Toyota Recalls:

Revealing the Value of Secure Supply Chain

by

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To my wife Hye-kyung Jung and son Andrew Gu

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LIST OF SYMBOLS OR ABBREVIATIONS

APAS	Authoritative Product Attribute Service.
EAN.UCC	European Article Numbering-Uniform Code Council.
EPC	Electronic Product Code.
EPCIS	Electronic Product Code Information Services.
GDSN	Global Data Synchronization Network.
GLN	Global Location Number.
GPC	Global Product Classification.
GS1	Global Standards One.
GTIN	Global Trade Item Number.
ONS	Object Naming Service.
PAS	Product Attribute Service.
RFID	Radio Frequency Identification.
RoR	Ruby on Rails.
SCM	Supply Chain Management.
UPC	Universal Product Code.

GLOSSARY

Authoritative Product Attribute Service A product attribute service developed for GS1 by Stephan Karpischek, Goodman Xiaoyuan Gu and Christian Floerkemeier at Auto-ID Labs, MIT and Auto-ID Labs, ETH Zurich. APAS features trustful key product attributes that are jointly constructed with supply chain members, and is accessible via mobile and PC., p. 83.

Electronic Product Code Information Services A standard for business event and product information sharing amongst members/trading partners in a supply chain or between enterprise processes. It defines the interfaces for representation and exchange of product related data, i.e. capture interface and a query interface to obtain and share business event information, p. 98.

EPCglobal Network A network of interconnected EPC Information Services that provide access to dynamic and real-time instance-level serialized information about the movement of individual products as they pass through the supply chain., p. 46.

Global Data Synchronization Network An IP-based interconnected network of interoperable B2B data pools and a global registry known as the GS1 Global Registry, which enables companies to exchange standardized and synchronized supply chain data with their trading partners using a standardized Global Product Classification., p. 46.

Global Standards One An international not-for-profit association and standards body created by consolidating former EAN International and Uniform Code Council. GS1 dedicate itself to the development and implementation of global standards and solutions to improve the efficiency and visibility of supply and demand chains globally and across multiple industry sectors. The GS1 System of standards is the most widely-used supply-chain standards system in the world, p. iii.

Object Naming Service A registry that maps the location (represented with a URL) of the resource of instance level dynamic information for a specific product, to the specific identification of the product (represented with an Electronic Product Code). It is part of the EPCglobal Network, p. 99.

SUMMARY

The warning bells are ringing. Once a global auto giant with a gold-plated reputation for safety and reliability, Toyota has stumbled. Its engineering excellence and traditional craftsmanship are being watered down by years of nips and tucks. With a torrent of high-profile recalls at the beginning of the new decade and a series of highly publicized legal charges, Toyota is all over the headlines.

Following a business strategy that sacrifices its customer-first focus but in favor of driving shareholder value, Toyota gradually has shifted away from the tenet of lean manufacturing. Seeking cost leadership and market leadership has gone too far, and differentiation through quality, reliability and fuel efficiency becomes blurred. The execution of such business strategy in the past few years has lured Toyota to rush into relationships with suppliers it has not adequately vetted and to apply questionable security measures as it sourced parts from all around the world. In so doing, Toyota has been constantly adding stress to the security of its supply chain. In the end, its risk mitigation capability does not improve and quality standards have lapsed.

Globalization and commoditization have forced today's businesses to focus on cost-cutting and growth to achieve profits of struggle to survive. Consequently, offshoring and outsourcing have become common practice. In such a competitive environment, supply

chain is the lifeblood of a business and supply chain security is well-recognized as a competitive advantage and even a marketing tool. Security Secure supply chain is critical in product quality assurance and combating counterfeit, for which authoritative product attribute service represents an urgent need.

For a long time, product attribute service is considered a Business-to-Business application. Trading partners of a supply chain build and share product information amongst themselves. Consumers are basically excluded from accessing such information. On the other hand, typically, product information provided to the end consumers are maintained by individual retailers. Such an approach is heterogeneous, error-prone, inaccurate, incomplete, and it undermines consumer confidence. There is a gap for authoritative product attribute service (APAS) that can provide uniform, validated, timely and complete product info to the end consumers.

With APAS, consumers will play an active role in monitoring and contributing to the security of the supply chain. With a mobile barcode scanner or mobile RFID reader in hand, consumers will become a vibrant force in combating counterfeits, detecting 'bogus' status and reducing illegal trade. Consumers will benefit from such new capability by protecting their rights to buy genuine products with correct status and through legitimate channels. In addition, a spectrum of important mobile commerce applications will be made possible, such as trustful product attributes retrieval, attribute-based product search and comparison, product rating and commenting.

With APAS, brand owners and other supply chain partners will see unprecedented possibilities such as direct customer-facing product marketing e.g. product recommendation, individualized coupon promotion, as well as direct user feedback on feature request and

defect report. All of this will allow them to build competitive advantages with shorter user interaction cycles, more fragile to user demand variation, targeted and efficient product design, responsive product recall, and more effective in attacking counterfeits.

In this thesis, I strive to provide a timely in-depth analysis on the mechanisms behind Toyota's crisis, especially the linkage between business strategy and supply chain security. I will relate secure supply chain to competitive advantage, and authoritative product attribute service to secure supply chain. Based on this, I perform strategic analysis and propose an architectural design for product attribute service. As a proof of concept, I design and implement a prototype of APAS with decent size of APAS repository and support for both mobile and PC clients.

To this end, I first formulate the problems and explain the motivations behind secure supply chain and product attribute service. I then give an overview of the journey of Toyota from the synonym of quality to the reminder for product recalls. To provide further more background knowledge, I will examine business strategy and competitive advantage, together with secure supply chain, in the following two chapters. In particular, I will be deliberating on the causality between business strategy and supply chain strategy, and how supply chain vision and strategy can lead to operational executions that are sources of QA crises. In the next section, I provide details on architectural design for Authoritative Product Attribute Service. Afterwards, I describe the prototyping and implementation of APAS that covers the backend product attribute repository, the web backend that powers the APAS, as well as the Android-based mobile frontend. Finally, I summarize with concluding remarks and outline directions for future research.

CHAPTER I

INTRODUCTION

1.1 Problem Formulation

The recent Toyota recalls of 11 major models and over 9 million vehicles shocked the world [1]. In 2nd Quarter 2010 alone, Toyota reckons that the recalls could cost the company at least $2b in repair costs and lost sales [2], let alone tarnished a once-mighty brand and robust market cap of the firm. Toyota has already lost 5 percent of its market share in the US, with further drops anticipated [3].

James Lentz, Toyota's U.S. Sales Chief, was questioned by the United States Congress committees on Oversight and Investigations on February 23, 2010, as a result of recent recalls. In the meanwhile, Toyota went to court for the first time on March 24, 2010 [4] because a group of law firms across 20 states, dubbed the Toyota Action Consortium, sued the auto giant to recoup losses in the resale value of Toyota vehicles due to deaths and injuries caused by accelerator pedal malfunctions. The case would cost Toyota at least $40 billion [4], not taking into account human toll of motorists who have been injured.

On April 5, the National Highway Traffic Safety Administration of Department of Transportation (DOT) was seeking a fine of $16.4 million (the maximum penalty possible under current laws for a single violation) against Toyota for knowingly hiding and delaying at least four months in notifying the agency on the "sticky pedal" defect in its cars [5].

Toyota recalls uncovered the unprecedented vulnerability of its supply chain [6]. The root cause behind this brand-threatening crisis for Toyota is its changing business strategy. In recent years, Toyota has been pushing cost-cutting towards the extreme in order to drive both its bottom line and top line. Deviating from a customer-first business strategy, Toyota

has been focusing primarily on driving shareholder value. Cost-cutting combined with ambitiously seeking economies of scale has resulted in Toyota's rapid expansion in the past few years, and has led it to rush into relationships with suppliers it has not adequately vetted [7]. Sourcing new parts around the world and even relying on exclusive suppliers played a role.

Toyota's recalls underscore the role of the supply chain as the lifeblood of a corporation. If quality assurance fraud such as that experienced by Toyota is a major challenge to the security of supply chain, yet another supply chain security hole is counterfeit elements within the chain. According to Katz's study in 2009 [8], 7% of goods sold globally are estimated to be counterfeit, which represent some $600 billion faked value. This has caused approximately 750,000 job losses in the USA alone. World Trade Organization (WTO) also estimated that total damage of counterfeiting cost Japan some 2.3 trillion Japanese Yens per year in 2001 [9]. Fig. 1 shows a map of worldwide seizures of counterfeit goods as reported by the Counterfeit Intelligence Bureau, as an indication of the severity and magnitude of the problem.

Counterfeit goods entering the supply chain, either intentionally or unintentionally, can be devastating. A firm can outsource manufacturing, but it cannot outsource responsibility – it is ultimately responsible for products bearing its brand names.

It quickly becomes apparent that trouble-free is not the same as fraud-free – seemingly smooth supply chain operations will not manifest looming risks automatically. With businesses facing global integration and globalization of supply chain operations, supply chain security and secure supply chain has moved up to the lists of priorities of top executives.

Figure 1: Seizures of Counterfeits in 2008 (Source: Counterfeit Intelligence Bureau)

1.2 The Need for Secure Supply Chain and Product Attribute Service

Toyota is not alone in product recalls. According to US Consumer Product Safety Commission (CPSC) and WeMakeItSafe.com, the number of product recall incidents (approximated) has been following an upswing pattern in the past 10 years for goods sold in the US market, implying the degree of severity of both quality assurance flaws and supply chain flaws.

At the 2005 IBM Supply Chain Management Executive Conference, top executives from 15 leading companies reached such a common understanding that a secure supply chain that is able to identify and mitigate risks, tightly integrated with a firm's business strategy, and able to adding to competitive advantage and driving the top-line growth is are the core of future supply chain management evolution [10].

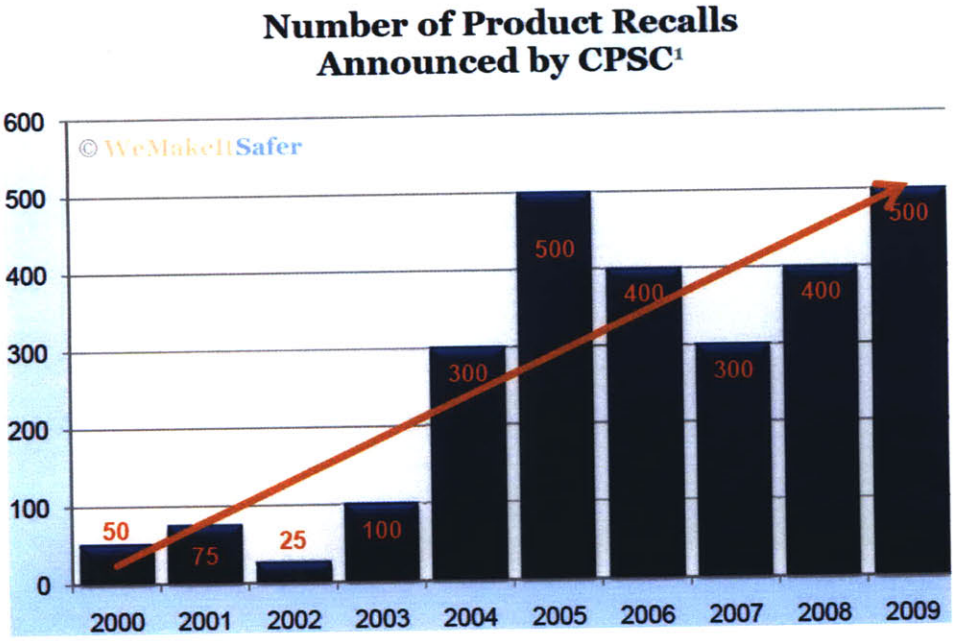


Figure 2: Overall Trend of Product Recalls (Source: WeMakeItSafe.com)

Globalization and commoditization has been forcing today's businesses to focus on cost-cutting and growth – strategies to leverage supply chain operational efficiency and economies of scale. But a level up is to integrate supply chain strategy with business strategy and use supply chain execution as a catalyst for business transformation and innovation. As this level, supply chain strategy is more result-oriented and targeted - supply chain management focuses on customer perception and shareholder value.

In the case of Toyota, we have seen how failures in supply chain operations (in particular sourcing security) severely affected market share, the top-line, brand value and market cap. On the flip side, a more secure supply chain could have helped create even greater customer satisfaction and shareholder value for Toyota.

Secure supply chain is critical in product quality assurance and combating counterfeit, for which authoritative and unified product attribute service represents an urgent need. For a long time, product attribute service is considered a Business-to-Business (B2B) application. Trading partners of a supply chain build and share product information amongst themselves. Consumers are basically excluded from accessing such information. On the

other hand, typically, product information provided to the end consumers are maintained by individual retailers. Such an approach is heterogeneous, error-prone, inaccurate, incomplete, and it undermines consumer confidence. There is a gap for authoritative product attribute service that can provide uniform, validated, timely and complete product info to the end consumers.

With such new service, consumers will play an active role in monitoring and contributing to the security of the supply chain. With a mobile barcode scanner or mobile RFID reader in hand, consumers will become a vibrant force in combating counterfeit, detecting wrong status and holding back illegal trade. They will benefit from such new capability by protecting their rights to buy genuine products with correct status and through legitimate channels. In addition, a spectrum of important mobile commerce applications will be made possible, such as trustful product attributes retrieval, attribute-based product search and comparison, product rating and commenting.

Brand owners and other relevant members of the supply chain will benefit from the new service too. They will see unprecedented possibilities such as direct customer-facing product marketing e.g. product recommendation, individualized coupon promotion, as well as direct user feedback on feature request and defect report. All of this will allow them to build competitive advantages with shorter user interaction cycles, more fragile to user demand variation, targeted and efficient product design, responsive product recall, and more effective in attacking counterfeits.

1.3 Research Questions, Contributions and Structure

In this work, I intend to answer the following research questions:

- How business strategy and competitive advantage are linked to supply chain?
- Why changes of business strategy can result in executions in the supply chain that adversely impact the value propositions of a firm?

- How the dynamics in a firm's value chain and the greater value system, in particular, variations of the linkages within a value chain and between the value chains of a value system, will affect the value activities?
- What role does security play in supply chain and competitive strategy?
- How can authoritative product attribute service help achieve a more secure supply chain?
- What are some of the architectural considerations on APAS?

The contribution of this thesis are: first of all, it provides a timely in-depth analysis on the truth behind the Toyota recall crisis; second, it studies the relation between secure supply chain and competitive advantage, between product attribute service and secure supply chain, as well as the linkage between Toyota's failure of implementing secure supply chain and the outbreak of product quality problems; third, it proposes a viable and promising architecture design for secure supply chain, with emphasis on provision of authoritative product attribute service; fourth, this work serves as an important high-level guideline in counteracting quality assurance fraud and counterfeit in secure supply chain with product information sharing and synchronization.

The remainder of the thesis is structured as follows: I first give an overview of the journey of Toyota from the synonym of quality to the equivalent of product recall. I then deliberate on the causality between business strategy and supply chain strategy, and how supply chain vision and strategy can lead to operational executions that are sources of QA crises. In the next section, I provide details of architectural design for secure supply chain, centering on PAS, and explain how such service can help achieve a more secure supply chain. Afterwards, I describe the prototyping and implementation of PAS that covers the backend product attribute repository, user and service management, as well as the mobile frontend. Finally, I summarize with concluding remarks and outline directions for future research.

CHAPTER II

THE RISE AND FALL OF TOYOTA

2.1 Toyota: A Brief History

Toyota Motor Corporation is a multinational corporation headquartered in Toyota City, Aichi, Japan. Toyota owns and operates Toyota, Lexus and Scion brands and has a majority stake in Daihatsu and Hino Motors, and minority shareholdings in Fuji Heavy Industries, Isuzu Motors, Yamaha Motors, and Mitsubishi Aircraft Corporation. In addition to car manufacturing, Toyota is in financial services with its Toyota Financial Services division, and it also builds robots. The Toyota Group, including Toyota Motor Corporation, Toyota Financial Services and Toyota Industries, is one of the largest conglomerates in the world boasting some 522 subsidiaries. Toyota is the world's largest auto maker by sales, and is ranked among Forbes' leading companies.

Toyota was founded by Kiichiro Toyoda in 1937 as a spinoff from Toyota Industries to create automobiles. It launched its first product, the Type A engine, in 1934, followed by its first passenger car, the Toyota AA. Cars were built on a modest scale, with only 1,757 produced in 1943. During World War II, due to severe material shortages, Toyota built only a handful of military vehicles for the Japanese Army. At the end of the war, Toyota resumed civilian vehicle production. Models produced during that time were the 27-horsepower Toyopets, designed for handling tough Japanese road surfaces after the war, and for fuel efficiency. By 1955, the production capacity of Toyota was about 8,400 cars per year.

Toyota entered the North American market in 1958. With recorded 919 Toyopets sold, the result was dismal. Toyota managers learned a big lesson - full-sized Chevrolets and

Fords were more appealing to American buyers, and Toyota's American dream hinged on its ability to develop cars meeting the needs of local customers.

In 1964, Toyota struck back with the Corona, i.e. "Crown" with a 90-horsepower engine, it was able to handle 90 mph on American roads with ease. Priced at $2,000, Corona sold modestly at 6,400 in 1965, but skyrocketed to 71,000 in 1968. The result of 1971 model year was even more impressive – 300,000 sold. Following this initial success, Toyota entered the game of muscle car in full swing and with unbridled horsepower, head in head with auto giant Volkswagen. Blessed by the 1973 oil embargo and 1978 fuel shortages, Toyota prospered in the changing automotive landscape. It capitalized on the American car owner's hunger for a well-built, fuel-efficient car. New Corona, the Corolla and the Celica sold like hot cakes. By the 1980s, Toyota has firmly established itself as a serious player in the North American auto market. In response to the US import tariffs and Chicken tax (e.g. 25% tax on imported commercials vans), Toyota, together with other Japanese car manufacturers, began building plants in the U.S. by the early eighties.

With its Lexus line, Toyota headed for luxury car market in 1989. Recognizing the trend of fuel-economy concerns and downsizing, Toyota attacked the weakness of classical luxury brands such as Lincoln and Cadillac, further eroding Detroit's automotive market share. In the 1990s, Toyota began to add many larger and more luxurious vehicles to its lineup such as the a full-sized pickups T100 and Tundra, several lines of SUVs, a sporty Camry Solara, as well as the Scion brand. Toyota overtook Chrysler and Ford in worldwide sales and surpassed General Motors in 2008. It also held the title of the most profitable automobile maker (US $11 billion in 2006). Toyota has consistently ranked near the top in quality and reliability surveys by J. D. Power and Consumer Reports.

Toyota's ambition never stops, and the new theme is green. Growing its worldwide production base on the one hand, Toyota has committed itself to leading the charge towards developing even more fuel-efficient and environment-friendly vehicles. The company's

hybrid-powered (gasoline-electric) sedan – the Prius, although not the Industry's first hybrid car (it was Honda Insight by the way), is by far the most successful one. Toyota has sold more than 1 million hybrids since Prius' debut in 1997. The third-generation Prius, launched in 2009, became an instant hit. Toyota's is planning to make Prius its own brand and expanding its production to 1 million per year, not counting hybrid versions of Highlander SUV, Camry, and Lexus GS, RX, and LS models. In the meantime, Plans for bringing to market plug-in hybrids and flex fuel vehicles (run on bioethanol) are live.

However, the global automotive industry downturn as result of credit crisis, widespread recession, and foreign currency fluctuations, has also hit Toyota hard. Sales fell by about 22% in fiscal 2009 and the company reported its first net loss since 1950. A conflict with General Motors in mid-2009 has led Toyota to shut down the New United Motor Manufacturing Inc. (NUMMI), a joint venture with GM, planned in April 2010. Some 4,700 employees become jobless as a result. In late 2009, the company also announced the sale of Toyota Financial Services Securities Corp. (the brokerage unit of its financial arm) to Tokai Tokyo Financial Holdings.

2.2 Toyota Production System and Lean Manufacturing

Toyota pioneered *Lean Manufacturing* and is the creator of the much acclaimed *Toyota Production System* (TPS) [11]. An integrated socio-technical system, TPS comprises Toyota's management philosophy, practices and systems thinking. It organizes all aspects of manufacturing, logistics, operations, as well as interactions with suppliers and consumers. Developed by Taiichi Ohno, Shigeo Shingo and Eiji Toyoda between 1948 and 1975, TPS is a major precursor of the more generic Lean Manufacturing.

In its essence, TPS and lean manufacturing is focused on five pillars [12] that are combined in a mutual supportive way:

- Lean product design

- Supply chain coordination
- Lean production and just-in-time inventory management
- Customer/supplier relation management
- Management of the integrated enterprise

Toyota's recent managerial values and business methods are known collectively as the *Toyota Way* [13], an initiative launched in April 2001 under the headings of Respect People and Continuous Improvement. Toyota summarizes its values and conduct guidelines as five principles:

- Challenge
- Kaizen (improvement)
- Genchi Genbutsu (go and see)
- Respect
- Teamwork

In the same vein, the Toyota Way is characterized as:

- Long-term orientation as the basis for management decision making, even at the expense of short-term goals
- Respect business partners and suppliers by challenging them and in the meantime helping them improve
- Make decisions slowly by consensus – considering all options, but implement them rapidly
- Rigorous process for problem-solving and root cause analysis, with visual aid

- Driving organizational learning though continuous problem solving, relentless reflection and continuous improvement
- Adding value to the organization by developing its people, in particular, growing a hierarchy of leaders and great teacher/coaches and creating a cascading pathway for teaching of systemic problem solving
- Build a culture of stopping fixing defects, but rather getting quality right the first time (i.g. extremely high initial quality)

2.3 The Rise of Toyota: Uncover the Secret

Even Toyota has been extraordinarily open about its practices, few manufacturers (including rivals such as GM, Ford, and Chrysler) have managed to imitate Toyota successfully. It appears that tools and practices such as Kanban card or Andon cord, that many outsiders try to copy are not essential to TPS.

Decoding the real secret behind Toyota's success at microscopic level, Spear and Bowen disclosed, after a whopping four-year long study [14], that Toyota's stellar performance can be attributed to its rigidly scripted and enormously flexible operations - an approach with a continuous series of controlled experiments. Whenever Toyota defines a specification, it establishes a hypothesis and then tests it through action.

Each activity, connection, and production path are designed according to rigidly-scripted rules, and must have built-in tests that can surface problems immediately. Continual response to problems has made this seemingly rigid system extraordinarily flexible and adaptive to accommodate changing customer demands. More importantly, such a scientific method/controlled experiment is not imposed on Toyota workers but ingrained in them. By engaging staff in such activities, Toyota has cultivated a learning organization that is able to constantly innovate and improve, and few managed to replicate.

While I completely agree with Spear [15] and Senge [16] on crediting Toyota's success

to rigid experiment and organizational learning, I do think at macro level, the real drivers behind the rise of Toyota is its business strategies. Recall that in Chapter 3, I discussed five value propositions businesses pursue as competitive advantages, namely product leadership, speed to market, customer experience, price competitiveness, and choice extensiveness.

It is clear that Toyota has centered its business strategy on customer satisfaction/orientation, rather than a mere driving shareholder value. With this value proposition, Toyota's competitive strategies are apparent: differentiation and cost leadership. With differentiation, Toyota sets its focus on product quality/safety and reliability. With cost leadership, Toyota sets its focus on affordability and fuel efficiency. These two focuses address exactly what customers value.

To better understand the causality behind the rise of Toyota, I conducted a System Dynamics [17] causal-loop analysis with the Vensim [18] modeling tool. As illustrated in Fig. 3, Toyota's business strategy, in particular competitive strategy, has been focused on product leadership (using metrics such as quality/safety and reliability), price competitiveness (using and fuel efficiency and affordability) and customer experience. Due to this business strategy and putting customers first mentality, Toyota has devoted itself to process improvement – conducting controlled experiments and honing organizational learning skills. Continuous process improvements have allowed Toyota to design and manufacture vehicles that satisfy customers' increasing needs on safety, reliability, fuel efficiency, and affordability (cost-effectiveness). All of this has contributed to collective customer satisfaction, hence helped establish Toyota's stellar reputation and win market share.

Word-of-mouth promotion is just such a powerful tool in advertising and marketing arsenal. As it is used in favor of Toyota in a positive manner, this reinforcement loop has been proven to be very powerful in Toyota's , when it dominated over the balancing loop which I will addressing in the next section.

Parallel to this macro level view, Womack and Jones, in their seminal work, "Lean

Thinking" [19] lay out five principles/steps on lean thinking, with step one being "to develop a thorough understanding of 'why' the customer is buying your product". Or, in other words, 'how' does the customer value the product or service a company produce. As a matter of fact, Toyota cars are considered unstylish or a little off the mark, but Toyota still thrived because consumers put such a high premium on quality and reliability.

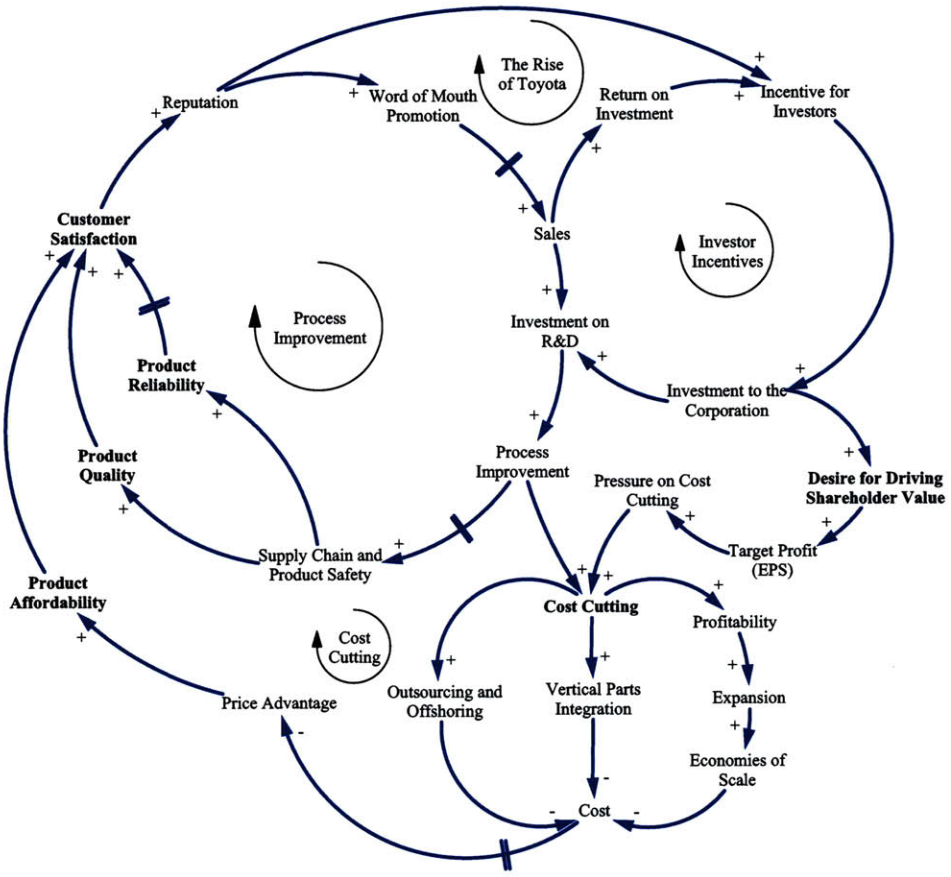


Figure 3: Causal Loop Analysis: The Rise of Toyota

2.4 Toyota Recall Incidents

However, at the turn of the decade, two years after it swept past the ailing General Motors to become the world's No. 1 automaker, the legendary Toyota is in danger of being locked in a spiral of decline.

September 2009 marked the very first major recall of Toyota [20]. The major issue was gas pedals sticking on floor mats that caused deadly 'sudden acceleration'. In one case in San Diego, the floor mat of a Lexus snagged the gas pedal and sent it up to 120 miles per hour before the vehicle crashed into a SUV and totaled both. Following this incident, Toyota launched a recall of 8 models and 3.8 million affected vehicles – the biggest in automotive history. In the same year, two separate recalls followed: one was for the "sticky pedal" problem as a result of aging pedals sticking in a partially depressed position, and another for braking problems on Prius hybrid. At the end of year, Toyota has recalled 4.2 million vehicles worldwide.

Year 2010 is hardly a more smooth year for Toyota. In another blow to the company's long-standing reputation for quality, Mid January, Toyota Motor Sales USA announced [21] recalling 2.3 million vehicles in the USA to correct a problem that could cause the vehicles' gas pedals to stick. Model affected including 2009-2010 Toyota RAV4, Corolla, Matrix, 2005-2010 Avalon, 2007-2010 Camry, 2010 Highlander, 2007-2010 Tundra and 2008-2010 Sequoia. A week later, Toyota issue another recall of 1.09 million more vehicles in the U.S. [22], including 2008-2010 Highlander, 2009-2010 Corolla, 2009-2010 Venza, 2009-2010 Matrix, and 2009-2010 Pontiac Vibe.

Toyota then decided to expand the recall of over 1.8 million cars across Europe and in China for the unintended acceleration problem [23]. At the later stage, another call put 2007-2010 Prius onto the list as well after identifying problems in the ABS system. In a later recall incident on April 6, 2010, Toyota planned to recall 12,984 vehicles in South Korea because of faulty floor mats and sudden acceleration, affecting Camrys and Camry hybrids, as well as Lexus ES350 sedans. On April 16, 2010, MSNBC reported [24] yet another major recall by Toyota, some 600,000 1998-2010 model year Sienna minivans were affected due to potential road hazard that might be created by spare tire cables subjected to rust and break, i.e. corrosion from road salt could cause a spare tire to fall off the car. It appears that not only those who drive in front of a Toyota should worry, but also those who

drive behind.

On the other hand, in January 2010 Toyota suspended temporarily US sales and production of all eight models related to safety recall. Later in march, Toyota announced to halt production in France and Britain for 12 days due to poor sales following vehicles recalls. At the time of writing, Toyota has recalled well over 9 million vehicles worldwide for flawed parts including accelerator pedals and sticky floor mats that could cause unintended accelerations of cars and trucks, as well as faulty ABS and spare tires [25]. It is estimated that the recall could cost the company at least $2b in repair costs and lost sales [2]. Toyota has already lost 5 percent market share in the US, with further drops to come [3]. The once mighty brand has been tarnished and bullish marker value has plunged.

Toyota's problems are not only on the financial side. James Lentz, Toyota's U.S. Sales Chief, was questioned by the United States Congress committees on Oversight and Investigations on February 23, 2010, as a result of recent recalls. In the meanwhile, Toyota went to court for the first time on March 24, 2010 [4] as the result of a group of law firms across 20 states, dubbed the Toyota Action Consortium, suing the auto giant to recoup losses in the resale value of Toyota vehicles due to deaths and injuries caused by accelerator pedal malfunctions. The case could cost Toyota at least $40 billion, not taking into account motorists who have been injured.

On April 5, 2010 the National Highway Traffic Safety Administration of Department of Transportation (DOT) sought a fine of $16.4 million (the maximum penalty possible under current laws for a single violation) against Toyota for knowingly hiding and delaying at least four months in notifying the agency on "sticky pedal" defect in its cars [5]. A few days later on April 10, according to a panel of judges, lawsuits against Toyota for sudden acceleration issues were consolidated in a federal court in Santa Ana, California [26].

2.5 Demystify the Crisis

The downturn of Toyota and recent recall incidents can be attributed to its changing business strategy. Toyota seems have lost its root of putting customers first [27]. Instead, it has been aggressively seeking volume and profit at all costs. While not necessarily mutual-exclusive, it is apparent that the priority for customer satisfaction has been replaced by priority for driving shareholder value. With the new priority, Toyota has adopted mainly two business competitive strategies: namely market leadership and cost leadership. Under such strategies, Toyota has undergone aggressive global expansion and cost-cutting.

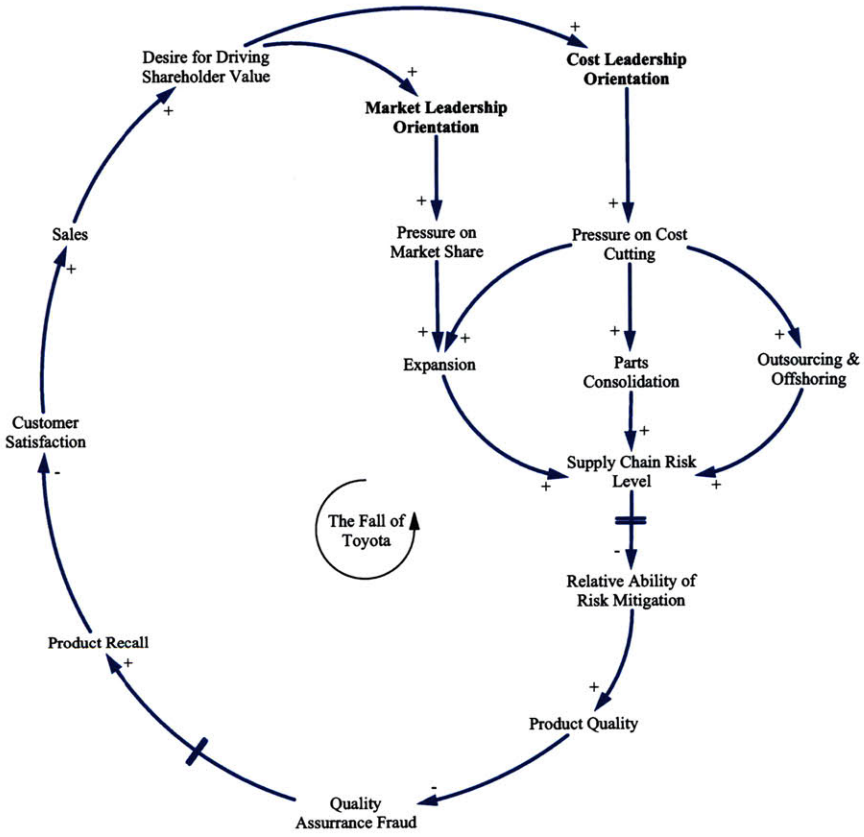


Figure 4: Causal Loop Analysis: The Fall of Toyota

Certainly, squeezed cost is translated into reduced cost of goods sold (CGS), hence a higher gross margin. Toyota's stock price will benefit from improved profitability, so do

executive bonuses [8]. With such an incentive mechanism in place, driving shareholder value and growing a greater bottom-line has elevated Toyota's target profit [28], and has put tremendous pressure on cost-cutting. As can be seen from Fig. 4, Toyota's cost-cutting is achieved mainly through three channels:

- Outsourcing and offshoring: seeking the most cost-effective parts and labor all around the world
- Parts consolidation: consolidate as many number of parts as possible into one
- Expansion as a result of profitability, and for even better economies of scale, localizations as well as closer production to sales.

Unfortunately, all of these three channels are straining the tension of the global supply chain of Toyota, and raising its risk level.

Worldwide outsourcing, coupled with the lack of authoritative information of the products produced by its new suppliers, have inherent hazards to the security of supply chain. Toyota is known as using exclusive suppliers for its parts (a problem known as 'single point of failure'), and delegating quality assurance of the parts to the suppliers. Hence, once quality problems occur, it is nearly impossible to source equivalent parts from an alternative source instantly. This is best illustrate by the recent Toyota recalls due to accelerator pedal issue. Toyota had to rely on the sole supplier for the gas pedals, CTS Corporation at Elkhart, Indiana, to redesign and manufacture the gas pedals, before the old parts can be replaced. Naturally, this has greatly hampered the agility of the supply chain and become one of the security holes.

With parts consolidation, although reduced variety has helped slashing costs involved in sourcing and assembly, this unfortunately also means a defect in a single component affect all downstream assemblies and products. It is a matter of fact that Toyota shares parts across multiple platforms and vehicles. Depending on the location of the defect and

the degree of integration, sometimes for an upstream defect, its amplification effect (reverse to the Bullwhip Effect [29]) can be devastating.

Rapid expansion, in addition to being subject to the same kind of risk associated with outsourcing, has put Toyota's resource and risk mitigation capacity under constraints. Toyota's R&D, process improvement and risk management efforts can no longer keep pace with daunting requirements stem from volume and varieties of new products and their corresponding operations.

With risk-management capacity being weakened on the one hand, and blinded by ambitious cost-cutting and expansion on the other, Toyota's relative ability of risk mitigation plummeted. It can no longer maintain the same level of quality control and engineering rigor. This led to deteriorating product quality, and appearance of major quality assurance frauds (such as malfunctioning accelerator pedals, sticky floor mats, leaky oil tubes as well as falling spare tires). Product recalls mushroomed (sadly a poisonous one), customer satisfaction suffered. *The volcano erupts as the crust stretches beyond its limits.*

Here, Word of Mouth kicked in again. Remembering that Word of Mouth can act as a 'double-edged sword', and a negative Word of Mouth spreads much faster than a positive one. Tarnished reputation of Toyota spreads like wildfire as Toyota is all over the headlines, for recalls, lawsuits and so on. It's often nearly impossible for a business to overcome negative word of mouth with conventional advertising or promotion techniques.

Hiding and delaying report of defects has made the matter even worse. Actually, while looking at statistics on the number of NHTSA consumer complaints of unintended acceleration per 100,000 vehicles sold in the US for 1999-2009 model years in Fig. 5, Toyota's position is not that dismal. However, due to Toyota's dominant market share and huge customer base, as well as its publicity, the negative force of the word-of-mouth is very destructive.

As a result, troubled sales during these recall periods has forced Toyota to desire less

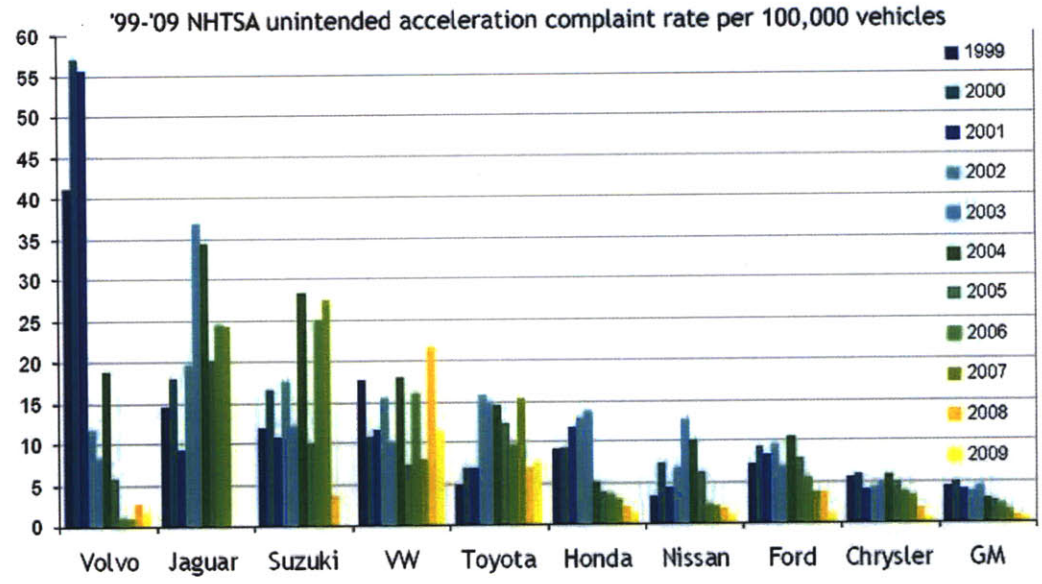


Figure 5: Complaints of unintended acceleration/100k vehicles (Source: Wikipedia)

for shareholder return. This is then translated into less pressure for target profit and cost-cutting. Hopefully this balancing loop will help Toyota realign its business strategy and bounce back.

In summary, it is obvious that Toyota has jeopardized its gold-plated reputation for quality and reliability by failing to put the needs of its customers first but rather pursuing volume at all costs and focusing solely on driving shareholder value and growing its bottom line.

2.6 Lessons Learned

With over 9 millions vehicles recalled and billions of dollars evaporated, Toyota recalls' success is still a no sure bet [30]. Debate on whether the unintended acceleration problem is due to mechanical problems or electronic problems or both has heated up [31]. Many consider that the incidents indicate a system failure rather than a series of missteps. In hindsight, as Mr. Press, once the highest-ranking American at Toyota with a seat on the

board of directors, recently precisely pointed out [1]: "The root cause of their problems is that the company was hijacked, some years ago, by anti-[Toyoda] family, *financially oriented* pirates," The financial pirates, he said, "didn't have the character necessary to maintain a customer-first focus."

What this means is a fundamental shift of business strategy by the top management. It appears that with this shift, some of the biggest mistakes [32] Toyota has made and hopefully lessons it has learned are:

- Embarking on a program of radical change that underlying strengths are forgotten or abandoned. By dramatically change its business strategy to financial performance and shareholder returns, Toyota has forgotten its customer-first root. For decades, millions of buyers around the globe have selected rather 'dull' Toyota cars and trucks, paying a premium for their safety and quality. Toyota obviously has departed from its tradition and strengths.

- Pinning hopes on unproven strategies. Toyota's aggressive cost cuts following a cost leadership strategy is pursued without integrating it with quality and safety. This is unproven and highly risky. Nevertheless Toyota has decided to walk with only one leg and then stumbled.

- Hiring a visionary leader from outside with little understanding of what made the company great in the first place. Often, the leader best able to halt a downward spiral will be an insider who knows how to build on proven strengths while simultaneously identifying and eradicating weaknesses [33].

- Inappropriate and insufficient mitigation of supply chain risks. External factor: intensified global-wise competition. Internal factor: Neglection of customer-orientation but seeking high growth, market share, financial performance and shareholder returns.

Business strategy put aside, using the Seven Imperatives Framework as described earlier (see Fig 10), Toyota is weak in fitting its TPS and traditional lean manufacturing model into an optimized global operation model. More specifically, Toyota was incapable of optimizing its global operation architecture for scale, access, flexibility and risk mitigation.

In the changing global competitive landscape, to stay in the game and beat its competitors, a firm needs to focus on strategy that seeks the right balance between cost-reduction and risk management, between customer orientation and shareholder return, as well as between growth/expansion and sustainability management.

CHAPTER III

BUSINESS STRATEGY AND COMPETITIVE ADVANTAGE

3.1 Business Strategy

While business strategy and strategic management are very interesting topics by themselves, I will be focusing on competitive strategy in this study.

3.1.1 Defining Business Strategy

According to Johnson and Scholes [34], business strategy is defined as:

> *The long-term direction and scope of an organization, with which it achieves advantage through the configuration of resources, meets needs of markets, and fulfills stakeholder expectations*

At a top level, business strategy is concerned about:

- Environment: what external factors that might affect the business' competitiveness should be considered?
- Stakeholders and needs: who holds a stake in the business and what are his/her needs?
- Direction: where is the business heading for in the long haul?
- Resources: what resources can a business draw on?
- Scope and market segment: what are the main focus (products/services) of a business and which markets segments should it compete in?

- Differentiation: how can a business differentiate itself from and beat the competitions?

- Cost leadership: how can a firm gain and sustain cost advantage? What are some of the levers to pull?

From another perspective, business strategy is hierarchical, meaning that it mainly resides at three levels:

- Corporate Strategy. Often an essential part of "Mission Statement" of a business, corporate strategy emphasizes on driving shareholder value by defining overall purpose and scope of the business. It is heavily influenced by investors' acts to guide strategic decision-making throughout the business.

- Business Unit Strategy. Strategic decisions at business unit focus on choice of products, meeting needs of customers, competitive advantage over competitors, exploiting or creating new opportunities etc. Therefore, the emphasis is put on how a business competes successfully in a certain market.

- Operational Strategy. Strategic decisions at operation level focus on issues of resources, processes, people etc. A typical example here is supply chain strategy, which forms a key part of overall business strategy along with strategies for areas such as information technology, product development, human resources, marketing and finance. The mission of operation strategy is to ensure each part of business is organized to follow corporate and business-unit level strategic direction, and specific operational strategies many link directly to and support corporate and business unit strategies.

3.1.2 Strategic Management

To address the above-mentioned concerns and formulate these three level strategies requires sophisticate strategic management. By definition [35], strategic management refers to:

The process of drafting, implementing and evaluating cross-functional decisions that help achieve the long-term goals of an organization. In this process, the organization specifies its mission, vision and objectives, develops policies and plans to achieve its objectives through a series of projects and programs, and allocates resources to implement these policies and plans, as well as evaluates its performance using e.g a balanced scorecard.

Typically, strategic management involves three phases, namely strategic analysis, strategic decision, and strategic execution, which are detailed as follows.

Strategic Analysis

The tasks of strategic analysis are to assess the business' position in the ecosystem and market, analyze it strengths and weaknesses compared to its competitors, as well as understand the important external factors that may influence that position. A number of frameworks can be used to carry out these tasks, such as:

- Porter's Five Competitive Forces Analysis [36] - a tool to for identify and evaluate the forces and intensity of competition in a given industry.
- Competitor Analysis - a collection of techniques evaluate a business' overall competitive position.
- Directional Policy Matrix - a technique with which a business can assess its competitive strengths.
- Critical Success Factor Analysis - a technique to identify the areas in which a business must outperform the competition in order to survive.
- PEST Analysis - a technique to understand the overall ecosystem in which a business operates.
- SWOT Analysis - a technique to surface key issues arising from the assessment of a business' internal and external factors.

- Scenario Planning - a technique that can simulate plausible scenarios that a business might encounter in the future.
- Market Segmentation - a technique to identify similarities and differences between groups of customers.

Strategic Decision

Following strategic analysis, this phase typically involves capturing stakeholder needs and goals (aka the "ground rules"), identifying strategic options, making strategic decisions and evaluating selected strategic options. Some of the important strategic decisions are vertical integration, expansion and new market entry.

Strategic Execution

This is often the hardest part, and the moment when many management consultants run away with their suitcases when being asked to do so. Strategic execution demands rigid planning and translation into concrete actions, after a strategy has been analyzed and formulated.

3.2 Competitive Advantage

Competitive advantage is about how well a business can put it strategies into practice. It is fundamentally about the ability to create and sustain value creation for customers, and to do it by exceeding the costs of doing so. Here, value to customers is what customers are willing to pay.

This, according to Michael Porter [36], is typical exemplified as

- Cost leadership (sustainable cost advantage)
- Differentiation (from the competitors)
- Focus (product and market segment as well as the scope of the firm's activities)

To analyze the sources of competitive advantage, one must adopt a systematic approach in examining all activities a business perform as well as the interactions among these activities. Porter's competitive force analysis and diamond model are classical methods of top-level competitive advantage analysis.

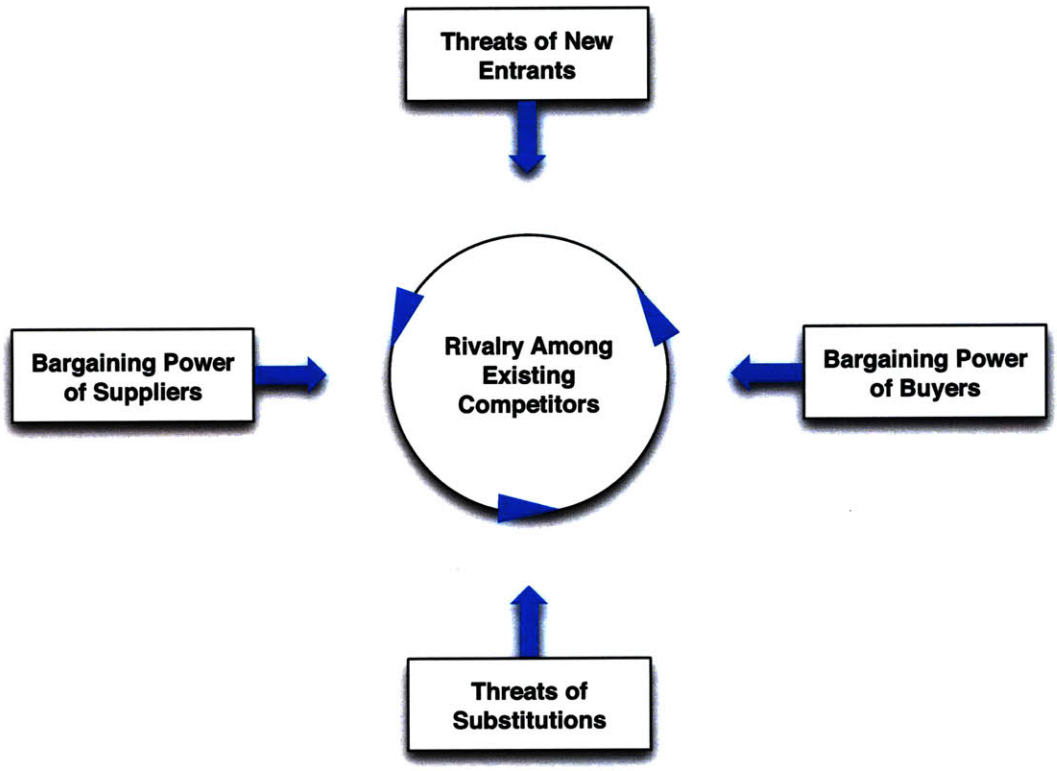


Figure 6: Five Forces That Shape Industry Competition

As depicted in Fig. 6, a systems thinking over the competitive landscape of an industry must consider 5 different competitive forces, namely:

- Bargaining power of suppliers, such as those who supply materials, parts, labor/services, funds, technologies, information, standards etc
- Bargaining power of the buyers, including customers and customers of customers
- Threat of new entrants - potential newcomers who are planning to get into this industry

- Threat of substitutions: products of services that are good enough to disrupt as alternatives
- Rivalry among existing competitors: how intensive are competitions amongst incumbent players

All these five forces have impacts on the cost structure of the firm and its products/services, the differentiation propositions, as well as the focuses of its activities. Form another angle, as shown in Fig. 7, understanding the relative competitive position and advantages of a firm in a certain industry can be done though the assessment of four areas [37]: demand conditions, factor conditions (strengths and weaknesses), strategy, structure and rivalry, related and supporting industries, plus arbitrage on either variations of demands or policies.

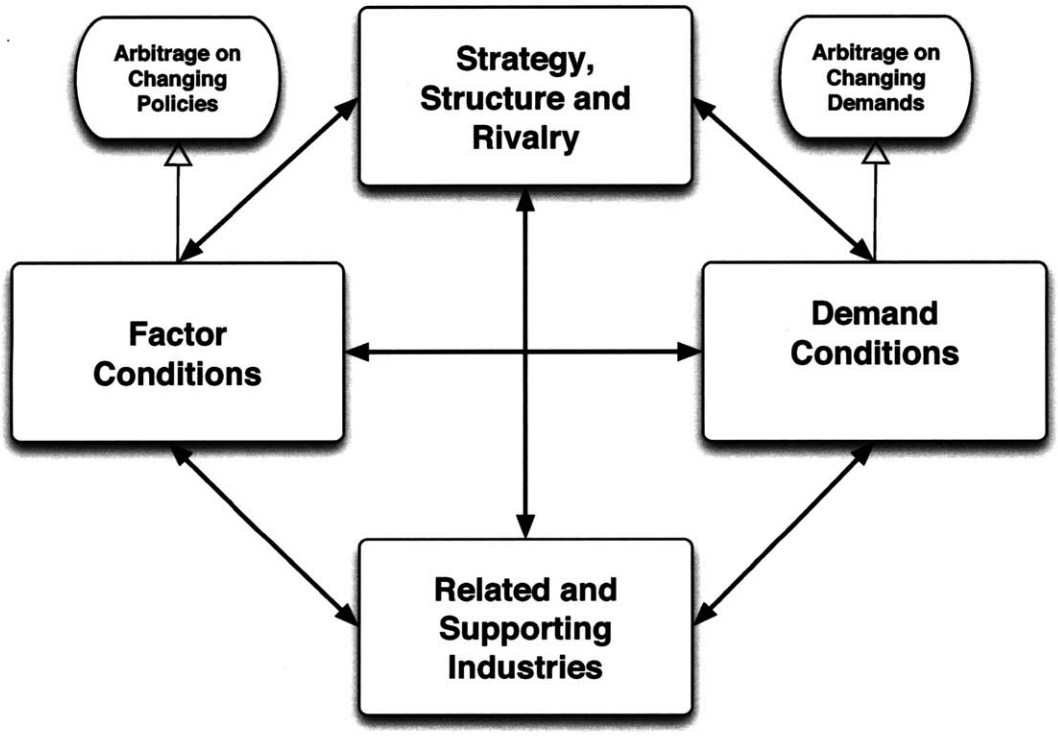


Figure 7: Diamond Model of Understanding Competitive Advantage

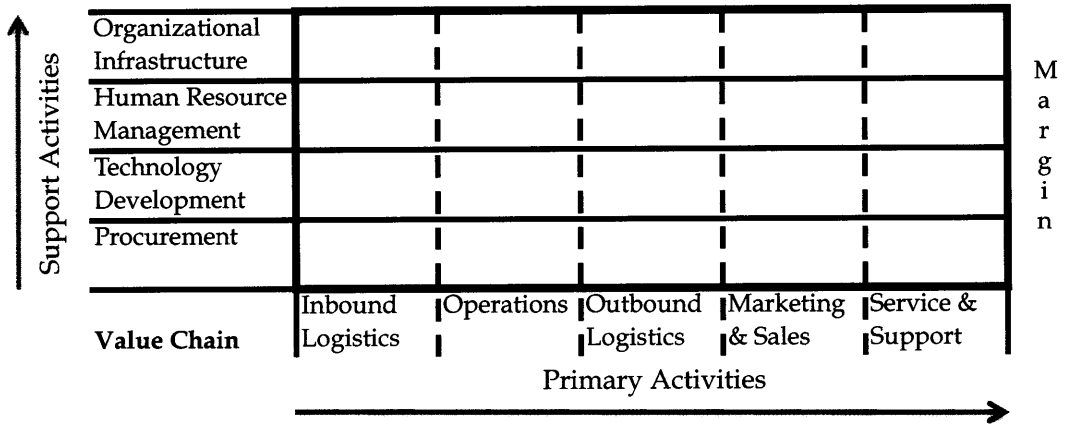
In practice, it is with the value chain and its outer value system, that a business disaggregates the suppliers, customers, and many other stakeholders into a discrete and interrelated

activities for value creation.

3.3 Value Chain

Value Chain [38] is a *framework that divides a firm's activities into economically and technologically distinct 'value activities' that part of the firms day-to-day business*. The amount the buyers are willing to pay for a product or service decides the value a business creates. If the value a business creates exceed the cost of value creation, then a business is profitable. Competitive advantage stems primarily from two channels: more value creation (e.g differentiations in product leadership, time to market, variety, customer services) or low cost (e.g. cost leadership and market leadership).

Table 1: Michael Porter's Value Chain



Value activities, as shown in Table 1, can be classified into 2 types and 9 generic categories.

- Primary activities: for activities that are part of the physical creation of a product or service, such as inbound and outbound logistics, operations, marketing and sales, services. As can be easily understood, inbound logistics, operations, and outbound

logistics are the three main points where supply chain is linked to the value chain, in particular the primary activities of the value chain.

- Support activities: for activities are generally considered as providing infrastructure, knowledge and inputs to make the primary activities happen. These include infrastructure (e.g. management, IT, legal work, finance and accounting), human resources, research and development, as well as procurement.

Since no firm is isolated from the real world, to zoom out, the value chain for a business is an element of a larger stream of activities dubbed as "value system". Such a system include the upstream value chains of the suppliers, the downstream value chains of the distributors/channels, as well as the value chains of the buyers/customers, as illustrated in Fig. 8.

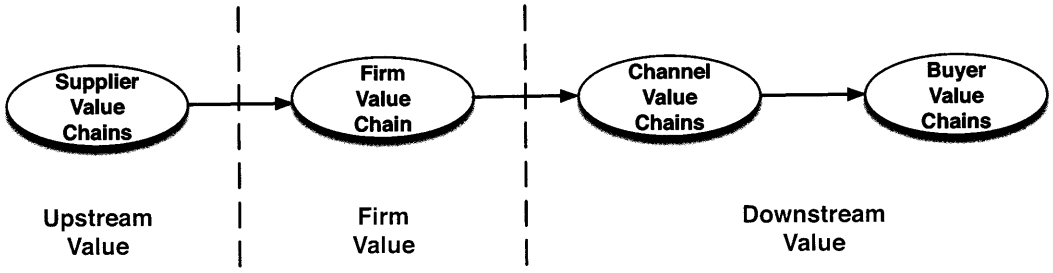


Figure 8: Value System and the Zooming of Value Chain

It is worth noting that values are added along the paths of the value system, and linkages not only connect the value activities within a firm, but also between a firms value chain and those of its suppliers, channels and buyers (directly or indirectly). Hence when a firm changes its business strategy, the linkages amongst its value activities might vary, so do the linkages within the greater value system and amongst various value chains. On the other hand, the firm can creating competitive advantages if it is able to optimize locally for its internal value chain, and optimize globally for the whole value system. E.g. a firm can coordinate and delegate quality assurance responsibility of the parts it uses for a certain

product to the suppliers to reduce lead time of the product within the firm's own process, just as Toyota has been doing for so many years.

CHAPTER IV

THE VALUE OF SECURE SUPPLY CHAIN

4.1 Supply Chain and Management

4.1.1 Defining Supply Chain

A supply chain [29] is a *network of interconnected businesses (known as supply chain members) involved in the moving and provisioning of product or services required by end customers*. As shown in Fig. 9, a typical supply chain spanning from the suppliers to the consumers, and it is a system involving organizations, people, technologies, information, resources, activities and the interactions amongst them.

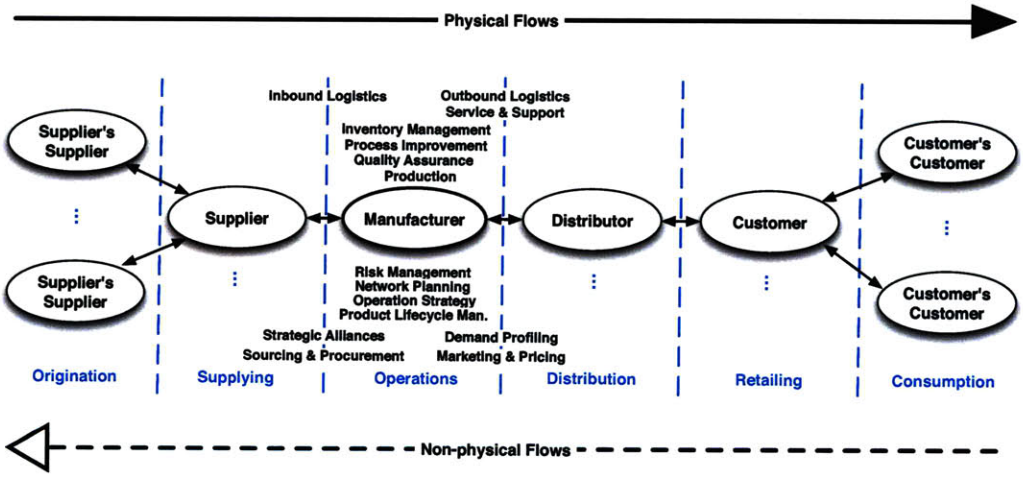


Figure 9: The Supply Chain Network

More specifically, to a manufacturer, major entities who participate in a supply chain include suppliers and suppliers' suppliers, customers and customers' customers, channel distributers or wholesalers, repackagers, retailer, all external to the firm. Within the firm, functions related to supply chain are typically either operations or support, although not

mutually-exclusive and the boundary can be relaxed. The internal functions form an X shape in the middle of Fig. 9.

Operations-related functions take a primary role, which maps them to the primary value activities as described in Chapter 3.3 on value chain. They can be exemplified by (but not limited to): manufacturing/production, inbound logistics, outbound logistics, process improvement, quality assurance, inventory management, network planning as well as service & support.

Business-related functions are in a support role, which maps them to the support value activities of the value chain. They can be exemplified by (but not limited to): operations strategy, customer demand forecast/profiling, marketing and pricing, risk management, sourcing and procurement, technology and product development, product lifecycle management, as well as strategic alliances and customer relation management.

The interfaces between the manufacturer and upstream suppliers are usually inbound logistics, sourcing and procurement, as well as strategic alliance. The interfaces between the manufacturer and downstream entities as usually outbound logistics, demand profiling, marketing and pricing, service and support.

Function-wise, a supply chain's activities transform resources and materials into products or services delivered to end customers. According the Supply Chain Operations Reference Model (SCOR) [39] developed by the Supply Chain Council, during this transformation, two types flows are typically involved: namely material flow and information flow, as illustrated in Fig. 9. I call them physical flows (as they can be raw materials, parts, work-in-progress inventory, and finished goods inventory or services) and non-physical flows (e.g. information, financial, legal) instead, as I feel these terms are more to the point.

Physical flows (in direction of the solid arrow head and solid line) typical occur downward from the suppliers to the operations functions of the manufacturer, then to the distributors, retailers and finally to consumers. Non-physical flows (in direction of hollow arrow and dashed line), although occur primarily upward, can be bidirectional especially

within the internal supply chain of a business. The directions of the physical flows and non-physical flows are not absolute – meaning there is no clean separation. For instance, in case a product recall happens, there are information flow, financial flow or even legal flow from the manufacturer downward to the consumers, and there are physical flow (in the case of Toyota, parts returned to the supplier for repair or replacement) from the manufacturer upward to the supplier.

4.1.2 Supply Chain Management

According to the Council of Supply Chain Management Professionals (CSCMP), *Supply Chain Management integrates supply and demand management within a firm and across the whole supply chain. It focuses on planning, controlling and coordinating all major business functions and processes such as sourcing and procurement, conversion, logistics and partnership in a holistic, cohesive and efficient manner.*

In other words, SCM is primarily concerned with the efficient integration of suppliers, factories, warehouses and stores so that merchandise is produced and distributed in the right quantities, to the right locations and at the right time, and so as to minimize total system cost subject to satisfying service requirements.

Therefore, the ultimate goals of SCM are:

- To improve the long-term performance of the individual firms and the supply chain as a whole, through systemic and strategic coordination of the business functions and the tactics across these business functions within a particular business and across all businesses within the supply chain [40].

- To satisfy the needs of customers and add value to shareholders through efficient use of resources and integrating key business processes across the supply chain [41].

To realize the above goals, supply chain management must tackle these issues:

- Operations Strategy: on sourcing strategy (exclusiveness, geographies), replenishment strategy (pull, push or hybrid), push-pull boundary [29], operating control (centralized, decentralized or shared); delivery scheme (direct shipment, pool point shipping, cross docking, or direct store delivery), transportation mode (truckload, railroad, airfreight, ocean freight), as well as transportation control (owner-operated, private carrier, common carrier, contract carrier, or 3rd party logistics).

- Information Sharing: process integration should be partnered with sharing of key information such as demand profiles, inventory levels, product attributes, transportation records.

- Inventory Management: location, type, and levels of all types of inventories, such as raw materials (RM), work-in-progress (WIP) and finished goods (FG).

- Network Planning: on number, location and missions of suppliers, production facilities, distribution centers, warehouses, cross-docks and customers.

- Global Optimization: a systems approach when planning logistical activities in order to achieve the lowest logistics cost across the whole supply chain by considering trade-offs between local optimizations.

- Cash-Flow Management: on arranging payment terms and instruments to allow timely, safe, and reliable funds exchanges between members of the supply chain.

It is worth noting that instead of managing individual functions and tackling the above issues in isolation, successful SCM requires integrating activities into key supply chain processes. Such integration can be exemplified by collaboration between the manufacturer and suppliers on e.g. joint product development and information sharing on demand profiles. Operating an integrated supply chain mandates continuous information flows and sharing that are part of these representative integrated supply chain processes [41]:

- Customer relationship management

- Customer service management
- Demand management
- Order fulfillment
- Manufacturing flow management
- Supplier relationship management
- Product development and commercialization
- Returns management

4.2 Relating Supply Chain to Business Strategy

Global competition continues to intensify. The traditional company competes against company approach has shunned away as companies are competing primarily on the nimbleness of their supply chains. Of each individual supply chain, the loosely coupled and self-organized network of participants cooperate to provide product and services while each participant strives to maximize its profit, giving rise to a concept called *Extended Enterprise*. The new breed of competition, hence, is supply chain versus supply chain. This requires a holistic approach to the management of the supply chain that focuses on systems thinking and global optimization across the whole supply chain.

In today's ever-increasing economic volatility and uncertainty, supply chain is frequently disrupted and must be highly dynamic and adaptive. Global reach of sourcing and manufacturing, turmoil in financial market, fluctuations of price and availability of key commodities, natural disasters, all have been stressing a firm's supply chain [42]. To stay in competition in such a dynamic climate, it is mandatory that supply chain strategy be tightly synchronized with business strategy.

According to a study by Accenture [43] completed at end of 2008, in which 1500 executives across the globe from more than 600 companies in 10 industries (48% of them with no less than $1 billion in annual revenue) were interviewed, 89% of the executive admitted that supply chain is core to business success - it accounts for 50-70% of total costs and more than 50% of assets. Companies that can master dynamic supply chain can leverage it to their advantages – the winners possess the ability to align supply chain operations with the value proposition of the business and to invest in areas that entail highest customer satisfaction and best shareholder return.

In this research, Accenture also identified seven general guiding principles that underpin superior performance of a supply chain. As illustrated in Fig. 10, high performance hinges on the one hand the alignment of supply chain strategy to business strategy. This basically refers to how supply chain can create value, deliver value, adapt to dynamics of business segments, as well as optimize operations in an integrated global model. On the other hand, high-performing supply chain depends on the firm's ability to execute supply chain strategies and turn them into business practices. This includes mastery of core competences through selective investments, insightful and responsive IT infrastructure and technology platform, as well as the human factor – highly competent workforce and high-performance-oriented culture.

4.3 Secure Supply Chain

4.3.1 Definition and Significance

With such level of importance of supply chain to business strategy, the security of supply chain to ensure its high performance is crucial. Derived from the work of Closs et al. [44], I define secure supply chain as:

> *a holistic and systemic approach to the application of policies, strategies, and technologies to protect the assets, human capital, processes and information*

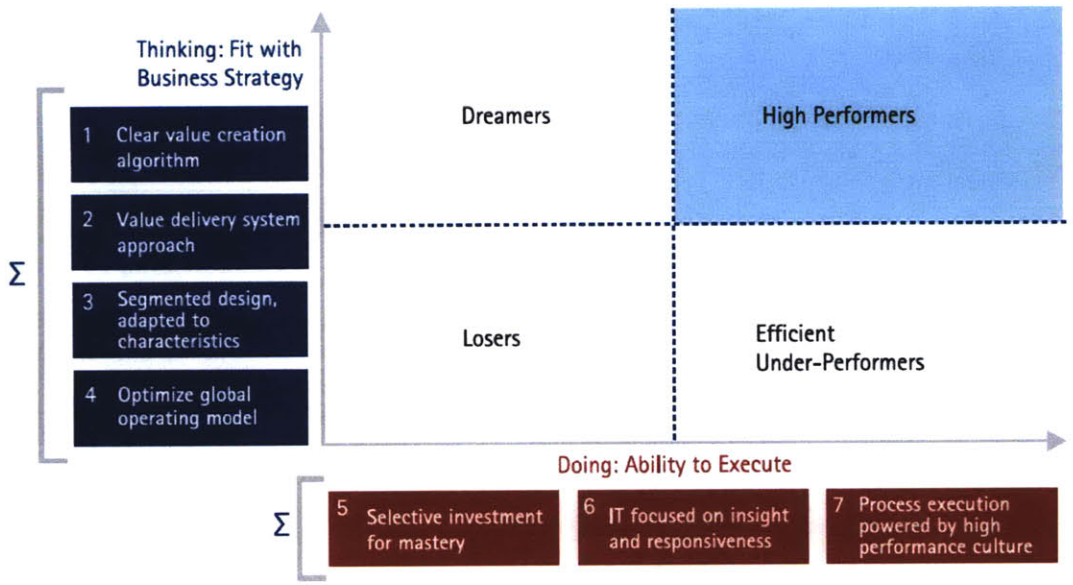


Figure 10: Seven Supply Chain Imperatives (Source: Accenture)

of a supply chain against risks and hazards.

Today, business of all sizes are operating in a globalized environment in which risks of all kinds, physical or non-physical, are fighting for the top spot on the corporate agenda [45]. Organizations are facing new types of risk and threats that are never before experienced. Consequently, conventional wisdom about risk mitigation needs to be revisited. Risk management ought to take a more refined and integrated approach to security and risk management of supply chain.

At the strategy level, it is vital that the senior management of a firm believe that security provides competitive advantage and is even a marking tool, and view secure supply chain as an integral part of the strategy and performance of a business [45]. Since there is a real connection between risk mitigation and the sustainability of the firm and its ability to drive customer satisfaction and shareholder value, security is considered a revenue center rather than a cost center.

4.3.2 Supply Chain Risks

Risks lurk along the entire length of a supply chain. They can be as diverse and extensive as unauthorized access, counterfeit, illegal trade, wrong status, delays in lead time and logistics, inaccurate demand profiling/forecast, uncertain supplier relationships, stock-out due to inappropriate inventory management, unstable political climate, terrorism attacks, fluctuations in financial market and exchange rates, natural disasters etc. The list is endless (for a more extensive enumeration, see [8] and [46]).

For purpose of this study, we will be focusing on mainly three types of product-related risks: namely wrong status, illegal trade and counterfeit. Tab. 2 enumerates these three types of risks, their more detailed classifications as well the points at which risks are introduced into the supply chain. As can be seen from the table, key issues of a product-oriented secure supply chain can be classified as [47]:

- The status of the product after shipping: challenged by wrong status such as product recall due to quality assurance frauds or contamination, and scrapping.
- The legality of product trade: challenged by illegal trade such as gray-market and black market sales.
- The authenticity of the product: challenged by counterfeit, which can be exemplified by fake label, relabel, fake product, adulteration or Substitute.

With respect to information security in supply chain, it is critical to keep the operation-relevant information and the way information is accessed secure, for the sake of proper functioning of a supply chain. Information security in the context of supply chain means:

- No one should see things s/he should not: this is collectively known as authentication: only authorized users are allowed to access information about the supply chain, and authorization: the access rights of a user should comply to predefined policies.

Table 2: Select Risks to Supply Chain and Their Entry Points

Category		Manu.	Distributor	Repackager	Retailer	Consumer
Wrong Status	Recall	X		X		
	Scrapping		X	X	X	
Illegal Trade	Black Market		X	X	X	
	Gray Market		X	X	X	
Counterfeit	Fake Label			X		
	Relabel		X		X	
	Fake Product		X	X	X	
	Adulteration			X		
	Substitute		X		X	

- What is seen is correct. This requires the IT system of a supply chain provide accurate and authoritative information.

- What is needed is provided in time. This asks for real-time performance of the supply chain information system in terms of response time and availability.

4.3.3 Benefits of Secure Supply Chain

Proper mitigation of the above-mentioned risks not only underpins the correct functioning of the supply chain, it will also exhibit many benefits. A recent study [48] has quantified the tangible business benefits of secure supply chain, such as:

- More supply chain visibility (50% increase in availability of supply chain data, 30% increase in timeliness of shipping information);

- Better product safety (e.g., 38% reduction in theft/ loss/ pilferage, 37% reduction in tampering);

- Less delays: close to 30% reduction in problem identification time, response time to problems, and in problem resolution time, 29% reduction in transit time, 28% reduction in delivery time window, 49% reduction in cargo delays, 48% reduction in cargo inspections/examinations during customer clearance;

- More efficient inventory management (14% reduction in excess inventory, 12% increase in reported on-time delivery);
- Process improvement (43% increase in automated handling of goods); 30% reduction in process deviations,
- Higher customer satisfaction (26% reduction in customer attrition and 20% increase in number of new customers).

4.3.4 Enabling Technologies for Secure Supply Chain

To construct a secure supply chain and received these benefits, a number of technologies can be adopted. Tab. 3 illustrates countermeasures for the three types and nice categories of product-related risks in supply chain. Basically, three sorts of technologies are relevant [47]:

Table 3: Countermeasures to Select Supply Chain Risks

Category		Covered By EPC System			Not Covered
		Mass Seria.	Attr. Service	Tamper Alert	Phy. Veri.
Wrong Status	Recall	X	X		
	Scrapping	X	X	X	X
Illegal Trade	Black Market	X	X		
	Gray Market	X	X		
Counterfeit	Fake Label	X	X		
	Relabel			X	X
	Fake Product	X	X	X	X
	Adulteration	X	X		
	Substitute			X	X

- Mass Serialization: This refer to the approach of uniquely identifying products at instance level (not class-level such as using barcode) so that authenticity, status and legitimacy verifications can be conducted. This requires a number of building blocks such as i) ID Encryption (e.g. using an encrypted RFID tag) so that only authenticated and authorized parties are allow to get access to (i.e. decrypt) the identification

information of a product; ii) Access Control to deal with who possesses the capability to access encrypted product info and what are their access rights; iii) Identification Management: as a complementary feature to handle after exposure of ID and in case ID is not encrypted and enforced with access control. Mass Serialization using e.g. technology such as RFID servers as an important foundation for critical security functions such as product authenticity, legitimacy and status verification.

- Product Attribute Service: With PAS, product document management processes such as track (record trading history and verify product status by retrieving prepositional information), trace (identify and remove suspicious products), and certification (record status verification) can be done electronically and in real-time. In addition, product status management during transit is vital to secure supply chain. Here both product recall (after product design-time or production-time flaws are detected), or contamination/expiration (after shipment but before consumption) require sophisticated status management. Documents management and status management can be realized with technology such as EPCIS [49].

- Object Name Service: as a resolver and reflector service, ONS allows for lookup of serial-level product information based on a unique serial ID, e.g. RFID.

- Tamper & Relabel Alert: this refers to the capability and technology that can detect breach of the product and/or product packaging through automatic alerting and converting such event into tampering and re-labeling alert logs. In the container shipment industry, this has been widely deployed, e.g. the ESeal [50].

4.3.5 Value Proposition and Value Delivery

Two essential issues secure supply chain aims to solve: how can security in supply chain create value for customers, and what are the best ways to reach them. This boils down to value proposition and value delivery.

Table 4: Security Countermeasure to EPC System Components Mapping

Countermeasures		EPC	Tag	Reader	Middleware	EPCIS	ONS
Mass Seri.	Encryption	X	X	X	X		X
	Access Control		X	X	X		
	ID Management					X	X
PAS	Doc. Management					X	
	Status Management					X	X
Tamper Alert	Temper Proof Tag	X	X	X			

Using the three types of competitive advantages as discussed in Sec. 3.2 and the framework as described in Sec. 3.3 on five key value propositions, the value propositions of a secure supply chain can be any of the blow five factors.

- Price competitiveness: by minimizing the risk level of a supply chain, trading partners are in a good position of fending off or reducing the likelihood of the occurrences of supply chain frauds and increasing the probability of catching frauds. Product recalls and their destructive chain effect can be very costly as illustrated by recent Toyota incidents. Fraud ramifications such as vendor charge backs, lawsuits and regulatory audits, product rework or salvage, diluted brand value, lost market share, manufacturing downtime, logistics and distribution interruptions are not only heavy drags on the balance sheet, but also have chain effect that goes beyond accounting. Although there is a cost for investing in risk mitigation etc. in a secure supply chain, the benefits it brings often well offset such cash outflows.

- Product leadership: a secure supply chain help ensure high initial quality of products and early detection of fraud/flaws, hence is critical in building differentiation factors such as safety, quality and reliability.

- Time to market: low-risk supply chain generally has more robust, smooth and agile key functions such as sourcing, logistics, operations and distribution, which all together usually result in shorter time to market.

- Customer Experience: secure supply chain typically has better customer experience and customer credit, and can more efficiently leverage limited customer service resources of a firm.

- Growth: secure supply chain will allow for more organic and rational growth, with the capability of risk mitigation of a firm scale with the increase of volume and market share (through e.g. market segments, products and product varieties, channels as well as geographies).

It is therefore critical to choose a razor-sharp value creation algorithm. As a secure supply chain approaching a world-class operations, it becomes increasingly difficult to fulfill multiple value proposition orientations and growth orientations in parallel, due to intensified competitive forces. Also, some of the orientations might be mutually-exclusive under certain situation [43]. Therefore, with a well articulated value proposition orientation and making effective operational tradeoffs, a secure supply will be able to help build appropriate operating models to fulfill needs of different customer segments and value propositions. Furthermore, a secure supply chain will be better at determine which security-savvy customers to target, where are they located, and how to reach them.

While value propositions answer how to create value for customers, value delivery in secure supply chain has a lot to do with how to actually reach customers and realize value creation. This requires the following:

- Adopt systems thinking: think enterprise, not department; think the whole supply chain, not just one firm; think out-of-box on external factors, not just the supply chain itself. Zooming in and zooming out the supply chain allow for value delivery for beneficial stakeholders at all levels. Through managing up, managing down, and managing peers, equilibrium of the ecosystem of all trading partners can be realized. Globally optimized supply chain risk level will render the system at the optimum of its business performance.

- Leverage state-of-the-art technologies: leading Business Intelligence (BI) and Enterprise Resource Planning (ERP) solutions including, e.g. Product Lifecycle Management (PLM), Auto-ID solution such as RFID and other EPC schmes, EPCglobal initiatives such as EPCIS and GDSN, EDI and web services, as well as analytic software are just some of the examples.

- Transform the supply chain into a value delivery system: approaching the supply chain with a systems perspective as depicted in Fig. reffig:valueDelivery, it is an ecosystem of supply chain trading partners, with three mega processes as product development, order-to-deliver, and sever and returns, as well as involving 6 types of flows – physical, informational, financial, legal, digital, and service. Identifying the focuses on certain partners, processes and flows to innovate while baring the holistic view in mind will allow a secure supply chain to seize a greater number of opportunities to excel.

- Beef-up risk assessment and mitigation: This involves a number of considerations such as: i) financial and operational target setting and performance tracking need to be security risk adjusted; ii) the risk levels of each link in the supply chain as well as their correlation to profit-generation and customer value creation need to be assessed; iii) optimal balances and tradeoffs between fixed and variable costs, and between service level and costs need to be well understood; iv) the roles, capabilities and constraints of trading partners on risk management in a supply chain need to be well-coordinated.

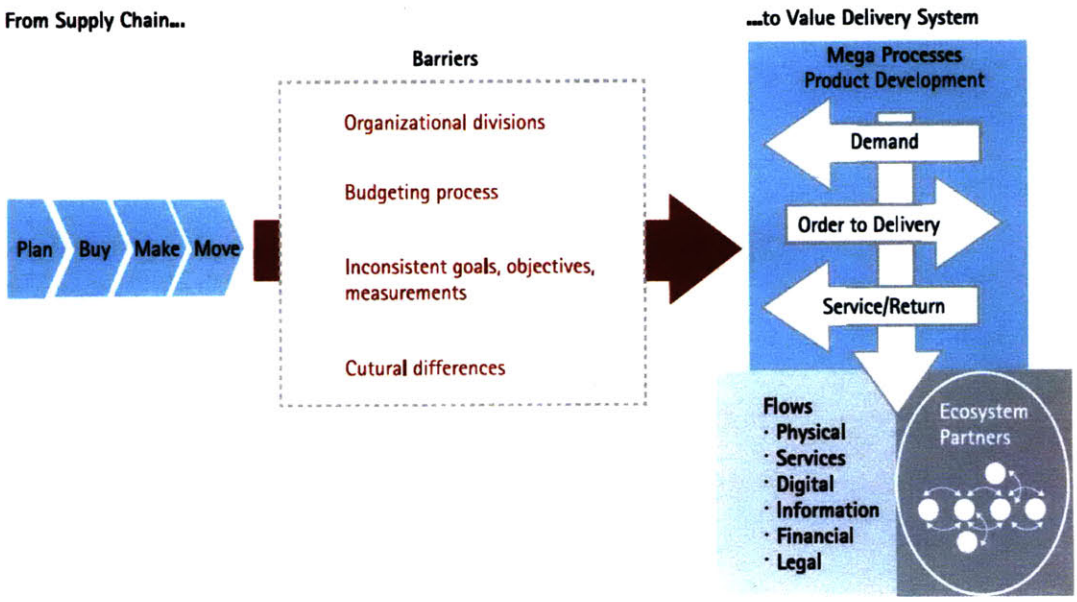


Figure 11: Supply Chain as a Value Delivery System (Source: Accenture)

CHAPTER V

AUTHORITATIVE PRODUCT ATTRIBUTE SERVICE

Ever shopped around, and became frustrated about that each store has slightly different descriptions of exactly the same product? Annoyed at finding out errors in product description at your favorite online store? Wished one day you could search for a product by its attributes to narrow down the criteria from a myriad of choices? Worried about whether the Ralph Lauren shirt you are going to pay at the cashier is a fake?

Authoritative Product Attribute Service (APAS) is the cure to these pains. Even today, product attribute service is considered a Business-to-Business application. Trading partners of a supply chain build and share product information amongst themselves with services such as Global Data Synchronization Network [51] and EPCglobal Network [52]. Consumers are basically excluded from accessing such information. On the other hand, typically, product information provided to the end consumers are maintained by individual retailers. Such an approach is heterogeneous, error-prone, inaccurate, incomplete and lack of consumer confidence. There is an urgent need for authoritative product attribute service that provides uniform, validated, timely and complete product info.

In this chapter, I will talk first about the related work with respect to systems for product information sharing. I will then deliberate on the use cases of Authoritative Product Attribute Service, and strategic considerations on this service.

5.1 Related Work

5.1.1 Global Data Synchronization Network

Currently, there are number of systems such as Global Data Synchronization Network, UCCNet, Transora, WWRE that allow for generic product info sharing. However, as mentioned a bit earlier, these B2B systems are designed for trading partners in a supply chain to exchange and synchronize class-level static product attributes.

GDSN, the best-known of the four, and an initiative from GS1, ensures the quality of of static information capture and dissemination for trading legal entities and their products/services. Supply chain trading partners share static information such as product attributes and company registration information with each other in order to facilitate transactions. GDSN has made this process consistent and accurate by utilizing EAN.UCC System standards, global identification numbers and business messaging standards. As shown in Fig. 12, key building blocks of GDSN include:

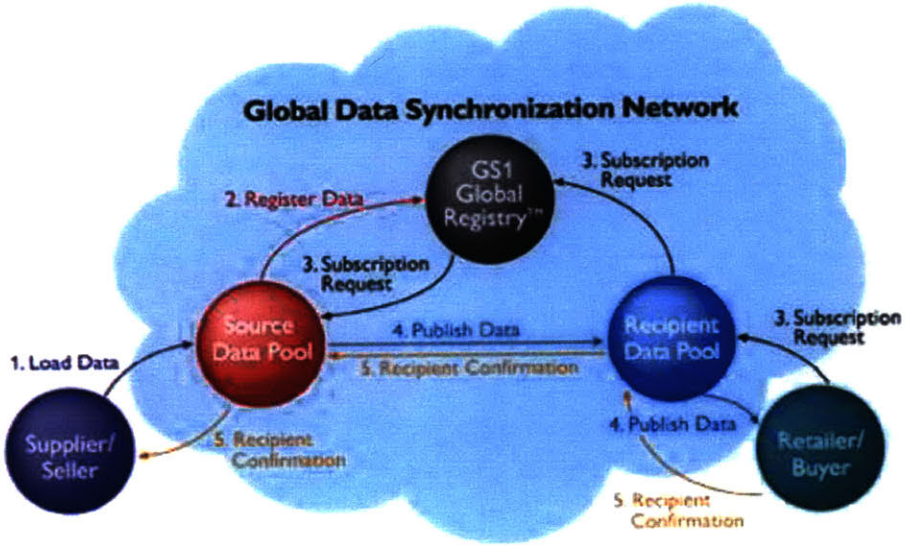


Figure 12: GDSN System Components and Interactions (Source: GS1)

- Identity schemes. The Global Location Number and the Global Trade Item Number can uniquely identify a class of product and its origin. While GLN represent legal

entity, trading partner and location, GTIN is the identifier for a type of trade item such as product or service. Common implementations of GTIN are 12-bit Universal Product Code and 13-bit European Article Number (EAN) that are collectively known as barcode. Barcodes are machine readable with a red-laser barcode scanner. Companies assign and manage their own GLNs and GTINs, following predetermined Company Prefixes and the EAN.UCC Standards.

- Interoperable data pools. These repositories are built with the help of or by members who participate in GDSN-compatible supply chain. Companies register their location information, GTINs, GLNs, their corresponding product/service attributes as well as a list of authorized parties who are allow to access such information with a data pool.

- GS1 Global Registry. As a single entry point for all trading partners of a supply chain, GDSN global registry locates products or partner data across all participating data pools for a given GTIN or GLN.

- Synchronization mechanism and communication protocols that define data schema and rules for supply chain data exchange. Should any updates become available for a company, such changes are populated to all members of the supply chain. With such, GDSN can assure all trading partners are using identical, accurate, up-to-date and standard-compatible data.

5.1.2 EPCglobal Network

Different from GDSN, EPCglobal Network [53] focuses on providing visibility and access to dynamic history information, i.e. the states of individual products/services as they move along the supply chain. EPCglobal fills in the blank of no globalized standards and methods for gathering and communicating real-time instance-level (meaning serialized and specific/unique to a single trade item) dynamic supply chain information. Such capability is very invaluable to secure supply chain functions such as track, trace, and verification.

In the figure below, the system components of EPCglobal Network, registration of EPC with the system, distributor registration with the system, the visibility of dynamic supply chain information, ONS' role in the system, as well as retailer and trading partners' view through the EPCglobal Network are illustrated [52].

The combination of GDSN and EPCglobal Network has made it possible to have comprehensive, integrated approach to static and dynamic information sharing and electronic collaboration amongst supply chain trading partners, with the exception of end consumers.

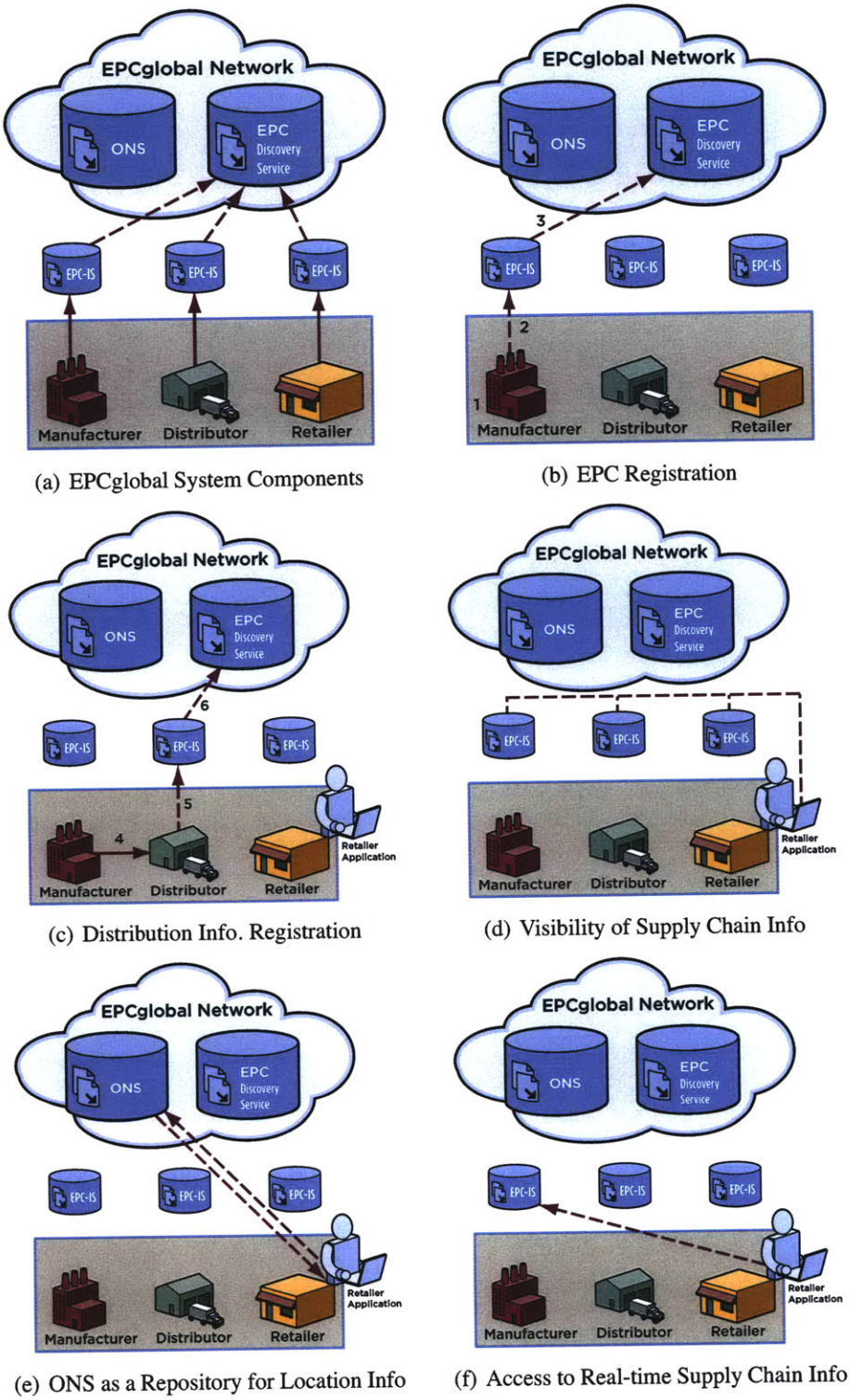
5.1.2.1 Electronic Product Code

The Electronic Product Code (EPC) [54] was created at the MIT Auto-ID Center, and currently managed by EPCglobal, Inc., a subsidiary of GS1. Successor to the widely-deployed barcode technology, EPC is a family of coding schemes designed as a low-cost identity standard to allow for automatic tracking. Due to its ability of uniquely identify each individual trade item (as opposed to only the manufacturer and class of products like barcodes do), EPC is becoming the standard for global RFID deployment, and serves as a core element of EPCglobal Network.

An underlying wireless technology for EPC is Radio Frequency Identification. RFID couples tiny chips with micro antennas to form a so-called RFID tag. The chip contains (to its minimum) the unique identifier. The antenna emits radio signal which can be detected by a RFID reader in short range (in case of a active tag). Large-scale tagging and tracking can be achieved as RFID-equipped trade items move across the supply chain.

5.1.2.2 EPC Information Services

EPC Information Services (EPCIS) [53] is a breakthrough and standard in business event and product information sharing amongst members (trading partners) in a supply chain or between enterprise processes. A bridge between the physical world and the information world, it defines the interfaces for representation and exchange of product related data,



(a) EPCglobal System Components

(b) EPC Registration

(c) Distribution Info. Registration

(d) Visibility of Supply Chain Info

(e) ONS as a Repository for Location Info

(f) Access to Real-time Supply Chain Info

Figure 13: EPCglobal Network Illustrated (Source: Verisign)

i.e. capture interface and a query interface to obtain and share business event information. EPCIS allows for secure access and exchange of high-volume, dynamic, event-driven, instance-based (unique to each product instance) and serialized product information, cost effectively and with fine granularity. Similar to GDSN, EPCIS is a B2B system rather than a consumer-facing system – information shared in EPCIS is not supposed to be exposed to end consumers.

EPCIS has the following characteristics:

- Key capabilities of product authentication and product attributes visibility. By leveraging Electronic Product Code and mass serialization and integrate them with sophisticated information and communication systems, identity/authentication of product and visibility of authoritative product attributes are at the core of EPCIS.

- Built-in security features for authentication and authorization. EPCIS leverages advanced security mechanisms – it enables the use of digital signatures for identity management, the use of multiple message transport bindings that include authentication (e.g. SOAP over HTTP with TLS for web services and XML over AS2). It also gives the users full control over data creation, access right definition, and on-demand data sharing. E.g. as part of the query interface, arbitrary business rules, to decide which events to deliver to the requestor and which information to include within those events can be enforced.

- Standardized data model, interfaces and query mechanism. EPCIS provides standard data model, capture and query interfaces to enable product status track and trace, product authentication, diversion detection etc across the whole supply chain.

- Openness. EPCIS is an industry-neutral, technology-neutral standard and it discourages vendor lock-in. Interoperability is assured with tests conducted by a consortium of 20+ chosen companies (known as the EPCIS-SAG).

Due to the above characteristics, EPCIS has laid down the foundation for security, visibility, accuracy, and automation throughout a supply chain. Today, EPCIS has seen applications in domains such as Retail Supply Chain (RSC), Healthcare Life Sciences (HLS), Transport and Logistics (TLS) etc.

Fig. 14 depicts the architecture of an EPC Information Services.

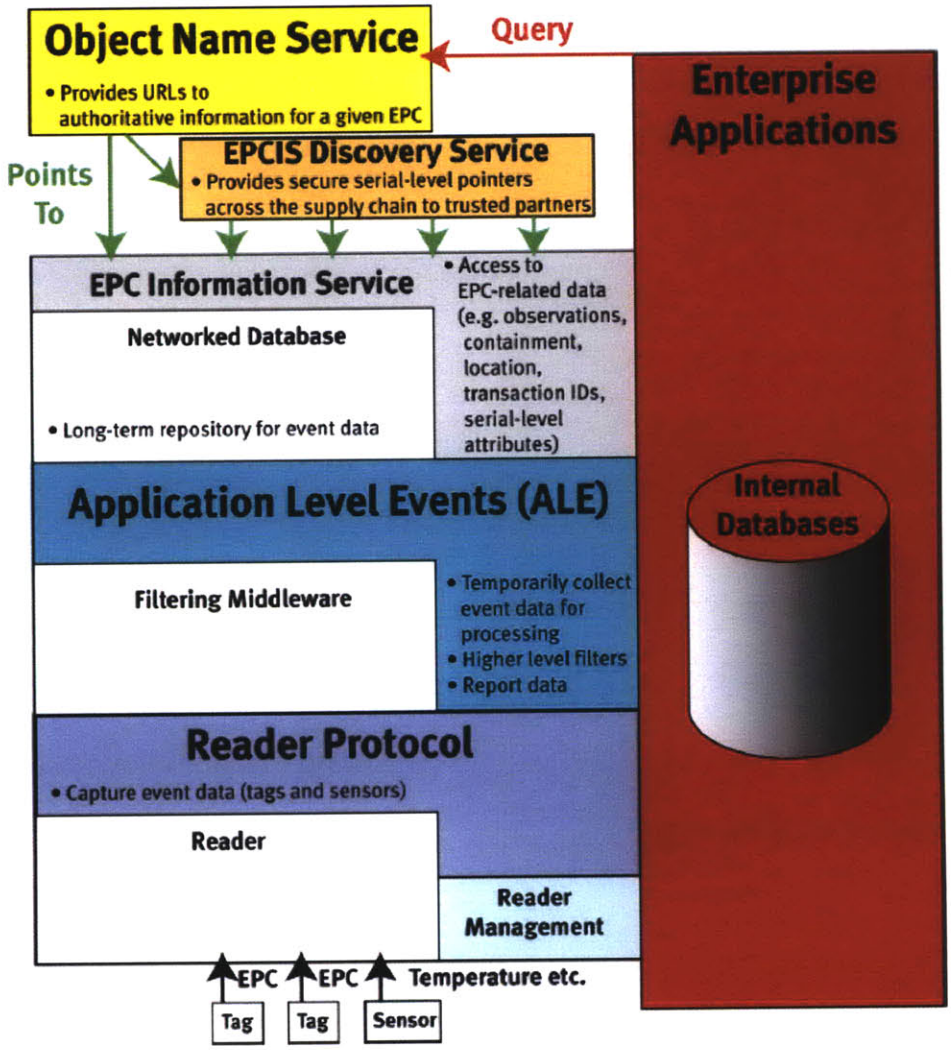


Figure 14: Architecture of EPC Information System (Source: Mark Harrision)

The EPCIS specification framework is organized into several layers [49], as depicted in Fig. 15

- Abstract Data Model Layer that specifies the generic structure of EPCIS data and general requirements for creating data definitions within the upper Data Definition Layer.

- Data Definition Layer that specifies the semantic, abstract structure and content of data exchange in EPCIS. A data definition module is defined using the Core Event Types Module, following the corresponding Abstract Data Model Layer rules.

- Service Layer that defines service interfaces through which EPCIS clients interact with each other. This includes the Core Capture Operations Module (which defines the EPCIS Capture Interface that EPCIS Capturing Applications use to deliver Core Event Types to target clients), and the Core Query Operations Module (which defines both the EPCIS Query Control Interface and the EPCIS Query Callback Interface that EPCIS Accessing Applications use to retrieve previously captured data.

- Bindings that glue the Data Definition Layer and the Service Layer with actual implementations. For example The data definitions in the Core Event Types data definition module are realized through binding to an XML schema. The Core Capture Operations Module is realized with bindings for Message Queue and HTTP.

As shown in Fig. 16, although EPCIS is an integral part of the EPCglobal Network, it differs from elements at the lower layers of the later in: i) EPCIS deals with both historical and real-time data; ii) EPCIS goes a step further from raw EPC observations by incorporating semantics such as the understanding of the business context in which the EPC data were captured; iii) EPCIS's operating environment – embedded in corporate IT infrastructure makes it more diverse and multi-faceted.

5.1.2.3 Object Naming Service

Object Naming Service (ONS) is a resource discovery mechanism and lookup service that produces the location of the resource (in the form of a Uniform Resource Locator, or URL)

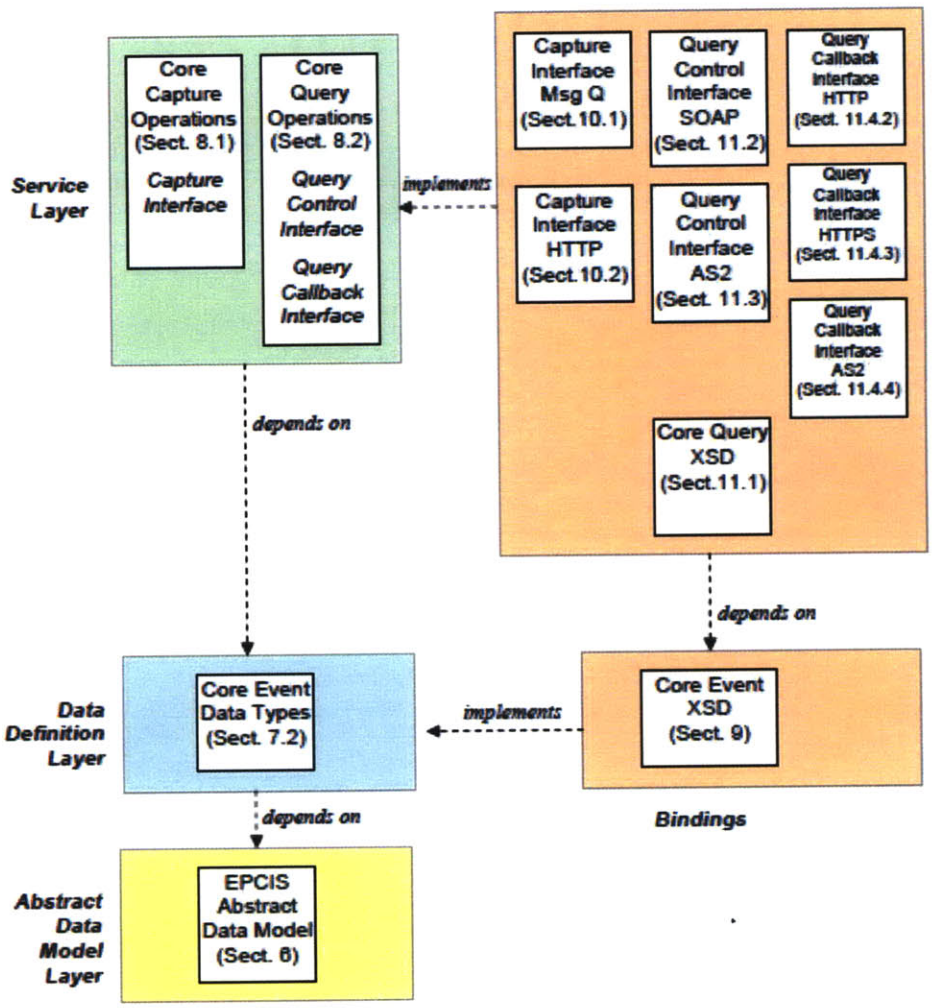


Figure 15: Layering of Standard Specifications of EPCIS (Source: EPCglobal)

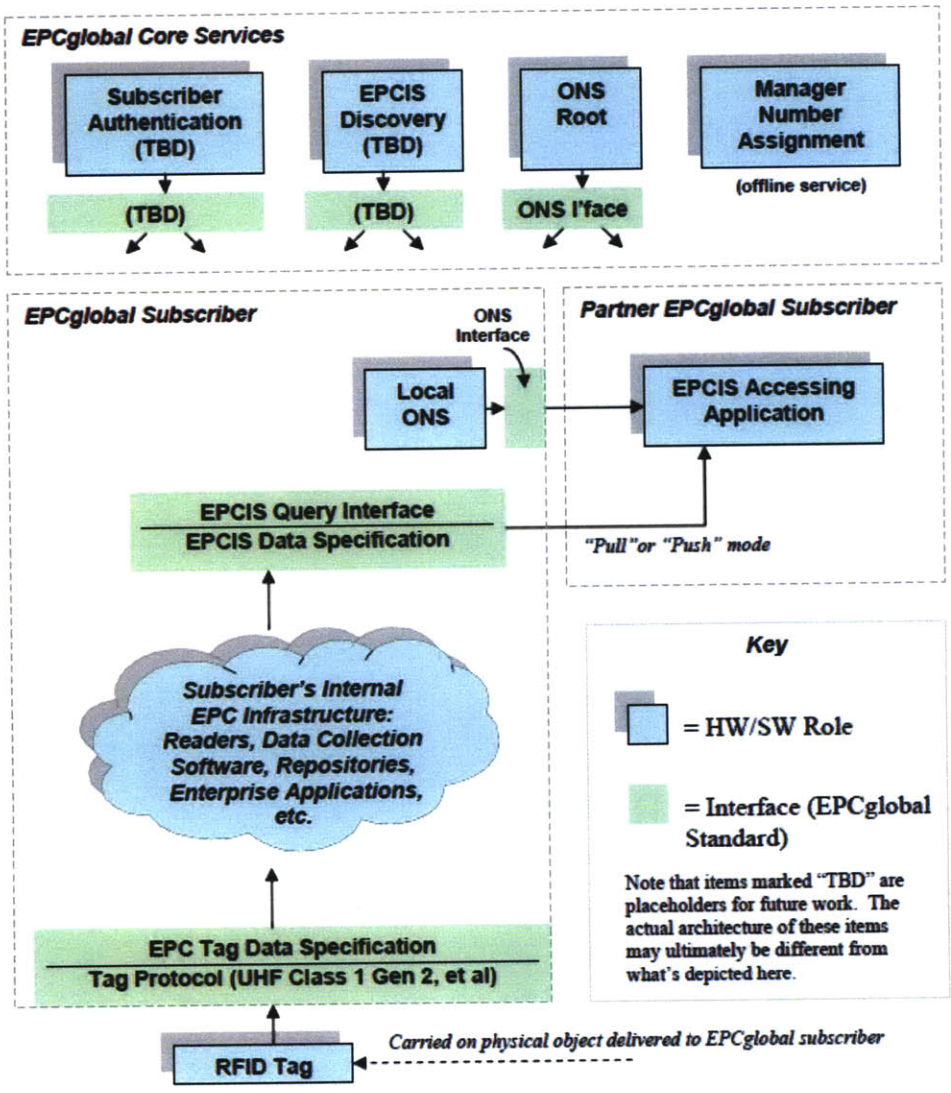


Figure 16: Core Services of EPCIS (Source: EPCglobal)

of an EPCIS repository designated and implemented by the EPC Manager for a given EPC. In case of that data management entity is unknown for a given EPC, ONS is a prerequisite for EPCIS. Simply put, for an EPC, ONS will find out the entity who is responsible for managing data for it, and EPCIS defines the format the actual data is organized and exchanged.

5.2 The Missing Link - Authoritative Product Attribute Service

The above two systems for product information sharing, namely GDSN and EPCglobal, are not consumer-facing by their designs. On the other hand, accessible product attributes to the end consumer are typically provided and maintained by retailers. This has a number of limitations:

- Non-Authoritative and lack of consumer confidence
- Error-prone and often inaccurate
- Lack of common standard and format
- Inconsistent between the vendors
- Variable quality of the information

Therefore, there is a missing link between the consumers and the existing B2B supply chain information sharing systems such as GDSN and EPCIS. APAS will bridge the gap and extend the reach of these systems to a step further. With APAS, consumers will play an active role in monitoring and contributing to the security of the supply chain. With a mobile barcode scanner or mobile RFID reader in hand, consumers will become a vibrant force in combating counterfeit, detecting wrong product status and holding back illegal trade.

To the consumers, APAS will protect their rights to buy genuine products with correct status and through legitimate channels. In addition, APAS will provide such possibilities

as trustful product attributes retrieval, attribute-based product comparison, product rating and commenting.

To the brand owners and other members of the supply chain, APAS will offer unprecedented possibilities such as direct customer-facing product marketing e.g. product recommendation, individualized coupon promotion, as well as direct user feedback on feature request and defect report. All of this will allow them to build competitive advantages with shorter user interaction cycles, more fragile to user demand variation, targeted and efficient product design, responsive product recall, and more effective in attacking counterfeits.

5.2.1 Use Cases of APAS

APAS will not only satisfy the basic needs of consumers on acquiring trustful and authoritative product information, but also become the enabler for a myriad of applications. Some of the use cases of APAS are:

- Track, trace and verify status of a product: This will allow the consumer to access certified class-level and serial-level product attributes in order to find out product trading history, verify product status, and ensure that the product is genuine, with correct status and comes through legitimate channel.

- Search for a product for certain features: This will offer the consumer the possibility of configuring feature set or inputing key words, and then search for matching products and give product recommendations.

- Compare features of similar products: With very fine product category classification granularity, comparing features of a group of products can be made possible via interactions using a web interface.

- Review and rate a product: User ratings and reviews, coupled with statistical analysis of them, can provide direct feedback to the brand owner for product design and innovation. They can also help identify risks to the supply chain in a very timely

manner and serve as part of the 'early warning system' of the brand owner. A filtering mechanism might be considered to extract only legitimate information from the user.

- Study market segments: To the brand owner, allowing direct feedbacks from the end consumer, such as product search and comparison profile, review and rating, feature request, bug/defect report, will provide valuable inputs for market study and sales data monitoring.

- Promote products to the consumers via E-coupons: To the brand owner, an electronic coupon delivered directly to the user's cellphone after the query of product attributes, can offer a brand-new product discount experience. It is fast, efficient, reliable, targeted and even individualized. E-coupon can also help monitor effectiveness of promotion – answering questions such as "is the promotional item selling better"?

5.3 Strategic Considerations

5.3.1 Competitive Forces and Competitive Advantages

As illustrated in Fig. 17 five forces determine the likelihood of success and profitability of PAS (in the case that PAS is geared towards for-profit), as they influence the required investment, cost of operations as well as pricing. While potential entrants and substitutes primarily drive the cost of all aspects of operations, the bargaining power of clients as well as is the bargaining power of suppliers (be it inflows of original product information, funds, technologies, standards/policies, or test results) touch upon mainly pricing and cost of investment.

Naturally, not all five forces are of equal importance for PAS. A superior competitive strategy for PAS will rest heavily on better understanding of the five forces and industry structure, as well as choosing the right emphasis and focus. While top-priority is given to

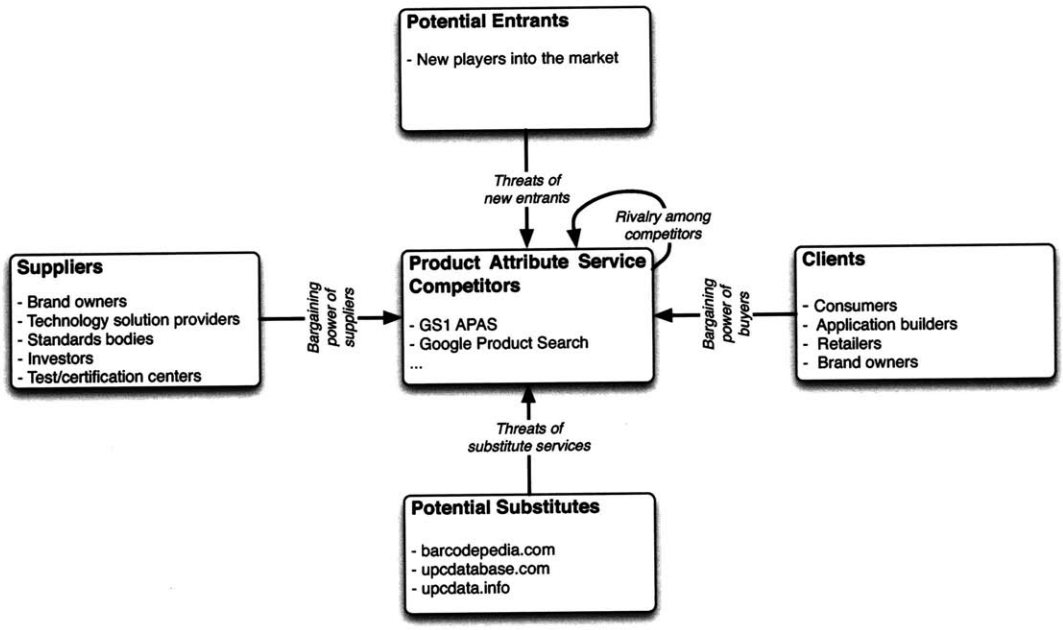


Figure 17: Competitive Forces for Product Attribute Service

satisfying buyers' needs, it is critical not only to create unique value for clients of PAS, but also indeed capture value. Therefore a provider for PAS must be aware of the if PAS is a high value-creating service (can be roughly understood as high-revenue business) at all, and if yes, its ability to capture value (can be roughly understood as decent margin).

The industry structure of PAS can be characterized as:

- Weak bargaining power of buyers and weak existing competition. To date, there is no such authoritative product attribute service on the market. Hence, demand is greater than supply.

- Strong bargaining power of suppliers. This is due to a large extend, product attributes have to be sourced from brand owners, to be validated and offered with the help of technology solution providers and certification centers, must comply with standards and regulations, and it requires funds to build the infrastructure.

- Strong rivalry such as technical powerhouse such as Google, given its dominance in

the online world, can be a heavy-weight new entrant.

- Weak substitutes, as existing UPC databased not only are very limited in size and coverage, but also lack the level of authority GS1 has to offer.

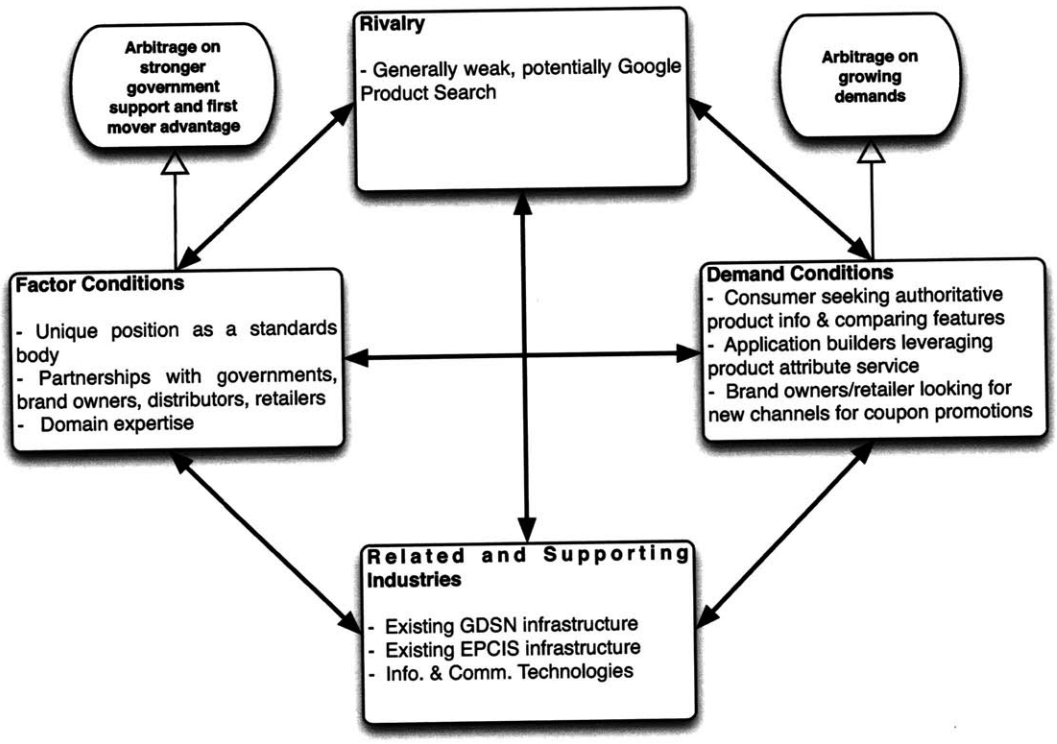


Figure 18: Virtual Diamond Model of PAS Competitive Advantages

Put ourselves in the shoes of GS1, a promising candidate for launching the Authoritative Product Attribute Service, its competitive advantage, as depicted in Fig. 18, can be understood as follows:

- Demand conditions: generally good, with growth for the years to come.
- Factor conditions: excellent working relationships with all kinds of supply chain trading partners such as suppliers, brand owners, distributors, retailers.
- Rivalry: weak at this stage, so it is better to exploit First Mover Advantage.

- Supporting industries: excellent existing infrastructure such as that provided by GDSN and IPCIS, and the nowadays advanced information and communication technologies.

- Arbitrages: strong government support is anticipated in protect consumer rights and promote supply chain security. Especially, the later can contribute to 'The Homeland Security Initiative'.

5.3.2 Fit into the Value Chain

It is also necessary to see how these competitive advantages reside in the value chain. Recall in Section 3.3 and Table 1, we described two types and nine categories of value activities that constitute the value chain of a firm. Using a brand owner/manufacturer, one type of user or so to say 'buyer' of APAS, the availability of authoritative product attributes as well as other value-adding features will have multifaceted impact on the value chain of the firm.

As can be seen from Table 5, for primary activities of the value chain of a firm (e.g. a brand owner that contributing to APAS), APAS will influence:

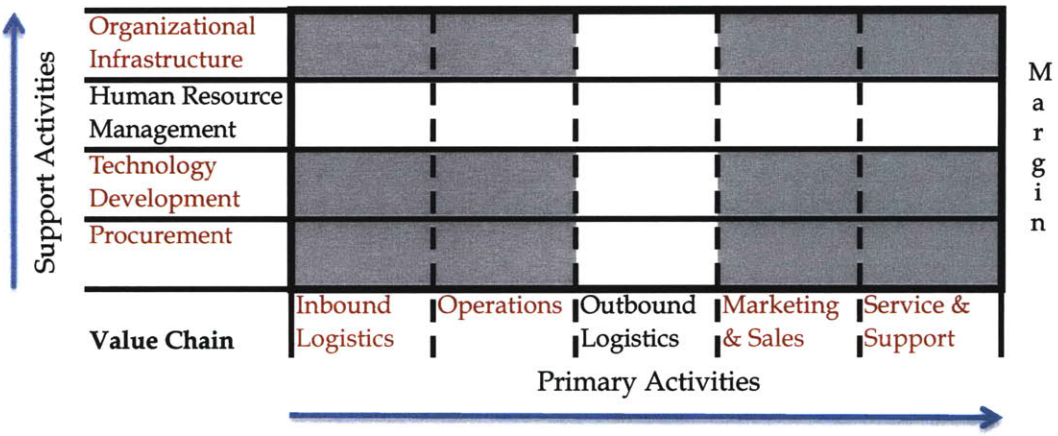
- Inbound Logistics: APAS's capability of providing both class-level and serial-level critical certified product attributes will allow for more secure parts sourcing, and reduce the risk level of the supply chain. It is also justified in the use case 'Track, trace and verify status of a product'.

- Operations: just as the way it is justified in use case 'Track, trace and verify status of a product'

- Marketing and Sales: just as the way it is justified in use case 'study market segments', use case 'search for a product for certain features', use case 'review and rate a product', and use case 'promote products to the consumers via E-coupons'.

- Service and Support: just as the way it is justified in use case 'study market segments', use case 'search for a product for certain features', use case 'review and rate a product', and use case 'promote products to the consumers via E-coupons'.

Table 5: Positioning of APAS in the Value Chain of Brand Owner



For support activities of the value chain of a firm that contributing to APAS, APAS will influence its:

- Organizational structure: e.g. the Information and Communication infrastructure, just as the way it is justified in use case 'Track, trace and verify status of a product' .
- Technologies Development: just as the way it is justified in use case 'Track, trace and verify status of a product' and use case 'review and rate a product'.
- Marketing and Sales: just as the way it is justified in use case 'study market segments', use case 'search for a product for certain features', use case 'review and rate a product', and use case 'promote products to the consumers via E-coupons'.
- Procurement: just as the way it is justified in use case 'Track, trace and verify status of a product'.

5.3.3 Strategic Options

Understanding the competitive forces and competitive advantages, and the relation to the value chain, the provide of APAS still need to consider the following strategic options.

- Stakeholders and Needs: which stakeholders and needs should APAS address first? The consumer or brand owner?
- Direction and timeline: where is a business heading for in the long run? How to get there?
- Scope and Market Segment: what are the main activities (products/services) of the business and which market segments should it compete in?
- Competitive strategy: how can it differentiate itself from and beat the competitions? Would it be built-in trust mechanism, working relation with brand owners, or position as a standards body?
- Resources: what resources can it leverage? Would it be assets, relationships, technical competence, or facilities?
- Environment: what external factors that might affect the business' competitiveness should be considered? Would it be competitors who are preparing to launch such service, or resistance from brand owners to provide original product attribute data?

Putting it all together, GS1 is in a very promising position to launch APAS, thanks to the aforementioned competitive advantages. However, given strong bargaining power of suppliers and strong potential rivalry, controlling cost of investment and operations, and the business model as well as the timing of launching the service are critical to the successful of APAS. Approaches to cost leadership, differentiation and focus should be carefully examined. [1]

[1] Due to time and resource constraints, a full-fledged study of strategy analysis, decision and implementation is more appropriate as a future work.

CHAPTER VI

ARCHITECTING AUTHORITATIVE PRODUCT ATTRIBUTE SERVICE

6.1 System Architecture: The Basics

According to Edward Crawley [55], system architecture is in its simplest term, *function related by concept, in order to form*. More specifically, *architecture is about mapping function to form*. Here, function refers to processes operating on operands, and form is the structure (abstraction of entities and their relationship) of the instrument object.

Both function and form are attributes of a system. Function is about processes (activities, operations and transformations) that result in externally-delivered value of the system and meeting the performance goals of the system. Form, on the other hand, is about structure and objects of the system, as well as the perception of the system on what it is about.

The primary goals of system architecting are to simplify complexity, resolve ambiguity and focus creativity. To achieve such goals, system architecting needs to perform a number of tasks such as the embodiment of concept, the allocation of function to elements of form, as well as definition of interfaces among system elements and between the system and its context. These tasks are associated with a couple of principal work items [55], such as:

- Defining a clear, complete, consistent and attainable set of function-oriented goals.
- Describe the context the system operates, and the whole product/service context.
- Describe the concept of the system.
- Describe the main function of the system, and decompose it.

- Describe the highest level form of the system, and decompose it.
- Analyze timing, operator attributes, costs, risks, and the implementation, operation and evolution plans.
- Ensure functional decomposition is performed and interfaces are in controlled form.

Architecture is important as it is the primary link between benefit and cost. Or in other words, the competitive advantage stems from product leadership – superior architecture design of the product is a decisive factor of mapping cost to benefit. This is because architecting can provide leverage within a single project, exploit commonality across projects, separate functions from the interfaces through abstraction, and allow new solutions to emerge.

In the remaining part of this chapter, I will try to address some of the above-mentioned issues and work items of system architecting of the APAS.

6.2 Stakeholders and Their Goals

System architecting starts out with identifying stakeholders and their needs, ranking of the stakeholders based on the importance of their outputs to the system, and identifying primary beneficiary and its goals. This is followed by establishing a clear statement of the goals for the system in a way that the goals are human understandable, complete, consistent, and attainable within resource constraints.

6.2.1 The Eco-system

The Ecosystem of APAS is populated. Think APAS and its related supply chain as a system, major stakeholders can be classified into two categories, stakeholders that are internal to the system, and stakeholders that are external to the system. Fig. reffig:pasStakerholderNeeds serves as a complete list of the stakeholders of APAS and their needs.

- Internal stakeholders are trading partners of a supply chain, such as the suppliers,

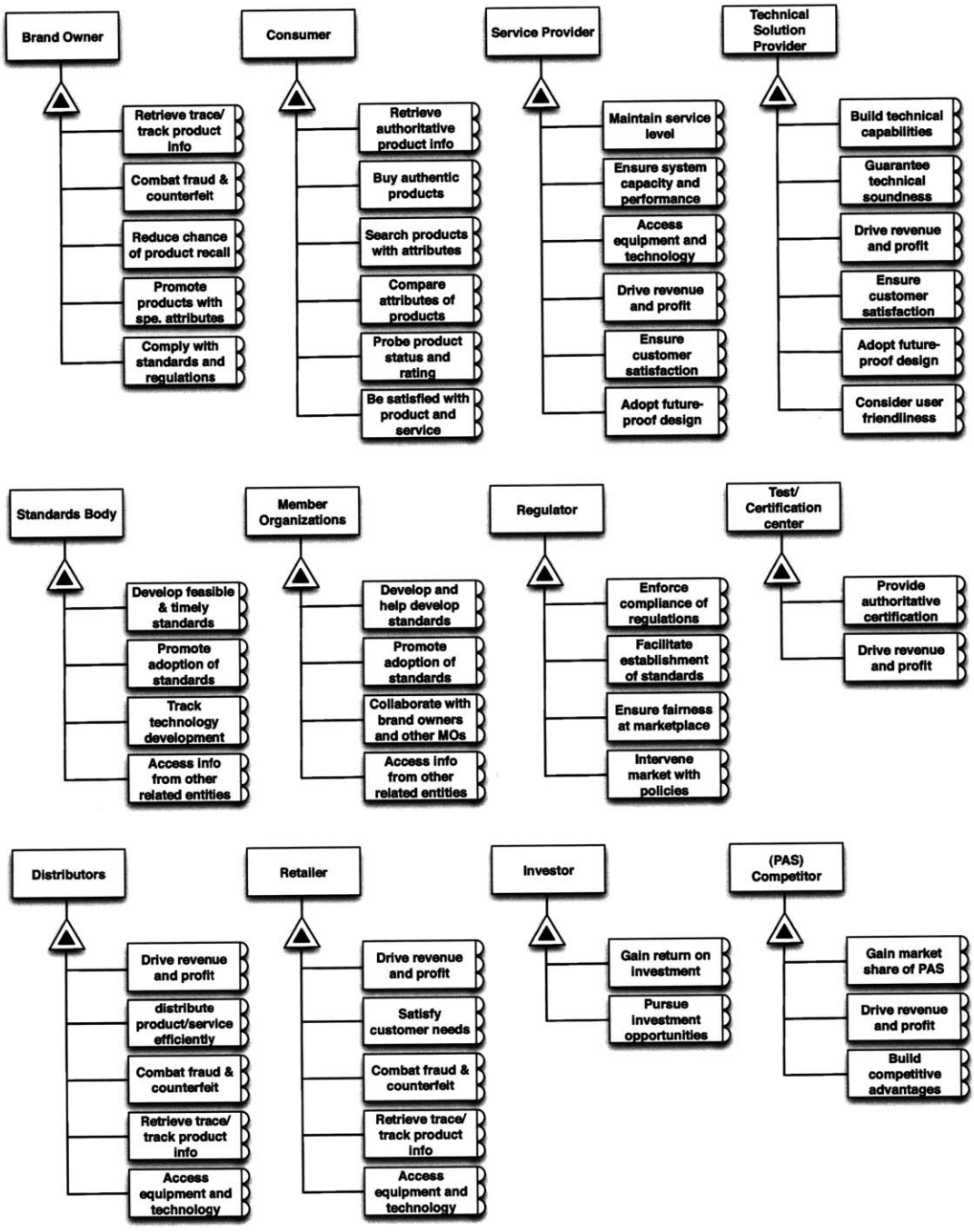


Figure 19: Stakeholders and Their Needs in Product Attribute Service

supplier's suppliers, brand-owners (BO, the firm/company/manufacturer, identified with company prefix), distributors, retailers, and consumers.

- External stakeholders are those who have influences on the function and form of the system, such as regulators, standards bodies, member organizations (MO, country representative of standards bodies), test/certification centers, , PAS service providers, technology solution providers, investors, PAS competitors (existing competitors, new entrants or substitutes), as well as business partners exterior to the supply chain.

  Analysis of these stakeholders, based on the importance of their outputs to the APAS system, indicates that regulator, consumer, brand owner and service provider (for APAS) are 4 types of stakeholders with highest priorities, as illustrated in Fig. 20.

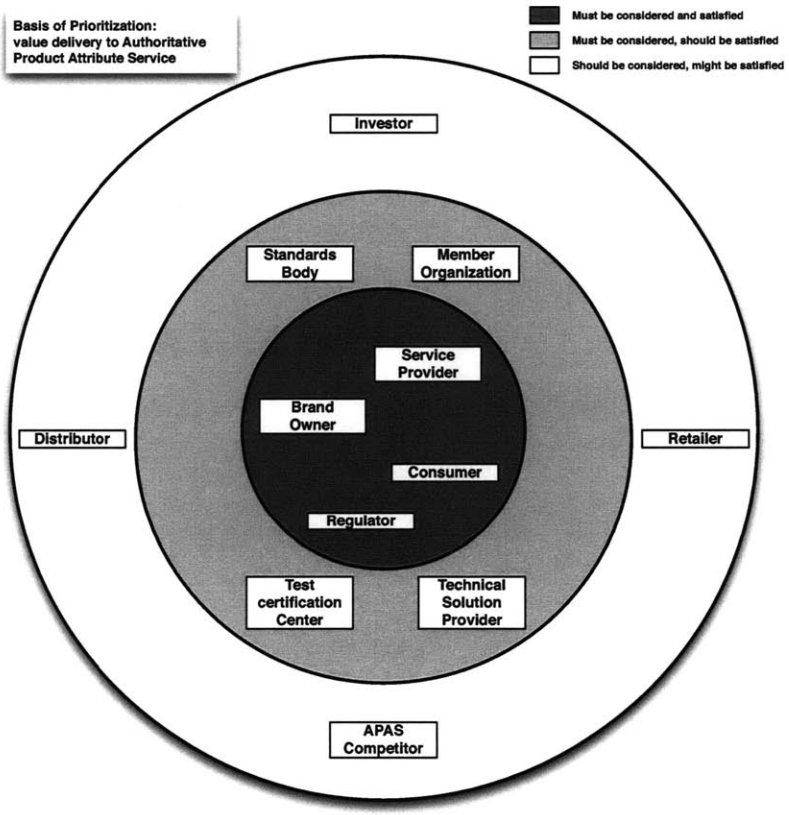


Figure 20: Prioritizing Stakeholders

However, in terms of the benefits they receive from the APAS, the main beneficiaries (or beneficial stakeholders) are consumers and brand owners - which are the principal users of the system. Since consumers benefit most from the functionalities provided by APAS, and APAS creates most value for them, the primary beneficiary is consumer[1].

Consumes will benefit from capabilities of protecting their rights to buy genuine products with correct status and through legitimate channels. They will also benefit from features such as trustful product attributes retrieval, attribute-based product comparison, product rating, commenting and recommendation.

Brand owners will benefit from direct customer-facing product marketing e.g. product recommendation, individualized coupon promotion, as well as direct user feedback on feature request and defect report. All of this means shorter user interaction cycles, more fragile to user demand variations, targeted and efficient product design, responsive product recall, as well as more effective in striking counterfeits.

6.2.2 The Goals of the System

The goals of the APAS system can be collectively described as:

- System aspects: APAS should demonstrate good performance, meet service-level agreement, have sufficient capacity, be able to access needed resources such as technologies and equipment, and should be designed in such a way that it is reusable, future-proof, cost-effective and easy to maintain.
- User aspects: APAS should satisfy users' requirement, not only on functions, but also on user-friendliness.
- Environment aspects: APAS should deal with regulatory issues, and should generate return on investment in the long-term.

[1] Due to the time and resource constraints, for this study, I limit the system architecture work on addressing the consumer only

Among these descriptive goals, some are critical to the success of the APAS, and are strictly constrained. Others are of relatively low importance, and are loosely constrained or even not constrained. These descriptive goals are categorized by importance and rigidity as follows:

Critical Goals

- Regulatory issues (comply with regulations and conform to industry standards, strictly constrained)
- Service level (accuracy, consistency, response time, availability, reliability etc., strictly constrained)
- System performance (throughput, latency, error rate, scalability, etc., strictly constrained)

Important goals

- Customer satisfaction (user-friendliness, affordability, accessibility, configuration flexibility, customer support)
- User friendliness (ease of use, flexible configurations) (loosely constrained)
- Access to technology and equipment (loosely constrained)
- Return on investment (loosely constrained)
- System capacity (storage, processing, network bandwidth, etc.) (loosely constrained)

Desirable goals

- Reusability (not constrained)
- Degree of future-proofing (not constrained)
- Cost-effectiveness (not constrained)
- Ease of maintenance (not constrained)

6.2.3 Testing Goals for Completeness, Consistency, and Attainability

For the goals developed, it is necessary to test their completeness, consistency, attainability and human resolvability. In general, goals are complete, if all upstream (e.g. from the users) influences are captured or reasonably excluded; goals are consistent, if performance metrics are not contradictory to each other; goals are attainable, if they can be met with allocated resources; goals are human resolvable, if goals are clear, concise, have their solution neutral forms, and are aligned with problem solving strategy. The workflow of goal testing is depicted in Fig. 21 [55].

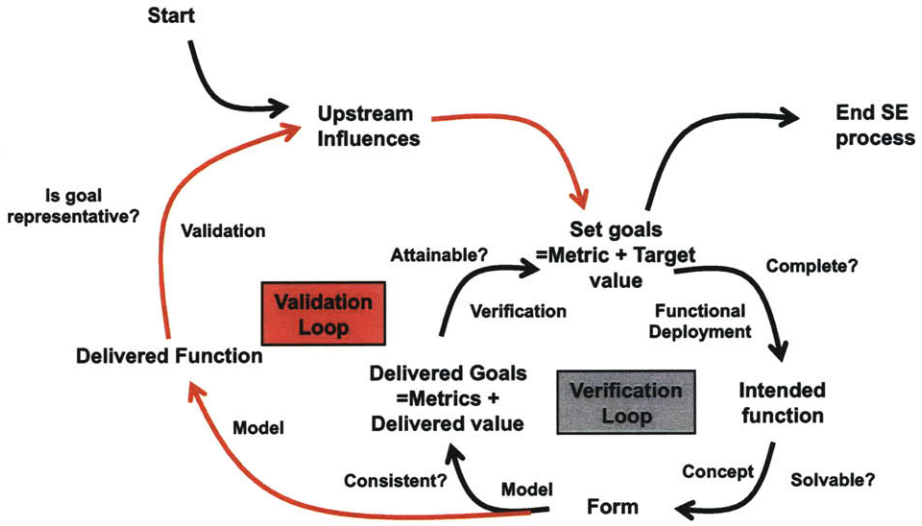


Figure 21: Workflow of Goal Testing

As part of the outer Validation Loop, the process starts with addressing influences of the upstream processes. In the inner Verification Loop:

- To test the completeness of the goals, it is necessary to verify whether influences from all upstream processes as captured, such as: financing, regulatory and pseudo-regulations, corporate strategy, customer needs, competition, employment as well as alignment with other enterprise ventures. Once the time functional description is made, goals are considered complete.

- To test the consistency of the goals, it is necessary to resolve and develop the concept and models, and perform logical examination (such as requirement review, walk through) or reference to the model, often times with the help of automation of goal/requirements/specifications.

- To test the attainability of the goals, it is necessary to simulate all goal metrics and their delivered value with the model, and verify whether product and strategic goals can be reached within technology limitations and meet development schedule, resource, and risk constraints.

- To test the human resolvability of the goals, it is necessary to verify whether goals are clear, concise, have their solution neutral forms, are aligned with problem solving strategy, and can help assign functions to forms.

Upon finishing the inner verification loop, the procedure returns to the outer Validation Loop. To test the representativeness of goals, it is mandatory to validate delivered function and other attributes against needs of corresponding upstream processes. This can be done through iterative validations on the notion of actual system in some abstract forms. Such validation and verification can go on and on for a number of iterations, until the process completes. If all upstream processes are verified and validated for completeness, consistency, human solvability, attainability, and if all goals are represented and meet their performance metrics, chances are all goals are met, and the needs of the stakeholders are satisfied.

6.3 Context of the Service System

Consider the APAS a designated 'Service System', it needs to be joined to and supported by other 'supporting systems' in order for the APAS to realize its functions and deliver its value. Some of the typical supporting systems are the legal system, the financial system, the

IT and Telecom infrastructure. The sum of the service system and the supporting systems constitute the 'whole service system', as illustrated in Fig. 22 [55]. Here the whole service system lies within a larger use context.

Such context can be understood as mobile commerce, secure supply chain, globalization, competitive landscape, product counterfeit, as addressed in Section 4.2.

Use context, whole service system and service system constitute three layers of views of the system - at use context layer, it is possible to zoom-in to the smaller whole service system, and further to service system. Vice versa, at the service system layer, depends on the type of issue to resolve, one might zoom-out to the bigger whole service system, and further to the use context. Zooming is a principle of system architecting.

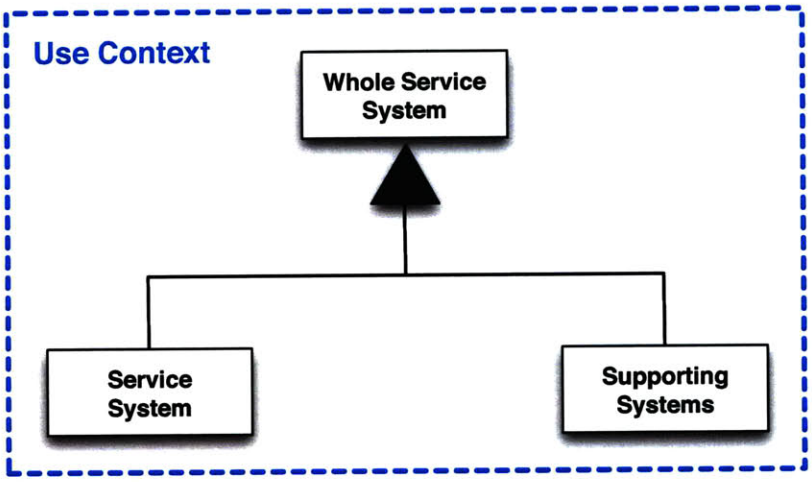


Figure 22: Service System and Its Context

6.4 System Goal Statement, Intent and Concept

With a clear, complete, consistent and attainable set of goals defined, and a broader context in which the APAS service system sits described, it is ready to formulate the concept of the system.

Simply put, concept is a system notion, idea or mental image which maps function to form. It is a combination of specific system operating process and operand, specific system

form object, and related through the generic form object, as depicted in Fig. 23 [55].

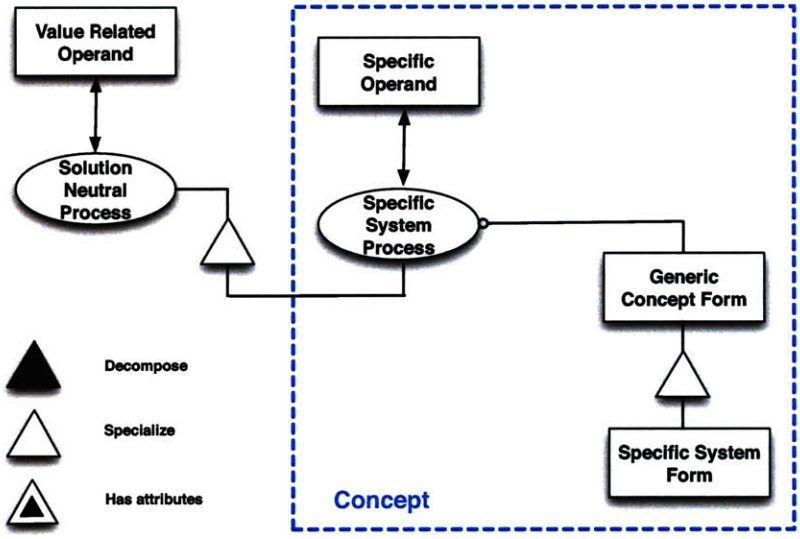


Figure 23: Formation of The Concept

Within the concept, a system always operates on one or more operands. Here, an operand refers to the object that a process of a system is acted upon. Value delivery of the service system hinges on changing the attribute of one of the operands that is associated with value creation for the users of the system. Due to its importance to value creation, it is necessary to specially designate the value related operand.

It is worth noting that a product is unity of both its physical form and its informational representation - it covers the physical word plus the informational world. Hence, the top level operand (also called level 0) is the product.

As shown in Fig. 25, in the case of APAS Service System, there are a number of operands that the processes of the APAS might operate on, e.g. the informational description of the product (including product attributes), the tag/identity code of the product, and label, the packaging and so on. I consider product information the value-related operand, and product attributes the value related attribute.

Accordingly, the solution-neutral statement of value related transformation is providing, and the solution-specific statement of value related transformation is describing. Important attributes of value-related operand and solution-neutral transformation are, providing authoritative information of a product should be user-friendly, cost-effectively and with good service level to the users. In the same vein, important attributes of solution-specific transformation are authentically, accurately, consistently, and reliably.

Hence, a general level0 system goal statement is:

> To *provide information of a product to the users of the service system user-friendly, cost-effectively and with good service level*
>
> By *describing product information authentically, accurately, consistently, and reliably*
>
> Using *a Product Attribute Service.*

However, this is way too broad and vague for this study, and is not specifically tailored to the need of the primary beneficiary – the consumer. Therefore, I have revised the level0 system goal statement as follows:

> To *provide authoritative information of a product to the consumer user-friendly, cost-effectively and with good service level*
>
> By *describing key product attributes of identifiable products authentically, accurately, consistently, and reliably*
>
> Using *an Authoritative Product Attribute Service backed mobile application that is GS1 Standards Compatible.*

This level0 goal statement is with these descriptive goals:

- user friendliness goal

- cost-effectiveness goal
- good service level goal
- authenticity goal
- accuracy goal
- consistency goal
- reliability goal
- standard compatibility goal

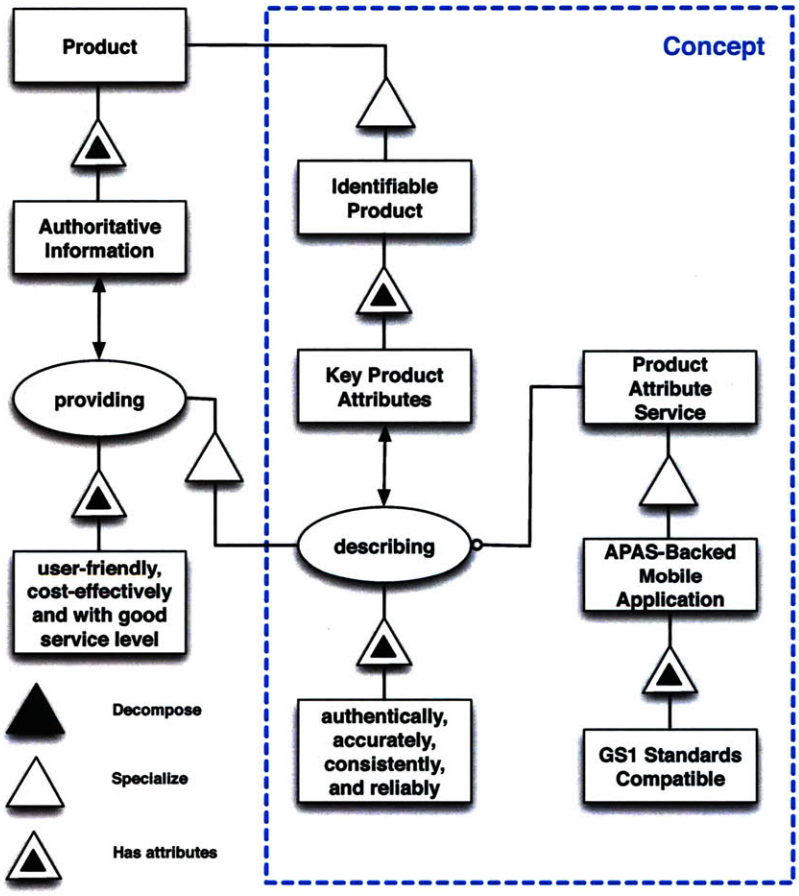


Figure 24: APAS-backed Mobile Application: System Concept

The revised level0 system goal statement gives rise to the concept of the system – map the function of 'describing key product attributes of an identifiable product authentically, accurately, consistently, and reliably', to the form of 'Authoritative Product Attribute Service-backed mobile application, which is GS1 standards compatible', as described in Fig. 24.

Fig. 25 below gives a broader picture that covers the need of the user (primary beneficiary), the goal/intent of the system, the top-level function, as well as the top-level form. The allocation of the top-level function to the top-level form, with the interface of mobile application, constitutes the system concept.

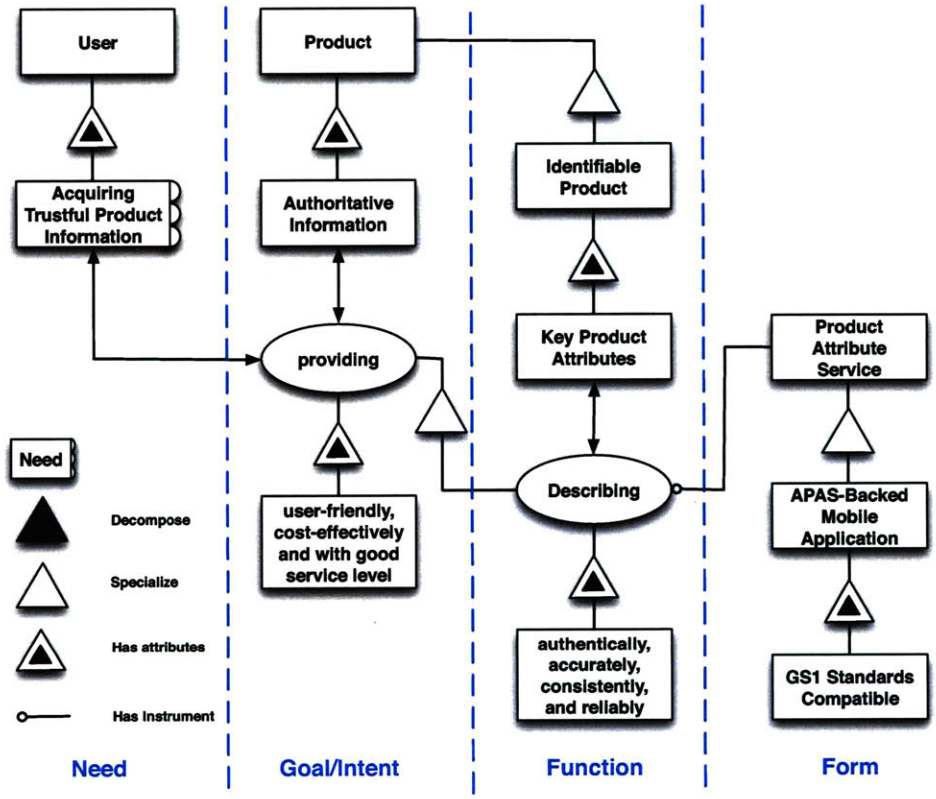


Figure 25: APAS: Need, Intent, and Function to Form Mapping

At this stage, it can be easily understood that within the level0 goal framework, the value-related and primary process within the function is *describing key product attributes*, while the operand it operates on is *an identifiable product*. The object (as part of form) is

Authoritative Product Attribute Service-backed mobile application. Here are, however, a number of supporting processes that are related to value creation and delivery, as detailed in Table 6. Together with the operands they operate on, the interfaces, as well as the form the function is allocated to, they make up the level0 architecture of the APAS.

Table 6: APAS Level0 System Arhitecture

Process	Operand	Interface	Form
Describing critical product attributes	Product Info	Browser	APAS-backed Mobile App.
Authenticating user	User Profile	Browser	
Authorizing user access rights	User Profile	Browser	
Allowing user configuration	User Profile	Browser	
Identifying product	Product Info	Tag/Code	
Ensuring user friendliness	Service Level	Browser	
Building global registry service	Registry	Web	
Discovering APAS service provider	Session	Web	
Providing communication mechanism	Session	Web	
Ensuring service level	Service Instance	Browser	

6.5 Example Decomposition and Interfacing

To derive the level1 goals, a general rule of thumb is that the aforementioned level 0 processes (part of level0 function) become the level 1 goals. Following this guideline, the primary process of level0 function 'describing key product attributes' is used to develop one of the level1 goal. [2]

An example level1 system goal statement could be:

[2]Due to space and resource limit, I will be focusing only on the level0 primary process and its decomposition.

To *describe key product attributes of identifiable products authentically, accurately, consistently, and reliably*

By *transforming key product attributes according to GS1 standards*

Using *APAS backend server application*

While also (supporting processes):

- Capturing product data from existing supply chain data pools
- Performing validation of product data on authenticity, accuracy, consistency and timeliness
- Defining data schema for authoritative product attributes
- Constructing APAS repository for storage, backup, query and update
- Formatting data for delivery of key product attributes to the APAS client
- Delivering key product attributes to the APAS client

Decompose the level0 processes has resulted in the above level1 primary process and supporting processes. Associating them with operands constitutes level1 functions. Allocating these functions to form, as well as defining the interfaces make up the level1 architecture for APAS. Table 7 shows part of the architecture as the result of decomposition of level0 primary process.

At this stage, I have:

- Defined a clear, complete, consistent and attainable set of function-oriented goals.
- Described the context the system operates, and the whole service context.
- Described the concept of the APAS.

Table 7: APAS Level1 System Arhitecture

Process	Operand	Interface	Form
Transforming key product attributes	Product data	API to APAS Server conversion engine	APAS Server application
Capturing product data from existing supply chain data pools	Product data	API to GDSN and/or EPCIS	APAS Server application
Performing validation of product data	Product data	API to APAS Server validation engine	APAS Server application
Defining data schema for authoritative product attributes	Relational database tables	Database Management System Interface and driver	Database Management System
Constructing APAS repository for storage, backup, query and update	Relational database tables and storage space	Database Management System Interface and driver	Database Management System
Formatting data for delivery of key product attributes to the APAS client	Product attributes (information)	API to JSON Generator	JavaScript Object Notation (JSON) file
Delivering key product attributes to the APAS client	IP Packets	API to Protocol Stack, socket interface	Network interface (HW) and protocol stack (SW)

- Described the main function of the system, and decomposed it.
- Described the highest level form of the system, and decomposed it.
- Ensured functional decomposition is performed and interfaces are in controlled form.

Due to space limit, it is more appropriate to cover the complete decomposition of all related functions and forms for the remaining part of level1, and also down to level2. Furthermore, as preparation for deployment and operation, it is necessary to analyze timing, operator attributes, costs, risks, and the implementation, operation and evolution plans. These aspects are considered a logical part of future work.

CHAPTER VII

PROTOTYPING AUTHORITATIVE PRODUCT ATTRIBUTE SERVICE

7.1 Development Environment

7.1.1 Hardware Platforms

The software development for APAS was carried out on such hardware configurations:

- APAS Server: MacPro4.1, Intel Xeon Quad-Core 2.66 GHz, 8 GB RAM, 4-bay Hardware RAID5, Gigabit Ethernet network interface, running Mac OS X Server 10.6.3 (10D573) Advanced with Darwin 10.3.0 Kernel.
- APAS Client: MacBookPro5.1, Intel Core 2 Duo 2.4 GHz, 4GB RAM, AirPort Extreme (802.11 a/b/g/n) network interface, running Mac OS X 10.6.3 (10D573) with Darwin 10.3.0 Kernel.
- APAS Mobile Client: Google/HTC Nexus One: Qualcomm QSD 8250 1.0 GHz CPU, 512 MB RAM, 3.7 inch (diagonal) widescreen WVGA AMOLED touchscreen with 800 x 480 pixels, HSDPA 7.2 Mbps/HSUPA 2 Mbps and Wi-Fi (802.11b/g) network interfaces, running Android Mobile Technology Platform 2.1 (Eclair).

7.1.2 Agile Software Development Method

Agile software development is known as a number of software development methodologies for projects that are highly iterative by nature. In such projects, requirements change on-the-fly and solutions evolve as result of tight collaboration between and within self-organizing cross-functional teams. Extreme Programming (XP) is an example and is used

in the development of APAS.

The XP method emphasizes on short development cycles and frequent software releases, code reviews, testing and adaptation. With this, XP is well suited for rapid prototyping and implementation of high-quality software solutions that are aligned with requirements of customers and other stakeholders. Also, it can avoid costly rework that sources from deeply down in the workflow due to late detection.

7.1.3 Ruby on Rails Development Framework

Ruby on Rails [56] is an open source web application framework by utilizing the Ruby language [57], a high-level object-oriented programming language similar to Java. Used jointly with an Agile method, RoR is nowadays a mainstream web development framework for rapid development, deployment, and maintenance of web applications.

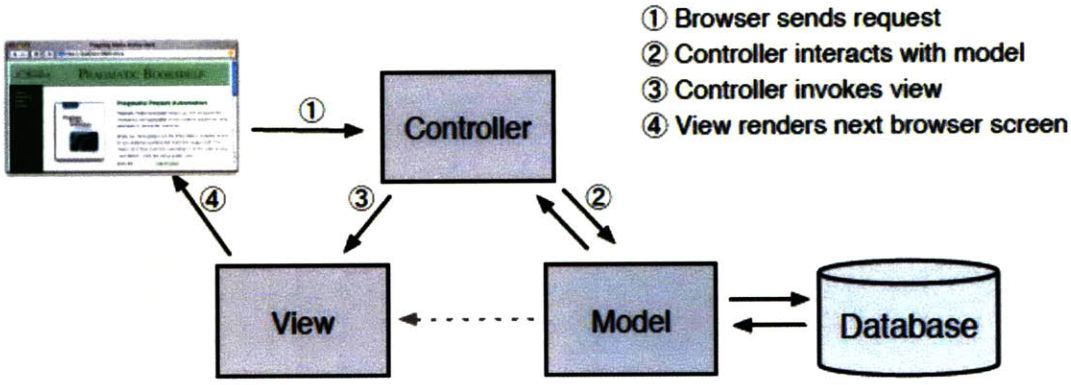


Figure 26: Model-View-Controller Structure (Source: Pragmatic)

Similar to many web development frameworks, RoR uses a structure dubbed ''Model-View-Controller' (MVC) (see Fig. 26 [56]) to organize web applications' code space. However, superior to other options, RoR has a built-in set of tools to get web-development head start really quick. These tools include i) 'Scaffolding' that can automatically generate part of the models and views essential for operating a website; ii) the build system 'Rake'; iii) the web server 'Mongrel'; iv) the database manipulation tool 'Migration'; v) automated tests. Rails automatically creates test stubs in parallel to coding. These tools and Rails

together provide a basic development environment for backend web applications.

For Authoritative Product Attribute Service, the core APAS web backend has been developed with RoR, which includes two separate services: service for the brand owners to participate in building the APAS repository, and service for the users of APAS (i..e. APAS client) to access key product attributes. The former service is organized into the package 'gs1dir_mgmt', and for the later one 'gs1dir_products'.

7.1.4 Eclipse Integrated Development Environment

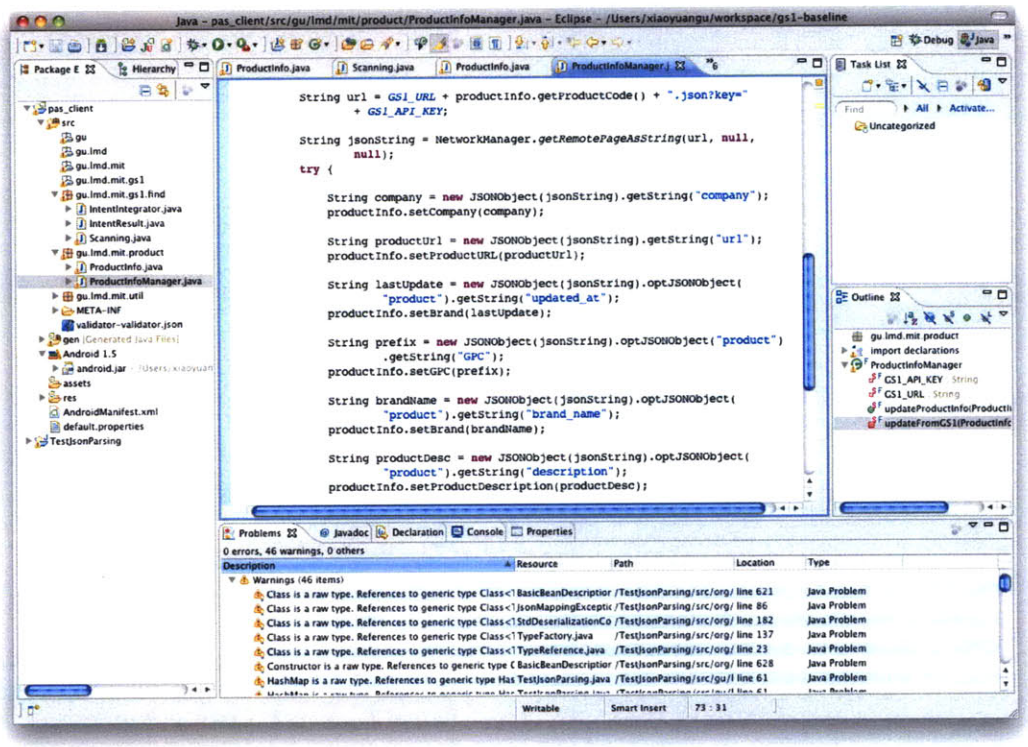


Figure 27: Eclipse Integrated Development Environment

Eclipse [58] is an open source integrated software development environment (IDE). Written in Java, Eclipse can be used to develop industry-strength software with all major programming languages. The real strength of Eclipse is its open and extensible plug-in system. By deploying plug-ins, Eclipse provides countless new functionalities on top of

the (relatively small) runtime system.

The Eclipse runtime system hinges on the Rich Client Platform (RCP) (shown in Fig. 27) that consists of the following components: i) the Core platform that boots Eclipse and runs plug-ins; ii) the JFace that enables the MVC structure; iii) the Eclipse Workbench that manages views, editors, perspectives, and wizards; iv) the bundling framework Equinox OSGi; v) the Standard Widget Toolkit (SWT).

For this project, the Eclipse Java Development Tools (JDT) is used for the development of the APAS client application, and part of the APAS server application related to building the APAS repository. The software development work of APAS benefited from Eclipse's integrated approach, powerful debugging functions, as well as seamless interworking with the Android Software Development Kit (addressed in the next section).

7.1.5 Android Software Development Kit

Android [59] is a open source software stack initiated by Google for mobile devices. It includes a Linux-based operating system, middleware and key applications.

The basic architecture of Android (shown in Fig. 28) includes 5 top-level elements. From bottom up, these are the Linux Kernel, the runtime and libraries, the application framework, and Android applications. APAS client is designed as an Android native application. It reuses the Barcode Scanner 3rd party Android application for barcode recognition. It also uses the Activity Manager, Window Manager, View System etc. in the Application Framework. In addition, It adopts the Webkit and SSL from the Libraries, as well as leverages the display, camera and network interface drivers of the kennel.

The Android Software Development Kit (SDK) provides APIs and tools essential to develop applications for the Android platform using the Java programming language. It seamlessly integrates with the Eclipse IDE with the ADT Plugin. Debugging for Android application is made easy with the Android Virtual Device (see Fig. 29) and Android Debugger (see Fig. 30).

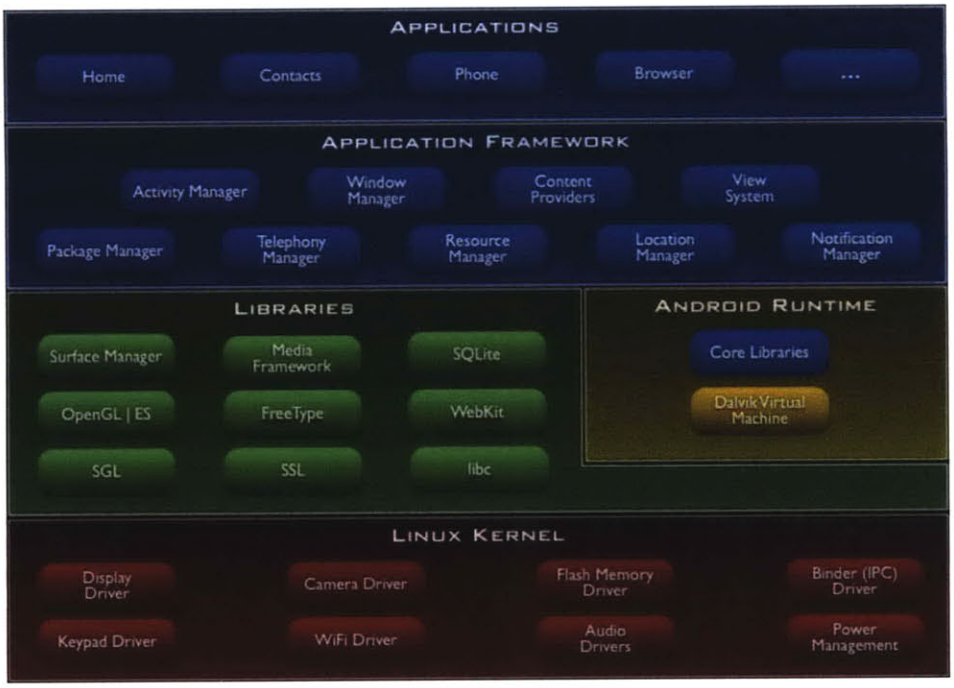


Figure 28: Architecture of Android (Source: Android)

Figure 29: Android Virtual Device as Part of the Android Development Kit

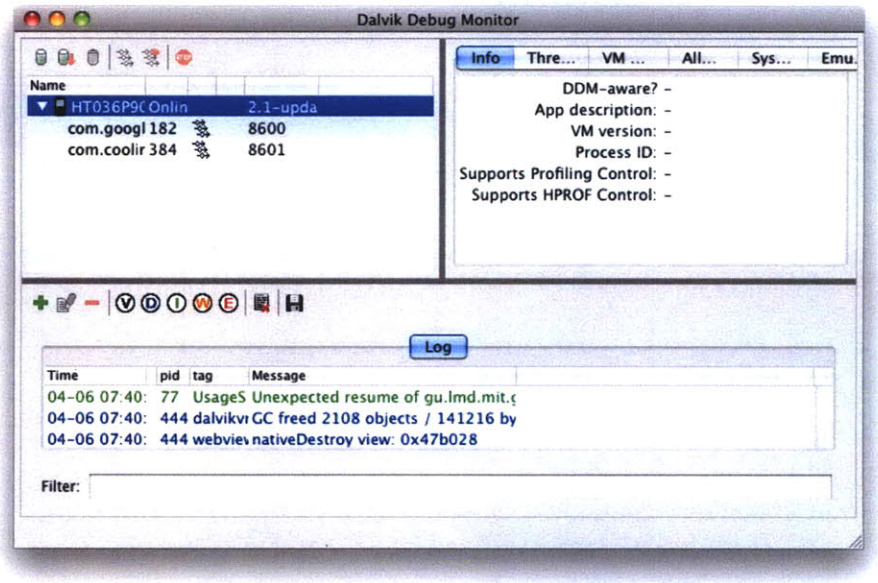


Figure 30: Android Debugger as Part of the Android Development Kit

7.1.6 Configuration Management with Subversion

Subversion [60] and command name svn [61] is an open source software configuration & change management and revision control tool. It is now called Apache Subversion.

Subversion enables collaborative editing and sharing of data. Conventional revision control systems that use a lock-modify-unlock model to prevent accidental override due to concurrent editing on the very same data. With such system only one user who acquires the lock is able to commit changes. Problems associated with this LMU approach are three-fold: hefty administration overhead, unnecessary serialization and false sense of security.

Subversion uses a Copy-Modify-Merge approach. With this approach users can work concurrently and makes changes without any locks. They each have a personal working copy of the central repository's files and directories. Subversion can intelligently merge the changes made by the users and resolve conflicts if necessary. As a result, productivity is greatly boosted and administrative overhead is minimum.

In the development of APAS, Subversion is used throughput – for configuration &

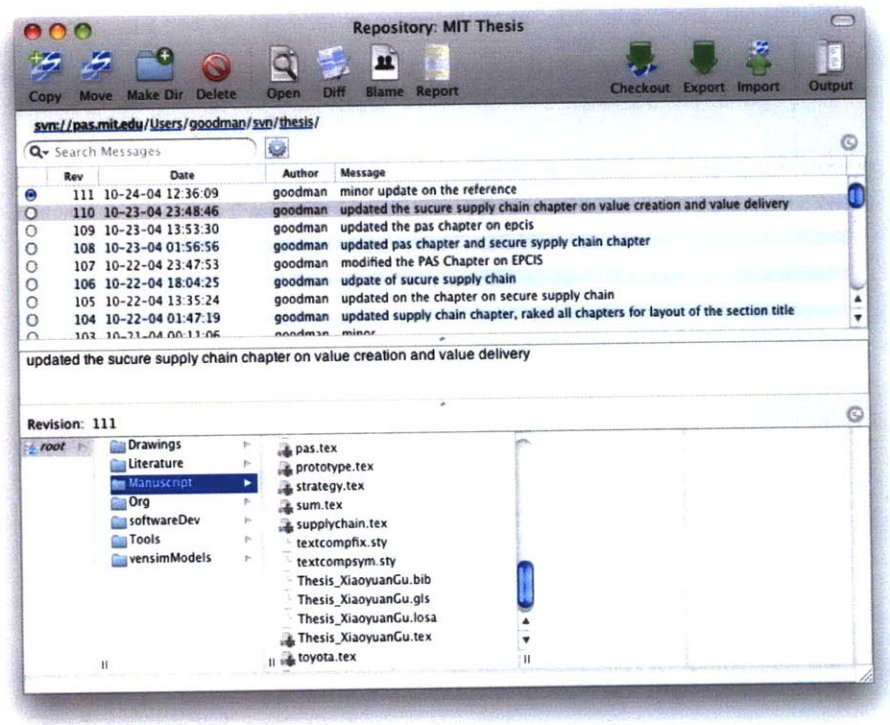


Figure 31: SVN Repositories Used for Configuration Management

change management of concurrent software development, as well as for authoring this thesis (shown in Fig. 31).

7.2 The APAS Frontend

7.2.1 PC Frontend

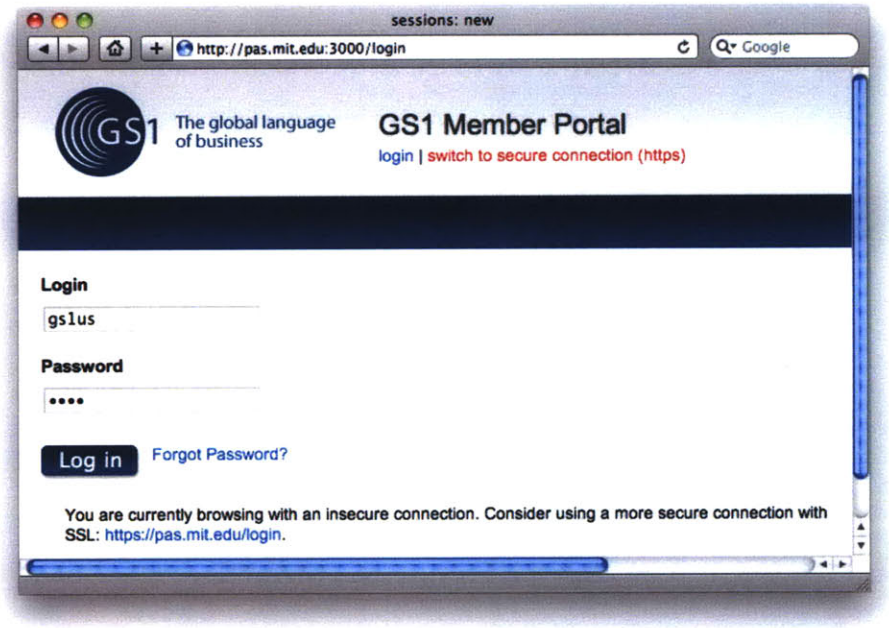


Figure 32: Web Interface for Brand Owners

The PC-based frontend of APAS is primarily designed for the brand owners to insert product attributes related records into the APAS repository. The start page of the web interface is shown in Fig. 32. And it is also used as a secondary or backup product attributes lookup service to the primary mobile based APAS client. This is helpful in case a user does not have access to handset with Internet connections, or the handset does not have a built-in camera or cannot scan a barcode or read an IFID tag (a future feature).

Fig. 33 shows the query of an HP InJect cartridge by inserting its GTIN code with a PC-based browser. The query result is given in Fig. 34. Only some of the key product

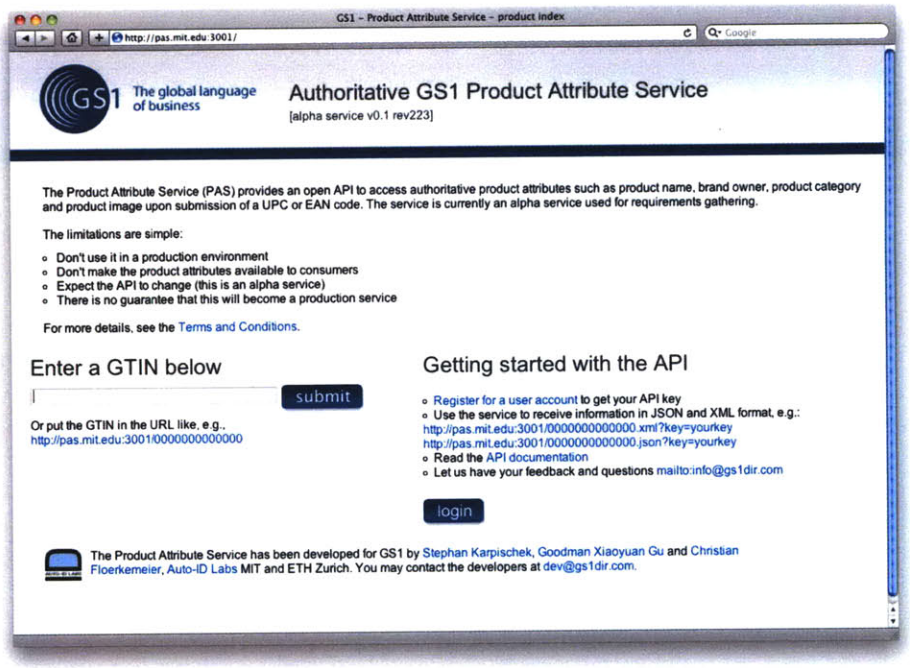


Figure 33: PC-based APAS Client (Start)

attributes are presented for demonstration purpose.

7.2.2 Mobile Frontend

The android-based APAS mobile client has been developed within the scope of this work. The appearance of the APAS mobile client as a Google Android application is shown in Fig. 35. It is on the first row and second column of the phone screen, with the application name GS1 APAS and an Android Application icon.

Double clicking the application icon will bring up the startup page of the APAS client application. As shown in Fig. 36, the interface showing the GS1 logo and a button to allow to trigger product code scanning (in this case barcode).

Fig. 37 shows barcode scanning in action, with the user aligning scanning area and the built-in camera of the cellphone adjusting focus.

With the scanned barcode and the application performs image recognition and decoding of the barcode. If this step is successful, the user is notified, as show in Fig 38.

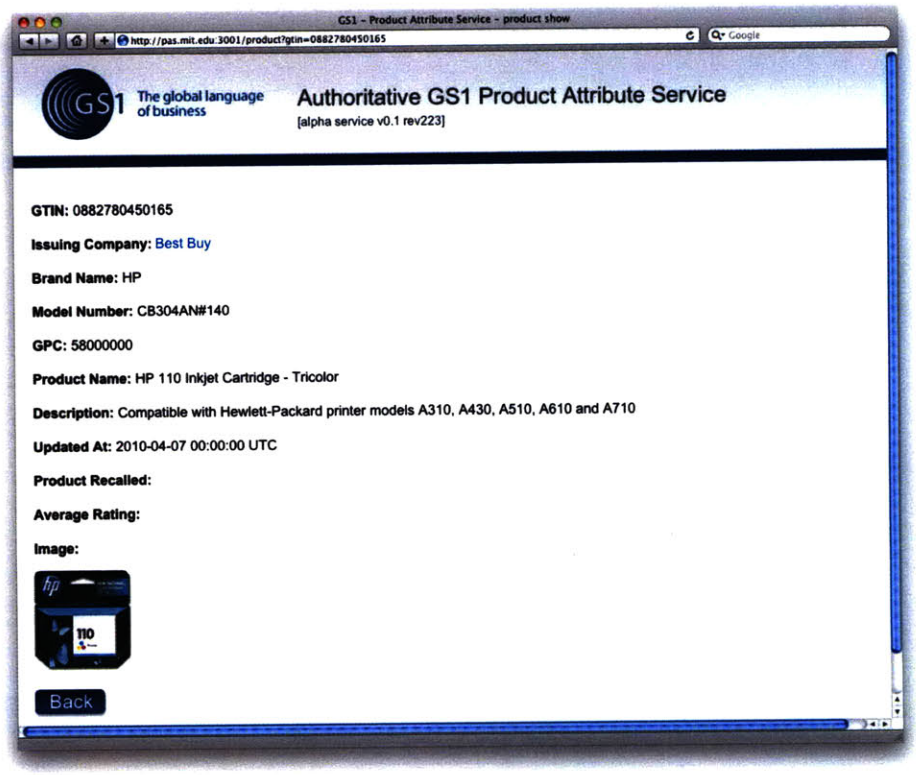


Figure 34: PC-based APAS Client (Result)

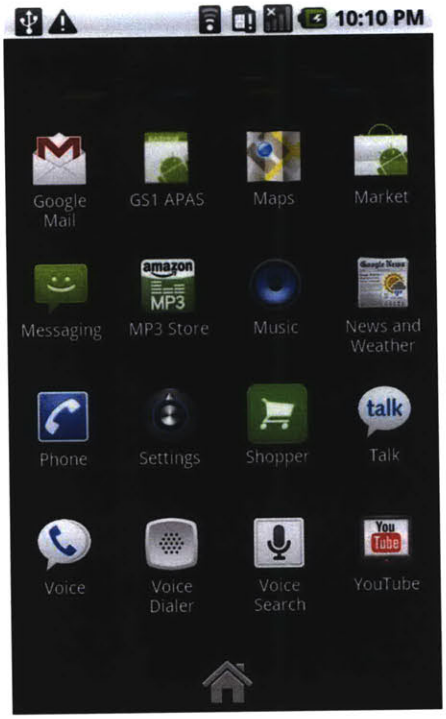


Figure 35: APAS as a Google Android Mobile Application

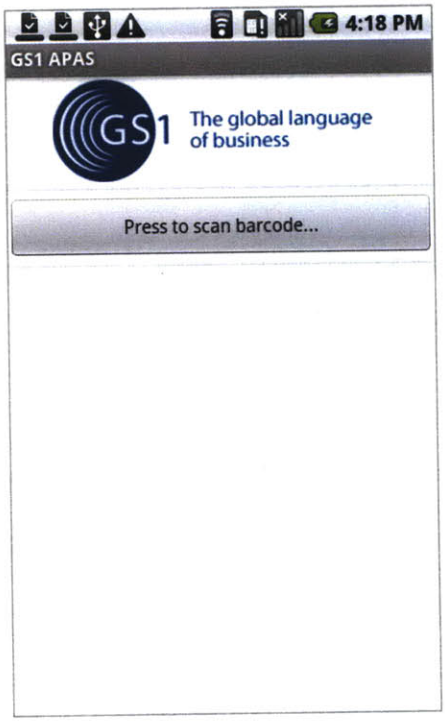


Figure 36: The Launch Page of the APAS Mobile Client

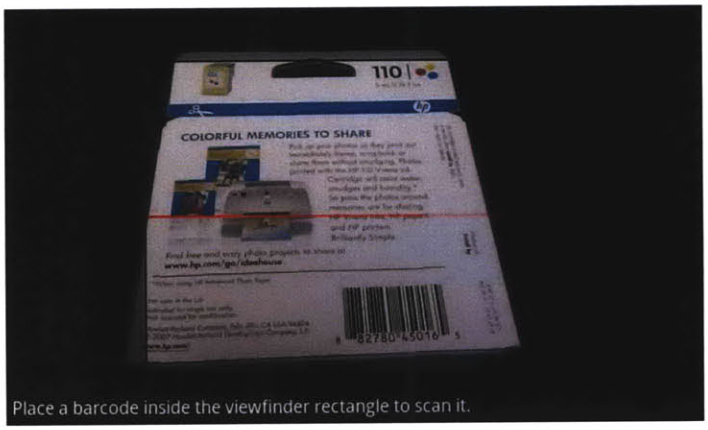


Figure 37: Barcode Scanning in Action

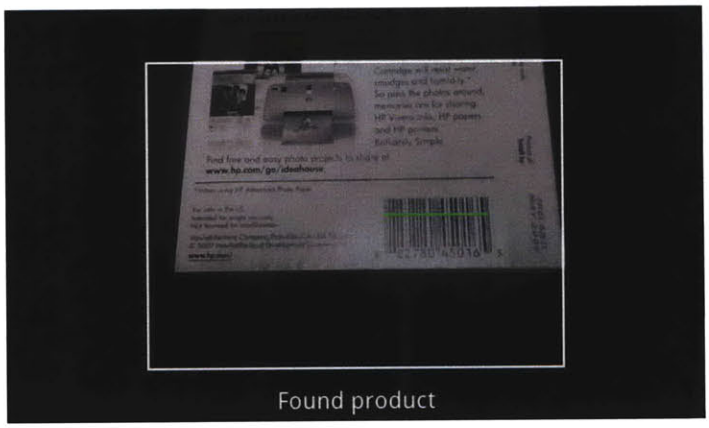


Figure 38: Notification of Successful Product Code Recognition and Decoding

The APAS client then interacts with the APAS backend to query for product attributes associated with the product code (in this case GTIN). The APAS server returns the results in forms of a JSON file via the web, and the APAS client parse the file and extract relevant product attributes and format the data using standard html page, as shown in Fig. 39.

Figure 39: Authoritative Product Attributes Rendering on the Mobile Front End

7.3 The APAS Backend

The backend APAS package dubbed 'gs1dir_gs1dir_mgmt' are developed to fulfill these functions that were defined in Section 6.5 in the level0 architectural design of APAS:

- Authenticating user: this is done by allow users to register as member, and allocate the API key to them.
- Authorizing user access rights: this is done mainly for a brand owner to have full access only to the products it is responsible for based on its 'Company Prefix' .
- Identifying product: this is done by uniquely identifying a class of products with

GTIN, at the product attribute databases, the JSON file transmitted, the product barcode scanned, and the product attribute result rendered.

- Ensuring user friendliness: this is done by providing clean and easy Graphic User Interface for the mobile client, and straight-forward web client.

- Providing communication mechanism: this is done by adopting standard communication protocols for IP-based networks, and using the API key for encryption to ensure security.

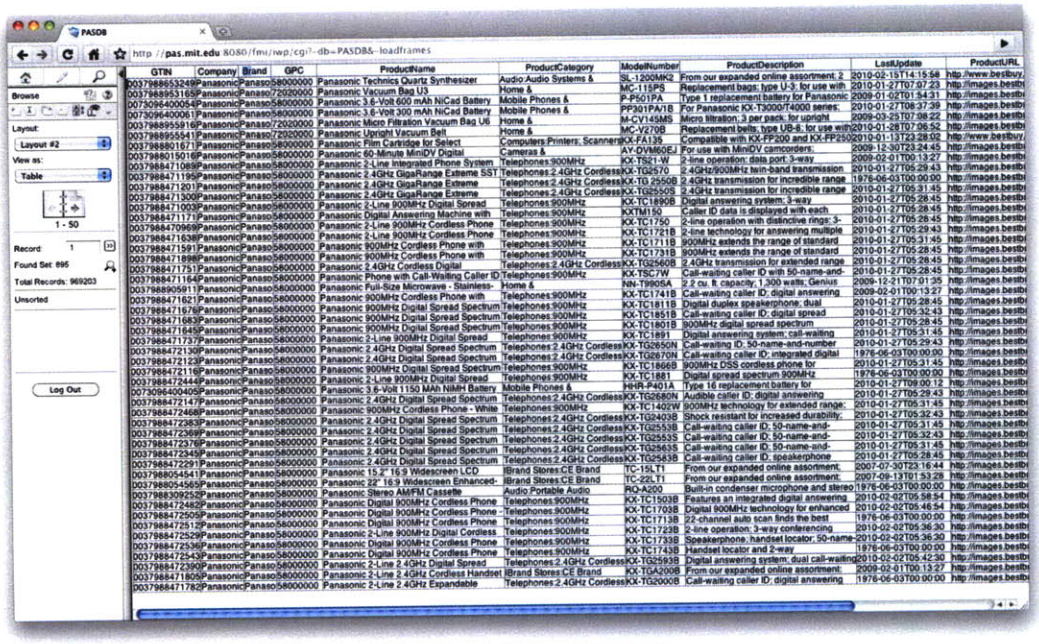
The backend APAS package dubbed 'gs1dir_products' are developed to fulfill these functions that were defined in Section 6.5 in the level1 architectural design of APAS:

- Capturing product data from existing supply chain data pools: this is done from two source at the current stage: Best Buy Remix in the US [62] and GS1 Canada.

- Transforming key product attributes according to GS1 standards: this is done with: i) parsing the Best Buy Remix product archives in JSON format [63], and utilizing the JACKSON [64] parsing library; ii) transforming the proprietary Best Buy product category types to GS1 GPC codes, and the UPC codes used by Best Buy to GS1 standard 13-bit GTIN codes and assigning code format.

- Defining data schema for authoritative product attributes: this is done within the productInfo package at the codebase, and the design of the FileMaker and SQLite database schemas. The later uses a Ruby file for its database schema.

- Constructing APAS repository for storage, backup, query and update: this is done by using the FileMaker [65] database for online web browser-based viewing (see Fig. 40) and updating of database records, local database management (see Fig. 41) and the development.sqlite3 local database to power the APAS server instance.



GTIN	Company	Brand	GPC	ProductName	ProductCategory	ModelNumber	ProductDescription	LastUpdate	ProductURL
00037988653249	Panasonic	Panaso	58000000	Panasonic Technics Quartz Synthesizer	Audio:Audio Systems &	SL-1200MK2	From our expanded online assortment: 2	2010-02-15T14:15:58	http://www.bestbuy.
00037988953165	Panasonic	Panaso	72020000	Panasonic Vacuum Bag U3	Home &	MC-15PS	Replacement bags; type U-3; for use with	2010-01-27T07:07:23	http://images.bestb
00730964000548	Panasonic	Panaso	58000000	Panasonic 3.6-Volt 600 mAh NiCad Battery	Mobile Phones &	P-P501PA	Type 1 replacement battery for Panasonic	2009-01-02T01:54:31	http://images.bestb
00730964000616	Panasonic	Panaso	58000000	Panasonic 3.6-Volt 300 mAh NiCad Battery	Mobile Phones &	PP301PA/1B	For Panasonic KX-T3000/T4000 series;	2010-01-27T08:37:39	http://images.bestb
00037988955916	Panasonic	Panaso	72020000	Panasonic Micro Filtration Vacuum Bag U6	Home &	M-CV145MS	Micro filtration; 3 per pack; for upright	2009-03-25T07:08:22	http://images.bestb
00037988955541	Panasonic	Panaso	72020000	Panasonic Upright Vacuum Belt	Home &	MC-V270B	Replacement belts; type UB-6; for use with	2010-01-28T07:06:52	http://images.bestb
00037988801671	Panasonic	Panaso	58000000	Panasonic Film Cartridge for Select	Computers:Printers; Scanners	KX-FA135	Compatible with KX-FP200 and KX-FP250	2010-01-13T23:28:02	http://www.bestbuy.
00037988015016	Panasonic	Panaso	58000000	Panasonic 60-Minute MiniDV Digital	Cameras &	AY-DVM60EJ	For use with MiniDV camcorders;	2009-12-30T23:24:45	http://images.bestb
00037988471089	Panasonic	Panaso	58000000	Panasonic 2-Line Integrated Phone System	Telephones:900MHz	KX-T931-W	2-line operation; data port; 3-way	2009-02-01T00:13:27	http://images.bestb
00037988471195	Panasonic	Panaso	58000000	Panasonic 2.4GHz GigaRange Extreme SST	Telephones:2.4GHz Cordless	KX-TG2570	2.4GHz/900MHz twin-band transmission	2010-01-27T05:29:43	http://images.bestb
00037988471201	Panasonic	Panaso	58000000	Panasonic 2.4GHz GigaRange Extreme	Telephones:2.4GHz Cordless	KX-TG2550B	2.4GHz transmission for incredible range	1976-06-03T00:00:00	http://images.bestb
00037988471300	Panasonic	Panaso	58000000	Panasonic 2.4GHz GigaRange Extreme	Telephones:2.4GHz Cordless	KX-TG2550S	2.4GHz transmission for incredible range	2010-01-27T05:31:45	http://images.bestb
00037988471003	Panasonic	Panaso	58000000	Panasonic 2-Line 900MHz Digital Spread	Telephones:900MHz	KX-TC1880B	Digital answering system; 3-way	2010-01-27T05:28:45	http://images.bestb
00037988471171	Panasonic	Panaso	58000000	Panasonic Digital Answering Machine with	Telephones:900MHz	KXTM150	Caller ID data is displayed with each	2010-01-27T05:28:45	http://images.bestb
00037988470969	Panasonic	Panaso	58000000	Panasonic 2-Line 900MHz Cordless Phone	Telephones:900MHz	KX-TC1750	2-line operation with distinctive rings; 3-	2010-01-27T05:29:43	http://images.bestb
00037988471638	Panasonic	Panaso	58000000	Panasonic 2-Line 900MHz Cordless Phone	Telephones:900MHz	KX-TC1721B	2-line technology for answering multiple	2010-01-27T05:31:45	http://images.bestb
00037988471591	Panasonic	Panaso	58000000	Panasonic 900MHz Cordless Phone with	Telephones:900MHz	KX-TC1711B	900MHz extends the range of standard	2010-01-27T05:28:45	http://images.bestb
00037988471898	Panasonic	Panaso	58000000	Panasonic 900MHz Cordless Phone with	Telephones:900MHz	KX-TC1731B	900MHz extends the range of standard	2010-01-27T05:28:45	http://images.bestb
00037988471751	Panasonic	Panaso	58000000	Panasonic 2.4GHz Cordless Digital	Telephones:2.4GHz Cordless	KX-TG2560B	2.4GHz transmission for extended range	2010-01-27T05:28:45	http://images.bestb
00037988471164	Panasonic	Panaso	58000000	Panasonic Phone with Call-Waiting Caller ID	Telephones:900MHz	KX-TSC7W	Call-waiting caller ID with 50-name-and-	2010-01-27T05:28:45	http://images.bestb
00037988905911	Panasonic	Panaso	58000000	Panasonic Full-Size Microwave - Stainless-	Home &	NN-T965SA	2.2 cu. ft. capacity; 1,300 watts; Genius	2009-12-21T07:01:35	http://images.bestb
00037988471621	Panasonic	Panaso	58000000	Panasonic 900MHz Cordless Phone with	Telephones:900MHz	KX-TC1741B	Call-waiting caller ID; digital answering	2009-02-01T00:13:27	http://images.bestb
00037988471676	Panasonic	Panaso	58000000	Panasonic 900MHz Digital Spread Spectrum	Telephones:900MHz	KX-TC1811B	Digital duplex speakerphone; dual	2010-01-27T05:28:45	http://images.bestb
00037988471683	Panasonic	Panaso	58000000	Panasonic 900MHz Digital Spread Spectrum	Telephones:900MHz	KX-TC1851B	Call-waiting caller ID; digital spread	2010-01-27T05:32:43	http://images.bestb
00037988471645	Panasonic	Panaso	58000000	Panasonic 900MHz Digital Spread Spectrum	Telephones:900MHz	KX-TC1801B	900MHz digital spread spectrum	2010-01-27T05:28:45	http://images.bestb
00037988471379	Panasonic	Panaso	58000000	Panasonic 2-Line 900MHz Digital Spread	Telephones:900MHz	KX-TC1891	Digital answering system; call-waiting	2010-01-27T05:31:45	http://images.bestb
00037988472130	Panasonic	Panaso	58000000	Panasonic 2.4GHz Digital Spread Spectrum	Telephones:2.4GHz Cordless	KX-TG2650N	Call-waiting ID; 50-name-and-number	2010-01-27T05:29:43	http://images.bestb
00037988472123	Panasonic	Panaso	58000000	Panasonic 2.4GHz Digital Spread Spectrum	Telephones:2.4GHz Cordless	KX-TG2870N	Call-waiting caller ID; integrated digital	1976-06-03T00:00:00	http://images.bestb
00037988472116	Panasonic	Panaso	58000000	Panasonic 900MHz Digital Spread Spectrum	Telephones:900MHz	KX-TC1866B	900MHz DSS cordless phone for	2010-01-27T05:31:45	http://images.bestb
00037988472444	Panasonic	Panaso	58000000	Panasonic 2-Line 900MHz Digital Spread	Telephones:900MHz	KX-TC1881	Digital spread spectrum 900MHz	1976-06-03T00:00:00	http://images.bestb
00730964000405	Panasonic	Panaso	58000000	Panasonic 3.6-Volt 1150 MAh NiMH Battery	Mobile Phones &	HHR-P401A	Type 16 replacement battery for	2010-01-27T09:00:12	http://images.bestb
00037988472147	Panasonic	Panaso	58000000	Panasonic 2.4GHz Digital Spread Spectrum	Telephones:2.4GHz Cordless	KX-TG2680N	Audible caller ID; digital answering	2010-01-27T05:29:43	http://images.bestb
00037988472468	Panasonic	Panaso	58000000	Panasonic 900MHz Cordless Phone - White	Telephones:900MHz	KX-TC1402W	900MHz technology for extended range;	2010-01-27T05:31:45	http://images.bestb
00037988472383	Panasonic	Panaso	58000000	Panasonic 2.4GHz Digital Spread Spectrum	Telephones:2.4GHz Cordless	KX-TG2403B	Shock resistant for increased durability;	2010-01-27T05:32:43	http://images.bestb
00037988472369	Panasonic	Panaso	58000000	Panasonic 2.4GHz Digital Spread Spectrum	Telephones:2.4GHz Cordless	KX-TG2553S	Call-waiting caller ID; 50-name-and-	2010-01-27T05:31:45	http://images.bestb
00037988472376	Panasonic	Panaso	58000000	Panasonic 2.4GHz Digital Spread Spectrum	Telephones:2.4GHz Cordless	KX-TG2553S	Call-waiting caller ID; 50-name-and-	2010-01-27T05:32:43	http://images.bestb
00037988472345	Panasonic	Panaso	58000000	Panasonic 2.4GHz Digital Spread Spectrum	Telephones:2.4GHz Cordless	KX-TG2563S	Call-waiting caller ID; 50-name-and-	2010-01-27T05:31:45	http://images.bestb
00037988472291	Panasonic	Panaso	58000000	Panasonic 2.4GHz Digital Spread Spectrum	Telephones:2.4GHz Cordless	KX-TG2583B	Call-waiting caller ID; speakerphone	2010-01-27T05:28:45	http://images.bestb
00037988054541	Panasonic	Panaso	58000000	Panasonic 15.2" 16:9 Widescreen LCD	iBrand Stores:CE Brand	TC-15LT1	From our expanded online assortment;	2007-07-30T23:16:44	http://images.bestb
00037988054565	Panasonic	Panaso	58000000	Panasonic 22" 16:9 Widescreen Enhanced-	iBrand Stores:CE Brand	TC-22LT1	From our expanded online assortment;	2007-09-13T01:53:28	http://images.bestb
00037988309252	Panasonic	Panaso	58000000	Panasonic Stereo AM/FM Cassette	Audio:Portable Audio	RQ-A200	Built-in condenser microphone and stereo	1976-06-03T00:00:00	http://images.bestb
00037988472482	Panasonic	Panaso	58000000	Panasonic Digital 900MHz Cordless Phone	Telephones:900MHz	KX-TC1503B	Features an integrated digital answering	2010-02-02T05:56:54	http://images.bestb
00037988472505	Panasonic	Panaso	58000000	Panasonic Digital 900MHz Cordless Phone -	Telephones:900MHz	KX-TC1703B	Digital 900MHz technology for enhanced	2010-02-02T05:46:54	http://images.bestb
00037988472512	Panasonic	Panaso	58000000	Panasonic Digital 900MHz Cordless Phone	Telephones:900MHz	KX-TC1713B	22-channel auto scan finds the best	1976-06-03T00:00:00	http://images.bestb
00037988472529	Panasonic	Panaso	58000000	Panasonic 2-Line 900MHz Digital Cordless	Telephones:900MHz	KX-TC1723B	2-line operation; 3-way conferencing	2010-02-02T05:36:30	http://images.bestb
00037988472536	Panasonic	Panaso	58000000	Panasonic Digital 900MHz Cordless Phone	Telephones:900MHz	KX-TC1733B	Speakerphone, handset locator; 50-name-	2010-02-02T05:36:30	http://images.bestb
00037988472543	Panasonic	Panaso	58000000	Panasonic Digital 900MHz Cordless Phone	Telephones:900MHz	KX-TC1743B	Handset locator and 2-way	1976-06-03T00:00:00	http://images.bestb
00037988472390	Panasonic	Panaso	58000000	Panasonic 2-Line 2.4GHz Digital Spread	Telephones:2.4GHz Cordless	KX-TG2593B	Digital answering system; dual call-waiting	2010-02-02T05:42:30	http://images.bestb
00037988471805	Panasonic	Panaso	58000000	Panasonic 2-Line 2.4GHz Cordless Handset	iBrand Stores:CE Brand	KX-TGA2006B	From our expanded online assortment;	2009-02-01T00:13:27	http://images.bestb
00037988471782	Panasonic	Panaso	58000000	Panasonic 2-Line 2.4GHz Expandable	Telephones:2.4GHz Cordless	KX-TG2000B	Call-waiting caller ID; digital answering	1976-06-03T00:00:00	http://images.bestb

Figure 40: Web View of Authoritative Product Attribute Service Database

- Formatting data for delivery of key product attributes to the APAS client: this is done by using JSON format, which has quite a few advantages over XML. These advantages include improved simplicity for both human and machine, low parsing overhead, better extensibility, and being well suited to data-interchange over the web. For this purpose, JSON is called 'The Fat-Free Alternative to XML".

- Delivering key product attributes to the APAS client: This is done with JSON over HTTP over TCP. JSON file sent by the APAS web server and received at the APAS client allows the client to easily turn JavaScript objects into string-based data that can be interpreted with very little overhead.

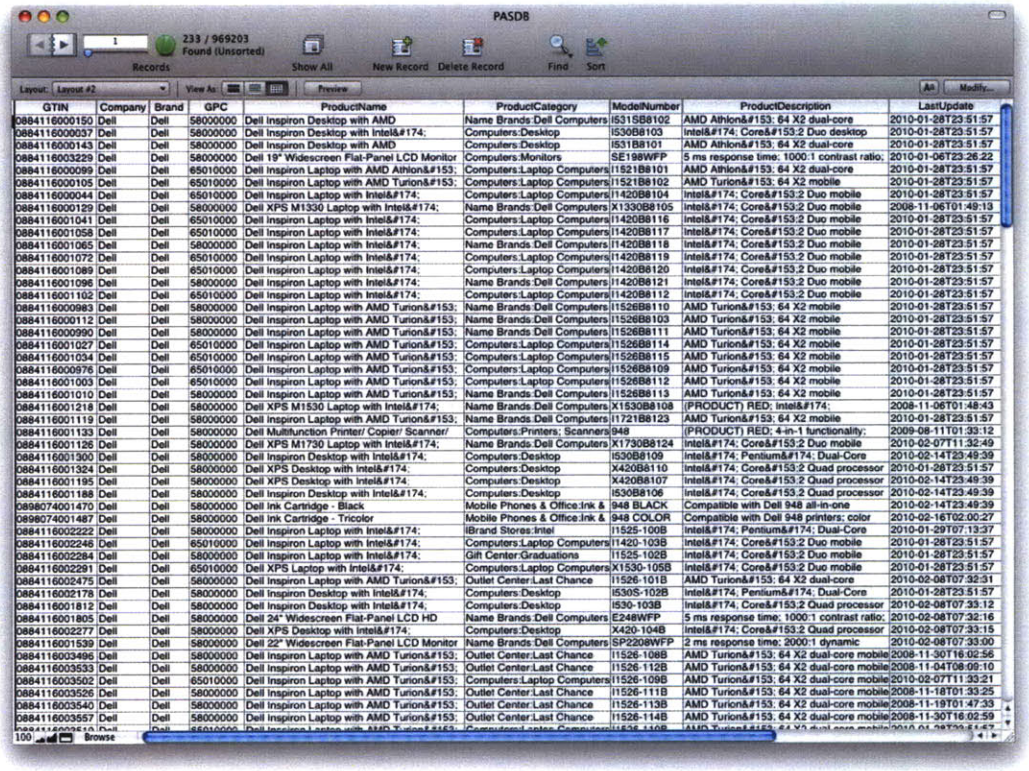


Figure 41: Authoritative Product Attribute Service DB Engine

CHAPTER VIII

CONCLUSIONS AND FUTURE WORK

8.1 Concluding Remarks

In this thesis, I performed a timely and in-depth analysis on the mechanism behind the Toyota's recent recall crisis. I have investigated the linkages between its business strategy and supply chain strategy, between the value chain of Toyota and the rest of the value system. My study has revealed that variations in the linkages in the value system have caused elevated risk level of the supply chain of Toyota. Failure to mitigate such risks has led to the outbreak of product quality problems hence the recall crisis.

Insecure supply chain is definitely detrimental to the competitive advantage of Toyota, as proofed by Toyota's suffering market leadership, cost leadership, and its value proposition of differentiation through product quality and reliability. In short, the value of secure supply chain to a business's competitive advantage is easily understandable.As one of the via paths towards secure supply chain, I have proposed authoritative product attribute service. I have also performed strategic analysis and architectural design for the APAS.

As a staring point and proof of concept, prototyping APAS was carried out using the Ruby-on-Rails web development framework, SQLite3 and Filemaker database backend, and Google Android based mobile frontend. With GTIN as the product code, retrieval of about 12 essential product attributes are made possible for nearly one million products spanning from home and office appliances, electronics accessories, to CDs, DVDs, and computer and video games.

8.2 Directions for Future Research

Apart from what has been achieved in this work, I have identified a few directions for future research and development.

1. Mobile phone based RFID reader: In 2004, Nokia offered a kit that enabled workers equipped with cellphones to scan RFID tags remotely and transmit data via their cell phones – the world's first RFID-enabled GSM cell phone was released at the CeBIT 2004 trade show in Germany [66]. Half a decade later, the role of cell phone as RFID reader still have not caught much attention. This however is changing. According to a number of sources [67], RFID is set to be a part of the coming iPhone 4G in the mid of 2010, both as reader and tag. It is reasonable to speculate that other smartphone makers will join the game. 2010 appears be a great year for RFID in the consumer market. By turning cellphones into RFID readers, it has made possible for the consumers to access serialized product information for individual product instances, i.e. dynamic product attributes related to product status and safety, trading history etc. Getting familiar with and utilizing the new APIs for RFID reader functionalities to be provided by major smartphone makers are high on the TODO list of the APAS project.

2. Certification and validation of product attributes. Currently, the product attribute service repository is built with a single source of data from Best Buy Remix archives. In order to launch production level authoritative product attribute service, all information related to product, class-level and serial-level (if so desire), needs to be validated and certified. This can be either done in-house at the APAS provider, by leveraging the existing infrastructure such as Global Data Synchronization Network and Electronic Product Code Information Services, or outsourced to a 3rd party certification center or technology solution provider. Some of the approaches might be considered are web-crawling, machine learning, statistically analysis.

3. Synergies with existing provider of GDSN and EPCglobal Network. Distributed and scalable APAS information system that involves Object Naming Service or similar discovery mechanism. This requires incentives for the brand owners to participate in providing original data and validating product attributes, as well as infrastructure support and service provisioning from member organizations of GS1. Such a distributed architecture will ensure better scalability for resource utilization and load balancing, as well as better service level in terms of response time and hit ratio.

4. Product category code tagging: it would be ideal that for new products, manufacturers will assign accordingly GPCs to them according to the GS1 standards. In reality, a reverse engineering approach has to be in place in order to deal with legacy products that whose product attribute information did not incorporate the GPC, but is wide use on the market. It would be a daunting task for either the APAS providers or the venders to input this information to their systems, considering their limited resources and the sheer size of the data. I would like to propose to leverage users around the world to participate in tagging and validating such information, following a user-centered innovation approach as descried by von Hippel et al [68] [69]. In this case, an authoritative PAS provider will offer the web users a platform that adopts Web 2.0 technologies to allow collaborative and interactive user content generation of tagging information that collectively render more and more accurate product classification according to the standard. Web taggers will monitor each others work, which serves as a means of quality assurance. Reputation-based incentive and reward system (e.g. top tagger ranking based on accuracy and hits) can be used to motivate such voluntary activity. This approach actually has been used in image content tagging by google in building its image search engine with the application called "Google Image Labeler" [70].

5. Enabling other use cases. For the current APAS prototype, the principal function

is providing information on authoritative products attributes. However a number of other value-added functions can be considered, such as compare and select products based on their attributes, certified rating and commenting information, as well as coupon based promotion. Also, upgrading the current coverage of product attributes to include such product recall history, standards and certification info can be of interesting to both the end consumers, retailers and brand owners.

APPENDIX A

SAMPLE CODE LISTINGS

In this section, I include source code samples that are part of the APAS client which cover product attributes definition, Android Client construction, product attribute retrieval, as well as code samples that part of APAS Server which cover parsing JSON objects from RAW data, databases manipulations etc. [1]

Listing A.1: Code for Product Info

```
1  public final class ProductInfo {
2
3      // The name of the firm or brand owner who issues an EPC
4      private String Company;
5      // brand name
6      private String Brand;
7      // RFID , GTIN for UPC or EAN that uniquely identifies a product
8      private String ProductCode;
9      // The convention of the product code, e.g. UPC or EAN etc.
10     private String CodeFormat;
11
12     // Global Product Classification Code
13     private String GPC;
14     // Official product title without brand name part
15     private String ProductName;
16     // Product classification related to GPC
17     private String ProductCategory;
```

[1] Due to disclosure policy, I have listed here only sample code. I can almost guarantee you it won't compile as-is, as a large portion of the code is not listed. But, they should give you some general impression on some of the key functions developed in the project. It is not meant to be used in a production environment at current stage

```
18      // Vendor specific model number for an item
19      private String ModelNumber;
20      // Specifications of an item
21      private String ProductDescription;
22      // Link to third party product data web page
23      private String ProductURL;
24      // Link to representative product photo
25      private String ImageURL;
26      // Timestampt of last product info update
27      private String LastUpdate;
28      // Place holder for dynamic HTML code for the product info
29      private String WebText;
30
31      // Whether the product has recall history
32      private String Recalled;
33      // Whether a promotion is associated with the product
34      private String CouponCodeInfo;
35      // Average rating from users
36      private String avgRating;
37      // Regulatory info for the standards apply
38      private String standardApplied;
39      // Date on which product is certified
40      private String dateCertified;
41      // Customer support telephone number
42      private String contactNumber;
43          ...
```

Listing A.2: Code for Android APAS Client

```
1 package gu.lmd.mit.gs1.find;
2 import android.app.Activity;
3 import android.content.Intent;
4 import android.os.Bundle;
```

```
5 import android.util.Log;
6 import android.view.View;
7 import android.view.View.OnClickListener;
8 import android.webkit.WebView;
9 import android.widget.*;
10
11 public void onActivityResult(int requestCode, int resultCode, Intent
      intent) {
12     if (requestCode == 0) {
13         WebView webScanResult = (WebView) findViewById(R.id.
               webScanResult);
14         webScanResult.getSettings().setJavaScriptEnabled(true);
15         if (resultCode == RESULT_OK) {
16             String key = intent.getStringExtra("SCAN_RESULT");
17             String format = intent.getStringExtra("SCAN_RESULT_FORMAT");
18             ProductInfo proinfo = new ProductInfo();
19             Initialize product attributes
20             proinfo.productInfoInit();
21             proinfo.setCodeFormat(format);
22             proinfo.productCodeUpdate(proinfo, key);
23             ProductInfoManager.updateProductInfo(proinfo);
24             webScanResult.loadData(proinfo.getwebText(), "text/html", "
                   utf-8");
25         } else if (resultCode == RESULT_CANCELED) {
26             String textCanceled = "<html><body><b>Canceled!</b><br /></
                   body></html>";
27             webScanResult.loadData(textCanceled, "text/html", "utf-8");
28         }
29     }// end if
30 }// end onActivityResult()
```

Listing A.3: Code for Product Attribute Retrieval at APAS Mobile Client

```
1 private static final boolean updateFromGS1(ProductInfo productInfo) {
2
3       String url = GS1_URL + productInfo.getProductCode() + ".json?key="
4             + GS1_API_KEY;
5       String jsonString = NetworkManager.getRemotePageAsString(url, null
            ,
6             null);
7       try {
8          String company = new JSONObject(jsonString).getString("company"
              );
9          productInfo.setCompany(company);
10         String modelNumber = new JSONObject(jsonString).optJSONObject(
11               "product").getString("model_number");
12         productInfo.setModelNumber(modelNumber);
13         String imageUrl = new JSONObject(jsonString).optJSONObject(
14               "product").getString("image_url");
15         productInfo.setImageURL(imageUrl);
16         String productUrl = new JSONObject(jsonString).optJSONObject(
17               "product").getString("product_url");
18         productInfo.setProductURL(productUrl);
19         String lastUpdate = new JSONObject(jsonString).optJSONObject(
20               "product").getString("updated_at");
21         productInfo.setLastUpdate(lastUpdate);
22         String catID = new JSONObject(jsonString).optJSONObject("
              product")
23               .getString("GPC");
24         productInfo.setGPC(catID);
25         String brandName = new JSONObject(jsonString).optJSONObject(
26               "product").getString("brand_name");
27         productInfo.setBrand(brandName);
28         String productName = new JSONObject(jsonString).optJSONObject(
29               "product").getString("product_name");
```

```
30          productInfo.setProductName(productName);
31          String productDesc = new JSONObject(jsonString).optJSONObject(
32                  "product").getString("description");
33          productInfo.setProductDescription(productDesc);
34          // construct the webtext of product info
35          productInfo.makeProductInfoWebText(productInfo);
36      } catch (Exception e) {
37          return false;      }
38      return true;
39  }
```

Listing A.4: Code for Parsing JSON Files Containing Raw Data

```
1 for (int i = 0; i < listOfFiles.length; i++) {
2
3           jsonFileName = "jsonfiles/" + listOfFiles[i].getName();
4
5           if (!WRITE_TO_SINGLE_FILE) {
6               outputFileName = "csvfiles/" + listOfFiles[i].getName()
7                       + ".csv";
8               fWriter = new FileWriter(outputFileName);
9               pInfo.writeCSVHeader(fWriter);
10          }
11
12          if (ProductInfo.PRODUCE_DEBUG_INFO) {
13              System.out.println("Json File Counter: " + i + "\n");
14          }
15
16          try {
17
18              JsonFactory jf = new JsonFactory();
19              JsonParser jp = jf.createJsonParser(new File(jsonFileName
                    ));
```

```
20              jp.nextToken(); // skip the initial [
21              jp.nextToken(); // skip the initial {
22
23              while (counter <= NUMBER_OF_JSON_OBJECTS) {
24
25                  if (ProductInfo.PRODUCE_DEBUG_INFO
26                          || ProductInfo.PRODUCE_PRODUCT_INFO) {
27                      System.out.println("Counter: " + counter);
28                  }
29                  // go through the whole file
30                  search: while (jp.nextToken() != JsonToken.END_OBJECT)
                        {
31                      String fieldName = jp.getCurrentName();
32
33                      // check if to start a new run
34                      if ("manufacturer".equals(fieldName)) {
35                          jp.nextToken();
36                          pInfo.setCompany((jp.getText() == "null") ?
                                ProductInfo.STRING_NA
37                                      : jp.getText());
38                          pInfo.setBrand((jp.getText() == "null") ?
                                ProductInfo.STRING_NA
39                                      : jp.getText());
40                      } else if ("upc".equals(fieldName)) {
41                          jp.nextToken();
42                          pInfo.productCodeUpdate(pInfo, jp.getText());
43
44                      } else if ("categoryPath".equals(fieldName)) {
45
46                          int nameCounter = 1;
47                          // placeholder for category name in order to
                                search in the hashmap
```

```
48                  String categoryHolder = "";
49
50                  // extract and combine product category info
51                  // from the json file fields
52                  jp.nextToken(); // move over to the [
53                  while (jp.nextToken() != JsonToken.END_ARRAY) {
54                      String catField = jp.getCurrentName();
55                      // ignore first name object Best Buy
56                      if ("name".equals(catField)) {
57                          jp.nextToken();
58                          // current interest is the second and
                                third "name" tags
59                          if (nameCounter >= 2 && nameCounter <= 3)
                                {
60
61                              String temp4 = jp.getText();
62                              temp4 = temp4.replace(',', ';');
63                              categoryHolder += temp4;
64                              categoryHolder += ':';
65                          }
66                          nameCounter++;
67                      }
68                  }// end innermost while loop
69
70                  categoryHolder = categoryHolder.replace(',',';')
                        ;
71
72                  // integrity check
73                  if (categoryHolder.length() > 0) {
74
75                      // update GPC based on category name
76                      String key = categoryHolder;
```

```
77                  String value = (String) CatGPCTable.get(key);
78                  if (value != null) {
79                      pInfo.setGPC(value);
80                  } else {
81                      pInfo.setGPC(ProductInfo.
                            DEFAULT_GPC_CROSS_CAT);
82                  }
83
84                  if (ProductInfo.BUILD_CATEGORY_WHILE_PARSING)
                        {
85                      if (nameCounter > 3) {
86
87                          // insert the category info prefix
88                          // as
89                          // hash hey for those entries that
90                          // have
91                          // at least
92                          // two parts
93
94                          if (!categoryTable
95                                  .containsKey(categoryHolder)) {
96                              categoryTable.put(
97                                      categoryHolder, pInfo
98                                              .getGPC());
99                          }
100                     }
101                 }
102
103                 //trim the ending : for category name
104                 // and update product category name
105                 pInfo.setProductCategory(categoryHolder
106                         .substring(0, categoryHolder
```

```
107                                 .length() - 1));
108                     }
109
110                 } else if ("name".equals(fieldName)) {
111                     jp.nextToken();
112                     pInfo.setProductName(jp.getText());
113                 } else if ("modelNumber".equals(fieldName)) {
114                     jp.nextToken();
115                     pInfo.setModelNumber(jp.getText());
116                 } else if ("url".equals(fieldName)) {
117                     jp.nextToken();
118                     pInfo.setProductURL(jp.getText());
119                 } else if ("itemUpdateDate".equals(fieldName)) {
120                     jp.nextToken();
121                     pInfo.setLastUpdate(jp.getText());
122                 } else if ("shortDescription".equals(fieldName)) {
123                     jp.nextToken();
124                     pInfo.setProductDescription(jp.getText());
125                 } else if ("image".equals(fieldName)) {
126                     jp.nextToken();
127                     pInfo.setImageURL(jp.getText());
128                 } else {
129                     // for compound tag, point to [ if there is any,
130                     // and judge
131                     if (jp.nextToken() == JsonToken.START_ARRAY) {
132                         if (ProductInfo.PRODUCE_DEBUG_INFO) {
133                             System.out.println("Irrelevant Compound
                                field: "
134                                         + fieldName);
135                         }
136                         // skip everything between [ and ] and point
137                         // to ]
```

```
138                     jp.skipChildren();
139                 } // end if
140
141                 // do nothing for fields other than those of
142                 // interest
143                 // throw new IllegalStlateException
144                 // ("Unrecognized field '"+fieldName+"' !");
145
146                 // simple irrelevant tag instead
147                 else {
148                     if (ProductInfo.PRODUCE_DEBUG_INFO) {
149                         System.out.println("Irrelevant field: "
150                                 + fieldName);
151                     }
152                 }
153             } // end else
154
155             loop++;
156
157         } // end inner while loop for a run of a single GTIN
158
159         // routine for integrity check
160         pInfo.productInfoIntegrityCheck(pInfo);
161         // generate key product attributes to system console
162         pInfo.printProductInfo(pInfo);
163         // write to a csv file for key product attributes
164         if (ProductInfo.WRITE_TO_CSV) {
165             pInfo.writeToCSV(fWriter, pInfo);
166         }
167         if (ProductInfo.OUTPUT_TO_DB) {
168             //dbConnection.buildDB(pInfo);
169             if (ProductInfo.PRODUCE_DEBUG_INFO) {
```

```
170                     System.out.println("Number of file parsed: " + (
                            i+1));
171                 }
172             }
173
174             // create a new Product Info instance for the next
175             // instance
176             pInfo = new ProductInfo();
177             pInfo.productInfoInit();
178
179             jp.nextToken(); // skip the } for a product id/sku
180             counter++; // number of GTINs parsed
181
182         } // end outer while loop for parsing a complete .json
                file
183
184         // cleaning up after the while loop for parsing the
                complete json file
185         counter = 1;
186         jp.close();
187
188         if (!WRITE_TO_SINGLE_FILE) {
189             fWriter.close();
190         }
191
192     } catch (java.io.IOException e) {
193         System.out.println("Error in creating json parser: "
194                 + e.getMessage());
195     }
196
197 }// end of the for loop for file listing
```

Listing A.5: Code for Initialize Database Connection

```
1  public void makeConnection() {
2
3          String userName = (DB_TYPE_MYSQL) ? "userName" : "userName";
4          String password = (DB_TYPE_MYSQL) ? "password" : "password";
5          String url = (DB_TYPE_MYSQL) ? "jdbc:mysql://18.78.3.247;"
6                  : "jdbc:sequelink://localhost:2399;";
7          String dbsource = "serverdatasource=PASDB";
8
9          // REGISTER DRIVER if it is a FileMaker DB Source, not needed for
               MySQL
10         try {
11             if (DB_TYPE_MYSQL) {
12                 Driver d = (Driver) Class.forName("com.mysql.jdbc.Driver")
13                         .newInstance();
14             } else {
15                 Driver d = (Driver) Class.forName(
16                         "com.ddtek.jdbc.sequelink.SequeLinkDriver")
17                         .newInstance();
18             }
19         } catch (Exception e) {
20             System.out.println(e);
21         }
22
23         // GET CONNECTION:
24         try {
25
26             if (DB_TYPE_MYSQL) {
27                 DriverManager.getConnection("jdbc:mysql://localhost/test?"
28                         + "user=uname&password=passwd);
29             } else {
30                 con = DriverManager.getConnection(url + dbsource, userName,
31                         password);
```

```
32          }
33       } catch (Exception e) {
34          System.out.println(e);
35       }
36
37       // GET CONNECTION WARNINGS
38       SQLWarning warning = null;
39       try {
40          warning = con.getWarnings();
41
42          if (warning == null) {
43             System.out.println("No Warnings");
44             // return;
45          }
46
47          while (warning != null) {
48             System.out.println("Warning: " + warning);
49             warning = warning.getNextWarning();
50          }
51       } catch (Exception e) {
52          System.out.println(e);
53       }
54
55    }// testConnection()
```

Listing A.6: Code for Insertion into Database

```
1 public void buildDB(ProductInfo pInfo) {
2       // create Statement for querying database
3       try {
4          statement = con.createStatement();
5
6          if (ProductInfo.PRODUCE_DEBUG_INFO) {
```

```
7               System.out.println("Inserting into DB...\n");
8           }
9
10          int result = statement.executeUpdate("INSERT INTO PASDB ("
11                  + "GTIN, Company, Brand, GPC, ProductName, "
12                  + "ProductCategory, ModelNumber, ProductDescription, "
13                  + "LastUpdate, ProductURL, ImageURL" + ") VALUES ('"
14                  + pInfo.getProductCode()
15                  + "', '"
16                  + pInfo.getCompany()
17                  + "', '"
18                  + pInfo.getBrand()
19                  + "', '"
20                  + pInfo.getGPC()
21                  + "', '"
22                  + pInfo.getProductName()
23                  + "', '"
24                  + pInfo.getProductCategory()
25                  + "', '"
26                  + pInfo.getModelNumber()
27                  + "', '"
28                  + pInfo.getProductDescription()
29                  + "', '"
30                  + pInfo.getLastUpdate()
31                  + "', '"
32                  + pInfo.getProductURL()
33                  + "', '" + pInfo.getImageURL() + "')");
34
35          if (result == 1) {
36              if (ProductInfo.PRODUCE_DEBUG_INFO) {
37                  System.out.println("Insertion successful!\n");
38              }
```

```
39          } else {
40              System.out.println("Insertion failed!\n");
41          }
42      } catch (SQLException sqlException) {
43          sqlException.printStackTrace();
44          System.out.println("Exception for code: " + pInfo.
                getProductCode());
45      } // end catch
46  }
```

Listing A.7: Code for Query Database

```
1  public void runQuery() {
2
3      // query database
4      try {
5          // create statement for querying database
6          statement = con.createStatement();
7          System.out.println("Querying the DB...\n");
8
9          // query database
10         resultSet = statement
11                 .executeQuery("SELECT GTIN, GPC, Brand, ProductCategory
                       FROM PASDB WHERE Company='NEC'");
12
13         // process query results
14         ResultSetMetaData metaData = resultSet.getMetaData();
15         int numberOfColumns = metaData.getColumnCount();
16         System.out.println("Query Results:\n");
17
18         for (int i = 1; i <= numberOfColumns; i++)
19             System.out.printf("%-8s\t", metaData.getColumnName(i));
20         System.out.println();
```

```
21
22          while (resultSet.next()) {
23              for (int i = 1; i <= numberOfColumns; i++)
24                  System.out.printf("%-8s\t", resultSet.getObject(i));
25              System.out.println();
26          } // end while
27      } // end try
28      catch (SQLException sqlException) {
29          sqlException.printStackTrace();
30      } // end catch
31  }// runQuery()
```

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