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AUTO-ID CENTRE

WHITE PAPER

Product Driven Supply Chains

Alia Ahmad Zaharudin

CAMBRIDGE UNIVERSITY AUTO-ID CENTRE INSTITUTE FOR MANUFACTURING, UNIVERSITY OF CAMBRIDGE, MILL LANE, CAMBRIDGE, CB2 1RX, UK

ABSTRACT

This report explores possible new supply chain models driven by two technologies – Intelligent Products and Internet Communication Technologies (ICTs). Two product categories in two distinct sectors are looked at; high-end computer servers in the high-tech sector and frozen foods in the FMCG sector. The main aims of the project are:

- To understand the constraints and limitations of current supply chain models
- To explore possible models for supply chains driven by Intelligent Products
- To assess how Intelligent Products and ICTs can be utilised in these supply chain models and qualitatively determine the feasibility of these models

Data and information for this project was gleaned from desk research and interviews.

In the context of this report we refer to the Internet as an information transfer medium and its use as a system architecture backbone to support the transfer of data. The term "Intelligent product" is used to refer to manufactured products that have direct access to information about themselves, and which are empowered with a basic capability to support decision-making about their manufacture, distribution, usage and disposal. The ability to allow a product to make decisions is enabled by the emerging concept of software agents that exist with the physical product and which can flag up competencies and requirements to search for suitable 'routes', processes or partners. Radio frequency tags are the medium by which information is transmitted and received between a physical product and information stored about it on a network. Auto-ID technologies are therefore seen as the delivery mechanism for Intelligent Products.

WHITE PAPER

Product Driven Supply Chains

Biography

by Alia Ahmad Zaharudin
MEng. Candidate & Research Assistant

Alia is simultaneously studying for her Bachelors of Arts (Honours) and Masters in Engineering, both in Manufacturing Engineering, at Cambridge University. She will be graduating with both degrees in June 2001. Alia is at the Auto-ID Center for a brief stint as part of her Final Year Project. The main project scope is to look at new product-driven supply chain models, enabled by the advent of Intelligent Products and to a lesser degree, Internet Communication Technologies. Her analysis aims to cover both technical and organizational issues, including altered competitive position. In her spare time, Alia enjoys reading, listening to music and sampling exotic cuisine from various parts of the globe, preferably all at once. Her next destination – South America.

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Contents

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According to Fisher (1997), supply chains have two overarching functions. The first is a physical function, which involves converting raw material into parts and finished goods. The second is market mediation, which involves ensuring that the variety of products sold matches what people want to buy. The main limitations in supply chains at present are high inventory levels, long time duration for a product to get through the supply chain and low level of responsiveness toward changes in demand and supply. These limitations are commonly caused by the so called bull-whip effect (Forrester, 1958), as well as poor product visibility, poor information sharing amongst parties in a supply chain, and a mismatch between products and the supply chain that supports it. Each of these limitations can be addressed in part by the technologies discussed in this report.

The two case examples considered, have different current and future supply chain requirements. High-end computer servers require a responsive supply chain to assist with the market mediation function. The frozen foods supply chain is however required to be a lean and cost efficient chain to help the physical function. A model is proposed in this report for each of the product types. Applications of Intelligent Products as a means of supporting these two functions are suggested for each of the models. The main benefit areas identified are higher product visibility, the reduction in time and distance between point-of-supply and point-of-demand, and better decision-making enabled by the products themselves.

From the research, interviews and discussions, the hardware required for the above applications is feasible. The areas that require a lot of development are the standards, protocols and applications software. The existing business processes and industry structures for both sectors also require changing for the technology to proliferate in order to reach its full potential. The biggest hurdle though, is changing the mindset and attitudes of people, be it customer, retailers, manufacturers or suppliers, before the models and applications suggested in this report can be adopted.

1. INTRODUCTION

This project is an individual piece of work and was carried out over a period of seven weeks as part of the fourth-year of a Manufacturing Engineering course at Cambridge University. Below are outlined the main aim and objectives of the project, background information to the project, the deliverables and methodology.

1.1. Aims & Objectives

The main aim of this project was to research developments in two technologies – Intelligent Products that are enabled by Radio Frequency (RFID) tagging and Internet Communication Technologies (ICTs) – and explore possible supply chain models that can be enabled by these technologies. More specifically, the objectives of the project are as follows:

- To understand the constraints and limitations of current supply chain models
- To explore possible models for supply chains driven by Intelligent Products
- To assess how ICTs and Intelligent Products can be utilised in these supply chain models and qualitatively determine the feasibility of these models

1.2. Project Background

Why Supply Chains?
Supply chains of the past were characterised by adversarial relationships between supply chain partners, highly vertically integrated and focussed on processes and cost efficiencies. Today, more companies are realising that traditional core competencies such as product design, high-quality manufacturing and control of transportation routes are no longer enough to sustain competitive advantage. Traditional supply chains are facing upheaval by new supply chain models involving collaborative relationships and alternative channels for both information transmission and product distribution.

Fine (1998) in his book **Clockspeed** wrote, "The ultimate core competency is the ability to choose capabilities well". The greatest rewards go to the companies that can dynamically adapt to leverage capabilities and control the value chain. These capabilities are being driven by two factors – the level of technical innovation and competitive intensity within the industry[1]. The supply chain has evolved significantly over the past few decades and today it seems poised for yet another transformation driven primarily by technology and globalisation[2]. This technology change will involve a medium to enable fast, open standards for the transmission of information and the development of **agents** for Intelligent Products.

[1] Charles H. Fine (1998), **Clockspeed**, Perseus Books, Massachusetts.

[2] Mark Yeomans, Partner, E-supply chains, Management Consultant services, **PricewaterhouseCoopers**

This project looks at two technologies that fit the bill – the Internet for faster, more open information flow, and Radio Frequency (RFID) tagging for Intelligent Products. Intelligent Products are products, from finished goods, components and sub-assemblies to machinery, which are capable of basic decision-making relevant to its own destiny. The Internet is an ubiquitous medium for the transfer of information, both between and about Intelligent Products. Further details on these technologies and their capabilities are outlined in Section 3.

Why Intelligent Products and the Internet?
Intelligent Products that are capable of basic decision-making will potentially lead to automatic sorting, scheduling, routing, manufacture and distribution. The current roles of players in supply chains at present might change, offering new and distinct opportunities and challenges to current players and new

entrants. An Intelligent Product will require information about itself and other Intelligent Products to enable real-time decision-making. This transmission, receipt, processing and storing of information can be facilitated by Internet Communication Technologies.

The UK government has recognised the possible impact that these two technologies might have on Industry and the economy, and have allocated significant resources toward research in these fields. E-Minister Patricia Hewitt announced in March 2001 that the UK government is allocating £20 million toward funding a research centre on "Next Wave"[3] technologies and £30 million for development of e-business initiatives. This field is currently receiving heightened attention due to the accelerating convergence of IT and Telecommunications technologies and industries[4].

The supply chains of two companies in two different sectors are looked at in this project:

1. Fast Moving Consumer Goods (FMCG) – **Unilever Cold Chain**
2. High-Technology (high tech) – **Sun Microsystems Medium-High End range servers**

ESTIMATED SUPPLY CHAIN MANAGEMENT REVENUE BY SECTOR, 1999 ($$ IN THOUSANDS)

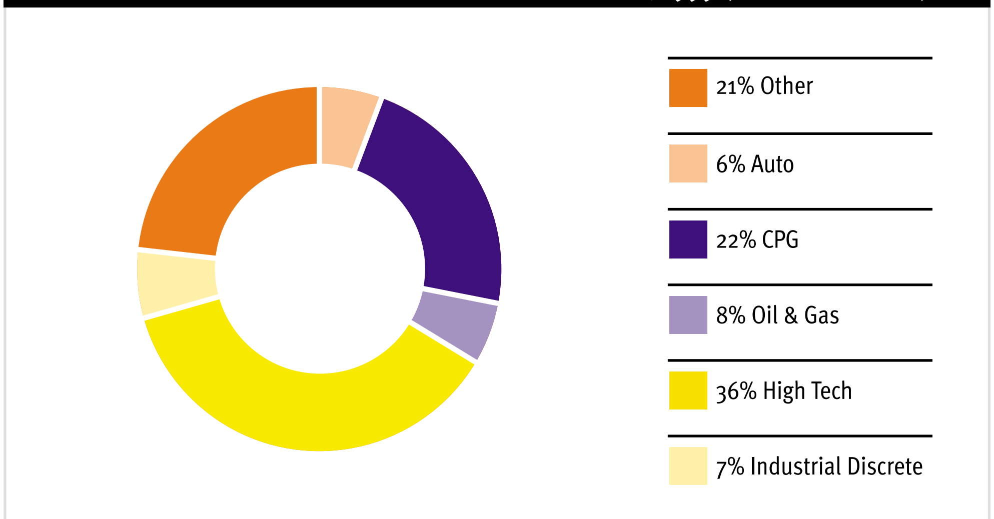


Chart 1: Source: Surgency Inc. (Sep. 1999)

Why These Two Sectors?

These two sectors were chosen to illustrate any differences that product clockspeeds might have on the proposed supply chain models. The products in the cold chain typically have a lifespan on the timescale of months as opposed to the products in the high-tech sector that have a timescale of years. However the duration between new product introductions (NPI) for frozen foods is much longer than for high tech products. Furthermore, the FMCG supply chain would give a reflection of a low value, high volume product. The high tech supply chain would give a feel for a high value, low volume product. In addition, these two sectors would be interesting to research as they are the biggest spenders based on annual revenues of the main software vendors for supply chain solutions[5].

Both companies researched (Sun Microsystems and Birds Eye Walls/ Unilever) are part of the Auto-ID consortium. The product ranges researched within these companies were selected in conjunction with the companies based on availability of data required for the project, product clockspeeds and relevance of expected project results to the companies' future supply chain initiatives in those product ranges.

[3] "Next Wave" technologies describe thinking machines that bring computing power into everyday gadgets. This includes **intelligent products**. "Next Wave" technologies is seen to be underpinned by "pervasive computing" or "ubiquitous computing", which is the growth of micro-computers embedded in a wide range of everyday devices that are able to communicate with each other and the internet, and observe and interact with their environment

[4] Department of Trade and Industry press release (P/2001/163), **HEWITT BACKS "NEXT WAVE" TECHNOLOGY WITH £70 MILLION PACKAGE, 19 March 2001**

[5] Based on annual revenues of eight leading vendors in supply chain management software market (Aspen Technology, Baan SCS, i2 Technologies, J.D. Edwards/ Numetrix, Logility, Manugistics, SAP SCMI, SynQuest). Source: **The Supply Chain Management Market Leaders**, Surgency Inc. (formerly known as Benchmarking Partners Inc.), Cambridge, Massachusetts, USA; September 1999

1.3. Project Benefits

The main benefits of this project were seen to be as follows:
1. To be used as a tool for companies to think about future supply chain initiatives.
2. To present to the Auto-ID centre possible supply chain models that utilise RFID technology currently researched and developed at the centre.

The deliverables of this project are this report and a presentation to the Board of Overseers of the Auto-ID Centre.

1.4. Methodology

1.4.1. Project Approach

This project was divided into three phases. A more detailed activity breakdown and project timeline is shown in Appendix 8.1.

PHASE 1	FOCUS
SCOPING	Background research into topics
	Firm up project scope and deliverables
PHASE 2	**FOCUS**
ANALYSIS	Data and information gathering
	Identify emerging trends in sectors
	Identify current and emerging technologies and standards
	Identify current performance measures for supply chains
	Company-level study
PHASE 3	**FOCUS**
SOLUTION GENERATION	Consolidation of data and information
	Possible models generated
	Feasibility issues identified

1.4.2. Research Areas and Approach

Research for the project covered three broad areas:
- Supply chain issues
- Sector background information (High-tech sector and FMCG)
- Technical issues

Interviews were carried out with personnel within the two companies researched, across a spectrum of functional divisions. Interviews were also conducted with people from a variety of backgrounds to get a feel for the main issues at hand. This included academics researching the topic, consultants developing emergent models, software vendors, industry research organisations, technology research organisations and the Department of Trade and Industry (Dti). A list of people interviewed and their contact details are included in the Appendix.

1.4.3. Analysis of Supply Chains
A methodical approach was taken for the Solution Generation phase. Fisher [6] (1997) argues that there are two distinct product-driven supply chain models, according to whether the product is a **functional** or **innovative** one. He also outlines a framework to determine whether a product falls into one category or another. This approach was used in determining the nature of the products looked at and in exploring possible models. A simplification of his model used in the project is given is Section 2.4 (Table 2). The characteristics of supply chains suitable for each type of product are also outlined there (Table 3).

[6] Marshall L.Fisher, **What is the Right Supply Chain for Your Product?**; Harvard Business Review, March–April 1997.

The Supply Chain Council [7], an independent not-for-profit organisation, is developing a Supply Chain Operations Reference (SCOR) model for supply chain management. The high-level model breaks down the supply chain to four distinct management processes: Plan, Source, Make and Deliver. This categorisation was adopted in identifying possible benefits that the Internet and Intelligent Products might have. An additional category was developed for this project: SERVICE.

[7] The SCC facilitates the application and advancement of state-of-the-art supply chain management systems and practices. It was founded in 1996 and has over 400 company members covering a wide range of industries.

The solutions presented in this report can be thought of as building blocks to design an entire supply chain. No complete model is presented here due to the wide possibilities available for different products. The feasibility model provides a framework by which to analyse resulting supply chains (Section 4.4.4).

2. CURRENT SUPPLY CHAIN MODELS

2.1. Overview

This section looks at current supply chain models and issues, emerging trends and sector specific issues. A model by which to analyse supply chains is also outlined.

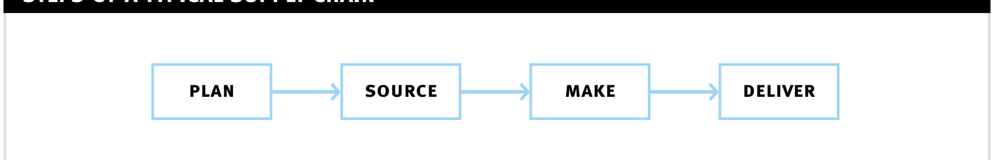
2.2. Current Models

Supply chains have two overarching functions [8]. The first is a **physical function**, which involves converting raw material into parts, components and finished goods. It also includes transporting all of them from one point to the other. The second is **market mediation**, which involves ensuring that the variety of products reaching the marketplace matches what people want to buy.

[8] Marshall L.Fisher, **What is the Right Supply Chain for Your Product?**; Harvard Business Review, March–April 1997.

A typical supply chain would consist of the following steps: Plan, Source, Make and Deliver.

STEPS OF A TYPICAL SUPPLY CHAIN



In the past, planning was carried out with only internal considerations, without much input from suppliers and/or customers. Supply availability and demand levels were shared on a limited basis and only to one level upstream or downstream in the supply chain. Sourcing and procurement could be done only on a local basis. Manufacturing was inflexible and done with large runs to reduce changeover times and achieve economies of scale. Deliveries of raw materials and finished goods were also done on a large-scale basis to get economies of scale from full-truck loads (FTL), hence the high levels of inventory in between deliveries. Service, particularly once a product is 'in the field' and to address end-of-life cycle issues, is neglected in most supply chains.

9 Mark Yeomans,
E-supply chain: revolution or evolution
PricewaterhouseCoopers

Traditionally, supply chains would be part of a single enterprise, or controlled by a single enterprise. Companies were highly vertically integrated and carried out all four main processes above. Manufacturers generally extracted most of the value and profits from the supply chain and possessed most of the market power[9]. The consumer was at the mercy of companies and had little choice in terms of product specification, delivery lead times, and prices. Customised products came with premium prices and took a long time to produce and deliver. There was low correlation between what the customer wanted and what companies produced. This resulted in two phenomena: unwanted existing stock becoming **obsolete**, as no one wanted those products, and **stockouts**, where customers could not get products that they wanted. Supply chain issues existed even though a single enterprise controlled the chain and had contact with the consumer.

Over the years industries moved to demerge and deconstruct as they realised that huge organisations could not adapt and respond quickly enough to changing consumer needs and technological advancements. Horizontal integration became fashionable, for example the computer industry today. Most delivery at present is outsourced to third party logistics companies. Still problems with supply chains persisted. The reasons for problems plaguing supply chains are less to do with how organisations are organised but more to do with **how** and **when** information flows all throughout the chain, which depend on how supply chains are organised. This issue will be addressed in detail below (see Section 2.4).

Research has shown that manufacturing power by country base has shifted drastically, particularly for the UK and Japan (see Table 1 below). The rise and fall of manufacturing powers, and the level of vertical or horizontal integration, can be argued to arise as a function of competitive intensity in the sector and level of technological innovation (Fine, 1998).

Table 1: Shares of world trade in manufacturers 1937 – 1990 (%). Source: Various sources, research gathered by the Confederation of British Industry (CBI)

	1930	1950	1960	1970	1979	1990
GERMANY	21.8	7.3	19.3	19.8	20.9	20.2
USA	19.2	27.3	21.6	18.6	16.0	16.0
JAPAN	6.9	3.4	6.9	11.7	13.7	15.9
FRANCE	5.8	9.9	9.6	8.7	10.5	9.7
UK	20.9	25.5	16.5	10.8	9.1	8.6

2.3. Supply Chain Management Issues

The main problems within supply chains are:

- High amount of inventory throughout the whole chain
- High length of time that a product takes to get through the supply chain
- Low responsiveness of supply chains to new products and changes in demand and supply

The real cost of carrying inventory is not so much the carrying or holding cost. Rather, it is the opportunity cost of slashing product prices to eliminate unwanted products and the missed opportunity of potential sales. The first two problems above drive the inability to respond to market changes in an efficient and profitable manner.

The problems above can be attributable to:

- The **bull-whip effect** [10] or the Forrester [11] effect (further explanation given below).
- Poor product visibility, especially around Work-in-Progress and inventories
- Poor information sharing and collaboration across players in a supply chain. Traditional relationships between buyers and suppliers across two companies have been adversarial.
- Mismatch between product and supply chain

Most supply chain initiatives at present focus on processes and cost efficiencies, rather than looking at the nature of product. There is a theory contending that supply chains are ineffective if they are not designed to suit the products they supply [12]. The mismatch between the product type and its supply chain can lead to the problems of high stock levels, long lead time between point-of-supply and point-of-demand and slow response to market changes. This is explained in the next section (Section 2.4). The bull whip effect is a phenomenon where the volatility of demand and inventories in the supply chain are amplified the further upstream it is. Major causes of the bull whip effect are:

Demand Forecast Updating

Forecasting is typically based on order history from the company's immediate customers, market intelligence and estimates from Sales personnel. An order placed by a downstream operation is seen as a demand signal. The planning manager in the company then adjusts his forecast and in turn, adjusts the orders upstream to the suppliers. The planning manager's perceptions and mistrust gets built into the adjustment of figures used and orders placed to suppliers.

Exponential smoothing enables future demands to be updated as the new daily demand data becomes updated. However, exponential smoothing would include any safety stock. The longer the lead times the higher the level of safety stock. Typically, due to the nature of products, manufacturing and delivery lead times increase progressively upstream of the chain – a phenomenon known as **clockspeed amplification** (Fine, 1998). Hence the orders placed by the company to its suppliers would have bigger fluctuations in demand to accommodate for lead times between resupply and safety stock.

Order Batching

Orders are usually batched to allow demand to accumulate before placing an order (Periodic ordering) or batched to coincide with internal evaluation cycles (Push ordering). For Periodic ordering, there are two possible reasons to batch orders:

1. Substantial order processing cost and time. P&G estimates that each invoice sent to a customer costs between $35 to $75 to process. This is due to the high level of manual intervention needed to its order, billing and shipment systems [13].

2. Slow-moving items may not be consumed fast enough to justify resupply and more frequent ordering.

For Push ordering, companies will see a regular surge in demand toward the end of a financial cycle. Often, these surges can be noticed at the end of an evaluation cycle for salespeople – either quarterly or annually. In order for them to fill quota, they may sign orders prematurely and **push** 'orders' from customers to the system. This is known as the 'hockey stick' effect.

Price Fluctuation

Lower prices are frequently a good incentive for both companies and consumers to purchase supply or goods in advance of actual need, predominantly in bulk quantities, a phenomenon known as 'forward buying'. The big culprits are manufacturers and distributors in the grocery industry. Roughly 80 percent of transactions between them were made in 'forward buy' arrangements commonly due to a manufacturer's

[10] Hau L. Lee, V. Padmanabhan, Seungjin Whang, **"The Bullwhip Effect in Supply Chains"**, Sloan Management Review, Spring 1997.

[11] Jay W. Forrester, **"Industrial Dynamics: A Major Breakthrough for Decision Makers"**, Harvard Business Review 36, no.4 (1958) pp 37–66.

[12] Marshall L.Fisher, **What is the Right Supply Chain for Your Product?**; Harvard Business Review, March–April 1997.

[13] M. Millstein, 'P&G to Restructure Logistics and Pricing', Supermarket News, 27 June 1994, pp 1, 49

[14] Kurt Salmon Associates, **'ECR: Enhancing Consumer Value in the Grocery Industry** (Washington D.C.: report, January 1993)

price offer [14]. When the product price returns to normal the customer stops purchasing until he has used up his inventory. Hence the buying pattern does not correspond to the consumption pattern, and variation of the buying quantities exceeds variation of consumption rate. Unusually low sales levels in the next financial period can result if the distribution channels are already saturated with product purchased in the previous financial period at lower prices.

Rationing and Short Gaming

When demand exceeds supply, manufacturers and distributors will ration supply of products. Customers, expecting that suppliers will ration products, will order more than actual demand in order to fill their requirements as they will not expect to receive 100% of the order. When demand subsides, orders will get cancelled. Customers might place duplicate orders with numerous suppliers, buy from the first supplier that can deliver until its requirements are met, and cancel the rest of the orders. This results from organisations making sound, rational economic decisions and **gaming** the potential rationing.

The challenges that supply chain issues pose for companies, industrialists, governments and academics alike are mainly in the following areas:

- Increase in mass customisation needs. The main effect of this is changing supply chain topologies and requires increased integration across the entire chain
- Extended enterprise development with increased levels of outsourcing
- IT/ Technology adoption and mastery to enable adoption of the first two concepts on a wide scale.

[15] H. Akkermans, P. Bogerd, E. Yucesan, L.N. Van Wassenhove, **'The Impact of ERP on Supply Chain Management: Exploratory Findings from A European Delphi Study'**, INSEAD WP 1999

[16] Source: Supply Chain Council, www.supply-chain.org, Pittsburgh USA.

Results of a European Delphi Study in 1999 [15] with 23 supply chain executives from various industries show that **integration of activities between suppliers and customers across the entire chain** pose the biggest challenge. Further results of this survey are shown in Appendix 8.2. The biggest quantifiable benefit of Supply Chain Integration would be **improved forecast accuracy** (25–80% benefit), followed by **inventory reduction** (25–60% benefit)[16].

2.4. Supply Chain Analysis Model

Fisher (1997) makes a distinction between i**nnovative products** and **functional products** and contends that there are two types of supply chains, one each to suit the two product categories.

Innovative products often have high product variations within a range and have unpredictable demand. They are usually more pricey and have better contribution margins. They require a market-responsive model to respond to fast changing product requirements and demand in order to minimise stockouts, forced price markdowns and obsolete inventory. The unpredictable demand for innovative products makes the market mediation function difficult.

Functional products have predictable demands and lower contribution margins. They require a physically efficient model that focuses on cost minimisation.

A full table showing the categories to analyse a product is given overleaf. The products in the high-tech sector (high-end servers) would be categorised as innovative products due to the high product variation, unpredictable demand and high contribution. The products in the cold chain can be either functional or innovative. A summary of characteristics for the two product groups researched for this project is included in the Appendix 8.3 (Table 5).

Overleaf is a summary of the characteristics required of a responsive chain for innovative products, and of a lean chain for functional products.

Table 2: Determination of Functional vs. Innovative product.

[17] Contribution margin equals Price minus Variable Cost divided by Price. It is expressed as a percentage.

	INNOVATIVE	FUNCTIONAL
ASPECTS OF DEMAND	Unpredictable demand	Predictable demand
PRODUCT LIFE CYCLE	3 months to 1 year	More than 2 years
CONTRIBUTION MARGIN [17]	20% to 60%	5% to 20%
PRODUCT VARIETY	High (Often millions of variants per category)	Low (10 to 20 variants per category)
AVERAGE MARGIN OF ERROR IN THE FORECAST AT THE TIME PRODUCTION IS COMMITTED	40% to 100%	10%
AVERAGE STOCKOUT RATE	10% to 40%	1% to 2%
AVERAGE FORCED END-OF-SEASON MARKDOWN AS PERCENTAGE OF FULL PRICE	10% to 25%	0%
LEAD TIME REQUIRED FOR MADE-TO-ORDER PRODUCTS	1 day to 2 weeks	6 months to 1 year

Table 3: Supply chain characteristics for responsive and lean chains.

	RESPONSIVE CHAIN	LEAN CHAIN
PRIMARY PURPOSE	Respond quickly to unpredictable demand in order to minimise stockouts, forced markdowns, and obsolete inventory	Supply predictable demand efficiently at the lowest possible cost
MANUFACTURING FOCUS	Deploy excess buffer capacity	Maintain high average utilisation rate
INVENTORY STRATEGY	Deploy significant buffer stocks of parts or finished goods	Generate high turns and minimise inventory throughout the chain
LEAD TIME FOCUS	Invest aggressively in ways to reduce lead time	Shorten lead time as long as it does not increase cost
APPROACH TO CHOOSING SUPPLIERS	Select primarily for speed, flexibility and quality	Select primarily for cost and quality
PRODUCT DESIGN STRATEGY	Use modular design in order to postpone product differentiation for as long as possible	Maximise performance and minimise cost

[18] E. Morash, S. Clinton, **'Supply Chain Integration: Customer Value Through Collaborative Closeness Versus Operational Excellence'**, Journal of Marketing Theory and Practice

The concept of a lean, cost efficient chain for functional products versus a responsive, collaborative chain for innovative products is supported by a study [18] carried out on 9,634 firms in the United States, Japan, Korea and Australia. The study categorises supply chain integration into three levels **Inter-organisational Operational Excellence, Inter-organisational Collaborative Closeness and Intra-organisational Process Integration**. A summary of the study results is presented below. The Operational Excellence model supports the functional product model, whilst the Collaborative Closeness model supports the innovative product model.

Table 4: Varying levels of integration

FORM OF INTEGRATION	ROLE OF SUPPLY CHAIN	EXTENT OF INTEGRATION	PRODUCT MANAGEMENT STRATEGY
INTER-ORGANISATIONAL OPERATIONAL EXCELLENCE	Supply chain is lean and cost efficient. Supply chain operations are standardised for efficiency.	Production systems are operated for efficiency and zero defects Suppliers chosen primarily on cost and reliability	Supports total cost reduction Products standardised, not customised. Products compete on competitive prices and offer minimal difficulty and inconvenience of use
INTER-ORGANISATIONAL COLLABORATIVE CLOSENESS	Supply chain is part of overall product offering of value to consumer	Collaborative fore-casting (Use same demand forecast) Collaborative scheduling (Use same schedule) Sharing capacity (Use same assets)	Supports differentiation strategies. Unique, key customers are targeted
INTER-ORGANISATIONAL PROCESS INTEGRATION	Supply chain man-agement focused on internal priorities. Job functions are are specialised.	Focus on hand-offs and interfaces between internal departments	Primarily supports cost reduction

[19] Charles H. Fine (1998)

A product can also be categorised by its 'clockspeed', or its rates of evolution. Other measures of clockspeed include **process clockspeed and organisation clockspeed**[19].

These frameworks were used to categorise the products investigated, to analyse them and to structure the solution generation process.

2.5. High-Tech Sector

2.5.1. Sector Overview

Products in this sector are innovative products due to the rapid rate of new products being introduced to the market. Demand is highly variable and contribution margins are high.

The industry did not always have fast product clockspeed though. Most enterprises in the high-technology sector were vertically integrated, particularly in the 1970s and early 1980s. Outsourcing was a rare occurrence, as companies tended to provide a majority of the key elements of their own computer systems. The big shake-up of the industry occurred in the early 1980s, when IBM released a modular product design with major components provided by Microsoft and Intel. Competitors started buying components from IBM's suppliers, bundled them into an IBM-compatible personal computer and beat IBM at their own game. This sparked off deconstruction of the industry.

The industry has seen the product clockspeed accelerate to the point where new products are introduced every two to five years with up to thousands of product variations within a product segment, as opposed to a new product being introduced every five years but with far fewer product variations. Products released now are increasingly modular, where suppliers carry out the sub-assemblies of key components. Increasingly, companies have customer service levels in mind when designing the product, but not necessarily the supply chain.

2.5.2. Current Models

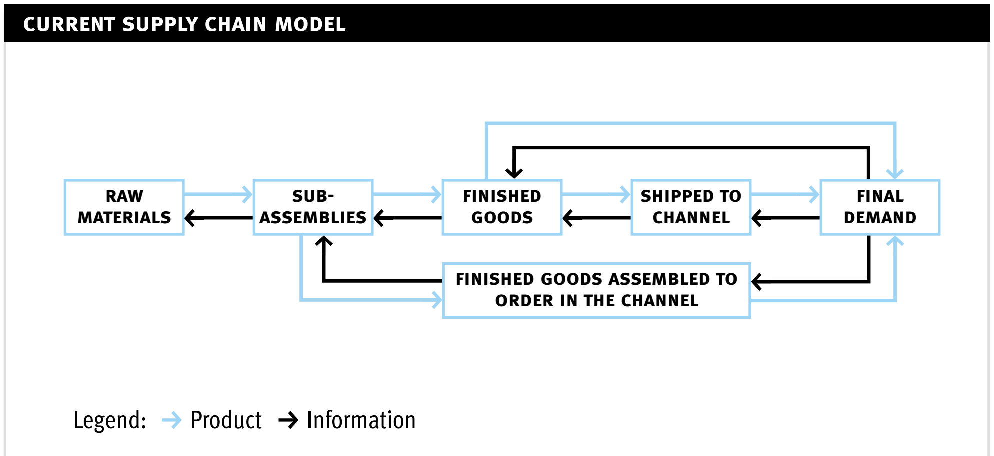
There are three main ways that a product progresses through the supply chain or from raw material until it reaches final demand, as illustrated in Diagram 1.

A summary of terms used in the diagram:

Table 5: Summary of terms in Diagram 1

TERMS	DESCRIPTION
RAW MATERIALS	Material that needs to be processed. E.g. Silicon fabrication, Plastic moulding for cases etc.
SUB-ASSEMBLIES	Components and parts. E.g. memory chips, drives, microprocessors etc. For distributive manufacture of a computing system, it can also mean separate parts e.g. the storage cabinet, monitor, central processing unit etc.
FINISHED GOODS	**Single product** E.g. a computer terminal **Computing system** E.g. A personal computer comprising keyboard, monitor etc.; A computing system or storage comprising various boards, processor and memory drives etc.
CHANNEL	Sales channel would involve resellers or a sales force.
ASSEMBLED WITHIN CHANNEL	**E.g. Assembly of a single product:** Instead of sub-assemblies being assembled into a finished product at one location, it is sent along to various locations and assembled along the way. **E.g. Assembly of a computing system:** The various boards and drives and other components from various locations can be assembled at a hub close to the end consumer
FINAL DEMAND	End consumer or organisation

Diagram 1: Current supply chain models in the High-Tech Sector



Most companies within the Industry have the supply chain model where product and information flow is sequential, or where information is shared only with suppliers one level upstream in the chain. This is especially true for the first two models explained below.

'Raw Material – Sub-Assemblies – Finished Goods – Shipped to Channel – Final Demand'.
This model has the strategy of Make-to-Stock and is tied down by high levels of stock throughout the chain. Finished goods are **pushed** to the end consumer. Stockouts and discounted pricing at the end of season are common.

'Raw Material – Sub-Assemblies – Finished Goods – Final Demand'
This model has the strategy of Make-to-Order. Some companies are starting to ship directly to end consumers, following the route. This disintermediation of resellers is possible via Internet sales but is not the norm. Alternatively, resellers act as triggers of demand in the chain after an end consumer orders a product.

'Raw Material – Sub-Assemblies – Finished Goods Assembled to Order in the Channel – Final Demand'
This model has the strategy of Assemble-to-Order. No product gets produced unless it has been ordered. Stock levels are low collectively throughout the chain. Dell is an example of a company following this route. This model would be the most responsive out of the three and would carry less inventory throughout.

2.5.3. Drivers

High-tech products are typically innovative products (Appendix 8.3). The main drivers that will impact the industry and become areas where competitive advantage will be gained are:

Mass Customisation

Customers want products that can be customised to suit their needs and budget. As products become more modular, customer switching costs decrease. Mass customisation has to be balanced with efficient capacity utilisation and efficient solution delivery. In addition, the design, sourcing and manufacturing processes have to occur concurrently to produce goods that customers will want within the timeframe that they want the product.

Performance and Increased Product Clockspeed

Performance of products is highly driven by the supporting technology, such as microprocessor speed. As the clockspeed of supporting technologies increase, customers will want the latest products. For example, the replacement rate for laptops or mobile phones is very high. Product innovation is key in this industry and companies have to be able to respond. High inventory levels will be a stumbling block to product innovation. For example, if a company has 50 days stock and a competitor has 12, when Intel come up with a new chip the competitor can potentially get a new product to market 38 days sooner.

Decrease Between Point-of-Supply to Point-of-Demand
The high values of high-tech products make inventory very expensive to keep and manage in the chain. Delivery lead time to the customer is less the core issue, especially for the higher-end products. More importantly, it is the ability for suppliers to respond rapidly to changes and not be weighed down by stock of materials, sub-assemblies and finished goods.

2.5.4. Strategies

To address the above issues efficiently and profitably, companies would ideally carry out the following:

- Assemble-to-Order models.
- Direct-to-consumer or direct-to-collection-point delivery
- Modular, open standard architecture of components to ensure compatibility
- Outsourcing of components
- Collaborative planning with suppliers

Certain supply chain models are designed to incorporate the above issues. One example is Dell. However, there is still a lack of information and product visibility throughout the chain. Furthermore, the concepts of **extended enterprises** and **virtual enterprises** are still not effectively addressed. Suggestions on how the Internet and Intelligent Products can alleviate visibility of information and product are proposed in the next chapter.

2.5.5. Current Best Practices

The **Direct Business Model** adopted by Dell is usually cited as best practice in the high-tech sector. Products are carried out on an assemble-to order basis and delivery is direct to the consumer. Michael Dell frequently cites the use of technology in the virtual integration of Dell's tightly controlled supply chain.

Another example of virtual integration is Sun Microsystems and the early adoption of JavaStations to enable employees to access their data from any computer in any of their global sites. Although this is integration is intra-organisational, this concept exemplifies the impact that connectivity to other parties can have.

2.6. FMCG Sector

2.6.1. Sector Overview

The majority of products in this sector are functional products as the product offering hardly changes dramatically over time. Demand is more or less predictable and margins are increasingly slimmer as both manufacturers and retailers attempt to slash prices. Certain products within any category might be innovative though. For example, standard ice cream flavours such as vanilla, chocolate and so on are still sold in tubs, and would be a functional product. However certain brands have come up with increasingly innovative flavours accompanied by equally innovative names. These would be innovative products.

The very high volumes of products that pass through the supply chain make product visibility very poor. This is coupled with adversarial relationships between manufacturers and retailers, making information transmission throughout the chain choked at various points. Supply chain models are usually inventory-centric and products are Made-to-Stock.

The products focused on in this project are non-meat frozen foods and ice creams. There are three main ways that these products can make its way through the supply chain from raw material until it reaches final demand, as illustrated in the next section.

2.6.2. Current Models

Non-meat frozen foods and ice cream products typically move through a supply chain via the channels shown on the next page.

A summary of the terms used in the diagram:

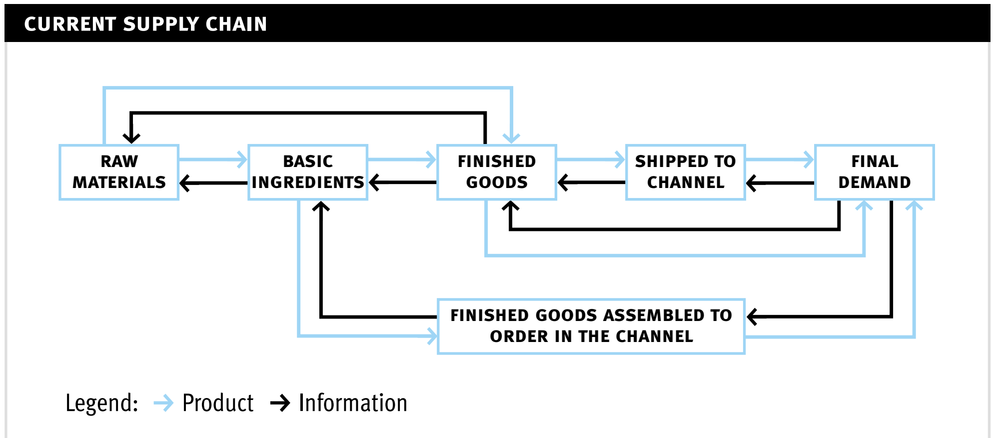
Table 6: Summary of terms in Diagram 2

TERMS	DESCRIPTION
RAW MATERIALS	Products that are direct from the source. E.g. vegetables and dairy products. This would also include ingredients that need to be processed before fit for either consumption or further processing.
BASIC INGREDIENTS	Raw materials that have been processed E.g. sugar, flavourings, frozen vegetables.
FINISHED GOODS	**Processing** Processing of basic ingredients and/ or raw material into products. E.g. Individual ice creams and freshly frozen desserts. **Packaging** Packaging of finished goods as a product fit for consumption.
CHANNEL	Sales channel would include wholesalers or retailers.
ASSEMBLED WITHIN CHANNEL	Basic ingredients that are packaged and processed in the channel. E.g. Soft ice creams that can be processed from basic ingredients at fast food outlets.
FINAL DEMAND	The customer. This would include both end consumers and food & drink outlets.

The majority of products are pushed through supply chains. Both product and information flow are sequential and not linked to each other. Demand signalling for a product starts with the retailer and is typically based on product history, seasonality and market information. This demand is sent to the supplier/ manufacturer. The manufacturer looks at incoming orders and adjusts its production plan. Planning cycles for manufacture are typically on a rolling basis over a period ranging from months to just over a year, depending on the product and organisation. Main factors taken into consideration are capacity in manufacturing plants and costs. Adversarial relationships between retails' buyers and manufacturers' sellers add choke points to the information flow in the planning process.

Sourcing is usually done centrally either through the country headquarters or the organisation headquarters. The main sourcing criteria are cost and quality of material. The manufacturing strategy emphasises asset utilisation, low cost and long production runs. Manufacturing is moving toward single-source products, where a product regardless of where its destination may be is made at a specific factory. The benefits from achieving economies of scale in manufacture outweigh additional transportation costs of finished good. Delivery is usually outsourced to a third party logistics company.

Diagram 2: Current supply chain models in the FMCG Sector



The three current main channels to get a product to the end consumer are:

'Raw Material – Basic Ingredients – Finished Goods – Shipped to Channel – Final Demand'.
This is the supply chain that a high majority of products follow, especially for slow-moving products such as frozen vegetables. This model has the strategy of Make-to-Stock and is tied down by high levels of inventory throughout the chain. Finished goods are pushed to the end consumer. Stockouts and discounted pricing at the end of season are common.

'Raw Material – Basic Ingredients – Finished Goods – Final Demand'
This model has the strategy of Make-to-Order and would be for large consumers such as restaurant chains. The number of consumers that buy directly from manufacturers is minimal as they usually buy from wholesalers.

'Raw Material – Basic Ingredients – Finished Goods Assembled to Order in the Channel – Final Demand'
This model has the strategy of Make-to-Stock for alternative sales channels. A good example would be the purchasing of basic ingredients to produce fresh, soft ice cream at fast food outlets or at convenience stores.

2.6.3. Drivers

Frozen foods and ice cream products are typically functional products (Appendix 8.3) but some can be innovative products. The main drivers that will impact the industry and become areas where competitive advantage will be gained are:

Lifestyle Aspect

Customers want products that are fresher and healthier. This will have an effect on the ingredients and processes involved in food processing, for example genetically modified food or the use of preservatives. The main impact on having fresher foods would be to reduce the time and/ or distance between point-of-supply to point-of-demand in the chain.

Erosion of Brand Loyalty

There has been a huge growth in the 'own brand' market, or products under the label of the retailer as opposed to the manufacturer. This could pose a big threat to manufacturers as retailers move into their domain of supplying products in addition to selling them.

As shelf space in a retail outlet is precious, retailers will want to put products that can sell. If products that tend to stockout lead to the customer going to a different retail outlet, the lost sale is two-fold to a retailer: the cost of a lost sale and the cost of the inventory left on the shelf that does not get purchased instead. Retailers will not want to sell products that cannot be replenished frequently or oversell frequently.

Alternative Purchasing Channels

The advent of the Internet as a window to a customer creates an alternative purchasing channel. This is particularly true for staple products such as bread, milk, eggs, vegetables etc. that can be done on a replenishment basis. It is also applicable to exotic products and ingredients. In addition, customers are also able to compare prices more easily and can form an idea about product costs, or **cost transparency** (see Section 3.1.3). The Internet can also be used as an information source on products post-purchase.

2.6.4. Strategies

To address the above issues efficiently and profitably, companies in a supply chain would have to increase integration, particularly for planning purposes and co-ordination of production and deliveries. In the future, the competition would be amongst supply chains rather than amongst individual companies. Possible strategies would include:

- Tighter integration between enterprises in a chain as part of Collaborative Planning Replenishment and Forecasting (CPFR)
- Higher product visibility from start to finish in the chain
- Direct-to-store delivery for certain businesses and products
- Use of alternative purchasing channels for more of a PULL approach by end consumers
- Better product category management
- Efficient Consumer Response (ECR)

There are a few business approaches already in place between companies addressing some of the issues above. Other efforts in place include Vendor Managed Inventory (VMI). Suggestions on how the Internet and Intelligent Products can alleviate visibility of information and product are proposed in the next chapter.

2.6.5. Current Best Practices

The most commonly cited example of Vendor Managed Inventory is Wal-Mart and P&G. P&G have visibility into Wal-Mart's in-store stock levels of Pampers diapers. P&G manage the stock replenishment process for Wal-Mart.

3. TECHNOLOGY OVERVIEW

In this section, the basic assumptions and capabilities behind the technologies that may be available for use in the future are established. Next, the current capabilities of existing technologies that form the base to future developments are outlined to give a reality check as to the feasibility and adoption of these future technologies.

3.1. Tomorrow's World

It is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change. – Charles Darwin

3.1.1. Overview

In the future, the business environment will be such that it is supply chains and competencies that compete, not companies and products. The key to survival and maintaining a competitive edge would be the ability to choose capabilities well and dynamically adapt to leverage those capabilities. One of the factors driving the need to adapt is the level of technical innovation within the industry [20]. Technological developments can help to increase product visibility and information flow. Below are

[20] Charles H. Fine (1998), **Clockspeed**, Perseus Books, Massachusetts.

outlined the technological developments that form the basis of my assumptions in generating possible supply chain models enabled by future technologies. Section 3.1.4 outlines some possible applications utilising these technologies.

3.1.2. Intelligent Products

Intelligent Products are envisioned as products that have a unique identity associated with it, can communicate with its environment, and can make and trigger basic decisions relevant to its own destiny. Intelligent Products will have tags attached to them or tags in-built into the product, and will have network connection to the Internet. Intelligent Products can either store information about itself on the tag, or have a unique identifier to point to product information that is stored on an external database. This identifier may be in the form of an electronic product code (EPC) where each Intelligent Product carries with it a unique digital identity. The argument for storing the information with the product is that retrieval of information would be faster and more efficient. However, this enables the information to be retrieved by any device that can 'read' the product. The argument for storing the information in an external database is higher security levels, as access to the product can be controlled remotely.

Each Intelligent Product will have an **agent** that is capable of flagging up product competencies, parameters and requirements to search for suitable 'routes', processes and/ or partners. **Agents** will 'reside' on computers and transmit and receive information to tags on the Intelligent Product via radiowaves (telemetry) or the Internet. The Auto-ID technologies being developed around radio-frequency tagging are seen as a delivery mechanism for Intelligent Products. More information on how the information gets transmitted and retrieved from the external database is discussed in the section on the Internet below.

Intelligent Products can be defined at five levels[21]:

[21] Dr. Duncan McFarlane, Institute for Manufacturing, University of Cambridge, UK.

1. Possesses a unique identification
2. Is capable of communicating effectively with its environment
3. Can retain or store data about itself
4. Deploys a language to display its features and production requirements
5. Is capable of participating in or making decisions relevant to its own destiny

The proposed models in this report assumes that Intelligent Products are capable of basic-level decision making, achieving levels 1 through to 5.

Intelligent Products form one of the three basic elements of an Intelligent System. An Intelligent System comprises the following basic elements[22]:

[22] Dr. Duncan McFarlane, Institute for Manufacturing, University of Cambridge, UK.

Intelligent Product
product and a software entity representing the description of the product, how it should be made (recipe) and to be able identify possible production routes.

E.g.: 'Intelligent computing server' or 'Intelligent bag of frozen peas'

Intelligent Resource
machining/transporting device that can negotiate its own tasks, schedule, manage and execute them

E.g.: 'Intelligent component assembler' or 'Intelligent food processor'

Intelligent Order
software and physical entity representing the products required, customer requirement and capable of negotiating with different manufacturing resources via intranet/internet

Agents are capable of transmitting information to other **agents** that it interacts with. For example, the components of an Intelligent Computer Server will be able to route themselves through assembly via an Intelligent component assembler.

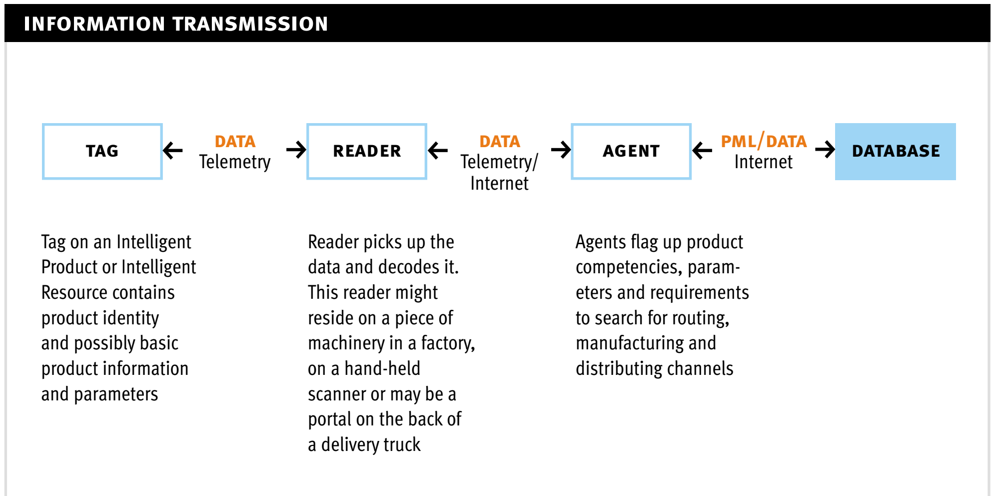


Diagram 3: Information Transmission

3.1.3. The Internet

The Internet is an ubiquitous medium used for the transmission of information. The Internet also encompasses Ethernet and Intranets, and includes Local Area Networks (LAN) and Wide Area Network (WAN). Access to the Internet of the future is assumed to be possible via mobile devices such as mobile phones, hand-held scanners, and also via wired devices. The interchangeability of devices and systems would be possible, perhaps via Bluetooth technology.

The Internet in this report refers to the Internet as an information transfer medium and its use as a system architecture backbone to support the transfer of data. Internet Communication Technologies (ICTs) refers to the technologies behind the user interface and connection. It also refers to the messaging standards and telephony involved.

The Internet for Information Transfer Between Agents

Agents that carry information with it on the tags can transmit and receive information directly from other **agents**. **Agents** that contain only an identifier to information that is stored on an external database may use the Internet to transmit and receive information. A basic diagram showing a possible method for the transmission, receipt and processing of information between agents might be achieved is shown on the next page. PML (Product Mark-up Language) is used to map an EPC from a product or resource to information about that product or resource. It would also be used to extract certain data about an intelligent product , resource or order and use it for data processing. It would be similar in fashion to XML (Extensible Mark-up Language), which separates data from structure to allow for data processing, and is advancement from HTML that only specifies how text is laid out.

The arguments for the method by which to receive and transmit information are numerous and are not covered in this report. The technical specifications for data transmission, processing and detailed technical architecture are beyond the scope of this project.

The Internet for Information Exchange

The overarching advantage of the Internet is two-fold: firstly real-time information flow and secondly access to that information in real-time, enabling rational, informed decisions-making leading to appropriate actions. Real-time information is made possible if numerous parties that have information affecting a product or service share that information. The two components of the Internet needed by users are a web browser and an Internet connection. This differs greatly from traditional Electronic Data Interchange (EDI) where a direct connection, usually via a leased telephone line or fibre optic cable, is required between the two parties exchanging information. The use of the Internet as an information exchange between companies is widely known as e-business.

The impact of easier access to real-time information can be revolutionary to both consumers and businesses. Possible impacts are listed in Appendix 8.4.

For businesses and supply chain management, the Internet can be used to support businesses in two ways:

1. Transactional Applications

– Provide information to facilitate the execution of business activities
– Provide transactional information to the decision support applications e.g. Production Planning or Procurement
– Focus is on intra-organisational integration, mainly at operational level

2. Decision Support Systems (DSS)

– The applications are used to optimise planning for manufacture, inventory management, distribution, customer service etc.
– This is done by the algorithms and heuristics that form the core of the application
– Focus is on intra-organisational and inter-organisational integration, mainly at tactical/ strategic level

The use of the Internet as a medium to transfer information transmitted and required by agents to and from external databases would fall under both categories above. The use of the Internet as an information transfer medium via Internet exchanges or e-business will also help the supply chain in terms of transactional applications and as a decision-support system.

3.1.4. Benefits

Most supply chain issues can be attributed to the following problems, as highlighted in Section 2.3:

– The **bull-whip** [23] effect or the Forrester [24] effect
– Poor product visibility, especially around Work-in-Progress and inventories
– Poor information sharing and collaboration across players in a supply chain. Traditional relationships between buyers and suppliers across two companies have been adversarial.
– Mismatch between product and supply chain

Intelligent products and the Internet can alleviate the problems above by increasing product visibility and enable tracking and routing of a product. Beyond that however, the possibilities with these technologies are unlimited. Some of the benefits are:

1. Self-Managed Products for Transportation

Products will 'know' where they want to go as they have the destination of the end consumer or collection point. If transportation were available similar to the Internet model, where space can be bought on trucks, products will be able to get to the end destination by itself (see Section 4.4.2.4).

[23] Hau L. Lee, V. Padmanabhan, Seungjin Whang, **"The Bullwhip Effect in Supply Chains"**, Sloan Management Review, Spring 1997.

[24] Jay W. Forrester, **"Industrial Dynamics: A Major Breakthrough for Decision Makers"**, Harvard Business Review 36, no.4 (1958) pp 37–66.

2. Self-Picking Products
Products will 'know' their due by dates and their end destinations. The picking agent can interact with the product agents to determine which product should be shipped out first, based on the due delivery date to end consumer, physical constraints of the transportation vehicle, due by date of the product or whatever constraints have been determined. These constraints would vary depending on the sector and product type.

3. Self-Routing Products for Manufacture
In a distributed manufacturing environment, product agents can contain processing requirements and parameters such as manufacturing process required, dimensions and tolerances etc. Machinery and other resources would also have an agent associated with it, outlining capabilities and capacity. Agents from both the resource and product are able to interact with each other to determine a match. Subsequently components can route itself along possible production routes.

4. Self-Manufacturing Products
Once a product has been routed to the appropriate machinery or resource, product agents can 'program' the machinery to carry out the required operations. The manufacturing parameters would be downloaded to the machinery agent from the product agent. Alternatively, software containing instructions and parameters can be sent to machinery agents from external sites via the Internet to interpret and use. Machines do not have to be programmed as the software will download 'instructions' to it for a particular part.

Applications of the benefits above are discussed in the Section 4 on Future Supply Chain Models.

3.1.5. Current Developments

– The migration of existing manufacturing systems to holonic systems is already being developed. Pilot studies have been carried out with some success, but usually raising more questions than is answered. [25]

– Wireless internet is developing fast. Technologies such as 3G, 4G, Bluetooth and GPRS are scheduled to roll out within the next 10 years. The adoption of wireless Internet by end consumers will be tremendous. In 2003, mobile Internet users will outnumber fixed-line users for the first time (Ericsson)[26]. The use of wireless Internet in a manufacturing environment is also being developed, but at a slower pace to end consumer Internet usage.

– Internet standards are fast developing. Standards for XML, or Extensible Mark-up Language, are in the process of being developed with initiatives such as RosettaNet and OpenBuy. XML standards for Internet EDI (Electronic Data Interchange) will reach maturity in about 10 years, according to discussions with software vendors i2 and IBM.

– Products that are Internet-enabled are already in development. LG, a Korean manufacturer, has already developed a working model. It currently is looking to tie-up with an Internet Service Provider. Intelligent Products with the capability to interact with tags, for example an intelligent microwave, are currently being developed.

– The use of the Internet for inter-organisational integration of information, or the extended enterprise concept, is still very limited. 55% of businesses surveyed listed the main driver of implementing a B2B solution as increasing internal process efficiency[27].

– Virtual Manufacturing Enterprise

[25] J. Matson, D. McFarlane, **'Assessing the Responsiveness of Existing Production Operations', Industrial Journal of Operations and Production Management,** Vol. 19 No 8 1999.

N. Gayed, D. Jarvis, J. Jarvis, **'A Strategy for the Migration of Existing Manufacturing Systems to Holonic Systems'**.

[26] **Understanding 3G**, Financial Times supplement, Summer 2001. www.ft.com/understanding3g

[27] B2B eCommerce: **From EDI to eMarketplaces, Reuters Business Insight 2001**

Globemen (Global Engineering and Manufacturing in Enterprise Networks) is a project under the auspices of the IMS (Intelligent Manufacturing Systems). Their vision of global manufacturing assumes a virtual enterprise comprised of globally distributed parties, each with its core competencies, coordinated by means of a globally networked IT infrastructure. The goal of the Globemen project is to define and develop the architecture for distributed global manufacturing. The project timeline runs over three years, from January 2000 – January 2003. The approach of Globemen is to address three main aspects of manufacturing: Sales & Services, Delivery process management and Product/Process Engineering. The deliverables of the Globemen project are:

- Generic reference architecture for virtual manufacturing enterprises.
- Specification of required methods & tools.
- Guidelines and handbooks for virtual manufacturing enterprises.
- A demonstration of system features.
- Industrial prototype implementations.

– Data and Communications Grid

The UK government is investing £20mn to develop a high-speed national grid of supercomputing power, for UK scientists and academics. This grid is expected to form the basis on which ICTs grids are developed for commercial use in the future. There are similar initiatives in the US and Germany.

4. FUTURE SUPPLY CHAIN MODELS

4.1. Overview

The biggest enabler toward innovation and competitive advantage will be technology. Below are possible models that utilise future technologies. The models are divided into the different stages of the supply chain: Plan, Source, Make, Deliver and Service. The models can be thought of as building blocks and can be pieced together to design a whole supply chain. Different models are suggested for the two different products researched, high-end servers (**innovative product**) and frozen foods (**functional product**). The models target different product types as both present unique opportunities and economics, and raise different internal managerial issues.

Suggestions for where future technologies might be used are put forward according to the main stages of the supply chain. A feasibility analysis is proposed highlighting eight issues to consider when assessing a model. This assessment is at present qualitative but can be adapted for quantitative analysis.

4.2. Generic Trends

There has been an increased focus on supply chain responsiveness and reduction in inventory. These have resulted in a change to performance metrics used, either internally or to assess suppliers/ partners. Below are some trends generic across sectors:

- **Reduction of distance between point-of-demand to point-of-supply**. This can be done in terms of a reduction in time that inventory spends at a level in the supply chain or in transit, and elimination or changing roles of middlemen/ channels.

- Increased attention paid on **supplier management even further upstream**. The practice of this is carried out in different manners across sectors. For innovative products, this means increased collaboration with suppliers. For functional products, this translates to heightened information to all suppliers upstream to allow for collaborative forecasting planning and replenishment (CPFR) and Efficient Consumer Replenishment (ECR).

- Changing focus from the amount of inventory there is in the chain, to **how fast inventory moves throughout the chain**[28]. This is particularly important for innovative products to counter obsoletion of stock. For example, supposing a company has 11 days inventory and a competitor has 50. If Intel came up with a new chip, the company can get a new product to market potentially 39 days sooner.

- Heightened **visibility of information** throughout the chain. Inventory tracking and control is continuous or frequent, and automatic. Data capture is carried out to ensure Performance, Quality, Regulatory Compliance and Security.

- Increased focus on '% of Sales' spent on logistics and transportation[29].

[28] Michael Dell, **The Power of Virtual Integration: An Interview with Dell Computer's Michael Dell**; J. Magretta, Harvard Business Review March-April 1998.

[29] David Bovet, Vice-President, **Mercer Management Consulting,** Boston, Massachusetts. Telephone interview conducted in May 2001.

4.3. Innovative Products – High-Tech Sector

4.3.1. Channels and Mediums

To get the product through the transition stages from raw material to final demand and utilisation, three main routes can be used as outlined in Section 2.5.2 (Diagram 1). As innovative products require responsive models, the most responsive would be via the route **'Raw Material – Sub-assemblies – Finished goods assembled to order in the channel – Final demand'**. However, this model is actually just the merging of the Finished Goods and the Shipped to Channel stages.

The speeding up of processes at each stage in the supply chain or in transit may be achieved with more efficient information flow and heightened product visibility. This has to be coupled with improved business processes and increased collaboration or integration between parties.

4.3.2. Proposed Models

The diagram overleaf illustrates three models[30] each with different stages where the customer order enters the supply chain. The ideal model for innovative products, including high-end servers, would be the Make to Order model. This coincides with the **'Raw Material – Sub-assemblies – Finished goods assembled to order in the channel – Final demand'** model. The Ship to Order and Pack to Order coincide with the **'Raw Material – Sub-assemblies – Finished goods – Shipped to channel – Final demand'**. The purchase stage in the models overleaf can be the retailer or external sales unit with accompanying inventory (Inventory Management stage), or it can be the purchase by the end consumer in which case there would not be and Inventory Management stage.

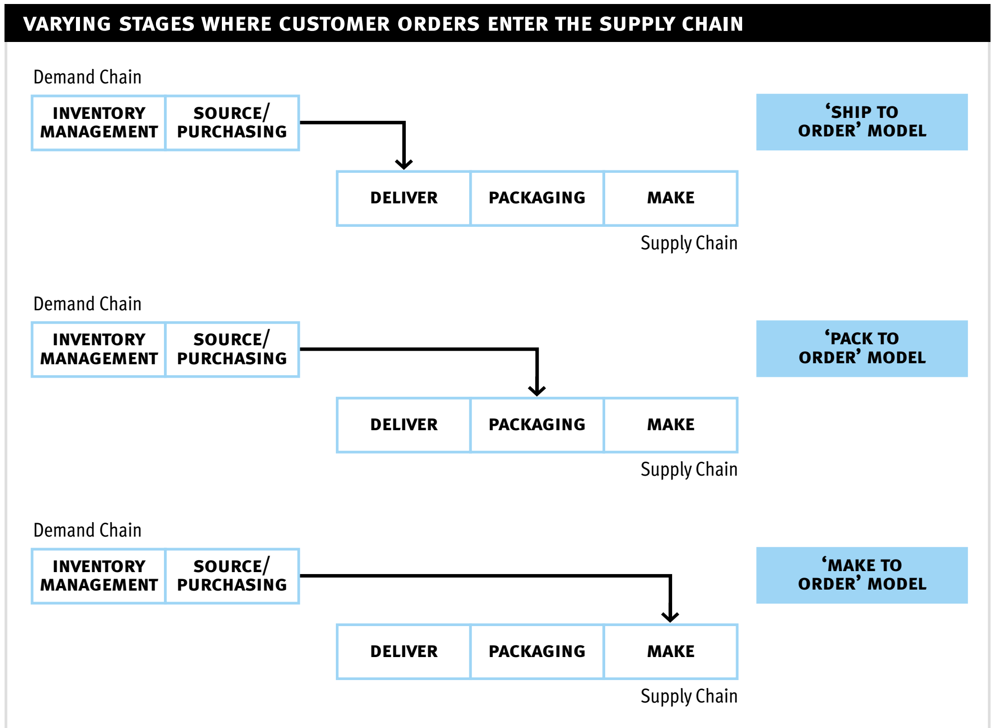
[30] Inspired by models presented by McKinsey in **'The Other End of The Supply Chain', McKinsey Quarterly No. 1, 2000**.

Below are suggestions on areas in which Intelligent Products and the Internet can help in the main stages of a supply chain, assuming the Make to Order model. Tags are assumed to be placed on Intelligent Products at the start of the chain by suppliers. The feasibility of this is discussed in Section 4.3.3.

4.3.2.1. Plan

With an increase in global sourcing, the use of the Internet as a window to source for material, sub-assemblies and products enables the creation of a virtual enterprise, where factories may be located in various parts of the country or the world. The need to integrate and co-ordinate activities across the enterprise is needed for high collaboration between partners. The Internet can be used as a medium of information transfer to ensure high connectivity between locations. More importantly, if demand in the chain is signalled direct from the end consumer to manufacturer, the manufacturer is in the driving seat of the chain and can deliver what the customer wants. The distance and time between point-of-

Diagram 4: Varying Stages Where Customer Orders Enter The Supply Chain



supply to point-of-demand is potentially decreased. Customisation of products will most likely be made up of modular components for easier product management.

Once demand has been signalled, possibly via the Internet, central headquarters can allocate fulfilment of that order to one of many manufacturing units around the globe based on manufacturing capability and capacity, and depending on location of end customer. Each complete customer solution is given a unique **Customer Solution** identity in the form of an EPC. The product specifications set out by the customer, process and assembly parameters and end customer details are associated with the EPC.

4.3.2.2. Source

END-USER

For the Make-to-Order model, demand is signalled direct from the customer to the manufacturer. The resellers and sales force have a changing role of assisting customers to piece together end solutions and to possibly redirect them to products using components that are higher in availability. This ensures that customisation of solutions are within the capability of the manufacturer whilst still meeting customer requirements.

MANUFACTURER

Global Sourcing

Sourcing can be done on a global basis via an e-procurement marketplace. This also ensures that the demand signal from the manufacturer is direct to the suppliers rather than via a third party. Quality and part conformance is of utmost importance in this sector as product recalls are damaging to reputation and costly. Hence the e-procurement marketplace will most likely have strict membership requirements.

Improved Product traceability
As parts are sourced from various suppliers, consistent product identification has to take place. Currently, a part may be identified differently by a supplier and manufacturer. Even if bar codes are used for that part, the technical specifications of that bar code may differ. For example, the supplier may recognise the part with a 10-bit bar code whereas the manufacturer uses a 12-bit bar code. The EPC associated with each component ensures that the information, stored externally in a database, is consistent throughout the chain.

Kitting process by Suppliers
For a responsive chain using open architecture, modular components, assembly time can be decreased if components arrive on the shopfloor as 'kits' ready to be assembled. If components making up a finished good have a unique **Customer Solution** EPC associated with individual component EPCs, the components can be matched up before assembly. This stage can be carried out either by the third-party logistics provider that manages the incoming inventory, or at the Goods In area itself. This can lead to automated picking of components if they are stored in a warehouse prior to assembly.

Activity Based Costing
Component sourcing from various parties can lead to inaccurate product costing if overheads are apportioned directly. With unique EPCs for each component, the relevant costs can be directly associated with individual products and Activity-Based Costing (ABC) can be carried out.

4.3.2.3. Make
Agile Manufacturing
With the increase in flexible machines that have rapid tooling interchange, changeover times, long runs and maximum asset utilisation are no longer the main drivers in manufacturing. A flexible machine would have an agent associated with it, outlining capabilities and capacity. A component would also have an agent associated with it, outlining processing requirements and parameters such as manufacturing process required, dimensions and tolerances etc. Agents from both the resource and product interact with each other and subsequently components get routed along possible production routes. This is carried out via and intelligent software that can negotiate with different manufacturing resources.

Virtual Manufacturing
Traditionally engineering drawings and product specifications are sent out on paper or electronically via PDF or XML files. Alternatively, software to decode specifications and information can be sent for agents to interpret and use. Machines do not have to be programmed as the software will download 'instructions' to it for a particular part. This is increasingly useful with the increase in global sourcing as control is still maintained over the manufacturing process. This is also good news for the smaller manufacturing outfits as it increases the advantages of outsourcing manufacture. 98.3% of manufacturing firms in the UK are classed as SMEs[31].

[31] Source: CBI's National Manufacturing Council, 2000

Virtual Assembly
With components being modular and 'open' in nature, they can be sourced from any supplier meeting requirements. If components forming a specific finished good have a unique **Customer Solution** EPC associated with individual EPCs, they can be automatically grouped together as a kit. If the specification of the end product is contained on the product agents, automatic assembly can take place using robots. The handling of the high-tech products is critical though due to its sensitive nature.

4.3.2.4. Deliver
Assemble in Channel
Customer solutions may be made up of more than one finished product. In the same way that components are associated with a unique **Customer Solution** EPC, multiple finished goods can be associated with a unique **Customer Solution** EPC. If the finished goods are sourced from various locations they can be

sent individually to the end user. For testing purposes, it might be collated first at a local hub nearest the end user for necessary integration and testing. This is moving toward the 'Finished goods assembled to order in channel' model (see Section 2.5.2). This is a move away from existing models where all or a majority of finished goods might be aggregated at a centralised centre before shipment to final customer.

Assembly in the channel would lead to direct deliveries to the end user. Agents on the products can 'talk' to the software that handles product routing for route optimisation. Direct shipment might cause an increase in transportation costs and would require tighter route planning and optimisation. The benefits are shorter lead time to customer, lower fixed overheads and less inventory in the chain. The ability to choose the delivery channel also increases empowerment of the customer in a supply chain.

Security
Security is an issue particularly for the higher end products. Tags might have GPS capabilities, which can interact with agents on the truck or in a warehouse. This can be used to monitor and track product movement between and at locations.

Storage and Transit Environments
Temperature and humidity controls are important for high-tech products. Tags might have Microelectronic Mechanical Systems (MEMS), which can be thought of as miniscule parts that have processing and mechanical capabilities. A MEMS tag can sense changes in external conditions and interact with the environment control agent to maintain optimal environment conditions.

4.3.2.5. Service
Product Traceability
Information about a product is usually lost once that product leaves the factory. Information about the end customer is typically held by the party at the Channel level (see Section 2.5.2), which is usually the reseller or the Sales unit. For servicing of the product, which is usually done by the servicing division or is outsourced, acquiring information about the product and customer details can be a lengthy, manual process. If information about the customer and product history is stored either on the tag or on an external database, service personnel can access the relevant information easily.

Remote Monitoring
Components and products have tags that are capable of monitoring performance and operating environment. Tags might contain Microelectronic Mechanical Systems (MEMS) that can sense changes in certain parameters (e.g. temperature, motion etc.). Agents can transmit information or raise warning alarms via the Internet if the product has Internet Connection. The remote sensing of machinery is already adopted in some industries. Remote monitoring would be particularly applicable to critical or valuable components, where predictability of mean time to failure and uptime of applications are important.

Pre-Visit Diagnostics
Beyond remote monitoring, agents can be programmed to carry out basic diagnostics on a component or product in the event of failure. At present, servicing of parts and products on high-tech equipment would require an initial visit to assess the failure and determine spare components and procedures needed to fix it. If the failure is serious and the repair work cannot be carried out in the first visit a second visit is necessary. Agents that can carry out basic diagnostic work and transmit this information via the Internet to the servicing team will thus eliminate a potential unnecessary visit. This is currently carried out by British Gas for domestic boilers.

End-of-Life Management
End-of-life management is usually not touched on in supply chain management literature. With the increased emphasis on industrial sustainability, companies can be made to be responsible for disposal

of large, bulky products. Products that can send a trigger to indicate that it is about to fail can initiate a collection process in the chain. For recycling purposes, intelligent products can contain information about processes and material involved in its manufacture. This information can be used for potential recycle or reuse of components.

4.3.3. Feasibility Analysis

– Tagging is assumed to take place at the start of the manufacture process. Tagging is carried out at individual part level. Alternatively only critical parts or sub-assemblies can be tagged. The issues to consider are cost of the tagging process, granularity of information required, benefits from that information, value of component and criticality of that component in either manufacture, assembly or in use.

– The cost of tagging is two-fold. First is the initial cost to install machinery to tag items, readers and make adjustments to the machinery or equipment needed for an intelligent product environment. Secondly is the on-going cost to tag each item and maintenance of the system. The initial costs are most likely to be borne by the individual parties. The on-going costs, particularly to tag items, are potentially borne by the supplier. An alternative cost sharing mechanism is to apportion it out based on value derived from the intelligent system. This is potentially weighted against the manufacturers, as they are most likely to receive the most benefits from increased information and product visibility.

  Considering the cost of material in the high-tech sector, which is typically over 60% of the overall product cost, the cost of tagging a product (tag, systems etc) is nothing compared to the benefits of high product visibility throughout the chain.

– Security surrounding accessibility of data is a primary reason that people are hesitant about intelligent products. The debate is mainly regarding control of data. There are two ways of storing information. One method is to store it on the tag itself. The second is to store the information on an external database and have the agents on the tag point toward that data via an EPC. The latter is the approach of the Auto-ID centre.

  Information stored on the tag is vulnerable to hacking by unauthorised personnel. Information on an external database is potentially more secure as access to it, either via wired internet or wireless devices, can be controlled.

– Flexible machines are possible but limited in flexibility and usage.

4.4. Functional Products – FMCG Sector

4.4.1. Channels and Mediums

To get the product through the transition stages from raw material to final demand and utilisation, three main routes can be used as outlined in Section 2.6.2 (Diagram 2). The solutions in this sector focus on the sourcing and delivery of finished goods from the perspective of the end consumer. As functional products require lean, cost efficient models for finished goods, the most lean would be via the route **'Raw Material – Basic Ingredients – Finished Goods – Final demand'**. The model where basic ingredients are 'assembled in the channel' is not focused on as it is assumed to be less widespread than the **'Raw Material – Basic Ingredients – Finished Goods – Final demand'** model. In the model suggested below, retail outlets might cease to have a function of carrying stock and as triggers of demand to end consumers via display of products. Retail outlets might serve as an intermediate warehouse for customers wishing to collect pre-selected and pre-paid goods purchased over the Internet.

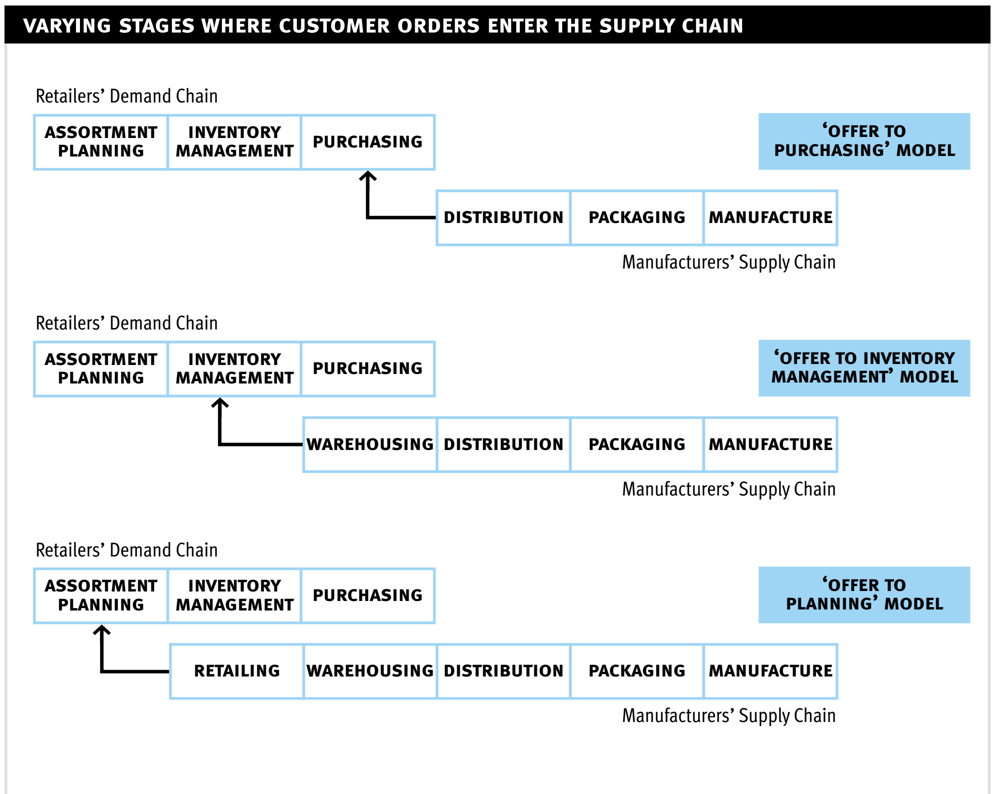
[32] Inspired by models presented by McKinsey in **'The Other End of The Supply Chain', McKinsey Quarterly No. 1, 2000**.

4.4.2. Proposed Models

The diagram overleaf illustrates three models [32] each with different variations of how the suppliers' value offering addresses the demand chain. The leanest model for functional products, including functional ice creams, would be the Offer to Planning model (third model). This model illustrates the increasing power of the manufacturer in the chain, to the extent that it can determine which products will be sold in which channel. The demand chains represent that of the traditional retailer. The supply chain represents that of the supplier.

Below are suggestions on how Intelligent Products and the Internet can help in the main stages of a supply chain assuming the Offer to Planning model. Tags are assumed to be placed on Intelligent Products at the start of the chain by suppliers. The feasibility of this is discussed in Section 4.4.3 .

Diagram 5: Varying Points Where Suppliers Offering Meets Demand



4.4.2.1. Plan

Demand is signalled directly by the end consumer, instead of by retailers, to manufacturers. Demand is raised via the Internet, either wired or mobile. Wired Internet devices would be through the Personal Computer and through white goods/ domestic appliances that have agents. Mobile Internet devices would be via Personal Digital Appliances (PDAs) and via 'vendor machines'. Further explanations are given in the Section 4.4.2.2 below.

Order processing and planning for production is carried out centrally based on product category. As product demand is more or less predictable, demand forecasting is now clearer based on customer orders, product history and market intelligence. Planning is carried out to allocate production capacity and volumes. The manufacturing focus for functional products is on asset utilisation to achieve economies of scale. This differs from the focus for innovative products. Hence, distributive manufacture is limited. If the main aim of the chain is to get product manufacture as close to the end consumer as possible, manufacture may be outsourced. If manufacturing were outsourced, close integration of operations would be feasible using Internet links between sites.

Granularity of information is most likely to be at case level. Ideally it would be at individual product level, if the cost of tags and intelligent systems can be kept low. Tags are attached to products at the manufacturing stage. It would be impractical to tag a product at the raw material stage or basic ingredients stage given the nature of the products that require a lot of mixing and processing.

If individual finished goods were tagged, it would be possible to put together an **order basket** of goods for end consumers that would have a unique EPC attached to it. Alternatively, each end consumer can have a unique identifier to always associate products purchased by that end consumer. This is further discussed in Section 4.4.3.

4.4.2.2. Source

END USER

A purchase can be made either in-store or remotely via the Internet, using both wired and mobile devices. Wired Internet devices would be through the Personal Computer and through white goods/ domestic appliances that have agents (in the form of tags and readers) attached to them. White goods would include refrigerators and freezers that can detect levels of a certain product. Domestic appliances would be a cabinet with an agent in the form of a tag and reader. If the product level falls below a pre-determined level, the agent on the white good can trigger a product re-order to be collected by the customer at the nearest retail outlet. Wired devices in the household can allow customers to check what products are available in the refrigerator or cupboard remotely, before making further purchases.

Mobile devices to order products would be via Personal Digital Appliances (PDAs), mobile phones and 'vending machines'. These vending machines would be similar to the rail travel ticket machines at UK train stations. Products can be selected and added to an 'order basket' via a touch screen and paid for either via credit card or forms of m-commerce. The goods cannot be acquired on the spot like conventional vending machines. Rather, an order basket will be collected at a chosen retail outlet later.

RETAIL OUTLET

At present, demand from retail outlets is signalled via a centralised purchasing department which has collated information from all outlets. Other retailers place orders to manufacturers as and when products are needed. With individual product tags, EPOS data can be used to signal demand to manufacturers to replenish items. Automatic replenishment is part of Collaborative Planning, Forecasting and Replenishment (CPFR), which falls under the second model (Offer to Inventory Management model) above. In this way, a minimum stock level is maintained at each retail outlet. With individual EPCs, suppliers can also differentiate between products that have already been 'bought' and 'paid for', and 'stock' products used as buffers.

In the 'Offer to Planning' model, retail outlets might cease to act as triggers of demand to end consumers via display of products. Retail outlets might serve as an intermediate warehouse for customers wishing to collect pre-selected and pre-paid goods purchased over the Internet. Innovative FMCG products, which are mainly impulse purchases, will still be displayed. The trigger for products would be via clever, external advertising mediums.

MANUFACTURERS

Manufacturers would source raw material and basic ingredients from suppliers more on a PULL system. As functional product demand levels are more predictable, it would be feasible to give supplier an estimate volume required over an extended period of time. However, actual deliveries would be just-in-time.

Global sourcing is also possible, with the use of the Internet. As manufacturers' supplies are quite easily substitutable, the main sourcing criteria may well be price, delivery lead times and quality. Product variety would be an **order winning** rather than an **order qualifying** criteria. Hence the e-marketplace would be a logical medium to source products at lower prices.

4.4.2.3. Make

Virtual Manufacturing

If finished goods are to be assembled in the channel, agents can be used to control the mixing and processing of ingredients at a remote site. For example, if basic ingredients are shipped to retail outlets to be mixed and processed onsite, the use of agents on the mixing and processing machinery will ensure that quality and consistency of product is ensured without having to reprogram machinery for each run.

Distributive Manufacturing

Distributive manufacturing, whether outsourced or in-house, would be more feasible with the use of agents to specify the production 'recipe'. Although manufacturing cycle times can be reduced with the elimination of individually programming each machine for different products, changeover times would still be quite long in this sector. This is due to the product nature which requires a complete clean-out of process routes (e.g. pipes, racks etc) after each changeover to avoid the contamination of taste, smell, texture and appearance. For example, the changeover time from dark chocolate to white chocolate takes 6 hours at the Cadbury factory and 3 hours for the reverse changeover. This is unlikely to change, even with the introduction of **agents**.

Centralised Manufacturing

Product routing, scheduling and sequencing can be carried out within a plant if manufacturing is carried out on a PULL basis. The routing, scheduling and sequencing can be determined according to demand, receipt of raw materials or basic ingredients and capacity. This would be an improvement over existing software as there would be higher product and information visibility with tags and agents.

4.4.2.4. Deliver

With tags and agents, an intelligent product will have the capability of 'knowing' and 'telling' other agents where it should go (Self-managed products for transportation). In the event that manufacturers can exert increased control over the buying process at the end consumer level, they will have a clearer idea of where a product is going. At present, a product will typically go through the factory warehouse, manufacturers distribution centre, retailers' distribution centre and retail outlet before reaching the end consumer. If manufacturers can exert more control at the retail outlet level, they can potentially ship products based on geographical location of end consumers or retail outlets rather than through numerous hoops.

Purchasing of Delivery Space

Products can potentially be shipped out based on geographical location of end destination, similar to the postal network. Space can be bought from third party logistics providers as and when needed, and routing of product toward end destination can be optimised. This would imply that products can be routed on an individual level. The practicalities of doing this is highly debatable, and it will be more feasible to route products at a case level.

This routing model is based on the Internet model where products are assumed to be analogous to data packets. Data packets 'know' their end destination, and routers in the network can route the data along the less congested routes. The flaw with the model is that data packets can be disintegrated and sent in random order or can be duplicated and 'flooded' through the network in order to increase the chances of getting the data packet to the end destination.

The model of product routing may work only for low volume products though, as otherwise full, regular truckloads to any destination are justifiable.

Mixed Pallets/Mixed Cases

Mixed pallets can be picked if individual cases can be identified and assembled as a pallet. At present, mixed pallets are possible but they are costly, as it would involve manual picking of cases. For even more flexibility, mixed cases would also be possible if individual products can be picked and placed to form a case. Mixed pallets and mixed cases are desirable, as they would enable smaller, more frequent deliveries to take place to the retail outlets.

Picking of individual products would allow individual customer orders to be put together, making home deliveries cheaper as well. The problem with home deliveries extends beyond the high picking costs. Fulfilment of orders, particularly of frozen goods, is a problem if customers are not home to receive them. An innovative home delivery company in Boston, Massachusetts invests in a small refrigerated box that is kept accessible within a time window, when the delivery man can deposit the frozen goods in the chilled box.

Control over Goods Receivable process

By passing products through scanners at entry and exit points of a storage location or a truck, the products' movements can be traced. Any discrepancies between delivery notes and invoices with the number and type of products that actually get delivered and received can potentially be eliminated. The 'disappearances' of items in transit contribute to a high proportion of the shrinkage of stock.

Environment Control

Temperature and hygiene controls are important for frozen food products. Tags attached to products might have Microelectronic Mechanical Systems (MEMS), which can be thought of as miniscule parts that have processing and mechanical capabilities. MEMS tags can sense changes in external conditions and interact with the environment control agent to maintain optimal environment conditions.

4.4.2.5. Service

Domestic Management for End User

Basic products can be replenished on a minimum level basis, where the order is triggered by intelligent white goods and domestic appliances. The settings on these appliances can be set up so that re-ordered products can be collected on a pre-specified day of the week.

Another benefit of intelligent products and tags to the end consumer is the ability to remotely check the type and number of products left at home on the shelves or in the refrigerator. This would be accessed via the Internet.

Pre-Sale Advice

In the event that the product level of a certain product run low, the intelligent domestic appliance can trigger a message to manufacturers inviting them to bid for advertising space, either on the end customer's television, PDA or via e-mail. In addition to information about choice of products, possible recipes or serving suggestions would be adding value to the consumer experience.

End-of-Life

Product agents can maintain a record of the environment that a product has been subjected to. This can lead to dynamic due-by dates, where they can change depending on environmental conditions that a product has been in. For example, a product that has been out in warmer temperatures for longer times might go off first. The agent on this product can flag this up in a picking process and the product might be picked before another product that has an approaching due by date but has been kept in optimal conditions. Alternatively, product agents can flag this up on an intelligent domestic appliance, such as a refrigerator, and a warning can be triggered to consume the product soon.

Information about the material used in packaging can be stored on with a product. This would aid in the recycling or reusability of products.

4.4.3. Feasibility Analysis

33 A. Mitchell, **'Acting as Agents', Multiple Buyer & Retailer,** March 2000.

– The model of 'Offer to Planning', which involves a decreasing role of retailers in the supply chain is possible. This occurs when the retailers move toward managing the consumer experience and become customer agents, sourcing and storing the products that people want to or already have purchased [33]. The feasibility of this occurring would depend highly on the relationship between manufacturers and retailers, and brand loyalty. Only the big manufacturers would be capable of having any clout in a supply chain to enforce changes toward exerting more control.

– The feasibility of white goods becoming intelligent products is materialising. LG, a Korean manufacturer who has presence in the high-end refrigerator market, has manufactured a product with Internet capabilities. The company has yet to tie in with any Internet Service Provider for full functionality of the product.

– Granularity of information is most likely to be at case level rather than at individual product level. Ideally it would be at individual product level, if the cost of tags and intelligent systems can be kept low. Tags are attached to products at the manufacturing stage. It would be impractical to tag a product at the raw material stage or basic ingredients stage given the nature of the products that require a lot of mixing and processing. However, in the future, information might be possible to attach to raw materials and basic ingredients in the form of liquid tracers. Health and safety issues are very important to maintain though in food products.

– Demand for functional products are more or less predictable. There will be less impulse purchasing of functional products unless there is a price slash. It has been shown that price fluctuations are detrimental to supply chains, hence it can be assumed that a risk-acceptable stock level of functional products would be plausible to manage.

– Data management issues will be sensitive, particularly when it relates to end consumers. Having a unique identifier for each end consumer will enable the build-up of a customer profile. This is already a contentious issue with the concept of loyalty programs at present. Hence the likelihood of this occurring is minimal.

4.4.4. Generic Model for Feasibility Analysis

The models for stages of the supply chain suggested above can be used as building blocks to design a supply chain. This, coupled with the framework to assess the nature of the product, can potentially lead to an effective supply chain design. The next step would be to gauge the feasibility of the models, not just in a technical sense but also against pertinent wider issues. To assess the feasibility of resulting models, the following framework is suggested as a checklist of issues to consider.

4.4.4.1. Main Drivers

The following issues would be important to consider as they can impact businesses and hence supply chains.

Table 7: Main drivers affecting feasibility of models

ISSUES	AREAS TO CONSIDER
TECHNOLOGY	– Functionality and availability of software and hardware – Friendly user interface – Technical support and backup – Impact on legacy systems – Implementation and maintenance costs
STANDARDS	– Messaging formats and data parameter definitions – Information transfer standards – Technical architecture standards
PRODUCT NATURE	– Security issues, especially for high value products – Product environment, for example temperature levels
MONITORING LEVEL /GRANULARITY OF INFORMATION	– Level of tagging to employ (Pallets – Cases – Individual products). The costs and benefits of the varying granularity of information have to be weighed up.
DATA ISSUES	– Data management – Data ownership. For example, consumer data, competitors' product volumes – Data accessibility and security. Which parties are allowed to access and decode data – Data storage
ORGANISATIONAL	– Re-organisation of business processes both internally and externally for efficient transfer of information across parties – Increase in trust levels and change of mindset
FINANCIAL	– Cost Benefit analysis – Management of liability and risk if products are in transit or in a neutral warehouse – Revenue sharing mechanisms – Cost allocation mechanisms
REGULATORY ISSUES	– Anti-trust legislation. For example, the European Commission and Federal Trade Commission have released statements regarding anti-trust guidelines for Internet exchanges. – Tax issues. For example, an e-market residing in the US will pay 40% or more in federal and state taxes. However, with careful planning, the entity can be established outside of the US and overall tax can be slashed to 15%.[34] – Quality Assurance and Health & Safety issues. For example, quick frozen foods are covered by a Temperature Regulation stipulating storage temperature

The areas within each issue above can be weighted to come up with a qualitative analysis model. Graphical representation of a qualitative analysis would be a useful and effective way of putting the message across. A possible weighting mechanism between 1 to 5 is suggested, looking at impact, feasibility and level of tagging:

[34] Source: PWC

Table 8: Suggested Weighting Mechanism considering Impact, Feasibility and Monitoring Level

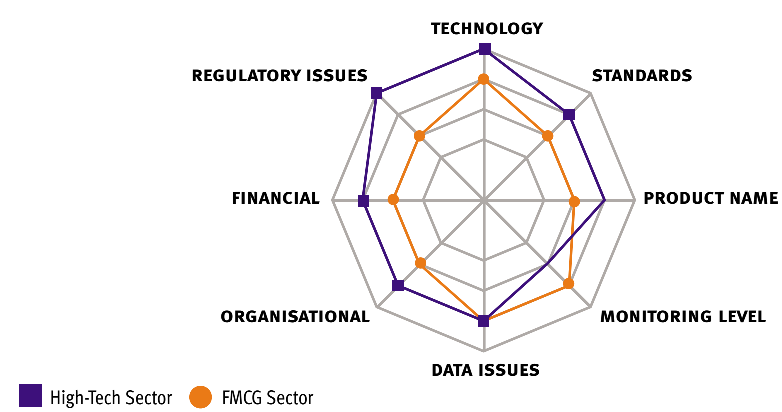
WEIGHTING	IMPACT	FEASIBILITY	MONITORING LEVEL HIGH-TECH SECTOR	MONITORING LEVEL FMCG SECTOR
1	Very negative impact	Impossible	Individual Parts	Granule
2	Negative impact	Possible, but difficult	Individual Sub-assemblies	Individual Sub-assemblies
3	Average impact	Feasible Finished Products	Individual Finished Products	Individual
4	Positive impact	Initiatives toward development in process	Individual Customer Solutions	Individual Cases
5	Competitive advantage gained	Standard processes already in place	Individual Shipments	Individual Pallets

An example of how the model might be used is illustrated for both the high-tech and FMCG sectors below. The weightings of the areas within each issue are subjective and based on the arguments outlined in Section 4.3.3 and Section 4.4.3.

From the diagram, it can be extrapolated that the high-tech sector is better poised to adopt intelligent products than the FMCG sector due to the nature of the products (high end servers versus frozen foods), the existing competition with the players in the industry and initiatives toward standards development from both a technical and business perspective. This assessment is purely subjective though.

Diagram 6: Feasibility Analysis for High-tech and FMCG Sectors

FEASIBILITY ANALYSIS FOR HIGH-TECH AND FMCG SECTORS



5. FURTHER RESEARCH

The scope of this project was rather broad, and hence analysis was limited to the qualitative aspects. Research also covered two companies in diverse sectors and hence the impressions obtained of the industry might be biased or narrow. As the analysis covered two sectors, it would be interesting to investigate whether there are similarities that can be extrapolated to other industries. Suggestions for further research to this project would be in the following three areas:

1. Quantitative assessment on the possible benefits to the companies researched. This would be accurate perhaps only to the level of order of magnitude, as the concept of intelligent systems are not translated into commercially available products and systems as yet

2. Look at other companies within the industry that operate similarly to get a reality check for whether the assumptions, and hence suggestions, would be applicable across the sectors researched.

3. Analysis of other sectors to fully flesh out the possibilities that intelligent products and the Internet can have on Industry. The operation of any company depends to a large extent on the market environment and the company's interaction with other companies in different sectors, perhaps in different sectors. The full possibilities of the technologies looked at in this project can be developed further.

6. CONCLUSIONS

Supply chains have two overarching functions. The first is a **physical function**, which involves the conversion of raw material into parts, components and finished goods, and also includes transporting all of them from one point to the other. The second is **market mediation**, which involves ensuring that the variety of products reaching the marketplace matches what people want to buy.

The main limitations in supply chains at present are high inventory levels, long time duration for a product to get through the supply chain and low level of responsiveness toward changes in demand and supply. These limitations are commonly caused by the bull-whip effect, poor product visibility, poor information sharing amongst parties in a supply chain, and a mismatch between products and the supply chain that supports it.

The solutions proposed in this report tackle the above problems in two ways. First, the nature of a product is established to determine whether it is an **innovative** or **functional product**. A responsive supply chain is needed for innovative products to assist with the **market mediation function**. A lean, cost efficient chain better supports a functional one to help with the **physical function**. A model is proposed for each of the product types. Secondly, the uses of Intelligent Products and the Internet are scoped to identify ways that these technologies can help alleviate or eliminate the problems listed above.

The model proposed for the innovative product adopts an Assemble-in-Channel and Make-to-Order approach. The model proposed for the functional product aims to decrease the distance between the point-of-demand to point-of-supply. It attempts to do this via alternative sourcing mediums for the end consumer, distributive manufacture and changing the role of the retailer in the chain.

The main benefits of Intelligent products and the Internet in the responsive chain are in the following areas: Self-Product Routing and Kitting Process, Virtual Assembly, Product Traceability and Remote Monitoring. The main benefits of the technologies in the functional chain are: Automatic Product Reordering for the end user, Picking and Packing Process for mixed pallets, cases and customer 'order baskets', and in End-of-Life Management.

Overall, Intelligent Products **shift the pivot point** in a supply chain at which finished goods are made-to-stock or made-to-order. Secondly, they also enable easier sourcing of numerous partners to form a supply chain or **increase branching networks**, as Intelligent Products can flag up parameters and requirements in order to progress through the chain. Thirdly, if Intelligent Products are able to make and trigger basic decisions relevant to its own destiny, they can lead to **increasing swap rates** between partners in a supply chain as any enterprise is no longer constrained by traditional business processes needed between two parties to carry out an activity in the chain.

From the research, interviews and discussions, the hardware required for the above applications are feasible. Some are already in the development phase or in the market. The development of intelligent **agents** is taking place, with the main medium being radio-frequency tags. There are numerous consortiums involved in the development of standards and technology of RFID tags. The areas that require a lot of developmental work are the standards, protocols and software for the applications. The existing business processes and industry structures for both sectors also require changing for the technology to proliferate in order to reach its full potential. The biggest hurdle though, is changing the mindset and attitudes of people, be it customer, retailers, manufacturers or suppliers, before the models and applications suggested in this report get adopted.

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8. APPENDICES

8.1. Project Timeline

PROJECT TIMELINE		
SCOPING PHASE	Preparation	– Background readings into topic. – Discussions with academics who have conducted field studies and with knowledge of topics researched. – Confirm site visits with companies. Prepare questionnaires. Agree **Approach & Deliverables** with companies.
ANALYSIS PHASE	As-is mapping	– Map supply chain: physical flow and information flow. – Data collection. Interview with personnel in companies, software vendors, research organisations, and government bodies. – Identify current performance measures and value-added activities.
	Analysis	– Identify opportunities for technologies.
SOLUTION GENERATION PHASE	To-be mapping	– Redesign/ streamline supply chain.
	Review	– Validate findings.
	Write-up/ Presentation	– Consolidate findings into report/ paper and presentation.

WEEK	1	2	3	4	5	6	7
Dates/Activity from	26/3	30/4	14/5	21/5	28/5	04/6	11/6
Dates/Activity to	30/3	11/5	18/5	25/5	01/6	08/6	13/6
Preparation	■	■	■				
As-is mapping			■	■			
Analysis				■	■		
To-be mapping				■	■		
Review					■	■	
Write-up/Presentation						■	■

8.2. Top 12 Issues in Supply Chain Management

Table 8: Source – H. Akkermans, P. Bogerd, E.Yucesan, L.N. Van Wasserhove, **'The Impact of ERP on Supply Chain Management: Exploration Findings from A European Delphi Study'**, INSEAD WP 1999

AREA	KEY ISSUES	% VOTES
INCREASE IN MASS CUSTOMISATION NEEDS – changing supply chain topologies – increased integration across chain	1. Further integration of activities between suppliers and customers across the entire chain 3. Mass customisation: complex assortments, shorter cycle times, less inventory 10. Greater transparency of the global marketplace 2. How to maintain flexibility in ERP systems to deal with changing supply chain needs	87 39 29 57
EXTENDED ENTERPRISE CONCEPTS WITH INCREASED OUTSOURCING	5. Supply chains consisting of several enterprises 7. Further outsourcing of activities such as physical distribution, finance and administration 4. Who will be in the driver's seat in supply-chain co-ordination	35 30 35
IT/TECHNOLOGY	6. Full exchange of information with all the players in the chain 8. Enhancements of IT-tools required to integrate the different parties in the supply chain 11. Internet technology will be the backbone to connect systems of partners in the chain 12. Standardisation of processes and information definitions, the rest if IT infrastructure 9. Globalisation: how to build worldwide ERP systems	35 30 26 22 26

8.3. Supply Chain Analysis for Products Researched

Table 9: Determination of Functional vs. Innovative Product for products researched

	INNOVATIVE	FUNCTIONAL
ASPECTS OF DEMAND	Unpredictable demand	Predictable demand
PRODUCT LIFE CYCLE	3–5 years	8–10 years
PRODUCT VARIETY	Low (3–5 variants per category)	Low
AVERAGE MARGIN OF ERROR IN THE FORECAST AT THE TIME PRODUCTION IS COMMITTED	Almost never for single configurable parts (Make-to-Order)	N.A.
LEAD TIME REQUIRED FOR MADE-TO-ORDER PRODUCTS	Days	Weeks

8.4. Impact of the Internet for Information Exchange

IMPACT	POSSIBLE EFFECTS
COST TRANSPARENCY	– Significant empowerment of the buyer – Impairs ability to obtain high margins. Premium price is questioned by the buyer unless additional benefits, services or products are bundled in. – Commoditisation of products and services – Weakening of brand loyalty
ALTERNATIVE DISTRIBUTION CHANNELS	– Disintermediation or changing role of middle men – Shorter distance between point-of-demand to point-of-supply
SUPPLY AND DEMAND CAN BE PUBLICLY ADVERTISED VIA A TRADING EXCHANGE	– Creation of free markets with demand and supply in perfect equilibrium – Market clearing occurs and equilibrium prices are paid for a product or service
SHIFTING OF THE DELICATE POWER BALANCE IN THE SUPPLY CHAIN	– Shift of power and higher value extraction from manufacturers to distributors, integrators and/or consumers

8.5. Contact List

ORGANISATION	NAME	POSITION
Unilever	Michael Clark	Principal Technologist, Corporate Research
Unilever Birds Eye Walls	Tony Heaney	Regulatory Affairs Manager
Unilever Birds Eye Walls	Shane Horgan	Production/ Sales
Unilever Birds Eye Walls	Jason Ruff	Quality
Unilever Birds Eye Walls	Andy Frank	Logistics
Sun Microsystems	Ronnie Kirkpatrick	BTSC
Sun Microsystems	Catherine Young	N.A.
Sun Microsystems	Martin Rutherford	European Logistics
Sun Microsystems	Martin Crook	N.A.
Sun Microsystems	Brian Waugh	N.A.
Sun Microsystems	Gary Jackson	N.A.
Sun Microsystems	Iain Donaldson	BTSC
Sun Microsystems	Richard Lord	BTSC
Sun Microsystems	Ronnie Glennon	BTSC
Sun Microsystems	Bryan Johnston	Finance
Sun Microsystems	Stephen Keith	IT
Sun Microsystems	Neil Wilson	N.A.
Sun Microsystems	Scott McChristie	N.A.
IBM	Mark Kerr	Senior Consultant, Business Innovation Services, Industrial Sector
Baan	Roel van den Berg	N.A.
Dti	Richard Foggie	Intelligent Products
Dti	Claire Williamson	N.A.
Dti	Pat McDonald	E-Science
Mercer Management Consulting	David Bovet	Vice President, Supply Chain Strategy Team
IGD	Peter Davey	Business Unit Manager, Supply Chain
Sloan School of Management, MIT	Charles Fine	Professor of Management
Leaders for Manufacturing Program, MIT	Jonathan Griffith	Director, Partner Relations & Administration
Auto-ID Center, MIT	Kevin Ashton	Executive Director
Auto-ID Center, MIT	Sanjay Sarma	Research Director
Auto-ID Center, MIT	Dan Engels	Program Manager
Auto-ID Center, MIT	Yun Kang	Graduate Student
Auto-ID Center, MIT	Robin Koh	Masters Student