Improving materials management in electronics manufacturing

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Improving Materials Management in Electronics Manufacturing

by

Mr. Robert E. Heaton
M.Sc. (Hons. Dunelm.), PgCertDMM, PgDipAF.

A Masters Thesis
Submitted in partial fulfilment of the requirements for the award of
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Loughborough University.

Loughborough University
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The companies in the industrial review for hosting visits and answering our questions.
Summary

The aim of this thesis is to determine how in-plant materials management in electronics manufacturing can be improved and to show how a strategy for improvement can be developed for Celestica Limited's Kidsgrove plant.

The literature was reviewed to bring out the current issues and topics of interest in materials management. An industrial analysis, through company visits and case studies, was carried out. A number of "best practices" were identified from the literature and the case studies. The "best practices" identified were prioritisation methods, outsourcing of value added services, shop floor control systems, focused stores, tailored logistics, use of computers, trace ability, use of technology or automation, automatic identification, maintaining data integrity, internet enabled supply-chain, JIT or hybridised JIT-MRP, kanban, linking and communication of MPS's, application of technology, kitting and recording actual usage of material.

An analysis was carried out of the Celestica Kidsgrove site. The approach was to investigate the in-plant materials management system. This system included working practices, processes, technologies etc. Thinking tools were then used to develop a strategy for improving the Kidsgrove site. The shared goal was to "manage materials excellently." The common objectives designed to reach that goal were to reduce stock holdings, improve data integrity of inventory records, model the build plan and improve materials management on the shop floor. The strategy is detailed in section 5.2.

The selection and implementation of software was discussed. An ideal approach was presented based on the experience and expertise gained at the Kidsgrove plant of Celestica Limited. This approach was very much based on using a project management methodology. The key stages and areas were business investigation and analysis, agreeing customer requirements, identifying stakeholders, creating a vision, costs and benefits, detailed investigation of the software, the decision stage, implementation, systems integration, measurables, the "benefits plan", organisational structure, culture, team working and training.
The changes that have been implemented or are still ongoing were reviewed, concentrating mainly on software and related technology. Automation was applied to the main warehouse by implementing a portable R.F. bar coding system. The TiMMS software was trialled, developed and implemented. A vision was presented to show how TiMMS fits into the strategy presented in the thesis. Two other projects were also reviewed due to their relevance; the material supply hub and the APS software. The “best practices” and ongoing projects are compared to the strategy and the holes are identified. It was then suggested that these should be added to the list of “best practices.”
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The ABC classification divides inventory into 3 classifications based on annual usage cost and other criteria.

Amalgamated Engineering and Electrical Union

Automated Guided Vehicle – These are typically robots that are programmed and controlled to store and retrieve.

Advanced Intelligent Programming (TiMMS software module.)

MPS scheduling and planning system.

Advance Planning and Scheduling

Automated Storage and Retrieval systems – this refers to computer controlled materials handling systems. They range from single robots to the control of a whole warehouse.

Automated Warehouse System

Supply-chain management and ERP system supplied by Baan.

Bill Of Materials

Business Planning and Control System. An ERP system.

British Standard Logistics. (Company.)

British Telecommunications. (Company.)

MRP system used at Sun Linlithgow

Contract Electronics Manufacturer. (Synonymous with EMS.)

Computer Integrated Manufacturing

Computerised Manufacturing Management System. An MRP system.

Material at a plant that belongs to the supplier. It is then paid for as it is used. In some cases the supplier also manages the materials.

Current Reality Tree

Cycle counting is a system for checking inventory records periodically to check their accuracy. The frequency of checking is often based on the ABC classification.

Data Acquisition and Control System. Manufacturing shop floor
control and reporting system.

DB2 IBM universal relational database system.
DFT Demand Flow Technology
EC(N) Engineering Change (Number)
EDI Electronic Data Interchange system
EIA Electronic Interchange Association
EMC Egan Marino Corporation. (Company)
EM3 Engineering and Manufacturing database.
EMS Electronic Manufacturing Services. (Synonymous with CEM.)
EOQ Economic Order Quantity. Refers to a calculation commonly used in MRP.
ERP Enterprise Requirement Planning
e-TiMMS Web enabled module of TiMMS software.
EV Expanding Value strategy
FAST Flow line Assembly Tracking System. WIP and Quality tracking system.
FCT Functional Test
FIFO First In First Out
FRT Future Reality Tree
FRT Failure Report Tracking system
GM General Motors. (Company.)
GRN Goods Received Note
GSM Fine pitch placement machine platform supplied by Universal. (Company.)
HMB Hand Mount Balancing (TiMMS software module.)
HP Hewlett Packard. (Company.)
HTML Hyper Text Mark-up Language
Hub A warehouse between supplier and customer. Typically the materials and logistics are managed for both parties.
I.C. Integrated Circuit
INCA Incoming goods control application.
I.T. Information Technology
IBM International Business Machines. (Company.)
ICL International Computers Limited. (Company.)
ICT In Circuit Test
ID Identification
Inc. Incorporated
JIT Just In Time. A philosophy of manufacturing and materials management.
Kanban Japanese word for card. Refers to the signal used in a material "pull" system.
LIFO Last In First Out
LOTS Location On-line Tracking System
Ltd. Limited
MES Manufacturing Execution System
MMS Machine Maintenance System (TiMMS software module.)
MPS Master Production Schedule
MRP Material Requirements Planning
MRP2 Manufacturing Resources Planning
OEM Original Equipment Manufacturer
OM Operations Management
OS/2 Operating System supplied by IBM
P.C. Personal Computer
P.L.C. Programmable Logic Controller
PABX Private Automatic Branch Exchange
PCA Printed Circuit board Assembly
PCS Parts Control System (TiMMS software module.)
PDX Phone Data Exchange
Pg.Cert.DMM Postgraduate Certificate in Design Manufacturing and Management
Pg.Dip.AF Postgraduate Diploma in Accountancy and Finance
PMS Production Management Software
Poka-yoke Japanese word for a failsafe method, often using a jig. For quality assurance in manufacturing.
QIN Quality Information Network
REA  Release number
RF   Radio Frequency
RIM  Reaction Injection Moulding process
RIP  Rework In Progress
RTM  Real Time Management (TiMMS software module.)
SCADA Supervisory Control And Data Acquisition.
SFC  Shop Floor Control
SFDC Shop Floor Data Collection
SKU  Stock kitting unit. Standard number of items within a kitting unit.
SMS  Schedule Monitoring System (TiMMS software module.)
SMT  Surface Mount Technology. Refers to the technology used to affix electronics components on to printed circuit boards.
SPC  Statistical Process Control
SSA  System Software Associates Inc. (Company.)
STAR Stores and RF bar coding system.
TiMMS Totally Integrated Manufacturing Management System. A software package comprising several modules.
TPO  Thermoplastic Elastomer Polyolefin. Environmentally friendly moulding material.
TQC  Total Quality Control
TQM  Total Quality Management
TRW  Automotive supplier. (Company.)
UNIX Uniplexed Information and Computing Service. Operating system.
UPS  Universal Programming Software used for the programming of Universal surface mount machines.
WIP  Work-In-Progress: refers to goods that are in the progress of being made; between raw materials and finished goods.
WLF  Warehouse Location Function (TiMMS software module.)
1. Introduction

The objectives of this chapter are:

- To provide a background to the thesis.
- To define the aims and objectives of the thesis.

1.1 Background

The aim of this thesis was to look at how in-plant materials management in electronics manufacturing can be improved and to present a specific example of how a strategy can be developed. The target in question was the Kidsgrove plant of Celestica Inc.

The headquarters of Celestica Inc. are in Toronto, Canada. Celestica provides contract electronic manufacturing (CEM) services to a number of large original equipment manufacturers (OEM). The Kidsgrove plant manufactures printed circuit board assemblies using surface mount technology. In 1994, the site entered the CEM market as Design to Distribution Limited, a wholly owned subsidiary of ICL. Celestica Inc. bought it in March 1997.

Captive manufacturers or OEM’s are thinking about outsourcing their manufacturing. This is because contract manufacturers have economies of scale, flexibility and improved expertise. For this reason, the contract electronics manufacturing market has a very high growth rate. There are 3 major global players in the CEM market; Solectron, SCI Systems and Celestica. The competition for business is fierce as increasing capacity is being strategically outsourced.
<table>
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<th>SCI</th>
<th>Solectron</th>
<th>Celestica</th>
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<tr>
<td>Reporting date</td>
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<td>Aug 2000</td>
<td>Dec 2000</td>
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<tr>
<td>Revenue</td>
<td>$8,342m</td>
<td>$14,137m</td>
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<td>Net Profit Margin</td>
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<td>$1,278m</td>
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Table 1. Summary of latest annual financials for the top 3 CEM companies.

The main competitive factors are reduced cost, improved responsiveness, flexibility and added value. In printed circuit board assembly, the majority of product cost is materials, so there is the opportunity to gain competitive advantage by improving the way in which materials are managed. This includes reducing the overhead costs attached to materials. These competitive demands also require reduced product introduction lead times and effective shop floor operations. To satisfy the customer better, Celestica Ltd. has set up teams as customer focused teams, which have one or more dedicated production lines. As part of its strategy, the implementation of appropriate and "best in class" I.T. systems was seen as a way of achieving these objectives. This strategy included the implementation of TiMMS shop floor data management software. TiMMS stands for Totally Integrated Manufacturing Management System.

The time scale of this thesis is as follows. The original industrial analysis, including the investigation of Celestica Kidsgrove, was in 1997. The review of implementation covers the time period up to the current date and the proposals refer to current and future initiatives.
1.2 Aims and objectives

The aims of this thesis were:

- To look at how in-plant materials management in electronics manufacturing can be improved.
- To show how a strategy can be developed for the Kidsgrove plant of Celestica Limited.

The objectives set to meet these aims are as follows:

- To review relevant literature and present current issues and topics of relevance to materials management in the electronics industry. Then to identify "best practices."

- To carry out a wider industrial analysis, focused on the electronics industry, mainly through site visits. Then to identify any additional "best practices" to those identified in the literature.

- To carry out an analysis of materials management and associated work practices at the Kidsgrove site of Celestica Limited.

- To make proposals to improve in-plant materials management at Celestica Kidsgrove.

- To review the selection, implementation and development of I.T. systems at Celestica Kidsgrove during the time frame of the thesis.

- To review the changes made since 1996 at Celestica Kidsgrove to materials management and related I.T. systems, with emphasis on the TiMMS software, based on the experience and knowledge of the author.

- To compare these changes with the proposed improvements and identify any gaps.

- To draw conclusions and recommend further work.
2. Literature Review

The objectives of this chapter are:

- To present current issues and topics of relevance to materials management in the electronics industry that can be found in the literature.

- To identify "best practices."

2.1 Introduction

The management of material is one of the key parts of running a successful business. Operations management has a wider brief than this, being the management of people, technology, systems and resources required to produce goods and services. (Render, 1997) This thesis however concentrates on those areas required to improve in-plant materials management in electronics manufacturing. This may include some enabling areas of supply-chain management.

This thesis splits the current areas of interest in to the following sections: materials management, shop floor control systems, the application of technology, and approaches or philosophies.

2.2 Materials management

Materials often account for more than 50% of manufacturing costs. (Prabhu, 1986) A total approach to materials management is required, taking in to account the requirements of other parts of the business. The typical organisational functions are set out, though it must be pointed out that this is a classical approach and that there may be other organisational structures that better suit the needs of each particular business.
In materials management there is a conflict created by the need to supply materials to production, providing efficiency, effectiveness and cost minimisation. (Lee, 1994)

Analysis tools are used for managing inventory, (Rönnholm, 1998) such as Krajicek’s matrix that categorises products as either volume, strategic or bottleneck. Then there is the classic ABC classification tool that is used along with cycle counting. These tools enable us to prioritise the management of materials to meet our goals of efficiency, effectiveness and cost minimisation.

The current trend in the electronics industry is for outsourcing of services. This includes materials management; the companies that offer these services are called distributors, because they distribute components. Most distributors say that contract electronics manufacturing is their fastest growing market segment. (Purchasing, 1998) Their materials management services include inventory planning and management, consignments, in-plant stores, bonded inventories, automated quote and order management response services, automated inventory replenishment, programming of integrated circuits (I.C.’s), kitting and technical support. Flexibility is crucial to serving the needs of contract manufacturers.

The electronics industry has had to cope with materials allocations. (Sullivan, 2000) This is where there is a world-wide shortage of material and production capacity that effects certain components. OEM’s are forced to buy from brokers on the “after market”, who sell second hand components. This places emphasis on materials management to control usage of material and know how many boards they can make and hence promise to customers.

2.3 Shop floor control systems

Shop floor control systems are designed to track manufacturing orders, work-in-progress and work centres in order to communicate their status. (Markland, 1998) This enables prioritisation, provides actual throughput times, tracks work-in-progress, provides efficiency measures and so on.
Controlling the flow of materials through the factory is very important. (Landers, 1995) This is called “shop floor logistics”. It is important to be efficient and effective in supplying materials to production. One way this can be achieved is by reducing the amount of materials handling required and secondly to have materials readily at hand. These are benefits provided by focused stores. The “type of commonality” of materials determines the “type of store” used to hold the components next to the production line.

Materials related costs and service level are often unbalanced, (Landers, 1995) meaning that money is either wasted providing a needless service to the customer or a customer is frequently left unsatisfied because the service is not focused or not enough money is spent in the right area. This is where “tailored logistics” is beneficial. In other words you must be able to tailor your logistics to a customer’s requirement. This can also be applied to logistics on the shop floor. An example of this is the “bread man” concept, where suppliers typically come in to the factory and manage the supply of specific materials. Deliveries may be made in set batch sizes for simplicity. This is called a “stock kitting unit.” (SKU) Another example is for suppliers to provide a “full kitting” service. (Rönnholm, 1998) This means that all the material required to make a product or batch is prepared as a single kit of parts and held in one place. This may also include some pre-manufacture and is designed to reduce costs by simplifying the logistics.

The goal of a successful shop floor control system is to reduce the manufacturing lead-time to processing time by effective integration of human, machine and I.T. (Information Technology) systems. (Bauer, 1991) This provides a much better approach than just looking at the I.T. systems in isolation. However, it is perhaps better to split I.T. and systems, because the systems should include work practices, processes and procedures. I.T. systems are covered further in the next section 2.4.

We are provided with a practical insight in to materials control by an article on Nortel. (Manufacturing systems, 1994) The example is of a materials inspection and tracking system that utilises bar coding. It defines a factory process for materials and materials tracking. It is important that processes are designed to help solve business needs and these will be specific to each business.
2.4 Technology

Technology and automation can be used to improve efficiency. (Rönnholm, 1998) Such as the application of robots, AS/AR, (automated storage and retrieval) AGV's (automatic guided vehicles) and conveyors. The technology must fit the conditions and application and the benefits must outweigh the costs.

Automatic identification technology is being used more and more to improve efficiency. Two examples are bar coding and R.F. tags. (Radio frequency) The three elements of a bar coding system and the benefits are explained in simple terms. (Markland, 1998) When implemented successfully there are actually many possible benefits of using bar coding and EDI, (electronic data interchange system) some of these being knock-on effects of other benefits. (Marcel, 1996) The application of computers and bar coding improve shop floor reporting. (Muhlemann, 1992) This text is specific about the reasons for using computers. Computers are used for their powerful number crunching capabilities and bar coding speeds up the collection of data and increases its accuracy.

The requirement for shop floor data collection is often provided by information technology. (Holder, 1995) The issues around implementation of an I.T. system are explored. Integrated I.T. systems and data integrity checking improve material control. (Bauer, 1991) This is one of the basic building blocks of materials management and control. The data integrity checking is often facilitated by the application of bar coding.

The combination of established working practices with the addition of technology forms a socio-technical system. (Winfield, 1991) This provides opportunities for job enrichment.

When using computers, it is also possible to have real-time feedback. (Muhlemann, 1992) This is where information is gathered, analysed and displayed to users in a useful format in real-time. This enables users to manage operations in real-time and make "up to the minute" decisions.
The costs and benefits of implementing a CIM (Computer Integrated Manufacturing) system, according to vendors require careful examination, because this focuses on the computer based solution. (Barrar, 1994) However, we also need to bear in mind the human factor and the changes to working practices required to achieve these benefits. In addition, it may be very difficult in practice to achieve these benefits using the vendor's software. Remember that the benefits are parts of the sales pitch and there may be holes or insufficiencies in the software that means you don't actually get what you want.

Advance Planning and Scheduling software (APS) uses special algorithms to balance material and capacity constraints simultaneously. The benefits of which are to reduce inventory, cut cycle times and improve customer service. (Michel, 1999) The type of APS system required depends on the type of the company's supply-chain. APS is primarily a decision making tool that takes in to account fluctuating demand, supply and shop floor conditions to help react to changing conditions on-the-fly. It can work on different planning horizons; strategic, tactical and operational. It is also possible to synchronise detailed plant-floor activities in discrete manufacturing to manage the arrival of material at specific work centres and to pace production.

Manufacturing Execution System (MES) software is used to manage plant-floor operations. (Fulcher, 2000) For some industries a tight link between MES, APS and ERP systems is critical to effective supply-chain planning. (Michel, 1999) MES systems collect data from the shop floor. Their functionality includes productivity monitoring, WIP tracking, detailed product control, routing and tracking, labour reporting, resource management and rework management. The benefits include improving quality, consistency and yield, reducing inventory, cycle time, rework and incorrect material or packaging. By capturing information about set-ups, run times, throughput and yield, managers can measure constraints and get a better understanding of manufacturing capacity.

Supply-chain efficiency is being improved in the electronics industry using the Internet, new electronic business interface standards and co-operation. (Anthony, 2000) These allow supply-chain partners to interact and view each other's data in real-time.
Previous EDI systems were not interactive. It can streamline order management, manufacturing, logistics and provide live views of inventory, order status, back orders, shipping dates, delivery estimates and other key data, cutting out the need for telephone and other forms of communication.

2.5 Materials approaches or philosophies

The differences between MRP, MRP2 and ERP are mainly evolutionary. MRP is a time phased order release system that schedules all orders whether internal or external such that everything required to manufacture a product arrives at the same time. The MRP system was extended to become MRP2 by adding rough cut capacity planning and feedback from the shop floor on the progress of orders to make it a closed loop system. In turn MRP2 was enhanced to become ERP by adding finance, distribution, human resource management and other “back office” functions. The implementation of ERP covers the entire value chain of the enterprise. (Siriginidi, 2000)

The MRP approach is based on dependent demand. I.e. the demand for components or sub-assemblies is determined by what makes up the final product. This is call the B.O.M. (bill of materials) The model includes lead-times for purchasing, manufacture and assembly. (Render, 1997)

Claims are made that the MRP (materials requirement planning) system is highly complex and unreliable. (Landers, 1995) Instead the simpler methodologies of JIT (just-in-time) are preferred, such as the use of kanban squares to control the pace of production.

The MRP and JIT methodologies can be hybridised. (Rönnholm, 1998) This can be achieved by having a selection method that determines how specific material is treated. I.e. which model does it fit best. There are benefits of using a “pull” or kanban system, from the JIT methodology, but the material has to meet certain criteria. To improve materials management, a study of the number of materials shortages and causes is recommended.
There are several aspects to the JIT methodology; kanban, inventory, layouts to promote efficient flow of materials and WIP, quality, supplier partnerships, scheduling techniques and communication of scheduling. (Render, 1997)

On the supply-chain side it is recommended that there is a material requirement forecast that is continually adjusted and communicated to the supplier. This is because any schedule is immediately out of date. It is important to share information and intelligence with suppliers. (Rönnholm, 1998)

Another theory to be assessed is the “theory of constraints” or bottlenecks. (Markland, 1998) This is closely linked to JIT. The system for improving the flow of WIP is termed “drum, buffer, rope.”
2.6 Summary of materials management “best practices”

Here is a summary of “best practices” that have been identified from the literature:

- Prioritisation methods. (E.g. ABC classification.)
- Outsourcing of value added services.
- Shop floor control system.
- Focused stores
- Tailored logistics.
- Use of computers or I.T. integration with business processes. (APS, MES, ERP, EDI.)
- Trace ability.
- Use of technology or automation.
- Automatic identification. (E.g. bar coding.)
- Maintaining data integrity. (E.g. cycle counting.)
- Internet enabled supply-chain.
- Hybridised JIT-MRP or JIT.
- Kanban system. (Part of JIT methodology.)

Further “best practices” will be identified from the industrial and company investigations. These will be added in to a company comparison matrix. This will provide a “best practice scorecard.”
3. **Industrial Review**

The objectives of this chapter are to:

- Present the information gleaned by the author from company visits that focused on the electronics industry, materials management and relevant I.T. systems.

- Make comparisons and draw conclusions.

Part of the methodology of this research was to visit companies and see how they manage materials. *(Leaney, 1997)* The seven companies visited and investigated by the author were:

- **Celestica**, Toronto, Canada (May 1997)
- **Ford Electronics**, Markham, Toronto, Canada (May 1997)
- **Nortel** (Northern Telecom enterprise networks), Canada (May 1997)
- **Decoma**, part of Magna (Global automotive systems), Canada (May 1997)
- **Sun Microsystems**, Linlithgow site, West Lothian, Scotland (1997)

This chapter is a summary of the reports. The detailed reports can be found in the Appendix 1 - Industrial reports.
3.1 Industrial analysis

To aid comparison and analysis, a generic framework was developed to show how different companies handle materials management and the supply-chain. This is shown by Figure 1. It shows how the Master Production Schedules are related in the supply-chain, different stores structures and processes, where and how technology is applied and the triggering mechanisms for supply. The trigger could come from a number of different sources. Trace ability can be defined by knowing exactly what material went in to which finished product. For example if a fault developed with the product that could be traced to the low quality of a particular component, this could be traced back to the batch of components from the supplier. This would then mean that should you need to recall product you know exactly which ones to recall.

**Generic materials flowchart**

(MPS) Master production schedules

- Customer orders
- COMPANY
- Supplier

- MRP
- Schedule of planned factory order releases
- Production
- Serial numbers/ Batches recorded
- Trigger for replenishment

- STORES
- Macro
- Micro (line side)
- Material used (recorded?)

**Figure 1. Generic materials flowchart.**
3.2 Celestica, Toronto, Canada.

Celestica’s MPS was determined by customer orders. This was then used by the MRP system (BPCS) to calculate the build plan and supplier orders. When the supplier delivered the raw materials they were received and set up on BPCS. The parts were then put away by the automated warehousing system. The daily schedule then determined when the kitters kitted the parts. They would pick a kit firstly with partial reels and then reels from the automated warehouse. The kit was then delivered to the line side ready for production that day. The DACS system was used for tracking the serial numbers of the boards in production.

![Celestica (Toronto) materials flowchart](Image)

Figure 2. Materials flowchart for Celestica, Toronto, Canada.
3.3 Ford, Markham, Canada.

The complete supply-chain was linked by EDI that provided automated ordering. In the case of customer orders 65% was daily and 35% was on a weekly basis, probably based on each specific component. The MPS was fed to the MRP system to provide the daily schedule of production. The Failure report tracking system (FRT) provided trace ability of safety products. The LOTS system provided a pull system for replenishing material; using bar coding for surface mount material and kanban cards for other material. Suppliers delivered 85% of material to a local warehouse and 15% of material straight to the factory, some of which goes straight to a line side store. Carousels were used to store surface mount material.

Ford Markham materials flowchart
(MPS) Master production schedules

<table>
<thead>
<tr>
<th>Customer orders</th>
<th>EDI 65% daily</th>
<th>Ford Markham</th>
<th>EDI 35% weekly</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MRP CMMS

Schedule of planned factory order releases

Daily schedule

Production

FRT (Failure Report Tracking) for safety products only: by serial number

Max cycle time: 30 mins

LOTS system

Material feeder replenishes based on kanban cards collected

In-house stores (split by product)

15% to in-house store or kanban straight to line

Kanban card placed in pocket

Surface Mount PC/barcode to order (2 reel buffer)

Micro (line side)

Carousels

Figure 3. Materials flowchart for Ford electronics, Markham, Canada.
3.4 Decoma, Magna, Canada

Decoma were the third tier of an automotive supply-chain. The MPS was closely linked at all levels. The MPS was split down by shipments and "daily buckets." The MRP system ordered material from suppliers, but the MPS "daily buckets" triggered the actual call off (kanban) of material. So this meant that suppliers could deliver material each day and in the case of moulding material large silos were topped up daily. When the raw material was received, the quantity, vendor and batch were recorded. When the material was replenished to production, the weight was also recorded in the MRP system. This gave an accurate record of how much was delivered to the line. During production, the lot code was recorded in the MRP system. This then enabled a yield or scrap percentage to be calculated for each lot. A kanban system using re-usable containers was used for delivery to the next tier in the supply-chain.

Figure 4. Materials flowchart for Decoma, Magna, Canada.
3.5 Nortel, Canada.

A customer forecast, including a quoted error, was used to create the MPS. This was then fed in to a separate MRP system. If they had an abnormal production order, they would run a simulation to see if they had the material to meet it. Orders were sent to suppliers by a variety of means; phone, fax, EDI and physical. Suppliers delivered material, either to be stored off-site or on-site, usually depending on whether they were large or small parts. RF bar-code scanners were used in the receiving area. Some suppliers even delivered direct to the factory floor. Workers scanned bar codes in the production area to pull material to the line on demand. The MRP system was also used to produce the daily schedule. In the assembly shop, work was controlled using magnetic labels for each unit ordered. For a common part of the system they used a kanban rack to trigger the build of another sub-assembly. I.e. when a rack was empty it had to be refilled. Common orders were built to stock and systems were configured to order. The boards and assemblies were tracked by serial number with the QIN system that used bar-code scanners.

*Figure 5. Materials flowchart for Nortel, Canada.*
3.6 **Siemens, Congleton, U.K.**

Siemens used the AMAPS system for scheduling and planning. This then fed to the MRP system, which in turn orders material from suppliers. 15% of incoming material was inspected. The stores areas were located all around the factory floor, split by product group. There were some large carousels and racked stores areas. There were dedicated material feeders within each group who operated a two-level (minimum and maximum) kanban system.

![Siemens materials flowchart](image)

**Figure 6. Materials flowchart for Siemens, Congleton, U.K.**

3.7 **Celestica, Kidsgrove, U.K.**

For the full analysis of Celestica Kidsgrove, see the next chapter. This flowchart and summary were included here for easier comparison with the other companies in the wider industrial review.
The Celestica Kidsgrove MPS was constructed from customer orders and their own forecast. This was necessary due to the fluctuating nature of customer requirements. A large stock buffer was used to cope with this. Ordering of material from suppliers was mostly automated by the MRP system. Suppliers delivered material to a local warehouse and as the material was put away the location was recorded on a card. Material in-feeders manually created a pick list at the line side, based on the stock levels contained in the “point of use” store and including kits required for low volume products, and then inputted it in to the MRP system. This “shopping list” was then picked at the warehouse and was delivered to the “point of use store” by the stores workers. This localised store provided the material for the machines. Limited trace ability existed via a paper record of reel changes. The FAST system recorded the serial numbers of the manufactured boards using bar coding and automatically decremented quantities of material used on the MRP system by downgrading. Any spoilage during production had to be recorded manually.

Figure 7. Materials flowchart for Celestica, Kidsgrove, U.K.
3.8 Sun Microsystems, Linlithgow, Scotland.

Sun have a corporate MPS that was split out by site. Then the Linlithgow site used a mix manager to predict and manage exact configurations of product. This was updated in real-time as customer orders came in. The MRP system used 60% EDI to send orders to suppliers. They then delivered to a warehouse that was 20 minutes away from the main site. Materials were called in from the warehouse based on the daily schedule. Carousels holding 5 to 10 days worth of stock were used to store material on the main site and material was “pulled” from these to the line side as required. Some bulky parts were delivered straight to the line. Cell controllers record spoilage and usage was recorded on order fulfilment by back flushing. There was a system for tracking assemblies that used bar-code scanners.

---

**Sun Microsystems materials flowchart**

(MPS) Master production schedules

- **Customer orders**
- **Corporate platform plan**
- **MIX MANAGER**
- **MRP (CAS)**
- **Supplier**

**SUN Linlithgoe**

- **Real-time plan split**
- **60% EDI**

**STORIES**

- **Livingstone Warehouse**
  - 20 mins
  - Carousels (5-10 days stock)

**Production**

- **Daily schedule**
- **Attrition / spoilage**
- **Schedule of planned factory order releases**
- **Backflush on order fulfilment (low value)**
- **Pull (low value)**

**Line side**

---

Figure 8. Materials flowchart for Sun Microsystems, Linlithgow, Scotland.
3.9 Company comparison matrix

The company comparison matrix is shown by Table 2 on the next page. In this table, each company investigated was given a score against each "best practice" identified in chapter 2. The scoring system is subjective. Ford Markham and Magna scored the highest in this scorecard. Celestica Kidsgrove was at the lower end of the scoring scale.
Company comparison matrix

Subjective score: 0=none, 1=poor, 2=good, 3=excellent

JIT/hybrid/MRP: 1=MRP, 2=some hybridisation, 3=Hybrid or JIT

Note: Where score is left blank, this is because not enough was known about the company in this area.

<table>
<thead>
<tr>
<th>Company:</th>
<th>Celestica Toronto</th>
<th>Ford Markham</th>
<th>Magna</th>
<th>Celestica Kidsgrove</th>
<th>Sun Microsystems</th>
<th>Siemens</th>
<th>Nortel Canada</th>
<th>Nortel Belfast</th>
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</table>

Table 2. Company comparison matrix for “best practices.”
4. Analysis of Celestica Limited’s Kidsgrove site

The objective of this chapter is:

➢ To provide an analysis of the original working practices in materials management at the Celestica Kidsgrove plant in 1997.

4.1 Original materials working practices (1997)

Figure 7 and Figure 9 show the overall materials process.

4.1.1 Supply to the shop floor

Material was ordered automatically from suppliers using the MRP system. When material arrived from suppliers it passed through “goods in”, inspection and was then “booked in” to main stores. The main stores were remote to the production site, so material needed to be available for all major boards. Customers’ requirements usually changed a lot from the original plan. So each business stream had strategically positioned “point of use” stores on the shop floor, which provided the flexibility to swap between boards quickly, as required by the customer.

For replenishment of high volume products, material in-feed workers checked the raw material levels on the “point of use” stores every shift. For low volume products they created a kit list of parts required. They manually raised the pick lists on the MRP system. The stores people picked these lists, recording any shortages, and delivered them to the shop floor. The stores operated using a card system to record where stock was put away. Shortages were later checked against the MRP system to assess the situation.

A surface mount machine signalled that a reel had been exhausted. The machine operator fetched a replenishment reel from the “point of use” store. They unloaded the spent
reel from the machine and feeder. Then the operator did a “buddy” check with another operator or supervisor. They loaded the fresh reel on the feeder, recorded the reel change and loaded it on the machine. Replenishment of flat packed parts on to machines was much the same, except that parts were topped up in the machine.

4.1.2 Data integrity and attrition management

Attrition is material that has failed to go through the assembly process correctly. E.g. rejected by machines or wasted by operators. Low-value attrition was scrapped, since this could not be recovered. Quantities were manually scrapped off based on the machine spoilage reports, which were printed out each shift. On high-value parts, we looked to recover these parts and in doing this any spoilage would be counted manually. If attrition was fed back in to production, it was not specifically tracked and monitored.

The WIP (Work-In-Progress) tracking system provided the MRP (Materials Requirement Planning) system with usage information by telling it the number of boards produced through each stage. This is called “downgrading” or “back flushing”. To improve data integrity we carried out cyclic stock checks. This is where stock checks are done periodically, depending on the importance or criticality of each part number.
Figure 9. Kidsgrove in-plant materials process. (1997)
4.1.3 Trace ability

A Goods Received Note (GRN) number was created by the MRP system. A bar coded label, including part number and GRN number, was affixed to the parts to link them to a specific supplier’s batch. A manual record of reel changes, by part number and time, was kept, so that if the wrong material was placed on to boards, this could be roughly linked to a window of built boards, using the WIP tracking system.

4.2 Critical analysis

4.2.1 Shop floor stock

The “point of use” stores contained enough material typically to sustain 24 to 48 hours of production. This was to avoid line stops by triggering a “red alert” when there was a shortage in main stores. Rush orders are costly and if we could improve inventory data integrity on the shop floor, this would dramatically reduce the number of “red alerts” and line stoppages.

To get a return, stock must be kept to a minimum and on the move at all times, to optimise cash flow. Stock levels were managed by the MRP system and simple replenishment rules. There is the opportunity to reduce stock levels by improving inventory data integrity and optimise levels on the shop floor by using scheduling information. This would reduce the risk of parts being spoiled due to excessive handling and exposure to the relatively harsher environment of the shop floor. The drawback of “back flushing” is that it depends on the boards recorded as they are built, but wastage is not recorded.

There was around £4m worth of parts recorded on the MRP system as being on the shop floor. Material was treated as good until it was manually scrapped off, yet physically speaking it could be anywhere; lost, attrition, scrap or it might still be in stores.
4.2.2 Data integrity and attrition management

The data integrity of the inventory records can be affected by human error. However, a study showed that for low value parts around 80% of the spoilage was unaccounted for. Before a stock check could be done, the data integrity might have gone so far out as to incur excess cost, such as a rush order to correct a shortage or in the worst case cause a line stop. You only need to run out of one part, within a whole product, to delay production of that product.

If the Bills of Materials used by the MRP system and the Engineering systems did not tie up with actual production, this would have an adverse effect on data integrity.

4.2.3 Validation and trace ability

Visual validation of parts is open to error, since there are many similar parts with similar part numbers. The effect of loading a wrong reel on to the machine can be devastating, meaning the reworking of many boards, lost production time and late delivery to the customer.

Trace ability is limited and the supplier’s batch of components (GRN) is not linked to finished boards. This means that more boards than necessary have to be inspected, since we suspect they may have a component fault. Implementing trace ability of individual reels or packs to a particular window of boards, will mean dramatic reductions in effort required to tackle such faults and will provide the added benefit of linking performance data to the supplier’s batch, enabling us to test different suppliers or versions of a particular component.
4.3 Analysis using a Current Reality Tree (CRT)

If you have a complex system that you wish to improve and you know that there are many issues and problems involved, then a Current Reality Tree (CRT) can help to analyse this. (Goldratt, 1994) The CRT is a thinking tool of the theory of constraints and it can be used to direct problem-solving efforts. Where there are many issues it is important to recognise that there are causes and effects. In addition the issues will not be completely independent of each other, there will be links between them. Underlying each system, it can be shown that there are actually 1 or 2 core problems.

This tool will be applied to the in-plant materials process and associated system at the Kidsgrove plant of Celestica Limited in the remainder of this section. The following chapter will then look at improving the system using a Future Reality Tree.

4.3.1 Undesirable effects of the “in-plant materials process and associated system”

The first step of the analysis requires definition of the situation or system that you wish to improve. Then you need to list or brainstorm a short list of problems. (Otherwise known as “undesirable effects”) It is therefore necessary to translate each issue or point that you wish to improve in to a negative point.

Here is the list of undesirable effects developed for the analysis of the Kidsgrove plant:

- The amount of stock held is costly. (Includes obsolescence)
- The build plan is highly variable.
- When the “point of use” stock falls below 48 hours worth this triggers an alert that the line may run short of material. ("Red alert.")
- Unforeseen materials shortages are costly.
- Data integrity of the stock records is poor.
- Line stops occur. (Due to material shortages.)
- It is thought to be cheaper to order material in batches.
- Operators have little regard for the importance and value of materials.
• Too much material handling spoils parts.
• A lot of spoilage goes unrecorded.
• If a wrong reel occurs it can be very costly.
• Material gets delayed.
• FIFO is not controlled.
• Attrition is excessive.

This list is the starting point for constructing the CRT.

4.3.2 How to construct a CRT

The best way of construction is to use sticky notes. Start off with two undesirable effects that seem closely linked. Then try to add additional sticky notes to make up logical “if, then” statements to lead in logical steps from one statement to the next and so on. The arrows in the CRT represent cause and effect relationships and can be read “if ‘one box’ then ‘the next box that the arrow points to’.” Thus the reality tree is slowly built up by adding sticky notes, adding in the other undesirable effects as you see fit. During construction, you will probably find that you have to change or rephrase what is written on the sticky notes and you come across statements that you think should have been in the original list of undesirable effects. This is quite normal and should be expected, as the construction of the reality tree helps you to fill in the gaps by making you think through the logic and dependencies. The construction of the reality tree can take a long-time; i.e. many hours and sessions.

The CRT helps us to identify the root causes of a system and analyse the likely effect of attacking each cause. I.e. you can determine the effect that solving one problem will have on other problems by eliminating the arrows. The CRT constructed for Celestica Kidsgrove is shown as Figure 10. There is also a commentary of the CRT diagram in the next section 4.3.3.
Figure 10. Current Reality Tree (CRT) for materials system at Celestica Kids Grove (1997)
4.3.3 Accompanying narration of CRT

This section accompanies the CRT diagram, Figure 10, and is an expansion or explanation of the relationships shown in the diagram.

If operators do not record spoilage as it happens and the small parts are difficult to handle and count, then a lot of spoilage goes unrecorded. This means that data integrity is poor and that either too little or too much material is ordered. With the former this means that unforeseen shortages will occur. With the latter it means that too much stock is held. If a lot of spoilage goes unrecorded then there are few corrective actions to reduce spoilage, since the information is insufficient. If this is the case then there is excessive attrition and spoilage that effects profits.

If an unforeseen material shortage occurs then there is not enough time to procure and receive replacement parts and if a specific part is required for a build then a line stop will occur. If a line stop occurs then there will be a failure to deliver the customer the amount that they want. If there is a failure to deliver to the customer the amounts of product that they want then there is a risk of losing the revenue of these boards and hence losing revenue from the customer. This has an adverse effect on profits.

In the absence of any other trigger, stock checks are done on a cyclic basis. This means that stock checks occur infrequently and are not focused leading to data integrity being poor. The build plan is not fixed, thus there must be flexibility to meeting customer requests or orders. So there are last minute changes when the customer asks for a specific board and quantity to be built. If this is the case then when a specific part is required, a line stop may occur as a result of unforeseen material shortages. In addition to counter any last minute changes enough stock is held to be able to make any board type for a 48-hour production run. This stock level is also used to trigger shortages and to check if parts are on order.

There can be many processes involved with getting materials from goods inwards on to the factory floor, which can delay material leading to unforeseen material shortages. If there are unforeseen material shortages then there is not enough time to procure and receive...
replacement parts. This leads to parts being obtained from another more costly source impacting profits.

If a part is wrongly labelled then the usual validation procedure will fail to pick up the invalid material and if a value check is not done or missed then this means that wrong reels occur and are very costly. If wrong reels occur then the material placed on to boards is wrong, therefore the boards will be wrong and rework will be required if the defects are to be corrected.

If there must be flexibility to meet customer orders then there must be stock held to meet a given requirement for any board type. This means that too much stock is held, particularly on the shop floor. If too much stock is held then this costs money in terms of holding this inventory and obsolescence eroding profits. In addition FIFO is not controlled. If shopping lists of material required for the shop floor do not take account of what is on the machine then too much material is ordered adding to the problem of holding too much stock.

If managers and supervisors do not stress the importance of materials and operators have not been trained or told the importance of materials then this means that operators are not allocated enough time to record spoilage, they have not been trained to record spoilage, they have little regard for the importance of materials, they do not know the value of materials, they do not often follow material handling procedures or use the right material handling equipment and have never worked out the total cost of inventory. Due to all this, operators do not record spoilage as it happens.

If the workforce have never worked out the cost of inventory then it is thought to be cheaper to work in batches due to the cost of picking, volume discounts and so on. This means that material is ordered in batches and is pushed to the line rather than following JIT rules. If this is the case then this also adds to there being too much stock being held.

If too much stock is held then there is too much materials handling. This means that parts are spoiled by excessive materials handling and the quality of parts is degraded. If operators do not often follow material handling procedures or use the right material handling
equipment then the quality of parts is degraded. If the quality of parts is degraded then the amount of attrition and spoilage increases. If parts are spoiled by too much material handling then there is excessive attrition and spoilage that costs money and this impacts profits.

If there is a lot of attrition, then attrition is recovered wherever possible and the material is recovered to go on to printed circuit assemblies. If recovered material is used then it is physically marked to give basic trace ability. This means that the quality of some built boards will be degraded because of too much material handling and recovery. If the quality of some built boards is degraded then the amount of testing, rework, diagnosis etc. increases and there is a higher risk that these boards will be scrapped and we will lose face with the customer. This would again result in the profits being eroded.
5. **Proposed improvements at Celestica Kidsgrove**

The objective of this chapter is to:

- Develop proposals, from the Current Reality Tree (CRT) analysis carried out in the previous chapter using a Future Reality Tree. (FRT)

### 5.1 Developing proposals from the CRT

#### 5.1.1 Core problem and conflict of CRT

Once the Current Reality Tree has been constructed, the core problem can be identified. The core problem of the CRT is the statement or box that leads to all others. I.e. it is either directly or indirectly the root cause of all the other problems.

In this case there are two boxes that are closely related. These have been highlighted in the diagram using a dotted box and asterixes. The following statement encapsulates the issue in one sentence:

“Most workers do not stress, know or have been trained the importance of materials and related costs”
It is also possible to identify the apparent conflict in the CRT. The conflict is caused by the conflicting objectives of the focus on production output and servicing the customer. The shared goal is to “manage materials excellently” and this creates the conflict. This is depicted in Figure 11.

![Conflict Diagram](image)

**Figure 11. Conflict diagram**

### 5.1.2 Assumptions of the conflict diagram

To improve the system, we need to find ways of breaking this conflict and hence addressing the core problems of the system. To do this we look at the assumptions behind each arrow of Figure 11, concentrating particularly on the conflict arrow.

The assumptions are as follows:

- If we look at the conflict arrow, which is “servicing production or the customer conflicts with reducing cost and improving efficiency of materials.” This assumes that excessive material must be held to service production or the customer and that it costs money to hold that material.

- Keeping production supplied with all materials is managing materials excellently, because otherwise the line will stop or the customer order will not be met.
• The build plan is not fixed, not known or is effected by other variables.

• Data integrity is good.

• In order to keep production going, they must not run out of materials. This assumes that the customer requires product, if not then this is just building stocks up. It also assumes that it costs more money to stop production than it does to hold too much material.

• Reducing stock will reduce costs, but not if they start running short of materials.

5.1.3 Possible actions to break assumptions

The next step of the analysis process is to think of courses of action that will break or override the assumptions made in the conflict diagram. The actions are as follows. N.B. The first 3 actions (below) are aimed specifically at breaking the conflict. (These actions will later be shown as “Injections” on the FRT diagram. The injection number is quoted in brackets after each action.)

• In order to service production or the customer better we need to hold less material and be more efficient. (This action becomes injection 1 in the FRT.)

• We don’t own raw material or finished goods or we don’t have to pay the warehousing costs. (Injection 2.)

• Make production or customer service more efficient by being able to predict requirements better. (Injection 3.)

• Teach people the importance and cost of materials management. Show them that with a little effort, big results can be achieved. (Injection 4.)
• Improve data integrity, ideally with minimal effort. E.g. make it part of workers’
everyday process. Also the knock-on effect of holding less material makes it easier to
maintain data integrity. (This action actually becomes closely related to objective 4.)

• Build to order. Hold less material, but still have it readily available from suppliers, with a
short lead-time. Be prepared to pay a bit more for this service, since to stop production
can be very costly. (Injection 5.)

• Work with the customer to try to predict the build plan and the variation. Models can be
produced for each customer-focused team using historical data, sets of conditions,
statistics etc. Provide flexibility to base materials on the product mix or capacity and
schedule. Develop rules for finished goods stock and production batches. (Injection 3
again.)

• Prioritise parts by the risk that they pose to stopping production. Prioritise boards by the
risk that they pose to not being able to supply the customer. (Injection 6.)

5.1.4 Common objectives of new strategy

The next step of the analysis process is to identify common objectives from the list of
assumptions in section 5.1.2.

The shared goal as quoted before is to “manage materials excellently.” The common
objectives designed to reach that goal are as follows:

• Reduce stock and hence cost of stock.

• Improve data integrity of inventory records, ideally with less effort.

• Model the build plan.

• Improve materials management on the shop floor.
5.1.5 Constructing a Future Reality Tree

A Future Reality Tree is a way of showing a future reality. Using the actions and objectives identified in sections 5.1.3 and 5.1.4 it is possible to construct a Future Reality Tree. The method of construction is virtually the same as for the CRT, using sticky notes and "if, then" logical statements. (See section 4.3.2.) The result is to produce a network of actions. It also helps by identifying additional actions required to meet the objectives. The tree can be seen as the vision and the network of actions as the strategy behind that vision. The word "network" is used because in the same way as the CRT a number of actions will be linked. The FRT constructed for Celestica Kidsgrove is shown on the next page as Figure 12.
Future Reality Tree for the "in-plant materials process and associated systems" at Celestica Kidsgrove

Figure 12. Future Reality Tree (FRT) for materials system at Celestica Kidsgrove. (2001)
5.2 Proposed Strategy

The actions of the FRT are now transferred in to list form as an alternative to the FRT and for ease of reference each action or proposal has a number that will be referred to later in this thesis.

1. Implement a kanban system to pull material as it is needed.
2. A supplier scorecard to improve on-time delivery consistency.
3. Record materials usage in real-time.
4. Use a material requirement model.
5. Raw material stock levels must be reduced in a controlled manner. As confidence grows in the accuracy of the inventory records, the material requirement model and supplier delivery, and the inventory should be reduced step-by-step.
6. Reduce the lead-time of material deliveries. Be prepared to pay a bit more for shorter lead-times with suppliers. This reduces the exposure to stock costs and obsolescence.
7. Arrange for material to be delivered on consignment.
8. Reduce order costs by using blanket orders, standard batch sizes etc.
9. Material is pulled from the supplier in small batches. (Kanban system.)
10. Keep transport costs down by utilising a materials hub or a distributor.
11. Delivery of material direct to a localised store on the production line, which reduces the cost or amount of materials movement. This can also reduce the lead-time of delivery.
12. Develop models of the build plan that take in to account customer requirements, historical data, flexibility, variability etc. This model is then fed in to the material requirement model. (Point 4.)
13. Build to order or have a kanban system for finished goods stock.
14. Be able to monitor and control usage and wastage. (Spoilage, attrition and unaccounted usage.)
15. Teach the workforce the importance of materials. This should include displaying the cost or value of wastage.

16. Make production accountable and responsible for recording materials usage.

17. Training to raise awareness of the importance of good materials management on the factory floor.

18. Actively use these measures to reduce materials wastage.

19. Improve the accuracy of the recording of material usage and wastage.

20. Record materials usage as it happens. Ideally make it an integral part of workers’ everyday procedures and make it easy to do.

21. Pick up data integrity issues earlier. Highlight key stock items and instigate focused stock checks.

22. Remove the “cushion of inventory”, thus exposing workers to process variability. Then solve the process variability problems. This should include measures to improve ongoing data integrity.

23. Share materials information with suppliers, such as your material requirement model.

24. Reduce wastage by instigating validation and trace ability of materials, including a value check immediately before they are used. (This proposal comes from the CRT.)

25. Use of I.T. systems and bar coding technology to make it easier to monitor and control materials on a large scale. (This proposal leads on from point 20 and is also listed as a “best practice.”)

26. FIFO (first in, first out) usage of stock to reduce the risk of obsolescence. (This proposal is directed at objective 1, reducing the cost of stock.)

27. Kitting of material for changeovers, including optimised kits. (This proposal is aimed at improving productivity.)

28. Reduce the risk of shortages, red alerts or line stops. Predict shortages and those components most at risk.

Note that points 24 to 27 do not come directly from the FRT. (Their derivation is explained in brackets.)
5.3 How “best practices” relate to proposals

This section looks at the list of “best practices” collected from chapters 2 and 3. Then it relates these to the proposed strategy. After each “best practice”, an additional comment may be given to help explain (or show more specifically) how the “best practice” is related to the strategy. When a point taken from the proposed strategy, presented in section 5.2, is referenced, this is shown in brackets. E.g. (Point x.)

- Shop floor control system – usually production oriented, includes “shop floor logistics”. Should be aimed at improving materials management on the shop floor. (Point 3.)

- Use of computers/I.T. integration with business processes. Use of I.T. for its powerful number crunching capabilities, to help control complex systems and to make data collection easier. (Point 25.)

- Bar coding – speeds data collection, improving its accuracy and quality. (Point 25)

- Trace ability – reduces rework, tracing of problems through the supply-chain and enables linking of data. (Point 24.) However, does not explicitly include validation of material. So this will be half of point 24.

- Data integrity – maintain and improve data integrity. (Points 19 and 21. Objective 4.)

- Focused stores – enables delivery direct to “point of use” and reduces the cost or amount of materials handling or movement. (Point 11.)

- Kanban (Points 1 and 9.)

- Tailored logistics. (Points 6,7,8,10 and 13.)
• APS – uses model of material and capacity constraints, taking into account demand, supply and shop floor conditions, to provide a build plan and material usage plan, can include flex. (Point 12. Objective 2.)

• Prioritisation methods. (Point 21.)

• JIT. (Points 1,2,5,6,8,9,10,11,13,18,22 and 23.)

• Outsourcing of value added services. (Points 7 and 10.)

• Electronic business interface standards (Point 2 and 23.)

There are gaps between the “best practices” and the proposed strategy. The points that are missing are as follows: 4, 14-17, 20, half of 24 and 26-28. By using the CRT and FRT thinking tools the solution will be concentrated on the core issues and the solution will be more complete and integrated. The FRT shows the preferred strategy. The gaps may be additional or new “best practices,” ones that may have never been quoted or documented. The differences may be due to the practicalities of implementing a solution for Celestica Kidsgrove. The problem with just implementing “best practices” is that improvement may be hit and miss and only partial benefits will be achieved.
6. Software selection and implementation

The objective of this chapter is:

➢ To discuss the selection and implementation of software based on the “best practices” evolved whilst doing implementation at Celestica Kidsgrove.

For successful software selection and implementation, an ideal process is presented. This is based very much on using a Project management methodology. The recommended approach is to tackle the implementation in stages as a number of projects. (E.g. selection, trial, development and implementation.) This is called a programme of projects. Not all steps have to be followed and they might also be followed in a different order. It may also be decided that more work needs to be done on previous steps in order to improve the process.

Here is a summary of the stages:

• Business process investigation and analysis.
• Agree customer requirements and identify stakeholders.
• Create a design, vision or scenarios.
• Software is investigated in detail.
• The decision stage.
• Implementation.

Decide what system you want to improve. Understand the customer and how they work. Involve the potential users as much as possible. Investigate current working practices, looking at how processes, systems, people, physical things and information interact. Flowcharting is a good tool for this. What are the goals and objectives of the system? What are the measurables of the system? What are the requirements of the system? How can the system be improved? One tool that is recommended is the Current Reality Tree, as used in
this thesis that allows analysis of problems, issues or faults of a complex system. This is the "before" picture.

One of the outputs of this stage will be to elicit and agree the customer requirements and expectations. This will define the scope of the project. This should make it explicitly clear to the users what they are going to get. This should include user acceptance criteria. The customers will include users and stakeholders. Stakeholders are typically people who care about the success or failure of the project, have authority over resources to be used in the project and are responsible for committing to and signing off the project. At this stage the customer requirements will be in the form of a functional requirement specification and a system requirement specification. I.e. why are we going to do the project and what are we going to change. As the requirements are translated into specifications, the level of detail increases. Ideally there needs to be support for the project at all levels.

Management support and buy in is crucial for gaining drive on a project. These may well be key stakeholders in the project, because their authority can be used to manage and control key resources. For example, where people block implementation, their authority may have to be used to remove this blocker. For example, there may be limitations on resources for various reasons. This is where management support can be crucial in order to resolve these issues.

Create a vision of the future system, charting the changed system in as much detail as possible. This is the system design specification and goes into further detail than the system requirements specification. This will show how the software functionality integrates with working practices and so on. This should include an impact analysis of the change. For example, changes in staffing levels and required training or include additional technical requirements that would be required. As a result of this there may be a number of scenarios. It should also include an analysis of how the measurables of the system will be changed to provide benefits and if there are any penalties. This would help form the basis of a financial justification.
Investigate what software is available and if necessary carry out an initial selection procedure. The decision criteria should include software functionality versus requirements, costs and benefits. Ideally demonstrations should be arranged as required.

Investigate software functionality and benefits in more detail. How can it be applied to improve the system? Ideally a trial software system should be set up to aid this investigation and evaluate the software in more detail. This will require a trial implementation. The implementation must be planned and should include demonstrations, training and using the system. The vision of the system should be followed as closely as possible to check that the software satisfies it and if the vision should be modified. It must be remembered that this is the implementation of change of which the software is only one part of the picture. The functionality should be checked against the requirements for any variances or discrepancies. This may result in a decision to develop the software to meet certain requirements.

The decision making stage will include several options that may include different software packages, the level of implementation, (i.e. what scenario of the vision is to be followed) a decision to do further trials or even a decision not to implement any software. This may include considering what technical developments are required to meet the requirements, which may result in the decision to delay implementation until these technical requirements are met.

The advantage of following this process is that it remains objective and means that you focus on your requirements. The end result will differ from what the salesperson says in that some functionality may not deliver the benefits that you expected, though in addition you may identify additional benefits or opportunities that were not sign-posted to start off with.

Systems integration is an important topic. It means that a system or some software must not be considered stand alone, but that other systems and the way they integrate or interface must also be considered. There are many benefits that can be achieved from doing this. Multiple systems can mean duplication and divergence of data, effort, cost, processes and standards. It will also mean additional people, training, hardware, software and support.
personnel. The divergence of effort may be typified by not being able to focus all effort on improving one system and may lead to conflicts. The ideal solution would be the development of a single I.T. system, as this would make it easier to integrate. However, this is never usually practicable, so the next best thing is to minimise the number of I.T. system and to integrate them into the total system using interfacing.

Ideally, even before you start to implement, measurables of the benefits should be established and measured. This should then show the benefits as the implementation progresses. In addition the implementation must provide the planning and process changes in order to get the most out of these tools. Measurables need to be defined as these are key to the project. It is usually difficult to get measurables for a project. That is why it is so important always to seek them, to set up easy ways of recording the measurables, even build it into the processes and work practices. They will demonstrate the success of the project in achieving its benefits.

It is a good idea to have a “benefits plan” which involves the implementers, users within the company and also the supplier. This plan can be regularly updated and is a record of what actions have been taken and what actions are required to get the deliverables and benefits from the implementation. For successful implementation there should be focus on the deliverables and the functionality required to achieve these. This should be the responsibility of the software provider. Secondly there should also be focus on the implementation requirements to reach the benefits. This is the responsibility of the customer. However, both parties need to understand the “benefits plan” and to work in partnership to reach these benefits. Any complex issues with the software will need more help and communication from the supplier to the customer. Just as any complex issues regarding implementation will need more help from the customer.

The change needs to be managed. A common obstacle is “resistance to change.” This would be characterised by users being happy with the system that currently exists and do not want to change to a new system for various reasons. For example, fear of the change because they don’t understand it, fear of losing their job, the resource required, blinkered views
because they don’t see the overall picture. This is where the “before” picture and the vision are useful as a communication tool for seeing the picture before and after.

The organisational structure and culture of the company needs to be taken into account. In the case of Kidsgrove, each customer is looked after by a dedicated team called a customer-focused team. This meant there was a need to treat each team as a separate project with different requirements. It also meant selling the system to each group in a different way. Of course there is a need for some commonality, such as generic processes or systems.

In a large company, where employees are split by functions and jobs, they may only use certain functionality of the software and may be unaware of interaction with the other parts of the system. This is a blinkered view. For example, it may be necessary for one person to input additional information to enable other users to get benefits from the system. The users must work as a team, which is in itself a big challenge. Additionally the software should enable the users to work as a team, more efficiently and effectively. It would also be useful to have a co-ordinator to help with the balance and overall picture of usage. Administrators and expert users can make recommendations as to how best the software is applied, identifying opportunities available to users and making them aware of these opportunities.

The training of users needs to be consolidated by practice and usage. The training will be most effective if it includes practical exercises, training documentation oriented to the needs of the user, guidance in how best to use the system, pitfalls to avoid and how to recover from mistakes. Users must be motivated and have the confidence to use the system. Worries about making mistakes can be alleviated by providing a separate training system. There also needs to be backing from management. Post training, users need ongoing support and training. With a continually developing piece of software, they need to be made aware of new functions and changes to the software.

The implementation itself should be carried out using a project management methodology. This must include a list of commitments and risks. This is to make sure that all parties understand what they need to do to achieve the requirements and benefits of the
implementation project and that risks are recognised and properly managed. There will be a project organisation and a list of resources.

The software and hardware needs to be specified and installed. The software needs to be configured and data needs to be set up as required by the implementation. There needs to be training and documentation, including work instructions. Third party management of the software suppliers can be very important to the success of the software. The final part of the implementation is to hand over the system to the customer-focused team. There should be a plan to provide ongoing support, but the team should be able to use the system with limited external assistance.
7. **Implementation**

The objectives of this chapter are:

- To review the changes made since 1996 at Celestica Kidsgrove to materials management and related IT systems, with emphasis on the TiMMS software, based on the experience and knowledge of the author.

- To review how some of these initiatives fit the proposals made in section 5.2.

### 7.1 Introduction to existing software

Chapter 4 covered the original materials system at Celestica Kidsgrove. IT systems were not covered in detail. This chapter focuses on the IT systems, how they have been applied and developed and how they can be applied to create a new improved system.

When looking at how business processes and systems have changed, it is necessary to review the software or IT systems that are an integral part of these systems. Before reviewing what has been developed and implemented with regards to software, it is necessary to introduce the reader to what existing software and IT systems existed at the Kidsgrove plant of Celestica Limited in 1996.

Firstly, there were the systems used around Goods in. When material arrived from suppliers, it was set up on OMAC, the MRP software, using a Goods Received Note (GRN). The next part of the process was to validate the material and to label it using the INCA software. The manufacturer's part number was input to the system, usually using a barcode. This was then validated against the Approved Vendor List (AVL) held by the EM3 software, a Quality and Engineering database. As a contract manufacturer the company must use suppliers approved by each customer. This was controlled using an AVL. Any material
outside the specification of the AVL required a concession, which is a temporary authorisation. It was necessary to access INCA, EM3 and OMAC separately.

Several systems were used for the programming of surface mount machines:

- **Panatools** supplied by Panasonic for Panasonic machines. This software was later called PanaPro as it was upgraded to later versions.
- **Siplace** supplied by Siemens for their machines.
- **UPS (Universal Programming Software)** supplied by Universal for their machines.

The TiMMS software has been under evaluation since 1996. TiMMS stands for Totally Integrated Manufacturing Management System. *(TiMMS, 1997)* TiMMS is an integrated I.T. system specifically designed for the electronics printed circuit board manufacturing industry. The software was initially designed for managing and controlling auto mount machinery. This is the automated production equipment used to manufacture printed circuit board assemblies. In 1996, TiMMS consisted of the following integrated modules:

- **AIP (Advanced Intelligent Programming)** – for programming of auto mount machines.
- **RTM (Real Time Monitoring)** – for monitoring of auto mount machines.
- **PCS (Parts Control System)** – for control of materials around auto mount machines.
- **WLF (Warehouse Location Function)** – for control of materials from a warehouse using portable RF (radio frequency) barcode scanners.

It was necessary to implement AIP before RTM and PCS. The materials management functionality was within the PCS and WLF modules.

**7.2 Goods in and warehousing software**

The STAR software was designed and developed to manage material in the warehouse. It was to control “part put away” in to inventory locations, periodic stock checking, picking of “shopping lists”, and record stock movements in to, out of and within
the warehouse. This was previously controlled using a card system. Most operations were controlled using portable radio frequency barcode software. This meant that the software was held on portable barcode terminals that use radio frequencies to communicate with the main centralised software. The STAR system was designed to meet company specific requirements for material control and also to provide an interface with the MRP system. Most of the functionality of STAR was directly related to material control transactions on OMAC, so in simple terms it was providing an interface to allow workers to use portable RF bar coding terminals rather than manual input. The STAR system has been implemented.

"Single transaction" functionality was also developed for the INCA software. This functionality meant that the operation of validating and labelling the materials was integrated by interfacing INCA with EM3 and OMAC. These developments were designed to make the materials processes more efficient and accurate. This functionality has been implemented.

A project was carried out to investigate the integration of the STAR software and the WLF module of TiMMS. Models of the functionality and data flows were created to aid analysis and comparison of the software. The findings identified differences and opportunities for integration. In the short-term there were some communications requirements. The long-term proposal was to integrate the functionality of the STAR software into the TiMMS software, by extending the capabilities of the software and interfacing with the MRP system. The benefits were to have a fully integrated and enhanced material control system that met the special requirements of the business. However, this integration was rejected as being impractical in terms of cost and time, despite the apparent benefits.

An interface was implemented between INCA and the PCS module of TiMMS towards the end of 1997. The labelling of materials was also changed to provide a unique barcode. These barcodes are generated by the INCA system and a file is also sent from this system to TiMMS listing the attributes of each batch of barcodes. The barcode is later scanned to "book in" parts on to the shop floor. The main drawback of the system is that INCA and STAR works in batches. TiMMS is the only system that uses unique barcodes for each item of stock.
7.3 Review of the implementation of TiMMS

7.3.1 AIP module

The TiMMS AIP module was proposed as the replacement to the other programming systems already in use. (Panatools, Siplace and UPS.) This presented the biggest challenge to the project, as any change away from the existing software or procedures was resisted by Engineers and Engineering managers, despite the claim that running these systems was inefficient, they were however effective.

In most cases this software was supplied “free” with newly purchased placement machines, but was of course part of the service. This was dedicated software written specifically for each supplier’s machines and hence was aimed at becoming efficient and effective at sequencing and balancing those machines. This was not always the case, as the TiMMS software started life within Sony when they were unhappy with the programming software supplied by Panasonic and thought they could do better.

In addition to programming software, these suppliers have started to sell shop floor control software at a cost. E.g. PanaCIM and related software from Panasonic. However, the functionality of these was far inferior to the TiMMS software, not to mention the drawback of running multiple systems.

Though these programming systems worked fine for a production line containing only machines from the same supplier, they could not deal with mixed lines (Mixed lines contain machines from more than one machine supplier.) making it a time consuming manual task to program the line. It also made it difficult to transfer product to other lines with different machine configurations.
The idea was that they would change from several different and separate programming systems to a single system utilising the TiMMS software. The advantages of doing this were:

- Standardisation.
- More efficient programs on some machines.
- The ability to cope with mixed lines
- The ability to transfer product between lines relatively quickly and easily.
- Elimination of multiplication of resource; data entry, system maintenance, training, software, hardware and so on.
- The ability to view all data on one system.
- Improved quality.
- Reduction of time or resource required programming the machines.

However, there were also a number of issues adversely effecting implementation. These were:

- Resistance by Engineers and Engineering managers.
- The effort and resource required to set up and maintain the TiMMS databases was greater than each singular system. The main reason for this problem was that the company was decentralised in to customer-focused teams.
- TiMMS had to be the master database and be kept updated by Engineers, though similar procedures would have been required with the existing systems.
- TiMMS support for new machines was slower and of lower quality than the machine suppliers.
- The TiMMS software was lacking in some areas; functionality, bugs and technical issues; compared to the existing systems.
- The complexity of the software was relatively high and the ease of use was low, meaning that a lot of training and expertise was required to implement and run the system.

All this meant that the negative impact of these issues had to be addressed to enable the implementation of the other TiMMS modules including PCS.
7.3.2 PCS module

A project was initiated to improve materials management site wide, focused on the shop floor requirements and utilising the TiMMS software. The software had previously been chosen, due to its strategic vision and innovative functionality. As well as enhancing the control of materials, the principal tangible benefits of the project were identified as:

- Reduced rework.
- Reduced stock holdings.
- Reduced spoilage.
- Reduction of material shortages that hold up operations.

These benefits were provided principally by the following functionalities:

- Trace ability of material.
- Monitoring the usage of material in real-time.
- Validation of material before it is used.
- Monitoring of spoilage.

There were many meetings to raise awareness of the software and to sell its benefits to interested parties. It became apparent that the key benefits of the TiMMS software were not provided by the AIP programming module, but by the line monitoring, RTM and PCS modules, mainly due to the information provided in real-time to help manage the line more efficiently.

An investigation of materials management was carried out, focusing on the production line. The findings of this have already been detailed in chapter 4. This involved interviewing many people from different job roles and teams to get a good all round picture of all the processes and issues involved. This included looking at things on the shop floor to understand how everything integrated; materials, machines, people, manual operations etc.
A survey of material stores on the shop floor was carried out to provide a database of how many storage locations there were, where they were and the total area taken up. This enabled tracking and evaluation of changes to the shop floor and materials layout.

The materials investigation also included an analysis of spoilage. It was either recorded manually from machine reports or was picked up by the cyclic stock checks. Some assumptions were made, but the conclusion was that most of the spoilage, roughly 80%, was not recorded "as it happened" making a case for improving the data integrity of the inventory records by recording spoilage in real-time.

There was an introductory visit to see the TiMMS PCS software in operation. The next step was to define the customer requirements, how materials management could be improved by using the software and what benefits should be focused upon. A major issue was disagreement and indecision over the customer requirements. It took a lot of discussion to get anywhere and reach a consensus agreement. Reasons for this were that there was not often an official document, stakeholders were not used to agreeing customer requirements and specifications in the detail that was required, and adequate resource was not allocated by them to do this.

Process modelling was done using flowcharting. This was used to show how integration of the software with everything else was possible, showing how the software could fit in with everything else, how additional functionality could be used to generate benefits, and where the current system needed to change to fit in with the software. When implementing a new I.T. system, there are two opposite poles of integration. The first would be where the software is changed to fit in with the current system. This may be impossible, impractical or too costly. There is also a danger that no improvement will be made. The second would be where the current system is changed to fit in with the software. This is not ideal for the same reasons as above and in addition training may be required or the software may not meet some basic or key requirements of the system. In conclusion, integration will end up being an acceptable compromise ground where both the new I.T. system and the old system change to create the new system.
Before implementation, it was necessary to train up an in-company expert to head the implementation team. This was achieved mainly through self-training on an on site installation of the software, following introductory training provided by the supplier. It was necessary for that person to keep abreast of many technical areas and learn new things continuously throughout the lifetime of the project. The functionality had to be understood in detail in order to understand how the benefits could be delivered, how they could be impacted by misuse or misapplication of the system, what training would be required, how to recover from problems and provide ongoing support and training to users.

A report was written and circulated to the stakeholders and interested parties, defining the scope, vision and implementation plan. Following from this a more detailed specification of the implementation was developed. The vision is detailed in the following section 7.4. Further visits were organised to demonstrate the software and see it in operation. Attendees included stakeholders, managers, implementers and other interested parties.

A customer-focused team was selected for the first trial implementation of PCS in 1998. This project was initiated by selling the software to the team, and then we agreed the scope of the implementation. For the planning stage, an implementation team was formed to discuss and agree the finer details of the project. This planning included many meetings covering familiarisation with the software, implementation planning, documenting current or team specific work practices, training requirements and a risk assessment. The progress of the project was monitored using a detailed project plan checklist, split in to stages and tasks within each stage; implementation planning, hardware installation, user support documentation, software configuration, training, data set-up, go live, ongoing support and options for further implementation.

An off-line training system was set up to be as complete a simulation as possible of the materials process on the shop floor. This was used initially to run through the procedures so that members of the customer-focused team understood them and ensure that they were agreed and fully documented. This was the final system design phase. The documentation included flowcharts, simplified instructions and a problem solvers guide. The latter was to help with dealing with deviations away from the procedure and how to correct them.
team also investigated in further detail the control of materials at the machine, tackling the practical issues of integrating manual operations with the software, the equipment was moved around to improve the ergonomics and visual aids were added to make it simpler for the operators to understand.

Training courses were run for all machine operators, shift leaders and materials personnel who would be using the system as part of their daily operational procedures. Training was tailored to fit each job role. Each operational group had different responsibilities and hence were trained to use different sets of functionality, but with some overlap. The first step of training was always the same, so that all users had an awareness of the parts that they played in the total system. Over 100 users were trained and supported during the lifetime of the project. The biggest challenge in the implementation of the software was that it had to be run around the clock, 24 hours a day, 7 days a week. This meant that initial training had to cover all shifts in a short space of time; otherwise the implementation of the system would not have run smoothly. It also meant that the system had to be supported round the clock following "go live." This led to further training being required on night shift, such that they were able to support themselves.

The initial "go live" fell down on a couple of occasions. Firstly, because there were problems with the customer-focused team releasing people for training. This reduced the effectiveness of the training, because it had to be done over too long a time frame, meaning that the trainees would forget the training. Secondly, because the FIFO functionality was not practical to implement and so this option was switched off. Following these teething problems, the system was successfully implemented and was running smoothly. Both trainees and trainers did the most learning once the software went live. Issues were dealt with as they occurred and the users got used to the system. Ongoing support was then provided to the users.

During the ongoing trial of the software, further technical issues, that would effect the data integrity of the data collected by the software, were tackled. These were mostly related to the interface between the Panasonic auto mount machines, its software and the TiMMS software. Due to lack of action from both the internal engineering team and the engineers' of
the machine vendor, it was never possible to solve these issues. In general there was little
desire by the customer-focused team to get benefits from the software.

One such issue effecting data integrity was supporting the use of the bad board mark. Each panel built on the production line was a printed circuit board assembly made up of 4 identical boards. The panel was broken down into 4 boards at a later stage in the production line. The component supplier also supplied us with marginally defective panels at a price reduction. These would have a quality issue where one board of the panel was a bad board. Placing a bad board mark over the appropriate fiducial mark on the board would identify this as a bad board. In theory this could then be used by the machine to automatically miss that board when building the panel and communicate this event to TiMMS to maintain data integrity. In practice the team were not using the bad board mark, but instead avoiding the issue by skipping the bad board from being assembled. This was not communicated by the machine to TiMMS, thus effecting the data integrity. The reason for not using bad board mark was that the supplier was not properly applying the mark, so a corrective action was lodged with the supplier.

Throughout the lifetime of the project, there was a need to manage the software supplier. An external development team supported the TiMMS system as part of a maintenance contract. The software was being continually developed based on an overall vision, requests and issues raised by their customers. A key area to the success of the project was with development of the software to meet the customer requirements. The typical procedure for this was that the implementers raised a development request or a software issue with the supplier on behalf of an internal customer, this would be prioritised and added to a list of issues, the supplier would allocate resource, then when a particular issue came to be tackled there may have been a need to liaise over the issue, the development would be done by the supplier, then there was a need to test or check that it met the requirements of our original request. If so then the development was complete and would be accepted and maybe signed off. If not, then there would be a feedback loop where further interaction and work would be required to complete it. Only with a large development would an official specification would be written, then there would be an additional cost over and above the standard maintenance contract that would be quoted for by the supplier for the acceptance of the customer.
One such large development undertaken for the Kidsgrove plant was the PCR (Parts Control Remote) sub-module. The internal Supply-Chain team, as part of the Hub project, initiated this work. (See section 7.5.) The requirement was to generate “shopping lists” for the hub from the TiMMS software. In actual fact, the PCR function was designed to cater for “shopping list” generation both internally and externally. It was aimed particularly at high volume product where the same material is ordered over and over again.

Further implementation and development of the software followed the trial implementation. This was determined by additional requirements or issues raised by the implementers or customer-focused team. These included full trace ability of material, the control of tray material, improved support for exchange mode and support for new machines. These points are explained in more detail in the following paragraphs.

An investigation was carried out into full trace ability. This looked at customer requirements, internal requirements and how the existing systems could be used to serve these requirements. Full trace ability meant trace ability of components by supplier batch, trace ability of printed circuit assemblies and linking these two pieces of information in time, such that they could be used to know which components went on to which boards. This would utilise bar coding technology.

The control of tray material referred to material that was typically supplied in flat packs as opposed to on a reel. The requirements were to control this material in a similar way to reeled material. This was made difficult by a lack of information supplied by the machine. It also required operators to follow new procedures in a disciplined manner in order to maintain control.

The improved support for exchange mode referred to the operational mode used by the surface mount machines. Instead of having one carriage of feeders they were capable of having a second mirrored carriage of feeders holding the same set up of feeders. The software had to be developed to support this mode of operation. A number of development were
required that covered many varied issues and requirements. For example, the alternate set of feeders had to be displayed to the operators as simply and intuitively as possible.

The support for new machine meant that the TiMMS software had to be developed to support new machine types as they were installed on site. They had to be integrated into the rest of the software as seamlessly as possible and any special functions or options needed to be included as well. This meant liaising with the software supplier, machine supplier and specialist engineers. Though the ultimate responsibility lay with the software supplier, they did not have the experience of working with the machine or knowing what information was output to the machine and having direct access to the specifications.

A second implementation project for the PCS module was undertaken in 2000. Due to tight time-scales and lack of resource, the scope of the project was much narrower. This was to implement the basic system, focusing on trace ability of reels. This project was successful, however the customer-focused team had no desire to take the software implementation any further, meaning that the benefits achieved were minimal.

Wider or further implementation of the TiMMS software was unsuccessful. A number of issues or reasons were identified. These are now being addressed. The issues identified were as follows:

- Lack of resourcing of the project both within Celestica and externally by the TiMMS development team.
- Lack of commitment from the customer focused teams to resource the project.
- The scope of the project was too big and not clearly defined, though this was not realised at the time.
- Without the structure of general project management disciplines, such as the definition of requirements, commitments and risk management, it was difficult to show progress on implementation, focus on the benefits and show that success had been achieved.
The general accessibility of the software, which was originally written on the OS/2 platform was a factor. This is now being resolved with the software being converted to run on the Windows NT/2000 platform. This is the same as the corporate platform and will improve accessibility.

Incorrect usage of the system, meaning that benefits were not achieved. Ideally there should be expert users that police the system to make sure that other users are using the system correctly.

The perception that the software did not deliver the benefits. It was very difficult to prove the measurables.

The software was still under development and relied too heavily on the customer having the technical expertise to help debug the software.

Technical issues with software-machine interface.

Thus, the Kidsgrove site has been implementing bar coding technology via the STAR and TiMMS software to improve material control from “goods in” to the “shop floor”. The next section details the vision for the implementation.

The existing modules of the TiMMS software were extensively developed. A number of additional modules were developed up until 2001. These were:

- SMS (Schedule Management System) – for scheduling of auto mount machines.
- HMB (Hand Mount Balancing) – for planning of hand mount operations.
- MMS (Machine Maintenance System) – for managing the maintenance of auto mount machines.
- e-TiMMS – RTM data has been web enabled. Also supports mobile devices.
7.4 Vision of TiMMS material control system

There are many potential benefits that can be provided from the functionality of TiMMS. The following section focuses on the material control functionality of TiMMS and shows how it can fit in to the proposed strategy for Celestica Kidsgrove identified in section 5.2. When a point taken from the proposal is referenced, this is shown in brackets. E.g. (Point x.)

The TiMMS Parts Control System utilises barcode technology to provide a material control system. A key part of the TiMMS system is to have each reel, pack or box of parts uniquely identified with a barcode label. This identifies the parts to the system whenever this label is scanned with a barcode scanner. Many operations can be carried out on the system, such as materials movements and transactions, and most of these are traceable by user, allowing specific feedback of issues to users and accountability.

TiMMS displays up-and-coming reel changes for each machine, so reel changes can be prepared for and down time minimised. There is validation against part number and trace ability, when parts are put on to or removed from the machine. To guard against wrongly labelled or faulty parts, it is possible to perform a value check or check the markings on the part, just before they are loaded on to the machine. (Point 24)

There are several methods for replenishing parts. There is a kanban system that can be used for picking individual reels or kits of parts in advance. (Points 1 and 27.) This can control parts on a FIFO first in first out basis. (Point 26.) Alternatively “shopping lists” can be generated for a number of warehouses, whether internal or external. This uses a complex model to calculate what parts need replenishment. (Point 4.) When the replenishment kit is received it is checked against the original “shopping list” to highlight any variances.

TiMMS automatically records boards built, machine pick up errors, part exhausts and operators can input spoilage. This means that all usage of materials can be recorded as it happens. (Points 3, 14 and 20.) The software can automatically monitor attrition against settable targets and transmit “quality alerts.” It records attrition by feeder, by time and by
reason, which allows problem solving and process improvement. (Point 18.) If attrition is re-used it will be assigned a unique serial number so that the same level of control and traceability can be maintained.

Scheduling is an important part of TiMMS. The schedule is used to predict when a changeover will occur and enables optimised kits to be prepared in advance. (Point 27.) This can improve productivity by reducing the time taken to change over to the next board. You can create pick lists and identify shortages in advance. (Point 28.)

Figure 13 shows the proposal of how TiMMS can be applied to integrate with the material control processes at Celestica Kidsgrove.

Figure 13. Proposed material control system
Table 3 summarises how the material control system would change from the original state to the future proposed state.

<table>
<thead>
<tr>
<th>Area</th>
<th>Original</th>
<th>Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Supply to production and stock levels</td>
<td>Pick list manually created. No &quot;handshake&quot; between stores and shop floor.</td>
<td>Automated pick lists, optimised kitting and a &quot;handshake&quot; with the shop floor.</td>
</tr>
<tr>
<td>2. Inventory data integrity</td>
<td>Affected by human error and unrecorded data.</td>
<td>Control and record usage of reels or packs by barcode.</td>
</tr>
<tr>
<td>3. Attrition management</td>
<td>Machine spoilage reports printed out and scrap manually entered.</td>
<td>All attrition accounted for; machine reports automatically recorded and operators manually enter scrap.</td>
</tr>
<tr>
<td></td>
<td>Cyclic stock checks.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Validation of parts loaded on machine</td>
<td>Visual checking of part number and carriage location plus a &quot;buddy check&quot;.</td>
<td>Automatic checking of new reel or flat pack and feeder using barcodes.</td>
</tr>
<tr>
<td>6. Trace ability of parts to built boards</td>
<td>Manual record of material replenishments, by part number and time, linked via WIP tracking system.</td>
<td>Automatic storage of all material replenishments and built boards by unique barcode.</td>
</tr>
</tbody>
</table>

Table 3. Summary of original versus proposed processes.

Referring to the proposed materials strategy, TiMMS PCS mainly helps us with the “data integrity” objective. It also enables us to do it with less effort by using bar coding technology and integrating it in to the new working practices. (Point 25.)

A drawback of the system is that it only controls material to auto mount machinery. There are plans to include other material such as hand mount and bare boards. TiMMS already supports planning of hand mount operations with the HMB module.
Reports can be produced to show materials wastage. The cost can be calculated and displayed to the shop floor workers. (Point 15.) This emphasises the importance of materials and the cost of wastage. By looking for discrepancies between these reports and actual, it is possible to improve the accuracy of the reports. (Point 19.)

TiMMS has a mechanism for stock reduction within the PCR “shopping list” module. The maximum and re-order point for the amount of stock is expressed in hours. If these values are reduced then the average amount of stock will be reduced. (Point 5.) “Shopping lists” can be generated for external supply point, which might be warehouses, suppliers or hubs. This would then facilitate delivery direct to “point of use.” (Points 9, 10 and 11.)

TiMMS helps production record how much material will be required, what is being used, wasted and updates this information in real-time. This means that they can be effectively accountable for usage and spoilage of materials. (Point 16.) It also effectively communicates to materials workers what material is required, freeing up their time to do something else.

7.5 Materials supply hub

A project was initiated by the supply-chain team to implement a materials supply hub. A hub is an external warehouse managed by a third party. In this case it was to receive and store certain parts from suppliers that we would then pull “on demand” from the supplier. This project was completed in 1999.

The practice of setting up and running a hub is a relatively new practice. A “supply hub” refers to a customer-supplier shared warehouse. The logistics takes materials from the supplier to the hub and then from there to the customer as it is requested. A key advantage is that both parties share the same information on what is in the warehouse. (Point 23 of proposed strategy from section 5.2.) This strategy aims to improve performance mainly by reducing costs, but in the bigger picture it could also be an enabler for JIT.
When there is a lot of fluctuation in the Supply-Chain (This may be due to consumer requirements, customer requirements or the effects of building in large batches.) JIT practice becomes more difficult, since material holdings must be so large to counter these effects.

**Costs before implementation:**

The supplier has the cost of finished goods stock and the cost of managing their warehouse. The customer has the cost of raw material stock and the cost of managing their warehouse.

There is low visibility of stock; the focus is usually on orders, not stock. The quantities ordered are usually large, since supply is remote. The supplier has little time or warning to adjust to fluctuation.

![Figure 14. Typical supplier to customer logistics process.](image)

**Costs after implementation:**

For the supplier, the finished goods stock may be reduced, though if material is consigned material this would not be true, since it depends who owns stock at what point. The cost of a warehousing is also removed. However, the supplier still needs to pay the hub to hold and manage materials. The result is to reduce the space required to store materials, thus creating space, providing opportunity for improvement of layout or expansion.
For the customer, the amount of raw material held is greatly reduced. Plus removing the cost of the warehouse. (Plus creation of space as per above.) However, the customer must pay for hub to pick and deliver materials.

**Figure 15. How the materials supply hub improves the logistics process.**

**Benefits:**

- **Economies of scale.** Costs in the Supply-Chain are reduced since many warehouses are amalgamated. *(Goldratt, 1994)*
- **The supplier of the warehousing service can be a dedicated warehouser with expertise, people, skills and equipment to manage the stock better and more effectively.**
- **Improved visibility of stock for customer and supplier.**
- **Customer can pull in smaller batches, since the warehouse is local.**
- **Any fluctuations can be seen sooner, so the supplier has more time to react.**
- **As confidence rises, the stock at the Hub can be reduced.**
- **The lead-time of ordering usually includes the time to make a batch. However if the supplier reduces their batch size, this in turn reduces the lead-time and hence the stock level.**
- **The move to local stores reduced materials handling and stock at both the customer and the supplier.** It would also enable delivery direct to the point of use. *(Point 11 of proposed strategy from section 5.2.)* It would also be prudent to reduce order costs. *(Point 8 of proposed strategy.)* Automating payment or using blanket orders might do this.
- **It provides the opportunity to start with a clean slate, look at old practices and cut out inefficiencies, to improve work practices.** It could also be argued that moving the
materials function from and internal to an external supplier will in the longer-term give a more professional and competitive materials operation.

7.6 APS system

Celestica Kidsgrove are in the process of planning and implementing advanced planning and scheduling software during 2001. The software is called APS and it is supplied by i2. There are three different modules; supply-chain planner, factory planner and demand planner. This enables modelling of the material requirement. (Point 4 of the proposed strategy presented in section 5.2.)

Demand planner works on both a corporate and a customer level. It takes the customer demand forecast and enables analysis and improvement of the supply-chain linkage with both customers and suppliers. The model can include contractual flex.

Supply-chain planner and factory planner take the forecast from demand planner and allow modelling of the build plan based on any number of material and capacity constraints. It also allows planning on a corporate basis taking in to account material and capacity on all sites.
8. Discussion and evaluation

The objectives of this chapter are:

➢ To analyse how things have changed at Celestica Kidsgrove since 1996, making specific and direct comparison to the proposed strategy presented in section 5.2.

➢ To analyse which points of the proposed strategy we are addressing and what gaps there are. This will then indicate where the company should be going.

Figure 16, on the next page, shows a comparison of ongoing projects and “best practices” with the proposed strategy. Each point of the strategy from chapter 4.3.3 is listed on the left-hand side of the table. Then the ongoing projects presented in chapter 7 are compared against the strategy. Where a project directly supports a point of the strategy it is given a tick ✓. A bracketed tick (✓) indicates that the project indirectly supports or enables a point of the strategy. In other words additional action is required to fulfil the point. Next the “best practices” identified in chapters 2 and 3 are compared against the strategy in the same way. The major “best practice” of JIT (just-in-time) is also shown in a separate column due to the many points it can potentially cover.

Next the holes or points not supported by the “best practices” or ongoing projects are identified and how this will impact achieving the objectives of the strategy. The amount that each will impact the objectives is hard to quantify, but as many actions are linked one missed objective may prevent achieving the whole objective. What this means is that the objective will only be partially achieved or not achieved at all.

The “best practices” do not address points 4, 14-17, 20, half of 24 and 26-28 of the proposed strategy presented in section 5.2. This will effect achieving objectives 1, 3 and 4. The ongoing projects do not address points 2, 13, 17, 21 and 22, again effecting objectives 1, 3 and 4, though to a lesser extent. The result of this comparison is to identify what additional points need addressing so that the strategy is most effective. Specific parts of the JIT philosophy would cover these points.
### Comparison of ongoing projects & best practices with proposed strategy

<table>
<thead>
<tr>
<th>Point</th>
<th>Abbreviated proposal</th>
<th>Ongoing projects</th>
<th>Holes</th>
<th>Best practices</th>
<th>Ongoing projects</th>
<th>Effects objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>TIMMS Hub APS JIT</td>
<td></td>
<td>Best practices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,9</td>
<td>Kanban</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Supplier scorecard</td>
<td></td>
<td>✓ ✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Record usage in real-time</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Material requirement model</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Staged stock level reduction</td>
<td>✓ (✓)</td>
<td>✓ ✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Lead-time reduction</td>
<td>(✓)</td>
<td>✓ ✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Material on consignment</td>
<td>✓ (✓)</td>
<td>✓ ✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Reduce order costs</td>
<td>(✓)</td>
<td>✓ ✓</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Minimise transport costs</td>
<td>(✓)</td>
<td>✓ ✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Delivery direct to point of use</td>
<td>(✓)</td>
<td></td>
<td>✓</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Develop build plan model</td>
<td>✓</td>
<td>✓ ✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Reduce finished goods stock</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td></td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>Monitor usage &amp; wastage</td>
<td>✓</td>
<td></td>
<td></td>
<td>0</td>
<td>3,4</td>
</tr>
<tr>
<td>15</td>
<td>Report cost of wastage</td>
<td>✓ (✓)</td>
<td></td>
<td></td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>Production made accountable</td>
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<td></td>
<td></td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>17</td>
<td>Materials training</td>
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<td></td>
<td></td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>18</td>
<td>Reduce materials wastage</td>
<td>✓</td>
<td>✓ ✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Improve accuracy - usage &amp; wastage</td>
<td>✓ (✓)</td>
<td>✓ ✓</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>20</td>
<td>Recording is easy &amp; enforceable</td>
<td>✓</td>
<td></td>
<td>0</td>
<td></td>
<td>1,4</td>
</tr>
<tr>
<td>21</td>
<td>Focused stock checking</td>
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<td>✓</td>
<td></td>
<td>0</td>
<td>1,4</td>
</tr>
<tr>
<td>22</td>
<td>Solve process variability issues</td>
<td></td>
<td>✓ ✓</td>
<td></td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>23</td>
<td>Share information with suppliers</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Validation &amp; traceability</td>
<td>✓ (1/2)</td>
<td></td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>I.T. &amp; barcoding</td>
<td>✓</td>
<td>✓ ✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>FIFO usage of stock</td>
<td>✓</td>
<td></td>
<td></td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>27</td>
<td>Optimised kitting</td>
<td>✓</td>
<td></td>
<td></td>
<td>0</td>
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</tr>
<tr>
<td>28</td>
<td>Predict shortages</td>
<td>✓</td>
<td></td>
<td></td>
<td>0</td>
<td>1,4</td>
</tr>
</tbody>
</table>

Figure 16. Comparison of ongoing projects and “best practices” with proposed strategy
9. Conclusions and further work

The objective of this chapter is:

➢ To make conclusions, present the findings and to identify opportunities for further work.

9.1 Conclusions

In light of the aims and objectives set in section 1.2 the following conclusions have been made:

- The literature was reviewed around the topic of in house materials management and “best practices” were identified. The thesis split the current areas of interest in to the following sections: materials management, shop floor control systems, the application of technology, and approaches or philosophies.

- The “best practices” identified from the literature were: prioritisation methods, outsourcing of value added services, shop floor control system, focused stores, tailored logistics, use of computers or I.T. integration with business processes, trace ability, use of technology or automation, automatic identification, maintaining data integrity, internet enabled supply-chain, the JIT methodology and hybridised JIT-MRP.

- A number of site visits and case studies of companies were documented. These were mainly, though not exclusively, in the electronics industry. Each company is different in terms of culture, strategy, processes, application of technology and materials management. They have evolved differently over time, operate in different environments and hence have developed different solutions to running their business.

- For the purpose of this thesis, it was necessary to compare the area of supply-chain and materials management. To aid comparison between companies, a generic flowchart was developed. See Figure 1 in section 3.1. This section then summarises the findings for each company, including a flowchart based on the generic one.
A score table was developed where each company investigated was given a score against each "best practice." Table 2 in section 3.9 is the company comparison matrix. The scoring system is subjective. Ford Markham and Magna scored the highest in this scorecard. Celestica Kidsgrove was at the lower end of the scoring scale.

An analysis of materials management and working practices at Celestica Kidsgrove was carried out in the light of the literature review and industrial review. The analysis looked at the supply of material to the shop floor, the management of inventory data integrity, attrition management, validation and trace ability of material.

The next stage of the analysis featured the use of a thinking tool called a reality tree: current reality tree and future reality tree. (Goldratt, 1994.) These were used to develop a strategy.

A current reality tree was used to show the cause and effect linkages of the system. This then enabled us to identify the core problem, desired goal and conflict. The core problem was "Most workers do not stress, know or have been trained the importance of materials and related costs." The shared goal was to "manage materials excellently."

There were four common objectives designed to reach that goal. These were:
- Reduce stock and hence the cost of stock.
- Improve data integrity of inventory records, ideally with less effort
- To model the build plan.
- Improve materials management on the shop floor.

A proposed strategy for improvement was developed from this by constructing a future reality tree. (FRT) This is a thinking tool that helps to create a vision and strategy for improvement. The proposed strategy is listed as a number of actions and this is detailed in section 5.2.

The approach of using the CRT and FRT thinking tools is very powerful, because it shows you how the "best practices" are relevant and how they can be put in to practice as
part of a larger system. It also shows that it matters less what "best practice" you apply, but more how you apply it in the context of the wider system.

- There are gaps between the “best practices” and the proposed strategy. The points that are missing are as follows: 4, 14-17, 20, half of 24 and 26-28. By using the CRT and FRT thinking tools the solution will be concentrated on the core issues and the solution will be more complete and integrated. The FRT shows the preferred strategy. The gaps may be additional or new “best practices.” Ones that may have never been quoted or documented. The differences may be due to the practicalities of implementing a solution for Celestica Kidsgrove. The problem with just implementing “best practices” is that improvement may be hit and miss and only partial benefits will be achieved.

- The selection and implementation of software was discussed. An ideal approach was presented. There is a distinct process as well as other areas of importance surrounding this. The process included the following stages:
  
  - Business process investigation and analysis.
  - Agree customer requirements and identify stakeholders.
  - Create a design, vision or scenarios.
  - Software is investigated in detail.
  - The decision stage.
  - Implementation.

- Other areas of importance include using a project management methodology, building management support, systems integration, measurables, benefits, management of change, organisational structure and culture, co-ordination of users to use the I.T. system as a team and consolidation of training.

- The changes made to materials management and related I.T. systems at Celestica Kidsgrove since 1996 were reviewed. There was an emphasis based on the TiMMS software, because this was where the main expertise and knowledge of the author lay. There was a discussion of software developments, implementations, benefits and the
issues surrounding these. This started with the software related to "goods in" and warehousing. Then moved on to the TiMMS software, its AlP programming module, then the trial implementation of the PCS materials management module. A vision was presented for the TiMMS material control system, primarily utilising the PCS module, showing how TiMMS fitted in with the proposed improvements presented in section 5.2. Other changes to materials management were the implementation of a materials supply hub and the APS advanced planning and scheduling software.

- The current strategy of ongoing projects and the list of "best practices" from section 2.6 were compared in section 8 using Figure 16. The findings of this comparison were that the "best practices" miss many objectives of the proposed strategy presented in section 5.2, indicating that there would be only partial success. The ongoing projects miss fewer objectives than the "best practices" suggesting that in the longer term a higher success rate will be achieved. The missing points would be covered by specific parts of the JIT methodology. So it should be a matter of implementing these points in addition to everything else.

- The following are the actions that are missed by the "best practices" and for this reason we should consider adding the following points from section 5.2 to the list of "best practices":
  
  • Use of a material requirement model. (Point 4.)
  • Monitoring materials usage, wastage and improving its accuracy. (Point 14.)
  • Making the recording easy and enforceable. (Point 20.)
  • Reporting the costs of wastage to operators. (Point 15.)
  • Production should be made more accountable for materials. (Point 16.)
  • Materials awareness training for production workers. (Point 17.)
  • Validation and complete trace ability of raw material through to the finished product. (Point 24.)
  • FIFO (first in, first out) usage of stock. (Point 26.)
  • Optimised kitting of material. (Point 27.)
  • Prediction of shortages. (Point 28.)
9.2 Further work

Suggestions for further work resulting from this thesis include:

- A more detailed benchmarking exercise could be carried out to define world-class performance. It would seek to define materials management measurables, examine the measures other people use and analyse whether these measures are effective.

- Carry out the same analysis as performed on Celestica Kidsgrove, on another site.

- To implement as many of the proposals as possible to prove the methods used.

- To use mathematical modelling or simulation. Model the old system and the proposed system, then test the models using real data.

- Develop a model of stock accuracy. Investigate the application of statistical methods (E.g. SPC.) to providing a measure of stock accuracy over time. This would then indicate the likelihood of materials shortages based on the current level of stocks, enabling stock checks to be focused and hence more effective.

- Investigate how materials handling and material process flows can help the strategy.

- To compare the different theories, models or systems of materials management to define advantages and disadvantages.
10. References


Appendix 1 - Industrial reports

A.1. Celestica, Toronto, Canada

A.1.1 Introduction

Celestica Toronto used to be the manufacturing part of IBM. As a strategic decision, the company split from IBM to set up on its own and with the backing of Onex, a venture capital company, set up as Celestica Inc. The Toronto site is the headquarters of the Celestica Corporation.

Their products are split in to three main areas:

- EMS (Electronic Manufacturing Services.) Current customers include Silicon Graphics, EMC, HP, NPR, Sun and Dell.
- Memory products
- Power products

The Celestica Toronto site is viewed as being mainly part of the EMS market place, although performance comparisons with competitors are difficult, because of their diverse product range. The overall market size in 1995 was £45bn with projected growth of approximately 30% p.a. The CEM/EMS market is consolidating, mostly through acquisitions. This consolidation enables economies of scale, such as pooled purchasing leverage. Turnover per employee is highest of the top three companies in the CEM market; Celestica, Solectron and SCI. This is due to the number of value added products that they have.

To succeed in the electronics industry there are five competitive challenges that must be considered and acted upon:

- Requirement for large capital investments.
- Shortening product life cycles. Data systems are critical to cope with shortening product life cycles.
- Recruiting, developing and retaining skilled personnel in a rapidly expanding market.
- The increasing complexity of technology.
- Planning, procuring and managing inventory.

A.1.2 Manufacturing

Surface mount machines:

- Panasonic beta-site - They have developed a strong partnership with Panasonic, such that a number of their suggestions are being actively added to their next generation of machines. The programming software used for these machines is Panatools.

- Universal – GSM-1 machines. The software for programming on this machine is not user-friendly. They have a method for creating programs for these using Panatools, which includes a converter for Panasert files.

They collect a lot of quality data from their environmental stress chambers. Their customers define product assurance. Their main requirement is reliability. They look at the customer's critical success factors and design their service to meet that. They manage the service and if necessary they will subcontract this contract work, if it is in the best interest of the customer.

A.1.3 People/Culture

The culture is value driven. They are promoting a “can do” attitude by handing out “can do” T-shirts. They encourage participation and communication. They believe the three critical success factors are skill, attitude and knowledge. Every new inductee covers attitude. They believe everybody should have the capability to be a “situational” leader.

They have two principal career paths; support and production. Half of the shop floor personnel have college degrees. They have a very successful internship scheme, where
university and college students spend 16 months in the company before their final year. Roughly 90% of those offered jobs take them up.

A.1.4 Materials strategy

Celestica Toronto has a "Materials white paper". They looked at the total supply-chain, including their suppliers, the company itself, their customer and even the customer's customer. They have monthly meetings in this supply-chain improvement initiative. There is a project status sheet that defines improvement projects, owners, potential benefits, targets, results to date, time scale and so on.

Some examples of improvement activities:

- EDI system: EDI is the latest thing, but in general companies are not using it effectively. How can it be used more effectively?
- Retraining materials workers in cycle counting.
- Developing decision assist tools that allow "what if" analysis.
- Developing a line-scheduling tool.

A.1.5 Materials processes

Their MRP system is included in their BPCS software, which is an ERP system. The BOM (bill of materials) is split down in to the stages of production, so that material can be downgraded. Downgrading means that the usage of materials is recorded to MRP in stages, so that materials can be more accurately controlled.

Components are received at the dock by the receiving department. The quantity, part number etc. are entered in to BPCS. They have a very large goods-in warehouse. This is automated and is controlled by AWS. (Automated Warehouse System.) Material is stored by pallet and AWS recalls materials by pallet. It can handle up to 4 part numbers per pallet. Sometimes parts need to be despatched straight to line as soon as they arrive, because they
are urgently required. There is no function in BPCS to handle this, so a flag is used in the quality system to identify shortages.

The customer order is for the final assembly. The shop order breaks this assembly down into sub-assemblies. The line schedulers use this information on BPCS to create a build plan. The build plan is used by the kitting team to supply material to production. A kitter will take a build or order quantity and kit parts by shop order.

E.g.  
Customer order  Model A 
Shop order  Board A1, board A2

Components are ordered on AWS and may take around 15 minutes to arrive in the kitting area. Kits are made up firstly from partial reels and secondly from fresh material. The kit is put on a kitting truck and transported to the shop floor. There are designated areas for kits next to surface mount production. This process is generally the same across the site. All high volume products are done this way. However, there are some exceptions for specific customers or products.

At the end of a build, material may need to be returned to storage. The quantity of parts left on a partial reel is estimated. They are returned to the kitting room, where there is some storage specifically for partial reels. If this is full, then the reel will be put back in to the warehouse on a pallet containing the same part. This system is flexible to changes in build plans and BOM’s, since material is kitted up as they go.

A.1.6 I.T. systems

DAPR is a shop floor control system and has an interface to BPCS. As part of being sold by IBM, they had to be ready to disconnect from IBM’s systems in April 1997.

DACS (Data Acquisition and Control System) is a customised I.T. shop floor control system. It is a global acronym for a suite of software tools. The main functions are quality and WIP tracking system. It is capable of tracking a million serialised electronic cards as they
pass through Celestica's assembly processes. Barcodes are used extensively to track boards through set locations and operators enter additional information, such as fault information. None of the supplied components are stored in DACS, apart from recording components used when repairing boards.

Each printed circuit board assembly has a unique identifier. This identifier consists of: 4 digits-EC engineering change number-REA release number. You can change the product name linked to this I.D. (E.g. if board is labelled wrongly.) You can define what type of production it is. (E.g. rework)

The database is DB2. Data is accumulated ahead of time. Summary tables are stored in the database to speed up reporting later on. You can look at performance by shift, for last week, by operator etc. Data is readily available for reporting for the last 3 weeks. Archived data can be brought out as required, back in to database. E.g. last month's quality report.

You can stop boards anywhere in process, for whatever reason, by stopping it pass through a workstation. Obviously this depends on the operator. They are working on alarms and monitors for operations. DACS monitors WIP and RIP (rework-in-progress) separately. They produce hot lists of WIP boards by age (e.g. 90/60/30 days old) to be found on shop floor. All test equipment is connected to the system. One person is dedicated to training users.

BPCS is Celestica's ERP system. BPCS was supplied by SSA and customised for the Celestica Toronto site. They have 6 business units and 14 different ways of using BPCS. BPCS provides information of parts consumed from Surface Mount machines and also at an assembly level. It looks after warehousing and the pull from stock. They plan to use it for the final assembly schedule and aim to supply their customers with the progress to order.
A.2. **Ford Electronics, Markham, Canada**

Ford Markham is part of the Automotive Components Division. It is in the process of becoming a profit centre as opposed to a cost centre. Their competitors include Motorola, TRW and Siemens.

A.2.1 People/Culture

They have a “white board” next to shop floor for displaying product or process measurables. These are reported from the shop floor database. Team members using the “white board” lead team meetings.

They have 80 engineers in a work force of 1500. Work-study or industrial engineers are attached to specific departments or products. They work a 3-shift system for surface mount equipment, since it is expensive equipment to run.

They have a number of different cultures. English is the second language for everybody. They teach workers basic English and maths. They have 17 cultures and 21 different languages in the day shift. They do not discriminate on language at the selection level.

They have training areas for computer skills and soldering. They have a large meeting room that can hold multiple teams, as well as smaller meeting rooms near the shop floor.

They have fixed starting wages and fixed pay rises each year. They do have a performance review, but it is not linked to pay. Redundancy is on a LIFO basis. All of the shop floor and two-thirds of the staff are in a union.
A.2.2 Manufacturing and material systems

They manage by focusing on cutting down wasted time, adding value, reducing defects and cycle time. For example, they focused on reducing the amount of finished product, and it is now all housed in the factory, as opposed to using an external warehouse.

Their shop floor data collection system is a standard Ford in-house developed suite. Their manufacturing systems utilise P.C.'s and P.L.C.'s as data collectors from the shop floor. They provide real-time information as a database. (Oracle database. They also use visual basic and Access.) They have both Windows and UNIX platforms with some OS/2 applications. They use data standards, including Ford's own. The majority of I.T. systems are to the Ford Corporate standard. The systems and software were selected to be configurable to Ford's many different sites.

They have 35 to 50 new products each year, which have major changes. Their process data is equipment oriented. Their product data is serial number oriented. This information is collected for every board. The data collected depends on each product and are Ford internal measures. I.e. they lay down their own stringent requirements. The aim is to link this data to the product in order to have full trace ability. The key data collection is for their safety-related products, such as air bags. Unique I.D.'s are used for safety products and other strategic products. They have trace ability of production lots to the equipment.

Their future plans include:

- Providing displays of key measurable of the shop floor in real-time.
- If equipment is down, this will trigger alarms, including pagers.
- Using calculations of the cycle time to control the rate of replenishment of materials.
- Automated scheduling.
- Decision support.

Other plants are doing similar things, using the standard software, but configuring it to their own needs.
A.2.3 Materials processes and I.T. systems

Schedules are propagated through the supply-chain electronically (EDI) to all customers and suppliers. I.e. the schedule is linked to the customer schedule.

85% of their material is supplied JIT to a local warehouse, 3 blocks away. Some material is delivered straight to the in-house stores. The local warehouse is provided as a service to their suppliers; they are charged for it, but at the same time it gives them the flexibility to remove material if it is needed elsewhere. The inventory level is not set formally, but is generally 1-2 weeks. 65% of finished products are shipped daily, 35% weekly.

The MRP system is CMMS, which is a Ford standard system. This handles scheduling down to the shop orders. The warehousing system is LOTS and this is linked to MRP system. The on-site warehouse is split in to product groups. However, there are some common items. Some items are delivered direct from the warehouse. They have a 10-year responsibility for replacement parts. This is handled by the MRP system.

They are currently implementing a pull system in the factory called “continuous flow manufacturing.” and hope to extend it to the warehouse. This includes a kanban system to control the pull of materials from the on-site warehouse to gravity feed racks on the shop floor.

The kanban card contains the following information:

- Point of use - e.g. refers to gravity feed rack.
- Part number and description.
- Product.
- Quantity.
- Serial number - number of card within set of cards for that part e.g. 2 of 5.
They have gravity racks on the shop floor, to promote FIFO usage. The kanban card triggers replenishment on consumption of material. The card from the box is placed in a pocket on the wall near the point of use store. As an alternative, they are looking at kitting materials.

They have reel and feeder validation on the machine by P.C. and bar code scanner. This information is also used to replenish parts electronically. There is a fixed float of 2 reels. They scan the bar codes of the reels that require replenishment and create a pick list. Then they have vertical carousels for storing surface mount parts. The highest volume parts will be replenished every 3 hours.

MPRESS - This is their buffer management system. This records movements of magazines of boards or work-in-progress. It is an in-house system that is Markham specific.

FRT (Failure report tracking system) - This records and reports failures. It will also record repairs; with safety products, the boards will be scrapped if they have been over-repaired.

They have an automated production line for making airbag equipment. After the first assembly stage, the boards are tested. The tester information is down loaded to the CIM system. Each model uses the same generic electronic module, but has a different mounting bracket. There is a count down of the quantity left in the batch. At changeover to the next model, the different brackets are accommodated by flexible software. The tests and bar coding are built in to the automation; e.g. vibration test. Testing is done to Ford standards, which are more rigorous than normal world standards.

At final packaging, a label is printed only when the quantity is correct. This label links to all the finished assemblies. For finished product, they use kanban boxes that get returned by the customer. They have a “milk run” for distributing their products. This means that the delivery goes round a group of customers, to save money and energy. At one assembly area, boxes of parts are brought from a staging area by trolley to the assembler. They remain on the trolley. Operators are responsible for updating their spoilage to the MRP
system. They do not have WIP tracking. They work out the total from the raw materials, finished goods and cycle time.

Stock checking is done twice yearly. These are wall-to-wall checks where the whole factory stops. They believe that the answer to improving data integrity was in I.T. The key is simplifying the processes and systems and then fit the I.T. system around these. They have 150-200 stock turns per year.

A.2.4 Manufacturing capability/Technology

Their core strength lies in automotive products; including safety and applications. They are a testing ground for new processes and technology, since they have flexible machinery and labour. They have an inert gas soldering process. Pre-forming of components is done in-house.

Production volumes vary from 60 per day up to 15,000 per day for highest volume. They use inspectors tactically to monitor areas of the process that are “out of control”. They use SPC at the end of the line. The operator has a paper-based colour drawing to show them the key parts. Production batches are 1000-2000 boards and do not usually take much more than a day to make. The production flow is “push” between assembly stages. They recycle around 70% of wastage; e.g. the fibre glass that surround their boards.

A.3. Decoma, Canada

A.3.1 Company and supply-chain

The Decoma group, within Magna, is a full service supplier of exterior vehicle appearance systems. This includes front and rear bumper systems, vertical body panels, lower body side systems, polymeric glazing systems and convertible top systems. Magna is a global group producing automotive systems.
In some cases they are a direct supplier to car assembly plants (tier 1 supplier), but the majority of their work is supplied to another member of the Decoma group (tier 2 supplier, e.g. paint plant)

The MPS is linked to the customer’s MPS. There are 4 weeks of firm orders and 4 weeks for planning. The production schedule breaks down the MPS in to shipments. It is expresses in daily “buckets”. This provides the trigger for ordering material from suppliers. For tier 1 customers supply is straight release, limited only by defined shipment times. Material is ordered from the MRP system dependent on volumes. The most frequent order is weekly. However, deliveries of moulding material will be daily, since there are many different types and grades of material.

A.3.2 Materials

The MRP system also covers production information and financials. The number of parts produced daily is recorded on the shop floor and transmitted electronically to the MRP system. Every team member has a go at scheduling the work. There are material feeders who are responsible for replenishing material as required. The weight of recovered material is recorded.

They have lot trace ability for material by shift. Barcode technology is not used. Incoming material is booked in to the MRP system, the details of which (quantity, vendor batch etc.) are keyed in. Then parts can be linked to the vendor batch. There is a numbering system for marking material. Raw material is supplied in to large silos or in boxes. Boxes are usually standard weights. Finished goods are supplied to the customer in two formats; caged stillages for large parts, re-usable kanban boxes for small parts. (Empty boxes are returned and re-used for packing and delivering finished goods.)

A.3.3 Manufacturing capability/Technology

The group can provide a total and global service. They are currently moving in to other areas and systems via a number of acquisitions. This plant concentrates on injection
mouldings for car fascias (bumpers, grilles etc.) Other plants within the group have reaction injection moulding (RIM) and hydro-moulding processes. The design of tools is done in a large multi-disciplined team.

They produce around 300 parts per machine per shift, with around 3-4% of that scrap. Most of this scrap is a by-product of the process and gets recycled. They have the capability to recover TPO and other materials by crushing it and feeding a small percentage back in alongside fresh material.

A.3.4 People/Culture

New workers are allocated a sponsor. The average length of service in the work force is 8 years. The company is very family oriented. They have family events and a number of company teams. They have a 5% profit sharing scheme, divided amongst all workers. They have a suggestion and improvement scheme.

A.4. NORTEL Northern Telecom Enterprise Networks, Canada

A.4.1 Introduction

Their main products are Magellan (data switch for communications and multi-media) and Meridian. (PDX voice exchange.) They also produce Vector, which can control a whole network. They have a number of strategic partners; Ford systems, Shiva, Lockheed Martin and Maltair.

A.4.2 Manufacturing capability/Technology

They have had 3 surface mount lines for 2 years. These handle 170 different models. Panasonic equipment was selected for placement accuracy. Printed circuit assembly (PCA) is high variety, low volume; so they are concentrated on reducing set-up times. They do set-up off-line (termed dynamic set-up) and they have common set-ups. This is based on
commonality of parts across a set of PCA’s and whilst it reduces set-up times, it also has a big effect on efficiencies. To reduce set-up time further, they have a lot of feeders, pre-set on feeder racks, stored for the various lines. They also have programming software, written in order to re-optimise programs “on the fly.” If a part is already loaded, then they leave it in that position or on the machine.

There is a maintenance white board on each machine. Any identified faults are recorded as they happen. Hand mount production is not dedicated to products. They produce graphical work instructions from planning software. Five designers produce templates for products. They aim to develop a product in 2-3 years. All new products must have backward compatibility. The plan is to build the PCA’s until they reach maturity and then subcontract the work out. Products are configured and assembled to order.

A.4.3 Manufacturing and materials systems

They have separate MRP and MPS systems. If they have abnormal production orders, they will run a simulation to see if they have the material to meet them. They have an improvement initiative focused on reducing the manufacturing lead-time. Their manufacturing lead-time is 7-10 days. The maximum procurement lead-time is 6 weeks.

Work is controlled in the assembly shop using magnetic labels showing customer orders. These are placed on a daily schedule board and placed on metal boxes as they are started. They used to allocate each box to be built by one person, but now they have split the work up in to stages, just like a balanced production line, because they found this to be more efficient. For a common part of the system they use an empty rack to trigger the build of another sub-assembly. For raw materials storage, small parts are in an on-site store, larger parts are stored off-site. Some suppliers, e.g. bare boards, deliver direct on to the factory floor.

Workers scan barcodes to request replenishment of parts. Some components work on a pull system. One area has a 2-bin kanban system. They use RF barcode scanners in the
receiving area. This allows workers to go to the parts to book them in, rather than having to
move the parts or keying-in the information.

Test is a major time contributor to the overall lead-time of a product. To reduce this
they now do functional testing and environmental stress testing ("burn in") in parallel. This is
done in massive walk-in ovens. Electronic products are more likely to fail early in their life,
so large improvements in reliability can be obtained by carrying out an accelerated start up.
This is called "burn in" and is done on the complete configured system before shipping.

A.4.4 I.T. systems

Their I.T. systems are focused on supporting Manufacturing. All systems were
developed in-house. Their ERP (Enterprise Requirement Planning) system started off as an
inventory control system. Then functionality was added in to support other functions; e.g.
planning, MRP, purchasing and order management. It is now a "fully interfaced system". The
different methods of interfacing are real-time, semi-on-line and batch. All Nortel plants have
their own version of this software. This is because each location looks after their own I.T. To
PMS (Production Management System) they have added kanban, back flushing and an EDI
system. They also have picking, packing and shipping software.

They are in the planning stages of implementing BAAN/4, a supply-chain
management and ERP system. The main reason for this is year 2000 compliance. The
estimated cost is around £2.5m for this site and in the region of £60m to £70m for the whole
of Nortel. They have carried out a top-level analysis of functionality. The majority of their
systems will be replaced, though they have set up a central software group in order to convert
3 major systems to be year 2000 compliant. Other software that may or may not be replaced
by BAAN/4 would cost £120,000 to convert.

QIN is a WIP and quality tracking system. Boards and assemblies are bar coded. The
label is scanned to track boards and assemblies. QIN is 4 years old. It has been written in a
HTML language, called Pearl. Basic data input and access is via 500 dumb terminals on a
network. More complex access to this real-time data is done on their Intranet. It accesses
multiple databases and presents data in a common format. You can see WIP in real-time. Assemblies can be linked to PCA’s etc. QIN does back-flush assemblies, but not at all stages.

A.4.5 Materials strategy

They have completed the first stage of their Demand Flow Technology (DFT) initiative. DFT contains JIT and other modern methodologies, bundled together in a training package supplied by a university.

Definition of forecast: “‘fore’ means look out! and ‘cast’ means throw out!” To improve the effectiveness of using a forecast, they include a +/- percentage error.

DFT enables optimisation of stock levels by calculating JIT buffers that can be used based on the times and variability of processes. They have a kanban system in place with their suppliers, communicating electronically, by phone call, fax or physical. They use a dual card system. An example rule is to wait until they have 5 cards before starting an operation. So far, they have improved stock turns of inventory and work-in-progress by around 40%. They now have roughly 23 stock turns per year. They have saved 20-30,000 sq. ft. of floor space and have increased throughput.

A.4.6 Insourcing/Outsourcing

Two years ago, Nortel would not have thought of subcontracting their work, but since they outsourced their low value-added work, their sales have doubled from $500m to $1bn. For example, through hole assembly was costing them a lot in overheads and maintenance, so they subcontracted it out. There are a lot of small companies doing through-hole now. Though they had to overcome the obstacle of the Union, before subcontracting.

It was quoted that GM do 80% of their work in-house, whereas Chrysler only do 40% Chrysler are apparently very good at managing their subcontractors.
A.5. Siemens, Congleton, U.K.

A.5.1 Introduction

The Siemens Group is the third largest engineering company in the world, employing 400,000 people. Their products include power, industrial and building systems, drives, automation, communications and information, health care, transportation, components, lighting and household.

The Siemens Congleton site was purpose built 25 years ago and produces variable speed drives, which control the speed of motors. Production output for variable speed drives is 400,000 per annum. 60% of all orders for the year take place in three months (April - June). One of their main products is called Micromaster. Siemens have six main customers. Their main customer is BSL who purchase variable speed drives. Their main competitors are Matsushita and Fuji.

During the last three years, turnover has expanded from £8M to £30M to £80M. This rate of expansion produces problems in terms of site expansion and labour availability. The workforce at Congleton is 450 in total, 250 of these are indirect. 60% of workers on the shop floor are female. The shop floor is well lit and the atmosphere has a good feel about it. There is one main union, the AEU.

A.5.2 Manufacturing capability/Technology

There are three surface mount lines for the three main products, using Siemens placement machines, followed by re-flow ovens and a Grassman line for assembly. The programming software for the Siemens machines is called Siplace. The shop floor is split into areas for surface mount assembly, hand mount assembly, in-circuit test, functional test, "burn in" test, box build and bench assembly. The production process is split into printed circuit assembly and product assembly. All faulty goods can be linked to a particular group.
A.5.3 Organisational

A three-year business process re-engineering initiative has been undertaken to increase efficiency and reduce costs. The first stage was re-organising the company structure and the second (which they are in the process of) is re-organising the production layout to make the production groups more efficient and effective.

The managers of each main area (e.g. PCA manufacture) are called process champions. The group leader looks after the product, recruitment, quality etc and manages the shop floor operators. All operators are briefed by their group leader for about 5 - 10 minutes at the beginning of their shift, to relay information on output targets, engineering changes etc. There are sixty engineers in total, who are product based. Covering production there are three project engineers, two technical industrial engineers and a number of standard time and process engineers.

A.5.4 Materials

Material costs account for about 80% of the product. They buy in the castings for their drives for assembly, and then manufacture the rest of the product. There are 58 variants within the product range. The product has an average life cycle of about six months (can vary from 3 - 12 months), and is then updated to a new version.

A kanban system (with min/max levels) is in operation with a MRP system for ordering materials. The AMAPS system is used for scheduling and planning, which is a derivative of a MRP system. There are dedicated material feeders within each group, who supply the operators with their materials. The stores areas are located all around the shop floor, mostly out of sight, but roughly located with respect to product groups. There are some large carousels and racked stores areas.

15% of the materials are inspected as they come in. They have an accredited vendor scheme, where class A suppliers are exempt from inspection, but are responsible for
problems. There are supplier development officers who are responsible for building up agreements with suppliers. All components are single sourced.

A.6. Northern Telecom, Monkstown, Belfast, N. Ireland

This report is based on a case study of their bar coding system (Manufacturing systems, 1994) and a telephone conversation with their materials manager in 1997.

A.6.1 Introduction

The 1994 report describes their business as the design and manufacture of data communication and telecommunication equipment. Monkstown had 880 staff with a turnover of $92m, making transmission equipment for BT and Mercury. There is another site in Galway, making the best selling Meridian PABX branch exchange units.

Now in 1997, their business is nearly all telecommunications. The turnover is over $200m. In terms of end sales, this level of hardware sales produces $500m of revenue, which includes subsequent after-sales of software and support.

They have an Expanding Value (EV) strategy, the aim of which is to reduce manufacturing lead-time, WIP and inventory levels, scrap and rework levels and non-value added time accounted to people and machinery. This enables them to improve response time to changes in market demand, improve quality and boost productivity.

A.6.2 Materials process

The complete materials process is as follows:

- Vendor sends bar-coded packages, to EIA standards. (Electronic Interchange Association.)
• The package labels and “receipt to factory” details are scanned into the materials system. Individual serialised labels are produced for each reel or box.

• The material inspection and tracking system controls sample inspections, using a skip-lot system. Delivery queries and anomalies are handled by an on-line system which records and controls prompt resolution.

• The rack location is recorded, to ensure FIFO. For stores management, all transactions are recorded directly in to the material system using RF terminals with integral laser scanners. Full cycle stock checking is carried out as part of the job of stores operators.

• Materials are issued by pick list. Stores operators are prompted by rack location. However, there is also unplanned stock issue.

• Issue of materials to the automatic board assembly area is a pull system, where an empty reel acts as a kanban token.

• Material usage is validated against the barcode. Start and finish times of reels are recorded.

• Individual PCA’s are bar-coded on the production line. They have detailed WIP and Quality tracking.

• Trace ability is based on matching the start and finish times against the boards assembled during that window.

• They enforce validation at the test stage.

• The boards are traceable in to a system build, since systems are given unique serial numbers. Thus, shipments and warranty can be tracked to the customer.

• They have a vendor accreditation scheme. Due to the number of new products and new suppliers, they inspect 20% of incoming batches, which is a part of their validation. The aim is obviously to reduce this.

They satisfy B.T.’s requirement for trace ability of materials. PCA’s are manufactured and tracked to an interim store. (From which they will go in to box build.) Each individual unit (reel, box) is uniquely identified by a serial number and there is trace ability back to received batches. The time of issue out of stores (to the shop floor) is recorded and this is
linked to the WIP tracking information. Stock is minimised on the shop floor, so trace ability is fairly good. The boards are linked together on assembly in to a box build (an assembly made up of several PCA's and sub-assemblies) and then the complete box is linked to the shipping slip.

Some of their replenishment system is JIT based, but not all. They use a 2-bin (kanban) approach. When a reel is finished it has to be placed back in the bins. All reels must be accounted for. Empty reels must be returned to stores, so that they can be recorded as empty. Then the stores system will point to the fresh reels (FIFO system) for replenishment.

The benefits of the system were:

- Cost reduction. Fewer people; 11 people inputting inventory data down to 4 people gathering using bar coding.
- Data integrity; cutting out inaccuracies, and missing out data.
- Shorter lead-times in process: cutting out delays.
- Better performance for customer.
- Trace ability; since implementation, their trace ability capability has been used a few times. (The problems have usually been caused by rogue deliveries from suppliers.)

A.6.3 Materials measures

The following tables show a few basic measurables of the materials processes:

<table>
<thead>
<tr>
<th></th>
<th>Cost of materials</th>
<th>Cost of overheads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totally assembled product</td>
<td>92%</td>
<td>8%</td>
</tr>
<tr>
<td>Totally manufactured product</td>
<td>66%</td>
<td>34%</td>
</tr>
<tr>
<td>Average</td>
<td>70%</td>
<td>30%</td>
</tr>
</tbody>
</table>

Table 4. Cost of materials
<table>
<thead>
<tr>
<th>Measurable</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-process</td>
<td>£10-13m</td>
</tr>
<tr>
<td>WIP</td>
<td>£8-9m</td>
</tr>
<tr>
<td>Finished stock</td>
<td>£10m (For a fast response to customers.)</td>
</tr>
<tr>
<td>Inventory turns</td>
<td>65 days</td>
</tr>
</tbody>
</table>

Table 5. Inventory costs and measures

A.6.4 I.T. systems

They have an Integrated Manufacturing Database. This system was developed in-house, based on an ICL system (QDOS) and a development at one of their American sites. It includes a WIP tracking and quality module, which is called the Material inspection and tracking system.

A.7. Sun Microsystems, Linlithgow site, West Lothian, Scotland

A.7.1 Introduction

Sun’s headquarters is in California, which includes their research and development centre. Japan provides around 20% of Sun’s revenue. This equates to 40% of Linlithgow’s revenue. The business is very cyclic, by quarter, with high volumes in the last two weeks.

A.7.2 People/Culture

At Sun people come first. Everybody has an annual appraisal. Some managers even do it quarterly. Improvement activities are channelled through Sun Teams. At any time, there are around 20 to 30 improvement teams. Their achievements are recognised though competitions right throughout Sun. These include a lot of Razzmatazz.
There is continual management of change. They call it "a culture of change." Sun look ahead strategically and take a lot of risks. E.g. they have decided to get out of surface mount manufacturing entirely within two years, and go for system build, where the most value add is. They work in partnership with both suppliers and customers; on quality, production methods and so on.

Electronic mail and voice mail are used a lot, so the office environment is quiet. It is open plan, but personal offices are corralled. They have a lot of facilities. They have an indoor gym with all the latest machines. They have outdoor facilities, including a driving range. They have an on-site career centre, managed by an external agency. It purposely does not deal with redundancies. It supports personal and professional development; library, one-on-one sessions and portable P.C.'s provide access to training courses etc.

A.7.3 Manufacturing operations

They use a third party supplier to do kitting off-site. They want to have a distribution firm on-site. Around 1990-93, they reduced the number of main warehouses world-wide from 17 to 1. Their MRP system is called CAS. They are implementing an Oracle database to run the business with, using Sun products. Sun have a corporate MPS that is split by site. Linlithgow uses a mix manager to predict and manage exact configurations. This is done in real-time as orders come in. EDI now covers 60% of their spend.

Materials management is a mixture of push and pull. High volume is mainly push, high value is mainly pull. They have three levels of stores. The main one is 20 minutes away in Livingstone. There are carousels in the factory, holding 5-10 days of stock. Then there is line side stock as well. Some parts, e.g. bulky metalwork, are delivered straight to the shop floor. Stores people replenish the line side stock. Call off of materials is against released orders, using the BOM.

The flexibility that is required of Sun leads then to have high inventory levels. Low value, ‘c-class’ components are back-flushed on completed orders. High-value, ‘a-class’ and ‘b-class’ components are called off by lot. They have cell controllers for managing attrition
on-line, (1-3%) but there is also attrition through handling etc. There is a system for tracking material flow, including recording the sub-assemblies that go in to making up a system. This uses fixed barcode scanners.

Their top 40 suppliers are managed using the Sun scorecard system, which covers 95% of their spend. This is a “total cost of ownership” model and is quantitative, looking at costs. The scorecard drives suppliers hard, but it has mostly led to the suppliers improving their competitiveness and winning extra orders from other customers, simply by being on the Sun scorecard.

A large part of their value chain is now external to Sun. 51% of their spend is with direct material suppliers. They have supplier feedback sessions, where they aim to get suppliers to tell them what they like and don’t like about working with Sun. The logistics group deals with customers.

They have a number of surface mount lines. Panasonic machines place all the small components. Larger components are placed by a variety of makes of machine. They are in the middle of developing flexible assembly and test cells. At the moment they have done desktop and servers. All cells can be changed over between the two types of products within 24 hours. In practice, several cells will stay with desktops in the long-term. They have a system for monitoring system test. This uses portable R.F. barcode scanners to record the locations of systems. They are planning to cater for larger servers and storage products.