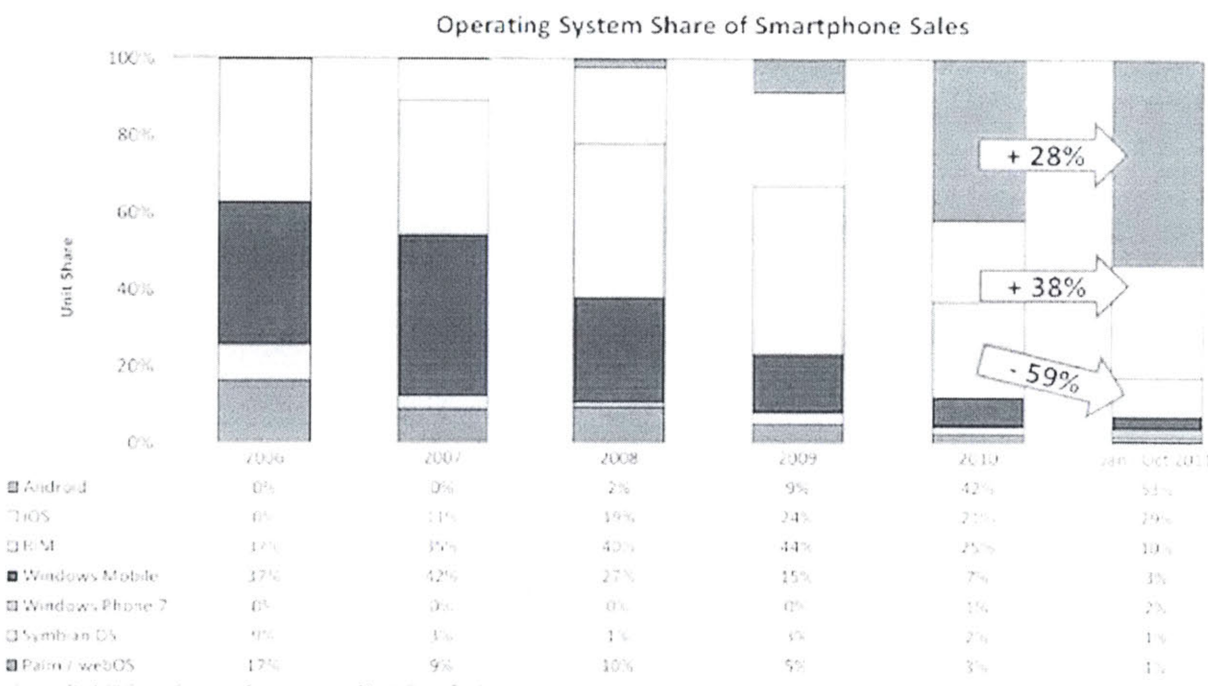

Figure 4: Historic market share for major smartphone ecosystems.

The figure above shows the historic market share for the major smartphone ecosystems, as well as recent growth rates for the Android, iOS, and RIM platforms. Windows Phone 7 (WP7) continues to seek broader awareness, app developer support, and partnerships with wireless service providers. Nokia's bet on WP7 is a huge win for Microsoft, because Nokia's large production volumes can help bring WP7 into the hands of many first-time smartphone users.

To seal the partnership, Microsoft offered Nokia broader control of several WP7 features. Currently, Nokia has developed Nokia-specific apps for navigation and music in order to differentiate its products. Nevertheless, we believe it is in Microsoft's long-term interest to ensure a consistent user experience and level playing field among its device OEMs.

Differences between the three ecosystems—Android, iOS, and Windows—will drive future sales. Therefore, the figure below summarizes some of the key features and differences among the three ecosystems.

	Android	iOS	Windows
Total Devices	hundreds	11	20
Total Apps	380,000+	500,000+	43,000+
Tablet-optimized Apps	Hundreds?	140,000	N/A
4G Support	LTE, HSPA+, WiMax	HSPA+	HSPA+
Cloud Integration	3rd party apps	iCloud	SkyDrive
Voice control	Commands with some Natural language	Natural language	Commands
Navigation	Free	3rd party only	3rd party or Nokia
Search Provider	Google	Google, Yahoo, Bing	Bing
Dual-core devices	Several	Two	0

Devices: iOS has the least number of devices, with 11 models spread across its iPhone, iPad, and iPod touch lines.

Apps: As the newest platform with a much smaller market share, it is remarkable that WP7 has gained over 43,000 apps. Microsoft's efforts to woo and support developers seem to have paid off.

Tablets: The tablet market is still immature for both Android and WP7, with Microsoft preparing its Windows 8 tablets for launch in 2012.

4G will drive the evolution of future smartphone apps. In the US, Android is best positioned, since it offers 4G phones on several service provider networks.

Cloud Integration: Released in Fall 2011, iCloud provides full syncing of content between iOS devices and Macs, including users' photos, music, contacts, reminders, browser bookmarks, notes, documents, calendar events, and some third-party apps. Android and WP7 provides limited contact syncing and app backups.

Voice control: Apple surprised everyone with its Siri platform, which allowed users to submit queries by speaking in natural language. Both Android and WP7 are striving to develop this feature for their future products.

Navigation: When Android launched late in 2009, it bundled an excellent voiced turn-by-turn navigation app. This provided a key differentiator compared to iOS, which relied on 3rd party apps costing over $50. The Nokia Drive app is a feature that differentiates Nokia devices from other Windows phones.

Search Provider: As of Dec 2011, Bing's US market share reached 15% of the desktop search market. Users prefer to search using Google, so being tied to Bing places WP7 at a disadvantage.

Dual-core devices: With WP7 lacking dual-core support, Nokia was unable to release high-end dual-core phones. This is a small example of how relying on WP7 limits Nokia's product offerings.

2.4.1 Ecosystem Analysis and Conclusions

Android and iOS are dominating the smartphone market, with their wide base of applications. Users of both platforms are highly satisfied with their experience, with 85% of Apple users willing to consider repurchasing an iPhone and 84% of Android users willing to consider an Android-based smartphone (source: "The Smartphone Market is There to be Won", GFK Insights4u). Furthermore, customers who have already invested in apps for one ecosystem will face switching costs when moving to another platform.

To break into the smartphone market, WP7 needs to offer new and valuable features. In our previous comparison, we showed that WP7 is a competitive smartphone platform, yet still lacks several key features. Windows Phone 8, slated for mid-2012, will address dual-core support, LTE, and high-resolution screens. Additionally, Microsoft can differentiate its offering by linking Windows Phone to the Office platform. A feature allowing users to sync Office files between their business computer, tablet, and smartphone may offer a compelling reason to choose the Windows Phone.

We believe the success of the Windows Phone depends on three factors: device functionality, wide availability of apps, and easy integration with business systems.

Device functionality: Nokia's designers and manufacturing planners can build competitive hardware showcasing the latest Windows Phone features. Nokia's success here will help Microsoft attract more developers to drive wider *app availability*.

Integration with business systems: Microsoft has an opportunity to target business users switching from RIM. However, in the US, many people are now using their personal smartphones for work, aided by software that allows easy switching between different profiles. This trend is already benefitting iOS and Android. Thus, Microsoft and Nokia should also target business markets in non-US and emerging countries, where users are beginning to discover smartphones. Driving US market share will be more difficult—Windows Phone has the best chance in the low and medium-range segments attractive to first-time smartphone users. The smartphone market is shaping up, and the Windows Phone must build by targeting multiple (if scattered) user segments.

2.5 Contract Manufacturer Landscape

In recent years, handset OEMs have outsourced slightly less than 30% of their production to contract manufacturers (including ODMs). This was motivated by a desire to manage quality and logistics in-house. Especially during the 2008 – 2009 downturn, OEMs brought outsourced production back in-house to optimize internal capacity utilization. More recently, with the popularity of smart phones, OEMs have found very few contract manufacturers with the capability to design and build smart phones. The only contract manufacturer capable of making smart phones, HTC, decided to build exclusively for its own brand.

The EMS provider and ODM dichotomy: Electronic Manufacturing Service (EMS) providers focus on providing manufacturing services, while Original Design Manufacturers (ODMs) offer more design services. So what is the difference between EMS providers and ODMs? Recent trends show that EMS providers are building their design expertise, placing themselves in direct competition with ODMs. So the differences between EMS providers and ODMs continue to shrink.

(Note: the numbers below for Foxconn and Flextronics include their revenues for non-mobile phone segments.)

Traditional EMS providers include Foxconn (annual revenues: $59.3B) and BYD Electronic ($2.52B). They offer extensive and cost-efficient manufacturing services, especially for construction of mobile phone enclosures and Commodity 3. ODMs include Flextronics ($28.7B) and Compal Communications ($490.5M). ODMs offer manufacturing services, but differentiate themselves by also offering services traditionally performed by the OEM's own R&D unit. By offering a one-stop shop for phone development and production, ODMs typically command higher prices.

Looking to the future, we expect the major OEMs to retain in-house design while outsourcing production of low and mid-range smartphones. Foxconn is poised to execute well in this environment, as it continues to build scale and increase vertical integration. For example, Foxconn recently purchased display maker Chimei Innolux, allowing it to offer its customers a one-shop solution for mechanical, display, and circuit board assembly. OEMs relying on Foxconn's extensive services can theoretically expect improvements in lead-time and cost. Nevertheless, other specialized suppliers still offer better quality and technology.

BYD is notable in being the most successful copycat of Foxconn's business model. It builds manufacturing facilities in low-cost locations co-located with OEM's production facilities. BYD also relies on building a vertical integrated supply chain to improve its cost-competitiveness. While BYD has yet to achieve Foxconn's scale and lacks in-house design expertise, we see BYD as the true challenger to Foxconn's low-cost EMS model.

Flextronics's future is the most uncertain: While the firm offers the most extensive design capabilities, it is continually challenged to compete against the extreme low cost structure inherent in its Chinese and Taiwanese competitors. Another ODM, Compal Communications, saw its fortunes improve by partnering with Nokia.[4] As Compal continues to build its in-house design competencies, it has potential to fill in the space of former ODM, HTC.

2.6 Overall Observations

Among the OEMs we have analyzed, the most successful have maintained strong competencies in sourcing, design, and supply chain management. Some examples:

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[4] "*Compal Communications* to see strong smartphone shipments to *Nokia* in 2Q12," Digitimes, April 24, 2012

- *Sourcing:* Apple retains full control of material procurement, and does not allow contract manufacturers much flexibility in quoting and selecting suppliers.
- *Supply Chain Management*: Samsung keeps 100% of final production in-house to better manage quality and logistics.
- *Design:* HTC is a technology leader, having released the first Windows phone, the first Android phone, and the first 4G phone.

By comparing with the laggards such as Motorola and Sony Ericsson, we can conclude that the leading OEMs:

- *Actively participate in key areas of the value chain:* Whether it is in sales, supply chain management, sourcing, or design, leaders prove that their participation is critical to the mobile phone value chain. (In other words, they don't simply splash their brand on an ODM-designed phone.)
- *Achieve large production volumes:* By standardizing designs and minimizing product variation, Apple has gained economies of scale even though it makes one quarter the number of phones annually as Nokia.
- *Maintain strong design competencies*: Firms differentiate themselves in key areas of the user experience: Apple through iOS, Samsung through excellent hardware and displays, and HTC through the features it has developed on top of the Android platform.

On the other hand, successful OEMs will outsource low value-added activities to their contract manufacturers. At the same time, OEMs must ensure that they maintain negotiating power over their supplier base. Thus, the right supply chain strategy will vary depending on the specific OEM's situation. Some approaches may include:

- *Developing vertical integrator capabilities to manage quality:* In their chase for low costs, contract manufacturers do not develop quality management skills for the long-term. While squeezing VIs on cost, OEMS also implicitly agree to monitor quality through their internal teams.
    - *Proposal*: OEMs should assess their quality resolution processes to determine whether problems can be solved more quickly and cheaply using the supplier's resources and teams. If the OEM pursues this strategy, they must be prepared to invest resources into their VI partner.
- *Standardizing components across product lines*: Doing so will improve purchasing economies of scale and also reduce inventories. Production forecasts require less safety stock when certain purchase orders can be pooled together. With more standardization, OEMs can realize less liability for over-forecasts and can more efficiently ramp down production.
    - *Proposal*: OEMs' product planning and R&D teams need to understand the true customer value of using new components vs. financial costs. Purchasing managers, who are happy to increase their work scope, must also be incentivized properly.

- *Enabling the VI to directly source components under the turnkey model*: Low cost purchasing is best achieved by sourcing in large volumes. Under this model, the VI will directly negotiate prices and manage quality for the components they source. The VI will charge the OEM a higher component price to account for the VI's management fee. This fee should still cost less compared to OEM's internal team managing the same activity.
    - *Proposal:* First, the OEM must help teach the VI's personnel how to manage component quality. Then, a combined sourcing team from the OEM and VI works together to develop sourcing and supply risk strategies. After a period of time, the VI's sourcing capabilities and costs can be measured to determine long-term savings.

In sections 6 and 7, we will develop a model to determine whether these recommendations make sense for Nokia's future supply chain. Our analysis will compare Nokia's supply chain models with historical performance. Then we will assess Nokia's future business needs and its impact on future supply chain performance. Only by quantifying data in this way can we make a recommendation for Nokia's future supply chain strategy.

3 Project Scope & Current State

3.1 Mobile Device Hardware Commodities

The most important components in a mobile device include the display, mechanics, and electromechanics. These component commodities are important to study for three reasons:

1. They typically represent technologically advanced components, which carry technological and production risk. These risks create uncertainty in achieving production, cost, and supply stability targets.
2. They require greater upfront investment in production and quality verification equipment.
3. These commodities represent entire industries and supplier bases.

3.1.1 Display

Display assemblies consist of a Display module and a Touch module. The Touch module is responsible for registering the user's "touch" input and the Display module provides the "display."

Display assemblies are fundamentally complex and require coordination with many suppliers. Technological complexity creates long lead-times for component and subcomponent sourcing, especially with the Display Driver Integrated Circuit (DDI IC) and Touch IC subcomponents. Although these IC's represent a small portion of the overall price of a phone, they are critical for Display and Touch functionality.

When planning for future product demand, sourcing managers must account for long lead-time delays in responding to volume changes with critical components. One solution is to directly manage sourcing for a critical subcomponent, by defining capacity, price, and component selection. The Display module supplier is then responsible for ensuring sufficient supplies of their product, which includes all critical subcomponents such as the DDI IC.

Display are a major factor in the end-user experience, and they are usually the most expensive components in the overall phone. Samsung's dominance in the Display market gives it distinct cost and supply advantages. First, Samsung supplies Display to several major OEMs.[5] This gives Samsung some insight into the products and volumes shipped by its major competitors. Secondly, by making its own components, Samsung can produce phones more cost-efficiently and undercut competitors. Lastly, by managing both Display and phone production, Samsung can cut their manufacturing lead-times and simplify logistics. Samsung's example shows how companies gain an advantage by controlling key elements of the product value chain.

3.1.2 Mechanics

Mobile phone Mechanics includes all structural and mechanical components used in phone production. This includes phone covers, keypads, antennas, internal assemblies to hold together

[5] Source: http://en.wikipedia.org/wiki/Amoled

components, etc. The mechanical area also includes subcomponents made using special materials, metals, and plastics.

Vertical Integrators such as Foxconn have capability to produce specific mechanical components in-house. They can then partially assemble the phone by placing the phone electronics, display, camera, etc. into the Mechanics enclosure.[6] This results in a partially assembled phone module which can be further customized and tested at a later step. Vertical Integrators, as their names imply, prefer to manufacture components used in their production. From both the OEM and VI perspective, there are several advantages:

1. The VI provides more value-added services, and can reap a greater share of the profit.
2. Producing Mechanics in-house makes its simpler for the VI to manage its mechanical component supply chain and quality. This consolidation reduces upfront lead-time and also reduces lead-time when troubleshooting component quality problems.
3. The OEM can simplify its supply chain management, since it can deal directly with the VI for all the services the VI provides.

The VI is also motivated to control more aspects of phone production, since doing so improves their negotiation power with the OEM. Similarly, the VI will also have more opportunities for cost reduction, and can pass along these cost savings to demanding OEM customers.

3.1.3 Electromechanics

Electromechanics components include components combining both electronics and mechanics. Common Electromechanics components include printed circuit boards (PCB), connectors, and audio components. The PCB connects all of the major electronic components of the phone, including the chipset and other wireless connectivity modules. Flexible Printed Circuits (FPCs) are a special class of circuit boards allowing electronic components to be mounted on a flexible plastic substrate. This technology gives designers more flexibility in styling and shaping the phone (e.g. for flip-phones and slider-phones). Due

[6] Foxconn Vertical Integration services: http://www.fih-foxconn.com/process/eCMMS.aspx

to the FPC's complexity, a specialized FPC supplier sometimes assembles the electronic components onto the flexible circuit, using surface mounting technology.[7] This introduces an added step in the supply chain and increases production lead-times.

Because electromechanics subcomponents directly affect the end-user experience, companies must carefully select these components. After component selection, quality can still degrade if the components are assembled and tested inconsistently. Thus, successful manufacturing requires active coordination between the OEM, audio supplier, and Vertical Integrator.

For example, audio performance usually benefits from open space (i.e. squeezing audio components in tight spaces muffles sounds and reduces audio quality). For this reason, there may be multiple audio components used across several products and form factors. This introduces added supply chain complexityfor hanset OEMs who manage multiple audio component suppliers.

3.2 Nokia Factories & Suppliers

This thesis considers Nokia's in-house production, and also manufacturing activities performed by suppliers and Vertical Integrators under Nokia's direction. A simplified organization of Nokia and its supplier relationships is shown below:

[7] Flexible Circuit Assembly description: http://www.altronicsmfg.com/flexible_circuit_pcb.php

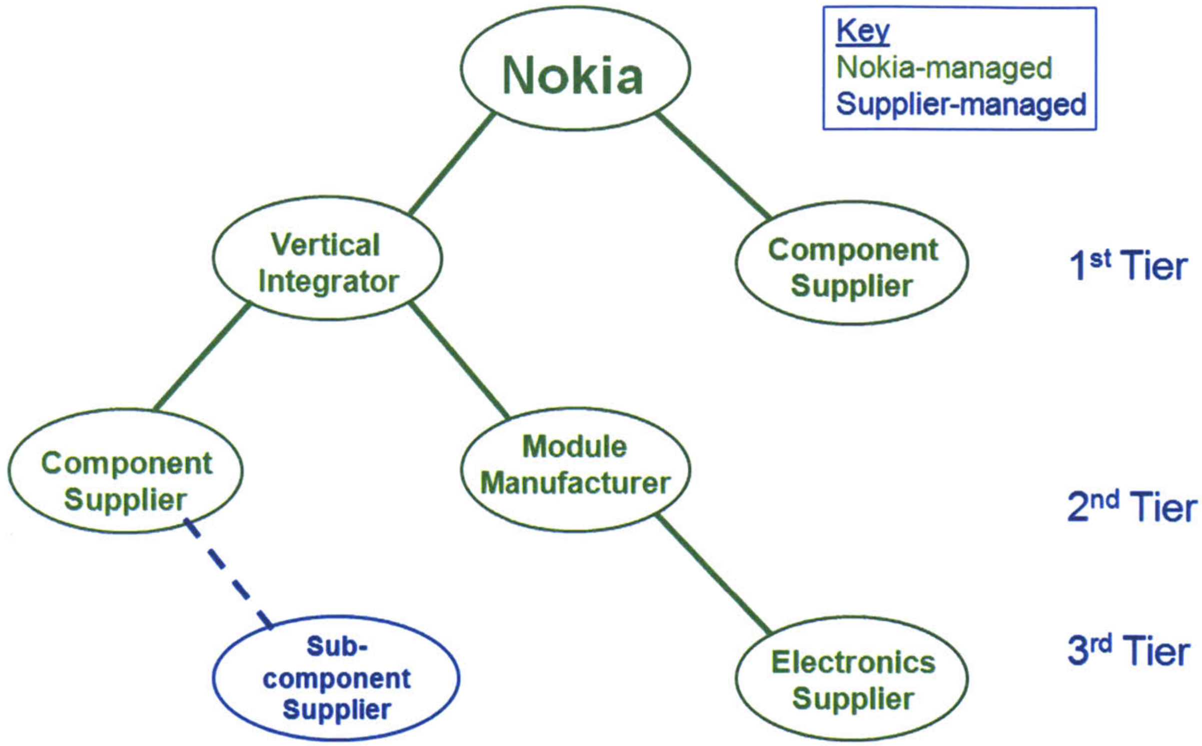

Figure 5: Nokia's management of 1st, 2nd, and 3rd tier suppliers.

1st tier suppliers ship product directly to Nokia factories. 2nd tier suppliers ship directly to 1st tier suppliers, and so on. Realistically, there can be several 5th tier suppliers for specialized components and subcomponents. Whether or not Nokia manages these N-th tier suppliers depends on a host of factors, including the component's supply shortage risk and overall financial value. Nth tier suppliers are usually managed only by the (N-1)th tier who is their customer.

Nokia directly manage 1st tier suppliers to ensure that its own factories receive steady supplies of materials needed for production. Nokia also manages 2nd tier suppliers because they provide components which can impact Nokia's own production. While this management approach reduces supply risk, it also demands greater coordination with suppliers and Vertical Integrators. This thesis investigates when it is optimal for Nokia to manage its suppliers. To perform this analysis, we will look at historical supply chain performance.

3.3 Business Models Considered

3.3.1 Assigned Vendor Assigned Price

Under the AVAP model, companies (usually OEMs) takes control of sourcing and supply chain management. The Contract Manufacturer takes responsibility for manufacturing and related activities. A brief example of an AVAP process:

(1) The OEM company and component supplier agree on 20 million units shipped over 10 months at \$10 / unit. The 10 million units will be split equally between two contract manufacturers.
(2) The company informs one of the contract manufactuers that they must purchase 10 million units over 10 months at \$10 / unit. These 10 million units will be ordered at a constant rate of 1 million units / month. To maintain a lean inventory, the CM orders these components on a weekly basis. The CM determines the specific number of units it will purchase weekly.
(3) The supplier delivers components directly to the contract manufacturer.
(4) The CM assembles the unit and ships product to the company.
(5) The company then pays the CM for the component costs plus the CM's manufacturing value added services.

Advantages: AVAP enables the CM to directly manage their short-term inventory, while following mid and long-term demand forecasts set by the OEM. The CM receives shipments directly from the supplier, reducing order lead-times. In theory, the CM should obtain better service from the supplier since they are paying for the components. Furthermore, the CM strives to ensure that the components they receive meet quality standards.

Disadvantages: More typically, the component supplier prefers to deal directly with the OEM on quality and supply issues. Since the OEM's sourcing team made the initial price and contract agreement, they are usually better informed than the CM on supply chain issues. The OEM's internal R&D teams are well equipped to solve quality problems that arise, and the component supplier prefers that the OEM arbitrates when the supplier and CM disagree on quality issues. Under AVAP, the OEM may incur higher costs required to actively manage product quality.

Suppliers offer different prices to different customers, depending on each customers' situation. When suppliers give favorable prices to one OEM, they prefer these terms to be kept secret from other customers. AVAP makes price confidentiality more difficult, since the CM must know the pricing terms to make its assigned purchases. Since the CM manufactures for multiple OEMs, there is risk that favorable pricing terms are leaked.

3.3.2 Buy & Sell

Under the B&S model, the company (OEM) takes greater control of component purchasing, in addition to upfront price negotiations. Under AVAP, the contract manufacturer pays the component supplier directly. However, in B&S, the company pays the supplier for components which the CM uses in its production. The CM still places orders directly from the component supplier and the component supplier still ships directly to the CM. Thus, when executed properly, B&S does not increase logistical delays for the CM to receive shipments from suppliers.

One of B&S's main advantages is that it keeps component prices confidential between the OEM and component supplier. However there is extra complexity for the OEM to manage financial transactions, logistics, and quality issues. To reduce lead-time in ordering components, all three parties—the OEM, CM, and supplier—can maintain integrated computer systems showing scheduled orders, payments, and materials in transit. These systems also enable the OEM to monitor inventory held by the CM and supplier. Using this information, the OEM can better allocate inventory across its supply chain.

When using the B&S model, OEMs can also take additional responsibilities for material planning, inventory management, and delivery planning. This requires more supply chain staffing and resources, but has potential to reduce excess inventories, especially when the OEM uses several contract manufacturers. These improvements are best realized in high-value components with greater risk of supply shortage. Thus, OEMs can selectively apply the B&S model to components which benefit from increased supply chain control. Lower cost and less risky components present fewer value-added opportunities for the OEM to manage. These components can be managed using alternative models, including AVAP or Turnkey (see below).

3.3.3 Turnkey

Under the turnkey model, the OEM defines the concept, industrial design, and specifications (at the module or entire phone level). The VI is then responsible for making the internal design and internal connection to meet the OEM's requirements.

An OEM typically uses the turnkey model to source components which they are unable to or choose not to produce in-house. For example, the OEM may obtain ready-made chipsets, displays, and batteries from its turnkey suppliers. The OEM then designs the whole product around these components. In some cases, the OEM may source entire modules using turnkey. (Modules integrate several components together into one package.)

OEMs wishing control quality directly can specify certain components which the turnkey provider must use. The turnkey provider will then source these components directly to create a customized solution. After defining the components used in the turnkey solution, the OEM may also define quality tests to be performed by the turnkey provider. Although the OEM incurs higher costs, it is better positioned to influence the final product offering.

With the turnkey model, the turnkey manufacturer usually demands a higher price for their greater contribution to the solution. However, the turnkey solution may still be the cheaper option, particularly if the OEM is sourcing from a specialized supplier with economies of scale. By using the turnkey model, the OEM chooses to manage the most important areas of product design and quality, while outsourcing other areas to specialist suppliers.

3.3.4 Original Design Manufacturing (ODM)

In the ODM model, the OEM purchases an entire product from an ODM, and then sells that product under its own brand. The ODM model is famous in the notebook industry, where Taiwanese ODMs design entire notebooks, which are subsequently branded and sold by US companies such as Dell and HP. In mobile devices, ODMs typically produce simpler solutions such as batteries, chargers, and bluetooth headsets.

A key characteristic of the ODM model is that the ODM owns and/or designs in-house the products they offer. For complex products, the OEM may work with the ODM in design and quality test. ODMs capable of providing full design and manufacturing services will demand a higher price for their solution. However, this does not necessarily mean higher overall costs for the OEM. For example, the OEM can save on costs for the additional services performed by the ODM, allowing the OEM to realize lower overall costs. Of course, cost is not the only major factor. The OEM and ODM relationship, as well as the ODM's understanding of the OEM's market are also crucial to the OEM's success.

A key dynamic in the OEM and ODM relationship is the profit margin allocated between the two parties. The OEM is primarily responsible for overall technical direction, software developer relations, marketing, and sales. The ODM is responsible for product design and manufacturing. Both parties may share responsibility for component selection, sourcing, quality management, logistics, and after-sales support. ODMs that capture a greater share of the overall responsibilities improve their argument for a higher share of the profit margins. As HTC has illustrated, ODMs who develop strong competencies can create their own brands and markets.

3.4 Desired Outcome with Business Model Recommendation

In this section, we first described the major component commodities used in phone production, including displays, mechanics, and electromechanics. These components represent the largest portion of the phone's hardware value and most directly impact the user experience. Thus, it is important to design a supply chain to effectively manage these components on several criteria, including technology, cost, quality, and supply availability.

Next, we briefly summarized how Nokia manages its production and supply chain. This process involves coordination between Nokia's own factories and suppliers. As mobile phone assembly increases in complexity, we see more and more subcomponent suppliers. These suppliers may not deal with Nokia directly, and instead supply critical parts to Nokia's component suppliers. Usually, they supply components that represent a small portion of the overall hardware value. Nevertheless, shortages at these subcomponent suppliers have potential to disrupt the overall supply chain and impact Nokia's production.

In order to better manage suppliers and prevent supply disruptions, we looked at several supply chain business models, including the Assigned Vendor Assigned Price, Buy & Sell, Turnkey, and Original Design Manufacturer Models models. Highlights of these models:

	Advantages	Disadvantages
AVAP	- Lower operating costs. - More flexibility for CM to work with component supplier.	- No price confidentiality. - Less visibility into component orders.
B&S	- Guaranteed price confidentiality. - Increases OEM's total purchasing power. - Allows quick changes to supplier portfolio.	- Large scale operation with increased operating costs. - More complex process to resolve quality issues between suppliers. - Possible increase in final product cost.
Turnkey	- Lower operating costs over long term. - CM gains more flexibility to select component supplier.	- Higher operating costs in short term. - Less insight into component supplier practices. - Loss in buying power and ability to influence quality.

ODM	- ODMs possess multiple design capabilities which can help OEMs diversify their product line and quickly launch new products. - Streamlined management for OEM.	- Risk to OEM's reputation if quality is mismanaged. - Loss in buying power. - Less OEM margin possible.

These models can be selectively applied depending on the type of product and component. For example, a smartphone's display can be procured using Buy & Sell, while it's speakers can be sourced using Turnkey. On the other hand, a basic phone's display may be procured using the AVAP model. Deciding which model to use for a component depends on several criteria, including technology, cost, quality, and supply availability.

When choosing between the AVAP, B&S models vs. the Turnkey, ODM models, the OEM should consider its relative purchasing power compared to the VI or ODM. How will the OEM's buying power change if it outsources component purchasing? Will the VI or ODM be able to purchase components more cheaply than the OEM? How should the OEM split responsibilities with the VI or ODM when transitioning to a new supply chain model? These questions will determine the OEM's capability to compete on price, quality, supply chain speed, and product design. A well designed supply chain gives companies flexibility to react to and attack its competitors. Along these lines, we will analyze the business models which can best shape Nokia's future supply chain.

4 Project Details

4.1 Detailed Hypothesis

Currently, Nokia implements variations of the Assigned Vendor Assigned Price (AVAP), Buy & Sell, and Turnkey models. We expect each of these models to confer different supply chain advantages and costs:

- With B&S, Nokia purchases directly from suppliers with 100% price confidentiality. We expect this to improve Nokia's negotiation power for component prices.

- B&S provides Nokia with supply chain visibility and more options to manage logistics. This can help reduce supply chain shortages.
- Under B&S, Nokia may experience higher operational expenses, as the company gain tools to tighten its supply chain management.

- AVAP requires less control than B&S and gives Nokia good control over component prices, supply, and quality.
- Since AVAP does not guarantee price confidentiality, we expect Nokia will receive slightly higher component prices using AVAP vs. B&S.

- In the short-term, Turnkey may impose higher costs, in order for Nokia staff to develop Vertical Integrator's capability to manage quality, supply, and cost.
- In the long-term, Turnkey may simplify Nokia's organization, streamline defect resolution, improve lead-times, and reduce costs.

Based on the characteristics outlined above, we believe that each of the three models is suited towards specific scenarios and goals. We have summarized several scenarios and goals, which provide opportunities for Nokia to make improvements in its supply chain. We also offer a hypothesis of the commodity areas which are most applicable to the specific scenario or goal. Additionally, we include the specific purchasing model which is most relevant to each case. In the following sections, we will evaluate specific commodity areas to determine whether they are applicable to these specific scenarios or goals.

Scenario / Goal	**Hypothesis**	**Applicable Purchasing Model**
Track inventory in-transit and at supplier sites.	Especially applicable for high-value commodities or in cases of supply risk. Successful implementation will require active coordination with a capable supplier.	Buy & Sell
Streamline own sourcing organization to reduce supply chain management Operational Expenses in the long-term.	Commodities with high OpEx and good historical supply chain performance may be the best candidate for future OpEx reductions. By streamlining sourcing of select commodities, Nokia may be able to maintain high product quality.	Turnkey
Give Original Design Manufacturer flexibility to source components used in their design.	Most applicable for commodities with good historical supply chain performance. Nokia may be able to reduce investment by allocating more purchasing responsibility to the ODM.	Turnkey

4.2 Research Methodology

This project set out to recommend optimal supply chain business models for Nokia's major component commodities. These business models include the Assigned Vendor Assigned Price, Buy & Sell, Turnkey, and ODM models.

A given program may use a different business model to manage each of its different commodity areas. Therefore, to select an appropriate business model, we will need to understand both Nokia's component commodity areas and major programs.

Below is a summary of the approach taken over the course of the project.

4.2.1 Phase 1 - Information Gathering

First, we needed to understand current performance across Nokia's component commodity areas. Sourcing for each component is led by a Commodity Manager, responsible for technology selection, purchasing, quality, and supply chain management. To understand Nokia's how Nokia historically managed its major component areas, I began by surveying Commodity Managers for major component areas.

With an overall understanding of our sourcing strategy, I visited Nokia's Beijing Operations team to understand day-to-day activities, including supplier management, logistics, cost negotiations, and quality engineering. I also met with representative outside of sourcing from these groups:

- R&D
- Finance
- Quality Assurance
- Product Planning
- Materials Management
- Factory Operations
- Program Management

Part of my project seeks to develop supplier capabilities to support new business models. I also visited the factories and offices of several component and subcomponent suppliers to understand their perspectives and current capabilities.

4.2.2 Phase 2 - Organization and Presentation

After organizing my findings from our China suppliers and managers, I began meeting one-one-one with members of Nokia's sourcing leadership team. I explained to them my initial findings—namely, that we can pilot a project using the Buy & Sell and Turnkey models. They, in turn, recommended several current and past pilot projects for me to benchmark against. These pilot projects applied new business models similar to the models I was investigating—by analyzing these models, I gained a sense of how my new business models will perform.

Next, I presented my findings and recommendations to the Sourcing leadership team, including representatives from legal and finance. The Sourcing financial controller suggested analyzing how these business models impacted Nokia's Operational Expenditures.

Based on additional feedback from the sourcing leadership team, I decided to focus on one specific program for a current Nokia high-end smartphone (Program A). To best observe the effects of the new business models, I could apply a combination of the Buy & Sell and Turnkey models whereever possible.

4.2.3 Phase 3 & 4 - Mock and Real Trial (Original Plan)

In Phase 3, we expected to conduct a mock trial by first selecting business models to apply across all component commodities used in Program A. To identify the "best" business model for a component category, we planned to take the following steps:

1. Work with Nokia Finance & Control to develop cost and supply criteria for selecting Buy & Sell for a specific component (e.g. what are our immediate and 1 year cost savings?). Identify

components with measurable cost savings from applying Buy & Sell. Then, select components to manage under Buy & Sell.
2. Interview component supplier managers to identify component areas with most supply risk. Analyze the number of quality problems arising for specific components in the previous year. Assess the severity of each problem on supply availability. Quantify these findings into a "quality risk rating." Select the three lowest risk components to consider for Turnkey.
3. Continue with AVAP model for remaining components. Review with Sourcing leadership team.

After Phase 3, we needed to understand how the new business models we selected could impact product quality, supply, and cost performance. Phase 4 of my project would quantify this performance. While historical performance data was readily available, only a few pilot projects provided metrics for the Buy & Sell and Turnkey models.

For Buy & Sell, we expected to obtain metrics from a recent pilot program. Nokia financial managers indicated that supply chain performance data would be available for September 2011 onwards. From this data, we expected to:

- Quantify Buy & Sell benefits: reduced time in supplier negotiations, improved pricing from component suppliers, and reduction in material shortages.
- Quantify Buy & Sell costs: increase in staffing to administer Buy & Sell, increase in lead times for product development and component changes, increased R&D resources to support Vertical Integrators.

For Turnkey, my project needed to estimate costs incurred by both Nokia and our suppliers. These costs would be impacted by changes in staffing, purchasing, legal liabilities, supply availability, etc. Furthermore, we expected costs to vary widely depending on components, suppliers, and vertical integrators involved in the Turnkey model. Even after accounting for these factors, we needed to predict how program costs would change in the long-term, as all parties gained experience working with the Turnkey model. To make accurate conclusions, we realized further discussions were needed with suppliers to understand their priorities and capabilities. Based on my field experiences, we made an initial hypothesis:

- In the short-term (<2 years), we expect the Turnkey model to incur costs associated with developing the VI's capabilities to manage quality, sourcing, and some design. Furthermore, we don't expect to see significant Turnkey benefits within the project's timeframe. Therefore, my project will estimate immediate costs with deploying Turnkey and assess whether these costs justify Turnkey's long term benefits.

After verifying this hypothesis, we expected to begin quantifying Turnkey costs, including: increases in staffing from Nokia to support the VI in transition, increased material costs, increased delays in quality resolution, decreased Nokia purchasing power.

By quantifying and understanding the full effects of the Buy & Sell and Turnkey models for a major Nokia program, we can provide justification for moving other Nokia programs to the new business model. For the final report, we plan to:

- Identify costs and benefits observed on pilot program applicable to other programs or component areas.
- Evaluate scalability of pilot to larger programs, including future Windows ODM production.
- Prepare 2 year plan including selected components for further study, VI capability areas to develop, and necessary structural changes to achieve desired staffing overhead.

4.2.4 Revised Plan

Our original plan was to launch a pilot project targeting specific business models and measuring Nokia's supply and cost performance. Our revised plan will collect and analyze some of the same data from Nokia's historical programs. Some of Nokia's past programs implemented aspects of the previous model we expected to pilot, which would help us make conclusions about our future business models. Further advantages with analyzing historical performance data included:

- Longer time period of observed results, approximating actual business cycles.
- Large-scale implementation, which more closely reflects Nokia's high volume programs.
- Detailed financial results and reports.

To begin, we want to analyze performance along three dimensions:

1. **Time**: how has our supply chain performance evolved as we changed products, suppliers, and business practices?

2. **Component Commodity Areas**: each component area is managed somewhat differently. By measuring their performance differences, we can highlight the advantages and risks observed using certain business models.
3. **Performance Metrics**: in order to compare performance across commodity areas, we need standard measures of cost, supply, quality, and technology performance.

The following list outlines data we can expect to collect from these three areas:

Time: Program performance data from 2008 – 2011, which we believe represent one business cycle, since the last industry downturn occurred in 2009.

Component Commodity Areas: including all components managed by the Nokia's Hardware and ODM Sourcing organization.

Performance Metrics: focusing on performance across four areas –

1. **Technology**: since early technologies are more difficult to manage, we needed to consider the *Maturity Level of New Components* used in production.
2. **Quality**: as reflected by standard measures, including:
    a. *Supplier Quality Action Requests*: the number of quality problems Nokia identifies requiring supplier involvement.
    b. *Field Failure Rates:* the percentage of phones that fail after being sold to the customer.
    c. *Batch Failure Rates:* the percentage of production batches with failures encounter after the phone is sold to the customer.
3. **Supply**: as indicated by two measures of how component shortages impacting Nokia's supply chain:
    a. *Number of Supply Shortage Surprises*: the number of shortages impacting Nokia's sales and caused by suppliers' inability ot deliver supplies which they previously confirmed.
    b. *Scale of Supply Distruption*: the number of sales units (phones) affected by shortage.
4. **Cost**: as measured by Nokia's own operational expenses.
    a. *Operating Expenses:* the ongoing cost for Nokia sourcing to manage each component commodity area.
    b. *Cost Reductions*: the degree to which Nokia has been able to drive down component costs after beginning production
    c. *Supply Line Management (SLM) Planning Accuracy*: the accuracy in which Nokia has been able to achieve its targets for component costs.

By analyzing how these metrics have changed over time, we expect to compare supply chain performance across our major component commodities. For example, if Commodity A has experienced frequent quality problems and supply shortages, could it be due to Commodity A's business models? How does

Commodity A compare to Commodity B in terms of supply chain management costs? If Commodity C improved on supply shortages after implementing a new business model, can that model also be used to improve Commodity A's performance? These are the questions which we expect to answer by analyzing historical program performance.

In our final report, we will organize the various component commodities by business models. From this, we will observe how certain business models impact areas of the supply chain. By highlighting each models' advantages and disadvantages, we can make a set of recommendations to answer these questions:

- Which business model to use to achieve certain supply chain targets?
- Which business models are applicable under certain scenarios? (Scenarios may vary depending on the product program, supplier capabilities, business goals, etc.)
- How do we structure the Nokia and supplier team to begin deploying the business model?
- What capabilities do we need to grow in our contract manufacturers and suppliers?
- When applying a new business model, what other new techniques can we implement?
- What risks can we expect to encounter and how should we balance risk management with supply chain efficiency?
- What are the short and long-term costs and required resources to deploy the new business model? What benefits can we expect to see across Nokia's programs and commodity areas?

5 Current State Analysis: Comparing Business Model Performance

5.1 Comparison Metrics to Analyze Program and Commodity Performance

Previously, we described the technology, quality, supply, and cost metrics we will use to compare performance across Nokia programs. Because various component commodities are managed using different supply chain business models, we will also consider the type of commodity in addition to the specific program. We previously listed several metrics which we will use in our analysis. Below is a more detailed summary of these metrics:

- *Technology maturity level (percentage of new components):* the number of new components introduced in the time period divided by the total number of components. Components which are variations on existing components will also be considered as new components.
- *Supplier Quality Action Requests*: the number of requests made by the supplier to investigate a quality problem for a specific component.
- *Field Failure Rates*: the number of failures for a specific component as a percentage of the total number of devices sold to customers.
- *Batch Failure Rates*: the number of batches with failures as a percentage of the total number of batches produced. This is an indication of production quality.
- *Supply shortage surprises*: the number of shortages impacting Nokia's sales and caused by suppliers' inability to deliver supplies which they previously confirmed.
- *Scale of Supply Distruption*: the number of sales units (including phones and related accessories) affected by the shortage.
- *Operating Expenses:* the ongoing cost for Nokia sourcing to manage a component commodity area.
- *Cost Reductions*: the percentage reduction in price which Nokia has secured from its supplier.
- *Supply Line Management (SLM) Planning Accuracy*: the accuracy in which Nokia has been able to achieve its targets for component costs.

To establish a framework before data analysis, let us consider how each of these metrics will be related to one another. We will review each metric and consider its causal impact on each of the other metrics.

5.1.1 Technology: New Component Counts

The percentage of new components indicates the complexity needed to manage the supply chain for new components. Typically, new components require new production processes, new quality measures, and possibly new suppliers. This increases supply chain management cost while potentially decreasing quality and supply levels, if production ramp-up proceeds slowly. In the long-term, new component improvements may also help improve supply chain performance.

When comparing different component commodity areas, we will find certain types of components which change designs more frequently. Those areas with more new components will experience greater supply chain uncertainty, since production factors have yet to fully determine the final cost, quality, and supply for the new component. However, some new components, especially those that are slight variations on existing components, may ramp up successfully and quickly improve supply chain performance.

In general, we expect the percentage of new components to:

- Increase the number of *Supplier Quality Action Requests*, as technology bugs are discovered more frequently in new components.
- Increase the number of *Field Failures* and *Batch Failures* if the new component encounters production difficulties.
- Increase the risk of *Supply Shortages* caused by difficulty ramping up new technologies.
- Increase Operational Expenses in the short term due to greater technology management costs.
- Decrease the accuracy of SLM Planning due to difficulties predicting technology ramp-up.
- Increase the amount of cost reductions, once technology ramps up and production economies of scale are achieved.

5.1.2 Quality: Supplier Quality Action Requests, Failure Rates

Quality pervades all aspects of the mobile device value chain. Early on, inefficient technology designs can increase manufacturing challenges and reduce production yields. More efficient designs allow for simpler, more cost-efficient manufacturing processes which benefit production scale over the long-term.

In the next step of the value chain, manufacturing tests will help select faulty components likely to fail in the field. These defective components indicate potential manufacturing improvements needed to increase product quality. Companies can also select the number and types of quality tests which components need to pass to meet requirements. Extensive tests increase costs and production times, and may only offer marginal improvements to the quality customers experience. However, decreasing quality requirements risks product sales and warranty costs in the future. Thus, what is "sufficient quality" is defined by company objectives. The supplier and OEM may also have different views and goals on product quality.

In certain cases, poor production quality results in entire batches of components being scrapped. Production failures may occur from a variety of sources. For example, the component manufacturer may have incorrectly calibrated assembly equipment, causing poorly assembled components which fail quality tests. Perhaps a subcomponent supplier ships defective parts to several suppliers. These suppliers may assemble the defective subcomponent before discovering the defect. Thus, quality problems can occur throughout the supply chain to create supply shortages.

Finally, poor quality may be an indicator of production difficulties which add to supply chain challenges. Poor quality requires technical rework and additional personnel to troubleshoot problems. This increases operational expenses for engineering and supply chain management. Uncertainties over production quality also increases planning uncertainties, negatively impacting product launch schedules. These challenges may cause supply chain managers to redirect their focus away from other areas in the short term. Such measures increase risk across the entire supply chain, possibly introducing additional quality problems. For these reasons, supply chain managers actively manage quality to keep problems at manageable levels. Achieving and exceeding quality targets also lower cost for manufacturers and allow for larger cost reductions:

In general, we expect Quality to impact Supply and Cost in these ways:

- A higher number of *Supplier Quality Action Requests (SQARs)* indicates more active quality management. This may reduce the number of field failures.
- A higher number of *SQARs* also indicates production quality challenges, which will increase the number of field failures.
- High *Batch Failure Rates* indicate production challenges, which can lead to supply shortages.
- Quality problems will increase Operational Expenses required to manage faulty quality.
- Quality problems increase the uncertainty of achieving production and cost targets. This may decrease SLM Planning accuracy.
- High production quality standards will increase overall management costs and lead to fewer cost reductions in the short-term.

5.1.3 Supply Shortage Surprises: Frequency and Scale

Supply chain managers work extensively to prevent supply shortages. Common strategies include selecting a second source supplier, who can provide backup supplies in case of shortages. However, if the primary and secondary suppliers both share the same subcomponent supplier, then there is also risk.—If the subcomponent supplier faces a shortage, then both the primary and secondary suppliers will both encounter production challenges. Preventing this risk requires that the primary and secondary suppliers maintain a different mix of subcomponent suppliers. This strategy reduces supply risk, but increases costs. At the very least, greater operational expenses are required to maintain secondary suppliers.

Because supply chain managers go to such lengths to prevent supply shortages, these disruptions happen infrequently. Certain component commodities encounter the lion share of supply shortages, for reasons we will investigate later. These shortages may be caused by the unique way in which these components supply chains are managed. Or they may be caused by the unique technologies required to manufacture certain components. Furthermore, each of these components represents an entire industry of suppliers, many of which share subcomponent suppliers. Perhaps the ecosystem of suppliers which Nokia has selected is also responsible for supply shortages. The reality will be a combination of these factors, which we will investigate.

In general, we expect supply shortages to:

- <u>Increase</u> the rate of *Supplier Quality Action Requests (SQARs)*. This can be caused by two reasons:
    a. Suppliers running into production challenges typically face quality problems requiring them to issue SQARs.
    b. Subcomponent suppliers hoping to ease shortages may relax quality test standards in order to raise production levels. However, downstream suppliers using the subcomponent will encounter more instances of poor quality, causing them to issue SQARs.
- <u>Increase</u> the number of *Field Failures.* We expect supply shortages to correlate to higher rates of quality problems, which lead to *Field Failures*. Furthermore, suppliers facing shortages are more likely to release subpar products.
- <u>Increase</u> *Operating Expenses* due to higher costs to manage the supply shortage. *Operating Expenses* are likely to grow further in the long term, as OEMs and suppliers strengthen control over their supply chains to prevent future shortages.
- <u>Decrease</u> *SLM Planning Accuracy*, since shortages lead suppliers to re-evaluate pricing on the components they sell.
- <u>Decrease</u> *Cost Reductions*, since shortages will increase the short-term price of components.

5.1.4 Cost: Operating Expenses, Forecasts, and Cost Reductions

Component prices are influenced by several factors, including the bargaining power of the OEM and component supplier, as well as competing suppliers within the same industry. Strong OEMs purchase in large volumes, and sometimes prepay for production in advance. These companies command a large share of the market and have bargaining power over even the largest suppliers. Mid-size suppliers aspire to become large suppliers by landing a sales contract with a leading OEM. Thus, there is no shortage of suppliers willing to sell to leading OEMs. Entrepreneurial suppliers drive extremely low costs, copy rivals, and sacrifice short-term gains to deliver attractive prices. Important OEMs receive not only the lowest prices, but also high priority and quality.

What happens when an OEM suffers a decline in purchasing volume and buying power? Motorola and Sony Ericsson have both experienced this outcome. Suppliers look at the sales potential among the leading OEMs and choose to service those who will drive future market share.

Besides achieving low component prices, OEMs also seek to minimize Operating Expenses. However, by lowering spending, firms must also trade off stronger control over their supply chain. More spending in supply chain management allows OEMs to influence higher quality components by conducting more frequent supplier audits. Higher spending also reduces supply risk by allowing OEMs to manage alternative suppliers. Experienced staff can better estimate production costs for certain components, by evaluating material and assembly costs. This knowledge can reveal what certain components should cost to manufacture, helping component price negotiations. Thus, OEMs must balance Operating Expenses with their overall supply chain goals. Strong OEMs are able to spread out their supply chain investment over huge purchasing volumes, enabling them to further their competitive edge.

From a cost perspective, we expect these correlations to the other supply chain metrics:

- Higher *Operational Expenses* will <u>improve</u> quality and reduce Failure Rates, if the OEM invests in extensive quality checks.
- Higher *OpEx* combined with effective risk planning <u>reduces</u> the risk of supply shortages.
- Higher *OpEx* aid OEMs in improving SLM Planning Accuracy.
- Higher OpEx will affect Cost Reductions in two ways:
    a. The OEM improves their bargaining position by gaining a better understanding of the component supplier's cost structure.
    b. If the OEM manages production too tightly, then the component supplier will mainly perform low-value added activities. In this case, the component supplier has less control of cost and is less capable of providing cost reductions.
- Intense cost reductions cause suppliers to skimp on manufacturing and material costs. While suppliers value long-term relations with important OEMs, they may accidentally introduce quality problems by pursuing extremely low costs.
- Excessive cost reductions may hurt OEMs during supply shortages. At these times, the component supplier is likely to prioritize similar OEMs who pay a higher price for the component.

5.2 Analysis of Metrics across Commodities

In the last section, we predicted likely correlations between metrics covering component quality, supply, cost, and technology maturity. Our analysis broadly surveyed the entire mobile device industry. In reality, each major component within a mobile device represents an entire industry, with unique suppliers, business practices, and technical challenges. We will now analyze each component commodity individually and predict how each commodity will perform on the same metrics we covered earlier.

5.2.1 Commodity 1

Commodity 1 represents expensive components key to the user experience. By sourcing from major Commodity 1 suppliers, Nokia benefits from simpler supply chain management, and also concentrates some supply chain risk. To manage this risk, Nokia cooperates with and selects Commodity 1 subcomponent suppliers. This allows Nokia to manage risk of subcomponent shortages. It also enables Nokia to customize subcomponent designs and influence future Commodity 1 features. For subcomponents with greatest supply risk, Nokia will Buy & Sell the subcomponent to the Commodity 1 supplier. By purchasing the subcomponent, Nokia ensures that it has stock in hand to meet production needs.

We expect to see the following qualities in the Commodity 1 sourcing area:

Operating Expenses: Nokia's focus on managing the Commodity 1 supply chain management requires higher OpEx outlays. Since Commodity 1 change frequently, we can expect high supply chain costs associated with managing new component technologies. Benefits from efficient supply chain management will be most visible in the Commodity 1 area.

Quality: Considering the complexity of Commodity 1 assemblies, we expect quality difficulties caused by frequent ramp-ups in new Commodity 1 technologies. Furthermore, since Nokia does not produce

Commodity 1, quality is highly dependent on the Commodity 1 supplier. With a complex set of subcomponents, it is difficult to identify the source of quality problems. This makes it difficult to assign responsibility for quality problems. We expect that this dynamic will increase quality problems in the final Commodity 1 assembly. Conversely, newer technologies have fewer capable suppliers, resulting in less ability to shift blame. Therefore, we will pay attention to whether newer components witness improved quality.

Supply: Advanced Commodity 1 components have historically been in short supply, due to a few number of premium suppliers. In these cases, we can predict a greater likelihood of supply shortages and possibly lower product quality. Since Nokia tightly manages several key Commodity 1 subcomponents, we can expect supply and quality problems to concentrate around Commodity 1 assembly processes.

Cost Reductions: Advanced Commodity 1 components continue to improve significantly each year, helping to drive frequent cost reductions. These cost reductions will benefit from:

- Additional suppliers entering the market to produce previously "high-end" Commodity 1 components.
- Commodity 1 technology leaders improving their production processes and yields to deliver lower costs.

Conclusion: With a technologically complex and diverse supply chain, Commodity 1 presents unique management challenges compared to other commodities. Nokia chooses to extensively manage its Commodity 1 sourcing due to its importance to the user experience. New technologies are difficult to manage and require high Operational Expenses. Commodity and mid-range Commodity 1 components present fewer technology and production uncertainties, and should result in fewer supply chain surprises. Nokia's strong control over the Commodity 1 supply chain will have the most influence for these areas in the Commodity 1 supply chain. On the other hand, advanced Commodity 1 components rely on new technologies and are offered by a fewer number of suppliers. This creates fewer opportunities for Nokia to manage the supply chain. A key question for Commodity 1 supply chain performance: How to efficiently manage leading technologies, while quickly transitioning them to low cost sourcing models?

5.2.2 Commodity 4

These are specialized components often specifically designed for Nokia products. Supply chain managers seek to limit the number of such product variations, in order to limit additional inventory and logistics management. Nevertheless the number of component variations will increase supply complexity, and add to supply risk. This in turn increases overall component manufacturing and supply chain management costs for both the OEM and supplier. Component variations also impact quality, since manufacturers sometimes encounter problems when making assembly line adjustments to accommodate a new component.

Subcommodity 4A and 4B consist of expensive components that can increase supply chain lead times. Due to their complexity, dedicated Subcommodity 4A suppliers require designs in advance to set up production. The Subcommodity 4A units are then sent to the Vertical Integrator for further assembly. Extra time is required in this exchange for the Vertical Integrator to receive shipments, verify quality, and finally assemble the Subcommodity 4A components. Because this process requires a long lead time, it presents a weak link in the supply chain. That is, if problems arise, the Subcommodity 4 supply chain lead time is more likely to cause a supply shortage. While OEMs can create "backup" plans and supply chains to ease potential shortages, these alternatives are costly and cannot easily reach large scales.

Based on our analysis of Subcommodity 4B and 4C business models, we expect the Commodity 4 supply chain to exhibit several performance characteristics:

Operational Expenses: Complex Commodity 4 assemblies increase costs needed to manage the supply chain. Nokia has preferred to use experienced suppliers who provide consistent quality and supply. These suppliers perform well because they invest in technology, quality, and supply chain management. In some cases, it is sensible to pay these suppliers for their expertise. On the other hand, Nokia should also identify other potential suppliers to drive cost competition.

Quality: Complex Commodity 4 assemblies create more opportunities for the supply chain to cause quality problems. For example, if defects are identified during final assembly, the actual problem could have been caused by either the supplier, Vertical Integrator, OEM, or even the shipping provider. Resolving and assigning responsibility for the defect requires further coordination among all responsible parties in the supply chain. For these reasons, quality is best managed by instituting successful development, production, and logisitics processes in advance.

Cost Reductions: To achieve cost reductions, OEMs should seek to develop a broad supplier portfolio. This is challenging to do in the Commodity 4 industry, where a few suppliers excel in quality and supply management. A strategy may be to source mature technologies and basic designs from new suppliers, and invest in these suppliers to raise their supply chain management capabilities.

Conclusion: Similar to the Commodity 1 industry, the Commodity 4 component industry is represented by specialized technology suppliers who charge a premium for their design, production, and supply chain management expertise. OEMs relying on these suppliers will gain advantages in supply stability and quality. This model also allows OEMs to closely work with suppliers on new technology developments, to further improve product performance and quality. At the same time, OEMs should look at additional suppliers more suited towards low-cost production. In such cases, OEMs should also make early investments in new suppliers to prevent costly quality problems from occurring later in the supply chain.

5.3 Performance Analysis of Commodities

In Section 5.1, we described the various supply chain performance metrics we will analyze, including: New Component Counts, Supplier Quality Action Requests, Batch Failure Rates, Supply Shortage Surprises, Operating Expenses, Supply Planning Accuracy, and Cost Reductions.

We will analyze half-year periods over a four year time period from 2008 to 2011. We count each half-year period as one data point.

We obtained the most data points for the Supply Shortage Surprises and Cost Reductions metric, including data from 2008 to 2011. However, we obtained fewer data points for the Supplier Quality Action Requests and Batch Failure Rates metrics, which only included data from part of 2010 and 2011. While we are still able to offer analysis for these area, we have less confidence in our recommendations on quality, because we have less data

To organize our analysis, we will analyze each component commodity area using the various metrics for Technology, Quality, Supply, and Cost.

Please note that the numbers used in the following analysis have been adjusted for confidentiality purposes. The adjustments have been made to allow relative comparison between individual data points.

5.3.1 Commodity 1

Technology Maturity: The number of new Commodity 1 introduced in each period roughly tracks the average across all commodities. In one instance over the past two years, the number of new Commodity 1 spiked at 36%, although the share of financial value for these components was only 13%, less than the amount for other periods.

Supplier Quality Action Requests: The number of cases opened were 268, 110, and 39, in three recent periods. Nearly all of these cases have also reached closure.

Batch Failure Rates: The percentage of batch failures is much higher than other components. However, this figure has dropped steadily during the last two years. We will look at factors causing this improvement in quality.

Shortage Surprises: Commodity 1 shortages have occurred consistently for the past two years. In one instance over this period, we witnessed massive Commodity 1 shortages due to quality issues in Commodity 1 production.

Operating Expenses: In the past three years, Commodity 1 OpEx has been roughly 17% of total OpEx for all the components in our study. In one instance during this period, Commodity 1 OpEx was much higher—27% vs. 15%.

SLM Planning Accuracy: In one instance over the past three years, the Commodity 1 sourcing team significantly over-estimated future Commodity 1 costs. However, SLM planning has been accurate since that time.

Cost Reductions: Commodity 1 tends to receive larger cost reductions than other components. However, this was not true in two instances over the past four years.

Analysis: From the above, we see continually improving batch failure rates over the past two years. Remarkably, the share of Operational Expenses dedicated to Commodity 1 has not increased over this period either. This leads us to believe that more effective supply chain management has contributed to the quality improvement.

5.3.2 Commodity 2

Technology Maturity: Commodity 2 show a higher than average number of new components. This is an area which Nokia focuses on to deliver customer value.

Supplier Quality Action Requests: The number of cases opened were 22, 124, and 55, in three recent periods. The few number of SQARs may be caused by the higher quality of Commodity 2 components which Nokia sources. These components are delivered as module solutions which are easier to integrate and test for quality problems.

Batch Failure Rate: The percentage of batch failures has consistently remained at low levels (around 0.32%). This points to the relative ease in managing Commodity 2 quality—The fact that Nokia sources from major suppliers who provide module solutions also help to decrease failure rates.

Shortage Surprises: Shortages have been minimal throughout the past four years. However, in one specific case, subcomponent shortages affected several of Nokia's Commodity 2 suppliers. This example shows the importance in managing a diverse set of subcomponent suppliers, able to substitute capacity with each other.

Operational Expense: Throughout the past three years, Commodity 2 OpEx has been roughly 8.2% of total OpEx for all the components in our study. By limiting OpEx spending, Nokia relies on the Commodity 2 supplier to manage supply, quality, cost, and technology improvements.

SLM Planning Accuracy: Commodity 2 SLM Planning Accuracy is comparable to other components. The number of new and advanced components possibly limits SLM planning from achieving very high accuracy.

Cost Reductions: Commodity 2 have attained greater cost reductions compared to other components. In the past year, while other components experienced fewer cost reductions, Commodity 2 continued to encounter roughly 9.3% cost reductions in each period. This may indicate that Commodity 2 prices are more dependent on industry and technology factors, rather than being caused by Nokia's supply chain management.

Analysis: The above data shows a consistent performance in the Commodity 2 supply chain: low failure rates, few shortages, stable costs and cost planning, as well as consistent cost reductions. Nokia can more easily manage the Commodity 2 supply chain by sourcing from large and capable Commodity 2 suppliers. These suppliers also provide module solutions which are easier to integrate and test for quality problems. However, one massive supply shortage which occurred in the past three years shows that even well-managed suppliers can be affected by problems in subcomponent supply chains.

5.3.3 Commodity 3

Technology Maturity: Larger and more complex Commodity 3 are more costly to redesign, so are refreshed less frequently.

Supplier Quality Action Requests: Commodity 3 faces the most SQARs of all components in our analysis. Between 1980 and 2790 cases were opened during two of the three most recent periods. Furthermore, although nearly all cases from one year ago have been closed, 382 of the 2726 cases initiated in one of the two most recent periods are still open. This indicates that certain quality problems may take longer than three to six months to resolve. These figures point to the difficulty in managing Commodity 3 quality.

Batch Failure Rates: Commodity 3 failure rates have consistently remained high, hovering over 4.4% for the past two years. This level is close to, but not as high as the figure for Commodity 1. We see a similarity between the two commodity areas. Both are complex assemblies that are difficult to manage for quality. However, unlike Commodity 1, the Commodity 3 area has shown no improvement in failure rates in the past two years.

Shortage Surprises: The Commodity 3 supply chain experiences supply shortages more frequently than any other area. Causes have ranged from supplier ramp-up challenges to subcomponent supplier shortages.

Operational Expenses: Over the past two years, Commodity 3 has maintained roughly 62% of the total OpEx for all the components in our study. This number varies across periods to confront specific challenges encountered in the Commodity 3 supply chain.

SLM Planning Accuracy: Surprisingly, the Commodity 3 area shows consistent SLM Planning Accuracy. Most other components have deviated in planning accuracy at least once over the past three years which we measured. However, Commodity 3 planning accuracy roughly tracks the average planning accuracy across all components.

Cost Reductions: Commodity 3 cost reductions have been lower than average historically. Recently, while cost reductions for other commodities have nearly vanished, Commodity 3 cost reductions have begun to outperform (around 8.6% reduction per half-year period). This shows that while Commodity 3 is not capable of large cost reductions, it is capable of delivering consistent cost reductions.

Analysis: The Commodity 3 and Commodity 2 supply chains are quite different. While Commodity 2 solutions are directly sourced as modules, Commodity 3 involves partnerships with Vertical Integrators to develop their Commodity 3 manufacturing and integration capabilities. This close relationship is seen by the high number of SQARs issued.—Vertical Integrators are actively involved in identify, managing, and reporting on quality problems. (The number of SQARs issued for Commodity 1 is far smaller, because VIs have less expertise in managing Commodity 1 quality.)

However, we see few gains from Nokia's strategy to develop VI capabilities. While Commodity 1 Batch Failure Rates have decline by over 82% in the past two years, the number for Commodity 3 has remained the same. This may be explained by Nokia's focus towards diversifying its portfolio of suppliers. While this approach reduces supply risk and promotes competition between Vertical Integrators, it sometimes forces Nokia to allocate production to less capable VIs. This strategy has helped Nokia develop its Commodity 3 suppliers broadly, but has not resulted in any focused improvements.

Yet this diversification has not helped Nokia avoid massive Commodity 3 shortages over the past 18 months. Despite increases in shortages, Commodity 3 is the only component area which continues to deliver decent cost reductions. We can explain this based on several factors:

- Nokia's diversification strategy has helped to promote cost competition between Vertical Integrators.
- Mass-market, basic phones exert a large influence on the Commodity 3 business. Nokia's basic phones remain popular in the market, allowing for large production economies of scale. This in turn helps to drive down cost for overall Commodity 3 purchasing.

5.3.4 Commodity 4

Technology Maturity: Commodity 4 experienced very high new component counts in two of the recent three years. New component counts for Subcommodity 4A and Subcommodity 4B remained in line with the average for those periods.

Supplier Quality Action Requests: The number of cases opened for Commodity 4 has remained low, ranging from 158 – 389 in each period. Due to the complexity of Commodity 4, we believe that suppliers simply do not have the expertise to detect complex quality problems. These problems may get passed along and found at a later stage.

Batch Failure Rates: Subcommodity 4C shows the highest rates of failures, around 7.6%. This may be caused by the sensitive nature of Subcommodity 4C components. Excessive handling during shipment and improper assembly can distort performance and result in higher failure rates. Subcommodity 4B failures can be affected by similar factors as Subcommodity 4C failures, although Subcommodity 4B assemblies are less complex. This can be seen in their higher than average failure rates of around 2.1%. Most surprisingly, Subcommodity 4B shows the lowest batch failure rates—less than 1%. One explanation: suppliers provide quality tests that prevent defective parts from being shipped to Nokia.

Shortage Surprises: In the previous four year period, only one instance has affected the entire Commodity 4 supply chain.

Operational Expenses: Overall OpEx slightly increased recently but has declined continuously since then.

SLM Planning Accuracy: In three instances over the past three years, the Subcommodity 4C team overestimated the future costs for their component areas. Otherwise, SLM planning accuracy has been in line with the average over the same period.

Cost Reductions: Overall Commodity 4 cost reductions have tracked the average across the periods in our study, with better than average performance during certain periods in the past three years. The

Commodity 4 area represents medium complexity components which are purchased as solutions from suppliers. With this in mind, we can expect the average cost reductions seen for Commodity 4 components.

Analysis: The biggest problem in Commodity 4 sourcing is quality, as seen in the high batch failure rates of Subcommodity 4C components and Subcommodity 4D. Despite these high failure rates, we observe few Supplier Quality Action Requests from Vertical Integrators. This means that VIs are not reporting failures which pass through their production. Furthermore, conducting quality tests is a time-consuming process which reduces production throughput for the entire device assembly.

The path to problem resolution incurs high costs. To begin, some defective components cannot be removed from the main phone assembly, and the entire product must be scrapped at a loss. If the defect rate is particularly high, then the VI must temporarily halt production, further disrupting the supply chain.

To identify the defect source, Nokia works primarily with the component supplier. (With their razor focus on providing low cost manufacturing services, VIs typically lacks the in-depth technical expertise required to identify and troubleshoot defects.) During this troubleshooting process, the component supplier is reluctant to share knowledge with the VI, for fear that the VI will steal their proprietary technology. As a result, VIs do not gain the knowledge to help them avoid similar problems in the future. In summary, Commodity 4 quality problems are identified too late in the supply chain, causing material losses and supply disruptions. Enabling the VI to identify defects earlier in production will improve product quality and cost. However, to make this possible, Nokia must first help the VI develop efficient quality management capabilities.

5.3.5 Commodity 5

Commodity 5 represents fairly simple products which are primarily outsourced.

Technology Maturity: the number of types of Subcommodity 5A and 5B types are kept at a minimum, in order to ensure standardization across Nokia's product line. On the other hand, new subcommodity 5C components are frequently introduced. These "new" components are not new technologies, so we don't expect them to introduce many supply chain challenges.

Supplier Quality Action Requests: Subcommodity 5A materials stands out with 814, 1188, and 686 cases opened duringduring the three most recent periods. 694, 873, and 478 of those cases were closed during the same periods, respectively. The high number of opened cases reflects the ease in identifying Subcommodity 5A errors. While nearly all cases seem to be closed after a year, there are about 43.2% recent cases still open.

Batch Failure Rates: There is no data available for other subcommodities, since those components are primarily outsourced. The defect rate on Subcommodity 5A materials is very low, which shows that the large number of SQARs helps to improve quality.

Shortage Surprises: Only 41 cases have occurred in the past four years. One of the cases was classified under Commodity 5 because it was a completely outsourced component. However, the case more closely resembles a Commodity 1 shortage, as the cause stemmed from shortages in a Commodity 1 subcomponent. In summary, Commodity 5 shortages occur for more complex components.

Operating Expenses: Commodity 5 OpEx has consistently remained at about 56.2% of total OpEx for the components in our study. This is a large amount, considering that Commodity 5 is represented by low complexity hardware which Nokia completely outsources.

SLM Planning Accuracy: Overall Commodity 5 planning accuracy has tracked the average planning accuracy for the periods in our study. Of the components within Commodity 5, only Subcommodity 5B planning accuracy has been more accurate than the average. We would expect more components within Commodity 5 to have high planning accuracy, because the Commodity 5 supply chain is less complex than that of more advanced components. The likely conclusion is that Commodity 5 cost managers are overly conservative in their planning.

Cost Reductions: While some data is missing, we see that Commodity 5 cost reductions track the average for all components in our study. This is rather surprising, since Commodity 5 does not consist of expensive components with high potential for cost reductions. One possibility: because suppliers have more freedom to manage Commodity 5 components, they have better incentive to make the efficiency improvements needed for cost reductions.

Analysis: The Commodity 5 supply chain is fairly stable, with few complex components, low failure rates, and consistent cost reductions. The high number of SQARs shows that suppliers will proactively manage quality if they know how to do so. We are most surprised by the high OpEx and average SLM Planning Accuracy. The Commodity 5 supply chain seems to be less complex than that of more advanced components, so we would expect lower OpEx. The data may point to inefficiencies in managing the Commodity 5 supply chain.

5.3.6 Commodity 6

Commodity 6 includes common subcomponents which are used across the electronics industry.

Technology Maturity: Commodity 6 show consistently fewer new component introductions. This fits the purpose of Commodity 6, which prioritizes large volumes over product variations.

Batch Failure Rates: The BFR has remained around 1.74% throughout the past two years. In order to improve the defect rate, Nokia may need to choose higher quality suppliers and accept higher component prices.

Supplier Quality Action Requests: Very few SQARs have been issued for Commodity 6. This may indicate that suppliers are uninterested in pursuing defective Commodity 6. With a manageable BFR rate of 1.74%, suppliers may conclude that it is simpler to accept and replace faulty components.

Shortage Surprises: 44 small instances of supply shortages have occurred in the past four years. The first half of 2008 experienced a shortage in "commodity." More recently, in the second half of 2011, the Japanese earthquake caused disruptions in subcomponent supplies affecting Commodity 6. In general, Commodity 6 components are widely available on the market, and we expect small and infrequent supply shortages.

Operational Expenses: Commodity 6 OpEx is roughly 10.2% of total OpEx for the components in our study. This is a small amount and seems reasonable given the relatively simple management required for Commodity 6.

SLM Planning Accuracy: Commodity 6 have predictable and stable prices, so we are not surprised to find that Commodity 6 have highly accurate planning accuracy.

Cost Reductions: Commodity 6 have achieved consistent cost reductions over the past four years. More recently, while other components faced fewer reductions, Commodity 6 continue to deliver about 17.1% cost reductions per period. This shows that Commodity 6 prices are influenced more by market forces than Nokia's purchasing power.

Analysis: From our data, we see a consistently well performing supply chain with fewer new technologies, acceptable quality, very few shortages, low operational expenses, good planning accuracy, and consistent cost reductions.

6 Supply Chain Model

6.1 Purpose of Model

Nokia sources components in these areas: Commodity 1, Commodity 2, Commodity 4, Commodity 3, and Commodity 6. Each of the six component areas we have studied is managed by a different group within Nokia. Furthermore, Nokia applies varying degrees of supply chain control to each component area. For example, Nokia gives the most freedom to suppliers to source and manage production for Commodity 5 components.

In the future, Nokia managers will want to adjust their level of supply chain control across the various component commodities. Changing the level of control will require Nokia to adjust its operational expenses and investments in its supply chain. This model will guide Nokia managers in choosing a supply chain strategy based on their financial priorities. We will also evaluate how each commodity area requires a different set of financial decisions.

6.2 Summary of the Model Framework

6.2.1 General Form of the Model

Let us consider a function $e(x, y)$ that represents Nokia's level of supply chain control.

$$e(x, y) = ax + by$$

where a and b are weighting factors, to be chosen based on Nokia's business priorities. We use a linear approximation as a first approximation for our model.

x represents Nokia's operational expenses in managing the supply chain. It does not include Nokia's purchasing costs for its components. Rather x quantifies the Nokia supply chain overhead required to consume one unit of production. As a hypothetical example, if $10 million in operating expenses is spent to manage the 100 million unit Commodity 2 supply chain, then $x = \$0.10$.

y represents the amount of investment Nokia dedicates to its supply chain. For example, certain supply chain models involve Nokia purchasing components and equipment upfront. In these cases, Nokia earns its return on investment after the final product is sold. Thus, y is related to cash flow because it describes the amount of capital Nokia ties up in its supply chain per unit of production. As a hypothetical example, if $100 million in investment is required for 100 million units of production, then $y = \$1$.

6.2.2 Specific Form of the Model Applied at the Commodity Level

Nokia organizes it supply chain management (SCM) functions into six categories, corresponding to component types. These six components are Commodity 1, Commodity 2, Commodity 3, Commodity 4, Commodity 6, and Commodity 5. Each component area has a dedicated SCM team and budget. Therefore, we will use a different function to specify each of the component areas. We will represent each component area as follows:

Table 1: List of Commodities and their representative functions

i	*Function*	*Commodity*
1	f_1	Commodity 1
2	f_2	Commodity 2
3	f_3	Commodity 3
4	f_4	Commodity 4
5	f_5	Commodity 5
6	f_6	Commodity 6

Let $f(x_i, y_i)$ denote the percentage of SCM control Nokia dedicates to component area i.

$$f(x_i, y_i) = a\frac{x_i}{x'} + b\frac{y_i}{y'}$$

for $i = 1, 2, \ldots 6$

where x_i represents the SCM operational expenses for managing component i.

and y_i represents the SCM investment dedicated to component i

x' represents Nokia's current total SCM operational expenses for all components

and y' represents Nokia's current total SCM investment for all components.

Thus $x' = \sum_{i=1}^{6} x_i$ and $y' = \sum_{i=1}^{6} y_i$

a and b are weighting factors.

Then

$$f_0(x, y) = \sum_{i=1}^{6} f(x_i, y_i) = a + b = G$$

where $f_0(x,y)$ represents Nokia's current level of SCM control.

We can set G = 1 so that each $f(x_i, y_i)$ is a fraction representing the percentage of total SCM control which Nokia dedicates to component area *i*.

Hypothetical Example: In 2012, Nokia decides to double its SCM operational expenses (x_i) and investment (y_i) for all components. (For simplicity, let us also assume that $a = b = 0.5$)

$$f_1(x, y) = \sum_{i=1}^{6} f(x_i, y_i) = 2a + 2b = 2$$

From the above, we see that SCM control has doubled from 1 to 2. We can relate this increased factor to other metrics defining Nokia's SCM performance. For example, product quality may improve as a function of Nokia's increased SCM control.

Next, we will solve for the x_i and y_i for individual component areas. This will allow us to calculate $f(x_i, y_i)$ for each component area and compare the level of supply chain control across component areas.

Solving for Operational Expenses (x_i)

Nokia's Operational Expenses (OpEx) for each of its commodity areas is summarized below.

For each commodity, we will use the average Operational Expense for the four most recent periods. We then take the total OpEx as the sum of the individual component OpEx.

By dividing the each Commodity's OpEx by the total OpEx, we can find the percentage of total OpEx dedicated to each commodity (x_i/x'):

In the table below, we approximate the percentage of OpEx which Nokia dedicates to various commodities. (For confidentiality purposes, we cannot provide precise financial numbers.)

Table 2: Obtaining x_i and x_i/x' for each Commodity Area

i	*Function*	*Commodity*	x_i/x'
1	f_1	Commodity 1	0.05
2	f_2	Commodity 2	0.10
3	f_3	Commodity 3	0.35
4	f_4	Commodity 4	0.20
5	f_5	Commodity 5	0.25
6	f_6	Commodity 6	0.05

Solving for Investment (y_i)

By considering the supply chain business model which Nokia applies to its commodities, we can approximate y_i on a scale from 1 to 10, where larger y_i indicates greater Nokia SCM for that commodity:

Table 3: Obtaining y_i and y_i/y' for each Commodity Area

i	*Commodity*	*Current Business Model*	y_i	y_i/y'
1	Commodity 1	Turnkey with some AVAP and Buy & Sell for key subcommodities	4	0.148148
2	Commodity 2	Turnkey	2	0.074074
3	Commodity 3	AVAP with some consignment	8	0.296296
4	Commodity 4	AVAP emphasizing heavier Nokia SCM	7	0.259259
5	Commodity 5	Full Turnkey for all subcommodities	1	0.037037
6	Commodity 6	AVAP, emphasizing lighter Nokia SCM	5	0.185185

where $y' = \sum_{i=1}^{6} y_i = 4 + 2 + 8 + 7 + 1 + 5 = 27$.

Note that we made a best assumption on the values in Table 4, based on our knowledge of Nokia's historical supply chain investment. From y_i/y', we can estimate the percentage of total Investment cash flow which Nokia is dedicating to each commodity area.

Impact of Nokia's Cash Flow on Supply Chain Investment and Operational Expenses

Table 4: Nokia's Operating Cash Flow (in Euros)

	2008	2009	2010	2011
Operating Cash Flow	3.2B	3.25B	4.78B	1.14B
Net Operating Cash Flow Growth	-59.42%	1.44%	46.97%	-76.19%
Net Operating Cash Flow / Sales	6.32%	7.93%	11.25%	2.94%

The table above shows Nokia's financial difficulties, as shown by its recent drop in operating cash flow. Nokia will find it increasingly difficult to obtain new debt financing, since it's credit rating was recently downgraded two notches by Fitch from A- to BBB.

Assessing Nokia's Supply Chain Investment: Difficulties in obtaining and moving cash will impact Nokia's supply chain decisions. Suppliers will be less willing to extend credit to Nokia and make investments required by Nokia. Most suppliers will demand earlier payments or charge a higher price to reflect Nokia's business risk. Some suppliers will demand that Nokia invest cash in advance for new equipment and components. Thus, Nokia's financial situation may place constraints on Nokia's ability to manage its supply chain. Our model will show the new business models available to Nokia under these constraints. Finally, we will recommend specific business models that help Nokia achieve its supply chain goals.

Assessing Nokia's Operational Expenses: Nokia's component purchasing costs are a significant factor in Nokia's cash flows. For a rough guide, consider that Nokia's produces over 300 million phones annually with component costs ranging from $20 to $200. In order to keep cash on hand, Nokia may find it attractive to outsource greater purchasing and supply chain responsibility to the supplier. Several alternative business models (e.g. the Buy & Sell model) allow suppliers to pay Nokia for the components which they then assemble. This new model frees up cash for Nokia earlier. It may also involve Nokia granting the supplier greater control over supply chain management. In some cases, Nokia may be able to purchase ready-made solutions which can then be sold to the customer and converted into revenue. As a result, Nokia can lower its own supply chain management (SCM) OpEx, since more responsibility is handled by the supplier.

<u>Determining the weighting values *a and b*</u>

Recall that $f(x_i, y_i) = a\frac{x_i}{x'} + b\frac{y_i}{y'}$

We first estimate the $f(x_i, y_i)$ as the proportion of supply chain control which Nokia dedicates to its various commodities. We will determine $f(x_i, y_i)$ by making our best assumption of a and b. a and b represent the weighting factors for OpEx (x_i) and Investment (y_i), respectively, which define overall supply chain control $f(x_i, y_i)$. In general, if one commodity has historically prioritized greater supply chain control compared to another commodity, then the first commodity's $f(x_i, y_i)$ will be larger. The difference between commodity $f(x_i, y_i)$ will depend on a number of historical supply chain prioritization decisions.

Table 5: Determining Nokia's current Supply Chain control

i	*Commodity*	x_i/x'	y_i/y'	a	b	$f(x_i,y_i)$
1	Commodity 1	0.05	0.148148	0.58	0.42	0.091
2	Commodity 2	0.10	0.074074	0.58	0.42	0.089
3	Commodity 3	0.35	0.296296	0.58	0.42	0.327
4	Commodity 4	0.20	0.259259	0.58	0.42	0.225
5	Commodity 5	0.25	0.037037	0.58	0.42	0.161
6	Commodity 6	0.05	0.185185	0.58	0.42	0.107

Model Constraints

We will first identify constraints on Nokia's Operational Expenses (x_i) and future Investments (y_i). This will help us estimate a new set of functions $\{f1, f2, \ldots, f6\}$ reflecting Nokia's revised levels of supply chain control.

Let us begin by evaluating Operational Expenses for Nokia Corporation as a whole. At the end of 2011, Nokia had 130,000 employees, of which 66,000 come from the Nokia Siemens Networks joint venture with Germany's Siemens AG *(Nokia to Cut 4,000 Jobs, Wall Street Journal, February 8, 2012)*. We will only consider the 64,000 Nokia staff outside the Nokia Siemens Networks partnership. To understand how Nokia is reducing its OpEx, consider how the company announced plans to shed 14,000 jobs since February 2011. This represents a reduction of nearly 20% of the workforce in the past year.

These job cuts include substantial reductions in manufacturing operations worldwide. For example, in September 2011, Nokia cut 3,500 jobs and closed its Cluj factory in Romania. In February 2012, Nokia cut another 4,000 jobs at smartphone manufacturing plants in Europe and Mexico. The cuts represent 2,300 of the 4,400 jobs in Hungary, 700 out of 1,000 in Mexico, and 1,000 of 1,700 factory jobs in Finland. In total, four of Nokia's nine manufacturing sites are affected.

With these cuts, Nokia seeks to significantly reduce Operational Expenses for its manufacturing operations. Besides consolidating manufacturing to its Asian facilities, Nokia is also outsourcing more production to contract manufacturers and original design manufacturers (ODM) such as Compal.[8] ODM business models typically involve the ODM taking responsibility for product design, manufacturing, and aftermarket service. Because ODMs design the product, they can choose components which are customized for their production and procurement capabilities. This means that ODMs are in a strong position to directly purchase components used in their production. ODMs capable of independently designing, selecting, and purchasing components can take additional responsibility for managing product quality and the product supply chain. Thus, by outsourcing to ODMs, Nokia can substantially reduce its supply chain control and Operational Expenses. We will reflect this change by reducing the value of f, representing Nokia's SCM control.

6.2.3 Estimating Future Operational Expenses (x_i)

Consider that Nokia has reduced nearly 20% of its workforce, with broader cuts in its manufacturing operations. Also consider that Nokia can further reduce its supply chain OpEx with continued

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[8] "*Compal Communications* to see strong smartphone shipments to *Nokia* in 2Q12," Digitimes, April 24, 2012

outsourcing. With these factors, we reasonably expect that Nokia can reduce its future supply chain Operational Expenses by 34%. We can approximate this as:

$x_{New} = \sum_{i=1}^{6} x_{iNew} \sim 0.67$

We extend this approximation to:

$x_{iNew} \sim 0.67x_i$, for $i = 1,\ldots,6$

Using the above equation for x_{iNew}, we can calculate new component OpEx as follows:

i	*Commodity*	y_i	x_i/x'	x_{iNew}
1	Commodity 1	4	0.05	0.0335
2	Commodity 2	2	0.10	0.067
3	Commodity 3	8	0.35	0.2345
4	Commodity 4	7	0.20	0.134
5	Commodity 5	1	0.25	0.1675
6	Commodity 6	5	0.05	0.0335

6.2.4 Estimating Future Investment Levels (y_i)

We can estimate Nokia's future Investment levels by considering its reduced cash flows. In 2011, Nokia's cash flows were $1.14B, less than a quarter of 2010 cash flows. This number is also roughly one-third of cash flows for each of the years 2009 and 2010. As a result, we expect Nokia to seek reduced supply chain investment, by pursuing new business models with suppliers. The Buy & Sell model and Turnkey models, in particular, allow suppliers to advance component purchasing costs and charge Nokia after building the final product. Such business models can be extended so that most supply chain investment costs are borne by suppliers. We expect Nokia to vigorously reduce its Investment costs, to the extent that is possible. We can represent new Investment levels as:

$$y_{New} = \sum_{i=1}^{6} y_{iNew} \leq 0.51$$

Here, we expect Nokia to target a 65% reduction in Investment levels over the long-term, which fits more closely with its reduced cash flow. However, in the near-term (<2 years), we expect Nokia to achieve 75% towards its target, which results in $1 - 0.75*0.65 = 0.51$.

We expect Nokia to reduce Investment costs equally across the component areas it manages, so that the proportion invested in each component area is similar to previous levels. This is possible to the extent that most of Nokia's suppliers are relatively large companies with the experience and financial capability to finance production for Nokia. (Furthermore, some suppliers have suggested a willingness to adopt this arrangement.) We previously estimated the proportion of investment in each of Nokia's component areas:

i	*Commodity*	*Current Business Model*	y_{iOld}	y_{iOld}/y'
1	Commodity 1	Turnkey with some AVAP and Buy & Sell for key subcommodities	4	0.148148
2	Commodity 2	Turnkey	2	0.074074
3	Commodity 3	AVAP with some consignment	8	0.296296
4	Commodity 4	AVAP emphasizing heavier Nokia SCM	7	0.259259
5	Commodity 5	Full Turnkey for all subcommodities	1	0.037037
6	Commodity 6	AVAP, emphasizing lighter Nokia SCM	5	0.185185

The new share of investment for each component area can be represented as follows:

i	*Commodity*	y_{iOld}/y'	y_{iNew}/y'
1	Commodity 1	0.148148	0.0755555
2	Commodity 2	0.074074	0.0377777
3	Commodity 3	0.296296	0.151111
4	Commodity 4	0.259259	0.1322221
5	Commodity 5	0.037037	0.0188889
6	Commodity 6	0.185185	0.0944444

where New Investment costs (y_i) are calculated as: $y_{iNew} = 0.51 * y_{iOld}$ and $y_{New} = \sum_{i=1}^{6} y_{iNew} \leq 0.51$

6.3 Quantifying Nokia's Future Supply Chain Control

In addition to projecting x_{iNew} and y_{iNew}, we can also estimate f_{iNew} as the proportion of future supply chain control which Nokia will dedicate to each of its commodity areas. We will determine f_{iNew} by making our best assumption of a_{New} and b_{New}. a_{New} and b_{New} reflects how Nokia can prioritize OpEx (x_i) and Investment (y_i) to manage its future supply chain.

We first estimate f_{iNew} with the constraint that $f_{New} = \sum_{i=1}^{6} f_{iNew} \leq 0.6$. We believe this estimate for f_{New} is reasonable considering similar reductions in x_{iNew} and y_{iNew} that we have shown earlier.

Table 6: Determining Nokia's Future Supply Chain control

i	*Commodity*	a	b	$f(x_i,y_i)$	a_{New}	b_{New}	f_{New}
1	Commodity 1	0.58	0.42	0.13	0.34	0.66	0.061257
2	Commodity 2	0.58	0.42	0.08	0.34	0.66	0.0477135
3	Commodity 3	0.58	0.42	0.31	0.34	0.66	0.1794633
4	Commodity 4	0.58	0.42	0.22	0.34	0.66	0.1328265
5	Commodity 5	0.58	0.42	0.2	0.34	0.66	0.0694167
6	Commodity 6	0.58	0.42	0.06	0.34	0.66	0.073723

Note that the sum of f_{New} for $i = 1,\ldots6$ is 0.56 compared to $f(x_i,y_i) = 1$.

The table above compares values of a, b, and f_i which represent Nokia's current and future supply chain. We see that values for a_{New} are lower than a for all commodities. On the other hand the values for b_{New} are higher than b for all commodities. This shows that as Nokia decreases its supply control, it will initially encounter small impacts from lower Investment. As Nokia makes further reductions in Investment, it will transform its supply chain model. As a result, further reductions in Investment will begin to make larger impacts to supply chain control. This shows that Nokia must maintain a certain amount of investment in its supply chain. To maintain the optimal level of supply chain control, Nokia must make a combination of reductions in both OpEx and Investment.

6.4 Identifying Correlations between Supply Chain Control and Performance

To determine Nokia's future supply chain performance, we can first look at historical supply chain performance across a range of component commodities. Nokia manages its commodity areas with varying levels of control. We quantified this previously by assigning:

$f(x_i, y_i) = a\frac{x_i}{x'} + b\frac{y_i}{y'}$ *(Total Supply Chain Control for Commodity i)*

x_i *(Supply Chain Operational Expenses for Commodity i)*

y_i *(Supply Chain Investment for Commodity i)*

We can look for indicators of future supply chain performance in two areas:

- Within a single commodity area, we can observe historical variances in supply chain performance.
- Across commodities, we can look at historical performance of commodities with a range of supply chain control (high, medium, and low values of f_i across commodities).

6.4.1 Approach to Organizing Data

In the Appendix, we have collected data on Nokia's supply chain performance from 2008 to 2011. The data tracks key supply chain performance metrics related to new technology introduction, supply availability, product quality, and cost. We will analyze correlations by organizing our data as follows:

Time period: We will study four half-year periods between the second half of 2009 to the first half of 2011. (There are several gaps in data for periods before 2009.)

Commodity Groups: We will organize commodities based on their level of supply chain control: Commodity 3 (High Supply Chain control), Commodity 4 (Medium-High SC control), "Commodity 2, Commodity 5, and Commodity 6" (Low SC control). We chose to group Commodity 2, Commodity 5, and Commodity 6 because they represent commodities for which Nokia maintains less control (low f_i).

Metrics: We choose the following metrics, which provide the most complete data: Technology Maturity Level (characterized by the % of new components introduced during the time period), SLM Planning Accuracy, Cost Reductions, Batch Failure Rates.

By organizing our data under the guidelines above, we will have roughly 12 to 16 data points for each of the three commodity groups described above.

6.4.2 Method to Normalize Data

The three commodity groups we have chosen further consist of subcommodities.

Even within a commodity, different subcommodities exhibit different supply chain characteristics. For example, complex Commodity 2 assemblies may exhibit a higher failure rate than less complex Commodity 6 assembly. In order to make useful comparisons between these subcommodities, we first normalize their supply chain metrics. For example, to normalize the Commodity 2 failure rate, we take the average Commodity 2 failure rate from 2009H2 to 2011H1 and subtract this result from the individual period's Commodity 2 failure rates. This shows us how supply chain decisions across time have increased or decreased the failure rate compared to the average. We perform the same normalization for all other commodities and subcommodities. Normalization enables us to see how certain commodity metrics perform above or below average over time. After normalizing our data points, we take these steps to find correlations between supply metrics:

1. Focusing on a specific time period, we can see how individual metrics compare with each other.
2. We organize the commodities into the three groups described above (Commodity 3, Commodity 4, and Turnkey solutions).
3. Within each commodity group, we collect data points for each subcommodity from 2009H2 to 2011H1. We obtain 12 - 16 data points for each supply chain metric. These metric relate either to supply availability, cost, technology , or quality.
4. We compare different metrics by correlating the 12 - 16 data points representing each metrics. This allows us to see relationships between supply and cost, for example.
5. We repeat steps 4 and 5 for each of the three commodity groups.

Using the steps above, we found several correlations between various supply chain metrics. This shows us how Nokia's choice of supply chain control influences the relationships between supply performance. We describe these correlations in the next section.

6.4.3 Correlations between Supply Chain Performance Metrics

Commodity 3 (High Supply Chain Control)

The Commodity 3 commodity has historically involved a high-level of supply chain control. We find a high degree of correlation between SLM Planning Accuracy and Cost Reductions, as well as a small correlation between Cost Reductions and Tech Maturity Levels.

Correlation	SLM Planning Accuracy	Cost Reductions	Batch Failure Rate	Tech Maturity Level
SLM Planning Accuracy		0.853015268	0.041703712	-0.08072986
Cost Reductions			-0.050195993	-0.322968676
Batch Failure Rate				0.172740796
Tech Maturity Level				

SLM Planning Accuracy describes how accurately Nokia is able to forecast the future cost of its phone components. Positive values for SLM Planning Accuracy indicate that actual component costs were higher than predicted. Values of SLM Planning Accuracy are generally negative, which implies that Nokia managers predicted higher costs than actually observed. When Cost Reductions are high, Nokia managers will increasingly over-predict actual component costs. We believe Nokia managers are estimating conservatively, in case the Cost Reductions fail to materialize.

Cost Reductions are weakly correlated to Technology Maturity Levels. That is, an increase in the number of new components will slightly diminish Cost Reductions and increase prices. The fact that new component costs increase only slightly is a positive indicator for Nokia's Commodity 3 supply chain. Nokia is able to refresh Commodity 3 designs at a small cost penalty. This indicates either of two possibilities:

- Nokia suppliers have developed efficient systems for switching production to new Commodity 3 designs.
- Nokia has strong leverage over Commodity 3 suppliers and force them to maintain low cost production. Either these costs are "eaten" by the suppliers or the suppliers achieve reduced performance in other areas: quality, supply availability, etc.

Conclusions: We see that Nokia's high level of Commodity 3 control exerts strong cost pressure on suppliers. Nokia managers are keen to "buffer" their estimates when Cost Reductions are especially high.

If component cost reductions are the main benefit from strong supply chain control, then there may be less quality and supply availability risk for Nokia to reduce its Commodity 3 supply chain control.

Commodity 4 (Medium-High Supply Chain Control)

We find a high degree of correlation between Cost Reductions and Tech Maturity Level, with a medium-high level of correlation between: SLM Planning Accuracy and Cost Reductions, Cost Reductions and Batch Failure Rates, and SLM Planning Accuracy and Tech Maturity Levels.

Correlation	SLM Planning Accuracy	Cost Reductions	Batch Failure Rate	Tech Maturity Level
SLM Planning Accuracy		0.645321571	0.277739282	-0.533037219
Cost Reductions			0.505859019	-0.802995754
Batch Failure Rate				-0.209626451
Tech Maturity Level				

The Commodity 4 commodity shares similar types of correlations which we found for Commodity 3. For Commodity 4, there is an even stronger correlation between Cost Reductions and the Technology Maturity Level. That is, new component introductions lead strongly to higher cost reductions. This can be explained by two factors:

- New Commodity 4 technology drives efficient products at lower costs. Furthermore, Nokia's suppliers obtain high initial yields to immediately realize the lower cost of new components.
- By exerting less control in Commodity 4, Nokia provides suppliers with greater opportunities to achieve lower costs with new components.

To understand the importance of each factor, Nokia should further analyze data specific to certain suppliers and technologies. This will show whether Nokia's supply chain management significantly affects the correlation between Cost Reduction and Technology Maturity Level.

The Cost Reductions metric also has a medium correlation with Batch Failure Rates. Low Batch Failure Rates are related to large cost reductions. One possible explanation: If suppliers can achieve higher yields, they will be able to provide greater cost reductions. If Nokia is able to secure lower prices when suppliers improve their quality, then Nokia's supply chain management is contributing to lower purchasing costs.

There is also a medium correlation between SLM Planning Accuracy and the Technology Maturity Level. The correlation shows that Nokia managers will underestimate cost reductions during periods many new components are introduced. New component introductions, ostensibly, are related to higher cost reductions (as we showed earlier). This behavior again shows managers conservative approaches to recognizing future cost reductions.

Conclusion: We find a greater number of strong correlations in Commodity 4 than in Commodity 3. This is surprising considering that Nokia exerts more "control" in the Commodity 3 supply chain. With more resources dedicated to Commodity 3, we expect more predictability in its supply chain. What we see for Commodity 4 shows that either Commodity 3 supply chain control is inefficient, or there is a technology difference between Commodity 3 and Commodity 4 which affects their respective supply chains. If differences in technology are not a strong factor, then the Commodity 3 area is less efficient than the Commodity 4 area in controlling for supply chain predictability. In such a case, we can model the Commodity 3 supply chain after the Commodity 4 supply chain to attain greater predictability. It is the author's opinion that Nokia's Commodity 3 suppliers are lacking in their capability to manage production and supply chain control. Therefore, if Nokia wants to outsource greater responsibility to Commodity 3 suppliers, it must first invest in developing these suppliers capabilities.

Commodity 2, Commodity 5, and Commodity 6 (Low Supply Chain Control)

We have fewer data points due to gaps in Nokia's recorded data. However, we do find a strong correlation between Batch Failure Rates and Cost Reductions. We also find small correlations between the Tech

Maturity Level and both Batch Failure Rates and Cost Reductions. Note that all three metrics we applied have some degree of correlation with each other.

	Batch Failure Rates	Cost Reductions	Tech Maturity Level
Batch Failure Rate		0.843157293	-0.304002376
Cost Reductions			-0.373890633
Tech Maturity Level			

The strong positive correlation between Batch Failure Rate and Cost Reductions suggest that Nokia can achieve good quality and good cost reductions by continuing with its current Commodity 2 suppliers.

There is low level of correlation between Batch Failure Rates and the Technology Maturity Level. That is, the Batch Failure Rate decreases slightly in relation to a larger number of new components introduced. This shows that Turnkey suppliers are skilled in achieving better quality during new production runs. Either of two possibilities may be a factor:

- Turnkey suppliers focus more on quality when producing new components.
- New components bring technologies enabling higher quality production and lower failure rates.

Furthermore, we see a small correlation between Cost Reductions and Technology Maturity Levels. The correlation illustrates that small cost reductions follow new component introductions. Considering that Turnkey suppliers achieve high quality rates, we expect this may result because:

- Suppliers achieve lower costs when switching to new technologies. However, they are not passing the full savings to Nokia.
- Since Turnkey components (with the exception of Commodity 2) are less complex, suppliers are able to realize fewer cost reductions when transitioning to new types of production. Therefore, they provide fewer cost reductions to Nokia.

We expect both of the reasons above to play a role in the low cost reductions. To see whether technology is important, we can decompose the analysis to focus on Commodity 2, which represents an advanced component. However, we have insufficient data points to perform this analysis.

Conclusion: For Turnkey components, quality seems to improve with additional cost reductions and new component introductions. This is a positive relationship indicating a well managed supply chain. Nevertheless, Nokia may not be realizing the full cost reduction when suppliers transition to producing new technologies. Since Nokia takes less control of the Turnkey supply chain, we can expect that suppliers will have more opportunity to keep profit margins for themselves.

6.5 Summary of Analysis

In our analysis, we first identified values to represent current levels of Operational Expenses (x_i) and Investment (y_i) dedicated to various commodities in Nokia's supply chain. We then estimated the proportion of supply chain control (f_i) which Nokia allocates across its commodities. Then, we used the equation:

$$f(x_i, y_i) = a\frac{x_i}{x'} + b\frac{y_i}{y'}$$

to obtain a and b, which represent weighting factors describing how changes in OpEx and Investment affects Nokia's supply chain control. If a commodity has a smaller value for a or b, then Nokia has greater freedom to decrease OpEx or Investment for that commodity, respectively.

a and b are also representations of Nokia's supply chain model (at least from an OpEx and Investment perspective).

Next, we projected Nokia's future levels of OpEx and Investment by assigning new commodity values x_{iNew} and y_{iNew}. We then re-evaluated Nokia's future supply chain control to arrive at a new set of values f_{iNew}. Using a similar equation that we used previously:

$$f_{New}(x_i, y_i) = a_{New}\frac{x_{iNew}}{x'_{New}} + b_{New}\frac{y_{iNew}}{y'_{New}}$$

Later, in section 6.5, we identified correlations between supply chain metrics describing new technology introduction, supply availability, product quality, and cost. Specifically, we focused on metrics for Technology Maturity Levels, SLM Planning Accuracy, Cost Reductions, and Batch Failure Rates. To understand the relationship between supply chain performance and control, we organized Nokia's commodities into three areas:

- Commodity 3 representing a High level of supply chain control.
- Commodity 4 representing a Medium-High level of control
- Turnkey solutions, including Commodity 2, Commodity 6, and Subcommodity 5B materials, which represent a Low level of control.

By applying subcommodity data from 2009H2 to 2011H1, we were able to find several correlations between various supply chain metrics.

For Commodity 3, we found that Cost Reductions were correlated to SLM Planning Accuracy and the Technology Maturity level. We conclude that Nokia's main benefit from strong Commodity 3 control is in lower component purchasing costs. As a result, we expect that reductions in Commodity 3 control will impact purchasing costs more significantly than product quality and supply availability. We were most surprised that Commodity 3 has the fewest correlations despite having a high level of supply chain control. We are uncertain whether increasing control of the Commodity 3 supply chain will also improve predictability. The greater unpredictability may be caused by inherent difficulties in achieving high

Commodity 3 quality and technology. It may also be due to Nokia's inefficient practices in managing the Commodity 3 area.

The Commodity 4 area shows a strong correlation between Cost Reductions and the Technology Maturity Level. This tells us that new technologies drive efficient products at lower costs. We also see that low batch failure rates are related to large cost reductions. In general, Commodity 4 data shows more predictability than the Commodity 3 data. Furthermore, it appears that higher quality and improved technology helps drive Commodity 4 cost reductions. If this is true, then Nokia exerts sufficient control over Commodity 4 suppliers to drive these cost reductions.

While we have less data for the Turnkey solutions category, we find that all the metrics we analyzed result in correlations. Turnkey solutions is similar to Commodity 4, in showing cost reductions resulting from improved technology and quality. However, these correlations are weaker for Turnkey solutions than Commodity 4. In other words, there are fewer cost reductions resulting from Nokia's supply chain management. We can expect this because Nokia maintains a low level of control for Turnkey solutions.

With more complete data, Nokia can analyze individual subcommodities for supply chain correlations. This will reveal whether certain correlations are due to technology differences or Nokia's own supply chain management. Furthermore, Nokia can compare the Cost Reductions achieved in the Commodity 4 and Turnkey commodities. If Commodity 4 achieves greater cost reductions due to Nokia's supply chain management, then we can quantify the savings in purchasing costs. By comparing these savings to Nokia's supply chain operational expenses, we can evaluate the monetary benefit of increased supply chain control. Finally, we must not discount the relationship between supply chain control across commodities. Lessons learned from managing the difficult Commodity 3 category may enable improvements in Commodity 4. Therefore, decisions to reduce supply chain control in one area may affect Nokia's entire supply chain.

7 Conclusion

Nokia's future supply chain strategy will require trading off supply chain control to meet business and financial constraints. As Nokia reduces its supply chain OpEx and Investment, it will be challenged to meet supply chain performance targets for:

- Supply Availability: maintaining sufficient material availability to meet production demands. Furthermore, a flexible supply chain will allow Nokia to quickly ramp production to take advantage of spikes in product demand.
- Technology Introduction: managing the introduction of new components and features to differentiate Nokia products in a crowded marketplace.
- Product Quality: achieving high quality production to lower costs and win customers.
- Cost control: maintaining leverage over suppliers to realize low component and manufacturing costs.

In its quest for efficient supply chain performance, Nokia can apply several supply chain models, including:

- Assigned Vendor Assigned Price: Nokia directly negotiates prices and supply with component suppliers and instructs contract manufacturers purchase components under Nokia's negotiated price and supply terms.
- Buy & Sell: Nokia directly negotiates prices and supply with component suppliers and directly pays suppliers for components. Nokia then sells these components to contract manufacturers at a markup to achieve component price confidentiality.
- Turnkey: Nokia pays its contract manufacturers for a solution which meets Nokia's requirements. Suppliers are responsible for procuring all materials used to produce the solution.

Each of these models provide different advantages and risks for Nokia to meet its Supply, Technology, Quality, and Cost goals. To add further complexity, Nokia does not need to apply one specific model for its entire supply chain. Nokia's six commodity areas already apply different supply chain models to meet different business constraints and goals. For example, Nokia has dedicated the most supply chain management OpEx to the Commodity 3 area, which continues to be plagued by the greatest number of supply shortages and quality problems. On the other hand, the Commodity 6 supply chain requires much lower operational expenses, while meeting quality targets and achieving fewer supply shortages.

In the future, Nokia will be challenged to maintain efficient production while reducing supply chain OpEx and Investment. Reductions in OpEx and Investment will lead Nokia to decrease its control over several commodity supply chains. To better understand how these reductions impact future performance, we will examine our previous equation describing Nokia's supply chain control:

$$f(x_i, y_i) = a\frac{x_i}{x'} + b\frac{y_i}{y'} \qquad \textit{(Total Supply Chain Control for Commodity i)}$$

In the previous section, we identified how Nokia can adjust its supply chain control, $f(x_i)$, for each of the six commodity areas. We will also organize our recommendations by these commodity areas.

7.1 Commodity 1

Nokia exerts a Medium-Low level of supply chain control in the Commodity 1 area. Due to the high complexity of Commodity 1, Nokia outsources design and production to the industry leaders in Commodity 1 manufacturing. On the other hand, Nokia maintains some level of supply chain control in selecting the Commodity 1 subcomponents. Recently, Nokia has observed steadily improving Commodity 1 quality. These improvements are mainly due to improvements made by the supplier, since Nokia has not increased the share of OpEx which it dedicates to Commodity 1. On the other hand, the Commodity 1 supply chain still suffered from massive shortages in the second half of 2010, resulting from quality challenges encountered by a new Commodity 1 supplier. Additionally, Nokia saw much lower cost reductions in the first half of 2011, caused by a drop in purchasing quantity for high-end Commodity 1.

Nokia's largely "hands off" approach to managing Commodity 1 design and production means that suppliers are responsible for providing stable quality and supply. Due to the limited number of "high-end" Commodity 1 manufacturers, Nokia faces limited bargaining power when choosing specialized Commodity 1 suppliers. (In the future, as advanced Commodity 1 technologies become mainstream, Nokia may see greater choice and flexibility in choosing Commodity 1 suppliers. However, we will not draw any conclusions based on this one assumption.)

From our analysis in Section 6, we determined how changes in OpEx and Investment will affect Nokia's future supply chain control. Our previous results are summarized below:

Commodity	a	b	$f(x_i,y_i)$	a_{New}	b_{New}	f_{New}
Commodity 1	0.58	0.42	0.13	0.34	0.66	0.061257

We see that supply chain control will be significantly affected by reductions in Investment (due to the significant weighting factor *b*). On the other hand, Nokia has some freedom to lower OpEx with a smaller effect on supply chain control .This points to a future strategy in which Nokia outsources more supply chain management responsibility to its Commodity 1 suppliers. At the same time, Nokia should make key investments in Commodity 1 suppliers to ensure availability of high quality Commodity 1. We believe that major Commodity 1 suppliers have the resources to deliver continued improvements in technology and quality, with less guidance from Nokia.

The Turnkey model enables Nokia to outsource design and production responsibility to certain suppliers. Turnkey also gives Nokia the flexibility to pay suppliers after receiving the finished components. Thus, Turnkey potentially enables reductions in both OpEx and Investment.

We recommend the Turnkey model, with one exception: Nokia should make upfront investments to help suppliers build their Commodity 1 production capabilities. By investing in suppliers early on, Nokia can ensure steady supplies at reasonable costs. Nokia can also specify certain product features and requirements in the Commodity 1 it receives. Afterwards, Nokia should monitor the supplier to ensure that they will deliver on agreed levels of supply, quality, and cost. In other areas, Nokia should rely on the supplier to deliver on agreed terms. In this way, Nokia can reduce OpEx while maintaining reasonable control over its Commodity 1 supply chain.

7.2 Commodity 2

The Commodity 2 supply chain shows the best performance in several areas: low failure rates, few shortages, stable costs and cost planning, as well as consistent cost reductions. Nokia can maintain these advantages by continuing to source from large and capable Commodity 2 suppliers. Due to already low OpEx levels, we recommend that Nokia maintain its current levels of OpEx. Our previous analysis confirms this recommendation (see table below):

Commodity	a	b	$f(x_i,y_i)$	a_{New}	b_{New}	f_{New}
Commodity 2	0.58	0.42	0.08	0.34	0.66	0.0477135

We recommend the Commodity 2 supply chain as the best areas for Nokia to cut investment while maintaining a degree of supply chain control. To make the needed reductions, Nokia should consider negotiating new purchasing terms with Commodity 2 suppliers. Under these terms, Nokia can delay paying suppliers for components. In return, suppliers may demand that Nokia pay higher component costs. The Commodity 2 supply chain has historically shown high levels of quality and supply availability. We believe these trends will continue even if Nokia reduces its investment. Thus, Nokia will increase its cash flow and purchasing costs, while minimizing harm to quality and supply availability.

(While Commodity 2 supply availability has been good historically, Nokia witnessed Commodity 2 shortages in one instance over the past three years. Nokia should investigate the causes of this shortage to guarantee that future investment reductions will not lead to similar shortages.)

7.3 Commodity 3

The Commodity 3 and Commodity 2 supply chains are quite different. While Commodity 2 sourcing directly purchases module solutions, Commodity 3 sourcing focuses on partnerships with Vertical Integrators to develop their Commodity 3 manufacturing and integration capabilities. This model has incurred high OpEx, while failing to help Nokia achieve improvements in supply availability and product quality. However, Nokia's efforts in the Commodity 3 supply chain has allowed it to drive some cost reductions, by encouraging competition between suppliers.

In the future, Nokia is likely to shift production to fewer, higher end products. Lower Commodity 3 purchasing volumes suggest that Nokia should analyze the benefit of component cost reductions against high OpEx. Furthermore, Nokia's intensive supply chain control may be contributing to challenges in supply availability and quality. Witness the Commodity 1 and Commodity 2 supply chains, which involve much less control, but show better levels of supply availability and/or product quality.

Commodity	a	b	$f(x_i,y_i)$	a_{New}	b_{New}	f_{New}
Commodity 3	0.58	0.42	0.31	0.34	0.66	0.1794633

The large weighting factor b indicates that reductions in Investment will make a large impact on Nokia's control over the Commodity 3 supply chain. However, it appears that Nokia can decrease OpEx with less impact to the Commodity 3 supply chain. We recommend that Nokia maintain strict quality control while giving suppliers more flexibility to make design and production improvements. At the same time, Nokia should maintain its investment level to secure purchasing leverage over Commodity 3 suppliers.

Commodity 3 suppliers also gain experience in new manufacturing techniques by working with Nokia's competitors. To some extent, Nokia can take advantage of its competitors efforts spent towards building Commodity 3 supplier capabilities.

To reduce Commodity 3 supply chain OpEx, Nokia can pursue two approaches for the high and low-end:

- High-end: Reuse Commodity 3 designs found in popular products. By focusing resources on fewer designs, Nokia can increase Commodity 3 production quality and lower costs over the long run.
- Low-end: Rely on suppliers for innovation to reduce cost and increase production efficiency. Depending on the supplier, Nokia can set incentive systems where the supplier is rewarded when customers report few defects in the product's Commodity 3. This imposes greater responsibility on the supplier to manage and improve Commodity 3 quality.

7.4 Commodity 4

The Commodity 4 supply chain faces many quality challenges, as seen in the high batch failure rates for select subcommodities. Despite these high failure rates, we observe few Supplier Quality Action Requests from Vertical Integrators. This means that VIs are not reporting failures which pass through their production. The most likely reason is that VIs simply do not have the tools, processes, and technical knowledge to identify defects. This places a large burden on Nokia to manage Commodity 4 component quality. Quality management is one reason why Commodity 4 OpEx is the third highest among the commodities, behind Commodity 3 and Commodity 5.

Commodity	a	b	$f(x_i,y_i)$	a_{New}	b_{New}	f_{New}
Commodity 4	0.58	0.42	0.22	0.34	0.66	0.1328265

Our previous analysis shows that it is difficult to reduce OpEx and Investment without impacting Commodity 4 supply chain control (due to the values for both weighting factors a and b). Cuts in OpEx are likely to impact Nokia's ability to manage production quality. Furthermore, Commodity 4 components are highly specific to Nokia products, so Nokia cannot easily reduce its investment levels. We believe Nokia should identify poorly performing Commodity 4 suppliers and look for alternative suppliers. If

Nokia's new supplier offers better quality and supply availability, then Nokia will have more flexibility to reduce its supply chain OpEx.

After identifying its top performing suppliers, Nokia can then focus its purchasing with a few suppliers. Doing so will enable Nokia to spread its supply chain investment across fewer suppliers, and allow it to make reductions in overall investment. If Nokia pursues this strategy, it should be careful to maintain its long-term purchasing power. Future cost reductions depend on Nokia's ability to transition to new technologies with lower production costs. In Section 6.5, we found a high degree of correlation between cost reductions and new technology introduction. Thus, Nokia should ensure that its top suppliers have the capability to deliver new technologies which lead to lower costs.

Finally, similar to our recommendation for the Commodity 3 area, Nokia should focus on a few Commodity 4 designs and reuse these components across its product range. This approach greatly simplifies supply chain management, while allowing Nokia to reduce production costs and improve quality across large production volumes. However, while reusing certain designs, Nokia should strive to adopt new Commodity 4 technologies which improve quality. In our analysis from Section 6.5, we found a medium level of correlation between cost reductions and (production) batch failure rates. The correlation indicates that Commodity 4 quality improves with new technologies. Thus, Nokia's future Commodity 4 supply chain should be ready to introduce new technologies which improve component quality and cost.

7.5 Commodity 5

The Commodity 5 supply chain is fairly stable, with few complex components, low failure rates, and consistent cost reductions. The high number of Supplier Quality Action Requests shows that suppliers have the expertise to proactively manage component quality. Even though suppliers are highly capable of managing Commodity 5 design and production, Nokia still retains tight control over the Commodity 5 supply chain. The Commodity 5 category includes a variety of different turnkey components. This broad product range imposes high supply chain management costs.--Commodity 5 commodities consume the second largest share of Nokia's supply chain management OpEx, behind Commodity 3.

Commodity 5 procurement follows the Turnkey purchasing model, whereby Nokia purchases "ready-made" solutions from suppliers. The suppliers are responsible for designing and producing the solution to meet Nokia's requirements. We saw a similar model used in the Commodity 2 area, which resulted in high production quality and supply availability. The Commodity 5 supply chain shows similar supply and quality performance. Our previous analysis shows that Commodity 5 has similar weighting factors compared to Commodity 2:

Commodity	a	b	$f(x_i,y_i)$	a_{New}	b_{New}	f_{New}
Commodity 5	0.58	0.42	0.2	0.34	0.66	0.0694167

The value for *b* indicates that changes in Investment will have a lesser effect on Nokia's supply chain control compared to changes in OpEx. To maintain efficient control of the Commodity 5 supply chain, Nokia should first seek reductions in Investment. Since Commodity 5 suppliers have performed well in the past, we expect these investment cuts will mainly increase purchasing costs. Reductions in quality and supply availability are unlikely as long as Nokia continues to actively monitor its Commodity 5 supply chain.

Nokia's high Commodity 5 OpEx is partly due to the variety of components which require supply chain management. To streamline costs, Nokia should standardize on a smaller range of components used in its products. This may allow Nokia to lower inventories, reduce the risk of supply shortages, and save on OpEx required to manage the Commodity 5 supply chain.

Finally, Nokia can gradually reduce OpEx and observe effects on the Commodity 5 supply chain. The Commodity 5 area exhibits the best quality and supply availability out of all commodities. Combining this with Nokia's high Commodity 5 OpEx points to the possibility that Nokia is "over-managing" the Commodity 5 supply chain. To test whether this is true, Nokia should identify and implement several initiatives to reduce Commodity 5 OpEx. While these initiatives present some supply chain risk, we believe that Nokia and its suppliers can capably identify and solve supply problems which may arise.

7.6 Commodity 6

The Commodity 6 supply chain shows consistent performance, with very few shortages, low operational expenses, acceptable quality and consistent cost reductions. Nokia sources Commodity 6 under the turnkey model. When Nokia's contract manufacturers use Commodity 6 in their production, they will purchase these components at Nokia's negotiated price and supply (using the AVAP model).

Commodity	a	b	$f(x_i,y_i)$	a_{New}	b_{New}	f_{New}
Commodity 6	0.58	0.42	0.06	0.34	0.66	0.073723

Our previous analysis shows reductions in OpEx will significantly impact Nokia's control over the Commodity 6 supply chain (due to the weighting factor a). Nokia's Commodity 6 OpEx is already the lowest of all the commodities, so additional cost reductions will be small. Further reductions are also likely to introduce supply chain risk, without providing significant financial benefit. As a result, we suggest that Nokia maintain its current Commodity 6 supply chain, while focusing improvements in other commodity areas. Changes to the Commodity 6 supply chain introduce risk and create distractions without providing significant financial benefit.

7.7 Final Words

Ultimately, Nokia's survival depends on successful market adoption of its Windows phones. An efficient supply chain can support this goal by providing the tools to produce low cost and high quality products. Furthermore, an efficient supply chain enables Nokia to respond quickly to changes in consumer demand and new product technology. Our previous analysis shows how Nokia can best maintain supply chain control in the face of future business constraints. In particular, we quantified the level of supply chain control which Nokia can allocate across its commodities. This level of control will depend on the investment and OpEx which Nokia dedicates to its future supply chain. Our analysis showed that changes in investment and OpEx will affect each commodity area to a different degree. Using these results, we can recommend an efficient method for Nokia to maintain supply chain control.

Our recommendations, outlined in sections 7.1 to 7.6, provide a strategy which enables Nokia to maintain an efficient and responsive supply chain, while allowing for future business and financial constraints. We summarize our recommendations as follows:

- For critical, high technology components, Nokia should make strategic investments in its suppliers. This will ensure that Nokia receives future supplies at reasonable costs.
    - Applies to Commodity 1.
- Cut investment in commodities with good historical supply chain performance. Investments in these commodities are less likely to influence supply availability and product quality. However, Nokia should prepare for higher purchasing costs if it reduces investment.
    - Applies to Commodity 2, Commodity 5.
- Reduce OpEx and simplify management by standardizing on a smaller range of components.
    - Applies to Commodity 3, Commodity 4, Commodity 5.
- Reduce OpEx by enabling suppliers to take a role in improving production and cost efficiency.
    - Applies to Low-end Commodity 3.

- For Commodity 4, look to alternative suppliers and focus purchasing on a few top suppliers. This will help reduce OpEx and required Investment.
- Investigate whether Nokia is "over-managing" the Commodity 5 supply chain. Identify and implement OpEx reduction initiatives. Then, observe the impact of these reductions on supply performance.
- Keep the current Commodity 6 supply chain. Potential changes introduce risk and create distractions without providing significant financial benefit.

To implement these recommendations, Nokia can apply a range of supply chain models, including:

- Assigned Vendor Assigned Price, which offers a medium-high level of supply chain control. It is also Nokia's current model for most commodities.
- Buy & Sell, which provides a high level of supply chain control, in addition to component price confidentiality.
- Turnkey, which increases the supplier's scope of control over design, production, and supply chain management.

In general, applying the Buy & Sell model will increase Nokia's OpEx while applying the Turnkey model will reduce OpEx. Continuing with Nokia's current AVAP model will not significantly change OpEx. To reduce investment, Nokia can negotiate flexible purchasing agreements with specific suppliers. These agreements may be used in conjunction with either of the three supply chain models. However, the Turnkey model provides the easiest path to reducing both OpEx and Investment.

In Section 7.1, we presented several scenarios and goals which provide opportunities for Nokia to make improvements in its supply chain. We also presented a hypothesis of the commodity areas which are most applicable to the specific scenario or goal. Based on our performance evaluation of Nokia's supply chain, we can now determine the commodity areas which are applicable to these specific scenarios or goals:

Scenario / Goal	Hypothesis	Conclusion
Track inventory in-transit and at supplier sites. (Especially applicable in cases of supply risk.)	Especially applicable for high-value commodities or in cases of supply risk. Successful implementation will require active coordination with a capable supplier.	Commodity 1 consists of high-value components with high cost of supply shortage. Nokia can work with capable Commodity 1 suppliers to implement improved inventory tracking.
Streamline own sourcing organization to reduce supply chain management Operational Expenses in the long-term.	Commodities with high OpEx and good historical supply chain performance may be the best candidate for future OpEx reductions. By streamlining sourcing of select commodities, Nokia may be able to maintain high product quality.	Commodity 5 has both high OpEx and few historical supply shortages. Nokia should consider slowly reducing Commodity 5 OpEx while observing for negative supply chain impacts.
Give Original Design Manufacturer flexibility to source components used in their design.	Most applicable for commodities with good historical supply chain performance. Nokia may be able to reduce investment by allocating more purchasing responsibility to the ODM.	Commodity 2 has good historical supply chain performance and consistent quality. Nokia can consider allocating purchasing responsibility to an ODM and observing for negative quality and supply impacts.

Our previous hypothesis outlined the characteristics of certain commodities which are most applicable to achieving specific supply chain goals. Based on our performance evaluation, we have identified those commodities which meet the criteria stated in our hypothesis. Each of these commodities provides a good starting point for improving the supply chain to achieve one of the three scenarios or goals. We believe Nokia can evaluate a pilot project in each of these commodity areas to further improve its supply chain.

If Nokia successfully transitions to a more efficient supply chain, it will reap the benefits of lower production costs. The bigger challenge in this transformation is keeping Nokia's supply chain responsive to new product and technology innovations. At this time, Nokia and Microsoft will have already identified the key technologies which will differentiate Nokia's future products. For these crucial technologies, Nokia should ignore the recommendations in this thesis and instead place heavy bets to bring these technologies into production.

8 References

[1] Amaral, Jason, Corey A. Billington, and Andy A. Tsay. "Outsourcing Production Without Losing Control." *Supply Chain Management Review*, 8, no.8 (November - December 2004)

[2] Beckman, S., and Rosenfield D., *Operations Strategy: Competing in the 21st Century*, New York, NY, McGraw-Hill, 2007

[3] Ferry, J., *Flextronics: Staying Real in a Virtual World,* Strategy & Business Magazine Issue 37, Winter 2004

[4] Mentzer, M., *Inter-company Collaboration Within a Large Lean Supply Chain Initiative,* SM Thesis, Massachusetts Institute of Technology, June 2009

[5] Wu, J., *Wireless Handset EMS/ODM Struggle Despite Market Comeback*, iSuppli Global Manufacturing and Design Analysis, Jan. 2010