OPERATIONAL INITIATIVES IN THE FOOD INDUSTRY

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Abstract

This research attempts to investigate the use & applicability of lean thinking concepts in the food industry & to develop a strategy for the productive adoption of lean thinking in the food industry. In order to investigate the application of lean manufacturing concepts in the food industry, a lean manufacturing framework comprising of lean goals, lean principles and lean practices, has been developed through a systematic review of the literature.

Considering that the food industry is not one industry but a collection of several types of industry producing a diverse range of products and employing a varied range of processes, a food industry classification system is proposed on the basis of visits to various food plants and the available literature.

To investigate specific issues pertaining to the adoption of lean concepts in the food industry, a multiple case study research strategy approach is selected for the research investigation. This research investigation includes fifteen case studies. Except for one case study of a vehicle plant the rest of the case studies relate to food manufacturing plants. The case study of a vehicle assembly plant was selected in order to undertake a comparison with the food industry. The fourteen food manufacturing plants and the one vehicle assembly plant have been studied through a visit tour together with interviews, documentation and a questionnaire. Each case study has been described with regard to product, market, raw materials and process aspects of a plant. Subsequently the case studies have been assessed in order to understand the degree of leanness by examining the status of lean practices.

All the cases pertaining to the food industry were mapped on the food industry classification scheme to identify specific food industry types of each of the food plants. It is observed that the lean model widely adopted in a discrete manufacturing environment, particularly automotive, is not applicable as such in the food sector. Therefore, a lean approach consisting of lean principles, lean practices and lean vision has been suggested for continuous, batch and assembly type of the food industry which would enable food industry to stay competitive.

The major contributions of this research are, the development of a lean manufacturing framework consisting of goals, principles and practices which can be used to assess the leanness of any manufacturing plant, the development of a food industry classification system which would help researchers and managers to better understand the specificity of the production systems, an investigation of issues pertaining to the use and applicability of lean manufacturing in the food industry to help the food industry take advantage of operational improvement initiatives to stay competitive in today's global market, the development of a lean approach comprising of lean principles, lean practices and lean vision for the food industry which would enable the managers to transform their plants into lean plants.

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Chapter 1

Introduction

1.1 Background information

Demographic changes in the population of consumers and changes in consumer behaviour have influenced the food sector to a considerable extent in the developed countries where families have become smaller and the number of two income households has gone up significantly. Industrially produced goods are replacing traditional dishes that are prepared from raw products. Product variations are being introduced at an increasing rate as both the customer and the market become more fragmented and specialised. Ever increasing customer expectations and intense competition has resulted in more product types in terms of, for example, flavour, packaging size, and composition of different products in single packaging. The total market volume has not risen as fast as the number of products that are being offered with the consequence that there is a decrease in volume per product type.

In the past, the food and drink market in developed countries was run by a large number of small shops. The manufacturers controlled much of the marketing mix and the retailer's job was to provide a distribution system for the manufacturer's brands (Hogarth-Scoot, 1999). However, the retailing revolution in the last two decades has transformed the power balance from the manufacturer to the retailer's side. A few powerful retailers have taken the place of the manufacturer's dominance in the food market. Location of control in the food supply chain has moved from producer/manufacturer to retailers with the advent of huge amounts of point of sale data.

These retailers are now market drivers rather than market driven (Kumar, 1996). From the food processing industry point of view the linkage with the customer is only possible through retailers who control and regulate the market. Most of the food manufacturers have to do business with powerful retailers, who demand a wide range of products, short delivery times, frequent deliveries and regular price reductions. De-listing and reduced shelf space is one of the big threats (Hogarth-Scoot, 1999) to suppliers. In responding to the demands for an increasing range of sophisticated products, the food industry is faced with the task of efficiently switching production between product types. Retailer's own-label manufacturing is consistently reducing the net margin when compared to the production of manufacturer branded products. The low-cost leadership is the "prevalent" business strategy in the food industry

Not only is there the challenge of reducing costs to maintain margins against retailer's price pressures, there is also the issue of responding very rapidly to customer demands (Van Wezel et al. 2006) and controlling stocks for perishable raw materials. Availability of raw material to the food industry is also not assured due to fluctuating harvest conditions. In certain periods the industry may have insufficient capacity, whilst in other periods it may experience a dearth of raw material due to poor harvests. Other issues that affect the manufacturers are regulatory and health issues and the requirement of traceability of material usage at the lot level. Negligence on these issues and subsequent health problems has the potential to put a company out of business.

It is likely that the food industry in both developed and developing countries will grow rapidly. In order for a food industry to compete on the world stage, it is important that there is a mechanism in place that enables it to learn continuously and develop 'world class practice'. Every core area must be operated correctly and efficiently if a food processing business is to succeed. It is imperative that companies use appropriate business improvement tools available in order to reap their potential benefits.

Heightened challenges from global competitors due to the "flattening of the World"(Friedman, 2005) during the past two decades have prompted many manufacturing firms to adopt new manufacturing approaches, particularly, salient among these is the concept of lean manufacturing (Womack et al.1990). Many journal column inches have been devoted to the subject of "lean" since the seminal work of Womack, Jones and Roos (1990). Some authors have commented on how this work has stimulated academics and practitioners within various sectors of the manufacturing industry to assess the viability of applying lean manufacturing principles to their circumstances. In most cases, the acid test of the genericity of the subject and its associated techniques has been demonstrated through applications in high-variety, low-volume environments such as aerospace. A detailed look at the lean manufacturing literature reveals that a majority of it has been for industries handling discrete units that are fabricated and/or assembled during manufacturing. The process industries, although more automated than discrete industries at the process control level, lag behind discrete industries when it comes to research in overall production management. Application of lean manufacturing to the food sector has been limited

The food industry has for some time initiated numerous operational improvement initiatives such as Vendor Managed Inventory (VMI), Efficient Consumer Response (ECR) and Collaborative Planning, Forecasting and Replenishment (CPFR) as integrated models for supply chain management and operational excellence (Barratt and Oliveira 2001; Jones and Clark 2002). These initiatives, primarily instituted by the large retailers, have focused mostly on the downstream side of the supply chain from producer to customer and have not had much influence on the upstream side of the food supply chain (Van Donk, 2000). Despite a lot of discussion about collaboration between suppliers and retailers, encouraged by the ECR and CPFR movement, the main focus of trading partners has been to optimise their own systems. Moreover these initiatives have been limited to a few big retailers and manufacturers. Small and medium-sized food manufacturers are yet to reap its benefits, as they are not in a position to invest in the technology required for the implementation of these initiatives (Borchert, 2002). The review of literature shows that the majority of food industry companies have not been able to enjoy the benefits of operational improvement initiatives, such as lean manufacturing, which has evolved and developed in the automotive industry. The literature review revealed that though few lean practices such as 5S, standardised work, suggestion schemes and teamwork have been adopted and practised by the food industry, lean thinking as a holistic operations approach has not yet reached a stage of adoption where it is any way conspicuous as an improvement initiative within the food sector.

The environment within which a discrete manufacturing industry, such as the automotive industry, operates is quite different from the food & drink industry environment. The products offered by the food & drink industry have a very low product cost compared to products produced by an automotive industry. On the other hand, work-in-progress (WIP) and manufacturing lead-time in the automotive industry is quite high when compared to the food & drink industry. This means that the value of WIP is quite high in the automotive industry whereas the value of WIP in the food & drink industry is not very significant.

The purpose of this research is to investigate whether a lean philosophy, so successfully adopted by discrete manufacturing industries such as the automobile industry (Womack *et. al* 1990), can become a dynamic long-term viable operations strategy within the food industry. The theoretical perspective of this research is taken from Womack *et. al.* (1990) who reports that lean manufacturing can be universally applied by all industries. The argument proposed by Womack *et al.* (1990) of the universal application of lean is a highly controversial fundamental theory that can be found to be the root of nearly all the arguments / debates on the subject. However, the literature whilst highlighting many examples of successful implementation of lean within various industries also provided limited evidence of its application within the food industry. It is proposed that this research will address this void in the literature.

The results of the research contribute to the enhancement of the knowledge of the application of lean concepts and the direction of future research. The research extends work of authors such as Billesbach (1994), Jones and Clark (2002), Womack and Jones

(2003) as to what extent lean thinking has permeated the food industry and how the food industry can benefit from the adoption of lean thinking.

1.2 Research objectives

The research stems from the fact that while researchers & practitioners have widely used lean manufacturing principles and practices in the discrete industry, nobody has systematically investigated the applicability of lean principles & practices to the food industry. The concepts of lean thinking are relatively new to many operations managers in the food industry.

The aim of this research is to investigate the use & applicability of lean thinking concepts in the food industry & to develop a strategy for the productive adoption of lean thinking in the food industry.

The objectives of the research are:

1. To undertake a literature review of operational initiatives in the food industry.
2. To develop an appropriate lean manufacturing framework incorporating the work of academics and practitioners.
3. To develop a food industry classification based on the transformation system characteristics.
4. To assess the status of lean manufacturing in the food industry and benchmark with the automotive industry.
5. To compare UK/Indian food industry
6. To map the food industry on the food industry classification system.
7. To identify the key inhibitors and enablers of lean manufacturing in the food industry.
8. To develop a lean approach specific for the food industry.

The major contribution of this research is the development of a lean manufacturing which can be used to assess the leanness of any manufacturing plant. This framework provides future researchers a standard by which to compare and benchmark companies. This research has proposed a classification system for the food industry which would help researchers and managers to better understand the specificity of the production systems. This research has attempted to investigate issues pertaining to the use and applicability of lean manufacturing in the food industry. A lean approach for the food industry has been suggested which would enable the managers to transform their plants into lean plants. The identification of which lean practices are applicable and where and when they should be applied are the main contributions to new knowledge.

1.3 Research approach

In order to investigate the application of a lean manufacturing approach in the food industry, a lean manufacturing framework encompassing the work undertaken by various researchers and practitioners is first to be developed due to the fact that lean has evolved over time.

Considering that the food industry is not one industry but a collection of several types of industry producing a diverse range of products and employing a varied range of processes, a food industry classification system is proposed on the basis of visits to various food plants and the available literature. The classification helps to understand the scope of lean manufacturing in the food industry.

The purpose of this research investigation is to address the "how" and " why" research questions. The intent was not to formally test a hypothesis but to investigate specific issues with regard to the adoption of lean concepts in the food industry. For this purpose a case study research strategy has been found to be appropriate for the research investigation. Although case research is based on the analysis of a few number of cases to which only limited statistical analysis can be performed (Drejer et al., 1998), it is unconstrained by the rigid limits of a questionnaire and can give new help in the development and refinement of a theory.

Due to the fact that the food industry is not one industry but a collection of various industries producing a wide variety of food products, using different types of production processes, requires the use of multiple case studies in order to enhance the generalisation of a theory. This research investigation includes fifteen case studies. Except for one case study of a vehicle plant the rest of the case studies relate to food manufacturing plants. The case study of a vehicle assembly plant was selected in order to undertake a comparison with the food industry. The fourteen food manufacturing plants and the one vehicle assembly plant were studied through a visit tour together with interviews, documentation and a questionnaire.

The characteristics of the food manufacturing plants are mapped on the food industry classification scheme to identify specific food industry types for each food plant where a case study is undertaken. All cases were compared and classified on the basis of products, processes and market characteristics. Conclusions are arrived at by matching the evidence pattern in the different cases. A lean manufacturing approach for the food industry is proposed for each category of food plants.

1.4 Outline of the Thesis

The thesis is organised into eight chapters. Chapter 1 introduces the thesis and identifies the aim and objectives of the research and the approach to be taken. Chapter 2 presents a review of literature and provides an overview of the food industry and the lean manufacturing approach. It first discusses the characteristics, business & manufacturing challenges and operational improvement initiatives in the food industry and then describes how lean manufacturing has evolved and developed in the automotive sector to become a new manufacturing paradigm. A comprehensive review of literature of lean approaches is presented and its influence in the food sector is discussed.

Chapter 3 discusses the need for a lean manufacturing framework and presents a comprehensive lean manufacturing framework on the basis of available literature and industrial production models. The second objective of the research was to develop an appropriate lean manufacturing framework incorporating the work of academics and practitioners. Development of a lean manufacturing framework is a research deliverable, hence an important part of the research work which needs emphasising. This fact has compelled us to have its own chapter rather than incorporating it as a section in research methodology chapter.

Chapter 4 deals with the research methodology adopted to carry out the research investigation. A food industry classification is first developed on the basis of the literature and the visits to a number of food plants. Various available research strategies (for example experiments, surveys, case studies) were evaluated. A case study research strategy was considered appropriate for the research. A multiple data collection method comprising of a plant tour together with interviews, review of available documentation and a questionnaire, were used for the case study investigations. Chapter 5 describes fifteen case studies selected for the research. Each case study has been described with regard to product, market, raw materials and process aspects of a company. Subsequently the case studies have been assessed in order to understand the degree of leanness by examining the status of lean practices.

Chapter 6 analyses the data collected through the plant tours, interviews and questionnaires to identify the similarities amongst the food plants in order to place them under particular food industry types (continuous/batch/assembly). Case studies are then compared with regard to the extent of lean practices in the plants. All the cases were classified with regards to product, process and market characteristics. Each case study is analysed in order to identify specific product/process/market characteristics critical for the adoption of lean manufacturing principles and practices. Chapter 7 suggests a lean approach for each category of the food industry. Chapter 8 provides an overall conclusion of the research work and suggests scope for future research.

Chapter 2

Literature review

2.1 Introduction

This chapter presents a review of literature on operational initiatives in the food industry. The main aim of the research pertains to the use and applicability of lean manufacturing in the food industry and as such the chapter focuses on various aspects of lean manufacturing.

The purpose of this chapter is, to identify the specific characteristics, issues and challenges of the food industry which may influence the adoption of lean, to understand the evolution of lean over the years in order to identify key ingredients of lean and to know the extent of dissemination of lean in various industrial sectors, particularly in process and food sectors.

Section 2.2 describes the definition, characteristics and classification of the process industry. The food industry has been placed under the umbrella of the process industry as it handles non-discrete material. Section 2.3 elaborates on the specific characteristics of the food industry. These characteristics differentiate the food industry from a discrete manufacturing industry. Section 2.4 describes business and manufacturing challenges in the food industry and then discusses various operational initiatives (vendor managed inventory, efficient consumer response, collaborative planning forecasting & replenishment and lean manufacturing) within the food sector. Sections 2.5 & 2.6 focus on various aspects of lean manufacturing incorporating goals, benefits, practices and implementation of lean thinking. Section 2.7 presents a dissemination of lean thinking in the non-traditional sectors such as low volume high variety and the process sector. Section 2.8 discusses the extent of lean thinking in the food sector.

2.2 The Process Industry

The American Production and Inventory Control Society (APICS) defines process manufacturing as "production that adds value by mixing, separating, forming, or by chemical reactions by either continuous or batch mode" (Wallace 1992, p. 38). It also defines process flow production as " a production approach with minimal interruptions in actual processing in any one production run or between production runs of similar products" (Wallace, 1992, p.37). The above definitions present the essential constituents to categorise industries as either "process" or " discrete". The process industries employ process manufacturing, but they do not necessarily all employ a process flow production approach (Dennis and Meredith, 2000).

The definition of process manufacturing also highlights the type of manufacturing process as one of the important characteristics of the process industry. Manufacturing processes such as mixing, separating, forming and chemical reaction are generally used to produce non-discrete products and materials. Non-discrete materials are liquids, pulps, gases, powders and slurries, which change their shape and form constantly and cannot be held without containerisation (Dennis and Meredith, 2000). The industries that handle non-discrete material or product are clubbed together as process industries. The food industry has been placed under the umbrella of the process industry due to the fact that it processes non-discrete material..

2.2.1 Process industry vs. discrete manufacturing industry

A group of researchers (Taylor et al., 1981) suggested the product-process matrix, displayed in Figure 2.1, which provides a framework to highlight some of the differences between process industries and discrete manufacturing industries. The horizontal axis on the matrix represents the degree of product differentiation whereas the vertical axis on the matrix depicts the material flow continuum from a job shop to flow shop. The degree of product differentiation relates to the marketing environment of the business whereas the material flow continuum corresponds to the way the production process is arranged. This matrix is a modification of an earlier product/process matrix developed by Hayes and Wheelwright (1979). This classification scheme suggests that process industries can be categorised on the basis of two dimensions.

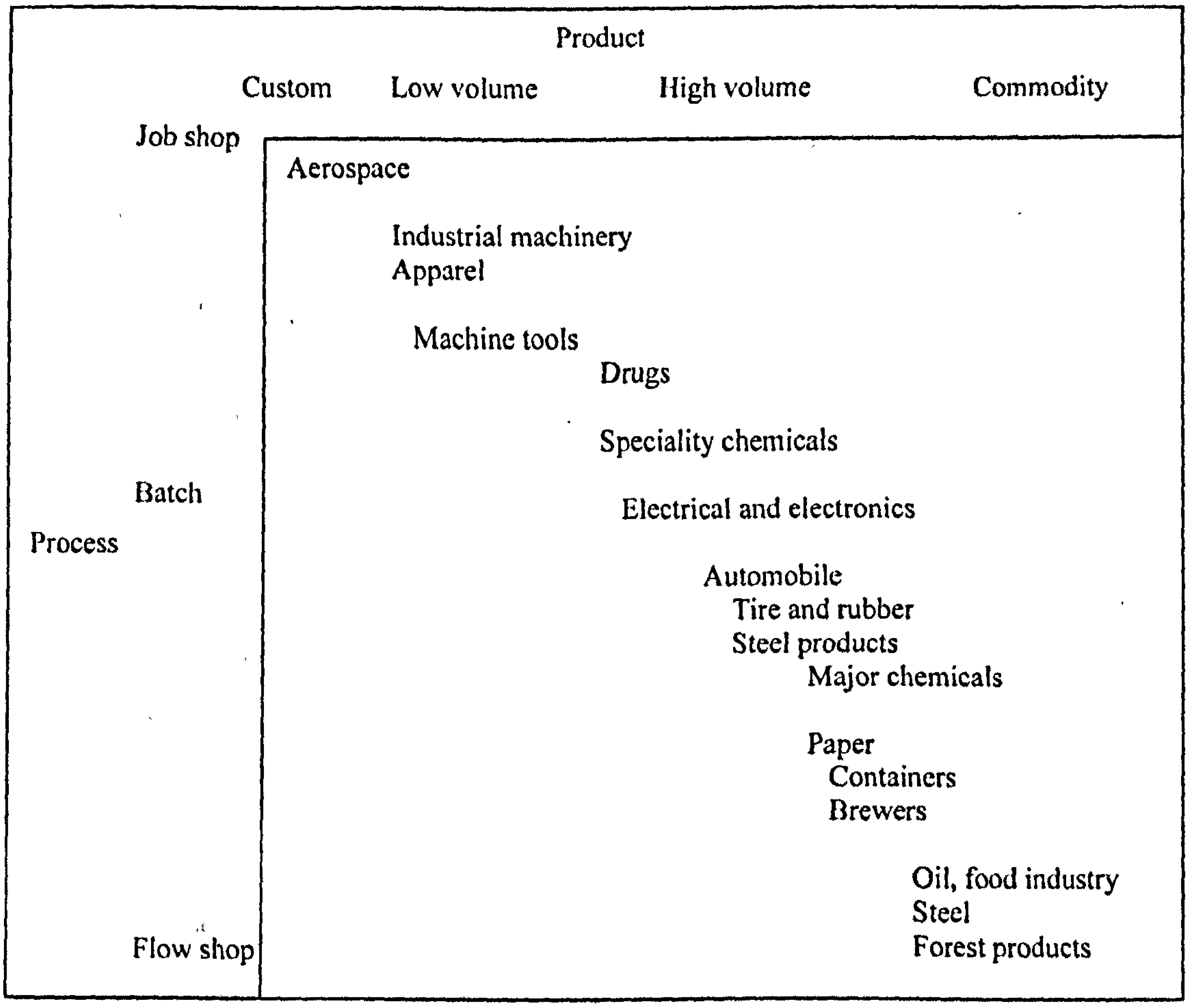

Figure 2.1: Industry classification (Adapted from Taylor et al., 1981)

In the past, process industries were mostly placed in the lower right part of Figure 2.1 due to low product variety and continuous manufacturing. However, a shift has been observed in the process sector environment and process industries now have started adopting market-oriented strategies which demand greater product variety, high service level and low cost. Some process industries are now in the centre of the matrix (Taylor et al., 1981). Safizadeh et al. (1996) also observed that some of off-diagonal companies correspond to process industries.

Many distinguishing features are reported in the literature, which can be considered as "typical" of the process industries. Although these features discriminate process industries from discrete industries, they are not necessarily present in every process industry (Fransoo and Rutten, 1994). Fransoo and Rutten (1994) highlighted variable process yield, variable quality, variable quantity/availability, divergent flow, and divergent bill of materials/by-products as important characteristics of the process industry. Ashayeri et al. (1996) reported twenty-eight features distinguishing process industries from discrete industries (Table 2.1).

	Process Industries	Discrete Industries
Relationship with the market		
Product type	Commodity	Custom
Product assortment	Narrow	Broad
Demand per product	High	Low
Cost per product	Low	High
Orders Winners	Price, delivery guarantee	Speed of delivery, product features
Transportation costs	High	Low
New Products	Few	Many
The Product Process		
Routings	Fixed	Variable
Lay-out	By product	By function
Flexibility	Low	High
Production equipment	Specialised	Universal
Labour intensity	Low	High
Capital intensity	High	Low
Changeover times	High	Low
Work in process	Low	High
Volumes	High	Low
Quality		
Environmental demands	High	Low
Danger	Sometime	Hardly
Quality measurement	Sometimes long	Short
Planning & Control		
Production	To stock	To order
Long term planning	Capacity	Product design
Short term planning	Utilisation capacity	Utilisation personnel
Starting point planning	Available capacity	Available material
Material flow	Divergent + convergent	Convergent
Yield variability	Sometimes high	Mostly low
'Explosion' via	Recipes	Bill of materials
By and Co-products	Sometimes	Not
Lot tracing	Mostly necessary	Mostly not necessary

Table 2.1: Differences between process industry and discrete manufacturing industry (Source: Ashayeri et al., 1996)

The process industry can be thought of as producing material rather than producing items as in the discrete manufacturing industry. They are typically characterised by low product variety, high volume and high fixed capital investment, concentrated in a small number of workstations (Fransoo and Rutten, 1994). Moreover direct costs represent only a small part of the total cost due to the high level of capital investment and the high set-up times (Taylor et al., 1981). Capacity utilisation has been considered the main performance measure in the process sector. In most discrete manufacturing operations, capital investment is less and is spread across many workstations. In the process sector, production equipment is often physically large and relatively fixed in nature. As a result, continuous process manufacturing operations are less flexible and therefore harder to change than discrete manufacturing.

In discrete manufacturing, reducing Work-In-Process (WIP) is often a challenge when compared to process industries. In the process industry generally there is less work in process due to the use of continuous manufacturing. When one process unit shuts down, the preceding and succeeding processing units must also be shut down (Taylor et al., 1981). For this reason the plant or line does not produce during major scheduled maintenance. On the other hand, process industries have a large percentage of their inventory investment in finished goods due to the adoption of make-to-stock (MTS) approaches. The finished goods inventory is used to buffer the plant from variations in product demand.

Production plans for discrete manufacturing industry often adjust plant capacity via changes in the workforce, which is accomplished by changing the amount of overtime or the number of shifts scheduled whereas in the process industries, plants are designed for a specified throughput, so it is very difficult to increase capacity with overtime or extra shifts as plants run seven days a week and three shifts per day (Taylor et al., 1981). Thus an increase in manufacturing capacity requires the design and construction of a new facility, which could take years.

Process industries require a few raw materials but many products are produced from these raw materials, whereas in discrete manufacturing industries end items typically contain many different components (Rice and Norback, 1987). In process environments, the product recipe or formula takes the shape of a bill of material (BOM). Product structure is often divergent rather than convergent. Fransoo and Rutten (1994) summarised different types of bill of materials (BOM) for process and discrete manufacturing industries (Figure 2.2). The bill of materials (BOM) in the process industries is comparatively shallow. This does not mean that the processes are simple as it generally happens in the discrete industries. Several highly complex processes require a few ingredients (Dennis and Meredith, 2000).

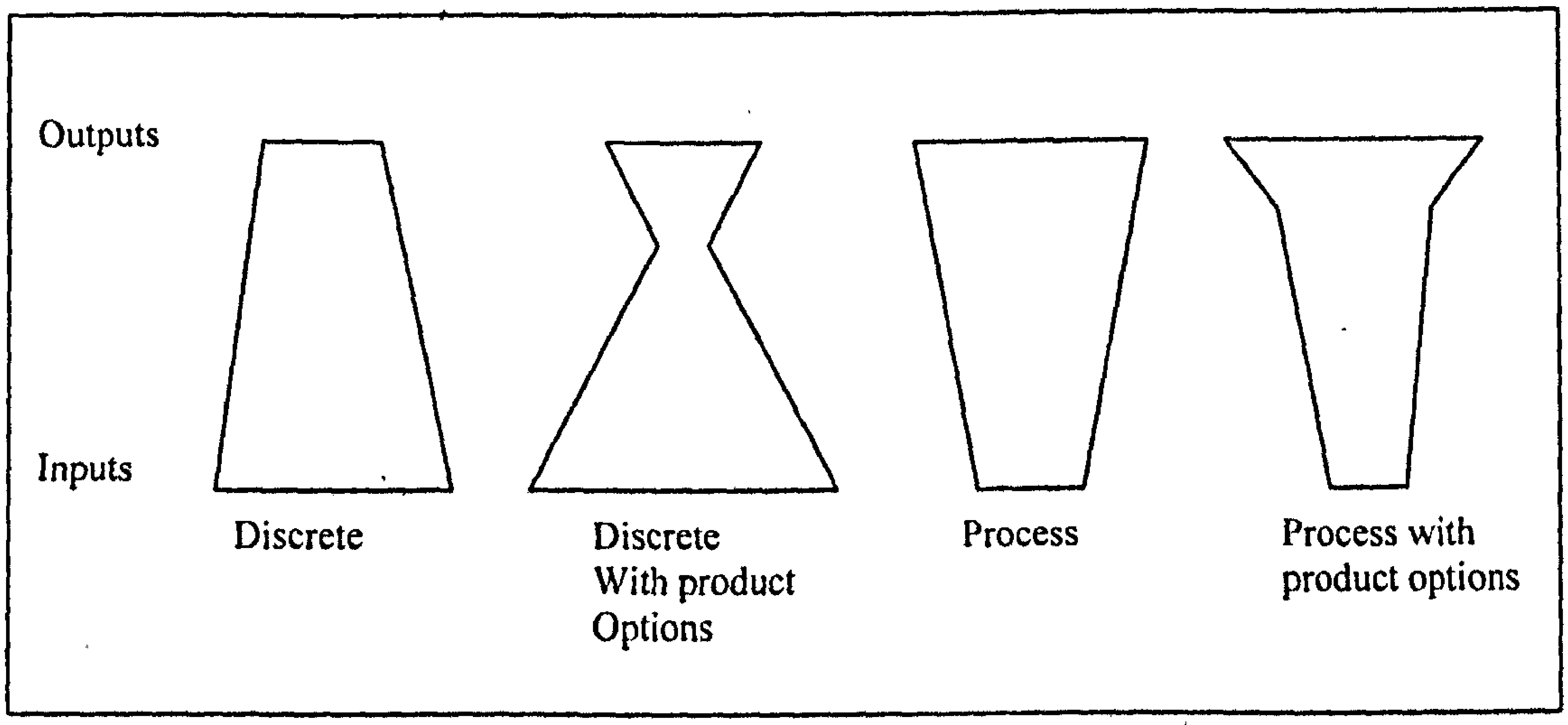

Figure 2.2: Process and discrete manufacturing bill of materials

In addition to process and product differences, it has been noted that the process industries are considered to lag behind the discrete industries in the identification and implementation of effective manufacturing management systems development tools (Dennis and Meredith, 2000; Crow, 1992).

2.2.2 Process industry taxonomy

Woodward (1965) divided the process industries into intermittent (batch production) and continuous (mass production) groups. Finch and Cox (1988) categorised six process firms as either make-to-stock, assemble-to-order or make-to-order. The effect of yield variability, bill of material levels, work-in-process inventory, run times, routings and flexibility were also taken into account.

Fransoo and Rutten (1994) presented a process industry typology, which comprised of two extreme production systems on a continuum. The two extreme production systems are Batch/Mix and Process/flow (Table 2.2). In batch/mix systems, the number of process steps is larger and the level of product complexity is higher. Intermediate storage is more common than in process/flow systems. Due to the increased product complexity compared to process/flow system, the share of raw material in the cost price is lower than in a process/flow system.

Batch /mix		Process /flow
Drugs Speciality Chemicals	Rubber Major Chemicals paper Brewers Steel	Oil

Table 2.2: Process industry taxonomy (Source: Fransoo and Rutten, 1994)

In a process/flow system, the actual processing time per unit is very small, but due to long changeover times and the high production rate, the batch size is relatively large. All products have the same routing due to the low product variety, low product complexity and small number of production steps. Low product variety coupled with large volume, justifies investment in specialised equipment. Value added is generally low. On the other hand the material costs account for 60-70 percent of the cost price (Fransoo and Rutten, 1994). Table (2.3) summarises the characteristics of both process/flow and batch/mix businesses

Fransoo and Rutten (1994) have taken the concept from Taylor et al. (1981) who classified all process industries along two dimensions i.e. degree of product differentiation and material flow complexity. They developed a one-dimensional typology to classify the process industry by combining these two dimensions. Discrete industries were excluded from this classification.

Process/flow businesses are characterised by	Batch/mix businesses are characterised by
• High production speed, short throughput time	• Long lead time, high work in process
• Clear determination of capacity, one routing for all parts, no volume flexibility	• Capacity is not well-defined (different configuration, complex routings)
• Low product complexity	• More complex products
• Low added value	• High added value
• Strong impact of changeover times	• Less impact of changeover times
• Small number of production steps	• Large number of production/process steps
• Limited number of products	• Large number of products

Table 2.3: Characteristics of process/flow versus batch/Mix businesses (Source: Fransoo and Rutten, 1994)

The APICS (American Production and Inventory Control Society) process industry definition also segregates the process industry into two types, batch/mix and process/flow. It defines batch/mix as " a process business, which primarily schedules short production runs of products" and process/flow as " a manufacturer who produces with minimal interruption in any one production run or between production runs of products which exhibit process characteristics such as liquids, fibre, powder, gases".

Subsequently Dennis and Meredith (2000) proposed seven sub-types of process companies (process job shop, fast batch, custom blending, stock hybrid, custom hybrid, multistage continuous and rigid continuous) by analysing 19 different process industry companies on the basis of 16 distinguishing characteristics (see Figure 2.3). These 16 characteristics were further classified in four categories (material diversity, material movement, equipment and run time). The identification of these seven subtypes of process industries has provided an enriched classification of the process industry transformation system.

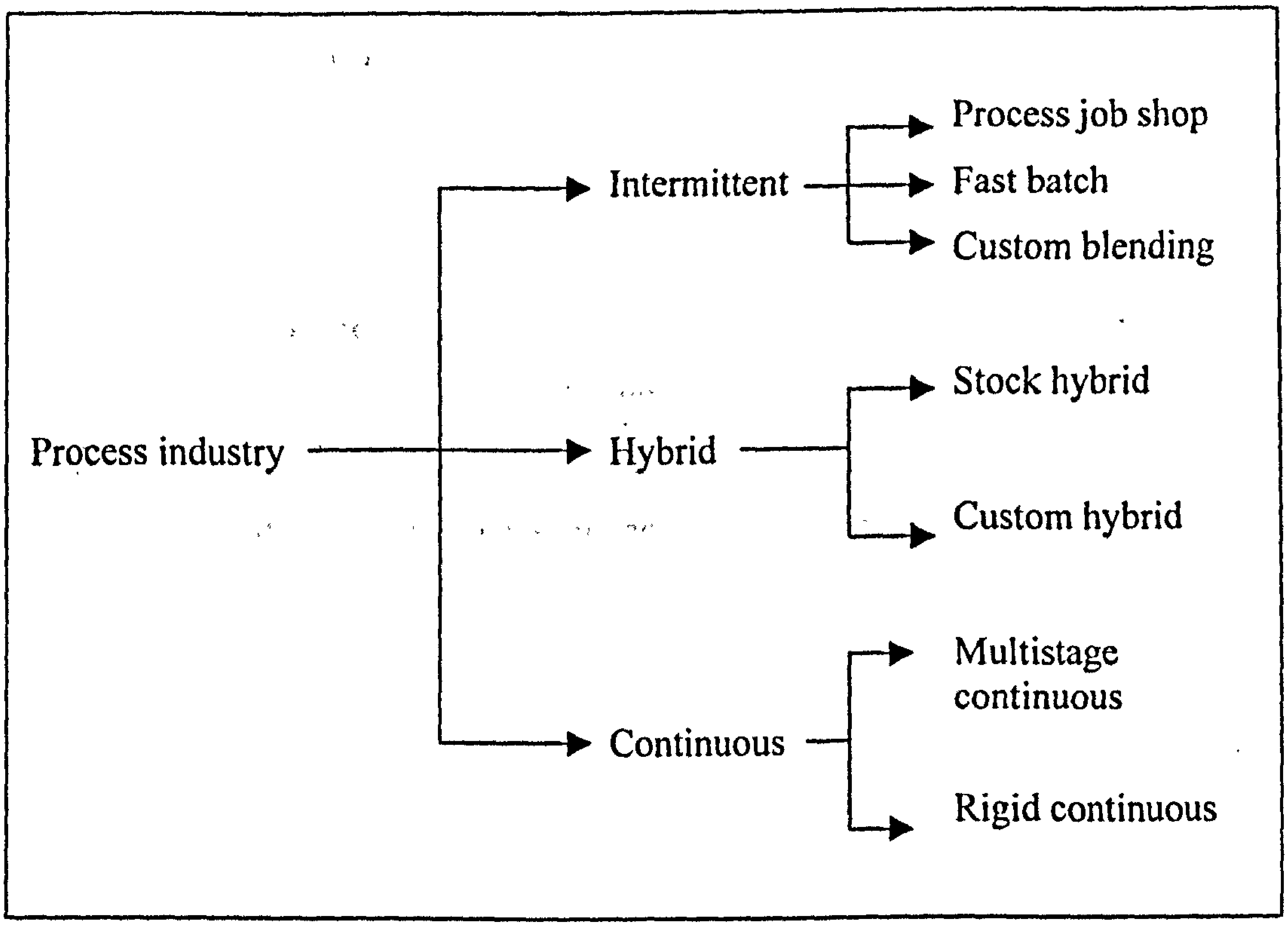

Figure 2.3: Process industry classification (adapted from Dennis & Meredith, 2000)

These seven sub-types are grouped into three generic types of process industries; intermittent, continuous and hybrid. Intermittent type process industries are characterised by functionally organised, general-purpose equipment and a high degree of flexibility. In hybrid type process industries some portions of production systems are organised functionally and other portions are organised in a production sequence. A continuous group is at the opposite end from intermittent process types. There are few routings and very little equipment flexibility.

Out of 19 process industries, which were analysed for the purpose of identifying the key differences between their transformation systems, five process industries (meat products, ice-cream, beverages, beer and baked goods) represented the food and drink sector. These five food and drink industries represented three subtype process industries (fast batch, multistage continuous and rigid continuous).

This classification has widened the understanding of the process industries, but is rather broad as it encompasses all types of process industries and cannot capture the distinguishing characteristics of the industrial sector within the process industry. Moreover, Dennis and Meredith's (2000) research was limited to the non-discrete portion of the process industry transformation system. This taxonomy, developed through exploratory study with limited sample size, was presented as a tentative proposition, which is required to be tested further to enhance its validity.

The food and drink industries are grouped together as a food group and are placed under the umbrella of process industry due to the fact that they handle non-discrete material. Although the food and drink industry shares numerous characteristics with the process industries, it also shows characteristics which are unique.

2.3 Characteristics of the Food & Drink Industry

The production of food products proceeds through a number of stages. Food products which come from farmers if consumed without processing, can be distributed directly to wholesale traders or retailers, though, most food products are processed and packaged before they are supplied to customers. The processing usually involves several producers. Some producers make commodity products that are used by other producers as well as by consumers. Others make consumer products only. Most enterprises that make consumer products deliver to the wholesale trade, which in turn deliver to retail traders. Figure 2.4 depicts an overview of various stages in the food and drink sector.

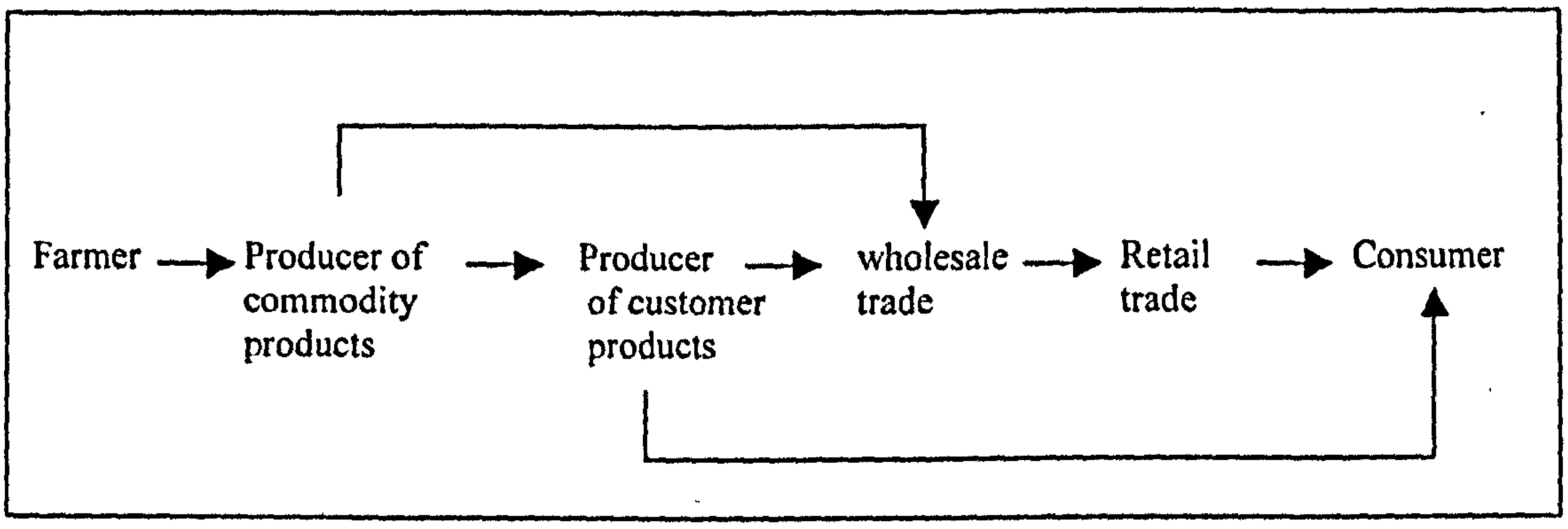

Figure 2.4: Stages in the food and drink sector

Meulenberg and Viaene (1998) illustrate the value chain of the food and drink sector, which proceeds from the farmer to industry to retailers to consumers (Table 2.4).

Farmer	Farmer	Farmer	Farmer	Industry
Consumer	Middleman	Wholesaler	Wholesaler	Farmer
	Consumer	Retailer	Industry	Industry
		Consumer	Retailer	Retailer
			Consumer	Consumer

Table 2.4: Food chains (Source: Meulenberg & Viaene, 1998, p.5)

The UK food and drink manufacturing industry prepares food and drink products ready for sale and consumption. This involves the sourcing of ingredients, processing, preservation and packaging. It also involves a range of processes including product research and design, taste testing, and marketing. Food and drink manufacturing is a major part of the food chain, which comprises agriculture and fishing, food and drink manufacturing, distribution and warehousing, wholesaling, retail, foodservice and catering.

In 1999, excluding imports and exports, the entire food chain was worth £ 56 billion, contributing 8% of the UK's GDP. It employed 3.3 million people (12% of the workforce)(MAFF 1999). The food and drink manufacturing sector was worth £18.7 billion equivalent to 2.6% of GDP in 1999 (see Figure 2.5).

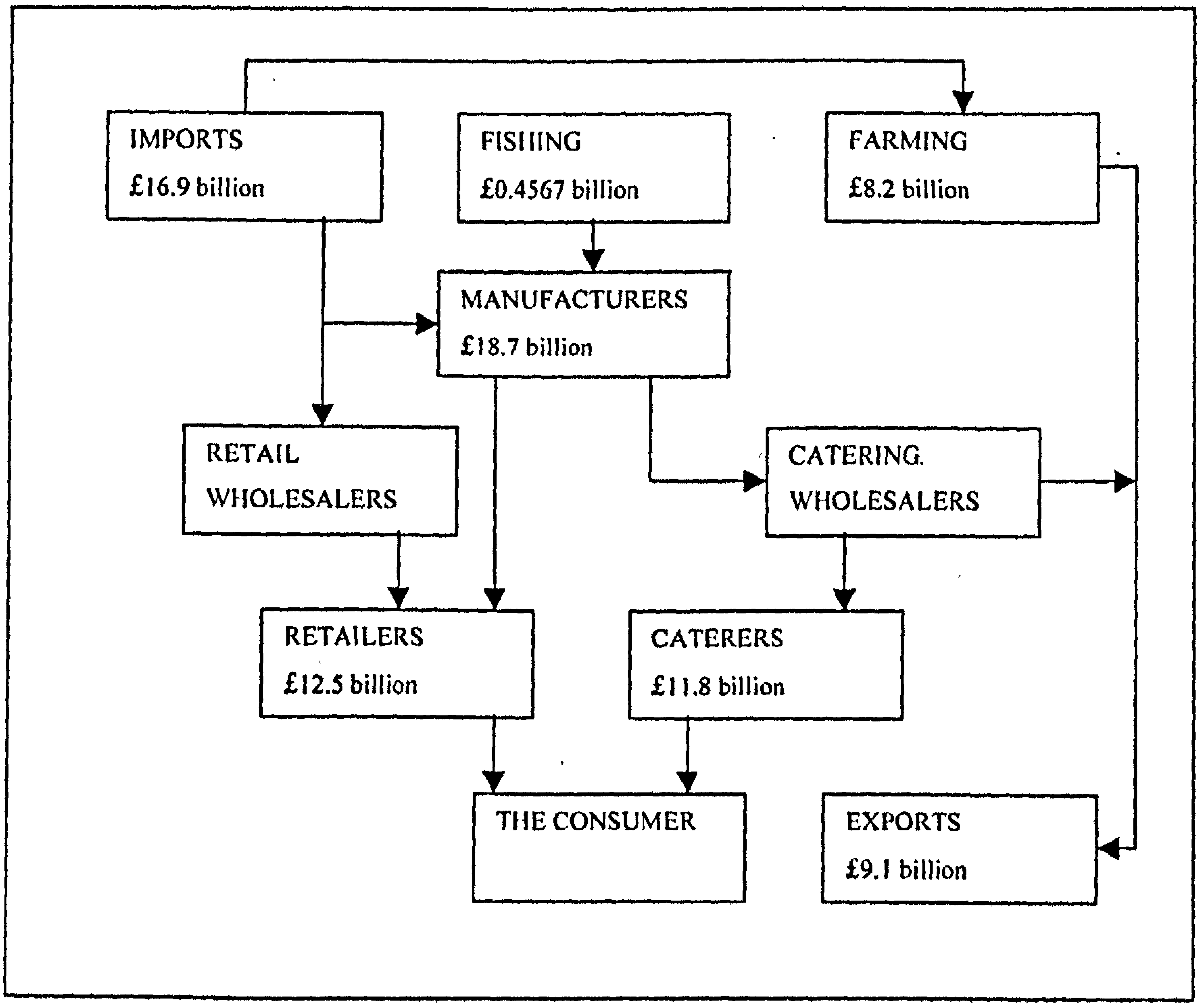

Figure 2.5: The food and drink supply chain in the UK (Source: MAFF 2000)

There are more than 10,000 food & drink manufacturing firms in the UK, of which 73% employ less than 20 persons, and 6% employ 200 persons or more (Table 2.5).

Employment size (persons)	Number of manufacturing units
1-9	6070
10-19	1725
20-49	1180
50-99	600
100-199	495
200-499	455
500-999	130
> 1000	45
Total	10700

Table 2.5: Food and drink manufacturers in the UK by employment size, 2001 (Source: ONS, 2002)

It is clear that the majority of the food and drink industry in the UK are small-scale industry employing few people (less than 50).

2.3.1 The food & drink continuum

The food and drink industry mainly transforms basic agricultural raw materials into a form, which is more acceptable for consumption. This covers a wide range of activities starting from the very simple, for example grading, trimming and packing of vegetables, to the production of complicated ready-to-eat meals. The amount of product differentiation in the food industry can be viewed as a continuum from customised products (ready-to-eat meals, cakes) at one end of the spectrum to commodity products (sugar, oil, flour etc) at the other end. Commodity products commonly have a limited number of products within a product family, while customised product families may have a large number of products. The marketing of commodity products emphasises product availability and price while customised product marketing emphasises product features (Taylor et al., 1981). The food and drink continuum can also be viewed as the horizontal axis of the product-process matrix as proposed by Taylor et al. (1981) with commodity food products at one end and customised food products at the other end.

2.3.2 Food and drink industry classification

Standard Industrial classification (SIC) was first introduced into the UK in 1948 for classifying business establishments by the type of economic activities in which they are engaged. Data on those organisations, which work with or produce the same product or service, is gathered together under the same industry heading (SIC code). The scheme works broadly to a level of four digits. The first two digits identifies the major industry group, the third digit identifies the industry group and the fourth digit the precise industry. UK SIC (92) follows the same broad principles as the relevant international system. There are 17 sections, 16 subsections, 60 divisions and 222 groups. The manufacture of food and drink products is placed as subsection DA under section D. Subsection DA is further divided into 10 groups (Table 2.6).

Groups under Section DA	Description
15.1	Production, processing and preserving of meat and meat products
15.2	Processing and preserving of fish and fish products
15.3	Processing and preserving of fruit and vegetables
15.4	Manufacture of vegetables and animal oils and fats
15.5	Manufacture of dairy products
15.6	Manufacture of grain mill products, starches and starch products
15.7	Manufacture of prepared animal feeds
15.8	Manufacture of other food products (bread, cake, biscuits, sugar, cocoa, chocolate, sugar confectionery, noodles, macaroni, tea and coffee, condiments and seasoning, dietetic food, soups)
15.9	Manufacture of beverages
16	Manufacture of Tobacco

Table 2.6: UK SIC (92) Industrial classification for food and drink sector (Source: ONS, 1996)

This classification is based on the types of economic activity and is one-dimensional. It does not take into account the differences in product/process characteristics of the food industries.

The food and drink industry can also be categorised into primary processing and secondary processing industries on the basis of the characteristic and destinations of their products. Thus the primary processing industry produces undifferentiated products with the majority of its output being sold to intermediate demand, whereas the secondary processing industry produces differentiated products, the majority of which are sold to final demand. Mainly grain milling, sugar and sugar by-products, animal feed stuffs and oils and fats can be considered as the primary food processing industry (Table 2.7).

The primary processing industry have typically been tagged as being a flow shop type environment where material travels in continuous flow fashion through highly automated and specialised equipment with few routings and minimal interruption. The primary processing industry is more likely to emphasise process innovation, rather than product innovation, in its competitive strategy, whereas the secondary processing industry is more likely to emphasise product innovations.

	Primary processing	Secondary Processing
Main Product	Sugar, Flour, Oils and Fats, Cereals, Poultry, Meat	Ready-meals, bakery products, Pizza, Pasta, Biscuit, Confectionery,
Basic operation	Milling, peeling, sorting, freezing, drying, cooling, heating	Mixing, shaping, extruding, decorating, texturing, coating

Table 2.7: Primary and secondary processing industry

The review of the literature reveals that there has not been any attempt to classify the food and drink industry on the basis of production system characteristics. Instead the food and drink industry has been considered as a part of the process industry.

2.3.3 Attributes of the food & drink industry

Virtually all industry supplies its products to an end-user market but if the product is food then it adds a few more dimensions to the challenge.

2.3.3.1 Material attributes

Raw materials used in food and drink companies fall into two groups, main materials and secondary materials. In the dairy industry, milk and cream are main materials, whereas chemical additives and flavours are secondary materials. There are very few types of main material and their market is very competitive. They constitute the key elements in the composition of the products. Relatively few ingredients are required to produce a food product, so production is mainly divergent because of the large variety of products that is created by different packaging forms and by-products (Van Donk, 2000). In other words, many products are produced from a few kinds of raw material, compared to the bill of material found in the automotive industry in which the end item may contain thousands of items.

There are also differences in the variety of raw materials used in food and drink companies. In other words products can be produced from a small or large variety of raw materials. In the beverage industries a relatively small number of raw materials are used. Meat processing requires only meat as the main raw material whereas ice cream requires raw material such as milk products, flavours, sweeteners, stabilisers, emulsifier and other ingredients such as fruit and nuts (Shreve and Brink, 1977).

The main raw material in the food industry is biological and a product of the natural world. Many food materials can vary considerably in their composition, quality attributes, processing properties and nutritional quality (Van Wezel et al., 2006). The quality of materials going into the process affects how and what is manufactured, as well as the quality of what is produced. The attributes of each incoming lot or unit can vary widely, which can affect the quality, quantity and consistency of the end product (Rutten, 1995, Fransoo & Rutten, 1994). As such, predicting the exact production output is difficult until each incoming shipment arrives and is analysed or goes into production. Moreover, companies must manage catch weights, variable formulations, special processing and grading procedures, whilst still meeting regulation and market demand. The raw material suppliers for the secondary food processing industry are mainly primary food processing industries that produce bulk products (Van Wezel et al., 2006).

Raw materials can be perishable, milk for example, and these types of products must be processed within a short span of time before they deteriorate. Often the supply flows of raw materials are not totally under control. This lack of control over supply can be observed in the case of dairy plants where the milk collected has to be pushed through the process due to the fact that the dairy plants generally have long-term agreement to take all the milk collected by the milk producers. The same problem is also present in the fish industry. Jensson (1988) developed a production scheduling decision system to deal with the randomness of fish supply. Management of the main raw material is often a top priority as the cost of it represents a major part of the total production cost.

The main raw materials, which are non-discrete, are usually stored in special storage equipment such as silos and tanks which must be taken into account by the production planning system (Taylor et al., 1981). The location of such storage equipment depends on the way it must be emptied or filled. Such storage equipment is of special importance in the food industry as it places constraining features within the operation. For example, storage equipment like tanks and containers may need to be cleaned when switching from one product to another and cleaning time has to be considered within the manufacturing schedule.

The short throughput times and the flow characteristics of the facility layout lead to a small amount of work-in-process compared to the stock of raw material and finished goods. The stock of finished goods is usually not stored for very long at the production facility due to a shortage of storage space and the perishable nature of the product (Van Donk, 2001).

2.3.3.2 Process attributes

The food and drink industries are characterised by plants operating at both ends of the manufacturing spectrum, from enterprises relying on manual methods of production and quality checking, to sophisticated automated plants running with a minimum of operator intervention. Van Donk (2001), Van Donk and Van dam (1996), Taylor et al. (1981), Soman et al. (2004) highlighted the following distinguishing attributes found in the food and drink industry:

- The plant is like a flow shop with capital intensive processes coupled with low product variety and high volumes.
- There are long (sequence-dependent) set up times between different product types.
- Due to long set-up times, high capital-intensive processes cause planning for long production runs and the stock of end products.
- Unable to provide mixed model production due to long sequence-dependent set-up time
- The product is measured in volume or weight unlike in discrete manufacturing.
- The product at all stages of manufacturing is perishable.
- The production processes have a variable yield and processing time.
- The processing stages are not labour intensive.
- Production rate is determined by capacity.
- Food industries have a divergent product structure, mainly at the packaging stage.
- Several recipes are available due to fluctuation in pricing, quality and supply of raw material.
- More and more plants have to obey strict regulatory control, which demands high safety through Hazard analysis and critical control points (HACCP) and traceability.

In most of the cases, a subset of these attributes is present. The presence of one of these attributes has the effect on the layout of equipment, control and planning of activities. For example, raw materials can only be stored for a short duration due to the perishability of the raw materials or limited capacity size (Soman et al., 2004). This problem can also be observed at the intermediate stock point. This means that postponement strategies as suggested by Van Hoek (2001) have limited applicability in a number of Food & Drink-industries.

The production of food products primarily proceeds through two phases: processing stage and packaging stage (see Figure 2.6). It usually involves both continuous and discrete operations. The discrete operation takes place later in the sequence where shaping, assembling, finishing and packing operations are performed. There are some food industries where products become discrete at the point of containerisation or during the last process, prior to the point of containerisation. For example, in making sugar, discrete units are not produced until the final step in the manufacturing process where sugar crystals are packaged. Starting from the processing of sugar cane until the last granulation stage, the activities are continuous where non-discrete liquid travels through the process.

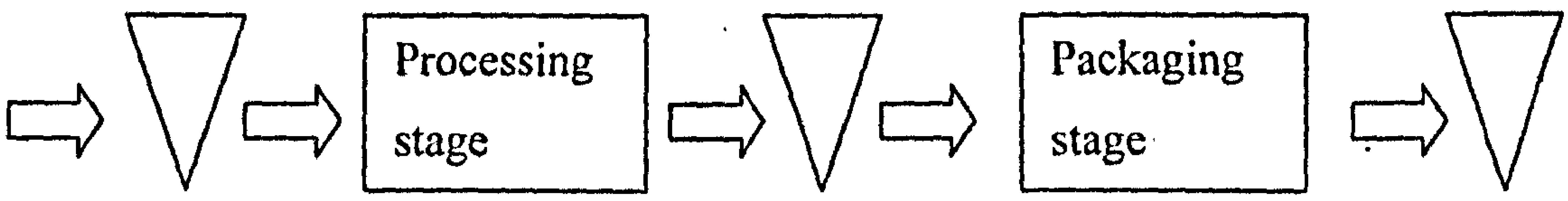

Figure 2.6: Food processing stages

2.3.3.2.1 Processing stage

The processing stage includes all kinds of physical, chemical, and biological processes, e.g. (Bruin, 1992; Macchietto, 1996):

- Separation processes (e.g., diffusional extraction, concentration of juices, separation of flour)
- Mixing or texturising processes (e.g., emulsion processes for margarine and ice cream, foaming of whipped cream, extrusion processes, dough making)
- (Bio) conversion processes (e.g., sugar fermentation to alcohols, roasting)
- Preservation processes (e.g., retorting to eliminate microbial, enzymatic or chemical spoilage).

Sometimes, there is a pre-processing stage independent of the main production process that is used to produce semi-finished products which allows decoupling of processes. Processes in the processing stage are often variable to a certain extent where the duration and yield of processes can both fluctuate. This uncertainty can result in control problems. Ways to deal with this are to use a mean yield in the recipe, create a safety buffer of raw materials that have the most variable yield, create safety time in the production plan (Fransoo & Rutten, 1994), or maintain a stock of end-products.

The processing stage has some characteristics that are associated with continuous or flow production because it deals with bulk quantities of homogeneous products. On the other hand some processes require batch production as operations such as mixing and heating, which takes place in kettles. Hygienic requirements also necessitates frequent cleaning which results in periodic interruptions for cleaning and hence the need for batch production. Lot traceability requirements also lead to separation into batches (Macchietto, 1996) and the effect of production in batches is that if quality is poor, the whole batch must be rejected (Fransoo & Rutten, 1994).

The processing stage employs both general purpose as well as specialised equipment. General-purpose equipment is used to produce different products whereas specialised equipment is used to produce high volume of the same product. In the baking industry, general-purpose equipment such as ovens and freezers are used to produce different products. On the other hand, the dairy industry uses specialised equipment such as pasturisers and homogenisers.

Semi-finished products are usually stored for short duration at the shop floor because shelf life and storage space is limited. Semi-finished end products and by-products are perishable which can restrict the level of finished goods inventory

2.3.3.2.2 Packaging stage

The packaging stage transforms products into discrete units and is generally labour intensive. Sometimes parts of the packaging stage are entirely manual. A packaging line stop can result in loss of goods. Production interruption occurs more often in the packaging stage than in the processing stage. The packaging stage uses mainly batch production where the output is a discrete product.

Packaging lines generally need some time before they run smoothly. After a major set-up a final adjustment of the set-up generally needs to take place when the packaging line is in full operation. This is one of the main reasons to avoid frequent set-ups.

The 'best before' date on the packaging must always be as late as possible, in order that retailers have the longest possible period in which to sell the products. The producer cannot produce to stock since the ' best before ' date must be as late as possible

2.4 Business and Manufacturing Challenges and Improvement Initiatives in the Food & Drink Industry

2.4.1 Business challenges in the food and drink industry

The food and drink market is not truly a single market. Rather it is a collection of markets with many different types of products, processes and needs. Each category of the food business has unique issues and needs.

Demographic changes in the population of consumers and changes in consumer behaviour have influenced the food and drink sector to a considerable extent in the developed countries as families have become smaller and the number of two income households has become larger. Industrially produced goods are replacing traditional dishes that are prepared from raw products. The developed world is moving towards convenience food and seasonal patterns in food consumption are disappearing. The life span of products is being shortened (Nakhla, 1995).

Product variations are developing at an increasing rate with both the customer and the market becoming more fragmented and specialised. Ever increasing customer expectation and intense competition has resulted in more product types with respect to, for example, flavour, packaging size and composition of different products in single packaging. The total market volume has not risen as fast as the number of products that are offered with the consequence that there is a decrease in volume per product type.

Before the 1970s the food and drink market in developed countries was run by a large number of small shops. The manufacturer controlled much of the marketing mix and the retailer's job was to provide a system for the manufacturer's brands (Hogarth-Scoot, 1999). However, the retailing revolution in the last two decades has transformed the power balance from the manufacturer to the retailer's side. A few powerful retailers have replaced the manufacturer's dominance in the food market. Over the last twenty years supermarkets throughout the developed world have both grown and diversified. Independent grocers, green grocers and butchers have declined sharply in numbers with the increase in supermarket opening hours

Meulenberg and Viaene (1998, p.19) state three reasons for this shift in the power balance.

1. Food retail chains have concentrated to an oligopolistic market.
2. There is a surplus of production capacity
3. Products are often only to a limited amount unique and producers are exchangeable

The retailers have introduced their own brands as alternatives to established brands of food manufacturers. For these brands, producers are relatively exchangeable, which results in an increase in the power potential of the retail organisation (Hutchins, 1997)

Van der Vorst (2000, p.5) provides an overview of developments in the food value chain (Table 2.8).

Stages in the supply chain	**Developments**
Growers/producers	Increasing production costs due to governmental rules concerning environmental and consumer related issues
Wholesalers	Scaling-up and concentration
	Global sourcing
Food industry	World-wide concentration of food producers
	Increasing power of retailers
	Differentiation by A –brands
	Advanced processing and information and communication technologies
Retailers	World-wide concentration of retailers
	Growing strength of supermarket own-label products
	More consumer knowledge through new information technologies
	Growing relative importance of supermarkets for grocery purchase
	New ways of distributing food to consumers
Consumer markets	Saturated markets
	Mass customisation

Table 2.8. Developments in the food value chain (Van der Vorst, 2000. p.5)

Today the structure of the food and drink market in the UK is characterised by the emergence of the major retailers and their own brands, bigger store size, greater retailer concentration, demand for one stop shopping, increased retailer access to information via electronic point of sale (EpoS), introduction of loyalty cards and a huge proliferation of choices. Technology has facilitated loyalty card developments, self-scanning and home shopping. These factors have resulted in a weakening of the manufacturer's power and influence (Hogarth-Scoot, 1999). From the food and drink industry point of view, the linkage with customer is only possible through the retailers who control and regulate the market. In the UK, four major food retailers - Tesco, Asda, J Sainsbury, Morrison/Safeway dominate the food and drink market. They have also influenced the structure, standards and economics of the food supply chain. These retailers are now market driving rather than market driven (Kumar, 1996).

However, retailers are operating in a mature, flat market where growth is difficult and consumers are increasingly more demanding. Consumers spend a decreasing proportion of their income on food as their incomes rise. Research shows that people in 'Western' societies consume less food every decade, as the result of increasingly sedentary life styles (MAFF 1999) and that despite this, a significant number of people are becoming overweight or obese (DoH 1992). This shows that total food consumption is unlikely to grow in these Western societies. Food retailers can only grow their business by selling more added value products, by increasing their market share or by diversification.

2.4.2 Manufacturing challenges in the food and drink industry

The quality of the food is dependent on time, humidity, temperature. This sets a limitation for the distribution chain with regards to availability of fresh food. The food products that are highly perishable, pose a big challenge for the manufacturer. Not only is there the problem of reducing costs to maintain margin against retailer's price pressures, there is also the need to respond rapidly to customer demands (Van Wezel et al. 2006) and to control stocks of perishable raw materials. Availability of raw material to the food and drink industry is also not assured due to fluctuating harvest conditions. On some occasions the industry may have an over provision of raw materials, whilst in other periods it may experience a dearth of raw material due to a poor harvest. Other issues that affect the manufacturers are regulatory and health issues, the requirement for traceability of material usage at the lot level. One health accident can potentially put a company out of business.

Traditionally, the food-processing industries organised their production systems in such a way that they produced in large quantities. Full use of capacity was necessary in order for the product to be inexpensive. As a result, production was made to stock and fast delivery from such stock was easy.

However, the retailing revolution in the 1970s and 1980s resulted in the growth in absolute and relative size of retailers and the replacement of manufacturers dominance in the food and drink sector of the UK. Retailers now regulate large parts of the marketing mix, which was earlier controlled by manufacturers. Most of the food and drink manufacturers have to do business with powerful retailers, who demand a wider range of products, shorter delivery times, frequent deliveries and price reductions. In responding to the demands for an increasing range of sophisticated products, the food industry is faced with the task of efficiently switching production between product types. De-listing and reduced shelf space is one of the big threats. Retailer brands present both opportunities and threats to manufacturers. On the one hand they represent an opportunity to produce on behalf of retailers and expand production volumes from existing processing plants. On the other hand, a retailer's own-label manufacturing is consistently reducing the net margin when compared to the production of manufacturer branded products.

The UK food and drink manufacturing sales for 1996 and 1999 by principal product categories are shown in Table 2.9. The total sales for 1996 and 1999 shows that the food and drink industry overall has struggled in recent years and has experienced deflationary pressures. The reasons for this decline can be attributed to an aging population, the low price-merchandising strategies adopted by larger supermarkets and the globalisation of supply sourcing.

	1996 (£k)	1999(£k)
Meats	9627	9480
Fish	1531	1532
Dairy operations and ice cream	6361	6077
Grain products	9961	10130
Fruit, vegetables and potatoes	3641	3679
Food products	38792	38297
Drinks	8158	7437
Total	46950	45734

Table 2.9: Food and Drink manufacturer's sales by principal categories in the UK (Source: Office of National Statistics, 2002)

In this scenario, the food and drink industry must be able to quickly respond to customer demands, manage different packaging forms, produce small quantities and above all they must do it efficiently. The vision of zero inventories or stockless warehouses is going to be the key objective for most retailers through insisting on daily ordering and delivery with lead times of less than 24 hours. According to Macchietto (1996), the food and drink manufacturing focus is expected to be on safe, efficient and responsive operation of plants producing a variety of products. The pressure on margins requires minimum wastage and a high resource utilisation. This demands maximum flexibility from manufacturing operations. The ability to handle short product runs, variable batch sizes, frequent speed changeovers, robust control of individual batch operations and the ability to quickly introduce new product formulations will be important.

Proliferating product choices are making it difficult for the food and drink industry and retailers to predict which of the goods will sell and to plan production and order in response to changing customer demand. As a result, the inaccuracy of forecasts increases along with the cost related to forecast errors. The retailers pass on this uncertainty to their producers. It is now common for retailers to order smaller quantities more frequently, instead of large quantities on a less frequent basis. They prefer a make-to-order (MTO) policy with short response times. Producing a very large number of products on a pure MTO basis is not viable because of the large number of set-ups that are required. Pure MTS is also ruled out because of the unpredictable demand and the perishable nature of products and the undesirable cost of carrying finished stock (Van Donk, 2001).

In addition, the 'best before' date on the packaging must always be as late as possible, so retailers have the longest possible period in which to sell the product. It also means that the producer cannot produce to stock, since the 'best before' date must be as new as possible (Van Wezel et al. 2006). Short term planning is a complex task in the food and drink industry due to sequence dependent set-up times, perishable materials, restricted capacity and short delivery times (Nakhla, 1995).

Food safety is a concern of governments across the world. From time to time, safety issues make big news in the global press. Amid growing concerns about food safety, regulators are becoming very strict on sanitation and food safety requirements. The introduction of the Food Safety Act of 1990 made the retailer legally responsible for all aspects of the food they sell. This has led food retailers to restrict their range of suppliers. HACCP is increasingly recognised as an effective vehicle for ensuring food safety. Its application covers the entire food production process from the purchase of raw materials through to end usage by the customer. The food industry, in light of vulnerability of their products to contamination, is under pressure to comply with HACCP standards.

2.4.3 Improvement initiatives in the food and drink industry

In the last two decades the food and drink sector has witnessed several improvement initiatives such as Vendor Managed Inventory (VMI), Efficient Consumer Response (ECR) and Collaborative Planning Forecasting and Replenishment (CPFR) largely motivated by the large retailers and superstores need to reduce the supply chain cost and to become responsive to customer demand.

2.4.3.1 Vendor managed inventory (VMI)

VMI is a specific automatic replenishment initiative developed in the mid 1980's, whereby the manufacturer (supplier) has the sole responsibility for managing the customer's inventory policy, including the replenishment process (Cook, 1998). VMI transfers the burden of inventory management to the material supplier while keeping customer service levels high with the help of information technology and trust in the relationship as its two important ingredients (Pohlen and Goldsby, 2003).

Real time information sharing enables the supplier to have information of the customer's inventory. Simultaneously the supplier also provides timely information with regard to the replenishment of inventories to the customer. Trust between trading partners makes the relationship work by ensuring the commitment to fulfil requirements.

Under the VMI model, the manufacturer receives electronic data that specifies the retailer's sales and stock levels. The manufacturer can view every item that the retailer carries, as well as point of sale data (POS). The manufacturer is responsible for creating and maintaining the inventory plan. This model helps to eliminate problems such as over-stocking and out-of-stock at the retailer/distributor level.

The most widely used technology in VMI is EDI (electronic data interchange). Typically the manufacturer reviews inventory stock balances daily by receiving EDI files from the distributor or retailer. The manufacturer then uses the inventory information, along with other information such as sales forecast and promotional activities, to calculate and create anticipated replenishment orders for the customer. After receiving an electronic acknowledgement of the planned replenishment, the manufacturer ships the order (see Figure 2.7).

The VMI manufacturer with the help of POS data replenishes demand at the retailer. The vendor/manufacturer monitors the depletion at the retail level and replenishes inventory. VMI focuses on the management of finished goods inventories and improved forecasting to handle the problems associated with independent demand.

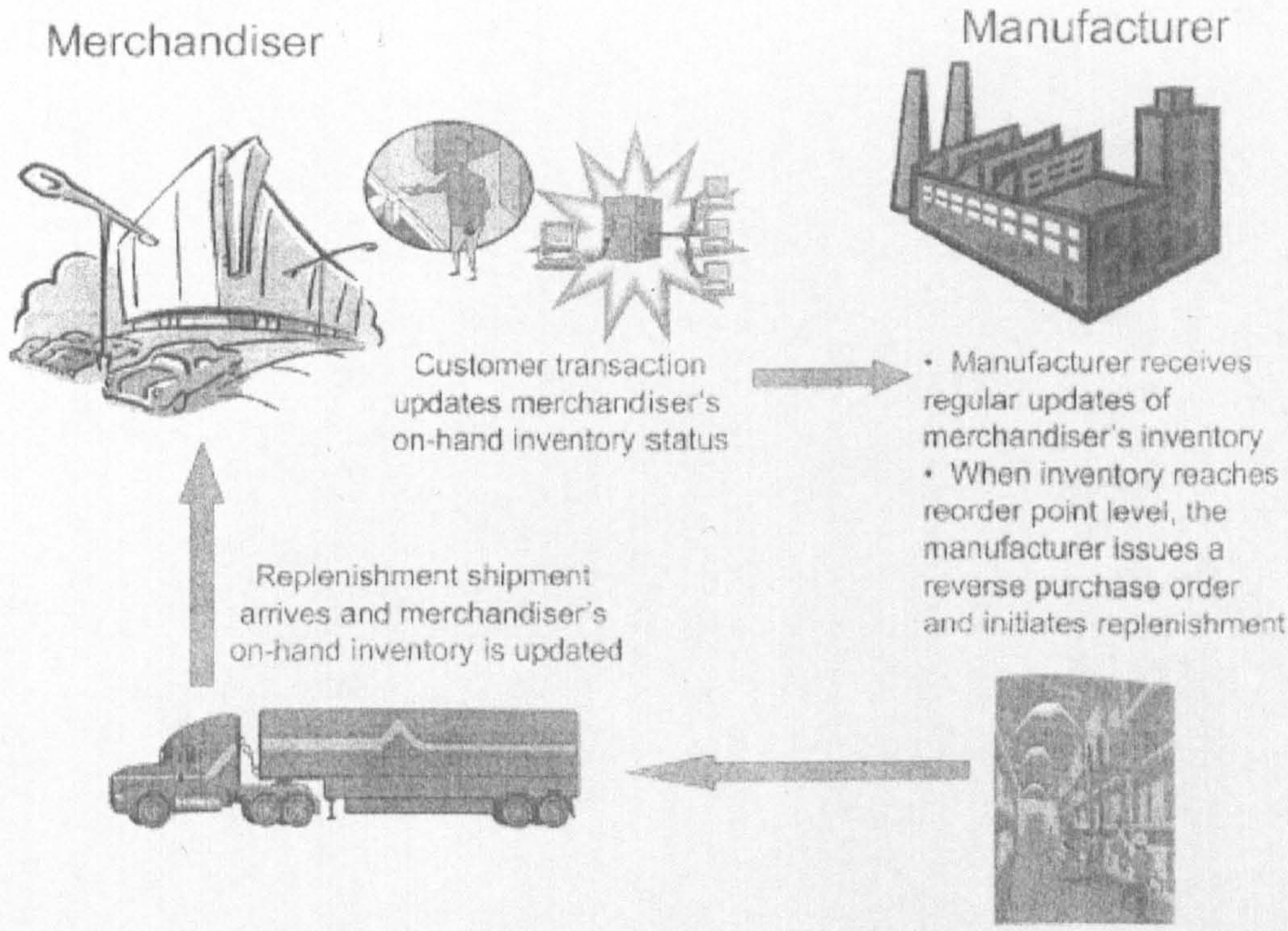

Figure 2.7. Vendor managed inventory (Source: Pohlen and Goldsby, 2003)

VMI focuses on assuring that products are replenished to stock in the most efficient way without manual information having to be transferred between customer and supplier. According to Cook (1998) two of the first companies to put theory into practice were Proctor & Gamble and Wal-Mart in the United States.

The major weakness of VMI lies in the insufficient visibility of the whole supply chain. VMI can work with a manufacturer supplying large volumes of a frequently replenished product with relatively stable sales. VMI is not an efficient tool to manage promotions, as there is no visibility of POS data, it only allows an after-promotion analysis. Because of its weaknesses, the Grocery sector has largely abandoned it.

2.4.3.2 Efficient consumer response (ECR)

The concept of sharing information about sales with vendors and developing a continuous and coordinated flow of products was introduced to the grocery industry by a coalition of trade associations under the name of Efficient Consumer Response (ECR) in 1992 (Robins, 1994). It is an industry-wide effort to bring together food manufacturers, distributors, brokers and retailers. The aim is to increase efficiency through new forms of cooperation and coordination that are often based on the application of information technology.

ECR primarily focuses on creating a demand-driven system and the full adoption of pull strategies based on the demand of the end user (Svensson, 2002). According to Zaire, (1998) the key purpose for launching ECR is to create a seamless chain where the key driver is the continuous flow of information and the dedicated focus is on the end consumer.

ECR relies heavily on electronic data interchange (EDI) and a strategic alliance between supply chain members to remove supply chain costs, which don't add value. This initiative is concerned with converting the grocery supply chain from a push system to a pull system, where trading partners collaborate and the replenishment of store products is triggered by the point of Sales (PoS) data (Harris et al., 1999).

"The ultimate goal of ECR is a responsive, consumer-driven system in which distributors and suppliers work together as business allies to maximise consumer satisfaction and minimize costs. Accurate information and high-quality products flow through a paperless system between manufacturing line and checkout counter with minimum degradation or interruption both within and between trading partners." (Hoban, 1993, p.1)

The emergence of the ECR initiative in the US grocery sector in the early 1990s and its subsequent adoption in Western Europe, represented a paradigm shift in the operation of the food supply chain, with adversarial trading relations between trading partners being replaced by co-operation and co-ordination. This was enabled by the sharing of information so as to become more responsive to the customers. Pearce

(1997) provides a detailed account of how ECR has been implemented at Birds Eye Walls, the largest food brand in the UK and emphasises the importance of trust between trading partners, the need for flexible information systems, a clear and detailed understanding of the consumer and an effective customer interface. This vertical partnership between trading companies in the supply chain seeks to co-ordinate their diverse activities to eliminate non value-adding cost (IGD, 1998).

The ECR initiative focuses on aligning activities and linkages in four processes that run through the entire supply chain: selection of product assortments, product replenishment, product promotions and new product introductions. ECR is primarily divided into two groups, namely a supply side and a demand side. The supply side incorporates efficient replenishment whilst the demand side incorporates efficient store assortment, efficient promotion and efficient product introduction strategies (Table 2.10).

Efficient Consumer response	
Supply –side	Demand-side
Efficient replenishment	Efficient store assortments
	Efficient promotion
	Efficient product introduction

Table 2.10: Elements of efficient consumer response (Source: Kurt Salmon Associates, 1993, p. 4)

Efficient replenishment focuses on shortening and eliminating cost in the order cycle, starting with accurate point-of-sale data. Efficient store assortments address how many items to carry in a category, what type of item, in what sizes/flavours/packages and how much space to give to each item. Efficient promotion addresses insufficient promotional practices that tend to inflate inventories the effect of which may not be fully passed through to the consumer to influence their purchasing decisions. Efficient product introduction addresses the entire process of new product development, which is subject to high failure rates.

To achieve these four efficiencies, ECR requires the following major business activities or initiatives (De Roulet, 1993)

- Category management
- Continuous replenishment programme (CRP)
- Computer assisted ordering (CAO)
- Flow through distribution (Cross docking);
- Integrated electronic data interchange (EDI)
- Activity based costing (ABC)

Despite the benefits and potential savings obtainable from ECR, a number of studies indicate that the diffusion rate of the concept has been slow in the US and Europe. Harris et al., (1999) investigated the applicability of ECR within the Australian grocery industry. They concluded that despite interest in ECR, there is no real commitment to its implementation due to the inefficient business practices of deal selling/buying and forward buying which push excessive inventory into the supply chain. Borchert (2002) highlighted the reasons for non-implementation and the problem of implementation within an ECR partnership in the German Food distribution industry. The general motivation to embrace ECR appears to be pressure from the large retailers. The ECR model and its successor CPFR assume that the information that drives the supply chain resides in the POS scanner data at stores.

2.4.3.3 Collaborative planning forecasting and replenishment (CPFR)

CPFR is a relatively new operations strategy leveraging the Internet and existing technologies to reduce overall inventories throughout the grocery supply chain, improve product availability and customer service. It can be seen as an evolution from ECR. The mission of CPFR is similar to that of ECR i.e. to share information by integrating both the demand and supply side processes and effectively planning, forecasting and replenishing customer needs through the total supply chain (Barrat and Oliveira, 2001).

CPFR represents an approach directed towards improving the visibility of demand. It is an attempt to coordinate the various activities including purchase and production planning, demand forecasting and inventory replenishment between trading partners. The aim of CPFR is to exchange selected internal information on a shared web server in order to provide for reliable, longer term future views of demand in the supply chain (Fliedner, 2003).

With CPFR, several issues were addressed and covered the gap left by previous initiatives (Barrat and Oliveira, 2001). The issues were

- the influence of promotion in the creation of sales forecasts,
- the influence of changing demand pattern in the creation of sales forecasts,
- the common practice of holding high inventory levels to guarantee product availability on the shelves,
- lack of coordination between stores, the purchasing process and logistics planning for retailers,
- the lack of general coordination in the manufacturer's functional departments,
- the multiple forecast developed within the same company.

CPFR is an attempt to replace the EDI approach. The EDI approach is slower, makes use of a variety of industry standards requiring trading partners to agree exact specifications and calls for manual entering of identical data by trading partners. EDI is more expensive than CPFR given its proprietary nature, variety of standards and the reliance on value added networks. Various issues were addressed such as the role of promotion in the generation of sales forecasts, the impact of changing demand patterns on sales forecasts, the lack of co-ordination between the store, the purchasing process and logistics.

Several partnerships in the food sector have been built based on a CPFR framework such as between Heineken and its distributors, Nabisco and Wegmans. Nabisco, a major international manufacturer of biscuits, snacks and premium grocery products, and Wegmans Food Markets, a 58- store supermarket chain in the US, jointly implemented a CPFR strategy for selected product categories in 1998.Wal-mart, the largest retailer in the world with over 3600 stores, is already using CPFR with more than 8 percent of their suppliers (IGD, 1999).

Because CPFR is relatively new, its impact on performance has not been empirically investigated to any degree, but anecdotal evidence highlights benefits such as increased sales, higher service levels, lower inventories, faster cycle times, shortened supply chain, a reduction in forecast errors and lower product obsolescence. CPFR applications to date have largely focussed on the food, apparel, and general merchandise industries. The main obstacles to the implementation of CPFR are (Fliedner, 2003)

- Lack of trust in sharing sensitive information
- Lack of internal forecast collaboration
- Availability and cost of technology/expertise
- Fragmented information sharing standards
- Aggregate concern (number of forecast and frequency of generation)

The food industry has been slow to embrace the partnership philosophy and the progress has been particularly slow upstream, where a distinct lack of trust between trading partners has made the task more difficult (Fearne et al. 2001). CPFR has been used only in certain parts of the food business to date.

2.5 The origin of lean manufacturing

Throughout the last century, the automotive industry has been emulated for innovative management thinking and generating ideas about how best to undertake manufacturing and assembly. It is the world's largest manufacturing activity and has been a source of inspiration and model for the organisation of production (Dankbaar, 1997). The automotive industry has been at the forefront of operational improvement initiatives in the manufacturing sector (Winfield and Kerrin, 1996). Since 1885, automotive manufacturers not only strove to perfect the automobile as a product, but also the processes and organisation needed to build it.

The manufacturing sector has been constantly looking for improvements in manufacturing processes in the past. The eighteenth century economist Adam Smith 's discussion on the division of labour in the manufacture of pins in " An Inquiry into the Nature and Causes of the Wealth of Nations" was one of the first illustrations of how to improve efficiency in production. The process of dividing tasks into components and assigning different workers to complete each task was one of the enablers of the efficiency improvements in the industrial revolution.

Taylor (1911), the father of scientific management, took a systematic approach to the organisation of production and focused on making workers' movements more efficient and organising work within the workspace to maximise the level of work. Henry Ford applied scientific management on a bigger level in the production of vehicles. His development of the moving assembly line coupled with interchangeable parts led to huge increase in productivity. Ford, with its model T created a new paradigm widely recognised as mass production, characterised by the complete interchangeability of standardised parts, a standardised product design, a large buffer of inventory to prevent any disruption in production and a hierarchical structure that controls and coordinates specialised and narrowly defined tasks (Womack et al. 1990). Before Ford, most vehicles were practically custom assembled in a job-shop fashion and sold at high prices. Ford's mass production condensed the span of worker control, production was rationalised and efficiency improved (Krafcik, 1988). Ford's plant was regarded as an exemplary model for its scale and efficiency. Mass production enabled the U.S. to become a dominant global economy and remained the dominant model for decades. Practically every other industry adopted similar methods (Womack et al., 1990). Mass production resulted in the reduction of product cost but at the expense of variety.

2.5.1 Emergence of the Toyota Production System

Western manufacturers in the post-war period were characterised by a 'Just-in-Case' philosophy where the production system was buffered against everything. Inventory levels were increased to buffer against unexpected quality problems, equipment breakdown, unexpected periods of absenteeism and so on (Krafcik, 1988). On the other hand, the Japanese incrementally applied new innovative, lean practices to improve their global competitiveness. Toyota initiated lean operations where inventory levels were reduced to an absolute minimum, so that costs could be decreased and quality problems detected and solved. The lean operations sometimes increased the chances of a production stoppage, but the potential benefits were very high.

With refinement and systematic integration of these innovative management practices, Toyota created a new manufacturing paradigm, which led to the emergence of the Japanese automobile industry on the world map. The success of the Japanese automobile industry was further fuelled by the two oil crises of the 1970s, which brought about soaring petrol prices and a rapid shift in demand towards the smaller cars. The mass production paradigm couldn't offer the solution to changing customer demand and increased competition. Mass producers set a limited target for themselves – 'good-enough', which transforms into the highest acceptable number of defects, a good enough level of inventories, a narrow array of standardised products (Womack et al. 1990). During this period of intense domestic competition in the Japanese market, an alternative production paradigm ' Toyota Production System (TPS)' emerged, which enabled the Japanese automotive industry to cope with dramatic changes in the world economy and overcome the turmoil and structural adjustment of the 1970s (Schonberger, 1982).

The TPS, propagated by the Toyota Motor Company, was characterised by a cost conscious, quality-focussed ideal of zero stock and continuous improvement, which led to the rise of the Toyota Motor Corporation in the automotive world market (Monden, 1983). The TPS is the result of a company specific effort to define and formalise the complex elements of a production system (Fujimoto, 1999). Toyota used "... the minds + hand philosophy of the craftsman era, merging it with the work standardization and assembly line of the Fordist system, and adding the glue of teamwork for good measure." (Krafcik, 1988 p. 42). Toyota achieved the capability of flexibly producing a wide variety of products using continuous flow principles. Krafcik compared the production system characteristics of craftsmen, Fordist system (mass production) and TPS (Table 2.11).

	Craftsmen	Pure Fordism	Recent Fordism	TPS
Work standardisation	Low	High, by managers	High, by managers	High, by teams
Span of control	Wide	Narrow	Narrow	Moderate
Inventories	Large	Moderate	Large	Small
Buffers	Large	Small	Large	Small
Repair Areas	Integral	Small	Large	Small
Teamwork	Moderate	Low	Low	high

Table 2.11: Production system characteristics (Source: Krafick, 1988)

It was Ohno (1988) and Shingo (1989) who developed many of the building blocks of TPS (Monden 1997). Whereas Ford's system of mass production evolved during a period of economic growth, the TPS propounded another method of production to accomplish maximum economic efficiency with a minimum of available resources. The basic tenet of the Toyota Production System was the unceasing pursuit of the elimination of stock (Monden, 1983). But the real aim was to lower costs and the elimination of stock was nothing more than a means to this end. The TPS followed a subtracted-cost principle which emphasises that the consumer sets the selling price and that the company will not make a profit unless it lowers cost by eliminating waste (Shingo 1989). Monden's publication "the Toyota Production System" provides a systems overview showing the inputs and intended outputs (cost, quality and quantity and respect for humanity) (Monden, 1983) (see Figure 2.8).

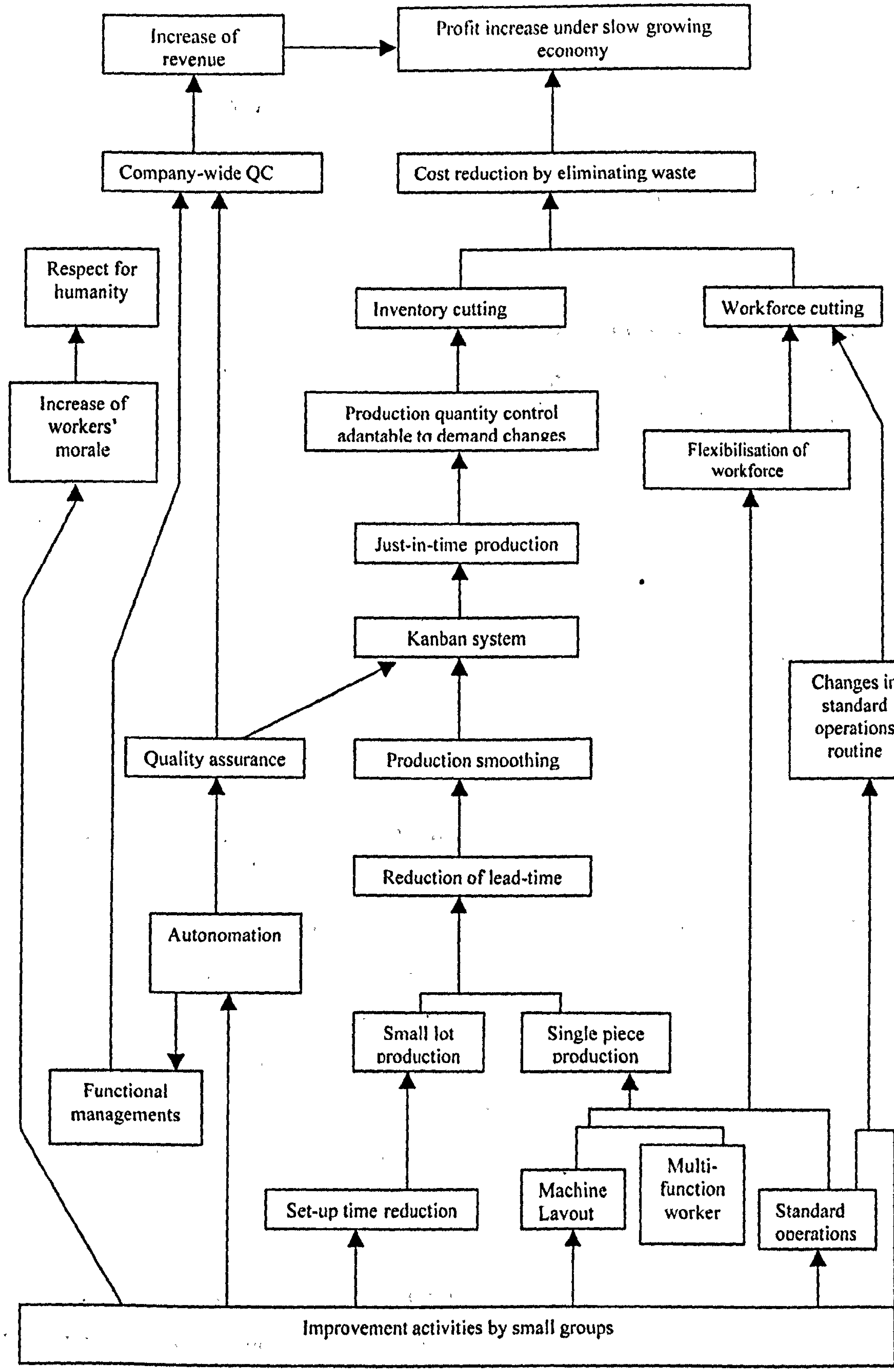

Figure 2.8: Toyota Production system: How costs, quantity, quality and humanity are improved (Source: Monden, 1983)

The TPS is based on the principles of lean thinking. Toyota devised its lean manufacturing system as an alternative to the mass production system which Toyota regards to be extremely wasteful of time, human effort, space, material and human potential. It pervades all aspects of the production and inventory control flow process.

The TPS included innovations such as Just-in-time (JIT) production systems, the kanban method of pull production, and respect for employees, autonomation, flexible workforce and high level of employee involvement for continuous improvement (Shingo, 1988; Monden, 1983; Ohno, 1988). Just-in-time means to produce the necessary units in the necessary quantities at the necessary time. Autonomation or " Jidoka" supports Just-in-time by never allowing defective units from a preceding process to flow into and disrupt a subsequent process. Jidoka allowed workers on the production line to exercise their own judgement and stop operations when any abnormalities occur. Then workers had to identify the causes and solve the problem. Such a system was in contrast with Fordist theories on de-skilling.

2.5.2 Diffusion of the Toyota Production System

Much of the early work at Toyota was applied under the leadership of Taiici Ohno (1988) to car engine manufacturing during the 1950s and later to vehicle assembly and to the wider supply chain during the 1970s (Hines et al. 2004). It was only during the 1980s that the secrets of TPS were shared with companies outside and manuals and books which were written in Japanese, were made available in English (for example Shingo, 1989; Monden, 1983).

Monden (1983, 1997) is credited with introducing the Just-in-Time (JIT) concept in the western world. He initially focussed on a limited set of JIT practices pertaining to the shop floor and emphasised the importance of small lot sizes, mixed model production, multifunction workers, preventive maintenance and JIT delivery by suppliers.

Since starting to introduce lean principles around 1950, Toyota has transformed itself from being a minor producer of just a few thousand vehicles into one, which produced more than a million vehicles in the 1980s. The surprise emergence of Japanese automakers, especially Toyota and the struggling U.S manufacturing industry caught the attention of academics and researchers to study the Japanese manufacturing approach and discover the secrets of its success (Schonberger, 1982; Im and Lee, 1989; Hay, 1988; Inman and Mehra, 1989; Flynn et al. 1990). The TPS was perceived to be a major rationale for Japan's competitive success (Schonberger, 1982; Hall, 1983; Lee and Ebrahimpour, 1984 Shingo, 1988; Mehra and Inman, 1992) and this system became synonymous with the ideal model of manufacturing for Japanese manufacturers and later to all companies throughout the world (Fujimoto 1999; Benders & Morita, 2004).

The setting up of Toyota transplants outside of Japan played a significant role in the evolution of the Toyota Production System. It propagated the company's production system to Western joint-venture partners. According to Boyer (1998), the setting up of transplants proved an " opportunity to pick out the real and permanent roots of productivity and quality from factors that are contingent upon the Japanese context". The operations at the transplants of Japanese manufacturers and suppliers, including Toyota, became a major focus of academic research (Fujimoto, 1999). Researchers looked into Eastern and Western manufacturing practices and attempted to analyse and explain the competitive advantage of the Japanese production methods. Although the introduction of the Toyota Production System in the U.S. sparked the interest for change, manufacturing improvement was insignificant (Shingo, 1988).

In the 1980s lean initiatives that had been developed in the Japanese automotive industries were propagated as stockless production, Just-in-Time manufacturing or world class manufacturing in the West (Feignbaum, 1983; Schonberger, 1982 1986). These lean initiatives were basically just another translation of TPS and were adopted initially, not as a coherent manufacturing framework in the West, but as a set of techniques. It improved the performance at the shop floor level, which produced only a localised effect but could not offer any competitive advantages at a strategic level.

The interest taken in early lean initiatives by the western manufacturing industry was limited until the publication of the book *The Machine that Changed the World*, which highlighted the performance gap between Toyota and other car manufacturers and fuelled the spread of lean initiatives as a coherent philosophy across all industries.

2.6 A review of lean manufacturing

The lean manufacturing concept, rooted in the TPS, evolved from a 5-year research project, the International Motor Vehicle Programme (IMVP), at MIT that involved 55 researchers worldwide. The project began with the aim to assess the impact of management practices on manufacturing performance, particularly productivity performance (Krafcik, 1988; MacDuffie, 1989, 1991) around the world. The main findings of this research were abridged in the book 'The Machine that Changed the World' (Womack et al., 1990). The study compared the mass production system, initially created by Henry Ford with the production system invented by Toyoda and Ohno, which was popularised throughout the Western world as lean manufacturing. This widely acclaimed research programme compared the performance of car assembly plants around the world. Womack et al. (1990) decoded the TPS and provided data on lean and non-lean plants within the automotive industry. The IMVP showed that the car assemblers, which demonstrated the highest productivity and quality, were based in Japan.

The Machine that changed the World (Womack et al., 1990) introduced the term "Lean" to the industrial world. The term 'lean manufacturing' was used to characterise the Japanese automakers that were producing the same volume of automobiles with less workers, less inventory, and less floor space, hence it was a leaner way of producing automobiles (Figure 2.9).

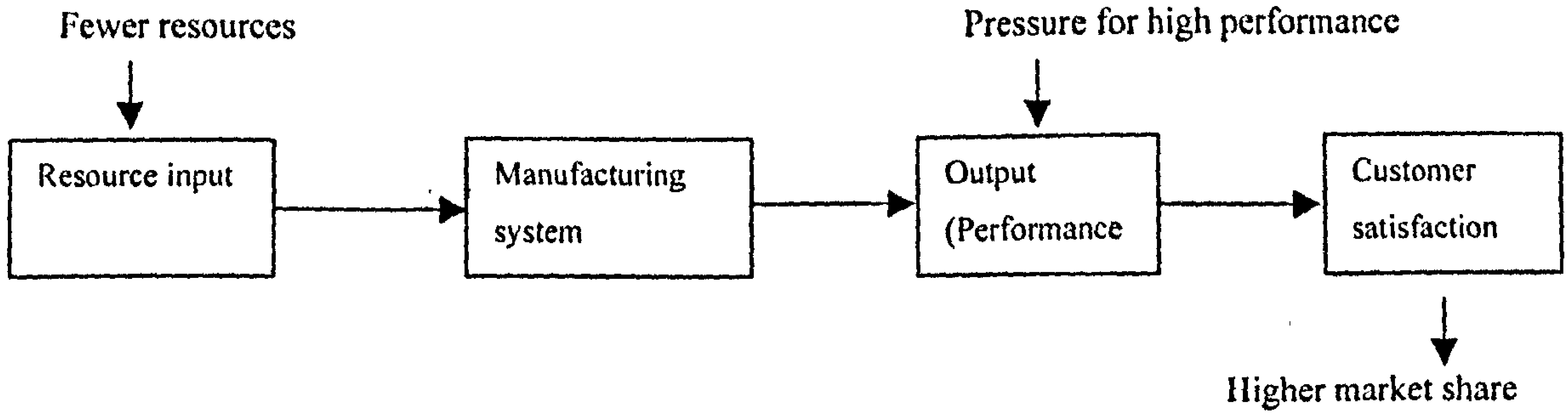

Figure 2.9: The essential element of lean manufacturing (Source: Katayama and Bennet, 1996)

In a lean operation fewer resource inputs are required by the manufacturing system and at the same time there is pressure for a higher output performance (Katayama and Bennet, 1996). It is a different way of conceptualising the entire production stream from raw material to finished goods and from product design to customer service. It is a new paradigm of manufacturing that seeks to minimise unnecessary time, material and effort in the production process. Within a firm's own manufacturing operation, it involves reducing buffers through a just-in-time inventory system, by producing only what is needed by downstream customers, whether internal or external, pushing down responsibilities for quality inspection and the specifications of work tasks to motivated, multiskilled workers organised into teams and harnessing ideas for process improvement from employees at all levels (Womack et al., 1990).

According to Womack et al. (1990)

"Lean producer, by contrast, combines the advantages of craft and mass production, while avoiding the high cost of the former and rigidity of the latter. Lean production is "lean" because it uses less of everything compared with mass production- half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever growing variety of products." (p.13)

The findings of Womack, Jones and Roos (1990) were further reinforced by studies carried out by the Boston Consulting group and the Anderson Consulting Group. Andersen Consulting (1993) concluded that Japan was way ahead of the UK in the autocomponent sector by a factor of 2:1 on productivity and on quality. Another study entitled *Made in Britain* conducted in the UK by Hanson from the IBM Consulting Group along with Voss from the London Business School showed that the adoption of lean manufacturing practices had a direct relationship to improvements in performance (IBM Consulting Group, 1993). The *Made in Britain study* made it clear that the larger the company, the more likely it was to have embraced lean practices.

Oliver et al. (1994) further provided evidence from 18 automotive component plants manufacturing four different product types. Five of these 18 plants displayed high performance on the measures of both productivity and quality. These five ' world class plants' are all located in Japan and showed consistent superior performance on a number of measures providing support for their lean production system.

Since the publication of the *Machine that changed the world*, lean manufacturing concepts have received much attention from the companies in the western industrialised countries, as it was considered to be a major cause for Japan's stronger competitive position (Oliver et al 1994). Lean manufacturing has become a dominant strategy for organising production systems and has had a major influence in the diffusion of a number of lean principles, initially amongst the extremely competitive car manufacturers. Western manufacturers took heed of the book's message in order to become competitive and have adopted many of the lean principles (McCullen and Towill, 2001).

Although *The Machine that Changed The World* coined the term 'lean', it did not propose a universal set of principles and techniques of a lean manufacturing model. However, this book sparked interest between academics and the practitioners for further research work to find out what constitutes lean manufacturing. Oliver et al. (1994) laid out the core characteristics of lean manufacturing, which comprises:

- Team-based work organisation involving flexible, multi-skilled operators taking a high degree of responsibility for work within their areas.
- Active Shop floor problem-solving structures central to continuous improvement activities
- Lean manufacturing operations manifested by low inventories, the management of quality by prevention rather than detection and subsequent correction, small numbers of indirect workers and small batch just in time production.
- High commitment to human resource policies
- Closer relationship with suppliers
- Cross functional development teams
- Integrated retailing and distribution channels so as to allow a make-to-order strategy operate effectively.

Lean manufacturing principles encompass a set of practices embodied inside the factory and along the supply chain (Oliver et al. 1996)(Figure 2.10). Inside the factory, lean manufacturing is characterised by Just-in-time production, small lot sizes, minimal inventories, small problem solving groups and human resource policies committed to harness the full potential of workers. Along the supply chain, integrated suppliers with frequent delivery of small batches, active information exchange permitting joint cost reduction activities, manifested in the application of lean principles.

Womack and Jones (1994) later on suggested the use of the term "lean enterprise" to broaden the scope of the lean thinking approach. Womack and Jones (1994) envisaged the lean enterprise as: "a group of individual functions and legally separate but operationally synchronised companies" (p. 93). The main idea behind it was to connect the separate links of the value chain to form a continuous value stream.

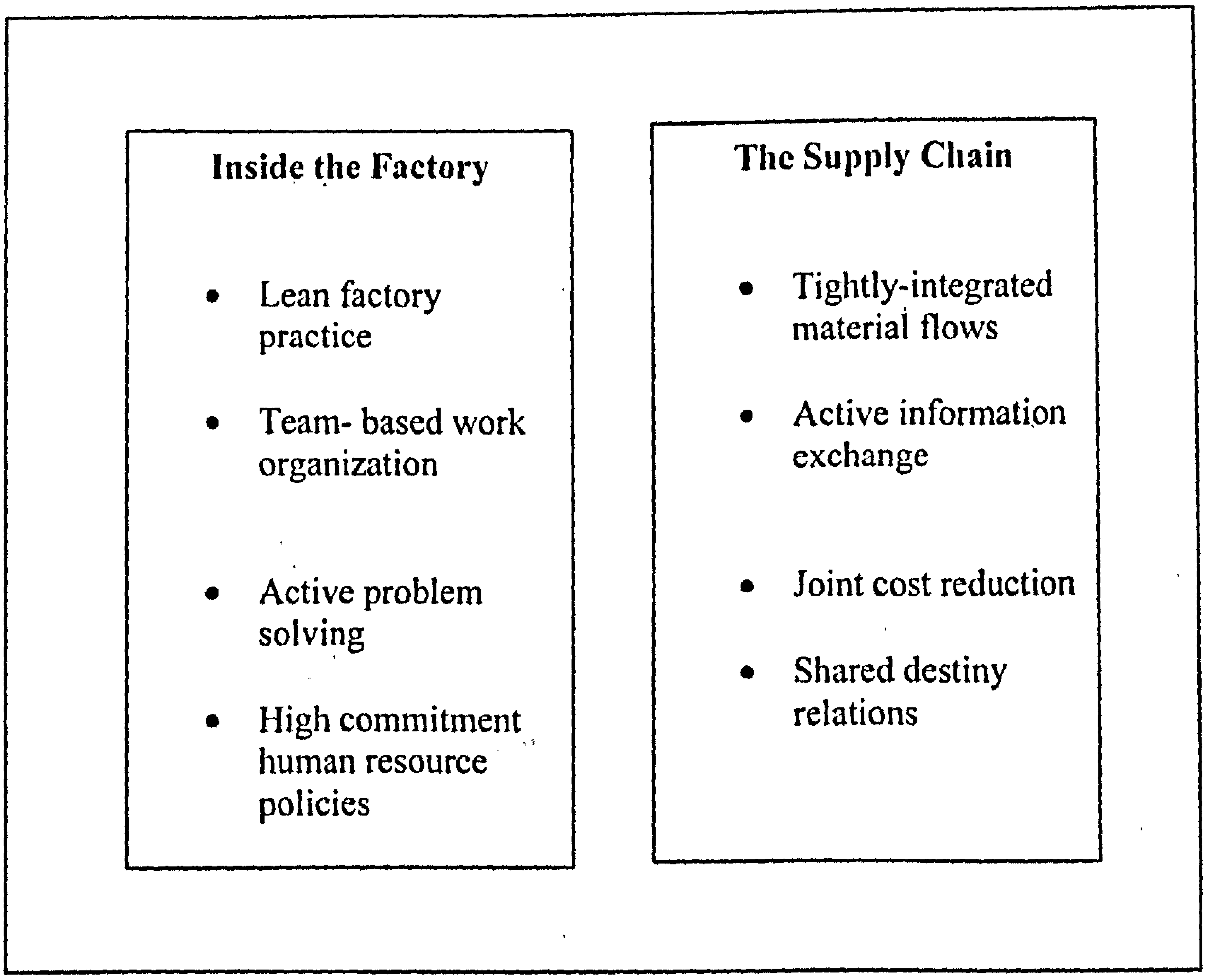

Figure 2.10. Lean manufacturing inside and outside the factory (Source: Oliver et al. 1996)

The lean enterprise concept represents the strategic aspects of lean manufacturing and focuses on the external networks of firms. Womack and Jones (1994) presented the case of Chrysler and Sony in the development of the lean enterprise concept.

"We have seen numerous examples of amazing improvements in a specific activity in a single company. But these experiences have also made us realise that applying lean techniques to discrete activities is not the end of the road. If individual breakthrough can be linked up and down the value chain to form a continuous value stream that create, sells and services a family of products, the performance of the whole can be raised to a dramatically higher level. We think that value-creating activities can be joined, but this effort will require a new organisation model: the lean enterprise"

(Womack and Jones, 1994 p. 93)

Womack and Jones (1996) in their book *Lean thinking* proposed a set of principles for achieving a lean enterprise. There are five main principles of lean thinking, value, value stream, flow, pull and perfection, encompassing all activities right from the product design stage to order delivery.

1. Value – define value from the standpoint of the customer, which means understanding the specific requirements of the specific customer.
2. Value Stream – identification and mapping of products that follow a similar path from raw material to the end customer. Mapping of the value streams help to identify waste in individual value streams, which can lead to an appropriate routes to the removal of waste.
3. Flow - involves ensuring the product flows continuously through the value creating processes
4. Pull - products should be pulled through the value stream at the demand of the customer rather than being pushed on the customer.
5. Perfection - the never-ending pursuit of eliminating waste in the system such that products can flow seamlessly through the value stream at the rate of demand

Developing and maintaining a continuous and uniform flow of a value-creating processes along a value stream or joining value streams is the key to making oneself lean (Storch and Lim, 1999). Continuous and uniform flow will reduce cycle time and work-in-progress levels and increase the throughput of each product. Lean principles demand the cooperation of all people along the value stream and with a quick set up capability for responding to changing customer demand. Warnecke and Huser (1995) advocated 'lean management' or 'lean industry' rather than 'lean manufacturing'

Ramarapu et al. (1995) grouped all lean elements into the five broader critical factors

1. Elimination of waste
2. Production strategy
3. Quality control and quality improvement
4. Management commitment and employee participation
5. Vendor/supplier participation

They concluded that the elimination of waste and production strategy are the most critical factors for a lean framework , followed by quality control and quality improvement, management commitment, employee participation and vendor/supplier participation.

Considering *The Machine That Changed The World* as a starting point, Karlsson and Ahlstrom (1996) developed a conceptual operational lean framework, which can be used to assess the changes taking place during the implementation of a lean philosophy. This framework is comprised of a number of principles characterising different functional areas and the overall strategy of a lean organisation (Figure 2.11). The lean framework was used in a clinical field study for operationalising the lean paradigm in order to be able to study the change processes and was used as a tool to evaluate the development taking place in order to become lean. The field study took place in an international manufacturing company producing mechanical and electrical office equipment which was in the process of implementing lean concepts.

In their lean framework Karlsson and Ahlstrom (1996) also defines ' lean enterprise' as a firm which uses selected best practices in all functional areas and in the management of external relationships. They considered a lean enterprise as consisting of four different parts: lean development, lean procurement, lean manufacturing and lean distribution. Lean manufacturing encompasses the whole manufacturing chain from product design and development, through to manufacturing and distribution.

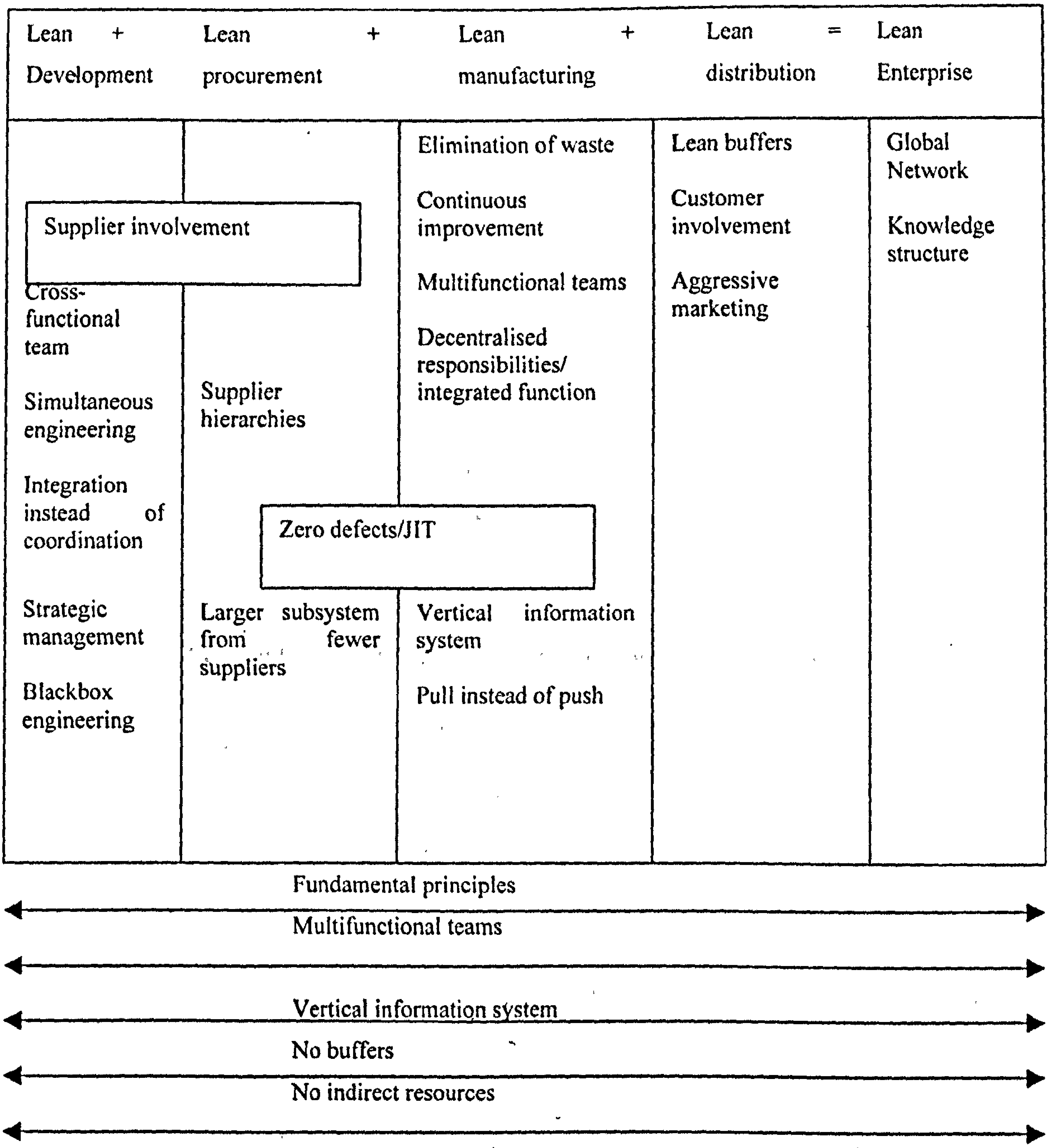

Figure 2.11. Lean framework (Source: Karlsson and Ahlstrom, 1997)

Karlsson and Ahlstrom (1996) suggest that lean should be viewed as a direction, rather than as a destination. The focus of lean effort should be on the changes in the determinant and not on their actual values. Karlsson and Ahlstrom, (1997) further developed the lean enterprise concept comprising a set of practices, which operationalise organisational change (Figure 2.12). Although Karlsson and Ahlstrom (1996) proposed a comprehensive lean framework, it still did not explicitly described fundamental principles of lean.

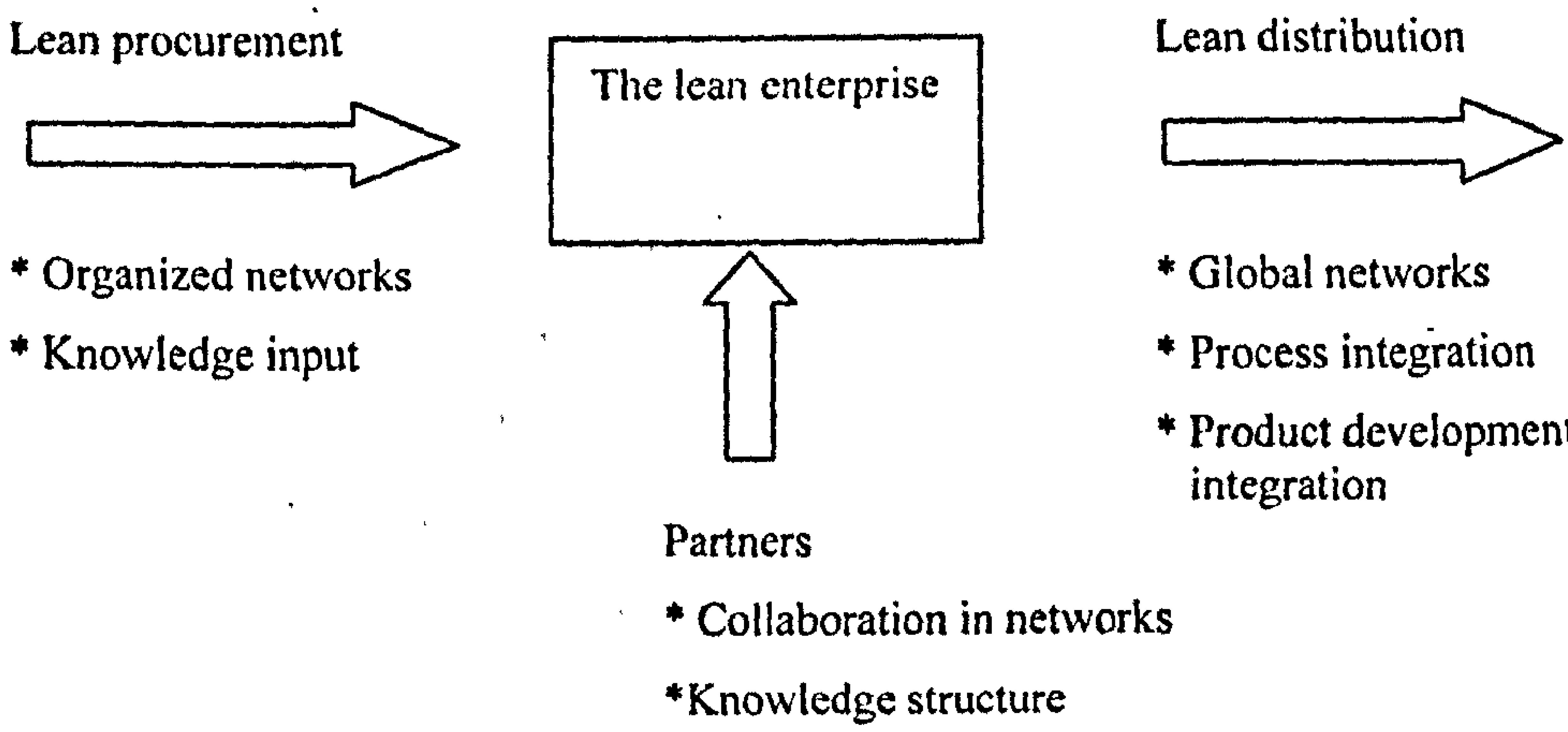

Figure 2.12. Lean enterprise model (Source: Karlsson and Ahlstrom, 1997)

It became clear that the lean approach requires the adoption of innovative practices not only in manufacturing but also in other areas of the organisation. Kosonen and Buhanist (1995) emphasised that a lean enterprise must use leanness and flexibility in its entire action principles.

Hallihan et al. (1997) summarised the following features and attributes of lean manufacturing

- manufacturing management philosophy of continuous improvement through the elimination of waste;
- elimination of the seven wastes is achieved using a diverse set of practices;
- involvement of a span of manufacturing stages including design, supply, production, distribution and sales & marketing;
- involvement of a span of manufacturing supporting functions including employee organisation, quality system, engineering, accounting & facility maintenance.

Levy (1997) conceptualised lean manufacturing as a tightly coupled, flexible system, with a rapid and frequent flow of goods and information. He applied the lean model, consisting of just-in-time delivery and low inventories; flexible manufacturing; and close relationships with suppliers and customers, in an international supply chain (printed circuit boards). Lean manufacturing focuses on improving the quality of inputs, keeping tight control over the production process, reducing the lead time at every stage, reducing lot sizes and set-up times and shortening product development cycles. It also requires closer cooperation with suppliers on quality and design-for-manufacture issues to ensure ease of manufacture. He concluded that lean concepts are more expensive or less effective in an international context as an international supply chains are a complex dynamic system in which disruptions due to quality problems, delayed deliveries, engineering changes and poor sales forecast interact with long lead-times to create huge costs.

James–Moore and Gibbons (1997) proposed a lean model comprising of 76 key practices and 68 performance metrics grouped in five areas, namely flexibility, waste elimination, optimisation, process control and people utilisation (Figure 2.13). These five areas capture the specific characteristics, which would contribute towards the achievement of leanness in a best-in-class company. These characteristics were based on the theoretical and empirical literature and on case studies such as Womack et al. (1990) and the Anderson Consulting Lean Enterprise Report. These characteristics would enable an assessment of the extent of leanness in different processes such as new product introduction, manufacturing, logistics, sales and marketing, product support and people management within a company.

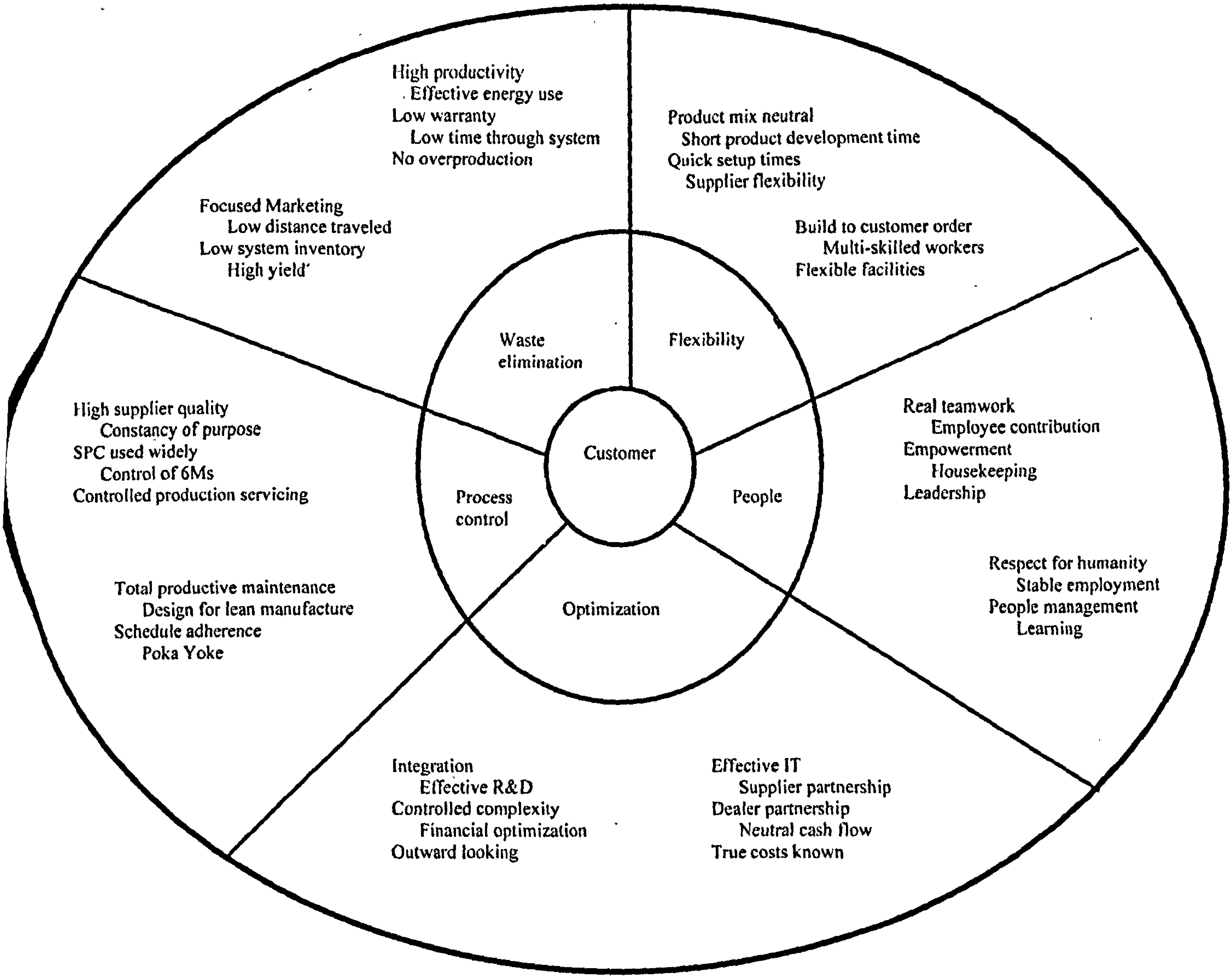

Figure 2.13. Lean model (Source: James-Moore and Gibbons 1997)

Panizzolo (1998) used a lean framework consisting of a number of improvement programmes or best practices that characterise different areas of the lean company. These areas were process and equipment, manufacturing planning and control, human resources, product design, supplier relationship and customer relationships (Table 2.12). Panizzolo(1998) suggested that the critical factor for effective implementation of lean principles would be the management of external relationships rather than internal operations. However, how to integrate the different value adding firms into the value chain is a challenging issue.

Areas of intervention	Improvement programmes
Process and equipment	Set up reduction Flow lines Cellular manufacturing Rigorous preventive maintenance "error proof" equipment progressive use of new process technologies process capability order and cleanliness in the plant continuous reduction of cycle time
Manufacturing planning and control	Levelled production Synchronised production Mixed model scheduling Small lot sizing Visual control of the shop floor Overlapped production Pull flow control
Human resources	Multifunctional workers Expansion of autonomy and responsibility Few level of management Worker involvement in continuous quality improvement Work time flexibility Team decision making Worker training Innovative performance appraisal and performance related pay systems
Product design	Parts standardisation Product modularisation Mushroom concept Design for manufacturability Phase overlapping Multifunctional design teams
Supplier relationship	JIT deliveries Open orders Quality at source Early information exchange on production plans Supplier involvement in quality improvement programmes Reduction of number of sources and distances Long-term contracts Total cost supplier evaluation
Customer relationship	Reliable and prompt deliveries Commercial actions to stabilise demand Capability and competence of sales network Early information on customer needs Flexibility on meeting customer requirements Service-enhanced product Customer involvement in product design Customer involvement in quality programmes

Table 2.12: Panizzolo's lean framework(Source Panizzolo, 1998)

Sanchez and Perez (2001) proposed a check-list model with 36 indicators to assess changes towards lean production, proposed from a review of the literature, and tested it in a sample of manufacturing firms (Figure 2.14).

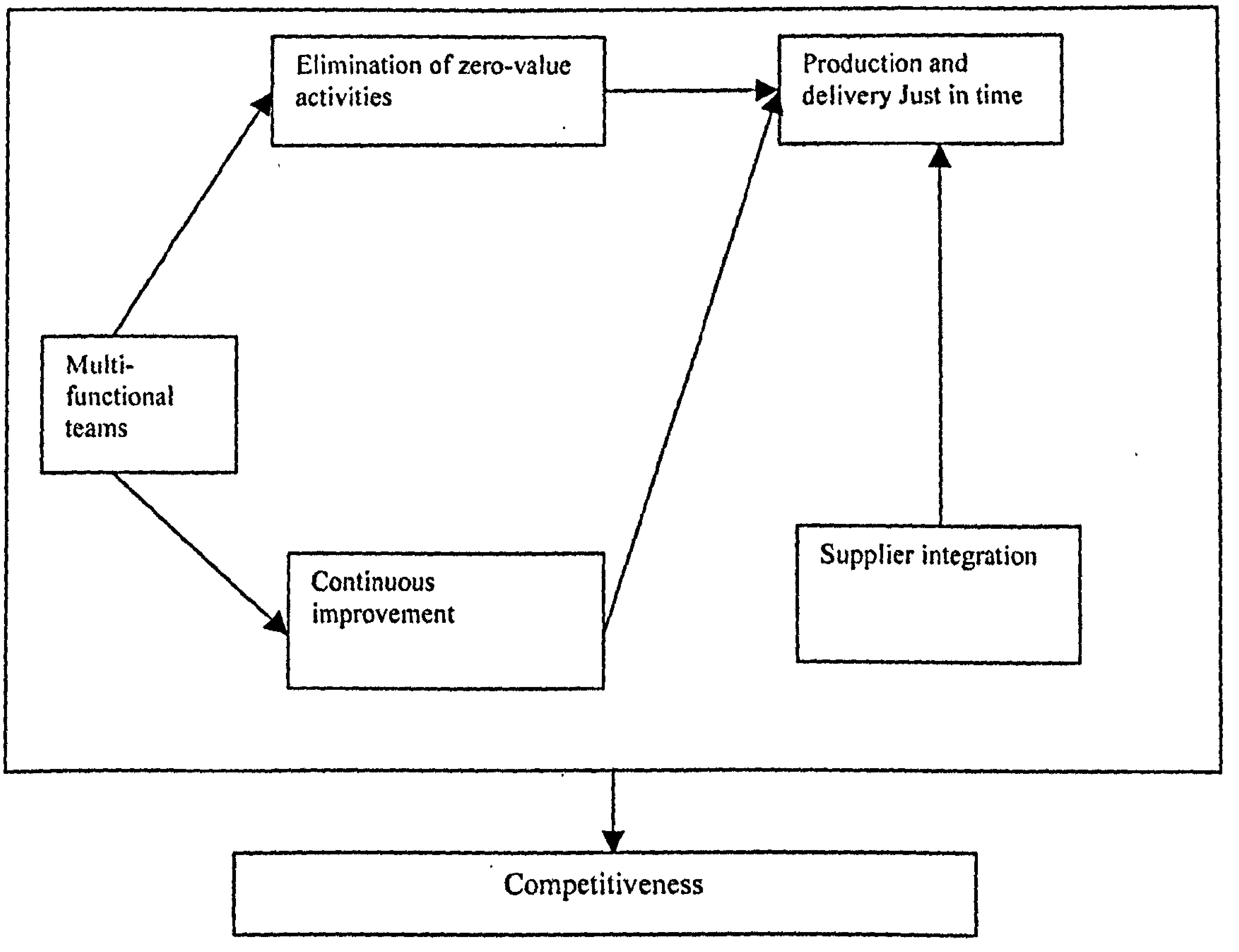

Figure 2.14. Lean checklist model (Source: Sanchez and Perez, 2001)

These 36 indicators are placed in six groups, elimination of zero-value activities, production and delivery just in time, multifunctional teams, continuous improvement, supplier integration, and vertical information systems. Some of these indicators have already been proposed in the Karlsson and Ahlstrom (1996) model.

Soriano-Meier and Forrester (2002) adopted the lean model consisting of 9 elements developed by Karlsson and Ahlstrom (1996) in their research work. They also incorporated the measurement of managerial commitment to lean production based on a model developed by Boyer (1996). They applied this model to test the generalisation made by Womack et al. (1990) in the tableware industry.

Scaffede (2002) discusses the lean manufacturing models adopted at the Donnelly Corporation, a global supplier of automotive mirrors, windows and door handles. This model included in-station process control, just-in-time, level production, equipment reliability, standards, problem solving, teamwork and continuous improvement as the main components of lean manufacturing.

Kojima and Kaplinsky (2004) presented a Lean Production Index which combined both objectively measurable data-sets and qualitative assessment made by key industry informants. The lean production index comprises of the flexibility index, the quality index and the continuous improvement index (Figure 2.15). The flexibility index is comprised of seven elements, which are

- Stockingholding levels;
- Set-up time reduction effort;
- In-plant usage of kanban;
- JIT delivery;
- Cellular layout;
- Team work and the role played by the team leader

Greater weight was given to the stock-holding score and set-up time reduction. The quality index comprises of a quality assurance system and an external defect performance measure. Continuous improvement was measured with respect to improvements over a 5-year period with regard to set-up time reduction, external quality performance and the degree of use of suggestion schemes. The lean production index was calculated by aggregating the average scores in each of three sub-indexes.

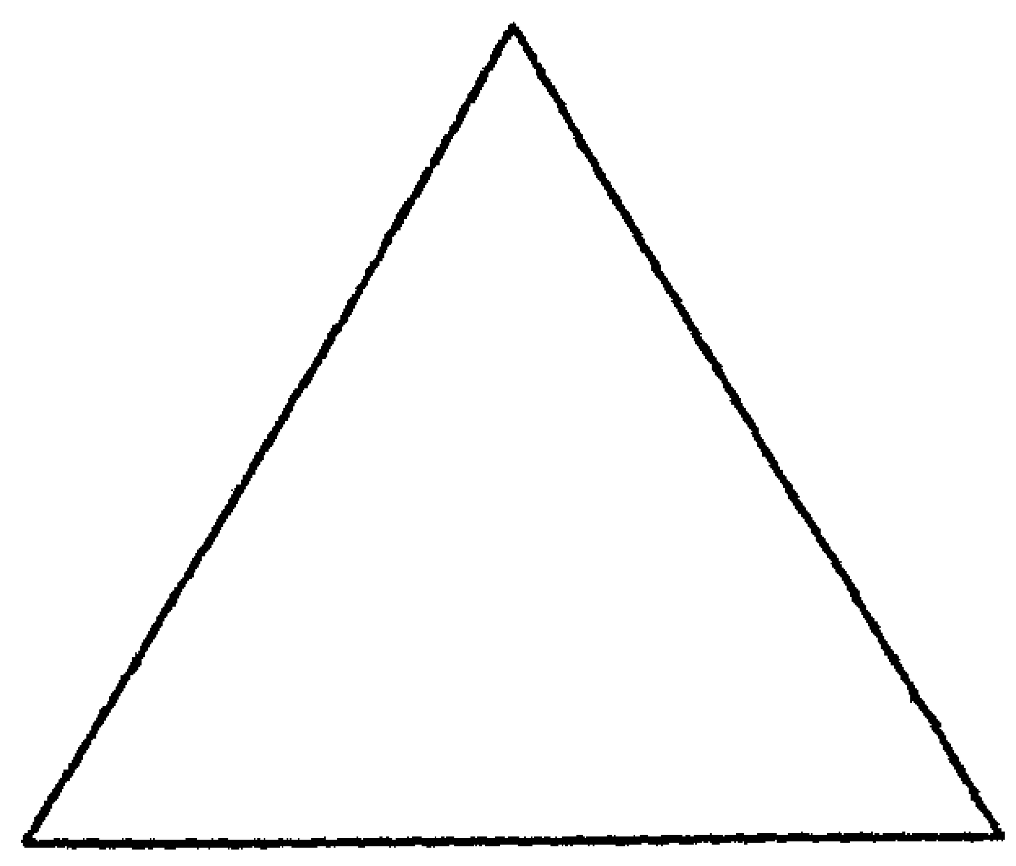

Figure 2.15. Lean manufacturing: three poles of changes (Source Kojima and Kaplinsky, 2004)

Hines et al. (2004) concluded that lean exists at two levels: strategic and operational. Lean at the strategic level focuses on customer value and can be applied everywhere, but lean at the operational level, which focuses on the shop-floor, has limitation. Any concept/tool that offers customer value can be considered as a part of lean at a strategic level even if the concept/tool is not part of lean at the operational level. The distinction of lean at the strategic level and at the operational level is key to understanding lean as a whole. Most of the lean implementation has been centred on the shop-floor.

Simons and Zokaei (2005) suggested that the success of lean manufacturing stems from a combination of practices, policies and philosophies.

- *Lean practices (tools and techniques)*: Standardised work, takt-time, just-in-time, levelled production, kanban (visual signal, 5S, autonomation system (Jidoka)
- *Lean policies*: TPM, long term relationship with customer, co-operation and transparency across the supply chain, visual control, Poke Yoke, enhanced problem solving ability of employees and enhanced participation
- *Lean philosophies*: waste elimination, striving on perfection, Kaizen (continuous improvement)

2.6.1 Classification of work done by various researchers

In the last several years, scholarly journals have published a number of articles that focus on various aspects of lean manufacturing. Appendix I provides a classification of the work done by researchers with regard to the methodology used, region's studied and contributions made to academicians and practitioners. This classification includes only those articles, which have been published after 1990 as the term lean manufacturing was only introduced with the publication of *The Machine That Changed the World* in 1990.

It was found that both surveys and case study research methods have been used extensively to investigate numerous issues of lean manufacturing. These articles revealed that lean manufacturing has diffused extensively and is not restricted to limited regions or countries or specific industries, though lean is a more mature concept in discrete manufacturing particularly automotive sector. A vast number of articles on the topic of lean manufacturing focus on the relationship between the implementation of lean and an organisation's performance. The majority of the empirical studies investigating the impact of lean implementation on operational performance are limited to one or two aspects of the lean philosophy.

2.6.2 Lean manufacturing goals

The overall goal of a lean manufacturing system is to improve a firm's productivity, quality, and flexibility (Schonberger, 1986; Hall, 1987; Womack and Jones 1990). Monden (1983) considered cost reduction as the primary goal of a lean manufacturing system. To achieve a cost reduction, production must adapt to changes in market demand without generating waste. He proposed three sub goals to achieve the primary goal

1. Quantity control, through which the system adapts to variation in demand with regard to quantities and variety.
2. Quality assurance, which ensures the supply of good units to the next process in the value chain.
3. Respect for humanity, which is required to utilise the human resource to achieve the primary goal.

Table 2.13 presents the lean manufacturing goals considered by the scholars. Scholars have viewed cost reduction, stockless production, high quality, and improved productivity, reduced lead-time and improved flexibility as goals of lean thinking. There is a wide consensus about lean manufacturing goals among scholars.

Author	Lean manufacturing goals
Monden (1983)	Cost reduction as the primary goal
Schonberger (1982)	Produce and deliver all kinds of goods only at the time needed
Hall (1983)	Stockless production and elimination of waste
Shingo (1989)	Achieve stockless production
Aggarwal (1985)	Obtaining low cost, high quality and on-time production
Womack and Jones (1990)	Improve firm's productivity, quality and flexibility
Karlsson and Ahlstrom (1996)	Increase productivity, enhance quality, shorten lead time and reduce cost

Table 2.13: Lean manufacturing goals

2.6.3 Benefits

A lean approach to production has been shown to lead to performance improvements (Cusumano, 1988; Krafcik, 1988; Sakakibara et al. 1990; Womack et al., 1990; Flynn et al., 1995). Lean practices and techniques are frequently associated with improvements in operational performance measures. A positive relationship exists between firm profitability and the degree to which waste-reduction practices are implemented (Fullerton et al. 2003). However, Lewis (2000) observed that lean does not naturally result in improved financial performance. The benefits of lean are realised by those firms, which exercise dominant market power (like automotive or supermarkets). Im and Lee (1989) suggested that the implementation of lean manufacturing is more beneficial for large manufacturers than small. Sakakibara et al., (1997) observed that lean practices create an indirect effect that works through an improvement of infrastructure by providing a set of targets and discipline for the organisation, rather than having a direct consequence on the performance.

A number of scholars (Schonberger, 1982; Womack et al., 1990; Oliver et al., 1994; Karlsson and Ahlstrom, 1996; White et al. 1999;) have provided lists of benefits claimed for plants implementing lean philosophies and systems. These include reduced lot sizes, lower inventory, improved quality, reduced waste and rework, improved motivation, greater process yield, increased productivity, increased flexibility, reduced space requirement, reduced lead-time and improved problem solving abilities.

The most consistent benefit from the adoption of lean found in the empirical studies is a reduction in inventory level (Billesbach et al., 1991; Fullerton and McWatters, 2001; Im and Lee, 1989; Norris et al., 1994; Huson and Nanda, 1995; Droge and Germaine, 1998). Droge and Germaine, (1998) observed a significant correlation between the levels of lean implementation and total inventory. Although reducing inventories may not be the primary purpose for implementing lean manufacturing, it is a natural consequence.

Fullerton and McWatters (2001) have demonstrated that implementing quality, continuous improvement and waste reduction practices embodied in the lean manufacturing philosophy can improve a firm's competitiveness. According to Sohal and Egglestone, (1994) the greatest improvement with lean manufacturing comes from market competitive positioning, customer relationship and quality constraints.

The greatest payback to be achieved by an organisation adopting lean manufacturing may result from the synergistic benefits of the lean techniques operating as a system (White and Ruch, 1990). According to Fullerton and McWatters (2001) the firms, which reaped the greatest benefits, were the high adopters of a complete set of lean practices. Although each element of a lean manufacturing system offers some benefits, these benefits will be localised in certain areas unless a system perspective is employed (Suzaki, 1987). A piecemeal implementation approach has led to mixed results often creating negative assessment of lean manufacturing potential (Clode, 1993).

2.6.4 Lean practices and techniques

Although a common set of lean practices remains to be specified within the research literature, different practices were suggested in several studies for successful lean adoption (Mehra and Inman, 1992; Sakakibara et al. 1993; Spencer and Guide 1995; Hum and Ng, 1995; McLachlin, 1997; White et al. 1999). A number of best practices commonly associated with lean manufacturing have been identified on the basis of the review of the literature. Table 2.15 presents a number of lean practices which have been identified during a review of the literature. These lean practices have been listed along with references.

There is a varying degree of frequency of lean practices. Pull systems, uniform workload, quick changeover, cellular manufacturing, visual control, multifunction workers, quality circles, JIT deliveries, reduction of suppliers have been used most frequently by scholars and practitioners. All these practices represent the multi-dimensional nature of lean manufacturing.

Lean practices	Source																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Quick change over	*	*	*	*	*	*	*	*	*	*	*			*	*	*	*	*	*	*	*	*			*	
Cellular manufacturing	*	*	*	*	*	*					*	*	*	*		*		*	*		*				*	
Visual control			*		*			*	*	*			*			*	*	*		*	*		*	*		*
Preventive maintenance	*	*	*	*	*	*	*							*	*	*		*	*		*			*		
Statistical process control					*		*			*	*							*				*		*		
5S			*	*						*								*		*	*					*
Mistake proofing			*				*	*		*						*					*	*	*	*		*
Quality system	*	*		*		*	*							*	*										*	
Standard work/operation							*	*		*													*			*
Cross-trained/multifunctional workforce	*	*	*	*	*	*	*		*	*		*	*	*	*	*		*	*	*	*		*		*	
Quality circle	*					*				*	*	*					*	*	*	*			*			
Continuous improvement programs		*		*	*					*		*		*	*					*			*			*
Team based problem solving (small group)							*				*	*	*			*	*					*		*	*	
Autonomation			*				*	*		*						*			*	*	*		*			*
Suggestion scheme							*						*			*	*	*				*			*	
Job rotation																*										

Table 2.14: Lean practices and their appearance in key references

Lean practices	Source																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
JIT deliveries			*	*		*			*		*	*	*			*	*			*		*		*	*	*
Reduction of number of supplier			*	*		*			*		*	*	*			*	*	*	*			*				
Long term contracts			*				*		*							*	*	*				*				
Active information exchange with supplier			*									*				*	*	*								
Supplier involvement in product design			*				*				*					*			*			*				
Supplier development activities			*								*		*													
Pull system	*	*	*	*	*	*		*	*	*	*	*	*	*	*		*			*	*	*	*	*	*	*
Uniform work load/ levelled production	*	*	*	*		*		*	*	*								*		*	*	*	*	*		*
One-piece flow		*	*							*				*	*			*					*			
Mixed model production			*					*		*										*	*		*			

Table 2.14 continued .

Source: 1. White and Prybutok (2001); 2. Shah and Ward (2003); 3. Pannizzolo (1998); 4. Chandra & Kodali (1998); 5. Ahlstrom and Karlsson (2000); 6. Fullerton et al. (2003); 7. Forza (1996); 8. Shingo (1989); 9. Womack et al. (1990); 10. Monden (1983); 11 Lewis (2000); 12 Sohal and Egglestone (1994); 13. Bamber and Dale (2000); 14. Flynn et al. (1999); 15. White (1993); 16. Sanchez and Perez (2001); 17. Oliver et al. (1996); 18. Ramarapu, et al. (1995); 19. Mehra and Inman (1992); 20. Hum and Ng (1995); 21. Hallihan et al. (1997); 22. McLachlin (1997); 23. Cochran et al. (2000); 24. Scaffede (2002); 25. Kojima and Kaplinsky (2004); 26. Simons and Zokaei (2005)

2.6.5 Lean implementation in discrete repetitive manufacturing environment

A big part of the success of the lean philosophy has come from the automotive industry, particularly in assembly line type processes. The application of lean manufacturing has been witnessed in almost all companies in the automotive industry in the Western world (Womack et al., 1990; Oliver et al., 1994). The spread of lean approaches was driven by mechanisms such as the Japanese US automotive transplants (Hall, 1982; Schonberger, 1982), joint ventures including NUMMI between Toyota and General Motors.

Although lean manufacturing has its origins in the automotive industry, other industries, particularly discrete, repetitive manufacturing companies, followed the footsteps of the automotive industry by embracing this new approach to improve their operations. Outside the automotive industry Omark Industries, Black & Decker, and Hewlett Packard were amongst the best-known early U.S. lean pioneers (Hallihan et al., 1997).

Lean concepts were disseminated into Canada and Europe through divisions of U.S. based Corporations (Hay, 1988). Womack and Jones (1996) demonstrated several case studies of discrete manufacturing companies making different products. They gave a detailed account of the introduction of lean principles within Pratt & Whitney, one of the world's leading aero-engine manufacturers. The principles of lean manufacturing are being applied in a variety of discrete repetitive manufacturing industries, outside of the automotive sector including personal computer manufacturing, wrapping machine manufacturing, domestic appliance, electronic equipment, elevator and air conditioning industries (Table 2.16).

The spread of lean concepts generated huge interest among researchers in order to understand and explore its implications. White et al. (1999) have investigated lean implementation differences between small and large U.S. manufacturers. They found that lean systems are adaptable and suggest that large U.S. manufacturers are more likely to implement lean systems than small manufacturers. Small manufacturers encounter different problems when implementing lean than those encountered by large manufacturers. Inman and Mehra (1990) suggest that small manufacturers require extensive training for lean implementation, but the lack of financial resources hinders their effective implementation. Large organisations are characterised by greater task specialisation, more levels in the hierarchy and more formalisation of behaviour, which pose different challenges when implementing lean.

Literature	Discrete repetitive manufacturing firms
Womack and Jones (1990); Arkader (2001); Motwani (2003); Bender & Morita (2004); Dong (1995); Sohal (1996); Scarbrough & Terry (1998)	Automotive
Lewis (2000); Oliver et al. (1994)	Auto-component plant
Kosonen & Buhanist (1995)	Elevator
Spencer and Guide (1995)	Air-conditioning firm
Levy (1997); Naylor et al. (1999)	Personal computer
Katayama and Bennet (1996)	PCB plant, refrigerator plant, air-conditioner plant
Toni & Tonchia (1996)	Domestic appliance
Karlsson & Ahlstrom, (1997)	Office equipment
McLachline (1997)	Electric motor, appliance, metal stamping, timber harvesting equipment farm equipment
McIvor (2001)	Electronic equipment

Table 2.15: Lean manufacturing in discrete, repetitive manufacturing industry

Voss and Robinson (1987) presented empirical data on the application of lean practices in the UK, while Billesbach et al. (1991) carried out a comparative study of lean implementation between UK and US-based firms.

It was found that repetitive manufacturing systems (assembly line/continuous flow) characterised by standardised product variety, long production runs, special purpose equipment (Table 2.17), appear to be more appropriate in employing lean practices than nonrepetitive manufacturing systems (project/jobshop) (White & Prybutok, 2001). The bias towards repetitive manufacturing systems can be attributed to the fact that the lean paradigm was designed and had its roots in a repetitive production system. In addition, initial adoption of lean in the West was started in repetitive manufacturing systems.

Characteristics	Manufacturing process	
	Nonrepetitive	Repetitive
Variety of products	Customised	Standardised
Material requirements	Difficult to predict	Very predictable
Scheduling	Uncertain, frequent changes	Fixed schedule, inflexible
Production runs	Short	Long
Setups	Different every job	Very few and costly
Type of equipment utilized	General purpose	Special purpose
Worker job content	High	Low
Worker skill level	High	Low
Control over suppliers	Low	High
Inventory levels		
Raw	Low	High
WIP	High	Low
Finished goods	Low	High

Table 2.16: Characteristics of repetitive and non-repetitive manufacturing systems
Source: White and Prybutok (2001)

The major focus of lean implementation is still the shop floor. Many firms in the West attempted to adopt specific elements of lean rather than implementing a complete framework (Hall, 1983; Im and Lee, 1989; Hines et al. 2004). The firms adopted those elements of lean, which were convenient and easy but not necessarily the ones that provided the greatest benefits. The majority of firms focussed on the waste elimination aspects of lean while ignoring flow and levelled production (Glenday, 2005).

However, Womack et al. (1990) proposed that not only is lean manufacturing a superior way for human beings to make things, but that the concepts of lean manufacturing can be applied in every industry across the globe.

" Yet in the end, we believe, lean production will supplant both mass production and the remaining outpost of craft production in all areas of industrial endeavour to become the standard global production system of the twenty-first century" (Womack et al 1990. p.278)

There has been considerable criticism of lean thinking. Many scholars have questioned and disputed the claim put forward by the proponents of lean (Cooney, 2002; Williams et al. 1992; Katayama and Bennett, 1996). The critics of lean manufacturing have argued whether lean manufacturing is merely an evolution of Fordism. There has been a debate on the extent to which it represents a new paradigm.

Williams et al. (1992) asserted that lean manufacturing practices have not been applied universally across Japan. It has also been argued that lean manufacturing is suitable only in a Japanese organisational culture. Even other non-Toyota Japanese automotive companies have not adopted the principles of lean to their fullest extent.

Holweg and Jones (2001) claimed that lean is still confined to car assemblers and first tier suppliers. Still the Western automotive producers use a " build-to-forecast" approach and building cars to customer order is a distant reality.

Cusumano (1994) discussed the limitations of lean manufacturing in terms of its undesirable effect, such as the lack of young labour willing to work in the factories, the excessive product variety and the extreme pressure on suppliers. Oliver and Hunter (1998) have shown scepticism for the competitive impact of leanness. They found no statistical significance between profitability and lean manufacturing. Hines et al. (2004) summarised the gaps in lean thinking (Table 2.18).

	1980-1990	1990-mid 1990	Mid 1990-1999	2000+
Key gaps	Outside shop-floor	Mainly auto	Coping with variability	Global aspects
	Inter-company aspects	Human resources, exploitation of workers	Integration of processes	Understanding customer value
	Systemic thinking	Supply chain aspects	Inter-company relationships	Low volume industries
	Auto assembly only	System dynamic aspects	Still mainly auto	Strategic integration
			Integrating industries	E-business

Table 2.17. The criticism of lean thinking (Adapted from Hines et al., 2004)

William et al. (1992) challenged the claim made by the proponents of lean manufacturing and asserted that the impact of lean in terms of improved productivity of a Japanese car assembly plants were exaggerated.

Engstrom et al. (1996) asserted that in some production systems, labour accounts for not more than 5-10 percent and hence lean manufacturing practices do not represent a significant source of potential improvement. Delbridge (1998) questioned the benefits of team working and empowerment promised by the adoption of lean practices.

Lean manufacturing has been perceived to employ fewer people which might result in downsizing. It was due to this fact that lean has been associated with "mean" because of the concept of downsizing. Downsizing is perceived to be a lean strategy from a management point of view, but does not make the company lean practically. Whereas it is often regarded as 'mean' by the employees which creates mistrusts between management and employees and hence is frequently associated with failure (Kinie et al., 1998). An organisation seldom gains the benefits of increased efficiency associated with lean production but reap all the drawbacks of meanness. Lean manufacturing has been observed as being exploitative to the shop floor workers (Williams et al., 1992).

Demand variability was considered as a critical inhibitor to the implementation of lean. As a result some scholars proposed agile manufacturing to cope with the demand fluctuation (Christopher and Towill, 2000; Hormozi, 2001; Yusuf and Adeleye, 2002). Katayama and Bennett (1996) asserted that the lean manufacturing model might not be robust enough as an approach to cope with changing and volatile economic and market conditions. It is unable to accommodate the variation in demand for finished products and wider economic and market conditions have not been taken into account. A small variation in demand can lead to production below the breakeven point. Toyota has a unique position that has facilitated the practice of JIT and kanban systems. They suggested a new production paradigm, adaptable production that can operate with lower fixed cost.

According to Cooney (2002), the lean model, whilst encompassing the whole of the manufacturing chain, ignores the external factors to which management must respond when steering a business and making choices about the kind of production practices that will be adopted in their enterprise. The characteristics of buyer-supplier relationships, the nature of social and political relationships and general business environment have an impact on the flow of value. This fact has been ignored by the proponents of lean manufacturing. Katayama and Bennet (1996) argued that benchmarking studies have benefited from close attention to actual practice, but in these studies other elements have been largely ignored. According to Lewis (2000) a plant's success depends on several factors and good management practice to improve value is just but one of them.

Cooney (2002) was sceptical with regard to the universal applicability of lean concepts claimed by its proponents. He argued that a pull system is a central concept of lean manufacturing, if it cannot be achieved due to business conditions or the nature of buyer-supplier relationships, then batch or mass flow become the only alternative. Lean manufacturing cannot accommodate the different circumstances faced by companies. It offers only a partial model of a manufacturing system (Cooney 2002). Batch production can embrace some of the lean practices but this does not mean that they are being transformed to lean manufacturing. Williams et al. (1994) asserted that the applicability of lean methods is irrelevant and unattainable in developed economies.

A lean manufacturing system is very efficient if everything runs perfectly but is extremely fragile if there is any kind of problem because with lean, the organisation shuns the expensive security in the form of surplus resources and relies on coordination of its various functions. It requires reliable processes and a collaborative environment (Oliver and Wilkinson, 1988).

2.6.5.1 Factors affecting lean implementation

A firm's reluctance to adopt lean thinking has been attributed to a number of factors including resistance to change, lack of understanding of lean practices, an incompatible workforce and workplace environment, lack of support from suppliers and ineffective performance measurement system (Wafa & Yasin, 1998; Fullerton and McWatters, 1999). It has been argued that lean methods may not be appropriate for all firms (Golhar & Deshpande, 1993).

Hum and Ng (1995) highlighted the following problems that lean companies encountered during their implementation process:

1. The problem of interfacing a lean system with an existing system
2. The lack of internal expertise on lean manufacturing
3. The difficulty in reducing set up time
4. Poor information and data accuracy

Production management policy has a significant effect on lean implementation. Several U.S. plants with a lean production policy realised performance levels equal to or better than some Japanese plants (Krafcik, 1988).

The plant age is a more important inhibitor to implementing lean practices than is unionisation. Shah and Ward (2003) found that large plants are more likely to possess the resources to implement lean practices than smaller plants. These findings are consistent with the literature (White et al. 1999).

2.7 Lean Thinking in Non-Traditional Sector

The dissemination of the lean thinking approach, particularly after the publication of '*Machine that changed the world,*' has initiated a debate in academia (Kenney and Florida, 1995; James-Moore and Gibbons, 1997) on the following issues:

1. Whether lean thinking as propounded by IMVP researchers has the universal applicability in the sectors other than the discrete repetitive manufacturing sector?
2. To what extent can it be transferred to other manufacturing industries?
3. If it can be transferred to other sectors then what will be the approach by which it will be adapted by traditional production systems?
4. What will be the impact of the adoption of a lean manufacturing system on the organisation's competitiveness?

Answers to all the above questions are not very conclusive, yet evidence of some aspects of a lean approach in different environments such as low volume & high variety and process sector can be found in the literature (Table 2.18).

Literature	Non-Traditional Industry
Koskela, (1992); Alarcon, (1997); Howell and Ballard, (1998); Ballard et al. (2003)	Construction industry
Storch and Lim (1999)	Shipbuilding
Billesbach, (1994)	Textile
Cook and Rogowski (1996)	Chemical
Roy and Guin (1999); Dhandapani et al. (2004)	Steel plant
Crute et al (2003); Mathaisel and Comm (2000); Jina et al. (1997); Michaels, (1999); Bamber and Dale (2000)	Aerospace
Simon and Zokaei (2004)	Red meat plant (Food industry)
Womack and Jones (1996)	Grocery store, Soft drink (Food industry)
Yingling et al. (2000)	Mining

Table 2.18: Application of lean thinking in non-traditional industry

2.7.1 Lean thinking in high product variety and low volume sector

Lean principles and practices at operations as diverse as low-volume (for example, air craft manufacturing), construction and shipbuilding are now being implemented (Table 2.19).

One of the most prominent lean manufacturing programmes outside the automotive industry is the Lean Aircraft Initiative (LAI) involving the US Air Force, MIT and 25 defence firms. Companies such as McDonell Douglas and Lockheed have adopted lean principles right from product design to product manufacture (Jina et al. 1997). Lockheed Martin's Aeronautics Sector in the US acknowledged 1999 as the year of lean and applied lean concepts to two of its fighter programmes and one military transport aircraft-manufacturing site. In the UK, BAE Systems' military aircraft plants have been employing lean practices in recent years (Crute et al. 2003). Lean concepts are being disseminated throughout the UK aerospace industry, with major initiatives also underway in many manufacturing firms including Airbus UK, Rolls-Royce plc, Smiths Aerospace and TRW Aeronautical System (Crute et al., 2003).

Bamber and Dale (2000) and Mathaisel and Comm (2000) looked into the possibilities of applying lean manufacturing principles in one aerospace company. They concluded that many of the techniques of lean manufacturing are not as powerful in the aerospace industry as they are in the automotive environment. The environment within which the automotive manufacturing companies operate is different from the aerospace industry. Aerospace industry undertakes generally make-to-order production where as the automotive industry operates under make-to-forecast production. Lean tools such as kanban, quick changeover and group technology were developed to reduce the risk associated with make-to-stock production strategies. Aerospace companies are not faced with the same risk so many of the lean practices are not as effective as they are in the automotive manufacturing environment (Bamber and Dale, 2000).

Crute et al. (2003) also examined the transferability of lean in the aerospace sector with the help of two longitudinal case studies and suggested that difficulties with the implementation of lean in the aerospace sector are not different from those of implementing lean in the automotive sector.

Jina et al. (1997) provided insights into some of the differences between typical high volume lean plants and high variety low volume (HVLV) plants such as aerospace (Table 2.20). The key problem with HVLV plants with regard to the adoption of lean thinking, is manufacturing system turbulence due to changes in schedule, product mix, volume and design, which has a greater impact in the HVLV plant than in a high volume plant. High volume, low/medium variety plants are able to weaken the impact of variability of the inputs into the manufacturing system by de-coupling the internal supply chain from the outbound supply chain. HVLV plants due to low volume and make to order business, cannot adopt a decoupling policy. Despite this difficulty lean principles can be adapted to the HVLV situation

Characteristic	**Lean plant**	**High variety low volume plant**
Typical annual volume	From 100,000 to 1,000,000 + units per year	From 20-500 and 5,000-20,000 units per year
Product variety and complexity	Medium, with no bespoke products, specialist products, separated into dedicated plants	Very high, though some bespoke products are delivered also. All manufacturing in the same plant
Degree of vertical integration	Medium and decreasing	Can be low, medium, or high- the specialist nature of products often inhibits any increase or decrease
Manufacturing planning systems	Stabilise by a degree of make to stock with primarily assemble to order	Low volume with make to order
Order-winning criteria	Variety, delivery speed, "All in" product features	Variety, custom bespoke product, "extra" features, delivery speed

Table 2.19: Comparison between the characteristics of a typical lean plant and a low volume high variety plant

Michaels (1999) discussed the experience of an aerospace company which deployed a lean supply chain initiative in 1995. The main factors that were considered as deterrents in achieving lean supply were

1. Company's past business
2. Poor alignment within the company
3. Confusion over role and responsibilities
4. The batch and queue system that produced financial success in the past

However, a lean supply chain initiative achieved a moderate success in a short period of time.

Storch and Lim (1999) explored the potential application of lean principles to the shipbuilding industry and proposed an approach to move the industry closer to lean manufacturing in terms of flow and offered a metric by which to determine how close to ideal flow shipbuilding is. Characteristics of the shipbuilding industry are similar to civil engineering and the construction industry. Both are non-repetitive built to order projects, which require a large amount of labours. Lean principles can be applied to devise the most efficient production process flows for the interim products such as subassemblies, outfit units and blocks to improve ship production.

Koskela, (1992), Alarcon, (1997), Howell and Ballard (1998), have looked into the extent to which a lean model can be applied in the construction industry. Green (1999), however, argued that the application of lean thinking in construction is based on a selective sample of the available literature. Ballard et al (2003) investigated the application of lean manufacturing concepts and practices to structural pre-cast concrete fabrication.

Yingling et al. (2000) explored the possibility of applying lean thinking in the mining industry. Some of the lean practices such as standardised work, quality-at-source, total productive maintenance, flexible workforce, set-up reduction and continuous improvement could be implemented in the mining industry. However, practices designed for flow were found to be difficult to transfer from manufacturing to mining.

Sakikibara et al. (1993) stated that although JIT was first adopted in a repetitive manufacturing environment, the applicability of JIT to a high product variety and low volume environment is undeniable. Some of the tools of JIT do not apply in these environments, such as Kanban.

2.7.2 Lean Thinking in the Process Sector

Although lean concepts have achieved widespread adoption in discrete manufacturing environments, managers have been reluctant to adapt lean practices in the process sector. Few attempts have been made to apply lean concepts in the process industries.

The Dow Chemical company in North America and one of its supply chain partners improved material flow in a continuous process chemical manufacturing environment by eliminating waste such as excess stock and transportation. By applying lean concepts to one major supply chain, Dow was able to improve demand forecast accuracy by 25%, decrease distribution lead time by 25% and decrease lead time variability by 50% (Cook and Rogowski, 1996). As a result, customer responsiveness increased while the level of inventory and transportation assets in the supply chain decreased significantly.

Although lean concepts have evolved in the repetitive discrete industry, with some adaptation they can be applied to the process industry (Billesbach 1994). Lean concepts can be used to benefit those process facilities which produce a discrete part somewhere in the process flow. Billesbach (1994) described the application of lean thinking at a DuPont Textile company. At DuPont's May plant in Camden, South Carolina where textiles are produced, JIT was used to fix the problem of product shortages, excessive backlogs, and lost or misplaced yarn at the spinning area. A pull system was used using a kanban approach (Billesbach 1994). The results were promising: 96% reduction in WIP, a working capital decline of $2 million and a product quality improvement of 10%. Billesbach (1994) highlighted few suggestions on the basis of this textile company's experience:

1. Inability to shut down equipment is not a barrier to implementing lean principles in the process environment.
2. Objectives and goals should be clear, visible and measurable
3. Emphasis should be on product flow rather than on improving an operator efficiency

Some of the basic principles of JIT systems, which have been traditionally associated with the discrete manufacturing industry, were pursued in the process industries. Roy and Guin (1999) have described JIT purchasing at a steel plant in India. It has been argued that the principles of JIT systems cannot be applied in a straightforward manner in a process environment. Dhandapani et al. (2004) applied some aspects of lean thinking in a steel company and demonstrated a reduction in production cost by 8% and a lead-time reduction of 50%.

Apart from a few reported cases, the application of lean thinking to the process industry has been limited because of reasons such as high volume and low variety products, large inflexible machines and the long set-up times that characterise the process industry. Process industries have been regarded as examples of push systems. Mirsky (1993) discussed the key problems of implementing pull techniques in process industries. He asserted that due to capital-intensive processes or resource constraints, capacity is fixed, but seasonality effects results in demand peaks, which surpass capacity. This requires planning to level production runs which is contrary to lean thinking.

Shah and Ward (2000) found that plants in discrete industries are more likely to implement lean than those in the process industries where kanban and small production lots are hard to imagine. On the other hand preventive maintenance practices are more likely to be implemented by plants in a process industry than in a discrete industry. This finding makes sense when one considers the high degree of importance placed on capacity utilisation in process industries (Hayes and Wheelwright, 1984).

The process industry can be thought of as producing material rather than producing items as in a discrete manufacturing industry. These two industries have features in common, the big difference being in the continuity of operation. In the process industry it can be very expensive to shut down a process as it creates a big challenge from a logistical point of view. However, almost every process industry rolls out a discrete part at the end, so lean concepts can be applied at this stage (Billesbach, 1994). Lean concepts are generally applicable to repetitive, discrete parts manufacturing but with some adaptation can be used to benefit a process industry. Typically, purchasing and quality improvement, inventory reduction, people involvement and waste elimination programs can be applied in process industries as well as in discrete manufacturing industries (Moras and Dieck 1992).

Shah and Ward (2000) suggest that lean practices are prevalent in all industries and the studies of lean manufacturing need not be limited to discrete manufacturing industries. A very pertinent question is how can the tools of lean manufacturing be adapted from a discrete to a continuous manufacturing environment. Although the process and discrete industry share several common characteristics, there are also areas where they are unique. The objective is to look at commonalities between discrete and continuous manufacturing where lean techniques from the discrete side are directly applicable and to also examine other areas where this may not be quite straightforward

2.8 Lean Thinking in the Food & Drink Industry

Although the food and drink industry has for some time initiated numerous operational improvement initiatives such as Vendor Managed Inventory (VMI), Efficient Consumer Response (ECR) and Collaborative Planning, Forecasting and Replenishment (CPFR) as integrated models for supply chain management and operational excellence (Barratt and Oliveira 2001; Jones and Clark 2002), these initiatives, primarily instituted by the large retailers, have focused mostly on the downstream side of the supply chain from producer to customer and have not had much influence on the upstream side of the food supply chain (Van Donk, 2000). Despite a lot of discussion about collaboration between suppliers and retailers, encouraged by the ECR and CPFR movement, the main focus of trading partners has been to optimise their own system. Moreover these initiatives have been limited to a few big retailers and manufacturers. Small and medium sized food manufacturers are yet to reap its benefits, as they are not in a position to invest in the technology required for the implementation of these initiatives (Borchert, 2002).

There are very few recorded studies, which have focussed on the applicability of lean principles in the food and drink sector. The concepts of lean thinking are relatively new to many operation managers in the food and drink industry. Nonetheless a few attempts have been made to apply some aspects of lean thinking in this sector.

Ritchie (1990) found that lean tools contributed to improved quality-service and higher profitability at Mcdonald's-Australia. Yasin and Yavas (1992) concluded that better lean practices of a fast-food restaurant in Atlanta have had a significant impact on quality, reduced inventory costs and decreased direct labour.

Iijima et al. (1996) discussed a hybrid Just-In-Time (JIT) logistics system (a combination between push-type and pull–type systems and PC networks) in a regional medium-scale food company located in Japan where there was a restriction of short delivery times in order to distribute fresh food to consumers.

Houghton and Portugal (1997) argued that growing competition has imposed a continuous need for incremental product innovation which creates a recurring problem of workload variation management and lowers the performance of the production planning process. They analysed single stage batch manufacturing as well as multi stage batch manufacturing committed to JIT production in an environment of incremental product innovation. The study was motivated by production problems following incremental product innovation within the food processing industry where it is usual for linear material flows to connect multiple processing stages. Reengineering is currently operating in a JIT snack food manufacturing plant, where it has significantly improved workload variations and has encouraged a managerial attitude for product innovation (Houghton and Portugal, 1997).

Beardsell and Dale (1999) examined the relevance of total quality management (TQM) in the UK food supply and distribution industry with the help of two case studies and confirmed the applicability of TQM. He and Hayya (2002) examined JIT manufacturing and its impact on quality in the food industry. They concluded that JIT manufacturing yields a positive impact on quality. JIT practices, popular in the food industry, are employee empowerment and on-time delivery. Moreover, quality measures have been embraced in the food industry due to the importance of food safety reasons. It was found that food supplies on a JIT basis has the stronger positive impact on product quality and on customer satisfaction (He and Hayya, 2002).

Ten years ago, Tesco, the UK's biggest superstore, initiated a long-term strategy to improve every aspect of its operation. Between 1983 and 1996, it introduced automation and technology such as POS scanning, centralised automated ordering, centralised distribution, automated warehouse control and EDI with its main suppliers. As a result, lead time to stores reduced from 7-14 days to two days, lead time from suppliers came down from 12-18 days to three days, stock reduced to 2.5 weeks from 4.4 weeks, product range increased from 5000 to 40000 SKUs (Jones and Clark, 2002). In 1996, it undertook value stream mapping of the whole supply chain. The work done since has cut stock in the entire supply chain to just 3.5 days. Jones and Clark (2002) found that superstore Tesco learned a great deal from Toyota's practices and has worked closely with its suppliers. Once Toyota learnt a lesson from the superstore way of working and now superstore Tesco initiated a series of process improvement based on Toyota's way of manufacturing.

Jones and Clark (2002) reported a case study of a contract processor, who bottles soft drink for several different brands, located next to a cluster of regional distribution centres belonging to a number of retailers, who applied a lean thinking approach to compress its value stream. The processor filled just enough of each product to replenish what was sold in the local region the day before. Cans and bottles were printed after being filled & closely synchronised with the needs of the filler. Products were shipped by frequent milk rounds to their destinations. This compressed flow has reduced the throughput time to 1-3 days, and product is only touched 20 times. Machine and transport effectiveness has increased to a considerable extent (Table 2.21).

	Traditional	Flow	Compressed
Touches	170	70	20
Throughput time (days)	20-60	5-15	1-3
Stocking points	7	2	1
Machine Effectiveness%	30-50	70-80	80-90
Transport Effectiveness%	30-50	50-70	70-85
Transport Trips	5	4	2
Decision point	8	2	1
Order amplification	4:1	2:1	1:1
Service level%	98.5	99.5	99.5
Basket fulfilment %(40 item)	55	82	98

Table 2.20: Soft drink value stream (Source: Jones and Clark, 2002)

Simon and Zokaei (2005) introduced some lean techniques, specifically Takt-time and standardised work, in red meat cutting plants to improve productivity and quality and reported the benefits of lean manufacturing in one specific area where meat is split down from a carcass into meat slices. He compared two sets of case studies, both traditional and advanced meat cutting rooms and reported different levels of productivity and quality. The traditional cutting rooms were producing at a faster pace than the customer demand rate, resulting in the waste of overproduction whereas lines in advanced cutting rooms run at a pace that the operator can apply standard operations and were paced to the customer demand rate. Simon and Zokaei (2005) concluded that advanced lines could operate with 25 per cent less labour cost due to improved line balance. The practices employed in the advanced plants were similar to practices used in a lean manufacturing system.

One of the biggest problems faced by the food industry today is the uncertainty of demand. In the food industry demand is very difficult to forecast and may fluctuate widely. With such uncertainty it becomes difficult to match production with demand accurately. Most managers in the food and drink industries have argued that they face chaotic demand from the retailers and can only protect themselves by holding large stocks, which means that production cannot be synchronised.

Jones (2001) however, asserts that EPOS data for most products is relatively smooth and it is the ordering system, which causes the demand variability. He further suggests that by increasing information visibility in real time, mismatch between production and retailer demand can be reduced. Unless the majority of retailers share information, production schedules will still be planned with a high margin of error (Whiteoak, 1993). This depends on the degree of co-operation between the retailer and the supplier, which still has a long way to go.

Another barrier to food processing companies in implementing lean is the law mandating that deliveries of raw material food items such as flour, sugar etc. must be inspected before they are put into production. The inspection process takes a long time and the company incurs significant inspection costs. Also some of the ingredients are procured from many distant places and events such as natural disasters and political upheaval can affect delivery (Beard and Butler, 2000). Redundancy programmes (reduction of work force numbers) and lack of employee education did not drive the food and drink industry to embrace some of the lean manufacturing practices. (Bamber and Dale, 2000)

Zaire (1998) stressed the retailers' changing requirements. The vision of zero inventory is going to be the key issue for most retailers through their insistence on daily ordering and delivery with lead times of less than 24 hours. The suppliers will be asked to perform better in terms of consistency, delivery reliability, quality of service, in addition to cost and speed. Suppliers will have to manage operations with increased flexibility and better predictability of demand.

The review of literature shows that the majority of food industry companies have not been able to enjoy the benefits of operational improvement initiatives, such as lean manufacturing, which has evolved and developed in the automotive industry. Though few lean practices such as 5S, standardised work, suggestion schemes, teamwork have been adopted and practiced by the food industry, lean thinking as a holistic operations approach has not yet reached a stage of adoption where it is any way conspicuous as an improvement initiative within the sector.

However, Womack and Jones (2003) maintained that

> "Lean food production and supply is completely feasible with the technologies and management techniques available today, and the current system is ripe for change. The important question is who will make the leap." (p.291)

It is this proposition that motivated this work to explore and investigate the extent to which lean thinking has permeated in the food and drink industry. The research will investigate and develop on the work of authors such as Billesbach (1994), Jones and Clark (2002), Womack and Jones (2003) as to how the food and drink industry can benefit from the adoption of lean thinking.

2.9 Summary

This chapter presented a comprehensive literature review incorporating characteristics of the food industry, business & manufacturing challenges and operational improvement initiatives (vendor managed inventory, efficient consumer response, collaborative planning forecasting & replenishment and lean manufacturing) in the food industry. It was found that operational initiatives such as vendor managed inventory (VMI), efficient consumer response (ECR) and collaborative planning, forecasting and replenishment (CPFR), primarily instituted by the large retailers, have focused mainly on the downstream side of the supply chain from producer to customer and have not had much influence on the upstream side of the food supply chain. Although lean concepts have achieved widespread adoption in discrete manufacturing environments, managers have been reluctant to adapt lean practices in the process sector because of reasons such as high volume and low variety products, large inflexible machines and the long set-up times that characterise the process industry. The literature also provided limited evidence of its application within the food industry. Though few lean practices such as 5S, standardised work, suggestion schemes, and teamwork have been adopted and practised by the food industry, lean thinking as a holistic operations approach has not yet reached a stage of adoption where it is any way conspicuous as an improvement initiative within the food sector.

Chapter 3

Development of a lean manufacturing framework

3.1 Introduction

Since the seminal work of James Womack and other IMVP researchers, a great attention from industry, academia and government has focused on lean manufacturing, with great deliberation on the Toyota Production System (TPS), but contributing little to what we mean by ' lean'. Few researchers asserted that lean is simply another word for the Toyota Production System. Whilst the literature is replete with elaboration on the topic of lean manufacturing, the models, which exist to represent lean manufacturing as a unifying framework, are rather intricate.

The definition of lean manufacturing is very vague and confused (Bartezzaghi, 1999). One of the major problems in the literature is the lack of consensus concerning the interpretation and meaning of lean manufacturing. The term has been used quite loosely. According to Ramarapu et al. (1995) the meaning and components of lean often vary depending on the author's background and experiences. Scholars have used different terms such as Toyota Production System, Just-in-Time, Lean Production and World Class Manufacturing to express a lean approach to manufacturing (Oliver et al., 1994). A number of scholars have also proposed a lean manufacturing framework (Ramarapu, et al. 1995; Karlsson and Ahlstrom, 1997; Sanchez and Perez, 2001; James-Moore and Gibbons, 1997; Oliver et al. 1996; Panizzolo, 1998), but there has not been a unanimous agreement on a unified single lean manufacturing framework. There is no consistent set of dimensions to define lean manufacturing which poses a big problem for researchers to agree with what is meant by lean in actual practice. It is argued that the major cause of the confusion is due to the broad nature of the meaning of lean in the literature (Ramarapu et al., 1995).

Lean as a concept has undergone a significant evolution beyond its roots in the automotive industry. Lean has moved away from simply being regarded as waste and cost reduction focus to an approach that seeks to enhance value to customers. In the 1980s and early 1990s there was a greater emphasis on quality in the literature (Hines et al., 2004). During the mid-1990s the lean manufacturing concept moved away from the elimination of waste approach to an approach that focused on customer value. It is the customer that ultimately decides what constitutes waste and what does not. Value is enhanced if wasteful activities and the associated costs are reduced. Value is also increased if additional features or services are provided to the customer (Hines et al., 2004).

Considering that lean has evolved over time, there is now a need to develop a lean manufacturing framework encompassing the work undertaken by various researchers and practitioners. This section presents a lean manufacturing framework based on the literature and available lean models.

3.2 Lean Manufacturing framework

Despite a number of lean manufacturing models available in the literature, there has not been a unanimous agreement amongst scholars with regard to its various principles and elements. More than 70 scholarly articles were rigorously reviewed to arrive at a common agreed set of lean manufacturing principles and practices. The articles reviewed were mainly published after 1990, as 'lean manufacturing' became a new manufacturing paradigm after the publication of *The Machine That Changed the World.*

The proponents of lean (Womack et al., 1990) have highlighted employee involvement through team based work organisation, close partnership with suppliers and customers, integrated customer driven production flow to be essential ingredients of a lean approach to manufacturing. Golhar & Stamm (1991) identified four basic principles (elimination of waste, employee involvement, supplier participation, total quality control) of lean manufacturing on the basis of extensive literature review. A number of lean practices were placed under these four principles.

Mehra and Inman (1992), Spencer and Guide (1995) have considered JIT production strategy, JIT supplier strategy and JIT employee education strategy as an integral part of lean strategy. Oliver et al. (1994) focussed on close relationship with suppliers, integrated material flows, employee participation through team based work organisation to continuous improvement activities and lean practices under lean paradigm. Ramarapu et al. (1995) identified elimination of waste, production strategy, quality control and improvement, employee involvement, supplier involvement and management commitment to be the key factors of a lean framework. Womack and Jones (1996) expanded the scope of lean manufacturing and asserted that the essence of lean approach is the continuous flow of products through value creating process at the demand of customer. Continuous and uniform flow will reduce cycle time and work-in-progress levels and increase the throughput of each product. Womack and Jones's (1996) concept of continuous flow focussed on aligning production with customer demand.

Karlsson and Ahlstrom (1996) proposed a lean manufacturing model consisting of elimination of waste, pull production, continuous improvement, multifunctional teams, vertical information system, zero defects and decentralised responsibilities. Following Karlsson and Ahlstrom's (1996) lean frame work, Sanchez and Perez (2001) put forward a lean model consisting of elimination of waste, continuous improvement, supplier integration, multifunctional teams, just-in-time production and delivery and vertical information system as its guiding principles. According to Hallihan et al. (1997) continuous improvement and elimination of waste are integral parts of lean approach. James-Moore and Gibbons (1997) proposed flexibility, waste elimination, optimisation, process control and people deployment as key elements of a lean framework. Levy (1997) conceptualised lean as tightly coupled flexible system which has the ability to customise a product, to produce to order or to shift quickly from production of one model to another on the same line. Panizzolo (1998) suggested a lean framework consisting of number of lean practices that represent different area of the lean company. Kojima et al. (2003) included flexibility, quality and continuous improvement in the development of the lean model. Simon and Zokaei (2005) suggested a lean framework consisting of philosophies, policies and practices. They considered waste elimination, continuous improvement, employee participation and striving for perfection as the guiding principles of lean.

To compete with Toyota Motor Company in a highly competitive automotive market, Ford Motor Company developed Ford Production System (FPS) as a worldwide, cohesive system that encompasses and integrates its manufacturing processes and interrelated product development system, order-to-delivery, supply and management processes (Marshall and Leaney, 2001). Underlying principles of FPS are:

- Employee involvement and empowerment through effective work groups developed through education, training and communication for continuous improvement.
- Zero waste through eliminating waste of materials, time, energy or the ideas of people
- Aligning production capacity with market demand
- Optimising production throughput by replicating and using best practices worldwide

Airbus Corporation, although being in the business of super high value, low volume market with make-to-order operations strategy embedded lean concepts in its Airbus Production System (APS) which is structured framework that contains a number of principles and practices of lean manufacture to provide continuous and sustainable improvement throughout manufacturing and support functions. APS consist of following elements:

- Just In Time and flexible work design to make the production responsive to customer demand.
- Employee empowerment through autonomation
- Supporting enablers
- Culture

TPS, FPS and APS developed by big corporation mainly engaged in discrete environment present the different version of the lean manufacturing framework. These industrial production models are not developed by the academia but by the practitioners.

The literature review revealed a number of lean models comprising of principles, tools and techniques. Though there is not a unanimous agreement on its content, but the work of various scholars shows a number of common principles and practices. The majority of the articles reviewed highlighted elimination of waste, continuous improvement and employee involvement as its guiding principles. It is observed during the process of literature review that in the late 1990s the focus of lean has shifted from the elimination of waste to enhancing customer value through aligning production with the customer demand. The flow concept has been propounded to bridge the gap between production and the customer demand. The prerequisite to the flow concept is the notion of supplier integration. Without establishing a close relationship with the suppliers, the concept of flow cannot be achieved.

The literature review and available industrial production models such as the Toyota Production System (TPS), Ford Production System (FPS) and the Airbus Production System (APS), suggest a lean manufacturing framework consisting of lean goals, lean principles and lean practices (Figure 3.1).

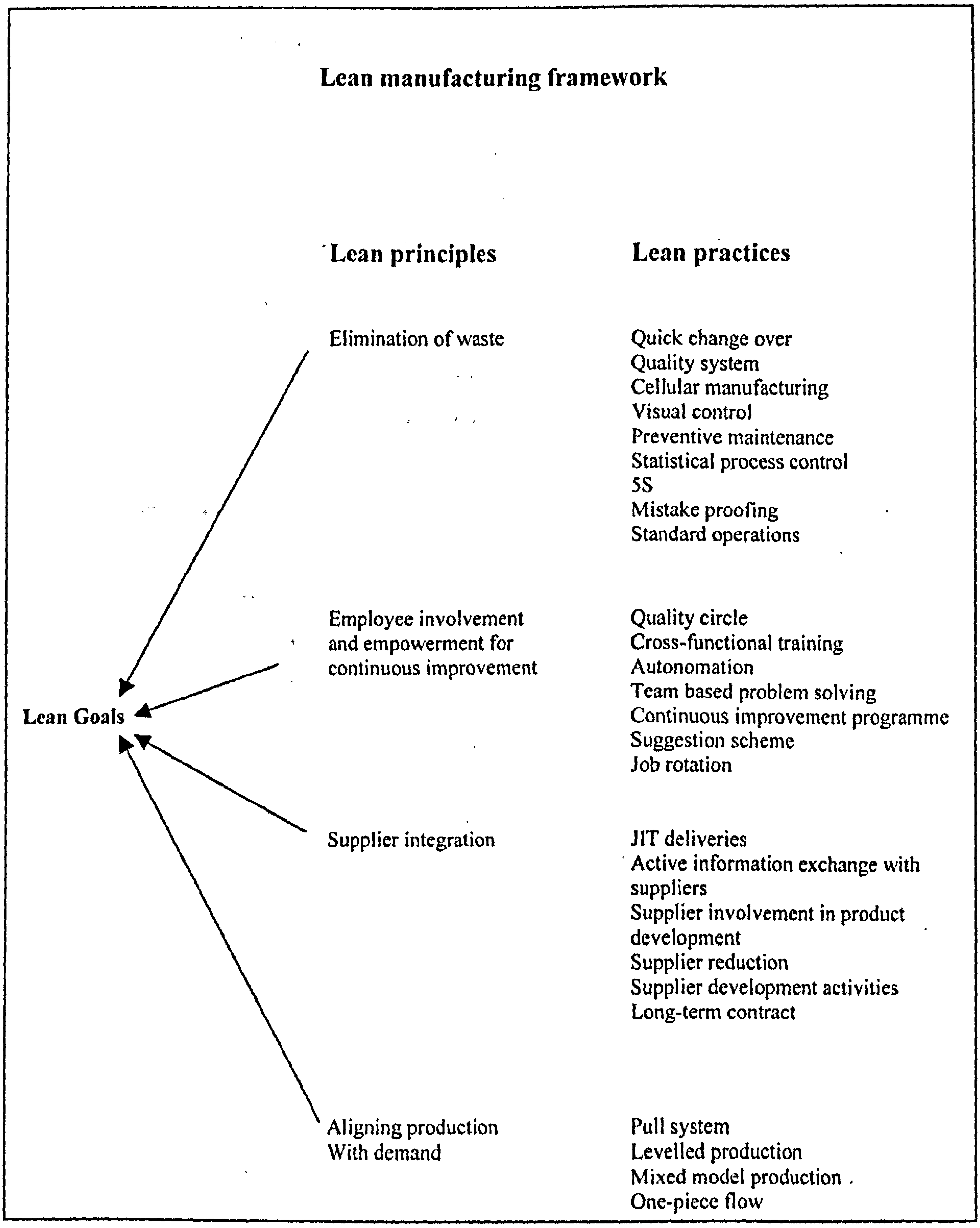

Figure 3.1 Lean manufacturing framework

This framework focuses on fundamental principles of lean (elimination of waste, employee involvement and empowerment for continuous improvement, supplier integration and aligning production with demand). Previous lean framework have not incorporated aligning production with demand as a key principle due to the fact that lean has evolved over a period of time and has become broader in its scope. This framework emphasises on enhancing customer value by improving flow. The focus of the flow is to align demand and supply through the use of pull systems, mixed model production, levelled production and one-piece flow. If demand fluctuates, then the production system should adjust itself to demand, which means that production should start building products only when the customer gives the signal.

3.2.1 Lean Goals

The primary goal of lean manufacturing in a factory or a company is to reduce costs, increase productivity, and improve quality in order to enhance customer value. This view has been confirmed by Monden (1983), Womack et al. (1990), Karlsson and Ahlstrom (1996), Sriparavastu and Gupta (1997), Sanchez and Perez (2001), Yusuf and Adeleye (2002), Scaffede (2002) and Motwani (2003). The Ford Production System's (FPS) operating philosophy is to build a customer-driven product at the lowest cost and in the shortest time with the highest quality. The Airbus Production System aims to achieve the highest quality below a target cost. Whether it is academia or the industrial world, cost reduction without compromising on quality to increase customer value has been given the utmost importance in making a manufacturing plant lean. These lean goals can be achieved by pursuing lean principles and practices in a holistic manner and not in a piecemeal fashion.

3.2.2 Lean manufacturing principles

A review of the literature and available industrial production models such as the Toyota Production System, Ford Production System, the Airbus Production System, revealed a common theme of lean manufacturing being comprised of four principles, namely

1. Elimination of waste
2. Employee involvement and empowerment for continuous improvement
3. Supplier integration
4. Alignment of production with demand

Schonberger (1986), Suzaki (1987), Golhar & Stamm (1991), though, highlighted total quality control as an integral principle of lean manufacturing. Few others have also considered quality assurance/zero defect/quality improvement to be a distinct principle of lean manufacturing (Ramarapu et al. 1995; Karlsson and Ahlstrom, 1997; McLachlin, 1997; Kinnie et al., 1998; Kojima and Kaplinsky, 2003; Mould and King, 1995; Cochran et al., 2000). Although it is agreed that quality has an important place and is a necessary condition for lean manufacturing, it cannot be regarded as an important component in the current business environment. In the 1980s, there was a strong emphasis on quality and quality was considered as an order-winner, but in the last decade, quality has been perceived more as an order-qualifier. Producing defective products in any way is regarded as' waste and should be part of the elimination of waste principle.

The emphasis on management commitment (Mehra and Inman, 1992; Ramarapu et al., 1995), vertical information systems (Karlsson and Ahlstrom, 1997; Crute et al., 2003), product development, chain of supply, shop floor management and after sales service (Warnecke and Huser, 1995) have also been highlighted as significant elements of lean manufacturing. It can be argued that management commitment and vertical information systems are important enablers of lean rather than core lean manufacturing principles.

3.2.2.1 Elimination of waste

The main goal of the lean manufacturing philosophy, as evolved and developed at the Toyota Motor Company, is to lower cost that is primarily achieved through the elimination of waste. The Ford Production System (FPS) approach to lean emphasises the elimination of unnecessary duplication and waste in its processes. Anything that adds complexity, cost and time and doesn't add value for the customer should be eliminated. The elimination of waste is the most fundamental principle of lean manufacturing. Waste here means everything that does not add value to the product (Monden, 1983). Lean manufacturing defines 'value' from the standpoint of customers (external or internal) in terms of specific products and tries to eliminate all waste.

According to Monden (1983), there are three types of operation that are undertaken in a manufacturing context, which can be categorised into:

1. Non-value adding (NVA): Activities such as waiting time, double handling are not necessary even under the present situation. These activities are pure waste and should be eliminated completely.
2. Necessary but non-value adding (NNVA): Activities such as walking long distances to pick up parts, unpacking deliveries may be wasteful but are necessary under the current operating procedures.
3. Value-adding (VA): Activities that involve the conversion or processing of raw materials or semi-finished products for which the customer ultimately pay for.

It is common to find that in a factory, less than 5 percent of activities actually add value, 35 per cent are necessary non-value-adding activities and 60 per cent add no value at all (Womack et al. 1990). In the present business environment, a customer is not willing to pay for non-value adding activity and therefore it must be eliminated.

The literature review revealed that there was unanimous agreement amongst scholars and practitioners on the 'elimination of waste' as an integral principle of lean manufacturing. There are seven commonly accepted wastes, which have been accepted by all scholars and practitioners.

1. Overproduction: This is considered a most serious waste as it prevents the smooth flow of goods or services. It tends to give rise to excessive lead and storage times and also leads to excessive WIP stocks.

2. Waiting: This waste occurs whenever goods are not moving. This waste affects both goods and workers, each spending time inactive.
3. Transport: Any movement in the factory can be viewed as waste. Transporting parts from one location in the plant to another doesn't add value to the product and also adds to the manufacturing lead-time.
4. Inappropriate processing: occurs where a complex solution is developed for a simple problem such as using a large inflexible machine instead of several small flexible ones. Over complexity encourages the employees to overproduce to recover the large investment in the complex machine.
5. Unnecessary inventory: The most important source of waste is inventory. Keeping excess parts and products in stock does not add value and so should be eliminated. It leads to an increase in lead-times, prevents the rapid identification of problems and increases space. Unnecessary inventory creates excessive storage costs. Various ways of reducing the levels of inventory are, to reduce set-up time and change layout to reduce transportation distance for parts. An efficient way of keeping inventory low is through decreasing lot sizes. A reduction of lot sizes also increases flexibility, making the switching between different products much easier. A reduction in set-up time is often essential for the elimination of waste.
6. Unnecessary movements: involves the ergonomics of production where an operator has to stretch, bend and pick up when these actions could be avoided.
7. Defects: A manufacturing part that is defective and therefore needs to be reworked is wasteful. In a lean system, quality assurance is the responsibility of everyone. This means that identification of defective parts is the responsibility of workers, not a quality control department. Workers are empowered to stop the line in the event that defective parts are found. A prominent feature of a lean system is the lack of employees dedicated to quality control. Instead of inspecting manufactured parts after a potential problem has occurred, the manufacturing process is kept under control to prevent defects from occurring in the first place. Producing fault free parts is a prerequisite to the implementation of a pull system.

3.2.2.2 Employee involvement and empowerment for continuous improvement

The literature also outlines the importance of employee involvement and empowerment for the purpose of continuous improvement (Table 3.1).

Literature	Lean principles: Employee involvement and empowerment for continuous improvement
Monden (1983)	Effective utilisation of human resources
Womack et al. (1990)	Transferring the task and responsibilities to front line workers
Schonberger (1986); Suzaki (1987); Hay (1988); Sakakibara et al. (1990); Golhar & Stamm (1991); Jones (1992); McLachlin (1997)	Employee involvement
Mehra and Inman (1992)	JIT education strategy
Womack and Jones (1994)	Striving for continuous improvement
Oliver et al. (1994)	Team based work, continuous improvement high commitment human resource policies,
Ramarapu et al. (1995)	Employee participation,
Mould and king (1995)	People involvement,
Hum and Ng (1995)	Strive for ongoing improvement
Spencer and Guide (1995)	JIT human relations strategy
Forza (1996)	Worker involvement,
Oliver et al. (1996)	High commitment human resource policies, team based work organisation
Hallihan et al. (1997); Fullerton et al. (2003); Perez and Sanchez (2000); Kojima and Kaplinsky (2004)	Continuous improvement,
Karlsson and Ahlstrom (1997)	Continuous improvement, multifunctional team, decentralised responsibilities, integrated function,
James-Moore and Gibbons (1997)	People utilisation,
Kinnie et al. (1998)	Involvement of all employees in a continuous process to improve product and job design, team working approach
Panizzolo (1998)	Improvement programme in human resources
Lewis (2000)	Commitment to continuous improvement enabled by people development
Simons and Zokaei (2005)	Kaizen (continuous improvement), enhanced problem solving ability of employees, enhanced employee participation,

Table 3.1: Employee involvement and empowerment for continuous improvement and key references in the literature

The employee involvement is evidenced through:

- empowering workers to interrupt product flow whenever they notice defects
- helping each other in the group and rotating the positions within the work group
- participation of each worker in the continuous improvement of the work system (Forza, 1996).
- contribution of ideas towards the continuous improvement of the work system.

A key element in the development of lean manufacturing has been on the organisational side, in particular the involvement of the individual. A lean organisation creatively involves employees by using their contribution in decision making and broadening their workplace skills (Hall, 1987; Schonberger, 1982). It shifts the maximum number of tasks and responsibilities to those workers actually adding value to the product, and has in place a method for detecting defects that quickly traces every problem, once revealed, to its final cause (Womack and Jones, 1990).

Forza (1996) also outlined that lean manufacturing plants are characterised by more

- use of small team problem solving,
- worker suggestions for improvement,
- decentralisation of authority
- use of multifunctional employees
- contact between managers, engineers and workers
- commitment to continuous quality improvement

Workers in a lean plant are expected to be multi-skilled operators, who can run multiple machines, do their own quality control and improve their own performance. Multi-skilled operators are important in a lean system in order that the manufacturing system can cope with the changes of mix and volume. This workforce flexibility supports production scheduling. Cross functional training helps in developing a flexible workforce that is capable of shifting to the place in the process where they are needed most to facilitate a smooth production flow. Cross training of workers is considered critical to the success of lean implementation (Inman and Mehra, 1993; Spencer and guide, 1995).

In a lean plant, where a customer regulates production pull, a worker cannot produce another unit until the worker at the next station gives the signal for the requirement of another unit. The output of each workstation is linked to the output of the other workstations. This situation requires that all workers must act as a team rather than as individuals. A greater empowerment of workers is also inherent in teamwork and group problem solving (Im and Lee, 1989). Working in a team allows decision making to be decentralised, which can help in managing uncertainty (Forza, 1996). In the lean plant, operators on the shop floor are organised into small groups, and these small groups accepts many of the tasks that have been earlier part of a specialist support groups (Oliver et al., 1996). Small group problem solving activities often provide solutions to production related problems leading to improvements in waste reduction and manufacturing cycle time (Sakakibara et al., 1997). It also leads to quality improvement and more control of the production processes.

Continuous improvement programmes are deep rooted at the core of lean manufacturing and require the involvement of all production employees (Sanchez and Perez, 2001). They encourage incremental improvements and individual problem solving skills at every level of the organisation. In the lean system, employees are motivated to participate in the decision-making process concerning production. Problems on the shop floor are opportunities for improvement of the process (Imai, 1997). It creates a willingness to deal with problems as soon as they occur. It also reinforces autonomation, which means autonomous authority of workers to stop production when abnormality occurs. The Toyota Production System describes *Jidoka*, where production workers have the ability to stop the production line.

Employee involvement for continuous improvement is achieved through quality circles and suggestion schemes. Quality circles provide the operators with the opportunity to make inputs to improve the system. Team-based systems of work organisation offer a more responsible and challenging work experience. The number of suggestions per employee per year and the percentage of suggestions, which are implemented, are indicators of employee involvement and participation (Karlsson and Ahlstrom 1997; Perez and Sanchez 2000). In lean plants, the workers contribute to the improvement of the work system through making appropriate suggestions.

Practices such as transferring the task and responsibilities to front line workers, team based work, JIT human relation strategies, enhanced problem solving abilities of employees, high commitment to human resource policies are employed to create an environment where employees use their hearts (attitude), hands (physical work) and heads (thinking) in a synergistic way to improve the work system continuously.

3.2.2.3 Supplier integration

Lean principles, particularly the elimination of waste and aligning production with demand, depend to a great extent on the role of suppliers. Hobbs (1997), Lee (1996), Minahan (1996), Romero (1991) and Wafa et al. (1996) stressed the significance of having a strong working relationship with suppliers. Success and failure in lean is directly correlated to the ability to establish supplier relationships that provide seamless supply. The timing, quality and quantity of deliveries of raw materials become vital when there is little or no safety stock in the system. In a lean plant 100% quality parts and materials need to arrive at the process when required. Suppliers must deliver parts and materials frequently in small quantities directly to the point of use, with minimal receiving checks (Womack and Jones, 1990; McIvor, 2001).

In a lean plant, buyers and suppliers need to work jointly as one cohesive team with long-term relations. The rapport between suppliers and customers along the value stream is critical to achieve leanness, hence the importance of supplier integration

(McIvor 2001). Close association with suppliers can offer a flow of merchandise from supplier to customer without waste (Lamming 1996).

Supplier integration has been well rooted in the literature with a number of scholarly articles highlighting the role of the supplier in creating a lean manufacturing system.

Literature	**Lean principle: supplier integration**
Suzaki (1987); Womack et al. (1990)	Close integration with supplier
Golhar & Stamm (1991); Ramarapu et al. (1995)	Supplier participation
Mehra and Inman (1992)	JIT vendor strategy,
Oliver et al (1994)	Close relation with suppliers,
Spencer and Guide (1995)	JIT vendor strategy,
Lamming (1996)	Lean supply
Oliver et al. (1996)	Active information exchange with supplier, , long term relationship with supplier,
Levy (1997)	Close relationship with suppliers
Kinnie et al. (1998)	Involvement of all suppliers in a continuous process to improve product, close relationship with component suppliers
Panizzolo (1998)	Improvement programme in supplier relationships
Naylor et al. (1999)	Integrated supply chain,
Perez and Sanchez (2000)	Supplier integration,
McIvor (2001)	Concept of lean supply
Simons and Zokaei (2005)	Cooperation and transparency across supply chain,

Table 3.2: Supplier integration and key references in the literature

Supplier integration was introduced first in the automotive industry and one of the pioneers of this was Toyota. Toyota structured its suppliers into different functional tiers with suppliers in each tier having different responsibilities. Toyota's first tier suppliers were assigned the task of working with the product development team. The Toyota philosophy was to encourage all the first-tier suppliers to communicate and share information with each other in order to improve the design process.

In the case of the automotive industry, the emphasis on the supply system was natural, as a large part of the manufacturing value of a vehicle is provided by component suppliers. It is estimated that purchased materials account for between 50 per cent and 80 per cent of the total cost of a manufactured product. It is further estimated that suppliers account for 30 per cent of the quality problems and 80 per cent of the product lead-time (Inman, 1990; Willis and Huston, 1990; Burton, 1988) so an organisation's inbound supply chain provides considerable scope for cost reduction.

Several reports published by IMVP have concentrated on the supply side (Lamming, 1993). Womack et al. (1990) devoted a chapter to emphasise the supplier's role in creating a lean manufacturing system. Lamming (1993) proposed a lean supply model of customer-supplier relationship based on the Japanese experience with automotive companies.

An ideal lean plant requires small but frequent deliveries of total quality parts from single sourced local suppliers with whom there is a close relationship based on mutual dependency and frequent communications. The supplier and manufacturer work together with a long-term perspective and where contracts are not awarded on the basis of price (Oliver et al., 1996). Good supplier relationships typically result from an open communication channel (Sohal and Egglestone 1994) with suppliers, which requires an active, regular and transparent information exchange dealing with all aspects from delivery performance to quality levels (Levy, 1997). To integrate suppliers effectively there needs to be an active exchange of data between the supplier and manufacturer and vice versa (Perez and Sanchez, 2000). The exchange of data may include schedule changes, design modifications, engineering changes and quality or delivery problems thereby increasing supplier responsiveness to change (Harrison and Voss, 1990).

Reducing a supplier base promotes good buyer/supplier relationships. It has been argued that multiple sources of supply increase the difficulty of managing the coordination of production scheduling and relationships (Manoochehri, 1984). A reduced supplier base permits the supplier to enter into a long-term contract and also realise the synergistic effects through effective coordination. A long-term relationship with the supplier promotes loyalty and reduces the risk of an interruption to supply (Schonberger and Ansari, 1984). It also ensures that cost is reduced in the long-term. Reducing the supplier base can enable suppliers to achieve substantial economies of scale (MacDuffie and Helper, 1997). The manufacturer will be able to reduce buffer stock when there is sufficient confidence in the supply relationship with vendors.

The supplier can play a significant role in the customer's components design/development and may help to reduce prototype development times (Sanchez and Perez, 2001). When suppliers are not involved in the component design, the manufacturer has to invest extra time and resources to solve any problem their supplier comes across during manufacturing the part that they have not designed (Cusumano, 1994). The idea here is that buyer and suppliers are locked together in a long-term relationship (Oliver et al., 1996). Another consequence of supplier involvement is the decrease in the number of suppliers and the increase in the length of contracts for the main components (Cusumano and Takeishi, 1991). This increased permanence in the contract allows the supplier to reduce lot production sizes and to increase the frequency of deliveries.

3.2.2.4 Aligning Production with Demand

Until the 1990s this principle was not given due importance and was often clubbed with the elimination of waste principle. It was thought that a mismatch between demand and supply creates waste and hence should be eliminated. Practices such as pull systems, mixed model production and one piece flow were considered as lean practices pertaining to the elimination of waste principle. In the mid 1990s, the lean concept further evolved and the principle of flow was highlighted by Womack and Jones (1996). Flow was seen as an important building block of the lean approach to align production with demand. The focus of the flow was to bridge the gap between demand and supply through the use of pull systems, mixed model production, levelled production and one-piece flow. The production system should produce only what is demanded by the end customer, no more and no less. If demand fluctuates, then the production system should adjust itself to demand, which means that production should start building products only when the customer gives the signal.

Alignment of production with demand and the elimination of waste principles are not mutually exclusive, rather both support each other. Essentially the elimination of waste helps to make the flow work by removing non-value added activities from the system and making the system more responsive to demand. It organises all the essential, value-creating production activities into the most efficient processes and makes the process flow with minimised interruption and variation. On the other hand, the elimination of waste necessitates the creation of product flow, through making production aligned to customer demand.

The key to success is the ability of companies to adapt to customer requirements and the only way to achieve this will be through producing at the pace of customer demand with little or no waste (Shah and Ward, 2003). This principle has been highlighted by the Toyota Production System as well as the Ford Production System. According to Monden (1997), the main goal of the TPS is to increase profits by reducing costs through the elimination of waste. In order to reduce cost, the production must quickly and flexibly adapt to changes in market demand without having wasteful buffers. This can be achieved through the concepts of pull systems and levelled production, which are essential ingredients for establishing flow in order to become lean. One of the basic principles of the Ford Production System is to align capacity with market demand by making full use of available capacity to schedule and build vehicles and components to satisfy the immediate demand (Marshall and Leaney 2001).

Various scholars have highlighted this lean principle with different words but connoting the same meaning (Table 3.3).

Literature	Lean principles: Aligning production with demand
Monden (1983)	Alignment of production system to demand fluctuation
Suzaki (1987)	Smooth production flow
Shingo (1989)	Production to order
Womack et al. (1990)	Pull production with smoothed demand,
Mehra and Inman (1992)	JIT production strategy
Womack and Jones (1994)	Continuous flow, alignment of all production activities
Ramarapu et al.(1995)	Production strategy
Mould and king (1995)	Alignment of flow with demand rate for the finished product
Spencer and Guide (1995)	JIT production strategy
Forza (1996)	Synchronic flow
Oliver et al. (1996)	Tightly integrated material flow
Karlsson and Ahlstrom (1997)	Just in time, pull instead push
McLachlin (1997)	Flow concept
Levy (1997)	Responsiveness to changing demand (Flexible manufacturing)
Kinnie et al. (1998)	Integrated production chain
Panizzolo (1998)	Improvement programme in process and equipment, manufacturing planning and control, and customer relationships area
Naylor et al. (1999)	Smooth demand/level scheduling
Storch and Lim (1999)	Alignment of value creating production activities, continuous flow
Yingling et al. (2000)	Continuous flow
Lewis (2000)	Improving flow of material and information, customer pull
Perez and Sanchez (2000)	Just in time
Cochran et al. (2000)	Pull system
Shah and Ward (2003)	Produce at the pace of customer demand
Crute et al. (2003)	Integrated production
Simons and Zokaei (2005)	Long term relationship with customer, cooperation and transparency across supply chain

Table 3.3: Aligning production with demand and key references

A lean manufacturing system aligns production to changing market conditions through information flow, which moves upstream, and through forward movements of the production flow pulled by the downstream needs which stems from the market (Womack et al., 1990; Forza, 1996; Sanchez and Perez, 2001). The starting point for manufacturing in a pull system is a customer order, which goes to final assembly and which orders parts from an upstream manufacturing process. Pull scheduling requires reduced batch sizes and fault-free parts. A Kanban system is just a means to operationalise a pull system and requires production smoothing to level the quantities and variety in the withdrawal of parts by the downstream process (Monden 1983). Only pull systems can expose all the problems at source, thus ensuring their elimination and driving the continuous improvement of the production system. A pull system also drives the use of visual controls, continuous improvement activities and the delegation of authority to front line employees.

3.2.3 Lean practices

Twenty-six best practices commonly associated with lean manufacturing have been identified on the basis of the review of the literature (See Chapter 2, Table 2.16). Table 3.4 summarises all lean practices. These practices have been classified with regard to four lean principles (elimination of waste, employee involvement and empowerment for continuous improvement, supplier integration and aligning production with demand). Lean practices such as Quick change over, Quality system, Cellular manufacturing, Visual control, Preventive maintenance, Statistical process control, 5S, Mistake proofing and standard work/operations belong to the elimination of waste principle.

Quality circle, cross trained/multifunctional workforce, autonomation, team based problem solving, continuous improvement programme, suggestion scheme, job rotation are deployed to involve employees in the process of continuous improvement.

JIT deliveries, active information exchange with suppliers, supplier involvement in product development, supplier reduction, supplier development activities, long-term contract helps in building closer relationships with suppliers as they are considered to be an important part of the value chain.

Pull systems, levelled production, mixed model production, one-piece flow are aimed at reducing the mismatch between demand and production. They all serve the purpose of making the flow smooth. These practices represent the multi-dimensional nature of lean manufacturing.

The lean manufacturing framework that consists of goals, principles and practices has been used to first ascertain the leanness of the food and drink plants selected for the study and then it was employed to identify reasons for the lack of its applications in the food and drink plants. The framework has been used as a reference framework to develop a suitable lean approach for the food and drink industry.

	Lean practices	Description
	Elimination of waste	
1	Set up time reduction/ Quick change over	An organized, scientific approach for reducing the amount of time, it takes to change a machine from producing one product to another.
2	Cellular manufacturing/ U shaped cell/ Flow cells	Manufacturing in a layout in which all or most of the parts and machines necessary to complete a part or assembly are in close proximity of one another. Production workstations and equipment are arranged in a product-aligned sequence that supports a smooth flow of materials and components through the production process with minimal transport or delay. It aims to move products through the manufacturing process one-piece at a time and at a rate determined by customer demand
3	Visual control	Use of visual signs and signals to communicate the status of an operation or production line. Visual controls include any graphical marking or other visual signal that serves as a quick and complete communication to an operator or manager. Some examples are andon lights, in-process kanban, schedule boards, standard work-in-process, color coded inventory boxes, defect bins, visually displayed tool, locations, etc.
4	Mistake proofing/ Poka-yoke	The use of fixturing and tooling to eliminate or reduce the possibility of errors being made in the assembly of the product. It uses sensors or other devices to detect errors that could cause defects.
5	Preventive maintenance	A maintenance strategy in which machines are checked or parts are replaced at specified time increments or machine (part) usage. It is a series of routines, procedures and steps that are taken in order to identify and resolve potential problems before they happen. It is essential for minimizing machine down time due to breakdowns
6	Statistical process control	Use of control charts to study processes and determine when the process is out of control.
7	5S/ house keeping	Five Japanese practices Seiri (sifting), Seiton (Sorting), Seiso (Sweeping), Seiketsu (Standardise), Shitsuke (Sustain) provide a methodology for creating and maintaining a clean organised workplace environment.
8	Standard work/ standard operating procedure	Defined as the best way of doing the job. It shows what, where, when and how tasks should be carried out to ensure customer satisfaction.
9	Quality system	This program attempts to establish quality as the top priority of the organisation's business objectives. It includes involvement in the quality efforts by all functions, employees and suppliers.

Table 3.4: Lean practices and their description

	Lean practices	Description
	Employee involvement and empowerment for continuous improvement	
10	Quality circles	An employee participation programme to involve employees in problem solving and decision making activities through the use of a facilitator.
11	Cross functional training/	Workers are trained and scheduled to do multiple jobs, thereby increasing the flexibility of the workforce to move to different cells and lines dependent upon the demand fluctuations.
12	Autonomation /Jidoka	Giving the operator the ability to stop an assembly line or cell flow when an error is detected in the process and designing a machine to stop automatically when it detects an error in the production process.
13	Continuous improvement programme	A focused improvement activities in which a cross-functional team spends several days analysing and implementing improvements in a specific work system
14	Team based problem solving	Solutions to problems that arise in the production process are generated at daily or weekly meetings facilitated by the operators affected.
15	Suggestion Scheme	Ideas contributed by employees for improving the work place.
16	Job rotation	Moving the worker regularly from one workstation to another so as to reduce monotony associated with the type of job.
	Supplier integration	
17	JIT deliveries	Suppliers deliver the right part, at the right place at the right time. It involves frequent delivery of parts in small lot sizes.
18	Active information exchange with supplier	The exchange of data pertaining to schedule changes, design modifications, quality problems, costs and volume electronically between the supplier and the customer.
19	Supplier involvement in product development	Involvement of supplier in the early design stage to shorten prototype development times
20	Supplier development activities	Customer helps the supplier in improving the quality of the parts supplied and reducing the costs.
21	Supplier reduction	Using fewer and more capable suppliers thereby ensuring that the buying company becomes an important customer to the supplier.
22	Long-term contracts	Awarding the purchase contracts for longer period to enforce a long-term relationship and reduce the risk of an interruption to supply. The contract is extended unless the supplier fails to deliver to the standards set by the customer

Table 3.4 continued

	Lean practices	Description
	Aligning production with demand	
23	Pull system	Consumption based replenishment system. Production is authorised only to replenish material that has been consumed by a downstream operation or by an internal or external customer.
24	Uniform plant load/levelled production	Development and use of a consistent and repetitive schedule across product offerings. The product/unit mix each day would be the same. A variation to the demand is handled through varying the frequency of the product/unit mix.
25	One-piece flow	Ability to make one part at a time without unplanned interruption or lengthy queue times This is contrasted with batch production, in which more than one part is processed at a station before moving to the next station.
26	Mixed model production	The ability to make several products on the same line in a random or sequenced order without a massive amount of changeover time.

Table 3.4: continued

3.3 Summary

This chapter discussed the need for developing a lean manufacturing framework. On the basis of the literature and available industrial production models, a lean manufacturing framework (see Figure 3.1) consisting of lean goal, lean principles and lean practices has been suggested.

Four lean principles (elimination of waste, employee involvement and empowerment for continuous improvement, supplier integration and aligning production with demand) have been identified which are highlighted by the majority of scholars and practitioners. Twenty-six lean practices, identified during the literature review were categorised with regard to these lean principles.

Chapter 4

Research Methodology

4.1 Introduction

This chapter presents an overview of the research methodology. It focuses on the overall research plan, data collection procedure and techniques that are based on the research questions as described in Chapter One. The overall research plan is summarised in Figure (4.1).

Two important components (the literature review and the lean manufacturing framework) of the research plan have already been discussed in Chapter 2 and Chapter 3. Section 4.2 presents a food and drink industry classification on the basis of transformation system characteristics. The need for the classification stems from the fact that the food and drink industry is not one industry but a collection of several types of industry producing a diverse range of products and employing a varied range of processes. The classification helps to understand the scope of lean manufacturing in the food and drink industry. The review of the literature also revealed that there has not been any attempt to develop a classification for the food and drink industry transformation system.

Section 4.3 presents the rationale for the strategy selected for this research investigation. Section 4.4 discusses a selection of cases in the field. Section 4.5 presents various data collection methods employed in the research inquiry. Various stages of case analysis are described in section 4.6.

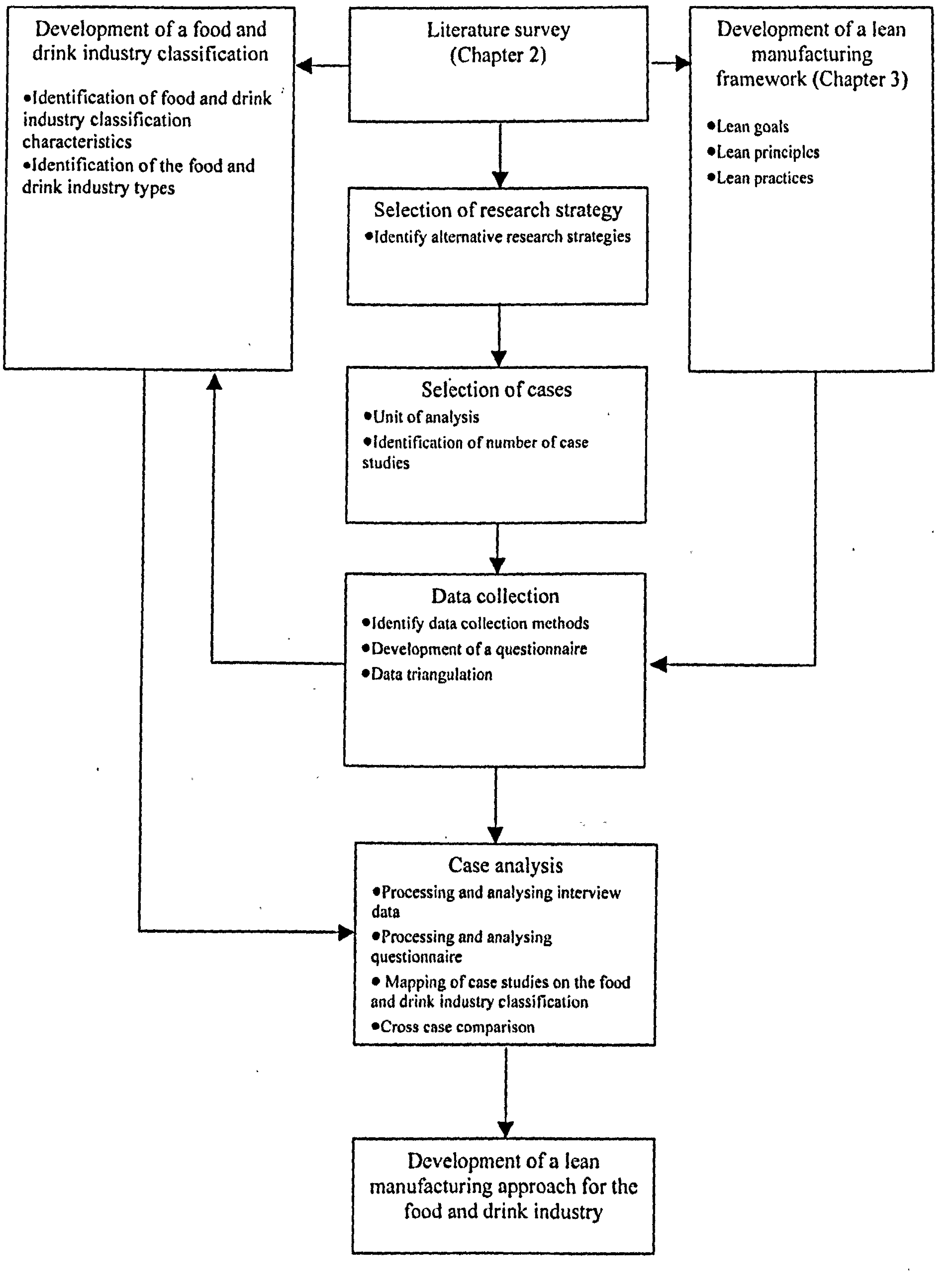

Figure 4.1: Research plan

4.2 Development of the Food and Drink Industry Classification

A classification of production systems offers researchers and managers to better understand the specificity of the production systems. According to Melcher et al., (2002) production system classification enables us to take managerial decisions regarding the choice of a new production system . A production system classification for the food and drink industry can provide with an improved understanding of the management of a wide variety of production systems employed in this sector. It is also sought to find whether or not the adoption of a lean manufacturing approach is dependent on the food and drink industry types and if so, what aspects of lean manufacturing is relevant to each food and drink industry type.

Although the UK Standard Industrial Classification System (SIC) 2000, classifies the food and drink industries on the basis of type of economic activities in which they are engaged, this classification is one dimensional and does not take into account the differences in product/process/market characteristics across all food and drink industries. From a production system point of view, it does not differentiate various food industries in a meaningful way. Apart from the UK SIC 2000 classification, no other classification of the food and drink industry has been reported in the literature.

Although the literature is devoid of an appropriate food and drink industry classification system, a few scholars Taylor et al. (1981), Fransoo and Rutten (1994), Dennis and Meredith (2000)) have suggested a classification of the process industry (Chapter 2). The food and drink industry has been perceived to be part of the process industry as it employs process manufacturing and often handles non-discrete materials.

Considering the food and drink industry as a subset of the process industry, the classification of the food and drink industry has been developed on the basis of visits to various food plants and the overall classification frameworks of Fransoo and Rutten (1994) and Dennis and Meredith (2000). Fransoo and Rutten's (1994) process /flow batch/mix continuum and Dennis and Meredith's (2000) generic type of process industries (intermittent, continuous and hybrid) suggest that the food and drink industry can be at least segregated into three groups. Although Dennis and Meredith (2000) have also proposed seven subtypes of process industries, these have not been further verified by other studies and were treated as tentative propositions. Taking Fransoo and Rutten (1994) and Dennis and Meredith's (2000) process industry classification as a starting point, a food and drink industry classification, consisting of three groups (continuous, batch and assembly) based on 11 characteristics, is proposed. These three groups represent continuous, hybrid and intermittent types of production systems.

4.2.1 Characteristics used for the Classification of the Food and Drink Industry

The literature suggests that the food and drink industry differs with respect to product and process characteristics. Table 4.1 identifies a total of 11 characteristics considered as significant for the purpose of classification. There are significant differences in the variety of ingredients used in the food industry. Edible oil, sugar and wheat flour plants have to deal with a few ingredients whereas chilled and frozen ready meal plants use a large number of ingredients per product as well as total number of ingredients. The total number of ingredients managed by a food plant is a function of the product variety and number of ingredients per product. The management of a large number of ingredients also gives rise to increased supply chain complexity. Oil and sugar processing plants have relatively simple supply chain structures when compared to, for example a convenience meal plant.

The level of capital intensity has an inverse relationship with the number of production employees. Oil, sugar and brewery plants are all characterised by a high level of capital intensity but a low number of production employees, whereas convenience meal plants are characterised by low capital intensity but have a large number of production employees.

The point of discretisation, which represents the point in a manufacturing process where a product becomes discrete, is generally at the point of containerisation. However, in the food industry it varies with the type of industry within its realm. There are food industries such as edible oil, sugar, soft drinks and breweries where products becomes discrete at the point of containerisation like the process industry, whereas food plants that produce ready chilled meals, frozen convenience meals, sandwiches become discrete relatively early in the process.

Characteristics	Description
Number of ingredients per product (Low/moderate/high)	Total number of raw materials required to make a finished product
Product variety (Low/medium/high)	Number of different finished products
Main operations	Value adding operations to convert raw materials to finished products
Level of capital intensity (Low/medium/high)	Money spent in plant and machinery
Equipment type (General/specialised)	Ability to produce different types of products
Number of production employees (Low/medium/high)	Number of employees on the shop floor
Level of flow interruption (Low/medium/high)	Degree of continuity of material flow
Number of routings (Low/medium/high)	Number of different paths available in the system for conversion process
Decoupling point (Early/middle /late)	Measure of customer order penetration
Point of discretisation (Early/middle /late)	Point where nondiscrete material becomes discrete in the material flow
Supply chain complexity (Low/medium/high)	Function of number of suppliers and supply chain levels

Table 4.1 Food and drink industry classification characteristics

Flow interruption, routings and equipment type relate to the diversity of the materials, which are processed by the transformation system. The equipment dimension determines the product variety, which the transformation system can produce. Location of the decoupling point determines how the transformation system copes with the fluctuation in demand.

Many other characteristics such as run time and product volume have not been considered relevant for the classification. The majority of food plants have a short run time, generally less than a day, except in the case of brewery and cheese plants.

A brewery plant has a long run time, often more than two weeks, because of the nature of the fermentation process. Dennis and Meredith (2000) have considered run time to be an important variable for the purpose of a classification of the process industry, which cannot be considered as an important variable for the food industry classification.

In contrast to discrete industries, where product volume is an important differentiating variable, either producing low volume (e.g. ships, aeroplanes, etc.) or high volume (car, electronic components etc), the food industry is engaged in high volume production. This is due to the fact that the food industry deals with low product costs in high capital-intensive environments. So product volume has not been considered as an important classifying variable.

4.2.2 The Food and Drink Industry Types

The food and drink industries share numerous characteristics due to the fact that they handle nondiscrete perishable materials. They are typically clubbed together as a general group. Consequently, the distinctions between different food and drink industries are not well understood. The visits to a number of food and drink plants as well as the literature suggest that the food and drink industry can be segregated into three groups from a production system point of view. These three groups were termed as continuous, batch and assembly.

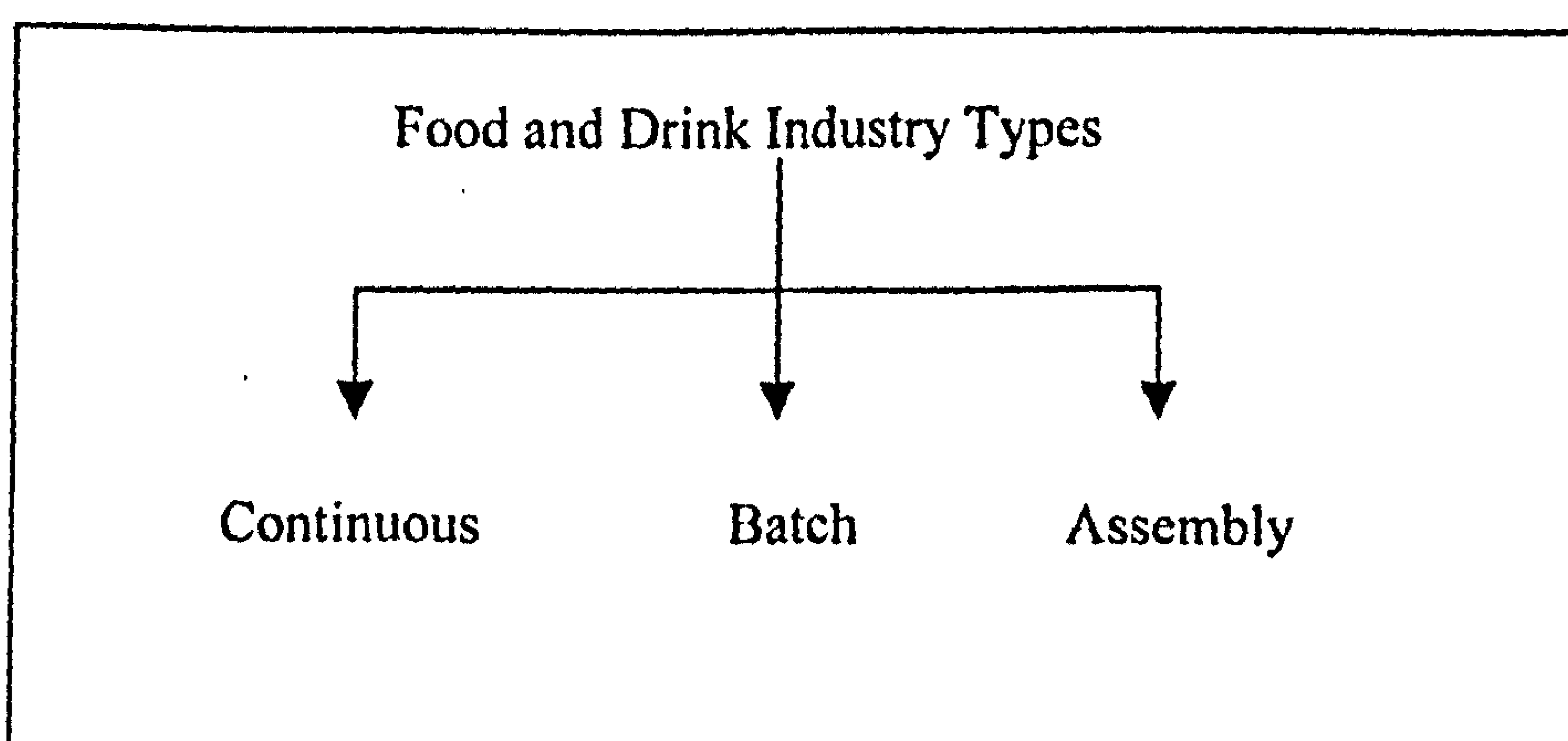

Figure 4.2: The Food and Drink industry types

These groups are organised by *how products are manufactured* and not by the *specific end product*. The groups were formed on the basis of Dennis and Meredith's

(2000) process industry classification. Dennis and Meredith (2000) has segregated the process industry into three generic groups: continuous, hybrid and intermittent.

The food and drink industry groups present a continuum from continuous, to intermittent type production systems. Continuous food and drink industries portray the characteristics of Dennis and Meredith's (2000) continuous group. The food and drink plants producing sugar, milk etc. can be placed under continuous food and drink industry. The group in the middle of the intermittent–continuous continuum is hybrid of an intermittent and continuous type transformation system. This group is termed 'batch' due to the fact that the plants under this group produce the goods in batches. The food plants under this group generally employ mixing and forming processes which requires mixing vessels. These mixing vessels have to be cleaned before it could produce another product variety which means goods have to be produced in batches. The group 'assembly' represents an intermittent type production system where various components that make the end products are assembled and packed. The components/ingredients are assembled in a predefined sequence and on to a predefined place. The visits to convenience meals, frozen food and sandwich plants also confirmed the naming of this group as "assembly" and not "discrete"/ "intermittent". Plant managers of these plants had a view that their process was similar to the assembly line of discrete manufacturing system such as an automotive plant. The segregation of the food and drink industry into three groups show that the production of beer has more in common with the production of sugar than it does with the production of sandwiches.

4.2.2.1 Characteristics of Continuous Food and Drink Plants

This group is characterised by few routings, little equipment flexibility and limited product variety (Table 4.2). All products follow the same routings. Commodity products such as pasteurised milk, edible oil & sugar are produced in these types of plant. For most of the time the product is in a non-discrete form, so products cannot be mixed in the same storage container, which requires cleaning during the switching from one product to another. This also puts a constraint on the production of a large product variety.

There are very few types of main raw materials/ingredients required to make one complete product. Their cost represents a major part of the total production cost. This makes the supply chain relatively simple, as only a few raw materials have to be procured. The plants procure their raw materials in bulk in order to remove the uncertainties with its availability. The bill of material is divergent which means more products are produced from a few raw materials (figure 4.3). Sometimes by-products are also produced during the flow of goods.

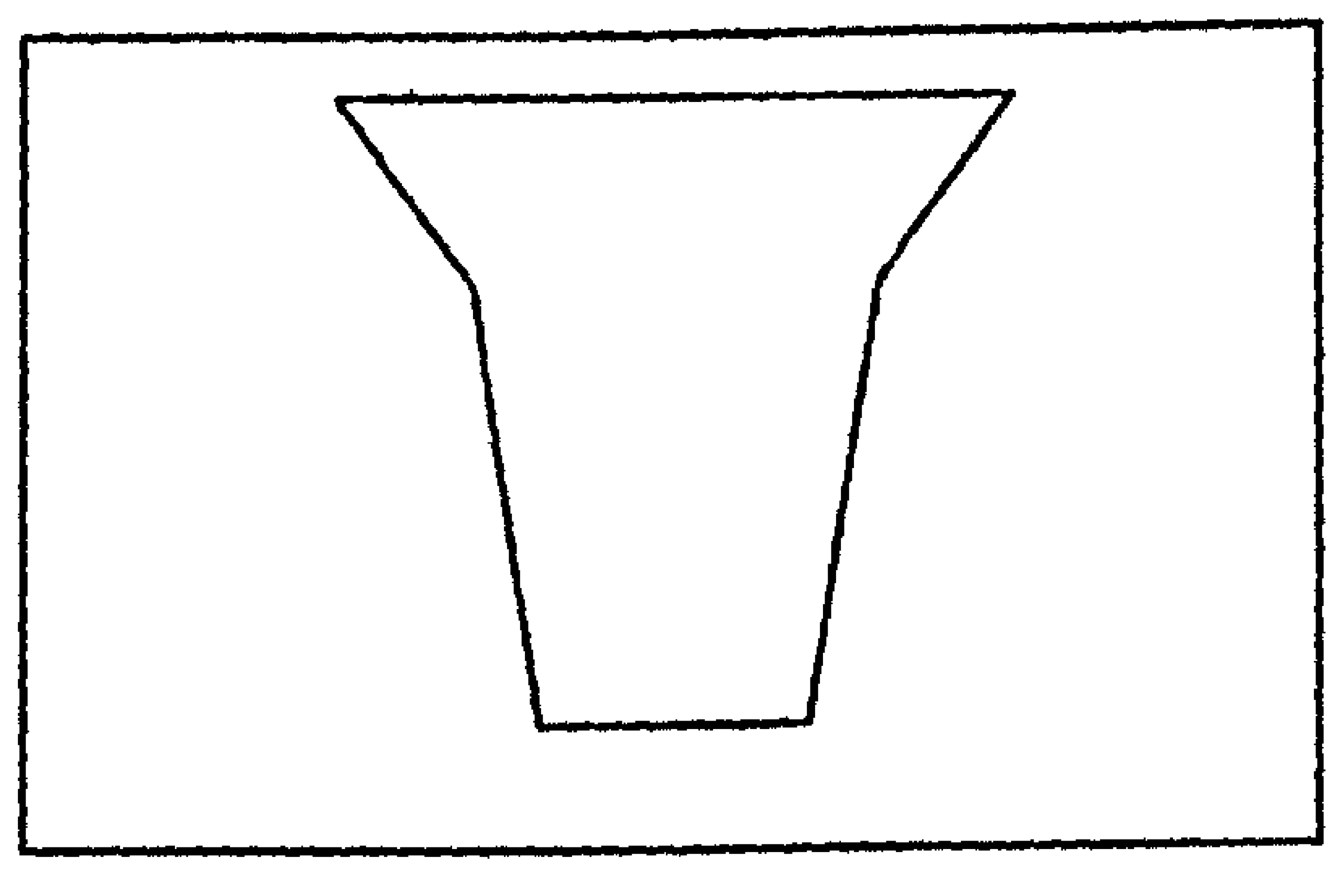

Figure 4.3: Bill of material in continuous food and drink plants

The main operations employed in such plants include disintegration, separation and dehydration and fermentation. These require special purpose equipment. There is hardly any interruption in the material flow and the product follows one route. The equipment is arranged according to the sequence of operations and is connected together by pipelines. This production arrangement means the decoupling point location is at the end of the flow of goods. Customer orders are fulfilled from the finished goods stock. There are a very few intermediate stock points which can be thought of as decoupling points.

The point of discretisation (POD) is very late and the product becomes discrete only during the packing stage. Processes before POD are mostly continuous and coupled to each other requiring little manual intervention. For example, in an edible oil plant, where the product does not become discrete until the final stage in the manufacturing process at which point, the oil is filled and packed into bottles/containers. Throughout the production stages the process is continuous. Little manpower is used to monitor the process as all processes are highly automated.

4.2.2.2 Characteristics of Batch Food and Drink Plants

This group deals with a large number of ingredients and moderate product variety (Table 4.2). Both general-purpose equipment, such as ovens as well as special equipment is employed. A few of the processes use a continuous type operation and a few are of an intermittent type. Overall flow interruption can be said to be moderate.

Operations are mainly mixing and forming. Mixing operations require a large number of ingredients. Products are produced in batches and the batch size is limited by the equipment size. For example, the production of butter requires churning of cream in a churner and the size of the churner determines the batch size.

The bill of material is convergent until the packing stage and then it becomes divergent because the packing line offers the same product to be packed in different sizes and forms (figure 4.4). There is relatively few routings when compared to an assembly group.

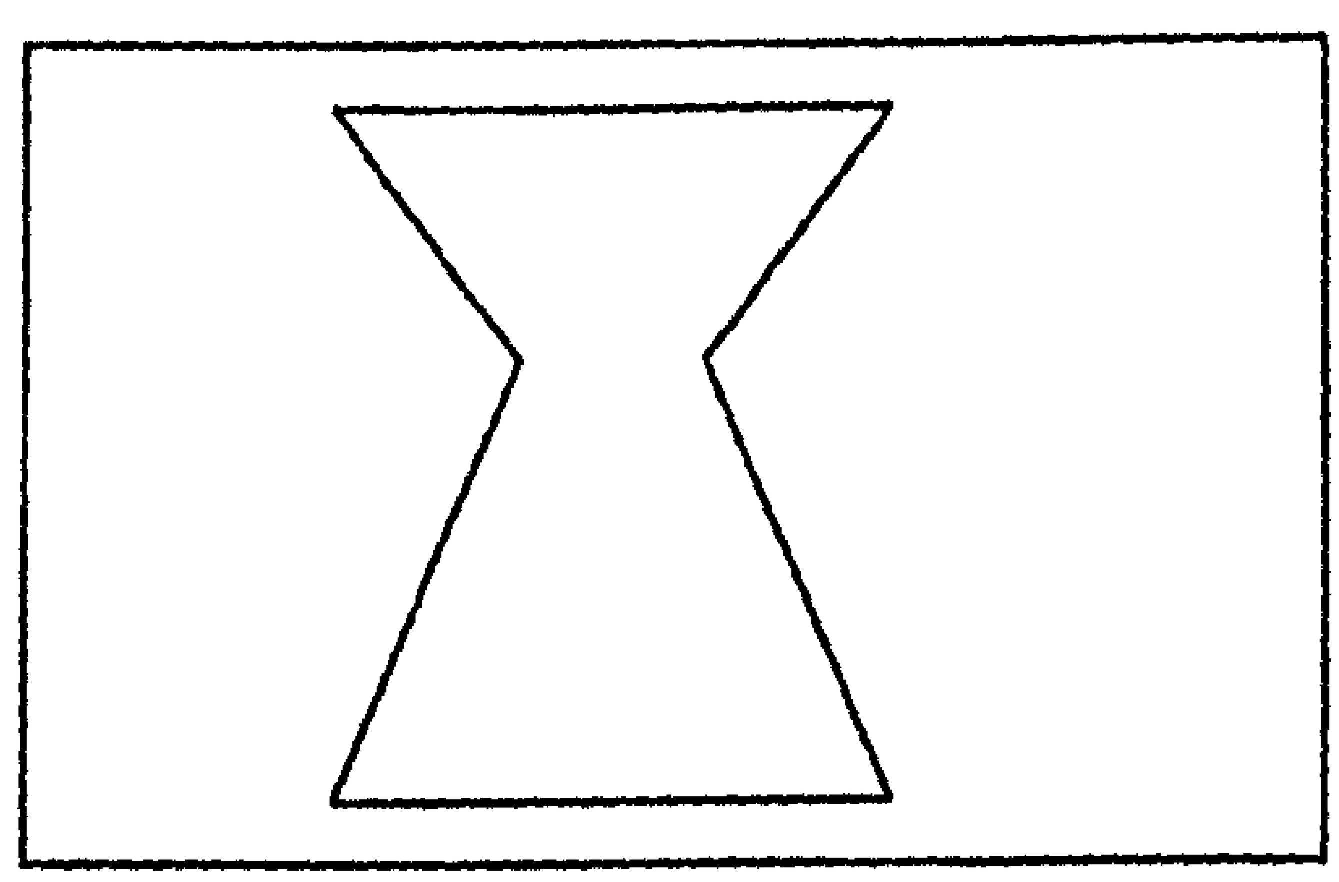

Figure 4.4: Bill of material in batch food and drink plants

Un-skilled manpower is generally employed at the packing stage and only a limited number of skilled persons are required during the actual processing. The point of discretisation is relatively late in the process and the product becomes discrete only during the packing stage. The decoupling point is generally either before or after the packaging stage.

4.2.2.3 Characteristics of Assembly Food and Drink Plants

The food and drink industry under this group offers greater product variety. Each product requires a large number of ingredients, which are either mixed/blended, cooked, assembled/assorted and then packed. The procurement of a large number of different ingredients produces high supply chain complexity. Ingredients are procured locally as well as globally. Some of the ingredients have a short shelf life, which requires a closer integration with suppliers.

This group is characterised by functionally organised, general-purpose equipment (such as mixers, blenders, chillers), a large number of production employees and a high number of routings (Table 4.2). General-purpose equipment offers flexibility as well as high product variety. High product variety is produced by mixing or assembling different ingredients as well as by installing parallel assembly lines. Few of the assembly lines are dedicated, producing large volumes of a particular variety, and others are non-dedicated producing a large variety of different products. A large number of production employees are required at the assembly stage where different ingredients are assorted. The bill of material is convergent/divergent.

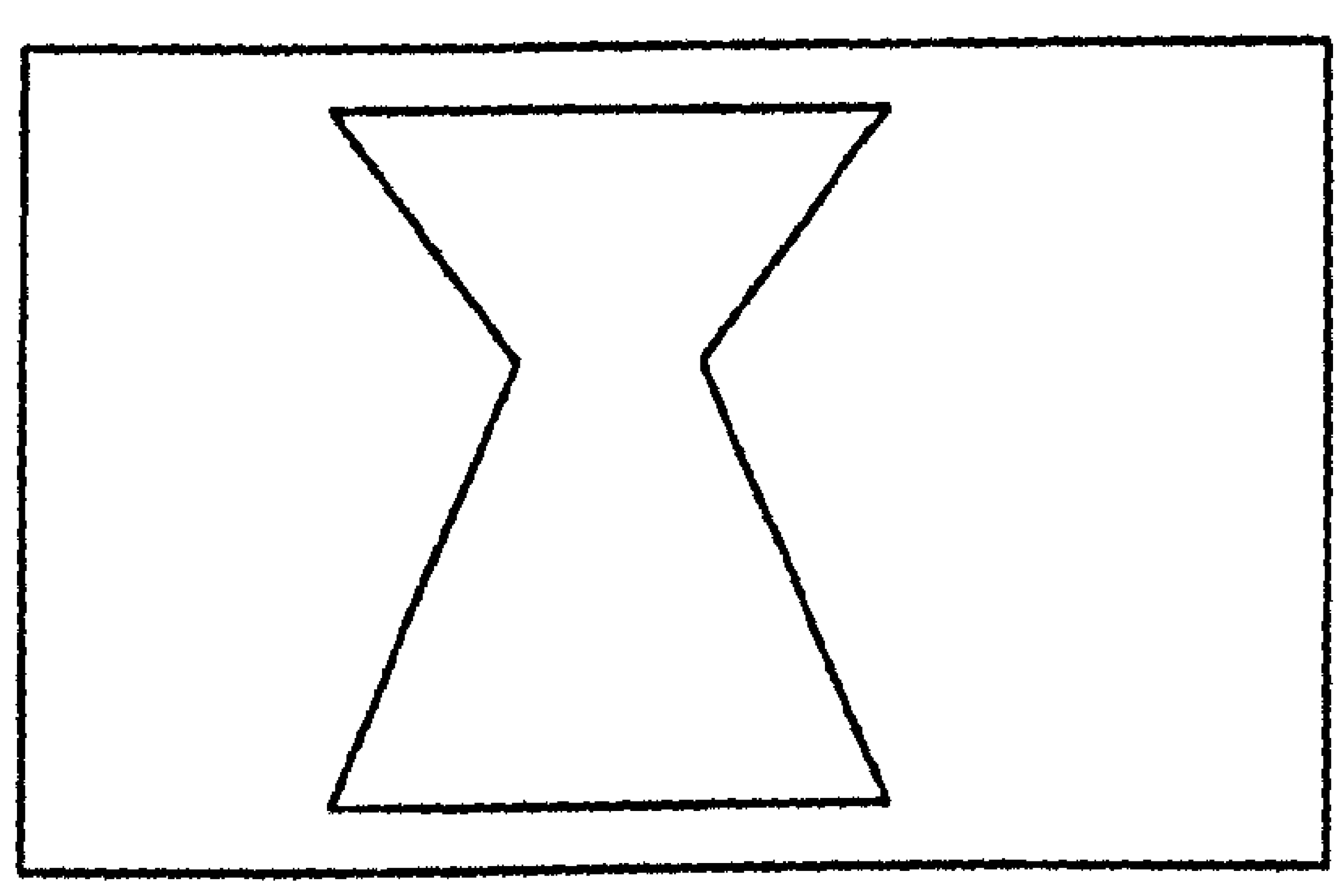

Figure 4.5: Bill of material in assembly food and drink plants

The point of discretisation is relatively early in the assembly type of food industries. This is due to the fact that the main operation is assembly, which requires containerisation right from the start. The decoupling point is generally located upstream of the assembly line. This is considered to be quite early in the process.

This group is at the opposite extreme from the continuous type of food and drink industry and is very close to the discrete industry. The majority of food plants producing convenience meals and assorted food products fall into this category.

	The food and drink industry types		
Characteristics	**Continuous**	**Batch**	**Assembly**
Product variety	Low	Medium	High
Number of ingredients per product	Low	Medium	High
Equipment type	Dedicated	Few general and few dedicated	General
Main operations	Disintegration, separation, dehydration	Mixing, forming	Assorting, assembly, mixing, cooking
Level of capital intensity	High	Medium	Low
Number of production employees	Low	Medium	High
Flow interruption	Low	Medium	High
Routings	Low	Medium	High
Decoupling point	Late	Late	Early
Point of discretisation	Late	Late	Early
Supply chain complexity	Low	Medium	High

Table 4.2: The food and drink industry types

4.3 Selection of Research Strategy

According to Yin (1994), three main conditions must be reviewed in order to decide an appropriate research strategy

1. The type of research questions.
2. The investigator's control over actual behavioural events.
3. The degree of focus on contemporary events as opposed to historical events.

Yin (1994) identified five distinct research strategies: case studies, experiments, surveys, archival analysis and history (Table 4.3). Survey research is appropriate where the aim is to describe and explain statistically the variability of certain features of population. It focuses on the question of who, what, where, how much, and how many. It has been argued that this method does not capture the details needed for gaining a deep understanding of the mechanics and reasons embedded in the processes examined.

Strategy	Form of research question	Require control over behavioural events	Focuses on contemporary events?
Experiment	How, why	Yes	Yes
Survey	Who, what, where, how many, how much	No	Yes
Archival analysis	Who, what, where, how 'many, how much	No	Yes/no
History	How, why	No	No
Case study	How, why	No	Yes

Table 4.3: Relevant situations for different research strategies
Adapted from Yin (1994)

According to Yin (1994), a case study is an empirical inquiry that investigates a contemporary phenomenon within its real- life context especially when the boundaries between the phenomenon and context are not clearly evident. Case study research has been seen in contrast with rationalism. Rationalism is concerned with explaining what happens and how, whereas, case study research is known as interpretivism and uses both quantitative and qualitative methodologies to help understand the phenomena (Meredith, 1998). As seen in Table (4.3), 'how' and 'why' questions are likely to favour case studies, histories and experiments. Case studies are preferred when there is a contemporary focus with a real life context and when researchers cannot manipulate the relevant behaviour. Unlike more specifically directed experiments, case studies require a problem that seeks a holistic understanding of the event or situation using inductive logic reasoning from specific to more general terms. It allows the researcher to concentrate on a specific instance and to identify the various interactive processes at work. These processes may remain hidden in survey research but can be crucial to the success or failure of a system or organisation. Case study research often examines the object or phenomenon from different directions and relies on multiple sources of evidence.

Case study research is the method that uses case studies as its basis. Meredith (1998) highlights three strong points of case study research, which were initially expressed by Benbasat et al. (1987):

- the phenomenon can be studied in a natural setting and meaningful, relevant theory is generated from the understanding gained through observing actual practice;
- the case method allows the more meaningful question of why, rather than just what and how, to be answered with a relatively full understanding of the nature and complexity of the complete phenomenon;
- the case method lends itself to early exploratory investigations where the variables are still unknown and the phenomenon not all understood.

Case study research has been subject to criticism on the grounds of non-representativeness and lack of statistical generalisability. Data collected is often open to different interpretations and potential ' researcher bias'. Case studies may be seen as having limitations with regard to transferability of the findings to other settings (Crute et al., 2003).

Although case research is based on the analysis of a few number of cases to which only limited statistical analysis can be performed (Drejer et al., 1998), it is unconstrained by the rigid limits of a questionnaire and models and can give new help in the development and refinement of theory. It has very high validity with practitioners. Pettigrew (1985) believed that case studies were useful in developing and refining generalisable concepts and that multiple case studies can lead to generalisation in terms of proposition. Many of the breakthrough concepts and theories in operations management, from lean production to manufacturing strategy, have been developed through case studies (Voss et al., 2002). Yin (2003) challenged the traditional concern over the lack of rigour of the case study method, e.g. limitedness and bias. He asserted that the case study method, when systematically designed, is a legitimate method for research. Yin (1994) argued that case studies are used for analytical generalisation, where the researcher's aim is to generalise a particular set of results to some broader theoretical propositions.

Considering all available research strategies, case study research has been found to be appropriate for this research investigation because the purpose was to address the "how" and "why" research questions. The intent was not to formally test a hypothesis but to investigate specific issues with regard to the adoption of lean concepts in the food and drink industry. Moreover the research did not aim to control or manipulate the behaviour of the respondents.

4.4 Selection of Cases

A case study research strategy needs the overall strategy to collect the data required in order to address the research problems under investigation and includes specifying the unit of analysis, case selection, data collection method and techniques used to analyse the data. The unit of analysis refers to the level of aggregation of the data during subsequent analysis. In this study the unit of analysis is the individual plant.

A key issue of the design of case study research is the number of cases included in a research inquiry as well as the selection of cases. A single case can be used to test an existing, well-formed theory. According to Yin (1994), the single case study can be used to determine whether a theory's propositions are correct or whether some alternative set of explanations might be more relevant. A single in-depth case study is often used in longitudinal research and enhances the opportunity for deeper understanding of a phenomenon. Ahlstrom (1998) chose a clinical methodology for studying the sequence of implementation of a lean system in a company. However, a single case study has the limitation of generalisability of the conclusions, models or theory (Voss et al., 2002). When one case is used, there are chances that it might include the risk of misjudging a single occurrence.

Multiple cases are preferable when the purpose of the research is to describe phenomena, develop and test theories. Multiple cases also permit cross-case analysis, a necessary feature for widespread generalisation of theories. The evidence from multiple cases is often considered more compelling and the overall study to be more robust. However, conducting multi-case studies requires more time and effort than other approaches. Multiple cases although reduce the depth of study, due to constrained resources it both enhances external validity and reduces observer bias (Voss et al., 2002). If multiple case studies are to be used for research then a vital question is the case selection or sampling. In case research it is often put together a sample of cases by selecting them according to different criterion (Yin, 1994). Each case should be selected so that it either expects similar results or produces opposing results for a predictable cause (Voss et al., 2002).

Considering the strengths and weaknesses of a single case study as well as multiple case studies, it was decided to use multiple case studies for this research investigation because:

- The food industry is not one industry but a collection of various industries producing a wide variety of food products and using different types of production processes. Although a single case can offer a deeper understanding of the case, it would not represent a broad spectrum of the food industry so the outcome of the research inquiry would have poor generalisation.
- Multiple case studies will enhance the external validity and will reduce the researcher's bias.

This research involved the investigation of fifteen case studies, which are required to enhance the generalisation. As such there is no rule as to how many cases should be included in a multiple case research investigation. One has to deal with the issue conceptually as to how many cases would give confidence in drawing conclusions. The number of cases selected depends on the detail required in each case study. A selection of fifteen case studies for this research investigation means that detailed case studies cannot be undertaken due to resource and time constraints.

Except for one case study of an automotive plant the rest of the case studies undertaken, involved food and drink manufacturing plants. The case study of a vehicle assembly plant was selected in order to undertake a comparison with the food and drink industry. The reason for this is due to the fact that lean manufacturing evolved from the automotive industry and then diffused into other industries, meeting with partial success due to differences in the respective environments.

Fourteen case studies were undertaken in food and drink plants producing a wide variety of food products (Table 4.4). The research sites varied in size, number of employees and available products. During the selection of the food and drink plants for this research investigation, care was taken not to include the food and drink plants employing only one type of production systems (e.g. continuous production system, intermittent production system). During research investigation some of the food and drink manufacturing plants were not considered due to the fact that it showed the characteristics of earlier case studies undertaken and there would have been too many case studies of one type with regard to the type of production system.

Some of the selected food and drink manufacturing plants were eliminated due to the fact that they either did not want to share information, they considered being confidential or they simply did not want to invest the time required to participate. In addition a few plants (wheat flour milling plant, bread manufacturing plant), although agreeing to participate in the research were de-selected because of their small size and scope.

The range of case studies undertaken for this research inquiry can be considered as fairly representative of the complete spectrum of the food and drink industry. Those selected for the research produced pasteurised milk, beer, biscuits, sliced meat, frozen meals, oil products, convenience meals, snack foods and sandwiches. These plants also represent the five food manufacturing groups in the UK standard industrial classification system's food manufacturing section (15.1-15.10).

It can be argued that research in operations management by its very nature must be rooted in the field and hence needs to be tested and implemented in the field. Field studies should be increasingly international in scope and not confined to one country or region due to the global nature of operations. Considering the global nature of operations, the research investigation was carried out in the food and drink industry not only located in the UK but also overseas, in order to enhance the scope of the case studies.

Case	**Product manufactured by the plant**	**Location of the plant**	**Position in supply chain**
Case 1	Pasteurised milk	India	Immediately upstream of customer and second tier to customer also
Case 2	UHT milk	India	Immediately upstream of customer
Case 3	Beer	India	Immediately upstream of customer
Case 4	Edible oil	UK	Second tier to customer
Case 5	Butter	India	Immediately upstream of customer
Case 6	Sweet biscuit	India	Immediately upstream of customer
Case 7	Sliced meat	UK	Immediately upstream of customer
Case 8	Savoury biscuit	UK	Immediately upstream of customer
Case 9	Snack Food	UK	Immediately upstream of customer
Case 10	Mayonnaise and salad dressing	India	Immediately upstream of customer
Case 11	Tea bag	UK	Immediately upstream of customer
Case 12	Convenience meal	UK	Immediately upstream of customer
Case 13	Frozen meal	UK	Immediately upstream of customer
Case 14	Sandwich	UK	Immediately upstream of customer
Case 15	Car	UK	Immediately upstream of customer

Table 4.4: Case studies included in the research investigation

Except for the edible oil plant, all the plants were 'next to customer' plants manufacturing a complete consumer product. The edible oil plant supplies oil to secondary processing industries such margarine manufacturers. The dairy plant also supplies its products to secondary manufacturing process plants such as butter manufacturing plant, as well as to end consumers. Except for the edible oil plant all the food cases considered were similar in that they have a process stage and a packaging stage.

4.5 Data collection

The case study method uses a variety of data collection methods such as direct observation, access to documentation and records, interview and questionnaire, which enables the researcher to capture the complex reality under investigation. Direct observation and interview enable a deeper understanding of the issues involved and enabled the data that may not have been captured in the answer to a questionnaire to be obtained.

The fourteen food and drink manufacturing plants and the one vehicle assembly plant were studied through a visit tour together with interviews, documentation and a questionnaire (Table 4.5). Wherever possible, documents pertaining to process flow, operating procedures, sales data, plant layout were collected from the research sites. This method comprising of multiple data collection techniques was considered the best method for gathering effective data on lean manufacturing, which is a complex multidimensional concept and relates to complex systems (Pannizzolo, 1998).

Case	Interview	Plant tour	Questionnaire	Documents
Case 1	Yes	Yes	No	Yes
Case 2	Yes	Yes	No	Yes
Case 3	Yes	Yes	Yes	No
Case 4	Yes	Yes	Yes	No
Case 5	Yes	Yes	No	Yes
Case 6	Yes	Yes	No	No
Case 7	Yes	Yes	Yes	No
Case 8	Yes	Yes	Yes	No
Case 9	Yes	Yes	Yes	No
Case 10	Yes	Yes	No	No
Case 11	Yes	Yes	Yes	No
Case 12	Yes	Yes	Yes	No
Case 13	Yes	Yes	Yes	No
Case 14	Yes	Yes	Yes	No
Case 15	No	Yes	No	Yes

Table 4.5: Data collection methods

The initial contact with each potential food plant was made by telephone and email. The primary purpose of these initial contacts was to

1 Determine a willingness to participate
2 Find out what category of product the plant belongs to
3 Obtain some preliminary ideas on the kind of manufacturing system used by the plant
4 Schedule an onsite meeting.

It took at least two and as many as 10 telephone calls and emails to obtain this information. Approximately half of those contacted required some written explanation of the research before they would give the request further consideration. The issue of security was very important because the research included sensitive data. For this reason it was decided that the research would give a fictitious name to the plants so that their identity could not be disclosed.

To minimise the use of everyone's time, preliminary information about the company was obtained prior to the on-site visit. Information was acquired from the Internet, the library, stockholder's' report and other such sources. Prior to each visit a list of questions was supplied to enable the personnel in each company to prepare their responses. The questions concerned the following topics:

- The current state of development concerning lean manufacturing practices.
- The company's current operations strategies and how they have been influenced by external and internal factors and conditions.

These efforts were followed by on site meetings in different companies. Table (4.6) gives details of the contact person who was interviewed in each plant.

Case	Function of the Interviewee
Case 1	Manager, production planning Manager, quality control, Assistant manager, procurement
Case 2	Manager, production planning
Case 3	Plant manager
Case 4	Operations manager Manager, production planning
Case 5	Plant manager
Case 6	Operations manager
Case 7	Operations manager
Case 8	Operations manager, Logistics manager
Case 9	Plant manager
Case 10	Plant manager
Case 11	Operations manager
Case 12	Operations manager
Case 13	Operations manager, logistics manager
Case 14	Plant manager, Operations manager
Case 15	Plant Manager

Table 4.6: Interviewee included in the research investigation

Visits to each company were extensively planned and combined interviews with physical tours. Firstly a semi-structured interview was carried out which generally took at least 2 hours. At the beginning of the interview, the first task was to introduce the research by outlining the objectives and briefly describing the lean manufacturing framework. The content of the interview mainly focused on information with regard to company's products, market, raw material and processes. Within each focused topic, there were several issues on which the respondents' views were sought. This methodology was based on the method described by Yin (1994), i.e. having some topics of discussion in mind rather than a fixed list of interview questions.

Interviewees included plant managers, purchasing managers, operations managers and logistics managers. After an initial interview, a plant tour was undertaken coupled with an informal semi-structured discussion. As and when questions arose during the plant tour, it was answered. The plant tour comprised of visits to all functional departments and brief question and answer sessions with department personnel. After the plant tour, a brief meeting was held with relevant personnel to clarify any outstanding issues. Wherever possible documents pertaining to production processes, sales figures, operating procedures & plant layout were collected. Anywhere from 2 to12 hours were spent to conduct each interview session and around 1 to 4 hours were devoted to each plant tour. In addition, approximately 1 to 3 hours were spent on the telephone and emails for follow up or clarification after each on-site visit. After each plant visit, a field report was prepared which included information regarding product, market, raw material and process characteristics of the plant.

Subsequent to the on-site visit, a six-page questionnaire was also sent to all companies (see Appendix 'II'). The questionnaire mainly dealt with issues pertaining to lean manufacturing principles and practices. A majority of the questions were either yes/no type or one word answer type.

4.5.1 Data Triangulation

As all research methodologies have intrinsic flaws, it is crucial to obtain corroborating evidence using a multiplicity of methods. The use of a variety of methods to examine a topic might result in a more robust and generalisable set of findings (higher external validity)(Scandura and Williams, 2000). Data triangulation allows the limitation of a research methodology to be complemented by the strengths of other methodologies. It is often associated with the view that both qualitative and quantitative methodologies can be used together, rather than being mutually exclusive. The main motivation for triangulating data is to increase validity of the data. Triangulation encourages the researcher to approach their research questions from different angles.

In order to establish construct validity, case studies require multiple data collection methods, the result of which hopefully converge. Yin (1984, p.78) identifies these methods as including:

- direct observation of activities and phenomena and their environment;
- indirect observation or measurement of process related phenomena;
- interviews – structured or unstructured;

- documentation, such as written, printed or electronic information about the company and its operation; also news paper cuttings;
- records and charts about previous use of technology relevant to the cases .

In this research investigation different data gathering methods were employed in order to obtain a reliable view of current practices in the food industry and to address the limitation that this kind of research involves. During the data collection, special attention was given to determine whether evidence from different sources converged on a similar set of facts. After all the evidence had been reviewed, it was documented and further reviewed by the company personnel. Such a review was found to be necessary for validating the data collection process (Motwani 2003). Since the case studies cover various products, plant size, market and region, the findings of this research can be generalised to any food and drink industry.

4.6 Case Analysis

The case analysis process in this research investigation has covered four major stages. These are

1. Processing and analysing interview data as well as data gathered during plant tour.
2. Processing and analysing the questionnaires
3. Mapping the food and drink case studies on the food and drink industry classification scheme
4. Conducting a cross case comparison among the food and drink manufacturing plants and between the food and drink manufacturing plant and the vehicle assembly plant. Cross case comparison or pattern is essential for enhancing the generalisation of any conclusions drawn from the cases (Voss et al. 2002).

In the first stage, after every plant visit, a report was prepared which summarised products, processes, materials and the market characteristics of each plant as well as the assessment of lean implementation in the plant.

The second stage of the case analysis processed data collected through the questionnaire and was compared with data collected in the first stage. Each questionnaire received from the company was compared to find any differences amongst the selected plants with regard to the adoption of lean. This was necessary to enhance objectivity.

Next stage involved mapping of the characteristics of the food and drink manufacturing plants on the food and drink industry classification scheme to identify specific food and drink industry types of each food and drink plants.

In the fourth stage all cases were compared and classified on the basis of products, processes and market characteristics. Conclusions were arrived at by matching the evidence pattern in the different cases.

4.7 Summary

This chapter discussed overall research plan employed to carry out the research investigation. A food and drink industry classification is first developed on the basis of the literature and the visits to a number of food and drink plants. The classification outlined three food and drink industry types: continuous, batch and assembly. These industry types were differentiated on the basis of 11characteristics pertaining to product and process aspects of the food and drink industry.

Various available research strategies (e.g. experiments, survey, case study) were evaluated. Case study research strategy was selected for this research investigation as the intent was not to test the hypothesis, but to investigate specific issues pertaining to the adoption of lean concepts in the food and drink industry. Subsequent to selection of case study as research strategy, issues pertaining to selection of cases were outlined. The multiple case studies were chosen to enhance generalisation of theory and external validity. A total of fifteen cases (fourteen food and drink cases and one car assembly case) were selected for the study. A multiple data collection method comprising of a plant tour together with interviews, documentation and a questionnaire, was considered for the case study investigation to increase validity. The process of case analysis is discussed at the end of this chapter.

Chapter 5

Case Studies

Fourteen case studies were undertaken in food & drink plants producing a wide variety of food products in order to investigate the applicability of lean manufacturing in the food & drink industry. The food & drink plants selected for the research produced pasteurised milk, UHT milk, beer, edible oil, butter, biscuits, sliced meat, snack food, tea bags, mayonnaise, frozen meals, convenience meals and sandwiches. One case study of vehicle assembly plant is also included to compare characteristics of the food & drink industry with an archetypal lean environment – the automotive industry.

The next section describes each of the case studies. Each case study is structured into six sections. Section 1 presents an introduction of the manufacturing plant. Sections 2, 3, 4 & 5 deal with product, market, raw materials and process characteristics of the manufacturing plant. Section 6 presents the lean assessment of the plant. The lean manufacturing framework developed in Chapter 3 has been used to assess the status of lean manufacturing in each plant. Reasons for the absence of particular lean practices have also been pointed out. The case studies are subsequently mapped on the food & drink industry classification developed in Chapter 4.

5.1 Case Study (1): Dairy Plant

5.1.1 Introduction

In June 1981, this dairy plant located in India, was commissioned as a unit of the Co-operative Dairy Federation for producing pasteurised milk and skimmed milk powder. It is part of a three-tier structure, that is, a dairy co-operative society at the village level, which in turn forms part of the district level milk producer union, which in turn is part of a state level federation. All three entities are autonomous but linked to each other.

To improve the efficiency and effectiveness of the plant performance, it obtained the certification as per ISO-9002: 1994 as well as food safety management certification (Hazard Analysis and Critical Control Points (HACCP)) in the year 2000. Recently, the dairy plant has initiated an ambitious project to develop an online data integration system (ERP solution) covering all activities in the organisation.

5.1.2 The Products

The dairy plant procures milk from small milk producers and supplies pasteurised milk to the end consumer as well as to secondary food manufacturers such as butter and UHT milk manufacturers. It provides four types of milk in two pack sizes (500 ml and 1 litre pack) to customers (Table 5.1), so does not deal with large product variety. The shelf life of the pasteurised milk is less than a week and is the main driver for its operational system.

Types of Milk	Fat%(Min.)	Solid-not-fat (SNF)%
Toned Milk	3.0	8.5
Standard Milk	4.5	8.5
Standard Gold	6.0	9.0
Double Toned Milk	1.5	9.0

Table 5.1: Types of pasteurised milk

5.1.3 The Market

The dairy plant sells its pasteurised milk through a network of over 1800 retail outlets spread over some 50 nearby towns. The supply of pasteurised milk to its customers is made twice a day. The milk and milk products are sold through a network of a mix of owned shops, agencies, and various institutions and milk parlours. Milk is collected from the milk producers around 5am and delivered to the retailers on the same day in the evening around 5pm.

On the one hand the plant experiences a wide fluctuation in customer demand and on the other hand it has to accept all the milk collected by the village level dairy cooperative society due to its long-term agreement (LTA). This leads to a significant gap between demand and supply.

The procurement and demand for milk in the years 2003 and 2004 are shown in Figure 5.1 and Figure 5.2. The production and sales of skimmed milk powder in the years 2003 and 2004 are presented in Table 5.2. The data clearly shows that during the summer season the sale of pasteurised milk exceeded the amount of milk procured, whilst in the winter season the procurement of milk exceeded the sales. The short shelf life of pasteurised milk does not allow the build up of a large level of stock. Conversely, the gap between demand and supply warrants the need to build up stock. This situation is quite typical in the dairy industry.

The surplus milk cannot be stored for a long duration as the shelf life of the milk is less than a week if stored below 6 degrees centigrade. As a result of this surplus, pasteurised milk is converted into skimmed milk powder, which can be sold in the market. Sales data for skimmed milk powder revealed that the demand is very low (see Table 5.1). The plant stores the skimmed milk powder for 4-6 months and is able to cope with the high demand during the summer season when skimmed milk powder is used to fulfil the extra demand.

Month	Milk procurement (Million litres)	Pasteurised milk sale (million litres)	Skimmed milk powder production (kg)	Skimmed milk powder sale (kg)
Jan. 03	14.0	8.1	128000	2
Feb. 03	12.4	8.4	62600	0
Mar. 03	11.4	8.8	0	0
Apr. 03	9.0	10.4	0	0
May 03	7. 4	11.2	0	0
June 03	6.1	12.0	0	0
July 03	5.7	11.3	0	5000
Aug. 03	6.6	11.1	0	0
Sept. 03	7.6	11.0	0	14000
Oct. 03	9.2	11.0	5700	67000
Nov. 03	12.6	10.2	9000	14000
Dec. 03	13.8	9.0	136000	0
Jan. 04	14.6	9.47	188000	0
Feb. 04	14.5	9.52	19800	0
Mar. 04	15.3	10.3	0	0
Apr. 04	13.5	11.1	0	0
May. 04	12.5	11.3	0	0
June 04	9.8	11.9	0	0
July 04	9.4	12.6	0	500
Aug. 04	11.2	11.96	0	0
Sept. 04	14.7	11.1	36900	30000
Oct. 04	15.8	11.5	9000	0
Nov. 04	15.2	10.9	14200	20000
Dec. 04	17.7	10.9	116000	0

Table 5.2: Milk procurement and pasteurised milk sales

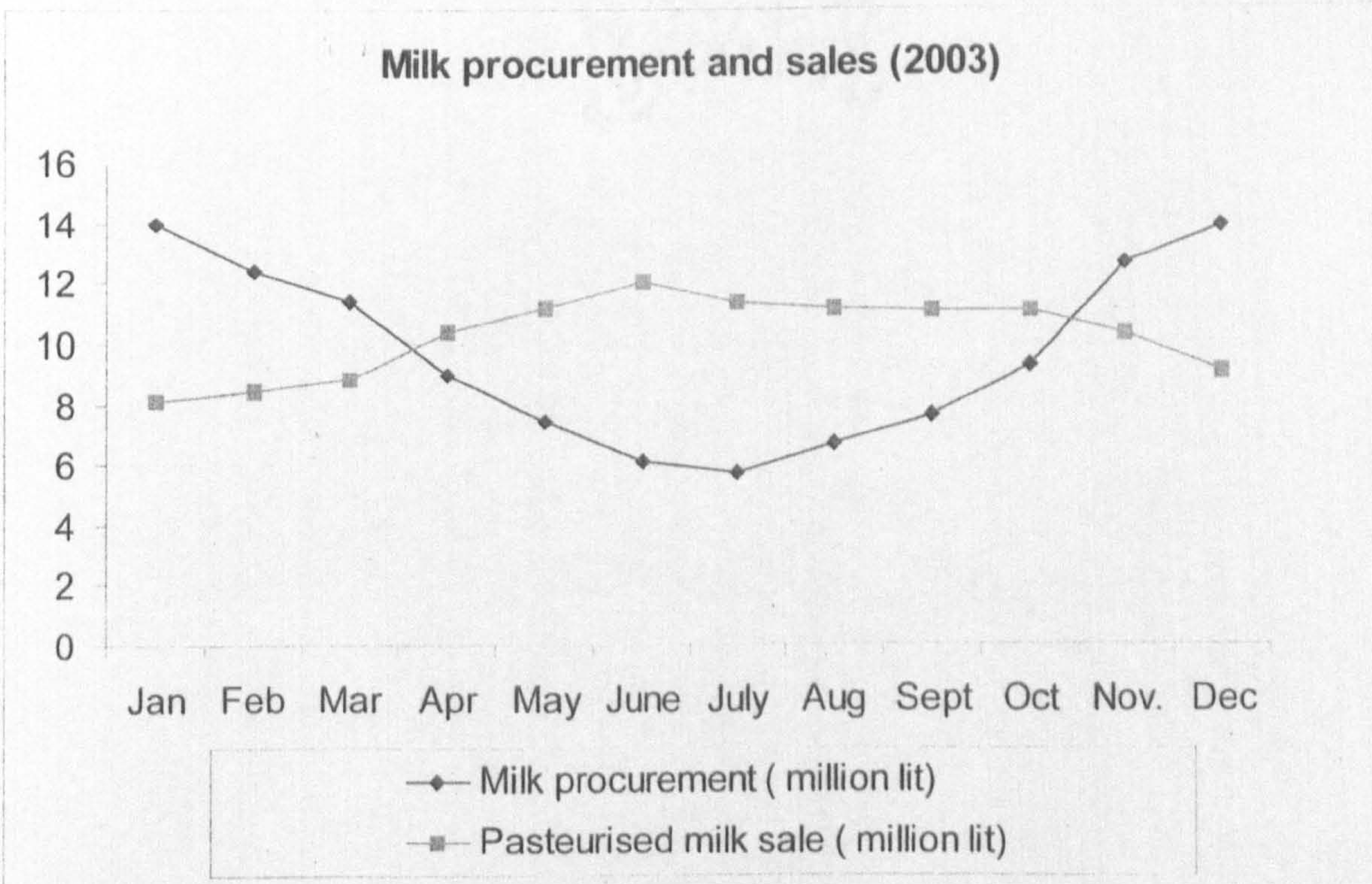

Figure 5.1: Milk procurement and sales (2003)

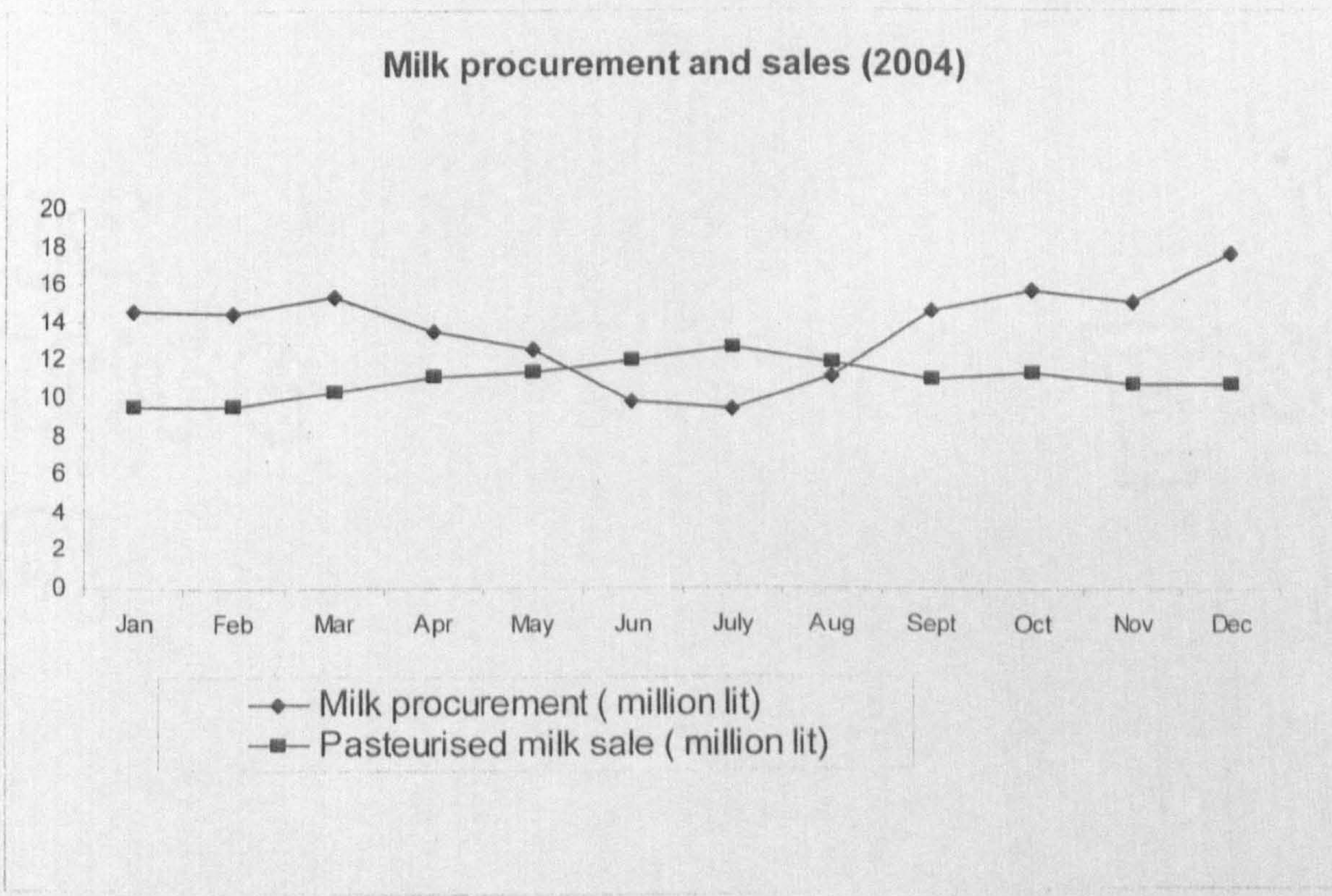

Figure 5.2: Milk procurement and sales (2004)

5.1.4 The Raw Material

The plant offers a limited product variety and each product requires only a few ingredients which means that the plant has to manage only a small number of raw materials. It procures its main raw material, milk, from milk producers through its network of over 1200 Village-level Dairy Co-operatives (DCS) spread throughout the nearby district. The plant has entered into an agreement to take all the milk collected by these co-operative societies so has no control over supply.

Milk supplied by the producers is weighed, samples drawn for quality testing and payment is made on the basis of quantity and quality of milk (Fat %). The dairy has introduced a PC-based Automatic Milk Collection Station (AMCS) which performs the on-line capturing of the fat content of the milk and its weight and automatically prints the payments slips. Simultaneously it stores the data for further use.

Since the villages are widely scattered and the milk is collected from milk producers at the same time (morning and evening), the dairy plant has installed 5 chilling centres at different locations based on the catchment area. Each chilling centre has the capacity to chill 60,000 litres of milk. All chilling centres start working at 8 am when the milk starts to arrive from the societies and stops working around 1pm when all the milk has been chilled and stored. The chilling centre starts again in the evening around 6pm when the evening milk comes in from the co-operative societies. The main function of the chilling centre is to receive, weigh, test, chill and store the milk. Once the milk is chilled it can be sent to the dairy plant. All the processing is done at the dairy plant. The chilling plant just prevents the deterioration of the raw milk.

The dairy plant arranges transportation of the milk from the doorsteps of the milk producers to the receiving point at the dairy plant and its chilling centres. A truck/lorry collects milk in containers from the co-operative societies and delivers it to the chilling centre or the dairy plant based on logistical requirements. Transporters have to deliver the milk as soon as possible because of its perishable nature.

Presently more than 85% of the district cooperative societies (DCS) have either an Automatic Milk Collection System (AMCS) or Electronic Milk Tester (EMT) in their milk shed. Besides the automation of village-level dairy cooperatives the Raw Milk Reception Dock (RMRD) at the dairy plant has been modernised by the installation of an RMRD automation network system which is the first of its kind in India. The RMRD automation Network System records data from the reception docks automatically, with entry of various parameters like route code, DCS code, sample number, number of cans, types of milk etc. Similarly the recording of milk quality analysis data, for example percentage of fat and solid-not-fat content is also provided. Procurement and input activities also include animal health coverage and the supply of cattle feed and improved fodder seeds to the members.

5.1.5 The Process

The manufacturing process is relatively simple and consists of chilling, pasteurisation, cream separation and packing as shown in Figure 5.3. Milk received at the reception dock, is pasteurised at not less than 78 °C for 15 seconds and chilled below 9°C. During pasteurisation, as and when required, milk is separated to have skimmed milk of 0.05% fat and cream having not less than 40% fat. The milk pasteurisation equipment can handle 10,000 litres/hour and there are 4 such sets of equipment. The milk separation equipment can also process 10,000 litres/hour of milk. Standard or skimmed milk is taken to the respective silos at a temperature not more than 9 °C.

During the winter, as the milk supply exceeds demand, surplus standardised milk is converted to skimmed milk powder. The surplus milk is first fed to a condensing unit to obtain a milk concentrate. The concentrate should have 45 $\pm$ 1 % total solids. The milk concentrate is taken to a drying unit that evaporates the moisture content in the skimmed milk powder. The skimmed milk powder is then packed in paper bags lined with a polythene liner or in tins. This skimmed milk powder is used to compensate for the shortfall during the summer season. The skimmed milk powder plant does not operate for six months during the summer season. The inventory of skimmed milk powder also increases during the winter season when surplus milk is converted into skimmed milk powder.

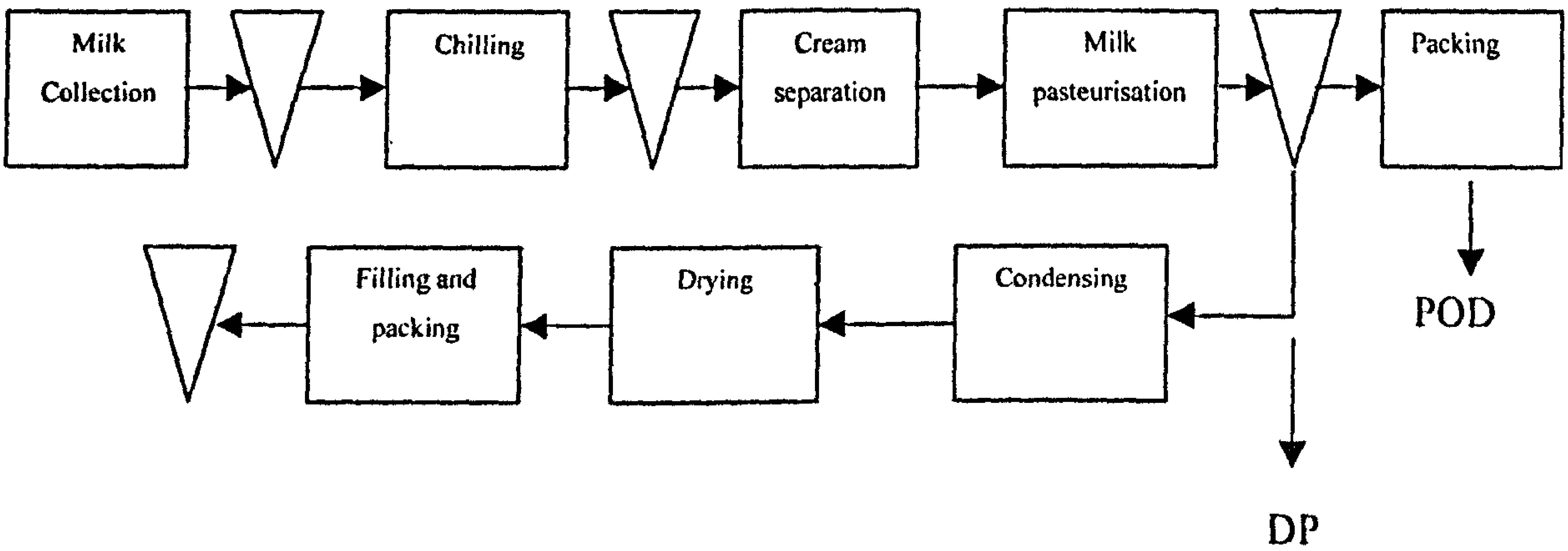

Figure 5.3: Process flow of dairy plant

The total inventory, that includes raw material, WIP and finished goods, is around 400,000 litres per day. This means that the plant retains only one day's inventory. The total capacity of the silos is also around 400,000 litres. The total time taken from collection to delivery of the milk to the retailer is 12 hours whereas the total processing time of 1000 litres of raw milk is just 10 minutes.

The point of discretisation (POD) is at the packing stage (see Figure 5.3). Before the packing stage the milk undergoes chilling, pasteurisation and the cream separation process and flows through a pipe line to tanks/silos. There is a daily clean up process which forms part of the hygiene and safety requirements. This clean up process is a sequence dependent activity which requires very little manpower to manage the processes. The decoupling point (DP) is at the standardised milk silo stage, which supplies milk to the packing stage. Standardised milk is kept in 5 silos with a total capacity of 200,000 litres. The milk silo is used to serve the customer orders as well as the secondary manufacturing plant.

5.1.6. Plant Assessment

The plant is characterised by low product variety, low product shelf life, high volume, few manpower, large number of suppliers, few operations, continuous manufacturing, high capital intensity (Table 5.3) which makes it a continuous type food & drink industry.

Pasteurised milk being a basic commodity item doesn't involve many value added processes, so price and service levels become the order-wining criteria for this industry.

Only 5S, preventive maintenance, standard operating procedures and statistical process control were being practised in the plant (Table 5.4). The most important lean principle, aligning production with demand, was found missing in this plant. No lean practices pertaining to these principles were observed. Although the short product shelf life should drive the plant to become lean due to the long term agreement with milk producers to take all the milk irrespective of demand, the plant experiences large stocks of skimmed milk powder. Discussion with the managers at various levels of the organisation revealed that most of the lean practices for example suggestion schemes, cross functional training, quality circles, supplier development activities, are applicable in the dairy sector.

It is worth mentioning that a supply chain analysis is outside the scope of the research.

5.1.7 Lessons learned

This case study demonstrated that the dairy industry should be a lean plant due to the short product shelf life but it experiences large stocks of skimmed milk powder due to the long term agreement with milk producer to take all the milk irrespective of demand. This is a typical characteristic of the dairy industry which makes it difficult to align its production with demand.

Characteristics	
Product	
Product type:	Perishable, Liquid
Product variety	8 SKUs
Product shelf life	4 days
Number of ingredients per product	3-5
Process	
Operations strategy	Make-to-stock (MTS)
Process type	Continuous
Decoupling point	late
Equipment type	Specialised
Process complexity	Low
Flow interruption	Low
Routings	Low
Number of major operations	4
Main operations	Heating, separation, cooling
Number of production employees	70
Labour skill input	Low
Production volume	600,000 litres per day
Level of automation	High
Process flexibility	Low
Point of discretisation	Packing stage
Change over time	3 hours
Work-in-progress	8 hours
Number of supply chain levels	2
Market	
Order winning criteria	Price, service level
Order qualifying criteria	Quality
Maximum demand deviation	> 50%

Table 5.3: Product/process/market characteristics of the dairy plant

Lean practices	Status of lean practices	Reason for absence of lean practices
Aligning production with demand		
Pull system	No	Obligation to accept milk from milk producer and transform it, independently of the demand for final products.
Uniform work load /levelled production	No	Little product variety
Mixed model production	No	Change over is sequence dependent
One-piece flow	No	Non-discrete material flow
Supplier integration		
JIT deliveries	No	Milk procurement is not linked to customer demand
Active information exchange with suppliers	No	Milk producers are small
Supplier involvement in product development	No	Product is not complex which calls for supplier involvement
Supplier reduction policy	No	The aim of the plant is to collect milk from large number of small supplier
Supplier development activities	No	Large number of small milk producers
Long term contracts	Yes	Ensures continuous availability of milk when customer demand is high
Employee involvement and empowerment		
Quality circle	No	Lack of awareness
Cross functional training	No	Job is relatively simple
Autonomation	No	Unskilled labour
Team based problem solving	No	Lack of management commitment
Continuous improvement program	No	Lack of management commitment
Suggestion scheme	No	Lack of awareness
Job rotation	Yes	
Elimination of waste		
Quick change over	No	Little product variety; change over is time consuming due to hygienic requirement
Quality system	Yes	
Cellular manufacturing	No	Little product variety
Visual control	No	Lack of awareness
Preventive maintenance	Yes	
Statistical process control	Yes	Ensures consistent quality
5 S	Yes	
Mistake proofing	No	Lack of awareness
Standard operations	Yes	

Table 5.4: Status of lean practices in the dairy plant

5.2 Case Study (2): UHT Milk Plant

5.2.1 Introduction

This plant, which is a secondary processing plant, is situated close to the dairy plant (case 1) and produces six types of UHT Milk. This plant was started in 1984 when there were only 4 such plants in the whole of India. It uses modern milk processing technology for its processes and operates in a controlled environment to reduce possible contamination of the milk. Only 50 production employees in two shifts are used to run this plant. It has been accredited to ISO 9000 and HACCP (Hazard Analysis and Critical Control Point).

5.2.2 The Product

Similar to case (1), this plant offers little product variety to its customers. Unlike pasteurised milk, UHT milk has a relatively high product shelf life (6 months) due to the sterilisation and sterilised packing process which controls microbiological growth in the milk. The UHT milk cannot be dispatched to the customers unless it receives a positive report from the microbiological lab, which takes four days. This means that four days of finished goods inventory is required to ensure the quality of milk and is a necessity of the system, which cannot be avoided. To this end, the plant has a policy to keep a safety stock of eight days.

5.2.3 The Market

The plant supplies its milk to the defence organisations, which are located in remote areas, and to metropolitan cities as an alternative to pasteurised milk. Total sales per year is some 9 million litres of which 6 million litres is to the defence organisation. It has a long-term annual contract with the defence organisation to supply milk on the basis of a staggered delivery system. Although the actual requirement of UHT milk is placed one month in advance, amendments to delivery schedules are common. The capacity of the plant exceeds the actual demand, so it can cope with any amendment of delivery schedules by extending the length of the shift. Service level is, therefore, an important consideration due to a penalty clause imposed by the customer.

5.2.4 The Raw Material

The plant requires a few raw materials and the number of ingredients per product is also very small. One of the main raw materials is standardised milk, which the plant procures from the dairy plant (case 1). It has a long-term agreement with the dairy plant for the supply of standardised milk. Due to its long-term agreement and close proximity with its main supplier it does not require a high raw material inventory. Another important raw material is the packing roll, which it purchases from a single supplier with which it also has a long-term agreement.

The plant has two raw milk silos each of 30000-litre capacity that can accommodate two and a half days of raw material inventory. In the raw milk silos there are electronic gauges which indicate the amount of milk remaining.

5.2.5 The Process

The plant employs few manufacturing processes which are arranged in the form of a product layout so there is no back tracking of materials. All processes are tightly coupled and automated which results in the requirement for a low number of direct production employees. Short throughput times also lead to a small amount of work in process compared to the stock of raw material and finished goods.

The manufacturing process consists of chilling, sterilisation, homogenisation and packing (see Figure 5.4). After conformity to specified requirements has been established, milk is transferred to the milk chillers through a clarifier. The plant is flushed with water before sterilisation starts. After sterilisation of the system, the milk is pumped from the chillers to the balance tank of the UHT plant and is processed at 139-144 °C with a holding period of 2 seconds in the holding section. The milk is then homogenised at 170-200 bar in the first stage and at 45-50 bar in the second stage. Packaging machines are also sterilised before milk is taken into the system. A sterile air column is maintained at the filling tube which is maintained at a temperature above 200 °C. The milk packs are automatically arranged in crates by the packaging machine and transferred to the finished goods store. Laminated paper required for the packing operation is also sterilised by treating with hydrogen peroxide. One sample in the batch of 126 litres is sent for microbiological test. This test takes four days which means the UHT milk cannot be dispatched until it gets a positive report. There are two sterilisers (4000 litres/hour) and three UHT milk-packaging machines (1800 litres/hour). The set up time of the steriliser is 2 hours.

Again the point of discretisation (POD) is at the packing stage (see Figure 5.4). The processes upstream of the POD are tightly coupled and automated which does not require a large number of production employees. The process and packing stages are also coupled and no buffer is required to separate these stages. Any equipment breakdown results in a complete plant stoppage. That is why this plant has established a preventive maintenance policy to improve overall plant effectiveness. No mechanism was found to be in place to calculate the overall equipment effectiveness (OEE).

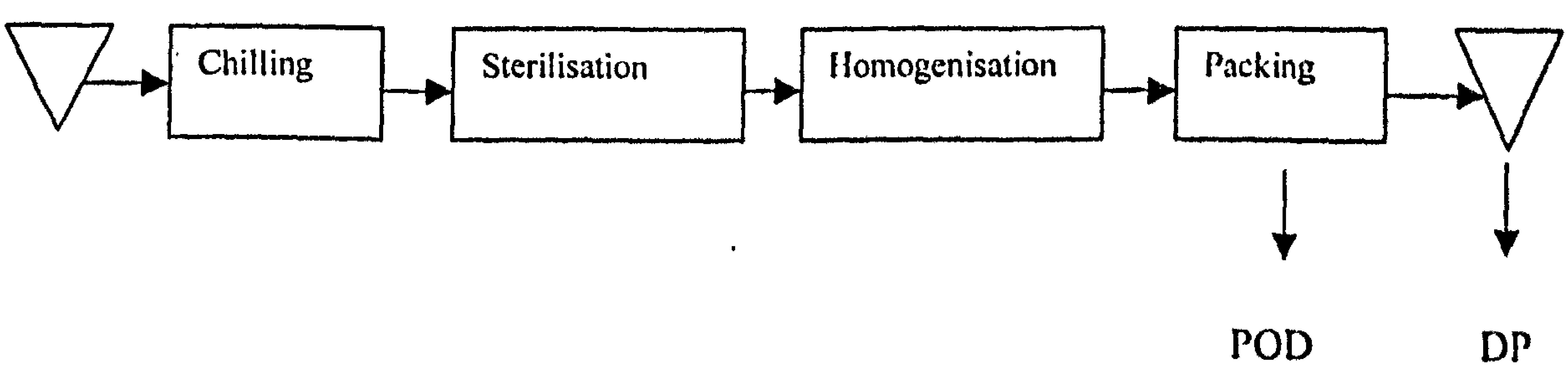

Figure 5.4: Process flow of UHT milk plant

There are only two locations for the decoupling point (DP), either at the raw milk silos or at the stock of finished goods (see Figure 5.4). At the time of the case study, the decoupling point was at the finished goods inventory stage due to the make-to-stock (MTS) production strategy.

The plant requires a controlled environment in terms of air quality and hygiene level and consequently shop floor employees are given training on food hygiene and 5S. Otherwise no human resource policies are pursued at shop floor level.

5.2.6 Plant assessment

The plant is characterised by low product variety, a continuous process with specialised equipment, few number of operations, few number of employees on the shopfloor (Table 5.5). It employs complex process technology for sterilisation, homogenisation and packing operations, which requires high level of capital intensity. It offers more opportunity for preventive maintenance. Although a preventive maintenance schedule was followed, there was no systematic method of calculating overall equipment effectiveness.

The plant has only one supplier for milk and packaging materials. Milk is procured from dairy plant (case 1) which also ensures continuous availability of consistent milk. Even though the plant is located very close to Case 1, it keeps two and half days raw milk inventory which can be reduced to just half a day.

Due to continuous operation, interlinked processes and very short processing time work-in-progress is very low, just 5 minutes of inventory. Due to this fact there is not much scope and benefit to reduce WIP in this plant. The major problem, which the plant faces is its vulnerability to equipment breakdown.

Lean practices related to the alignment of production with demand principle were not observed but few practices pertaining to supplier integration such as long term agreement and a supplier reduction policy have been in place (Table 5.6). During the visits and interviews with the managers there was no indication of the adoption of employee involvement and empowerment principle.

Characteristics	
Product	
Product type:	Perishable,
Product variety	6 SKUs
Product shelf life	24 weeks
Number of ingredients per product	3
Process	
Operations strategy	Make-to-stock (MTS)
Process type	Continuous
Decoupling point	Late
Equipment type	Specialised
Process complexity	Medium
Flow interruption	Low
Routings	Low
Number of major operations	3
Main operations	Sterilisation, homogenisation
Number of production employees	50
Labour skill input	Medium
Production volume	25000 litres per day
Level of automation	High
Process flexibility	Low
Point of discretisation	Packing stage
Change over time	2 hours
Work-in-progress	5 minutes
Number of supply chain levels	2
Market	
Order winning criteria	Price, service level
Order qualifying criteria	Quality
Maximum demand deviation	~20%

Table 5.5: Product/process/market characteristics of UHT milk plant

Low product variety and long shelf life also does not offer the benefits of quick changeover practice. There are six varieties of UHT milk which are produced with the help of two sterilisers and three packaging machines. It means 3 types of UHT milk can be made at any time. Although the decoupling point is at the finished goods store, it could feasibly be shifted to the raw material tanks/silos as run time is very short and one of the main raw material suppliers is close by. The decoupling point cannot be shifted to anywhere in the middle of the material flow as all processes are tightly coupled.

Lean practices	Status of lean practices	Reason for absence of lean practices
Aligning production with demand		
Pull system	No	Continuous process, non-discrete flow
Uniform work load/ levelled production	No	Non-discrete material and limited product variety does not necessitate levelled production
Mixed model production	No	Limited product variety
One-piece flow	No	Non-discrete material flow
Supplier integration		
JIT deliveries	No	Lack of management commitment
Active information exchange with supplier	No	Lack of management commitment
Supplier involvement in product development	No	Low product variety
Supplier reduction policy	Yes	Only one supplier for raw milk
Supplier development activities	No	Lack of management commitment
Long term contracts	Yes	Ensures continuous availability of milk when customer demand is high
Employee involvement and empowerment		
Quality circle	No	Little labour due to automation
Cross functional training	No	Job is relatively simple
Autonomation	No	Lack of management commitment
Team based problem solving	No	Limited labour, lack of management commitment
Continuous improvement program	No	Lack of management commitment
Suggestion scheme	No	Lack of awareness
Job rotation	No	Limited labour, few processes
Elimination of waste		
Quick change over	No	Change over is time consuming due to hygienic requirement
Quality system	Yes	ISO 9000 accredited and HACCP certified
Cellular manufacturing	No	Limited product variety
Visual control	No	Lack of management commitment
Preventive maintenance	Yes	Capital intensive plant
Statistical process control	Yes	Ensures consistent quality
5 S	Yes	
Mistake proofing	No	Lack of awareness
Standard operations	Yes	

Table 5.6: Status of lean practices in UHT milk plant

5.2.7 Lessons learned

The plant characterised by low product variety, a continuous process with specialised capital-intensive equipment and few number of operations offers more opportunity for preventive maintenance.

5.3 Case Study (3): Edible Oil Plant

5.3.1 Introduction

The plant supplies edible oil to secondary food manufacturers such as biscuit and margarine manufacturers. The plant is located in the UK and is on a dockside for logistical reasons.

5.3.2 The Product

The plant offers 50 different types of edible oil to its customers. The product variety is achieved by mixing different combinations of a small number of edible oils (for example rapeseed, palm oil and coconut oil).

It mainly processes and refines rapeseed and palm oil. It purchases a few other oils from the market and uses these oils to provide a unique solution in terms of producing a mix of different oils to its customer known as 'blend' oil. The 'blend' oil, which is a mixture of two or more oils, is made to order in the plant. Much of the product variety is achieved through 'blend' oils.

The 'base' oils are held in nitrogen-capped 'edible' tanks to inhibit oxidation. The customer order for 'straight oils' (rape and palm) is loaded direct from the 'edible' tanks, via a mass-flow meter, to the tanker. The product has a low shelf life, not more than a week and hence the plant cannot keep more than one weeks inventory on site. The edible oil is supplied to its customer by bulk quantity in tankers. This plant, unlike other food plants studied, does not have a packing stage.

5.3.3 The Market

This plant is in the business of selling high volume commodity food products to secondary food manufacturers. The product being a commodity item, means its cost is the primary order-winning criterion. The plant also enjoys a unique position by providing customised blended oils to its customer. So for this plant product cost as well as product variety become the winning order criteria. By having blend components on stock, the response to order time is low whereas other oil plants have to build the blend into their products' schedule.

Customer orders are based on staggered delivery schedules where the customer places a contract for forward deliveries at a fixed price to be delivered as and when they require within the contract period. Although the plant receives the customer order well in time, the signal for actual delivery is not confirmed well in advance which makes it difficult for the planner to freeze the production plan. The production plan for the week is scheduled one week in advance but it cannot be frozen, since additions, cancellations and reschedules are very common with up to 30% of the total order changed.

Few of the customer orders pertain to specific oils which require blending of various types of oils (say 50% rapeseed, 30% palm, 20% coconut). These types of orders carry a high profit margin and are generally fulfilled on the basis of a hybrid make-to-order /make-to-stock production strategy. These order are also accepted up until the time of blending.

The customers' demand can be influenced by the promotional scheme launched by big retailers. These promotional schemes affect the secondary processing industry which in turn also affects this plant. Moreover, this plant also experiences moderate levels of seasonal demand that also contributes to inaccurate forecasts. The fourth quarter is always heaviest for demand with August being the quietest period.

5.3.4 The Raw Material

This plant has to manage very few raw materials. The main raw materials are crude rapeseed oil and tropical oils such as palm oil. It also purchases six other edible oils from the market for blending purposes. The crushing plant located adjacent to this plant and managed by the same group supplies crude rapeseed oil. So this is a case of backward integration. The plant has to take crude oil produced by its sister company on the basis of the current traded price. Crude rapeseed oil availability is therefore assured for this plant. The plant is well integrated with the crushing plant but has to purchase all its products from the crushing plant. The crushing plant procures its main raw material, rapeseed, within the UK, but rapeseed being a produce of agriculture is not available throughout the year and so the crushing plant has to procure the rapeseed in bulk during harvest time. This leads to the build up of a high amount of raw material inventory for the crushing plant. A lot of this inventory is held off site in farm silos. Depending upon contract arrangements, this does not become part of the plant's inventory until delivery to site.

Another important raw material is palm oil, which is procured from different locations around the globe on the basis of price, variety and availability. Crude palm oil usually comes from South East Asia, Indonesia and Malaysia. It takes six weeks for the delivery of the oil. Shipping economics dictate the ordering of large 'parcels' of 3000-6000 tonnes. Crop failure and weather all contribute to supply insecurity and delays of up to six weeks on the arrival of a ship are not uncommon. Four to six weeks of inventory are kept to ensure its availability to the production process.

5.3.5. The Process

The plant mainly refines vegetable crude oil which involves neutralising, bleaching and deodorising processes (see Figure 5.5). All these three processes are tightly coupled to each other and use specialised equipment. The plant also has an additional process of blending where different oils are mixed together according to a set proportion to produce a 'blend' oil. A large product variety is possible due to this blending of oils.

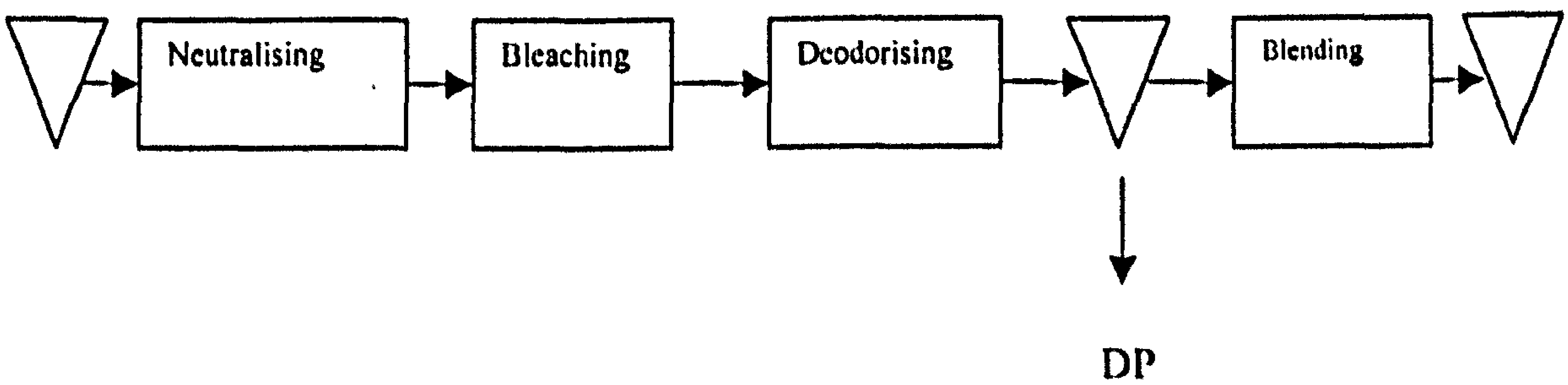

Figure 5.5: Process flow of edible oil plant

The plant has two separate refining processes, one for rapeseed oil and another for palm oil. The rapeseed refining process is a dedicated process so there is no requirement for any changeover as it does not process any other crude oil except rapeseed. The palm oil refining process offers little flexibility and can also process crude rapeseed oil. It takes at least one hour for the changeover from processing palm oil to rapeseed oil. As the plant refines around 1000 tonnes of the oil per day, even one-hour changeover is a significant cost in downtime. On average there are two changeovers per day on the palm oil refining process. The rapeseed refining line processes 600 tonnes per day whereas the palm oil line processes 400 tonnes per day.

Process times are pre-set dependent upon the characteristics of the material being processed and the speed of the chemical reactions (e.g. neutralisation) or physical processes (e.g. water-washing) that take place in a pre-defined sequence. It takes around 6 hours to refine the crude oil and another two hours to blend the oils, so in total it takes 8 hours to transform the input into output.

The plant has the capacity to store 10000 tonnes of edible oil as finished goods in a series of tanks of 100 tonnes capacity which can also store 17 types of oil. On average the plant stores 7000-8000 tonnes of oil which seems quite high, but this represents 5-6 days inventory of tropical oil and 3-4 days inventory of rapeseed oil.

All these processes involve continuous manufacturing and are highly automated involving a high capital investment. Little manpower is required to operate the plant. The plant is managed by just 46 employees, 30 of which are on the shopfloor. The plant has been designed to operate all year round and continuously without stoppages. Only during a serious break down does the plant stop producing. Sometimes production cannot take place because the plant has run out of crude feedstock. It is also a very important issue for the planner that sufficient tank space is available to receive the run otherwise 'output blocking' occurs. In the plant's parlance, 'Commercial Downtime' or CDT occurs when customer orders are less than the capacity and the plant has to stop because the edible tanks are full. This is regarded as a 'sales problem' and often attempts are made to carry out maintenance while the plant is down and 'book' the time to CDT. Restarting the plant is a problem after any type of shutdown and often off-specification oil is produced.

This is the only plant where there is no point of discretisation as there is no packing stage where non-discrete items become discrete. The oil is delivered to the customer in tankers and so the minimum quantity which can be delivered is equal to size of tanker.

The decoupling point is just upstream of the blending process (see Figure 5.5). A customer order for standard rapeseed oil or tropical oil, where there is no need for mixing of the oil, are served from the stock just before the blending process. Customer orders for specific blended oils are fulfilled by mixing different oils which takes just two hours. These orders are fulfilled only when the customer places a confirmed order.

The practice of continuing to produce out-of-specification oil even when a quality problem has been detected is accepted, with the aim of bringing it back into specification and blending off the good with the bad. The problem is that sometimes the process never produces good oil and results in significant amounts of out-of-specification oil.

Sometimes material is not processed correctly and three types of waste occur:

Out-of-spec material, because of equipment failure, e.g. caustic dosing fails to neutralise the oil, earth dosing fails to bleach the oil, filters fail to remove earth from the oil.

Poor yields, usually because too much neutral oil has been removed in the refining process.

Over-use of processing materials e.g. bleaching earth and caustic soda.

This leads to oil having to be 'reprocessed' i.e. recycled around all or part of the process which represents a waste of capacity.

5.3.6. Plant assessment

The plant is a classic example of process manufacturing characterised by fixed routings, dedicated tanks and pipelines, specialised equipment, computer-assisted automation and very few operators. The product, process and market characteristics of the plant are summarised in Table 5.7. Fixed routings and specialised equipment means that economy of movement is paramount in this plant. There is no manual handling of material.

It was revealed during the plant tour that the plant has a high raw material inventory, low WIP and high finished goods inventory. The raw materials cost represents 90% of the total product cost of the edible oils. One of the main raw materials, palm oil, is purchased from the supplier located outside and the oil is shipped to the plant from the dock. The plant has to purchase the full shipload of oil which results in a large amount of raw material inventory.

Production is limited by the capacity of the edible oil tanks which in general can accommodate less than one week's production. Serious overproduction is, therefore, not possible.

Characteristics	Value
Product	
Product type:	Perishable, Liquid
Product variety	50 SKUs
Product shelf life	1 week
Number of ingredients per product	3-5
Process	
Operations strategy	Make-to-stock (MTS)/ Blend-to-order(BTO)
Process type	Continuous
Decoupling point	Late
Equipment type	Specialised
Process complexity	High
Flow interruption	Low
Routings	Low
Change over time	High
Number of major operations	4
Main operations	Heating, separation, cooling
Number of production employees	30
Labour skill input	Low
Production volume	1000000 litres/day
Level of automation	High
Process flexibility	Low
Point of discretisation	No point of discretisation
Change over time	2 hours
Work-in-progress	4 hours
Number of supply chain levels	1
Market	
Order winning criteria	Price, product variety
Order qualifying criteria	Quality, service level
Maximum demand deviation	~ 20%

Table 5.7: Product/process/market characteristics of edible oil plant

Only a few lean practices pertaining to the principle of the elimination of waste have been observed in the plant (Table 5.8). This fact can be attributed to the typical product, process and market characteristics of the plant. The short processing time (6 hours), few workstations and continuous process has resulted in a low WIP. Low WIP coupled with low product variety has contributed to the absence of lean practices such as quick change over & visual control. High product volume and high capital investment has led to the adoption of preventive maintenance activities to reduce down time and improve overall equipment effectiveness (OEE). No practices relating to employee involvement for continuous improvement were observed (Table 5.8).

Lean practices	Status of lean practices	Reason for absence of lean practices
Aligning production with demand		
Pull system	No	Straight oils production based on forecast, 'blend' oils served from intermediate stock
Uniform work load /levelled production	No	Long change over time
Mixed model production	No	Non-discrete material
One-piece flow	No	Continuous flow of non-discrete material
Supplier integration		
JIT deliveries	No	Palm oil purchased from global suppliers
Active information exchange with suppliers	No	Distant suppliers,
Supplier involvement in product development	No	Raw materials are commodity item
Supplier reduction policy	No	Price as the basis of supplier selection
Supplier development activities	No	Supplier located overseas
Long term contracts	No	Variable quality due to produce of agriculture
Employee involvement and empowerment		
Quality circle	No	Little direct labour
Cross functional training	No	Little direct labour, simple job
Autonomation	No	Complex process control require specialised know how
Team based problem solving	No	Little direct labour
Continuous improvement program	No	Lack of management commitment
Suggestion scheme	No	Lack of awareness
Job rotation	No	Few process and few labours
Elimination of waste		
Quick change over	No	Change over requires cleaning of the plant pipe line
Quality system	No	Lack of management commitment
Cellular manufacturing	No	Non-discrete material flow, few routings, limited product variety
Visual control	No	Processes are automated and controlled from control room
Preventive maintenance	Yes	
Statistical process control	Yes	
5 S	Yes	
Mistake proofing	No	
Standard operations	Yes	

Table 5.8: Status of lean practices in edible oil plant

5. 3.7 Lessons learned

Despite the fact that the plant employs process manufacturing characterised by fixed routings, specialised capital-intensive equipment, it has been able to move decoupling point upstream.

5.4 Case study (4): Beer Plant

5.4.1 Introduction

This plant owned by a South African Brewery, is based in Northern India and has been in operation since 1990. It operates in an environment characterised by high volume and low product variety. It produces on average 1 million bottles (650 ml) per week and employs 50 production employees. Its proximity to New Delhi which is a major market, is among its strong points and has created a strong brand in the domestic market.

5.4.2 The Products

This plant is also similar to case (1) and case (2) with regard to product variety. The product has a comparatively long shelf life which offers scope to build stock. Although the bill of materials/recipe is quite shallow compared to other food products, beer is somewhat more complex due to the use of a slow fermentation process that requires close control of the process. The quality of beer depends on its ingredients, mainly malt, rice flakes and hops, which are the produce of agriculture and are prone to inconsistent quality.

5.4.3 The Market

The plant operates in a growing dynamic market where the competition is intense and the customer demand cannot be predicted accurately. Moreover customer demand shows a seasonal pattern. Demand for beer is more in the summer season than in the winter season. Brand and quality are order-winning criteria and the company has invested a lot in building the brand.

The plant sells its product to high street retailers, bars, pubs and hotels. The majority of the customers are long-term. Customer orders are satisfied through its warehouse where it has the policy to keep at least four weeks stock to cope with the uncertainty in demand. As beer has a long shelf life, the plant also builds up the stock for the summer season. It also employs temporary labour during the high season mainly used at the packing stage.

5.4.4 The Raw material

The plant requires a few raw materials such as malt, rice flakes, sugar, hops and yeast with malt being the main raw material. The plant keeps a one-week stock of malt which is purchased from malt miller suppliers around Delhi. Its suppliers deliver malt once a week. The raw materials are agricultural produce so the quality is variable. Inconsistent quality and price volatility inhibits a trusting relationship between the plant and its suppliers. No initiatives have been started to integrate suppliers with the plant's production system.

5.4.5 The Process

The manufacturing process involves malt milling, meshing, flocculation, fermentation and bottle filling (see Figure 5.6).The main raw material, malt, is sieved and cleaned before being fed to the malt milling process where it undergoes a three stage grinding operation. Malt milling is followed by meshing, lautering and flocculation processes, which takes place in a brew house where other ingredients such as hops, sugar and water are also added. One brew lot is equal to 16500 litres. This means that another variety of beer cannot be produced before the processing of 16500 litres of beer.

This brewed mixture when mixed with yeast is kept in a tank for 15 days where a slow fermentation process takes place which converts the mixture into beer. As the fermentation process is slow and the lot size is large, the plant has installed a large number of ' beer before bottling' tanks where different types of beer can be stored.

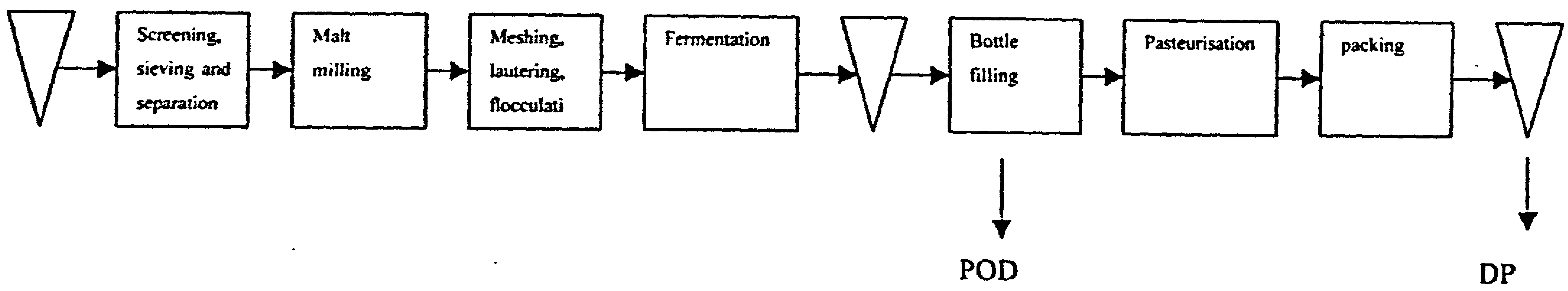

Figure 5.6: Process flow of beer plant

'Beer before bottling' tanks supply beer to the filling process, where the beer is filled in 650 ml bottles before being sent to the pasteurisation process and on to the packing process (see Figure 5.6).

The manufacturing processes are tightly coupled and automated which requires less manpower. The majority of the manpower is required at the packing stage. Moreover, a low level of manpower skill is required so there is little emphasis on training except in the area of food hygiene.

5.4.6 Plant Assessment

The few product varieties, large production volume, continuous manufacturing, low flow interruption and fixed routing characterise the plant which makes it a continuous type food and drink plant (Table 5.9). Moreover the long shelf life and unpredictable customer demand has forced it to adopt a make–to-stock (MTS) strategy. This is the only plant which experiences high WIP due to the slow fermentation process which also increases the average manufacturing lead-time.

The location of the decoupling point (DP) is at the stock of finished goods. This is due to poor supplier integration, demand seasonality, long changeover time and long shelf life. Long shelf life gives the opportunity to build stock during slack times. Although the location of the DP is on the downstream side, it can be shifted to the 'beer before bottling' tank if demand variability can be predicted accurately.

This is typical of all process plants where the main objective is to maximise the capacity of the plant. The plant being capital intensive and high volume does not require a large amount of direct labour. The majority of the direct labour is unskilled and so there is little emphasis on lean practices pertaining to employee involvement and empowerment principles.

Characteristics	
Product	
Product complexity	Medium
Product variety	10 SKUs
Product shelf life	24 weeks
Number of ingredients per product	5-7
Process	
Operations strategy	Make-to stock (MTS)
Process type	Continuous
Decoupling point	Late
Equipment type	Specialised
Process complexity	Medium
Flow interruption	Low
Routings	Low
Number of major operations	7
Main operations	Fermentation, brewing, pasteurisation
Number of production employees	50
Labour skill input	Low
Production volume	150,000
Level of automation	High
Process flexibility	Low
Point of discretisation	Bottle filling stage
Change over time	6 hours
Work-in-progress	20 days
Number of supply chain levels	1
Market	
Order winning criteria	Brand, quality
Order qualifying criteria	Price, service level
Maximum demand deviation	>50%

Table 5.9: Product/process/market characteristics of beer plant

No lean practices pertaining to aligning production with demand, supplier integration and employee involvement and empowerment have been observed (Table 5.10). This plant has adopted only a few lean practices such as preventive maintenance, 5S, standard operations and quality systems with regard to the elimination of waste principle (Table 5.10).

5.4.7 Lessons learned

The plant is characterised by few product varieties, large production volume, continuous manufacturing, low flow interruption, fixed routing, long product shelf life and wide demand fluctuation have led to adoption of make-to-stock (MTS) policy.

Lean practices	Status of lean practices	Reason for absence of lean practices
Aligning production with demand		
Pull system	No	All processes are tightly coupled and production is based on forecast.
Uniform work load /levelled production	No	Long changeover time
Mixed model production	No	Non-discrete material flow, low product variety
One-piece flow	No	Non-discrete material
Supplier integration		
JIT deliveries	No	Large economic transport size
Active information exchange with suppliers	No	Small suppliers
Supplier involvement in product development	No	Large number of suppliers
Supplier reduction policy	No	Variation in malt composition and quality
Supplier development activities	No	Price is main criterion for selection of supplier
Long term contracts	No	Quality of malt depends on supplier location
Employee involvement and empowerment		
Quality circle	No	Low number of employees
Cross functional training	No	Simple job
Autonomation	No	Un-skilled labour
Team based problem solving	No	Temporary and un-skilled labour
Continuous improvement programmes	No	Lack of management commitment
Suggestion scheme	No	Lack of awareness
Job rotation	No	Little direct labour
Elimination of waste		
Quick change over	No	Change over is sequence dependent
Quality system	Yes	
Cellular manufacturing	No	Low product variety and non-discrete flow
Visual control	No	Lack of management commitment
Preventive maintenance	Yes	
Statistical process control	No	
5 S	Yes	
Mistake proofing	No	
Standard operations	Yes	

Table 5.10: Status of lean practices in beer plant

5.5 Case Study (5): Butter Plant

5.5.1. Introduction

This plant is similar to the UHT milk plant (case 2), located adjacent to the dairy plant (case 1) and employs 50 people on the shop floor. It manufactures table butter and white butter. Table butter is sold to the end customer whereas white butter is supplied to the Ghee manufacturing plant.

5.5.2. The Product

This secondary processing plant only offers a limited product variety to its customers. Product variety does not impose a constraint on its production system. Though shelf life of butter is three months if stored below –16 degree centigrade, this reduces drastically if a low temperature is not maintained. Throughout its logistic system it requires cold storage.

5.5.3. The Market

The plant sells its products to retail outlets spread over some nearby 50 towns. It keeps a finished goods inventory of one week in cold storage. The order winning criteria in the butter markets are price and service level.

Table 5.11 presents butter production and sales for the years 2003 and 2004. Figures 5.7 and 5.8 depict fluctuation in sales for the years 2003 and 2004. Total production and sales of butter in the year 2003 and 2004 were 811 tonnes and 863.3 tonnes whereas total sales of butter were 727.3 tonnes and 831.8 tonnes in year 2003 and 2004. So 83.3 tonnes and 31.4 tonnes respectively of butter were overproduced in years 2003 and 2004 respectively. This overproduction is due to an error in the forecast of demand.

Month	Butter production (kg)	Butter sale (kg)
Jan.03	75000	64700
Feb. 03	73000	74000
Mar.03	90000	73400
Apr.03	56000	67500
May.03	40000	25000
June.03	15000	25500
July 03	43000	25500
Aug.03	69000	47000
Sept.03	86000	84000
Oct.03	79000	95000
Nov.03	90000	68500
Dec.03	95000	77600
Jan.04	85500	80800
Feb.04	90100	88500
Mar.04	84800	79700
Apr.04	69900	64000
May.04	79400	77900
Jun.04	81000	78700
Jul.04	30600	33700
Aug.04	15300	17700
Sep.04	77800	70600
Oct.04	74300	78800
Nov.04	76600	70700
Dec.04	97900	90700

Table 5.11: Butter production and sales

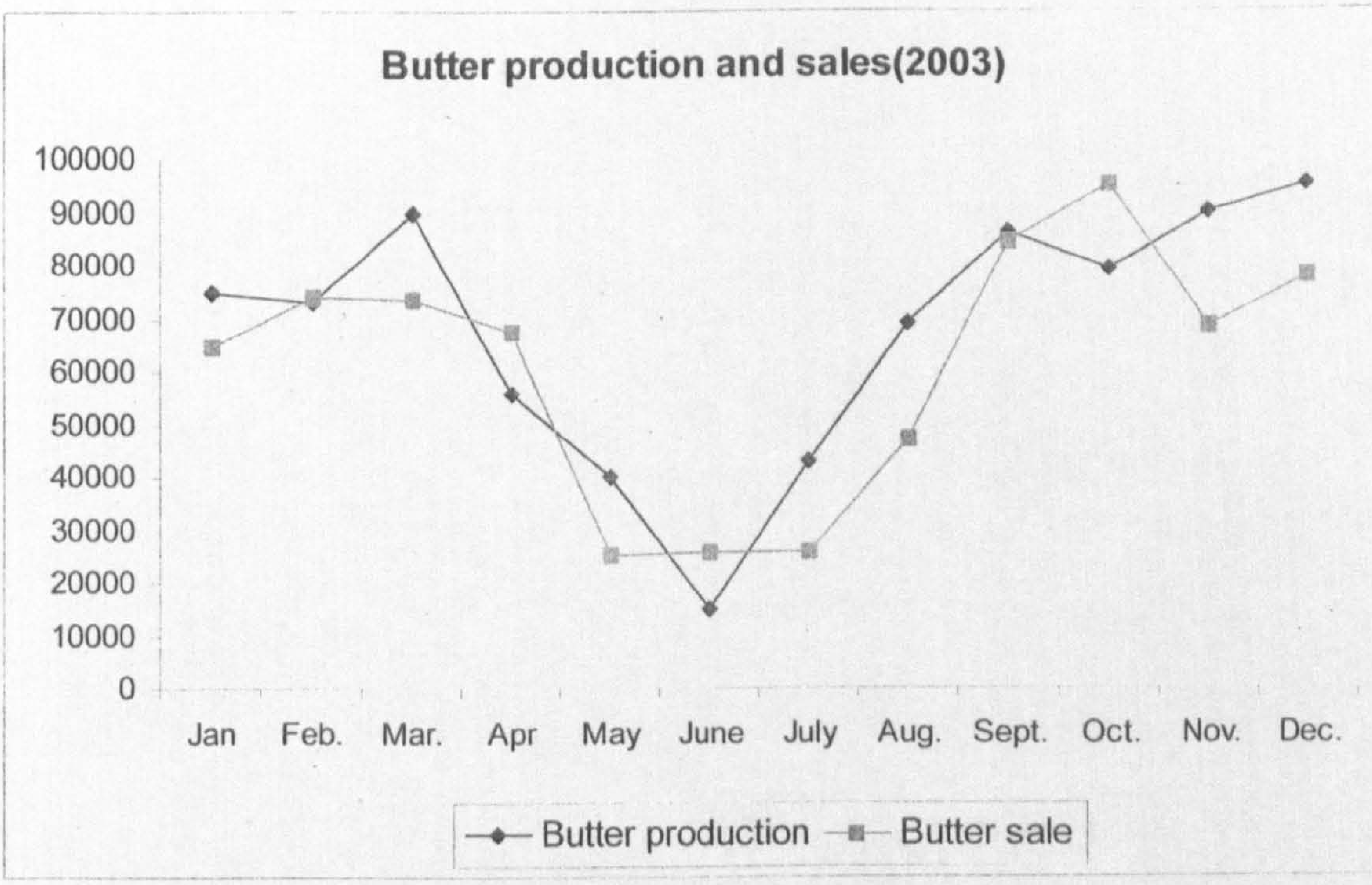

Figure 5.7: Butter production and sales (2003)

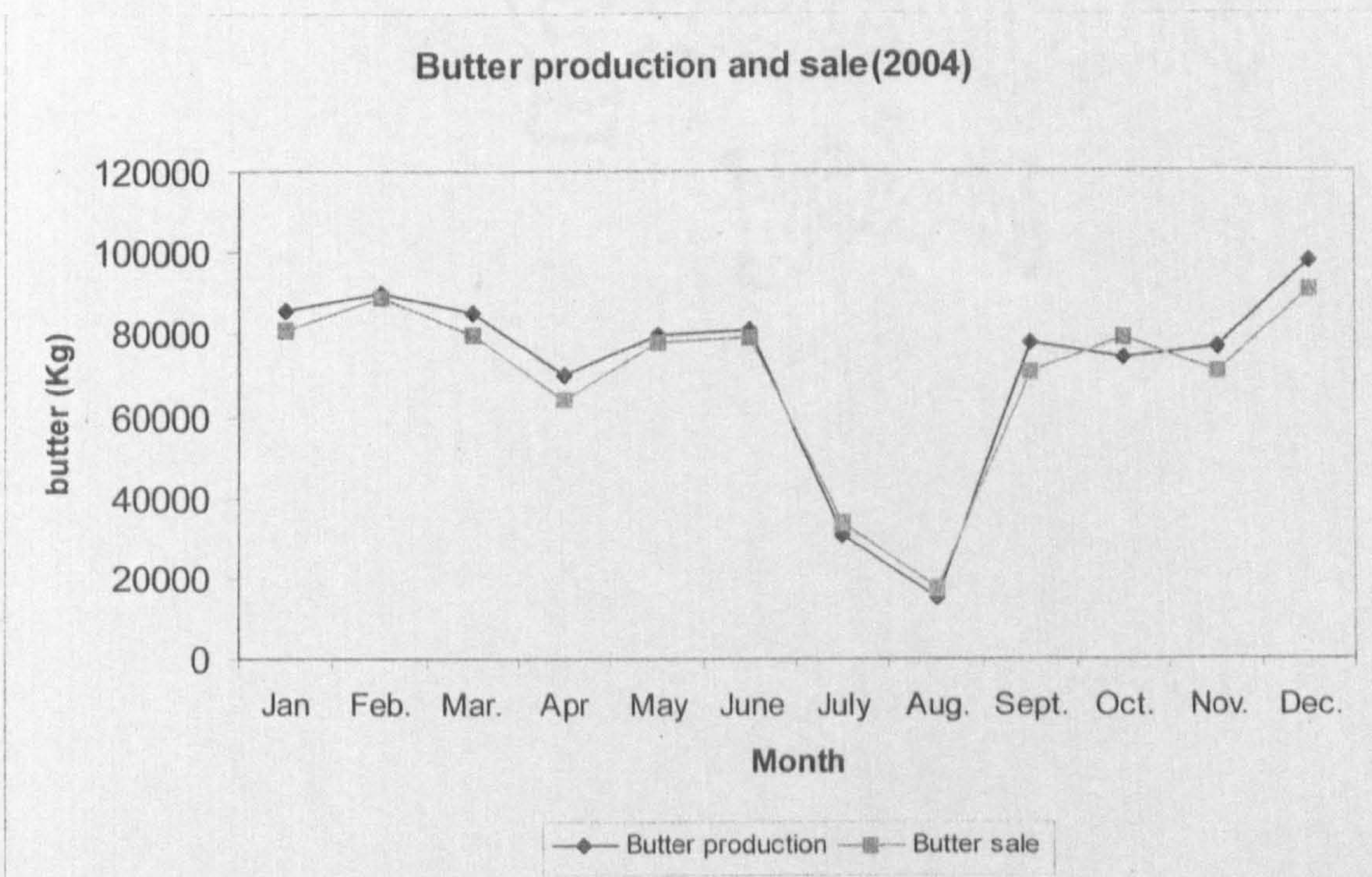

Figure 5.8: Butter production and sales (2004)

5.5.4. The Raw Material

The plant requires few raw materials. The main raw material is milk which it procures from the dairy plant (case 1). The plant has also entered into a long-term agreement to purchase milk from the dairy plant. It does not keep a high inventory of milk due to the short product shelf life with an average inventory of milk being less than one day. Packaging materials are purchased from three suppliers from whom it receives a delivery once per week.

5.5.5. The Process

The production process is relatively simple and consists of five main steps: cream separation, pasteurisation, churning, pre-working and packing (see Figure 5.9). Initially the cream is separated from the milk and pasteurised.

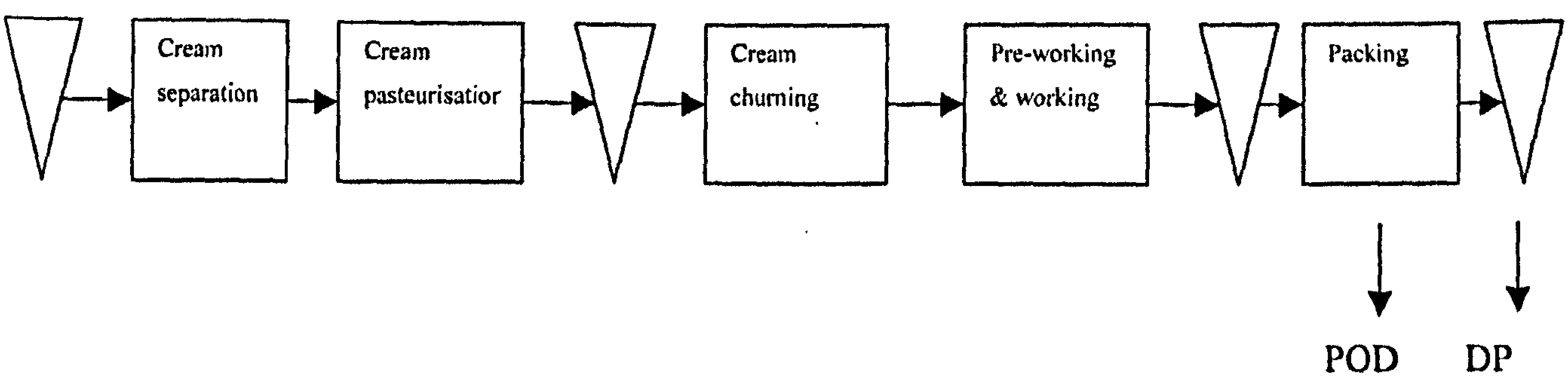

Figure 5.9: Process flow of butter plant

Cream is pasteurised at a temperature not less than 90 ^{O}C for 15 seconds with the outlet temperature not exceeding 15 ^{O}C. Pasteurised cream is stored in cream storage tanks at not more than 9 ^{O}C. Cream is taken to a butter churn of 4000 litres capacity where the cream is churned until peanut size granules are formed. The buttermilk is then separated and transferred to the raw milk tank / silo. Pasteurised water is added at an amount equivalent to the expected yield of butter at a maximum of 10 $^{\circ}$C. The cream is churned and the buttermilk is separated and transferred to a raw milk tank/silo. Next salt is added during the pre-working process to form a compact mass of butter prior to sending for packing. Due to cleaning and set-up times, a minimal batch-size is present at all stages.

5.5.6. Plant Assessment

This plant is characterised by low levels of raw material inventory, low WIP and high finished goods inventory. Table 5.12 highlights the product, process and market characteristics of the plant.

Characteristics	Value
Product	
Product type:	Perishable,
Product variety	6 SKUs
Product shelf life	3 months
Number of ingredients per product	7-8
Process	
Operations strategy	Make-to stock (MTS)
Process type	Batch
Decoupling point	Late
Equipment type	General and specialised
Process complexity	Low
Flow interruption	Medium
Routings	Low
Number of major operations	5
Main operations	heating, separation
Number of production employees	50
Labour skill input	Low
Production volume	15,000 kg per day
Level of automation	Low
Process flexibility	Medium
Point of discretisation	Packing stage
Change over time	1 hour
Work-in-progress	1 day
Number of supply chain levels	2
Market	
Order winning criteria	Price, service level
Order qualifying criteria	Quality
Maximum demand deviation	~20%

Table 5.12: Product/Process/Market characteristics of butter plant

The short shelf life of its raw material, milk, does not provide an opportunity for building a large inventory. Moreover the supplier of the milk is in close proximity which also does not warrant a large level of inventory. A few processes, low product variety, a product-type layout and short throughput time leads to low WIP. The plant has not embraced any of the lean practices pertaining to employee empowerment and involvement and aligning production with demand principles (Table 5.13).

Lean practices	Status of lean practices	Observation/reason
Aligning production with demand		
Pull system	No	Production is based on demand forecasts
Uniform work load /levelled production	No	Long changeover
Mixed model production	No	Change over is sequence dependent
One-piece flow	No	Non-discrete material flow
Supplier integration		
JIT deliveries	No	Lack of management commitment
Active information exchange with supplier	No	Lack of resources
Supplier involvement in product development	No	Low product complexity
Supplier reduction	Yes	
Supplier development activities	No	Lack of management commitment
Long term contracts	Yes	Ensures continuous availability of milk when customer demand is high
Employee involvement and empowerment		
Quality circle	No	Little direct labour, lack of awareness
Cross functional training	No	Job is relatively simple
Autonomation	No	Unskilled labour
Team based problem solving	No	Little direct labour
Continuous improvement programmes	No	Lack of management commitment
Suggestion scheme	No	Lack of management commitment
Job rotation	No	Few people
Elimination of waste		
Quick change over	No	Change over is time consuming due to hygienic requirement
Quality system	Yes	ISO 9000 accredited and HACCP certified
Cellular manufacturing	No	Limited product variety, non-discrete material flow
Visual control	No	Lack of management commitment
Preventive maintenance	No	
Statistical process control	Yes	Ensures consistent quality
5 S	Yes	
Mistake proofing	No	Lack of management commitment
Standard operations	Yes	

Table 5.13: Status of lean practices in butter plant

Although its main supplier is close by, lean practices such as JIT deliveries, active information exchange, supplier development activities and supplier involvement in product development have not been adopted.

High finished goods inventory is a big issue for the plant. The decoupling point is at finished goods storage. Processes before the point of discretisation consist of intermittent as well as continuous processes which means the decoupling point can be shifted upstream.

5.5.7 Lessons learned

The proximity of main supplier, few processes, low product variety, a product-type layout and use of intermittent as well as continuous processes offers an opportunity to this plant to shift its decoupling point (DP) upstream.

5.6 Case Study (6): Sweet Biscuit Plant

5.6.1 Introduction

The company which owns this plant, commands an approximate 40 per cent market share in the domestic biscuit market in India. It has 1,500 wholesalers catering to 425,000 retail outlets. The company has three manufacturing plants in India. The study has been carried out at one of its manufacturing plants near Delhi. This plant is ISO 9001 certified and produces 250 tonnes of sweet biscuits per day.

5.6.2 The Product

The plant produces 12 types of sweet biscuits. The bill of materials/recipe is relatively shallow and the product has a relatively long shelf life, which prevents the plant from adopting a make-to-order (MTO) strategy.

5.6.3 The Market

The plant caters for a market where price is an order winning factor and hence reducing cost and achieving a consistent quality are the main objectives. Over the years it has established a strong brand in the minds of the Indian consumer. The plant keeps at least two weeks finished goods inventory in its distribution centre. It does not experience wide fluctuation in demand, but has a long logistical chain which means it has to keep a high finished goods inventory.

5.6.4. The Raw Material

The main raw materials are wheat flour, sugar, oil, invert syrup, milk, salt, added vitamins and packaging materials. It keeps around 3 days of raw material inventory. The quality of the biscuits depends on the quality of the wheat flour and other ingredients.

The quality of the wheat flour fluctuates from supplier to supplier. Moreover the price of the wheat flour fluctuates and so the plant does not rely on a single supplier. For each main raw material there are 6-7 suppliers. A supplier is awarded business on a monthly quoted price basis. The plant has also installed a packaging plant within its premises which supplies all its packaging material and hence does not have to rely on an external supplier.

5.6.5 The Process

High capital-intensive plant, high change over time and low unit sale price of the product leads to a make-to-stock (MTS) operations strategy. The plant employs a comparatively large number of production employees but they are used mainly at the packing stage where the job is quite simple but monotonous and requires mostly unskilled workers. Processes before the packing stage are automated and capital intensive and use both general and specialised equipment. Changeover is required at two places, at the packing stage and at the moulding stage. The changeover at the packing stage takes less time as only packaging material has to be replaced, whereas the changeover at the moulding stage requires cleaning of the mixer and replacement of the die which takes 2 hours. Due to the low product unit price and high capital investment, changeover is limited to once per day.

All ingredients are sieved, mixed in a mixer and than moulded to a specific shape. The product is further baked, cooled and packed (see Figure 5.10).

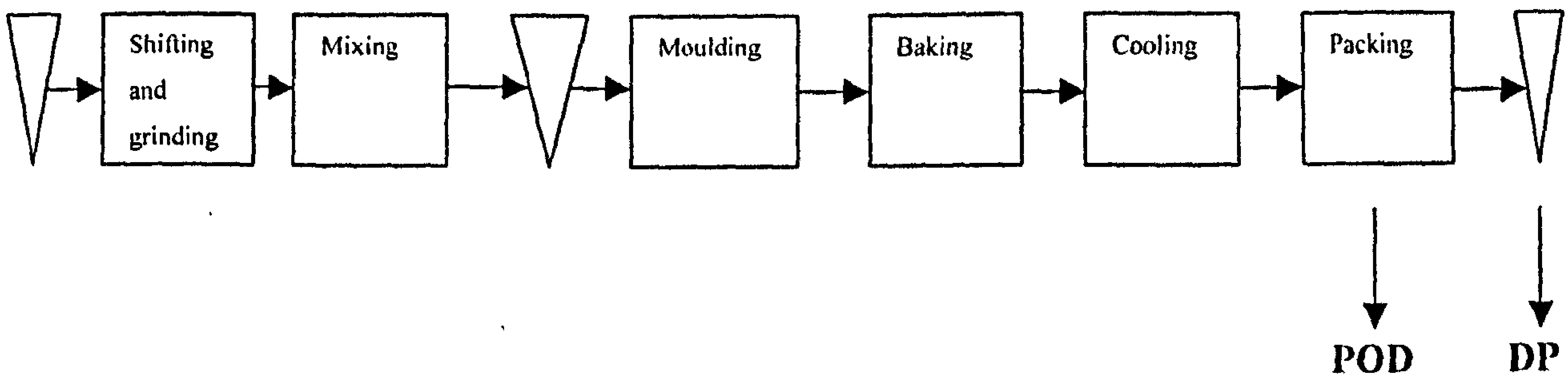

Figure 5.10: Process flow of sweet biscuit plant

The moulding, baking, cooling and packing processes are tightly coupled and the product becomes discrete at the packing stage. Except for the packing process all other processes are capital intensive and employ both general and specialised equipment. The decoupling point is at the finished goods stage (see Figure 5.10).

5.6.6 Plant assessment

This plant does not offer a high product variety, but produces large volume (Table 5.14). It competes in the market on the basis of price. Little product variety and high volume produces an economy of scale. Long changeovers, long product shelf life, price and service level as order winning criteria have contributed to the large batch production.

Although it has adopted the majority of lean practices pertaining to the elimination of waste and employee involvement and empowerment (Table 5.15), the plant has not embraced lean practices that can align production with demand and integrate its suppliers with its production system.

Characteristics	
Product	
Product variety	12 SKUs
Product shelf life	24 weeks
Number of ingredients per product	10-15
Process	
Operations strategy	Make-to-stock (MTS)
Process type	Batch
Decoupling point	Late
Equipment type	General and specialised
Process complexity	Medium
Flow interruption	Low
Routings	Medium
Change over time	2 hours
Number of major operations	6
Main operations	Heating, mixing, forming
Number of production employees	400
Labour skill input	Low
Production volume	1000,000 units per day
Level of automation	Medium
Process flexibility	Low
Point of discretisation	Moulding stage
Change over time	2 hours
Work-in-progress	2 hours
Number of supply chain levels	2
Market	
Order winning criteria	Price, brand
Order qualifying criteria	Quality, service level
Maximum demand deviation	~20%

Table 5.14: Product/process/market characteristics of sweet biscuit plant

This plant employs a comparatively large number of production employees. To harness the capability of its employees the plant has already initiated quality circles, KAIZEN on safety issues, hygiene and cost, "star of the month" and quality improvement teams for continuous improvement of the work place. Thirteen quality circles have been formed and 3500 to 4000 suggestions are received under KAIZEN within a period of six months. The employees are given a one point lesson at the start of each shift as part of their continuous development.

Although there is not much raw material and work-in-progress inventory, the plant keeps a large amount of finished goods inventory. When asked about the suitability of a pull system the plant manager was very sceptical due to the long changeover times.

Lean practices	Status of lean practices	Reason for absence of lean practices
Aligning production with demand		
Pull system	No	Production based on demand forecast
Uniform work load /levelled production	No	Long change over time
Mixed model production	No	Long changeover time, non-discrete material flow
One-piece flow	No	Non-discrete material flow
Supplier integration		
JIT deliveries	No	High economic transport size, distant suppliers
Active information exchange with suppliers	No	Small supplier, lack of resources
Supplier involvement in product development	No	Basic commodity raw material, short term purchase contract
Supplier reduction policy	No	Variable quality of raw material
Supplier development activities	No	Short term purchase contract, large number of suppliers
Long term contracts	No	Price is order winner for suppliers, variable quality of raw material
Employee involvement and empowerment		
Quality circle	Yes	
Cross functional training	Yes	
Autonomation	No	A large number of unskilled workers
Team based problem solving	Yes	
Continuous improvement programmes	No	Lack of management commitment
Suggestion scheme	Yes	
Job rotation	Yes	
Elimination of waste		
Quick change over	No	Long change over due to hygienic reasons
Quality system	Yes	
Cellular manufacturing	No	Moderate product variety, large volume
Visual control	Yes	
Preventive maintenance	Yes	
Statistical process control	No	Lack of management commitment
5 S	Yes	
Mistake proofing	Yes	
Standard operations	Yes	

Table 5.15: Status of lean practices in sweet biscuit plant

5.6.7 Lessons learned

Long changeovers, long product shelf life, price and service level as order winning criteria have contributed to the adoption of make-to-stock (MTS) policy.

5.7 Case Study (7): Sliced Meat Plant

5.7.1 Introduction

This plant handles the Danish Crown group's processing activities in the UK market. The company operates within four main product groups: bacon, luncheon meat, canned goods and poultry products. Moreover, it produces and sells processed meat products such as sliced goods, cooked products, as well as fried and marinated poultry products. The plant under study is based on the Wirral, UK. It is a relatively medium-sized plant producing 750,000 packs/week and employing 250 production employees. It supplies its products to leading Marks & Spencer (M&S) superstores.

The plant has been approved under the HACCP principles that govern the plant's own control procedures. Their control procedures cover the entire process from raw materials to finished products and their laboratories conduct daily bacteriological and chemical analyses of raw materials and finished products. The final control procedure consists of an independent, external veterinary inspection, and the overall result is a high standard of food safety. The level of hygiene is based on the Danish veterinary authorities' own very high specifications. The hygiene requirements cover the interior design of the building, the production processes, employees' clothing, behaviour and cleaning procedures.

5.7.2 The Product

It produces cured and uncured sliced meat products and has a large diversity of products due to differences in packaging sizes and labels. The bill of materials/recipe is relatively shallow due to using only a few ingredients and low product complexity.

The food products have to be safe and meat products have got a very short shelf life, which impose a number of constraints during its processing. Raw meat has a shelf life of 4 to 10 days but if uncured meat is cooked then the shelf life is increased by 12 days. If raw meat is cured then the shelf life is increased by 6 months. The final product has a shelf life of 9 days from which the customer wants a 6-days shelf life from the date of delivery. Due to the short shelf life the plant does not keep a finished goods inventory for more than 3 days.

5.7.3 The Market

The plant supplies its product mainly to one customer, M&S which makes its position very vulnerable. Although M & S provides two weeks sales forecast and also communicates daily sales figures. The plant deems this two-week sales forecast to be very inaccurate. It experiences a forecast error of more than 20 per cent. The customer, M&S superstore, asks for short deliveries but passes all uncertainty onto the plant which results in a wide demand fluctuation particularly during Christmas and Easter periods and also when M&S has a promotional sale at their stores.

The demand pattern is not stable and depends on the season (e.g. Christmas. Easter, winter, summer) and promotions schemes offered by M& S. M&S offers at least one promotion per product per quarter spaced only a couple of weeks apart. Demand varies between 550K packs per week (e.g. week before promotion) to 850K packs per week during promotion/Christmas/Easter week. This leads to fluctuations which makes it difficult to adopt an MTO as the process strategy even though the plant supplies to only one customer. Demand for high service levels and ever changing production schedules has forced it to adopt push manufacturing. M& S uses EPOS system at their stores but they rarely share this data with the plant electronically.

5.7.4 The Raw Material

Sliced meat products require few ingredients. M & S provides a list of raw material suppliers from which the plant can procure its raw meat and has to abide by this list of suppliers. The plant has a long-term agreement (LTA) with around 50% of its suppliers and more than 75% of the items are purchased under this long term agreement (LTA).

On average there are not more than 2 suppliers for each item. More than 50% of the raw materials are delivered to the plant more than once a week. The supplier's performance is measured regularly on the basis of quality, cost and delivery.

It is profitable for the plant to purchase pork meat in the lean season when the raw meat can be procured at low cost. The plant keeps on average an 8 weeks raw material inventory. Although raw meat has a short shelf life, it is increased by curing the raw meat.

The plant has built a high standard of quality that is firmly rooted in the selection process and by having a close cooperation with the slaughterhouses to ensure the quality of raw materials. Control of the quality of the raw materials extends to livestock feeds, breeding work, care and delivery of the animals, as well as the actual slaughtering procedure. On receipt of the raw materials and before they enter the production chain, they undergo extensive checks so that they are absolutely certain that they meet stringent specifications.

5.7.5 The Process

The production process of uncured meat products consists of casing, cooking, cooling, roasting/coating/smoking, slicing and packing (see Figure 5.11). In the case of cured meat products an additional process, curing, is required to enhance the shelf life of the product. All processing stages follow a product layout, so there is no back tracking with regard to material handling.

In the case of uncured meat products, raw material is cooked in the oven, followed by quick cooling in blast chillers. Following this, the product can either be stored in cold storage known as holding chillers as semi-manufactured product or processed (smoking/roasting/coating). The product is then sliced. This process has variable yield as some material is wasted in the slicing operation.

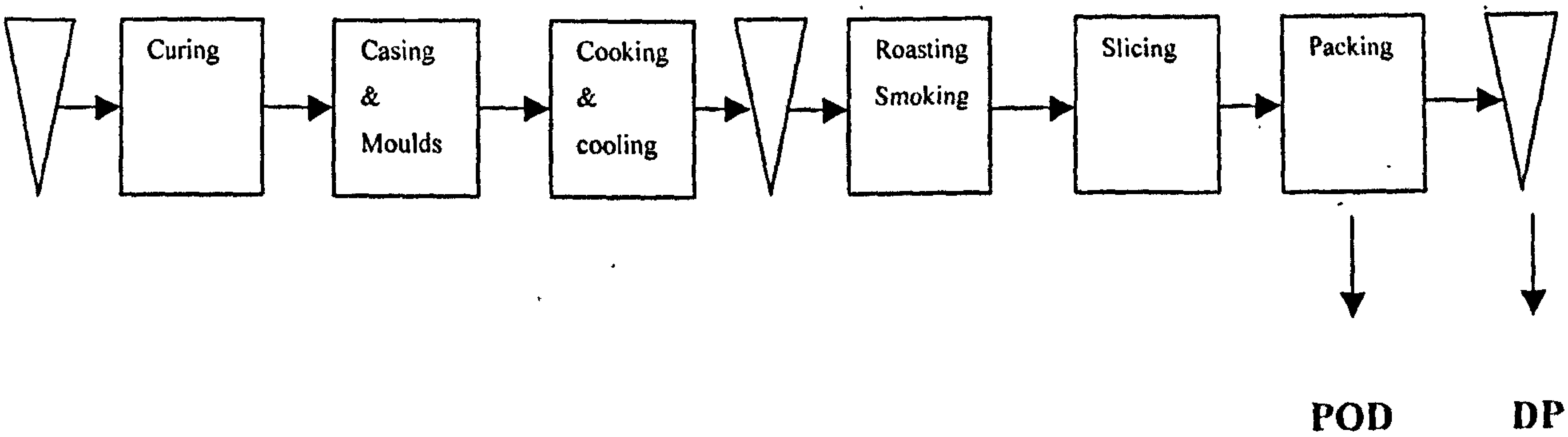

Figure 5.11: Process flow of sliced meat plant

There are 12 slicing lines which are customised by slicer /pack type. Each slicing line can produce 5-12 product types out of 60 total product types. The slicing process is followed by packing which involves metal detection, weight checking and labelling.

Due to the long cleaning and set-up time, most of the changeover takes place at the end of the shift when there is no production. All changeovers are scheduled in advance. Although the plant freezes the production schedule a day before production, changes in the production schedule at the last minute has become a routine.

Information regarding operation measurable, production data, quality problems and safety are displayed and updated regularly on the main notice board. Half of the operations are controlled using statistical process control techniques.

5.7.6. Plant assessment

The plant is characterised by short product shelf life, high product volume, moderate product variety and batch production (Table 5.16). Short shelf life of the end product puts a restriction on the amount of finished goods inventory, which cannot be more than 400,000 packs (3 days of production). This fact should drive the plant to become leaner. It was observed that even though there was not much finished goods inventory it has built more WIP at the expense of finished goods inventory. A curing or cooking process can increase the shelf life of the meat to six months. Curing/cooking offers an opportunity to build up an inventory of cooked or cured meat which can be used later for further processing. Another reason for the build up of WIP is due to the fluctuation in the price of meat.

Characteristics	
Product	
Product variety	60 SKUs
Product shelf life	1-2 weeks
Number of ingredients per product	7-10
Process	
Operations strategy	Make-to-stock (MTS)
Process type	Batch
Decoupling point	Late
Equipment type	Specialised
Process complexity	Low
Flow interruption	Low
Routings	Low
Change over time	High
Number of major operations	7
Main operations	Heating, separation, cooling
Number of production employees	250
Labour skill input	Low
Production volume	140,000 packs per day
Level of automation	Medium
Process flexibility	Medium
Point of discretisation	Packing stage
Change over time	25-30 minutes
Work-in-progress	10 hours
Number of supply chain levels	2
Market	
Order winning criteria	Quality, service level
Order qualifying criteria	Price
Maximum demand deviation	~25%

Table 5.16: Product/process/market characteristics of sliced meat plant

The plant buys raw meat during the lean season at a discount and stores it in the form of cooked meat or cured meat. Procuring the pork meat during low season when prices are quite low and having the ability to store it for a long period of time gives the plant a mechanism to cope with the seasonality of demand and the retailer's promotional activities.

The long change over and cleaning times puts restrictions on mixed model production. Changeover only takes place at the end of each shift which means that the batch size on one line will be one shift's worth of production. The fact that there are 12 slicing lines helps this plant produce 12 different products at any given time.

Wide demand fluctuation, short delivery times demanded by the customer, variable process yield, wide raw material price variation, long set-up/change over time compared to total run time has led to the adoption of a make–to-stock (MTS) process strategy. At present, the location of the DP is at the finished goods stock. This plant is characterised by having a product with a short shelf life and having a single customer. Having a long-term agreement with the customer should have moved its DP onto the upstream side, but due to demand volatility, high service level and long changeover it wouldn't be able to reap the benefits of an early DP. This plant has embraced the majority of lean practices pertaining to the elimination of waste and employee involvement and empowerment principles but practices related to the alignment of production with demand were not at all conspicuous during the plant visit (Table 5.17). This situation is not just specific to this plant, it has been observed in the majority of the food industry.

Although this plant has a long-term contract with its suppliers and procures its raw material from Denmark or Scotland, JIT deliveries are not possible due to geographical constraints. This plant has been trying to reduce its supplier base and has worked together with its suppliers to improve traceability and to ensure a consistent quality of meat.

Lean practices	Status of lean practices	Reason for absence of lean practices
Aligning production with demand		
Pull system	No	Forecast inaccuracy, promotional scheme
Uniform work load /levelled production	No	Long change over time
Mixed model production	No	Food safety and hygiene, long changeover
One-piece flow	No	Non-discrete material
Supplier integration		
JIT deliveries	No	Large economic transport size, distant suppliers
Active information exchange with suppliers	No	Small suppliers can't afford big investment in developing information system
Supplier involvement in product development	No	Low product and process complexity
Supplier reduction policy	Yes	
Supplier development activities	Yes	
Long term contracts	Yes	
Employee involvement and empowerment		
Quality circle	No	Lack of awareness
Cross functional training	Yes	
Autonomation	Yes	
Team based problem solving	Yes	
Continuous improvement programmes	No	Lack of management commitment
Suggestion scheme	Yes	
Job rotation	Yes	
Elimination of waste		
Quick change over	No	Food safety and hygiene requires cleaning the system
Quality system	Yes	
Cellular manufacturing	Yes	
Visual control	Yes	
Preventive maintenance	Yes	
Statistical process control	Yes	
5 S	Yes	
Mistake proofing	Yes	
Standard operations	Yes	

Table 5.17: Status of lean practices in sliced meat plant

5.7.7 Lessons learned

Despite the fact that the product has short shelf life, this plant has not been able to reap the benefits of an early DP due to demand volatility, high service level and long changeover times.

5.8 Case Study (8): Savoury Biscuit Plant

5.8.1 Introduction

This UK-based plant, which is owned by a multi national company, manufactures a wide variety of private-label and own-label savoury biscuits and has the capacity to produce 75,000 tonnes of biscuits per annum. Annual sales turnover at this plant is around £100 million. It supplies savoury biscuits to all major superstores and high street retailers. The plant operates on a three-shift basis with five working days a week.

5.8.2 The Product

It offers 80 types of savoury biscuits to its customers and manages it through 150 stock keeping units (SKU). This large variety originates from having differences in pack sizes, labels and brands. The product has a relatively long shelf life and as such management of shelf life is not a big issue, although the customer demands at least 75% of the shelf life at their end.

5.8.3 The Market

The biscuit industry operates in a very complex and competitive market environment. Large retailers in the UK dominate the market. These powerful retailers not only demand a high service level and price reduction from the biscuit manufacturers, but also put pressure on the suppliers to deliver the goods frequently. So price and service level are the order-winning criteria for the plant. Due to the low profit margin and dominance of the large retailers the plant is not in a position to invest significantly in plant modernisation.

The customer order is served from a centralised distribution centre which keeps at least three weeks of finished goods inventory. The plant replenishes the inventory at the distribution centre.

Table 5.18 shows biscuit production and sales in the year 2004. The plant has a typical customer demand profile. During the first six months the customer demand is very low before growing and reaching the highest in the month of December (see Figure 5.12). The company makes 80% of its profit in the last quarter of the year.

Month	Biscuit production (pallets)	Biscuit sales (pallets)
Jan.04	55000	60000
Feb.04	58000	62000
Mar.04	85000	80000
Apr.04	75000	69000
May.04	70000	68000
Jun.04	75000	70000
Jul.04	75000	72000
Aug.04	85000	71000
Sep.04	90000	75000
Oct.04	110000	70000
Nov.04	120000	140000
Dec.04	130000	180000
Jan- 05	57000	62000

Table 5.18: Savoury biscuits sales and production

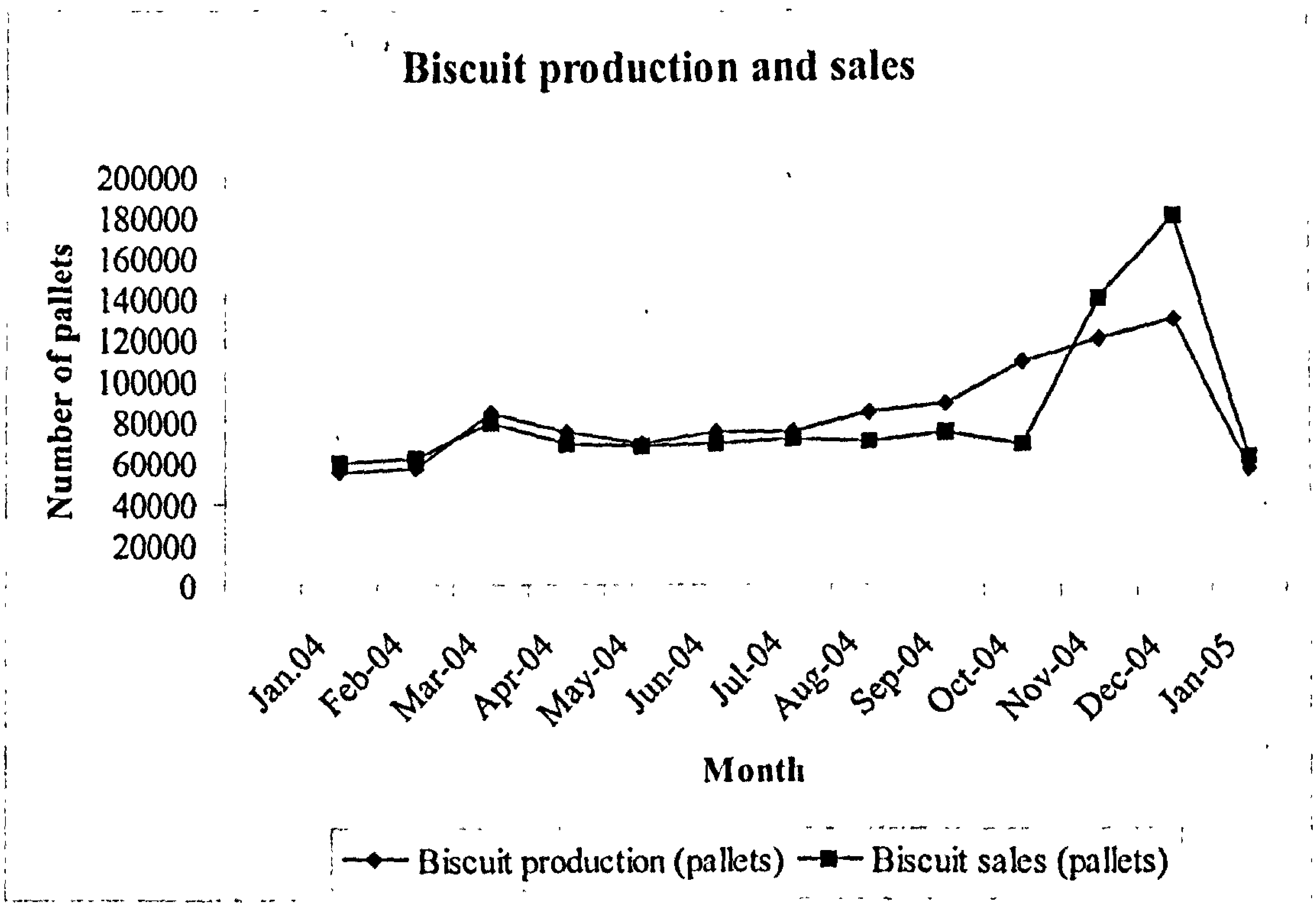

Figure 5.12: Savoury biscuits production and sales pattern

Although the plant has an EDI link with its main customers who help in estimating the demand forecast, customers do not freeze the orders well in advance which creates high forecast error. The plant experiences frequent amendments with customer orders. Moreover these customers launch promotional schemes (buy one get one free), which cannot be forecasted accurately.

5.8.4 The Raw Material

The recipe of savoury biscuits requires 10-15 ingredients. The large product variety also increases the total number of ingredients to be procured from a wide range of suppliers. The plant has to manage around 300-400 raw materials, which is comparatively large. It does not keep a raw material inventory of more than 3 days for the main ingredients.

Although the plant has to manage a large number of raw materials, the main materials are few in number. The suppliers deliver around 30% of raw materials once per week. It has established a long-term agreement with the majority of its suppliers with more than 75% of items being procured under this long-term agreement. For the majority of raw materials there are 2-3 suppliers with 75% of the raw material coming from qualified/certified suppliers.

5.8.5 The Process

The plant has adopted a make-to-stock (MTS) operations strategy. The production plan is made on the basis of a demand forecast and it experiences around 15-20% forecast error. An MTS operations strategy takes care of this forecast error but leads to an increase in the cost. Although it freezes the master production schedule 2-7 days before actual production, amendments are a regular phenomenon. The company has adopted a SAP system for planning and control activities.

The production of the biscuits consists of sifting, mixing, proving, moulding, baking, cooling and packing operations (see Figure 5.13). All ingredients are first sieved and mixed to form the dough. The dough is kept in a controlled area for "proving" for 4 to 6 hours. Proved dough is mixed with a few more ingredients and is further proved for a short duration (15 minutes). From here the dough is sent for moulding where dyes cut the flattened dough into the shape of the biscuit, which is then sent to a continuous baking system. Biscuits are then cooled and packed. Except for the proving process, all operations are coupled and have a short processing time.

The processing stage is also coupled with the packing stage and there is little inventory between these two stages. Work in progress is not more than 8 hours.

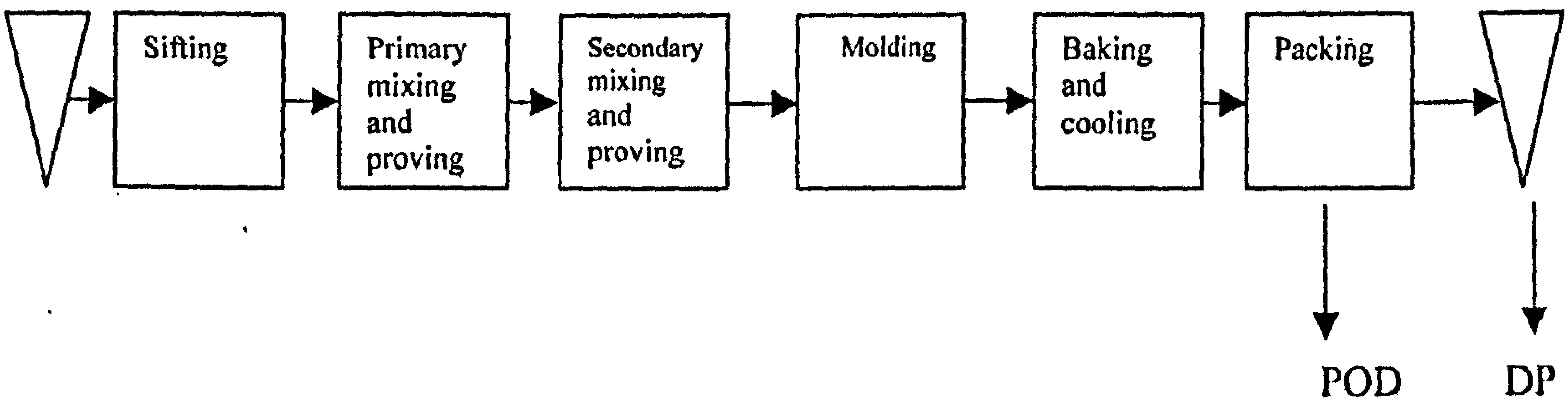

Figure 5.13: Process flow of savoury biscuit plant

There are six production lines, catering for 80 different types of products. Each production line can manufacture 10-15 different products. Changeover is long and it is sequence dependent. Most of the changeovers are manual but the changeover procedure is standardised. Some of the products like cream crackers run continuously for a week without any changeover. Even for other products there is only one changeover per shift. The plant has not invested in modern equipment which can facilitate quick changeovers. In certain situations it is not possible to make different flavoured biscuits in sequence because of the potential for mixing flavours.

The plant experiences a wide demand fluctuation with a wide gap between maximum demand and minimum demand. In the first quarter, the demand is around 15,000 pallets per week which increases to 45,000 pallets per week in the last quarter. The temporary labour is used from the third quarter onwards to build stock for the last quarter. The company keeps at least three weeks inventory in its distribution centre.

5.8.6 Plant assessment

The plant offers high volume as well as a high product variety (Table 5.19). The plant manages its product variety by having several production lines. Wide fluctuation in demand, high product varieties, high service level, frequent delivery to the customers and long change over times have forced the plant to embrace MTS as its operations strategy. Promotional schemes launched by all the major retailers also influence demand fluctuation to a considerable extent.

Characteristics	Value
Product	
Product variety	80 SKUs
Product shelf life	30 weeks
Number of ingredients per product	10-15
Process	
Operations strategy	Make-to stock (MTS)
Process type	Batch
Decoupling point	Late
Equipment type	General for mixing, baking & packing process and specialised for molding process
Process complexity	Medium
Flow interruption	Low
Routings	Low
Change over time	High
Number of major operations	8
Main operations	Heating, forming, cooling
Number of production employees	450
Labour skill input	Low
Production volume	250 tonnes per day
Level of automation	Medium
Process flexibility	Medium
Point of discretisation	Packing stage
Change over time	0.5-5 hours
Work-in-progress	7 hours
Number of supply chain level	2
Market	
Order winning criteria	Price, service level, brand
Order qualifying criteria	Quality
Maximum demand deviation	>50%

Table 5.19: Product/process/market characteristics of the savoury biscuit plant

The plant employs a large number of temporary labour to cope with demand seasonality particularly in the last quarter of the year. High product shelf life offers an opportunity to build stock during the slack period. Demand seasonality, promotional schemes and high service level have contributed towards shifting the decoupling point to the downstream side.

The plant has adopted the majority of lean practices pertaining to the elimination of waste and employee involvement and empowerment, but the alignment of production with demand principle has not found its place in its production system (Table 5.20). Though the plant has established a long-term agreement with its suppliers and has also reduced the number of suppliers to a great extent, no efforts have been made to integrate suppliers with regard to information exchange and joint development activities.

Visual control, 5S, preventive maintenance and statistical process control have been practised on the shop floor. Standard operating procedures (SOP) have been developed for each process and posted within view of the workers. Around 60% of operations are controlled with SPC.

Preventive maintenance responsibilities are defined for both maintenance and production workers. Time is allocated in the daily production schedule for workers to perform their preventive maintenance and cleaning duties and all employees are aware of good housekeeping practices. Display boards containing job training, safety, operations metrics, production data and quality problems are visible at each process and are updated regularly. There is a formal suggestion process in place to solicit ideas for improvements from all employees and to recognise their participation Operators are empowered to stop the line when a defective unit is found. There is a team responsible for analysing process defects and for identifying mistake-proofing opportunities

Lean practices	Status of lean practices	Reasons for absence of lean practices
Aligning production with demand		
Pull system	No	Forecast inaccuracy, promotional schemes
Uniform work load /levelled production	No	Long changeover time
Mixed model production	No	Long changeover
One-piece flow	No	Low product unit price, non-discrete material flow,
Supplier integration		
JIT deliveries	No	High economic transport size, distant suppliers
Active information exchange with suppliers	No	Lack of management commitment
Supplier involvement in product development	No	Low product complexity
Supplier reduction policy	Yes	
Supplier development activities	No	Lack of management commitment
Long term contracts	Yes	
Employee involvement and empowerment		
Quality circle	No	Lack of awareness
Cross functional training	Yes	
Autonomation	Yes	
Team based problem solving	Yes	
Continuous improvement programmes	No	Lack of management commitment
Suggestion scheme	Yes	
Job rotation	Yes	
Elimination of waste		
Quick change over	No	Sequence dependent set up
Quality system	Yes	
Cellular manufacturing	No	Non discrete material flow
Visual control	Yes	
Preventive maintenance	Yes	
Statistical process control	Yes	
5 S	Yes	
Mistake proofing	Yes	
Standard operations	Yes	

Table 5.20: Status of lean practices in savoury biscuit plant

5.8.7 Lessons learned

Demand seasonality, promotional schemes and high service level have contributed towards shifting the decoupling point to the downstream side. Moreover high product shelf life offered an opportunity to build stock during the slack period by employing a large number of temporary labour.

5.9 Case Study (9): Snack Food Plant

5.9.1. Introduction

This plant was set up in 1996 and is situated in the UK. It offers a large variety of processed nuts and produces around 7000 tonnes of processed nuts per annum. It is home to some of the UK's favourite brands with an annual sales turnover of £18 million. In addition, it manufactures private label products for most of the UK's major food retailers.

5.9.2. The Product

The company offers 50 varieties of processed nut products to its customers which is managed through 150 SKUs (stock keeping units). The shelf life of the product is around 20 weeks, from which the customer demands 75% of shelf life from the date of delivery. It has pioneered the use of nut coatings, as well as dry roasting and honey roasting, and has combined nuts with a range of tasty ingredients, including fruit, pulses and confectionery. It presents its products in resealable packs, selection trays, party pots and card canisters which are available in a variety of bag sizes from 50g to 500g.

5.9.3. The Market

It supplies its products to a few customers including high street retailers and public houses in addition to superstores. The majority of its customers are long term who demand a high service level as well as frequent delivery. The customer demand pattern is very erratic and seasonal. The demand at the beginning of the year hovers between 80-100 tonnes per week and then increases to the level of 190 tonnes per week in the month of December before dropping again (see Figure 5.14 and Table 5.21). The plant has to employ temporary labour after the middle of the year to fulfil the increased level of demand.

Month	Processed nuts production (tonnes)	Processed nuts sales (tonnes)
Jan. 04	250	300
Feb.04	310	320
Mar. 04	400	370
Apr. 04	450	430
May. 04	400	380
Jun. 04	380	395
Jul. 04	390	350
Aug. 04	410	395
Sep. 04	450	410
Oct. 04	500	450
Nov. 04	600	550
Dec. 04	610	725
Jan. 05	250	310

Table 5.21: Processed nuts production and sales

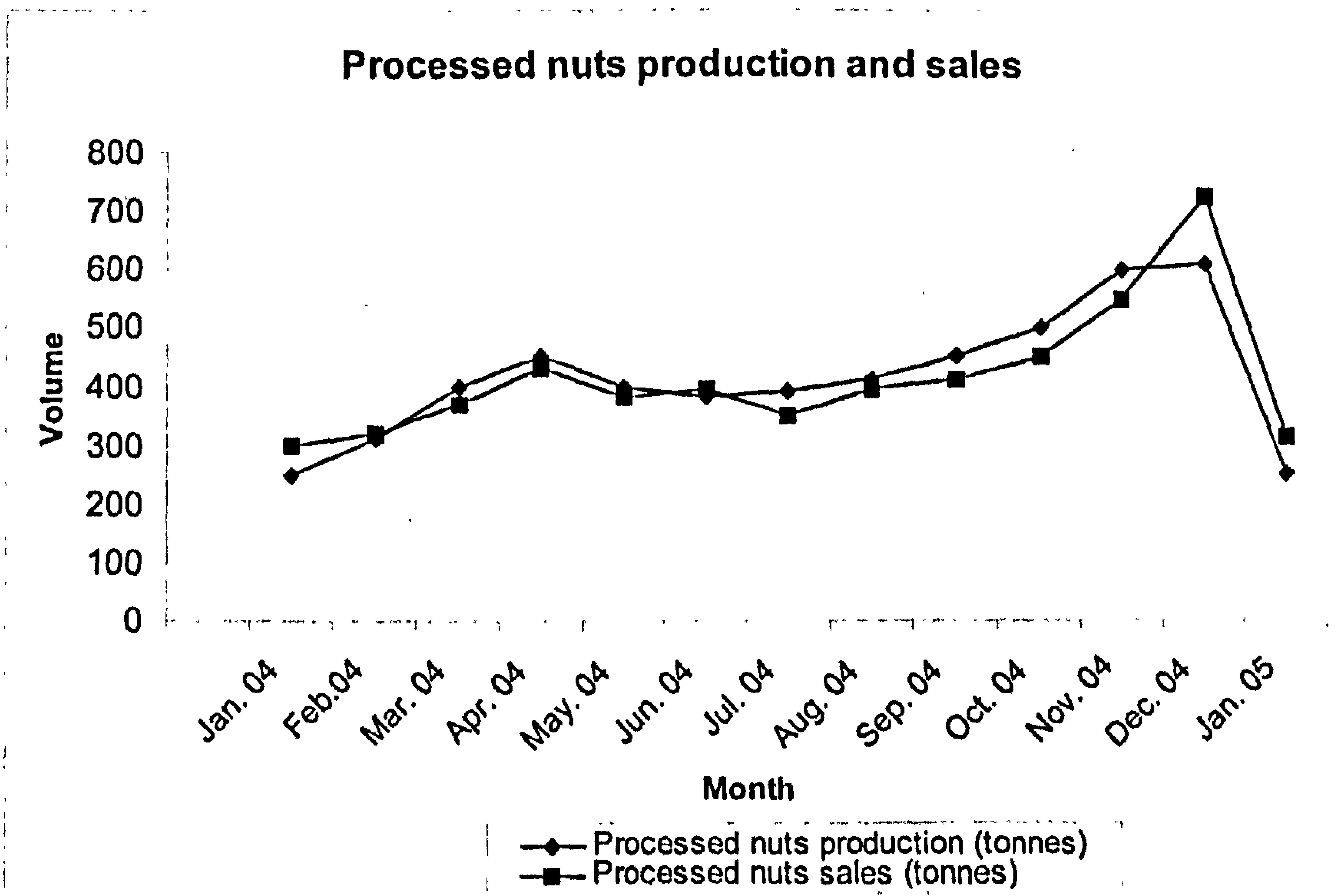

Figure 5.14: Processed nuts production and sales

Price, service level and brand are the order-winning criteria. The plant keeps less than four week's finished goods inventory and runs mainly on the basis of a make-to-stock (MTS) policy with few products being manufactured with make-to-order (MTO) strategy.

5.9.4. The Raw material

The plant imports a large variety of nuts from around the globe, including North and South America, India, China and Australia. The plant keeps on average three weeks of raw material inventory. The cost of the raw material is around 90% of the product cost, so the management of the raw material is an important issue.

Around 60% of its suppliers are long-term suppliers and more than 75% of the ingredients are procured under a long-term agreement. More than 75% of its raw materials come from certified suppliers. The average number of suppliers per ingredient is around 2. The main criteria for the selection of suppliers are cost and quality.

There is no formal system in place to measure supplier performance although quality, cost and delivery are considered in the selection of a supplier. Supplier development activities, supplier involvement in product development and information exchange through EDI have not been pursued in the plant.

5.9.5. The Process

The manufacturing processes involve husk separation, frying, roasting, coating and packing operations (see Figure 5.15). Initially the ingredients are cleaned and sorted before the outer husk is removed by blanching. Nuts are then fried or roasted and coated with various spices before being transferred to the automated packing line. The packing stage is automated.

Equipment used is of general type which supports product flexibility. Different types of products are manufactured using the same equipment by mixing different combinations of ingredients. The plant has three production lines, which are capable of manufacturing different products and uses a batch type production system where they run two or three batches in a shift. Batch sizes vary from 30kg to 16 tonnes which means the production system can accommodate variable batch sizes. Change over time is around 25-30 minutes and is scheduled in advance.

WIP is equivalent to one shift of production. The plant freezes its schedule three days before actual production but amendments to the production schedule are a common feature. On average the production schedule is changed once a week.

The decoupling point is at the finished goods store, whereas the point of discretisation (POD) is at the packing stage (see Figure 5.15). Processes before the POD are both intermittent as well as continuous type.

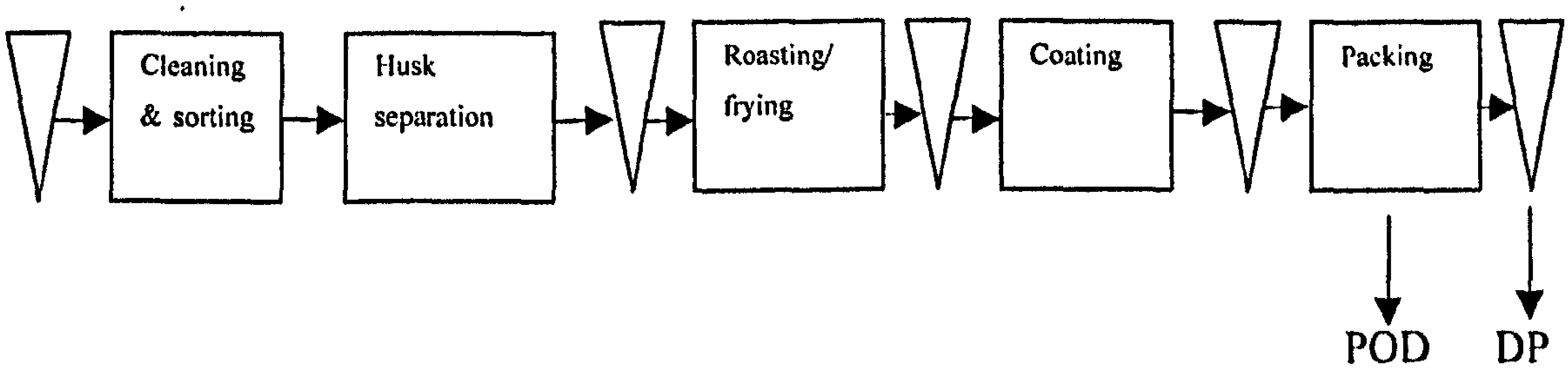

Figure 5.15: Process flow of snack food plant

5.9.6. Plant assessment

The plant is characterised by a relatively long shelf life, moderate product variety and low process complexity (Table 5.22). It employs continuous as well as intermittent manufacturing. The cleaning, sorting, husk separation and packing processes are continuous whereas frying, roasting and coating are intermittent. The equipment is relatively flexible and general purpose which means that the majority of the product variety can be produced with the same equipment. Mix model production in the real sense is not possible, as different products cannot be mixed on the production line for hygienic reasons. Nevertheless the plant produces different varieties daily by making the products in small batches.

Characteristics	
Product	
Product variety	50 managed through 150 SKUs
Product shelf life	20 weeks
Number of ingredients per product	10-15
Process	
Operations strategy	Make-to-stock (MTS)
Process type	Batch
Decoupling point	Late
Equipment type	General purpose for cleaning, sorting, frying and packing and specialised for coating and husk separation process
Process complexity	Low
Flow interruption	Low
Routings	Low
Number of major operations	5
Main operations	Heating, separation, cooling
Number of production employees	100
Labour skill input	Low
Production volume	40000
Level of automation	Medium
Process flexibility	Medium
Point of discretisation	Packing stage
Change over time	30 minutes
Work-in-progress	7 hours
Number of supply chain levels	2
Market	
Order winning criteria	Price, service level and brand
Order qualifying criteria	Quality
Maximum demand deviation	>30%

Table 5.22: Product/process/market characteristics of snack food plant

Cleaning, sorting and husk separation operations involve a large amount of material waste (10%) which is a big concern for the company. The cost of the main raw materials represents 90% of the product cost. This type of issue is common in the food industry where the main raw material is a produce of agriculture which contains unnecessary ingredients needing to be separated. The plant has a high raw material inventory, low WIP and high finished goods inventory. The plant has not embraced any lean practices pertaining to the aligning of production with demand principle (Table 5.23). A high service level, promotional schemes launched by the customers from time to time, long change over times and high forecast error have forced the plant to satisfy customer orders from stock.

Lean practices	Status of lean practices	Reason for absence of lean practices
Aligning production with demand		
Pull system	No	Demand seasonality, promotional scheme,
Uniform work load /levelled production	No	Long change over time
Mixed model production	No	Fear of mixing different flavours, long changeover time
One-piece flow	No	Non-discrete material flow
Supplier integration		
JIT deliveries	No	High economic transport size
Active information exchange with suppliers	No	Lack of infrastructure
Supplier involvement in product development	No	Commodity type raw materials, low product complexity
Supplier reduction policy	Yes	
Supplier development activities	No	Overseas suppliers
Long term contracts	Yes	
Employee involvement and empowerment		
Quality circle	No	Lack of awareness
Cross functional training	Yes	
Autonomation	Yes	
Team based problem solving	No	Lack of management commitment
Continuous improvement programmes	No	Lack of management commitment
Suggestion scheme	No	Lack of awareness
Job rotation	Yes	
Elimination of waste		
Quick change over	No	Sequence dependent set up time
Quality system	Yes	
Cellular manufacturing	No	Non-discrete material flow
Visual control	No	Lack of management commitment
Preventive maintenance	No	Lack of management commitment
Statistical process control	Yes	
5 S	Yes	
Mistake proofing	No	Lack of awareness
Standard operations	Yes	

Table 5.23: Status of lean practices in snack food plant

Various types of nuts are the main raw material and they are procured from suppliers situated in different countries, so JIT deliveries are not possible, although the raw materials are delivered once per week. Some of the raw materials, particularly the packaging material, can be delivered daily as suppliers are located locally. Although it has entered into a long-term agreement with the majority of its suppliers, they are considered as external members and have not been integrated with its production system.

Customer demand is erratic and seasonal and varies from 90 tonnes per week to 180 tonnes per week. It is observed that the majority of the food industry experience demand seasonality. Demand seasonality coupled with promotional schemes do not allow the plant to adopt a pull system.

The plant has not been observed to have any display boards showing operations metrics, production data and quality concerns. No equipment has a mechanism that brings the attention of a supervisor to a situation requiring assistance with a problem. All employees are conversant with good housekeeping practices. The plant has not adopted any formal preventive maintenance policy.

Direct production employees have been cross-trained and can carry out jobs at different workstations. The workers are also empowered to stop the production line in case of a quality problem. Suggestion schemes, quality circles, continuous improvement programmes and team-based problem solving are not practised on the shop floor.

The plant does not require a high skilled labour force as cleaning, sorting, husk separation and packing processes are automated and continuous and require only semi-skilled labour. Moreover the majority of the workforce is employed on the packing line.

5.9.7 Lessons learned

A high service level, promotional schemes launched by the customers from time to time, long change over times and high forecast error have forced the plant to satisfy customer orders from stock.

5.10 Case Study (10): Mayonnaise and Salad Dressing Plant

5.10.1 Introduction

This medium- sized plant, is situated near Delhi in India and offers a wide range of food products such as mayonnaise, salad dressing and chutneys, which is an up and coming market in India. It has been located at its present site since 1996 and over the years has developed a niche in the domestic market. It employs around 90 staff working on a two-shift pattern over 6 days and produces 2500 tonnes of food products per annum. This plant is also an HACCP certified plant.

5.10.2 The Product

The plant offers 80 product varieties including different pack sizes and labels. The products are value added items which helps the company command a premium position in the market. Each product requires around 10-15 ingredients. The products have a relatively long shelf life of around 6 months, so perishability is not an issue.

5.10.3 The Market

Although the mayonnaise and salad dressing market is quite small in size, it is a growing market with few competitors. The plant supplies its products to around 100 customers including high street retailers as well as institutional customers such as caterers, hotels and restaurants. The majority of its customers are long-term. In a short period it has created a brand image in the domestic market. Brand and quality are order-winning criteria. Although the production plan is based on a demand forecast, it does not experience a high forecast error. The plant maintains less than a week's finished goods inventory.

5.10.4 The Raw Material

There are 70-80 types of raw materials/ingredients, but only around 10 ingredients (eggs, skimmed milk powder, tomato paste, milk solids, sugar, oil etc.) are main materials and require close control. The suppliers deliver these main materials on a daily basis. There are around 30 suppliers for the main materials. A few ingredients (cucumber, coriander and spices) are purchased from the local market. The plant also keeps two weeks stock of the ingredients from suppliers which are geographically dispersed. It keeps one-month stock of packing material. The majority of its suppliers are long-term.

5.10.5 The Process

The manufacturing processes are relatively simple involving mixing, heating, and emulsification and packing operations (see Figure 5.16). Ingredients are first cleaned, mixed in a vessel according to the recipe and heated for 4-5 hours followed by cooling or emulsification. It is then transferred to the packing line. The packing stage is labour intensive with the majority of the workforce being employed here. A sample is taken from each batch for microbiological test.

The equipment used is of a general type which offers product flexibility. Different types of products are manufactured using the same equipment by mixing different combinations of ingredients. The plant uses a batch type production system where one batch is equal to the size of the cooking vessel. Changeover time is around 20-25 minutes. There is little WIP, equivalent to one shift of production. This may be due to the low number of processes and short run times.

The plant freezes its schedule one day before actual production which helps in lowering the finished goods inventory. The decoupling point (DP) is at the finished goods store and the point of discretisation (POD) is at the packing stage (see Figure 5.16). Supply chain complexity is very low due to the number of suppliers and because the raw materials are of a commodity type.

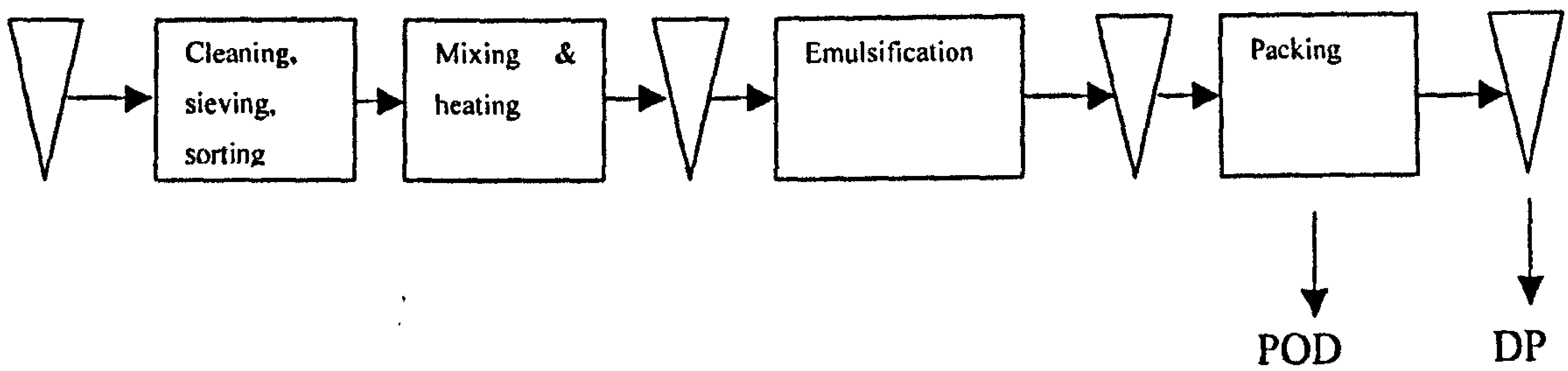

Figure 5.16: Process flow of mayonnaise and salad dressing plant

As the majority of labour is employed at the packing stage, a job rotation scheme has been implemented. Workers are empowered to stop the packing line if a quality problem occurs. A standard operating procedure has been developed for each workstation and all employees have been trained in good house keeping practices. The shop floor has a few display boards which show production targets, actual production status and quality defects.

5.10.6 Plant assessment

The plant produces a large variety of products but with a moderate volume when compared to the other food plants studied (Table 5.24). It could offer a high product variety due to the general-purpose equipment, short run times and the low number of processes.

Discussions with the operations manager along with the plant visit suggested that this plant does not implement any lean practices to align its production with demand. The operations manger had never heard of a pull system and levelled production. When asked about mixed model production he had a view that it would not be possible due to the possibility of mixing two flavours. Moreover the cooking vessel would have to be cleaned to make a mixed model production process work.

Characteristics	
Product	
Product type:	Perishable, Liquid
Product variety	80 SKUs
Product shelf life	24 weeks
Number of ingredients per product	10-15
Process	
Operations strategy	Make-to-order (MTS)
Process type	Batch
Decoupling point	Late
Equipment type	General
Process complexity	Low
Flow interruption	Low
Routings	Low
Change over time	High
Number of major operations	4
Main operations	Cooking, mixing & emulsification
Number of production employees	70
Labour skill input	Low
Production volume	8000kg per day
Level of automation	Low
Process flexibility	High
Point of discretisation	Packing stage
Change over time	20 minutes
Work-in-progress	6-8 hours
Number of supply chain levels	2
Market	
Order winning criteria	Quality, brand
Order qualifying criteria	Price, service level
Maximum demand deviation	~20%

Table 5.24: Product/process/market characteristics of mayonnaise and salad dressing plant

The majority of lean practices pertaining to the elimination of waste, such as standard operations, 5S, visual control, quality system, were embraced by the plant but quick changeover, preventive maintenance, statistical process control and mistake proofing were not pursued (Table 5.25).

It was also observed that except for the long-term agreement and reduction of supplier policy, no other practices pertaining to supplier integration were observed (Table 5.25).

Lean practices	Status of lean practices	Reason for absence of lean practices
Aligning production with demand		
Pull system	No	Forecast driven production
Uniform work load /levelled production	No	Long change over time
Mixed model production	No	Long changeover time
One-piece flow	No	Non discrete material flow
Supplier integration		
JIT deliveries	No	High economic transport size
Active information exchange with supplier	No	Lack of resources at the supplier end
Supplier involvement in product development	No	Ingredients being commodity type, small suppliers
Supplier reduction	Yes	
Supplier development activities	No	Lack of management commitment,
Long term contracts	Yes	
Employee involvement and empowerment		
Quality circle	No	Low number of employees
Cross functional training	No	Few and simple jobs
Autonomation	Yes	
Team based problem solving	No	Simple jobs
Continuous improvement programmes	No	Lack of management commitment
Suggestion scheme	No	Lack of management commitment
Job rotation	Yes	
Elimination of waste		
Quick change over	No	Cooking vessels require cleaning
Quality system	Yes	
Cellular manufacturing	No	Non-discrete material flow
Visual control	Yes	
Preventive maintenance	No	Lack of management commitment
Statistical process control	No	Lack of awareness
5 S	Yes	
Mistake proofing	No	Lack of awareness
Standard operations	Yes	

Table 5.25: Status of lean practices in mayonnaise and salad dressing plant

5.10.7 Lessons learned

Mixed model production would not be possible in this plant due to the possibility of mixing two flavours.

5.11 Case Study (11): Tea Bag Plant

5.11.1 Introduction

This plant is located in the UK and produces a large variety of blended tea bags. Around 6 million cups of its tea bags are drunk every day in the UK, that equates to 10,000 tonnes of tea bags each year. The brand is now one of the UK's favourite teas.

5.11.2 The Market

Tea is the UK's favourite drink and is a fundamental part of daily life for most consumers. This plant offers a product in virtually every sector within the tea category. It caters to a wide mix of customers from big superstores, small street shops and caterers. It offers its branded tea bags as well as own label brand to its customers. The brand is one of the top three brands in the category. Price and service level are order winning criteria in the tea market where customers demand a high service level as well as frequent delivery schedules.

The large variety of products offered by the plant is due to differences in pack sizes and labels and it is during the packing stage that the large varieties of tea bags are produced. This plant has adopted a pack-to-order (PTO) operations strategy. The plant builds up the stock of ten types of blended tea leaves on the basis of forecasted demand but these blended tea leaves are not sent for packing until the customer confirms the order. Once the plant receives a confirmed order the tea leaves are fed to the packing stage where they are packed in different pack sizes and relevant labels.

The plant does not experience a large forecast error and the production system is capable of adapting a 20% change in customer demand.

5.11.3 The Product

The plant offers a large variety of tea bags from traditional tea to herbal and fruit tea. Eighty percent of its production covers 20 types of tea bags in various pack sizes and offers 200 types of non-conventional tea bags such as herbal tea. It continues the practice of packing its round teabags into foil pouches holding only 40 teabags. In May 2004 the company successfully launched a Fruit and Herb tea which is the first time that the brand has moved away from its black tea-based beverages.

5.11.4 The Raw Material

Tea for the blended tea bags is sourced from many different high quality tea-producing countries. The backbone of the blend is a vacuum-packed Assam tea which comes from the main tea growing area in the North Eastern part of Assam in India. The blend includes further high grown teas from the quality tea growing areas of Eastern Africa and Southern India. The combination of all these tea leaves ensures that the plant consistently delivers a smooth refreshing cup of tea which caters specifically for the demands of the UK consumers. By picking the best quality leaves and vacuum packing its unique blend it retains freshness.

The main raw material, loose tea leaves, is a produce of agriculture and so availability is dependent on the vagaries of weather. Suppliers are also located at least 3000 miles away from the plant which means that the plant has to maintain a large buffer stock. Although a large inventory of loose tea leaves has not been observed in the plant, the plant has a large offsite storage facility for loose tea leaves stock which can store up to six weeks of stock. Daily loose tea leaves are supplied to the plant from this offsite store. Approximately 50% of its suppliers have a long-term agreement with the plant and there are not more than three suppliers for each item. Whenever it launches a new product in the market the company involves its supplier in the product development. More than 75% of its suppliers are certified and their performance is evaluated on the basis of quality, cost and delivery.

5.11.5 The Process

The manufacturing process is relatively simple as this plant just blends various tea leaves and packs them into different sizes according to customer requirement (see Figure 5.17). The plant is a high volume plant and processes 80,000 kg of tea leaves per day.

The main raw material, i.e. tea leaves, is imported and comes to the plant in the form of sacks. Sack handling was previously very labour intensive requiring 15 men depalletising the 70kg sacks of tea over five overlapping shifts during a 24-hour period. Even with the assistance of vacuum lifters it was still an arduous job with health and safety implications. Robots have now been installed and perform the same function automatically. There are two robotic cells, which unpacks all sacks. Both cells are identical and operate side by side but independently. Should one cell break down, pallets can be transferred across to the other so that blending can continue. This was considered an essential precaution as blending is the lifeblood of the factory so any interruption brings everything to a stop.

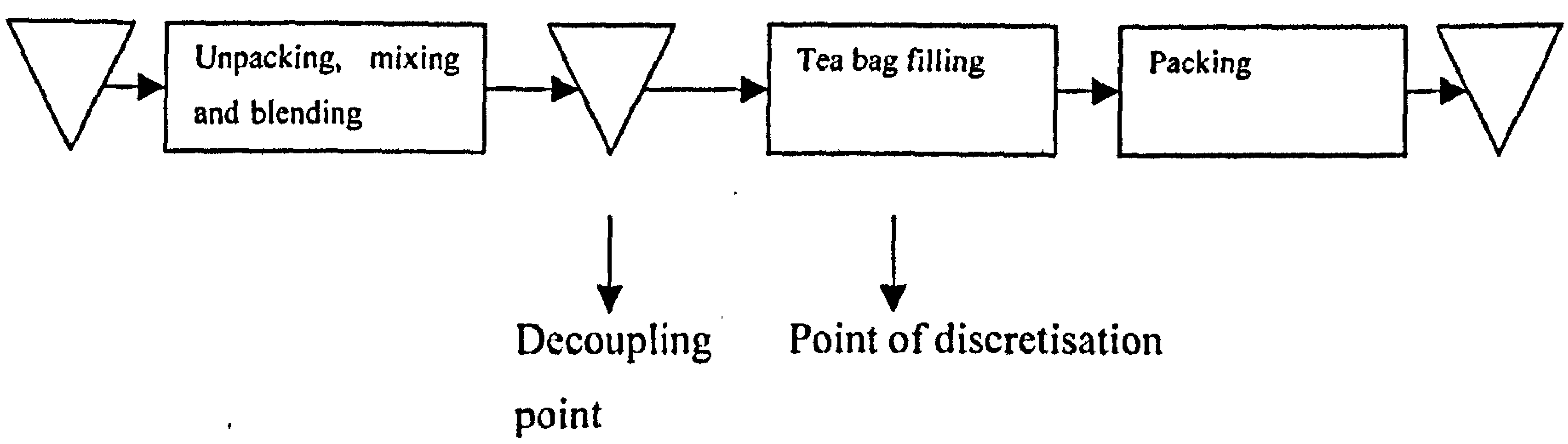

Figure 5.17: Process flow of tea bags plant

Currently only six staff are needed to oversee all blending activities from raw tea intake, through robot cell operation to sack opening and blending. There are five blenders each of which can process 10 tonnes of tea at any one point in time and it takes 35 minutes to blend the various tea leaves. Loose blended tea leaves are stored in one-tonnes sacks, which are then transferred to the filling area. The filling and packing line is continuous and automatic with each filling machine producing 2000 tea bags per minute. There are 5 filling machines for herbal tea and six machines for fruit tea. Fruit tea and herbal tea represent 10% of the total production. The whole plant can process 80 tonnes of tea leaves, out of which 65 tonnes represents traditional ordinary tea.

Being a high volume plant, on average only two changeovers per shift are performed. Each changeover procedure is standardised and takes at least one hour. All changeovers are scheduled in advance. Data pertaining to operations metrics and production data are displayed at each process. In the case of any quality defect, all processes are equipped with an electronic signal system that brings attention to any situation where assistance is required.

Each process has a standard operating procedure posted within view of the worker. Production employees have been trained in the basics of mistake proofing and all manual processes have been equipped with mechanical checks to support human judgement. Around 50% of the operations are controlled with statistical process control and bar charts and check sheets are used to identify problems.

The plant freezes its master production schedule one day before production. Even after freezing the master production schedule, changes frequently occur leading to more finished goods inventory.

5.11.6 Plant Assessment

The plant offers both high volume as well as high product variety (Table 5.26). This is achieved by installing a number of parallel, high-speed filling and packing lines. A Pack-to-order (PTO) strategy has made it possible to fulfil the customer order efficiently without building a huge stock. Although there is less finished goods inventory it has increased work in progress.

Characteristics	Value
Product	
Product variety	250 SKUs
Product shelf life	52 weeks
Number of ingredients per product	8-10
Process	
Operations strategy	Pack-to-order (PTO)
Process type	Batch
Decoupling point	Middle of the process
Equipment type	Specialised
Process complexity	Low
Flow interruption	Low
Routings	Low
Change over time	High
Number of major operations	4
Main operations	Mixing
Number of production employees	240
Labour skill input	Low
Production volume	60,000 Kg per week
Level of automation	High
Process flexibility	Low
Point of discretisation	Tea bag filling stage
Change over time	1 hour
Work-in-progress	2 days
Number of supply chain levels	1
Market	
Order winning criteria	Price, service level
Order qualifying criteria	Quality, Product variety
Maximum demand deviation	~20%

Table 5.26: Product/process/market characteristics of tea bags plant

A majority of the lean practices concerning the elimination of waste principles have been implemented (Table 5.27). The plant floor is marked out in terms of work areas, pathways and material handling aisles. All production employees have received training on good housekeeping practices. Each worker is allocated time in the daily production schedule to perform their preventive maintenance and cleaning duties. Preventive maintenance responsibilities are also defined for maintenance and production workers.

The company is trying to reduce changeover time at the packing line. Lean practices such as quality circles and suggestion schemes are not used in the plant. On the other hand, workers are cross-trained to perform a variety of tasks and have the requisite authority to stop the line in the case of a problem with the process.

Lean practices	Status of lean practices	Reason for absence of lean practices
Aligning production with demand		
Pull system	No	Demand forecast driven production
Uniform work load /levelled production	No	Long changeover time, high volume production
Mixed model production	No	Long changeover
One-piece flow	No	Non-discrete material flow
Supplier integration		
JIT deliveries	No	Distant supplier
Active information exchange with suppliers	No	Overseas suppliers
Supplier involvement in product development	Yes	
Supplier reduction policy	Yes	
Supplier development activities	No	Distant supplier
Long term contracts	Yes	
Employee involvement and empowerment		
Quality circle	No	Lack of awareness
Cross functional training	Yes	
Autonomation	Yes	
Team based problem solving	No	Lack of management commitment
Continuous improvement programmes	No	Lack of management commitment
Suggestion scheme	No	Lack of awareness
Job rotation	Yes	
Elimination of waste		
Quick change over	No	Sequence dependent changeover
Quality system	Yes	
Cellular manufacturing	No	Non-discrete material flow
Visual control	Yes	
Preventive maintenance	Yes	
Statistical process control	Yes	
5 S	Yes	
Mistake proofing	Yes	
Standard operations	Yes	

Table 5.27: Status of lean practices in tea bag plant

Although it has a long-term agreement with its suppliers due to their location, it has not been able to exchange information in real time and suppliers have not been able to deliver the tea leaves on a just-in-time basis.

The plant manager is not aware of a Kanban system but has been able to move the decoupling point to the upstream side which has resulted in a reduction in finished goods inventory. Long changeover times have not allowed the plant to pursue mixed model and levelled production.

5.11.7 Lessons learned

This plant has been able to shift decoupling point upstream by adopting pack-to-order (PTO) policy.

5.12 Case Study (12): Convenience Meals Plant

5.12.1 Introduction

The plant's mission is 'to be recognized as the leading convenience meal manufacturer in the UK'. It has been located on its present site since 1990 and employs around 500 staff working on a three-shift pattern over 5 days. The plant's annual turnover is in the region of £60 million per annum and produces around 400 tonnes of convenience ready meals per week which equates to approximately one million meals per week. It manufactures a selection of 150 convenience meals managed through 300 SKUs, which mainly focus on traditional, vegetable and international recipes within the platter, sliced meats in gravy, traditional British and British curry sector of the market place. These meals are produced along five frozen and two chilled production lines with around 1000 different ingredients being used in the manufacturing process. A computerised data logging system is used for continual monitoring of temperatures and key control activities. The logic flow through the design of the factory ensures the prevention of cross contamination whilst all production areas are temperature controlled. It has a formalised HACCP system in conjunction with a quality management system.

5.12.2 The Product

The convenience meal is now becoming one of the most important areas within the supermarket mix with branded and own label products available to the consumer via the major retailer. Convenience meals, which require the assembly of a large number of ingredients, are complex products when compared to other food products. Each product requires at least 25-30 components/ingredients and generally has a shelf life of 12 months, so perishability is not a big issue either for customers or this plant. All meals have to be kept below zero degrees centigrade which means customers, distributors and the plant require special storage facilities which increases the costs.

As the convenience ready meal market is a high growth market and the product life cycle is short (1-2 years), new product development is key to their business. The plant employs a wide range of skills such as chefs, home economists and food technologists working in partnership with key customers, continually developing new products. Every year it develops around 60 new products.

5.12.3 The Market

The plant supplies a wide range of convenience meals to key superstores, which include TESCO, ASDA, Iceland, Morrison, Sainsbury and CO-OP superstores. Therefore, in essence the plant has only seven customers. It mainly supplies to these superstores under their own label name which means price and the service level are the order-winning criteria. All customers are large and, as such, have the power to put pressure on the plant to reduce the product cost.

Customers provide the plant with a 3 months forecast, but also the plant has been given access to real time (electronic point of sale) EPoS data that allows the plant to smoothen the production plan. The customer freezes its order one day before production which puts a constraint on the adoption of an MTO process strategy. The plant fulfils the customer orders through stocks and does not keep more than two weeks finished goods inventory.

5.12.4 The Raw Material

The plant handles 1000 different ingredients that include dairy products, fresh and frozen meat, vegetables and seasonings. Raw materials are purchased from local suppliers as well as from global suppliers. The plant does not keep a high level of raw material inventory. For all materials which are procured from local suppliers, it keeps a one-day inventory, which means that all local suppliers supply the raw materials on a daily basis. Raw materials cannot be directly delivered to the production line due to the fact that they have to be inspected in line with food safety regulations.

Most of the suppliers are long-term suppliers. The company has to select suppliers from an approved list of suppliers. They are given a purchase contract for at least one year although some of the suppliers are on a two-year contract.

5.12.5 The Process

The plant has adopted an MTS strategy due to the high forecast error and high service level required by the customers. The plant keeps at least 3 weeks of finished goods inventory at all times which sometimes reaches 6 weeks.

The convenience meal is a product assembled within the plant by adding sauces and gravy cooked on site (see Figure 5.18). There are three main types of raw material needed to prepare a ready meal which are meat/fish/beef/chicken, vegetables and seasonings. Most of the raw materials are used like components which have to be assembled on an assembly line.

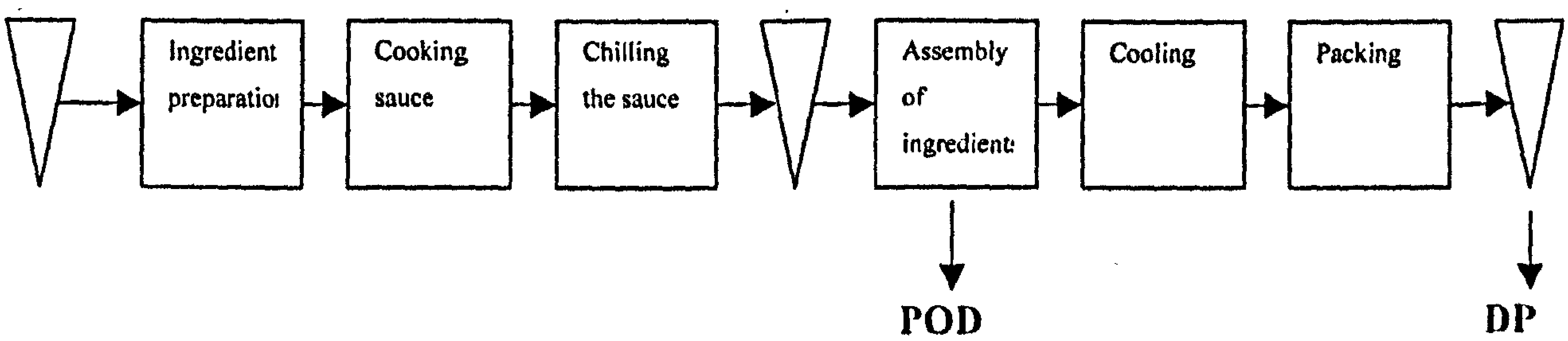

Figure 5.18: Process flow of convenience meals plant

First the sauce or gravy is prepared in large pots which can cook up to 1.5 tonnes of sauce at a time. This process involves mixing the sauce ingredients and heating the mixture before being quickly cooled in a chiller and stored in containers.

Various other components (vegetables, rice, meat) of the convenience meals are assembled on a production/assembly line. There are 8 assembly lines and each is capable of producing 40 meals per minute or 2400 meals per hour. Most of the manpower is employed at this stage with some of the lines being fully automated. All convenience meals are then sent to spiral chillers where the temperature is maintained at –32 degrees centigrade. Preservation is achieved by freezing which increases the shelf life of the meals to 12 months. The final stage in the process is where the convenience meal is packed, inspected and labelled.

5.12.6 Plant Assessment

The plant is a high volume and high variety plant (Table 5.28). This has been achieved by installing a number of parallel high-speed general assembly lines. A few of the assembly lines are general purpose, non-dedicated and the remainder are dedicated. This mix of dedicated and non-dedicated assembly lines produces a large product variety as well as a large volume.

The plant, although offers a high product variety does not employ levelled production or mixed model production due to the long sequence dependent changeovers. This means that each assembly line produces a batch of one type of product.

The majority of the labour is employed on the assembly lines and perform a repetitive job. That is why there is a strong emphasis on job rotation and teamwork. Workers are rotated every two hours or given a break to reduce boredom and increase teamwork.

Characteristics	
Product	
Product variety	150 product types and 300 SKUs
Product shelf life	52 weeks
Number of ingredients per product	20-25
Process	
Operations strategy	Make-to-stock (MTS)
Process type	Batch
Decoupling point	late
Equipment type	General
Process complexity	Low
Flow interruption	Medium
Routings	High
Change over time	High
Number of major operations	6
Main operations	Mixing, cooling, heating, assorting
Number of production employees	400
Labour skill input	Low
Production volume	200,000 meals per day
Level of automation	Medium
Process flexibility	Low
Point of discretisation	Assembly stage
Change over time	2 hours
Work-in-progress	6-8 hours
Number of supply chain levels	2
Market	
Order winning criteria	Price, service level
Order qualifying criteria	Quality
Maximum demand deviation	~20%

Table 5.28 Product/process/market characteristics of convenience meals plant

Compared to other food plants this plant has been pursuing more lean practices concerning supplier integration principles (Table 5.29). The plant has adopted a variation on JIT deliveries and has been exchanging information with its suppliers electronically.

5.12.7 Lessons learned

The plant has achieved a high volume and high product variety by installing a number of parallel high-speed general assembly lines. It could not adopt mixed model and levelled production due to long sequence dependent changeovers.

Lean practices	Status of lean practices	Reason for absence of lean practices
Aligning production with demand		
Pull system	No	Production based on demand forecasts
Uniform work load /levelled production	No	Sequence dependent changeover
Mixed model production	No	Fear of mixing of flavours
One-piece flow	No	Non-discrete flow before assembly
Supplier integration		
JIT deliveries	Yes	
Active information exchange with suppliers	Yes	
Supplier involvement in product development	No	Lack of management commitment
Supplier reduction policy	Yes	
Supplier development activities	Yes	
Long term contracts	Yes	
Employee involvement and empowerment		
Quality circle	No	Lack of awareness
Cross functional training	No	Lack of management commitment
Autonomation	No	Lack of management commitment
Team based problem solving	Yes	
Continuous improvement programmes	Yes	
Suggestion scheme	Yes	
Job rotation	Yes	
Elimination of waste		
Quick change over	No	Sequence dependent changeover
Quality system	Yes	
Cellular manufacturing	No	Non-discrete material flow before assembly process
Visual control	Yes	
Preventive maintenance	No	Lack of management commitment
Statistical process control	No	Lack of management commitment
5 S	Yes	
Mistake proofing	No	Lack of awareness
Standard operations	Yes	

Table 5.29: Status of lean practices in convenience meals plant

5.13 Case Study (13): Frozen Food Plant

5.13.1 Introduction

This plant is a leading supplier of frozen ready meals to a diverse range of customers, from contract catering & airlines to the large pub operators, retail & coffee shops. It has a manufacturing operation in north Wales since 1988 and currently employs nearly 200 staff. Recently it has opened a new 'state of the art' development kitchen at its manufacturing site enabling it to increase the number of new product lines.

5.13.2 The Product

The plant offers around 200 types of frozen meals to its customers and manages through 350 SKUs. This large number of SKU is due to varying pack sizes. Each product requires 25-30 ingredients including spices, vegetables and meat. These products are quite different from commodity products such as oil, sugar and flour where few ingredients are required to produce a complete product. Although the bill of materials is quite shallow, the product formulation introduces the complexity. The shelf life of the product is around 52 weeks which means that shelf life is not a constraint for this plant.

5.13.3 The Market

The frozen ready meal market has grown considerably in recent years. The market has been driven by several factors including consumer demand for convenience foods, a rise in freezer and microwave ownership, the demise of families sitting down to eat together and a rise in one and two-person households.

The plant operates in a growing market and supplies its products to pubs, restaurants, contract catering and retailers. The customer orders are fulfilled from its distribution division as well as directly from the plant. Sixty five percent of the orders are supplied through its distribution division and thirty five percent which are customer specific, are supplied directly from the plant. The plant is connected to its distribution division through an SAP system. There is little inventory at the plant level but the distribution division keeps a finished goods inventory of 3-4 weeks as price and service level are the order-winning criteria.

5.13.4 The Raw Material

The plant requires a relatively large number of ingredients due to the fact that each product requires 25-30 ingredients and also because the plant produces about 200 varieties of frozen meals. Some of the ingredients are common to most of the meals and by changing a few ingredients produces a large product variety. The majority of ingredients are procured from within the UK. The plant has adopted a policy of single sourcing and so most of its suppliers are long-term suppliers. These suppliers deliver short shelf life materials one day before they are required and for long shelf life products they deliver two days before production. So at the most there is only two days of raw material inventory.

Although the SAP system triggers the raw material order, it is not communicated electronically to the supplier. There is no electronic information exchange with suppliers.

5.13.5 The Process

Frozen meals require mixing, cooking, assembly, packing and cooling processes (see Figure 5.19). The ingredients are first cleaned and weighed according to product formulation. These ingredients are then mixed and cooked in a kettle/vessel for 30 minutes to 2 hours, based on the type of product. There are 7 kettles each of 500kg capacity and 2 kettles each of 1000 kg capacity.

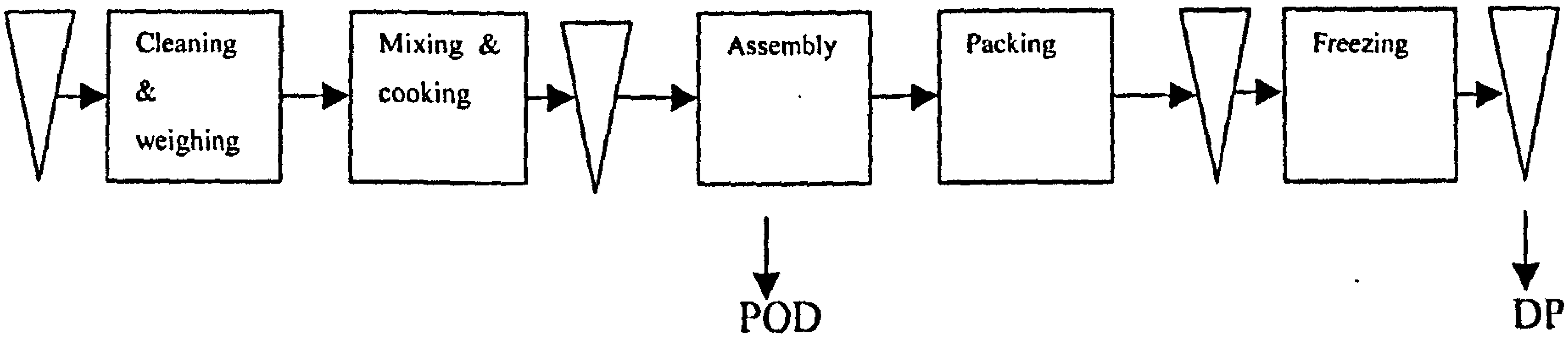

Figure 5.19: Process flow of frozen food plant

There are five assembly lines which produce 200 types of frozen meals. Each assembly line produces 42 meals per minute and on average the whole plant produces one million meals per week. The plant offers high product variety and high product volume. The majority of the labour is employed at the assembly stage. Job rotation is already in place to take care of the monotonous nature of the work. The change over time on this assembly line is between 30 minutes to one hour and is constrained by the size of the cooking kettle. Therefore, changeover can take place only after the processing of 500kg of materials.

The assembly lines are linked to the packing line where the product is stamped and packed. The product is then passed through a freezing chamber where the temperature of the products is reduced to –20 degrees centigrade. A few samples are taken from each batch and sent for a microbiological test as well as for a sensory evaluation test. This plant mainly employs general-purpose equipment such as kettles with a general assembly line enabling the plant to produce a large variety of products.

Due to food safety reasons the plant has been divided into three zones. Zone 1 is a low risk area where all cleaning, weighing, mixing and cooking of ingredients is carried out. Zone 2 is a high-risk area where the meals are assembled. Zone 3 is a low risk area where packing of the meals takes place.

The production planning and control department freezes its master production schedule one week ahead which is why the plant can manage with little raw material inventory and why raw materials are delivered more frequently when compared to other food plants.

The point of discretisation is quite early in the process when compared to other food plants. This is due to the fact that this plant is an assembly plant where products become discrete at the beginning of the assembly process.

5.13.6 Plant Assessment

The plant is characterised by a large product variety and large volume (Table 5.30). The large volume is managed by installing a number of high-speed assembly lines. Raw material inventory and work-in-progress have been very limited with a 3-4 weeks of finished goods inventory. The reason for the large finished goods inventory is due to the fact that the plant produces 200 types of meals and change over time is relatively high. Moreover the minimum batch size is 500kg which is dictated by the size of the mixing and cooking kettles.

The plant resembles a discrete manufacturing plant where the product becomes discrete quite early on in the process, so most of the lean practices which requires a discrete environment, would be possible in this plant. An important feature of the plant is that the mixing and cooking processes will not start unless they receive a signal from the downstream process i.e. the assembly line. This makes the plant a good candidate for pull production. Customer demand has not been found to be very erratic but a customer order is served from stock and plants operate on a make-to-stock policy. Here the opportunity to become lean can be realised.

Characteristics	
Product	
Product variety	200 product types and 350 SKUs
Product shelf life	52 weeks
Number of ingredients per product	20-25
Process	
Operations strategy	Make-to stock (MTS)
Process type	Batch
Decoupling point	Late
Equipment type	General
Process complexity	Low
Flow interruption	Medium
Routings	High
Change over time	High
Number of major operations	5
Main operations	Mixing, cooling, heating, assorting
Number of production employees	150
Labour skill input	Low
Production volume	220000
Level of automation	Medium
Process flexibility	Medium
Point of discretisation	Packing stage
Change over time	30-60 minutes
Work-in-progress	6-7 hours
Number of supply chain levels	2
Market	
Order winning criteria	Price, service level
Order qualifying criteria	Quality
Maximum demand deviation	~20%

Table 5.30: Product/process/market characteristics of frozen food plant

Equipment is relatively flexible which enables the plant to produce a large variety of products. Mixed model production is impossible due to the fact that different products cannot be mixed because of the potential of mixing of flavours. Surprisingly, even after the adoption of a single source policy and long-term contracts with suppliers, there is little information exchange electronically with suppliers. Table 5.31 summarises the status of lean practices in the plant.

5.13.7 Lessons learned

The plant resembles a discrete manufacturing plant so most of the lean practices which requires a discrete environment, would be possible in this plant.

Lean practices	Status of lean practices	Reason for absence of lean practices
Aligning production with demand		
Pull system	No	Production based on demand forecast
Uniform work load /levelled production	No	Sequence dependent changeover
Mixed model production	No	Fear of mixing of flavours in cooking vessels
One-piece flow	No	Non-discrete material flow before assembly process
Supplier integration		
JIT deliveries	No	Large economic transport size
Active information exchange with supplier	No	Lack of resources at suppliers end
Supplier involvement in product development	Yes	
Supplier reduction policy	Yes	
Supplier development activities	No	Lack of management commitment
Long term contracts	Yes	
Employee involvement and empowerment		
Quality circle	No	Lack of awareness
Cross functional training	Yes	
Autonomation	Yes	
Team based problem solving	No	Lack of management commitment
Continuous improvement programmes	Yes	
Suggestion scheme	Yes	
Job rotation	Yes	
Elimination of waste		
Quick change over	No	Sequence dependent changeover
Quality system	Yes	
Cellular manufacturing	No	
Visual control	No	Lack of management commitment
Preventive maintenance	Yes	
Statistical process control	No	Lack of management commitment
5 S	Yes	
Mistake proofing	Yes	
Standard operations	Yes	

Table 5.31: Status of lean practices in frozen food plant

5.14 Case Study (14): Sandwich Plant

5.14.1 Introduction

The company was established in 1977 and has grown to become one of the UK's leading independent suppliers of sandwiches and chilled snacks to the UK market with a turn over of £16-17 million. The plant manufactures all types of sandwiches, wraps, rolls, and baguettes for a number of supermarkets, high street retailers, petrol forecourts and convenience stores. It provides new recipes and snacks to meet the ever-changing palate of the demanding and discerning UK consumers.

5.14.2 The Product

The plant offers 90 types of different sandwiches and wraps managed through 150 SKUs to the UK market. Not only does it manufacture a large product variety, but also produces the sandwiches in high volume, some 10 million sandwiches per year.

The shelf life of sandwiches is extremely short. From the raw material stage to point of selling, sandwiches have a shelf life of P +3 days, here 'P' meaning production lead time. From the P+3 days the plant gets one day to manufacture and deliver to the customer and the retailer gets three days at their end to sell.

5.14.3 The Market

It operates in a very competitive market in the UK where price and service level are the order winning criteria. The customer base is very diverse, from small street shops to large retailers such as Asda and Tesco. Large retailers are equipped with EPoS systems and send their order through EDI, whereas small street shops place their order through fax/telephone and send their order for the next day at the end of the day. In total this plant caters to around 450 customers.

As is typical of the food industry, the real power lies with the large retailers, who demand high service level as well as low price. If a store or street retailers can't sell sandwiches during the available shelf life then it has to be discarded and the plant has to bear the cost. So wastage at the retailers is a very important performance indicator.

5.14.4 The Raw Material

The plant manages 250 types of different raw materials. The raw materials are purchased from suppliers located within the UK. Bread, which is an important raw material, is delivered twice a day, whereas ingredients for sandwiches such as fresh vegetables are delivered daily. All other raw materials are delivered once per week.

The plant does not have more than one or two suppliers for each raw material and have long-term agreements with the suppliers, although orders are placed daily by telephone or fax. Some suppliers are customer specified. Information with regard to the production plan is shared with the main suppliers, though there is no electronic information exchange with those suppliers. The plant has to purchase the raw materials from an approved list of suppliers according to customer requirements.

5.14.5 The Process

Due to the short shelf life of the product, the plant has adopted a make-to-order process strategy, so it does not produce any product unless it receives a confirmed customer order. The manufacturing process is relatively simple as this plant is an assembly plant where various ingredients are assembled on an assembly line to make a sandwich or wrap (see Figure 5.20). There are three assembly lines for sandwiches and one line for making wraps. All ingredients go through a preparation process where ingredients are washed, cleaned and chopped before being available to the assembly operation. It takes 20 minutes to prepare the ingredients for the assembly process.

The assembly line is divided into two sections, assembly and packing. The assembly operation is manual whereas the packing operation is automatic. It takes only 2 minutes to assemble and pack a sandwich. Each sandwich is assembled individually, so the point of discretisation is at the start of the assembly line. Change over at the assembly line is 3 minutes which means that it can produce all product varieties everyday. Typically they have 120 changeovers per day which makes this plant very different from other food plants. Due to the quick changeover time, the plant can even cater for batch sizes of a single sandwich, which helps the plant to become highly flexible.

The plant operates on a two-shift basis (day shift and night shift) and employs 300 employees on the shop floor. The nightshift has fixed operating hours but the day shift has flexible working hours. The plant has entered into an agreement with its labour force for variable working hours. It means some days when demand is high, the labour on the day shift will do extra hours to maintain the production schedule. This strategy enables the plant to cope with demand fluctuations and adopt a zero inventory policy.

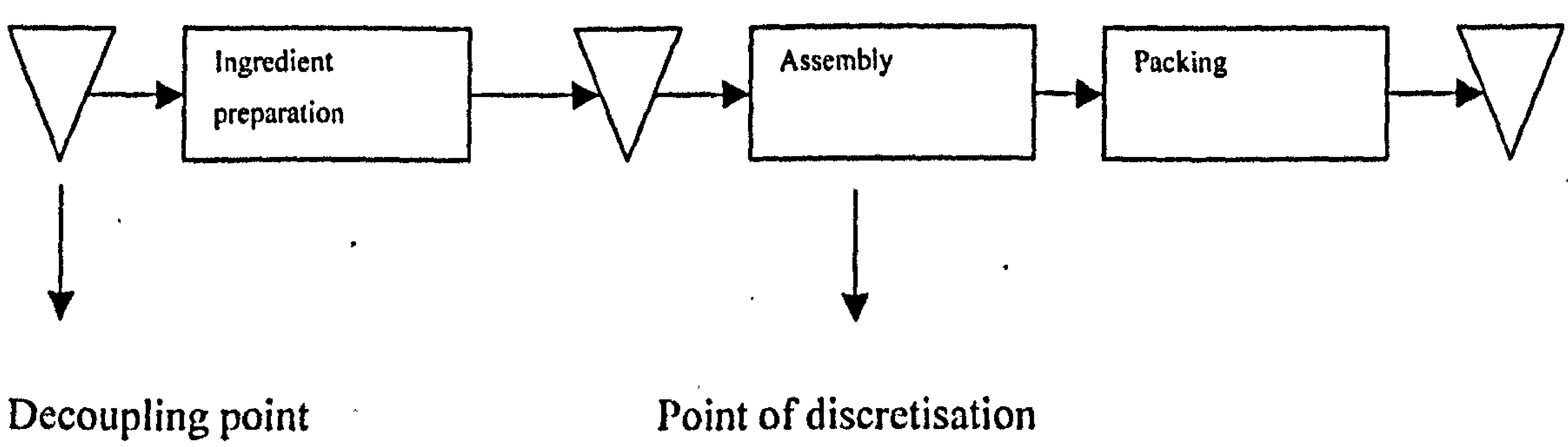

Figure 5.20: Process flow of sandwich plant

The plant has been equipped with a computerised production reporting system which is the backbone for its operation. It helps in managing a large variety as well as a large volume of products. The production reporting system tracks the current status of each assembly line and creates visibility of the production. The visibility is available to management only.

5.14.6 Plant Assessment

Table 5.32 shows the product, process and market characteristics of the sandwich plant. This plant is the only plant which follows a make-to-order (MTO) process strategy and is a very good candidate for the adoption of lean principles. Production is aligned to customer demand in a true sense. The reason for this typical behaviour is due to:

- Short shelf life of the product (three days for retailer and one day for the purpose of production and distribution). After three days, at the retailer, the product is regarded as waste and is discarded, which means a loss to the plant.
- High customer service level requirement and price are the drivers of the business.

Characteristics	
Product	
Product type:	Perishable
Product variety	90 product types and 150 SKUs
Product shelf life	3 days
Number of ingredients per product	8-15
Process	
Operations strategy	Make-to-order (MTO)
Process type	Flow shop
Decoupling point	Early
Equipment type	General
Process complexity	Low
Flow interruption	Medium
Routings	High
Number of major operations	3
Main operations	Mixing, assembly
Number of production employees	300
Labour skill input	Low
Production volume	50,000 units per day
Level of automation	Low
Process flexibility	Medium
Point of discretisation	Assembly stage
Change over time	3 minutes
Work-in-progress	2 hours
Number of supply chain levels	2
Market	
Order winning criteria	Price, service level
Order qualifying criteria	Quality
Maximum demand deviation	>25%

Table 5.32 Product/process/market characteristics of sandwich plant

The plant has embraced one-piece flow and mixed model production due to the quick changeover times and a make-to-order (MTO) process strategy (Table 5.33).

Lean practices	Status of lean practices	Reason for absence of lean practices
Aligning production with demand		
Pull system	No	The plant is not strictly using pull system but it is quite close to pull system due to MTO as operations strategy
Uniform work load /levelled production	Yes	
Mixed model production	Yes	
One-piece flow	Yes	
Supplier integration		
JIT deliveries	Yes	
Active information exchange with supplier	No	Small suppliers cannot invest in technology required for information sharing
Supplier involvement in product development	No	Low product complexity
Supplier reduction	Yes	
Supplier development activities	No	Lack of management commitment
Long term contracts	Yes	
Employee involvement and empowerment		
Quality circle	No	Lack of awareness
Cross functional training	No	Simple few jobs, un-skilled workers
Autonomation	Yes	
Team based problem solving	No	Un-skilled worker
Continuous improvement programmes	No	Lack of management commitment
Suggestion scheme	No	Lack of awareness
Job rotation	Yes	
Elimination of waste		
Quick change over	Yes	
Quality system	Yes	
Cellular manufacturing	Yes	
Visual control	No	Lack of management commitment
Preventive maintenance	No	Lack of management commitment
Statistical process control	No	Lack of management commitment
5 S	Yes	
Mistake proofing	Yes	
Standard operations	Yes	

Table 5.33: Status of lean practices in sandwich plant

Although there is virtually no finished goods, the stock and raw material inventory is one day for most of the raw materials, which indicates that this plant can be described as a lean plant, even though, few lean practices have been observed.

The decoupling point is just at the raw material store due to adoption of an MTO process strategy. All other food plants have their decoupling point relatively late due to the adoption of MTS process strategy. The plant offers a high product variety coupled with high volume and has general-purpose assembly lines, short run times (around 40 minutes) and quick changeover times (around 3 minutes).

The majority of the workforce is semi-skilled. A team manages each assembly line and a team leader is responsible for each team. The work at the assembly line is very monotonous in nature. This plant employs a large number of employees but has been unable to involve all their employees in system improvements on a regular basis.

Discussions with the operations manager revealed that the leanness of their plant is due to market drivers and the short shelf life of the product. It was not a deliberate move to make the plant lean but was just a necessity.

5.14.7 Lessons learned

This plant is the only plant which follows a make-to-order (MTO) process strategy and is a very good candidate for the adoption of lean concepts. The decoupling point is just at the raw material store due to adoption of an MTO process strategy.

5.15 Case Study (15): Vehicle Assembly Plant

5.15.1 Introduction

This vehicle plant with an installed capacity of 25000 vehicles per annum and a 3000 strong workforce is located in the UK and started in 2001 by redesigning an existing plant. It produces one of the strongest brands in the automotive world.

5.15.2 The Product

The vehicle is a product with an integral and closed architecture. In terms of structure, it is a very complex mechanical product consisting of a large number of components. Since a vehicle consists of a wide variety of material and parts the manufacturer is unable to manage all the manufacturing process on its own and so parts are made by a large number of parts suppliers. Currently the majority of first-tier suppliers are large-scale businesses with over 1000 employees. On the other hand, most of the second-tier suppliers, which provide parts to the first-tier suppliers, are typically medium and small- sized businesses with between 50 and 100 employees.

5.15.3 The Raw material

The plant has adopted early supplier development and the use of trusted suppliers with design and sub-systems integration capabilities. It introduced a very high level of modularity in the design of the new vehicle model and selected suppliers were made responsible for integrating whole sub-systems. As a result there are only four suppliers for all the interior systems of the vehicle. One supplier assembles the entire instrument panel and centre console, including steering column and wheel, airbags and audio system and delivers it in a single piece to the plant, where the operator simply fixes the whole panel in place with just four bolts.

The plant set up a logistic vision for a lean supply chain. Right from the beginning it decided to work with fewer suppliers for the new model. Most of the parts were sourced from suppliers with plants within a 100-mile radius. Suppliers responsible for supplying large, integrated sub-systems such as instrument panels and seats were required to locate their manufacturing or assembly facilities in an adjacent supplier park.

The key feature of an external logistics system for this plant is the intelligent collection system on a shift basis from suppliers based in the UK and on a daily basis from suppliers based in Europe and delivery to the plant within half-hour windows.

5.15.4 The Process

The manufacturing process consists of metal stamping, body construction, paint; trim, assembly and final inspection (see Figure 5.21). The body shop is equipped to provide a state-of-the-art facility designed for lean manufacturing. All robots are procured from a single manufacturer and have standardised controls so that any robot with in the body shop could be replaced within an hour.

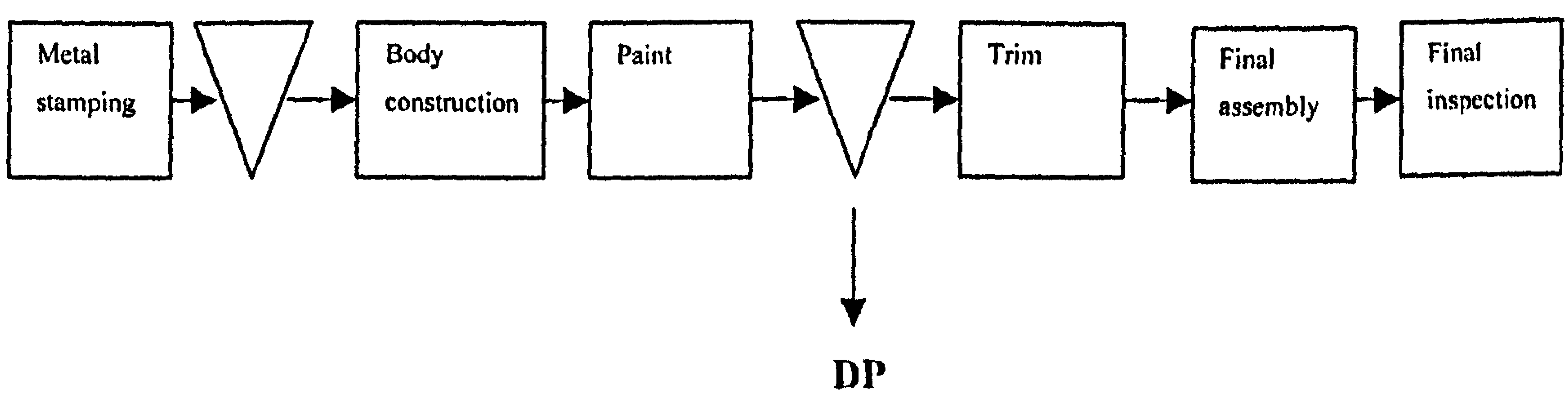

Figure 5.21: Vehicle assembly process flow

Based on the forecast of the orders and order line up a master production schedule would be prepared and 8 to 15 days of firm schedules issued. The logistic service provider operates the release of firm schedules in the form of manifests to suppliers and plants and pick-up sheets to truck driver. This manifest serves as an authorisation for the supplier to deliver parts to the drivers. The driver validates the shipment based on the manifest and would collect only the parts quantities specified. The driver has been empowered to take the decision with regard to excess or deficit of parts to be picked up. All suppliers also receive advance-shipping notices via EDI.

On the outbound shipment of finished vehicles, the plant takes complete responsibility for delivering the right vehicles at the right time to the dealers. The dealers have complete access to see their orders during the build phase and track them if necessary over the 15-16 day delivery lead-time.

The lean approach requires the operator to take up more responsibilities for the quality of their work and deal with any problems as soon as they occur.

5.15.5 Plant Assessment

The plant is characterised by high product variety, very large number of components and operations (Table 5.34). This plant has been judged as one of the best vehicle assembly plant in terms of implementation of lean practices in the whole of Europe.

It is practising all lean practices pertaining to alignment of production with demand, supplier integration, employee involvement and empowerment for continuous improvement and the elimination of waste (Table 5.35).

The plant layout was designed to ensure the most efficient flow of product. Line-side andon visible warning systems were introduced. Quality has become everyone's responsibility. Workers are given training on lean manufacturing concepts, tools and techniques.

Characteristics	
Product	
Product variety	>1million(possible variety)
Product shelf life	not important
Number of components per product	10000
Process	
Operations strategy	Assemble-to-order (ATO)
Process type	Flow shop
Decoupling point	Late
Equipment type	General purpose
Process complexity	High
Flow interruption	Low
Routings	Low
Change over time	High
Number of major operations	>1000
Main operations	Assembly and inspection
Number of production employees	3000
Labour skill input	Medium
Production volume	450
Level of automation	Medium
Process flexibility	High
Point of discretisation	First stage
Change over time	<10 minutes
Work-in-progress	4-5 days
Number of supply chain levels	5-7
Market	
Order winning criteria	Brand, design, quality
Order qualifying criteria	Service level, price
Maximum demand deviation	~20%

Table 5.34: Product/process/market characteristics of vehicle assembly plant

Approximately 80% of parts are received by using electronic kanban cards. Approximately 67% of the parts are received line side with 65% of these sequenced as per the production schedule. All parts have at least daily deliveries. There is a maximum of three-days supply in the parts warehouse. In the case of the supplier park, deliveries are based on a pull system with sequenced, line side, just-in-time replenishment and two hours trackside inventory. For UK suppliers, deliveries are pulled by the requirements of the line on a real time basis. Payment is based on production and not on receipt of supplies. European suppliers deliver on a daily basis to a central storage where materials from suppliers are received within a specified time frame and stored before moving them to the line. Suppliers are pooled within a milk-round distance using a third party logistics partner and intelligent collection. Global/rest of the world suppliers deliver with a lead-time of 21 days.

Lean practices	Status of lean practices	Reason for absence of lean practices
Aligning production with demand		
Pull system	Yes	
Uniform work load /levelled production	No	
Mixed model production	Yes	
One-piece flow	Yes	
Supplier integration		
JIT deliveries	Yes	
Active information exchange with supplier	Yes	
Supplier involvement in product development	Yes	
Supplier reduction policy	Yes	
Supplier development activities	Yes	
Long term contracts	Yes	
Employee involvement and empowerment		
Quality circle	Yes	
Cross functional training	No	
Autonomation	Yes	
Team based problem solving	Yes	
Continuous improvement programmes	Yes	
Suggestion scheme	Yes	
Job rotation	Yes	
Elimination of waste		
Quick change over	Yes	
Quality system	Yes	
Cellular manufacturing	Yes	
Visual control	Yes	
Preventive maintenance	Yes	
Statistical process control	Yes	
5 S	Yes	
Mistake proofing	Yes	
Standard operations	Yes	

Table 5.35: Status of lean practices in Vehicle assembly plant

5.15.7 Lessons learned

This plant is considered to be an exemplar for other vehicle assembly plants. It is practising all lean principles and practices.

5.16 The food and drink industry classification and the case studies

Data collected through the plant tours, interviews and questionnaires was analysed to find whether any similarities existed amongst the food plants and whether, based on any similarities found, can the food and drink plants be placed under particular food industry types (continuous/batch/ assembly). Table 5.36 displays the categorisation of all the case studies into specific food & drink industry types.

It was observed that case 1 (dairy plant), case 2 (UHT milk plant), case 3 (edible oil plant) and case 4 (beer plant) were very similar with regard to their production systems and dealt with a limited product variety, a small number of ingredients in finished good products, a high level of capital intensity, a small number of production employees, specialised equipment, low flow interruption and few routings (Table 5.36). The main operations in all four food and drink plants were separation, chemical reaction, heating and cooling, which do not require a large number of ingredients. A few ingredients per product coupled with low product variety have made their supply chain system relatively simple. All these characteristics identify these four food and drink plants as "continuous" types.

The plants producing sweet biscuits (case 6), sliced meat (case 7), savoury biscuits (case 8), snack food (case 9), mayonnaise and salad dressing (case 10) and tea bags (case 11) offered moderate product varieties (12-80). Each finished product produced by these plants requires a moderate number of ingredients (7-15) due to the use of mixing and forming operations in their production processes. More product variety and a larger number of ingredients have led to slightly more complex supply chain. These plants are characterised by specialised as well as general purpose equipment, a large number of production employees, a late point of discretisation, moderate level of capital intensity and short manufacturing lead-time times.

		Product Variety (SKUs)	No. of ingredients per product	Equipment Type	Main operation	Level of capital intensity	No. of production employees	Flow interruption	Routing	Decoupling point	Point of discretisation	Supply chain complexity
Continuous types	Case 1	8	3-5	Specialised	Heating, separation,	High	70	Low	Low	Late	Late	Low
	Case 2	6	3-5	Specialised	Separation	High	50	Low	Low	Late	Late	Low
	Case 3	50	3-5	Specialised	Separation	High	30	Low	Low	Late	Late	Low
	Case 4	10	5-7	Specialised	Fermentation	High	50	Low	Low	Late	Late	Low
Batch types	Case 5	6	7-8	General & specialised	Separation	Medium	50	Medium	Low	Late	Late	Low
	Case 6	12	12-15	General & specialised	Mixing, forming, heating	Medium	400	Low	Medium	Late	Late	Low
	Case 7	60	7-10	General & special	Forming, cutting	Medium	250	Medium	Medium	Late	Late	Medium
	Case 8	80	10-15	General & special	Mixing, forming, heating	Medium	450	Medium	Medium	Late	Late	Medium
	Case 9	50	10-15	General & special	Mixing, heating	Medium	100	Medium	Medium	Late	Late	Medium
	Case 10	80	10-15	General	Mixing, cooking	Low	70	Medium	Medium	Late	Late	Medium
	Case 11	50	10-12	General & specialised	Mixing	Medium	240	Medium	Medium	Late	Late	Medium
Assembly types	Case 12	300	20-25	General	Cooking, assorting	Low	400	Medium	High	Late	Early	Medium
	Case 13	350	20-25	General	Cooking, assorting	Low	150	Medium	High	Late	Early	Medium
	Case 14	150	8-10	General	Assorting	Low	300	Medium	High	Early	Early	Medium

Table 5.36: The food and drink industry classification and the case studies

These food plants (case 6, 7, 8, 9, 10 & 11) display the characteristics of the batch typology on the food and drink continuum. Though the butter plant (case 5) does not offer a large product variety, due to more flow interruption and the requirement for generalised as well as specialised equipments, it has been considered to be a "batch" type food and drink plant.

The plants producing convenience meals (case 12), frozen food (case 13), and sandwiches (case 14) show some characteristics of a discrete manufacturing plant. These plants produce the highest number of product varieties (150-350) and require a large number of ingredients (20-25) to make one complete product (Table 5.36). This fact also makes the supply chain more complex when compared to other food and drink industries, although still simple when compared to discrete manufacturing plants such as a vehicle assembly plant when considering product variety, bill of materials and supply chain complexity. These three food and drink plants mainly assemble a number of ingredients to make one finished product (sandwich, frozen meal and convenience meal). Assembly operations require a large number of production employees and the point of discretisation is at the start of the assembly stage, which is early for the food and drink industry. These three food and drink plants are therefore categorised as being "assembly" types.

5.17 Summary

The chapter discusses fifteen case studies in brief. There are fourteen case studies representing the food and drink sector and a single case study representing the automotive sector. Each case study has been described with regard to product, market, raw materials and process aspects of a plant. Subsequently the case studies have been assessed in order to understand the degree of leanness by examining the status of lean practices. The lean manufacturing framework which has been developed on the basis of the literature (chapter 2) is used to find out the leanness of the cases undertaken. All the case studies are further mapped on the food industry classification system.

Chapter 6

Case Analysis and Discussion

6.1 Lean manufacturing practices and the case studies

Following the plant visits, a questionnaire based on a series of practices describing lean manufacturing was sent to the senior managers of participating plants. Managers when asked a series of questions to indicate whether lean practices were present in their plant, the answers were found consistent with the data collected during the plant visits and during interviews with the senior managers.

It is found that the majority of the food and drink plants are practising a number of lean practices pertaining to the elimination of waste but practices relating to aligning production with demand are not evident in any of the food and drink plants except in the plant producing sandwiches (Table 6.1). The sandwich plant (case 14) has embraced one-piece flow and mixed model production. It also does not have much finished goods stock (less than a day) compared to other food plants. The raw material inventory was just one day for most of the raw materials which indicates that this plant can be considered as a lean plant. Although it employs a large number of production employees, very few lean practices pertaining to employee involvement and empowerment have been observed. The involvement of direct production employees in improving the work system was very limited with no small group activities.

The food and drink plants (cases 1-4) identified as "continuous" did not embrace the principles of employee involvement and empowerment as well as supplier integration.

Although the milk plant and oil plant have long-term agreements with their suppliers, active information exchange with suppliers, supplier development activities and JIT deliveries are absent.

The food and drink plants categorised as "batch" types (cases 4-11) embraced many of the lean practices related to employee involvement and empowerment and a few practices pertaining to supplier integration. The majority of the food and drink plants utilised job rotation to solve the problems related to the repetitive nature of the job. Suggestion schemes, autonomation, cross-functional training and team based problem solving were also practised by some of the plants categorised as "batch". None of these seven plants pursued lean practices such as JIT deliveries, active information exchange with suppliers and supplier involvement in product development, though long-term contracts with suppliers were pursued by five plants (cases 5, 7 9, 10, 11). The food and drink plants (cases 9-11) were also making necessary changes to reduce their supply base.

The food and drink plants categorised as "assembly" types were observed to be working closely with their suppliers and are pursuing more lean supply practices compared to the batch food and drink plants. Case 12 and case 14 are receiving the raw materials on a daily basis from their suppliers although not in a true JIT sense. The sandwich plant (case 14) procures its main raw materials, particularly bread and fresh vegetables, at least once a day. One of the important ingredients of a sandwich is bread which is delivered twice a day. These food plants are observed to be leaner than the other food plants but significantly less than the vehicle assembly plant (case 15).

The adoption of a lean manufacturing paradigm in the food and drink plants studied has been limited. The food and drink plants categorised as assembly types are noticed to be leaner than the other food plants. The reasons for a partial adoption of lean manufacturing are not immediately evident, so the data collected during the interviews and the data collected during visits to the plant are further analysed to understand and identify the specific reasons.

	Continuous				Batch							Assembly			
Lean practices	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**	**Case 8**	**Case 9**	**Case 10**	**Case 11**	**Case 12**	**Case 13**	**Case 14**	**Case 15**
Aligning production with demand															
Pull system															*
Uniform work load /levelled production														*	
Mixed model production														*	*
One-piece flow														*	*
Supplier integration															
JIT deliveries												∇		∇	∇
Active information exchange with suppliers												∇			∇
Supplier involvement in product development											∇		∇		∇
Supplier development activities							∇					∇			∇
Supplier reduction policy		∇					∇	∇	∇	∇	∇	∇	∇	∇	∇
Long term contracts	∇	∇			∇		∇	∇	∇	∇	∇	∇	∇	∇	∇

Table 6.1 Case studies and the lean manufacturing practices

* : Presence of lean practices pertaining to aligning production with demand

∇ : Presence of lean practices pertaining to supplier integration

Lean practices	Continuous				Batch							Assembly			
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12	Case 13	Case 14	Case 15
Employee involvement and empowerment															
Quality circle						□									□
Continuous improvement programmes												□	□		
Cross functional training						□	□	□	□		□		□		□
Autonomation							□	□	□	□	□		□	□	
Team based problem solving						□	□	□				□			□
Suggestion scheme						□	□	□				□	□		□
Job rotation	□					□	□	□	□	□	□	□	□	□	□
Elimination of waste															
Quick change over														O	O
Cellular manufacturing							O							O	O
Mistake proofing							O	O					O	O	O
Visual control						O	O	O		O	O	O			O
Statistical process control	O	O	O		O		O	O	O		O				O
Preventive maintenance	O	O	O	O			O	O			O		O		O
Quality system	O	O		O	O	O	O	O	O	O	O	O	O	O	O
5 S	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Standard operations	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O

Table 6.1: continued

□ : Presence of lean practices pertaining to employee involvement and empowerment

O: Presence of lean practices pertaining to the elimination of waste

6.2 Discussion

The food and drink plants selected for the study represent a broad spectrum of the food and drink industry. The majority of the food and drink plants produce products which have a low product complexity due to the small number of components/ingredients and the small number of value adding processes. The unit price of all food products produced at the plants studied is very low because of inexpensive ingredients and partly due to the low value added in the total cost. Also the cost of raw materials represents a major part of the total cost.

All the cases were classified with regards to product, process and market characteristics (see Tables 6.2, 6.3 & 6.4). Each case study is analysed so as to identify specific product/process/market characteristics critical for the adoption of lean manufacturing principles and practices.

6.2.1. Elimination of Waste

Except quick changeover, the majority of lean practices pertaining to " the elimination of waste" are being practised by the majority of food and drink plants considered. A major cause of the large finished goods inventory in any plant is the long changeover time. It is observed that stringent hygienic demands necessitated frequent cleaning. Cleaning between production of different products also contributed to long change over times. Changeover during the processing stages is sequence dependent and takes a long time, which makes changeover infrequent. Moreover even if the changeover takes less than one quarter of an hour, it is still very high in terms of loss of production because all the food and drink plants are high volume plants (Tables 6.2, 6.3 & 6.4). Compared to the vehicle assembly plant (case 15), the continuous and batch food and drink plants produced a few varieties of the product.

Although the food and drink plants producing sliced meat (case 6), savoury biscuits (case 8), snack foods (case 9), mayonnaise and salad dressing (case 10) and tea bags (case 11) deal with a large product variety, this is due to the different pack sizes and labels and not in terms of the variety of product types. This variation means that changeover is required mainly at the packing stage. Changeover during the packing stage requires the replacement of packaging materials, which come in the form of large rolls. The packaging rolls cannot be changed until one lot is finished which restricts the possibility of frequent changeovers even at the packaging stage.

The food and drink plants categorised as assembly types carried out more changeovers per day than the other food plants. This can be attributed to the high product variety, general-purpose assembly line and relatively shorter changeover time. The sandwich plant (case 14) needed only 3 minutes to change from one type of sandwich to another on the assembly line and practised 120 changeovers per day.

It was also found that the continuous type of food plant pursued preventive maintenance, which was missing in the assembly food and drink plants (cases 12 & 14). This difference can be attributed to the high capital intensity in a continuous type food plant, which drives the plant to utilise its maximum available capacity. Continuous food and drink plants are typical process plants where all the processes are interconnected and require little manpower to manage the processes. A centralised control unit manages all the processes.

	Case 1 (Dairy plant)	Case 2 (UHT milk plant)	Case 3 (Edible oil plant)	Case 4 (Beer plant)
PRODUCT				
Product complexity (Low/Medium/High)	Low	Low	Low	Medium
Product variety (No. of SKUs)	8	6	50	10
Product shelf life (No. of weeks)	4 days	24	1	24
PROCESS				
Operations Strategy (MTS/MTO/PTO/BTO)	MTS	MTS	MTS/Blend-to-order (BTO)	MTS
Process type (Batch/ Semi- continuous/ Continuous)	Continuous	Continuous	Continuous	Continuous
Process complexity (Low/medium/high)	Low	Medium	High	High
Number of major operations	4	3	4	7
Skill input (Low/medium/high)	Low	Medium	Low	Low
Production volume (Units/day)	600,000 litres/day	25000 litres/day	1,000000 litres/day	150,000
Level of automation (Low/medium/High)	High	High	High	High
Process flexibility (Low/medium/high)	Low	Low	Low	Low
Production employees (No. of employees)	70	50	30	50
Point of discretisation	Packing stage	Packing stage	None	Bottle filling stage
Change over time (Hours)	3 hours	2 hours	2 hours	6 hours
Work in progress (Hours of output)	8 hours	5 min	4 hours	20 days
Number of supply chain levels	2	2	1	1
MARKET				
Order winning criteria (Price/quality/ service level/ brand/ Design)	Price, Service level	Price, service level	Price, product variety	Brand, Quality
Order qualifying criteria (Price/quality/ Service level/ brand/ Design)	Quality	Quality	Quality, service level	Price, Service level
Maximum Demand deviation from mean demand (%)	>50%	~20%	~20%	>50%

Table 6.2 :Product/process /market characteristics of continuous type food and drink industry

	Case 5 (Butter plant)	Case 6 (Sweet biscuit plant)	Case 7 (Sliced meat plant)	Case 8 (Savoury biscuit plant)	Case 9 (Snack Food plant)	Case 10 (Mayonnaise plant)	Case 11 (Tea bag plant)
PRODUCT							
Product complexity (Low/Medium/High)	Low	Low	Low	Low	Low	Low	Low
Product variety (No. of SKUs)	6	12	60	80	50	80	250
Product shelf life (No. of weeks)	12	24	1-2	30	20	24	52
PROCESS							
Operations Strategy (MTS/MTO/PTO)	MTS	MTS	MTS	MTS	MTS	MTS	PTO (pack-to-order)
Process type (Batch/ Semi-continuous/Continuous)	Batch	Batch	Batch	Semi-continuous	Batch	Batch	Batch
Process complexity (Low/medium/high)	Low	Low	Low	Medium	Low	Low	Low
Number of major operations	5	6	7	8	5	4	4
Skill input (Low/medium/high)	Low	Low	Low	Low	Low		Low
Production volume (Units/day)	15000 kg/day	1000000	140,000 packs	250,000kg	40,000kg	8000 kg per day	60,000 kg
Level of automation (Low/medium/High)	Low	Medium	Medium	Medium	Medium	Low	Medium
Process flexibility (Low/medium/high)	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Production employees (No. of employees)	50	400	250	450	100	70	240
Point of discretisation	Packing stage	Moulding stage	Packing	Moulding stage	Packing	Packing	Tea bag filling stage
Change over time (Hours)	1 hours	2 hours	25-30 min.	0.5 – 5 hours	30 min.	20 min.	1 hours
Work in progress (Hours of output)	1 day	2 hours	10 hours	7 hours	7 hours	6-8 hours	2 days
Number of supply chain levels	2	2	2	2	2	2	1
MARKET							
Order winning criteria (Price/quality/ service level/ brand/ Design)	Price, service level	Price, brand	Quality, service level	Price, brand service level	Price, service level, brand	Quality, brand	Price, service level
Order qualifying criteria (Price/quality/ service level/ brand/ Design)	Quality	Quality	Price, Quality	Quality	Quality	Price, Service level	Quality
Maximum Demand deviation from mean demand (%)	~20%	~20%	>25%	>50%	>30%	~20%	>25%

Table 6.3: Product/process/market characteristics of batch type food and drink industry

	Case 12 (Convenience meals	Case 13 (Frozen food plant)	Case 14 (Sandwich plant)	Case 15 (Vehicle assembly plant)
PRODUCT				
Product complexity (Low/Medium/High)	Medium	Medium	Low	High
Product variety (No. of SKUs)	300	350	150	>1 million*
Product shelf life (No. of weeks)	52	52	3 days	500
PROCESS				
Operations Strategy (MTS/MTO/ATO)	MTS	MTS	MTO	ATO
Process type (Batch/ Semi- continuous/Continuous)	Batch	Batch	Flow shop	Flow shop
Process complexity (Low/medium/high)	Low	Low	Low	High
Number of major operations	6	5	3	>1000
Skill input (Low/medium/high)	Low	Low	Low	Medium
Production volume (Units/day)	200,000 meals	220,000	50000	450
Level of automation (Low/medium/High)	Medium	Medium	Low	Medium
Process flexibility (Low/medium/high)	Medium	Medium	Medium	High
Production employees (No. of employees)	400	150	300	3000
Point of discretisation	Assembly stage	Assembly stage	Assembly stage	First stage
Change over time (Hours)	2 hours	30-60 minutes	3 minutes	<10 minutes
Work in progress (Hours of output)	6-8 hours	6-7 hours	2 hours	4-5 days
Number of supply chain levels	2	2	2	5-7
MARKET				
Order winning criteria (Price/quality/ service level/ brand/ Design)	Price, Service level	Price, Service level	Price, service level	Brand, Design, quality
Order qualifying criteria (Price/quality/ Service level/ brand/ Design)	Quality	Quality	Quality	Service level, price
Maximum Demand deviation from mean demand (%)	~20%	~20%	>25%	~20%

Table 6.4: Product/process/market characteristics of assembly type food and drink industry

Cellular manufacturing and visual control were not present in the continuous food and drink plants (case 1-4). The few product varieties and a fixed routine do not call for the arrangement of workstations in a U-shaped format. Moreover, material flow in these plants was continuous without any back tracking of material. This fact makes cellular manufacturing irrelevant in these plants. Not only continuous food and drink plants but also other food plants do not pursue cellular manufacturing due to the fact that the majority of processes use the materials in a non-discrete form. Cellular manufacturing has been successful in discrete manufacturing industries where the product flows in discrete units.

6.2.2 Employee involvement and empowerment for continuous improvement

A majority of the food and drink plants employed either temporary labour or variable working hours to cope with demand fluctuations. The biscuit plant (case 8) makes 80% of its profit in the last quarter of the year. During the first six months of the year, customer demand is very low and then it starts growing. It is the highest in the month of December, so temporary labour is engaged from August onwards to build stock for the last quarter. Cases 7, 9, 12 and 13 also employ temporary labour on the shop floor. Although this policy works well to deal with the demand uncertainty, it does not create an environment where these temporary employees can be involved effectively to improve the production system.

It is observed during the research investigation that the continuous type food and drink industries (cases 1, 2, 3 & 4) characterised by a small number of production employees, high capital intensity, low value added and low product variety, have not been able to use its human resources effectively.

The batch and the assembly food and drink plants (Cases 6, 7, 8, 9, 11,12, 13 & 14). employ more manpower and also produce more product variety (Table 6.4 & 6.5). These food and drink plants have been observed to use job rotation, team-based problem solving and cross-functional training. The majority of labour in such food and drink plants is required at the assembly stage or at the packing stage, which involves repetitive work. This fact has called for rotating the job frequently as well as working in a team. No evidence has been noticed which could demonstrate prevalence of continuous improvement initiatives on the shop floor.

6.2.3 Aligning production with demand

Wide demand variability, limited shelf life, variable process yield, variable raw material quality and food safety issues have restricted the food and drink industry to align its production with demand. These factors, which are not present in the automotive industry, have added new dimensions to the complexity of food production systems.

6.2.3.1 Impact of demand variability and shelf life

When compared to the vehicle assembly plant (case 15), it was found that all the food and drink plants (cases 1-14) experienced wide fluctuating demand patterns which was manifested by

- weekly patterns, with peaks at the weekend
- seasonal demand changes with weather, holidays and festivals.
- promotional demand peaks which were difficult to predict
- random demand fluctuation

The demand pattern is the main critical factor in aligning production with customer demand; make too much and there is a wastage problem due to the limited product shelf life, make too little and there is a loss of sales plus potential lost customers. With food products that are often highly perishable, the production planning and control is difficult for the food and drink industry. It is not only the problem of reducing costs to maintain margins against the constant drive for price reduction by the retailers, there is also the issue of responding quickly to the customer demand and controlling the stocks of the perishable raw materials. Moreover, the perishable food products cannot be made for stock in slack times.

It is interesting to see the placement of various cases on the shelf-life/demand variability grid (see Figure 6.1). When demand variability as well as shelf life is high it makes sense to adopt an MTS process strategy but where the shelf life is short and demand variability is also low the plant has to be a lean plant. Low demand variability will not force the plant to build inventory for the future demand and the short shelf life will compel the food plant to produce and deliver the products to customer as fast as possible by making the plan lean.

Product shelf life	Low	Moderate	High
Long	Case 2	Case 11, Case 12, Case 13, Case 6, Case 10	Case 4 Case 8
Moderate		Case 5	Case 9
Short		Case 3	Case 7, Case 1, Case 14

Demand variability

Figure 6.1: Demand variability/product shelf life grid

The shelf life of pasteurised milk (case 1), sliced meat (case 7) and sandwiches (case 14) is very short, which forces the plants to fulfil the customer order as quickly as possible. This makes these plants good candidates for lean. These plants cannot build stocks in slack times due to the short shelf life of their product except during the low customer demand periods particularly with case 1 where raw milk is converted into some other form, which has a longer shelf life. That is why surplus pasteurised milk is converted into skimmed milk powder. The skimmed milk powder is then utilised to fulfil customer demand during seasons of high demand. This situation is typical of all dairy plants due to the long-term agreement which they have with their suppliers to take all milk irrespective of the customer demand. The sliced meat plant (case 7) has to offer a high service level and the customer insists on 75% of the product shelf life in its favour from the date of delivery. The short shelf life of sliced meat does not offer the plant the opportunity to build up a high finished goods inventory, but it can store the meat in the form of work-in-progress by freezing the meat before the slicing process. This strategy gives the plant an option to purchase the raw meat at a highly discounted price and also to cope with high product variety and high service level. The sandwich plant operates in a dynamic market environment where customer orders fluctuate widely and the shelf life of the product (3 days) is very short. A sandwich cannot be assembled on the basis of forecasted demand due to its short shelf life, which eliminates the possibility of the adoption of an MTS process strategy. This plant only starts production when it receives a confirmed customer order. It could adopt an MTO process strategy due to the small number of processes, short run time and its ability to carry out changeover within 3 minutes. A wide demand fluctuation is taken care of by varying the length of the shift. The duration of the night shift is fixed, but the duration of the day shift is dependent on the size of the customer orders. The case of the sandwich plant has demonstrated that the food industry can become leaner and can respond to market demand rapidly.

The shelf life of biscuits, beer, snack foods, frozen meals and convenience meals is relatively large which offers the possibility to build stock to cope with demand uncertainty and seasonality.

6.2.3.2 Impact of Order winning criteria:

The order-winning criteria influence the linkage between production systems and customer demand. The majority of the food plants studied operate in an environment where price and service level are the order-winning criteria. High service level required by the customers drive the food and drink plants to build stock from which the customer order can be fulfilled quickly. High demand variability can further reinforce an order fulfilment strategy by keeping a high level of stock. Cases 1, 4, 7, 8, 9, and 14 operate in an environment where service level and price are order-winning criteria and also experience a high demand variability. With the exception of case 14, cases 1, 4, 7, 8 & 9 have adopted a make-to-stock (MTS) production strategy.

	Low	Medium	High
Service level as order-winner	Case 2	Case 11, Case 12, Case 13, Case 3, Case 5	Case 4 Case 8, Case 7, Case 1, Case 9, Case14
Service level as order-qualifier		Case 6, Case 10	Case 4

Demand variability

Figure 6.2: Order winning criteria/demand variability grid

The edible oil plant (case 3) and tea bag plant (case 11) have also not embraced an MTS process strategy. The case of the oil plant provides evidence of a hybrid MTS/MTO or MTS/BTO (blend to order) process strategy which is unusual for a continuous type of food industry. The customer order for straight oils like rapeseed oil and palm oil are served from the stock but orders for the 'blend oil' cannot be served from stock due to the possibility of the large number of 'blends'. The large number of 'blend oils' is served on the basis of an MTS/MTO process strategy. Two straight oils, rapeseed and palm oil are refined and stored in tanks and four other straight oils are bought from the open market based on demand forecasts. The customer order for 'blend oil is served by mixing straight oils through a blending process after the confirmation of the customer order. By adopting an MTS/MTO process strategy it could offer a large number of product varieties. A similar approach is also adopted by the tea bag plant (case 11), where tealeaves are first mixed and converted into blends of tealeaves in the mixers. These blends of tea leaves are stored as the intermediate stock and are sent to the packing process only after receipt of a customer order, where they are packed in different sizes, shapes and label according to the customer requirements.

6.2.3.3. Impact of variable process yield and variable raw material quality

The majority of the food and drink industry deals with variable process yield due to variable raw materials, quality and composition, which creates uncertainty with regards to production throughput. It becomes difficult to align production with customer demand when throughput is uncertain. Throughput uncertainty generated due to variable process yield and variable raw material quality, which is not an issue in the vehicle assembly plant, has forced the food plants to create time buffers or physical buffers.

The problems of variable process yield and variable raw material quality are more prominent in the continuous food and drink industries (Cases 1, 2, 3 & 4) because they use the raw materials which are a produce of agriculture. The batch and assembly food and drink industries are less susceptible to variable raw material quality issues as they receive the majority of their raw materials from the primary processing food industry and not from the farmers.

6.2.3.4 Impact of decoupling point (DP)

The decoupling point (DP), the point that indicates how deeply the customer order penetrates into the goods flow and the point of inventory from which the customer orders are served and separate the order-driven and forecast driven activities (Van Donk, 2001), is found in all the food and drink plants considered (except cases 11 & 14) to be relatively late (Table 6.5).

Case Study	Location of DP	Reasons
Case1	Late, before packing stage	Low value added, wide demand fluctuation, short delivery time,
Case2	Late	Long cleaning time, packaging machine as bottleneck machine
Case3	Late, before blending process	Low value added, long changeover time, short delivery, high delivery reliability
Case4	Late, at finished goods stock	Long shelf life, demand seasonality
Case5	Late, at finished goods stock	Low value added, long shelf life,
Case6	Late, at finished goods stock	Long shelf life, low value added,
Case7	Late, at finished goods stock	Demand seasonality, retailer promotional schemes, high service level, high delivery reliability
Case8	Late, at finished goods stock	Long shelf life, high service level, demand seasonality, short delivery time
Case9	Late, at finished goods stock	Demand variability, long shelf life, high service level, short delivery time
Case10	Late, at finished goods stock	Long shelf life, long changeover,
Case11	Middle of the process	Large product variety originating from difference in packaging sizes, labels and brands, blender machine being bottle neck capacity,
Case12	Late, at finished goods stock	High service level, long shelf life, retailer promotional activities, demand seasonality
Case13	Late, at finished goods stock	High service level, long shelf life, retailers promotional activities, demand seasonality
Case14	Early, at the raw material storage stage	Short shelf life, short changeover time, greater information sharing with customers

Table 6.5: Case studies and the location of decoupling point

The position of the decoupling point has a great influence on deploying a specific process strategy. It also determines how much a plant can align its production with demand. If the location of the DP is upstream, it means that the plant can respond to the customer demand more effectively. Market and process attributes of the food and drink industry have consequences on the location of the DP (Table 6.6). Unpredictable demand, high service level, short delivery time, reliable and frequent deliveries have a downstream effect on the DP whereas a short shelf life has an upstream effect on the DP.

	Presence/value in the food and drink industry	Effect on location of the decoupling point
Market attributes		
Service level	High	Downstream
Response time	Short	Downstream
Predictability of demand	Unpredictable	Downstream
Specifity of demand	High, through great variety and best-before	Upstream
Process attributes		
Lead times and costs	High set-ups/cleaning times	Downstream
Predictability of raw materials	Low	Downstream
Product shelf life	Short	Upstream
Risk of obsolescence	High	Upstream

Table 6.6: The influence of market and process characteristics on the DP (Adapted from Van Donk, 2000).

The processes in the food industry might be unpredictable in their yield due to the natural raw material, which varies in quality and composition. The result of this situation has downstream effect on the DP. The majority of the food and drink plants are characterised by long set-up times, due to sequence dependent set-ups and long cleaning times, which shifts the decoupling point to the downstream side (Van Donk, 2000).

Case 11 has been able to shift the DP upstream of the packing stage and is located at the stock of blended tealeaves. Having the DP on the upstream side has allowed the plant to implement a hybrid MTS/MTO process strategy. Case 14 had its DP quite early in the process flow (Table 6.5). The reason for an early decoupling point can be traced to the short shelf life and short changeover time, though it experiences wide demand fluctuation, which goes against having an early DP.

In the case of the continuous food and drink plants, there are only two locations for the DP:

1. The stock of raw materials
2. The stock of finished products

Possible locations for the DP in a batch and assembly type food plant will also include the stock of semi-finished goods in addition to the two locations mentioned above.

Most of the continuous type food plants are characterised by tightly coupled processes, long changeover times and low value added which restricts the possibility of locating the DP at the stock of raw materials. Cases 1, 2, 3 & 4 have located their DP on the downstream side. The batch and assembly food and drink plants have a better chance of shifting the DP to upstream of the finished goods storage.

6.2.3.5 Impact of point of discretisation (POD)

Except with the edible oil plants, all food and drink manufacturing plants employed both continuous and discrete operations. Discrete operations are those that are performed on a single unit, or a group of units simultaneously, whereas continuous operations are those in which the operation doesn't produce distinct or discrete units. In fact in all the food and drink plants non-discrete units eventually become discrete at some point during the manufacturing process. The point of discretisation (POD) where non-discrete items becomes discrete, influences the production and customer demand relationship.

In all the food and drink plants, except assembly food plants (cases 12, 13 & 14), the point of discretisation (POD), where non-discrete unit becomes discrete, is relatively late in the process. It is observed, particularly with continuous food and drink plants (cases 1, 2 & 4), that all the processes before the POD are tightly coupled and involved mostly continuous operations. This fact imposes a restriction on the depth of customer order penetration.

Although the batch food and drink plants have the POD at the packing stage, theoretically it does not pose a problem in shifting the DP from the downstream side to the upstream side, as these types of plants don't use tightly coupled processes before POD, which means that the DP can be shifted to inventory locations before the POD. Only in case 11 could the DP be moved to a position before the POD, other wise in all other cases the DP was found to be after the POD.

Most of the lean practices (pull system, mixed model production, one piece flow etc) pertaining to the alignment of production with demand have evolved in the automotive sector, which operates in a discrete environment. Hence these lean practices will have more relevance in the discrete part of the food and drink plants. The POD in the assembly type of food plants is at the beginning of the assembly stage, which means a pull system, one–piece flow, and mixed model production can be applied after the POD. The sandwich plant (case 14) has presented evidence of mixed model production and one-piece flow. Cases 12 and 13 have not been observed to pursue these lean practices.

In the automotive industry reducing work in progress is often one of the high priorities due to the high level of work fragmentation, whereas in the food and drink industry the short throughput times coupled with continuous operations lead to a small amount of work in progress compared to the stock of raw material and finished goods. That is why most of the automotive plants have quickly embraced pull systems so as to reduce WIP. Moreover product cost in the automotive industry is very high when compared to the food and drink industry which means that even fewer products within the system or as finished goods inventory will cost a lot whereas due to low product cost of finished goods inventory in the food industry is not significant in monetary terms. All the food and drink plants have low WIP and short run times except the beer plant where WIP and manufacturing lead-time is very high. This fact is due to the very nature of the fermentation process to produce the beer, which demands a slow chemical reaction which takes a long time. This fact does not offer any incentive to food plant managers to try pull systems. Low product cost, coupled with long changeover time due to sequence dependent set up and continuous processes (except case 14) has put a limitation on the adoption of mixed model and levelled production in the food industry.

6.2.4 Supplier integration

In the automotive industry, the product is highly complex and requires thousands of parts to be assembled together. It necessitates the involvement of a large number of suppliers and makes the supply chain complex. The complex supply chain required in the automotive industry puts pressure on the vehicle assembly plant to work closely with their suppliers and also necessitates it to enter into a long-term relationship with its suppliers.

In contrast to the automotive industry, the food and drink industry requires relatively few ingredients/components to make the end products. The bill of material or recipe is quite shallow. A majority of the ingredients are commodity raw materials, which can be purchased from a wide list of suppliers across the globe. The supply chain is relatively simple in the food and drink sector and for the majority of the food and drink plants the order-winning criterion is price. Hence, there is a little drive for the food plants to establish long-term relationship with their suppliers.

Moreover, if the supply chain activities are geographically dispersed fast flow of information and goods along the supply chain required to make the food and drink industry lean, will be costly as well as complex. The sea shipments over a long distance make just-in-time delivery impossible while airfreight is too expensive for routine use (Levy, 1997). International communications on new product development and scheduling issues is not only costly but also less effective due to language and culture barriers. This fact coupled with fluctuating raw material availability and prices has not motivated the food industry to make their operations seamlessly integrated with their suppliers.

In the case of the continuous food and drink plants (cases 1, 2, 3 & 4), low product variety, and few raw materials/ingredients per product have made the procurement of the raw materials relatively simple. The majority of continuous food and drink plants face the problem of fluctuating raw material quality, which translates into more inspection and rejection or wastage. The JIT deliveries right at the point of use are simply impossible. Cases 1, 2, 3 and 4 manage only three to seven different types of raw materials, which are mostly commodity types. Cases 1, 2 and 4 procure their raw material locally whereas case 3 used to procure one of the main raw materials, palm oil, from geographically dispersed global suppliers. Comparatively the edible oil plant used to keep more raw material inventory to guard against the problems associated with sea shipments over a long distance. Although cases 1, 2 & 3 are pursuing long-term contracts with their suppliers, no other lean supply practices are observed. The situation of case 1 is unique due to the fact that not only has it set up a long-term agreement with its suppliers, it has also agreed to take all the milk collected by small milk producers irrespective of the customer demand. This situation creates a huge demand supply gap and leads to a significant amount of skimmed milk powder stock in a low demand period.

Batch food and drink plants (cases 5-11) produce more product variety (6-80) and require more ingredients per product (7-15). A majority of the plants (cases 5, 6, 7 & 8,) procure their main raw materials from primary food processing industries, which ensure consistent raw material quality. Hence, these plants had better predictable process yield compared to continuous food and drink plants. Although cases 5, 7, 9, 10, 11 have made long-term contracts with their suppliers, an emphasis on reducing the supply base is observed only in cases 9, 10, 11. Only cases 7 & 8 practise supplier development activities and case 11 involve its supplier in the product development process. The partial adoption of this lean principle was mainly due to the relatively low product complexity (cases 5, 6,7,8,9,10 & 11), price as order winning criterion (cases 5, 6, 8, 9 & 11), and high raw material price fluctuation (cases 6, 7, 9 & 11).

The assembly food and drink plants (cases 12-14) offer a comparatively large product variety (90-200) when compared to continuous and batch food and drink plants and also use more ingredients per product (8-25). All the three food plants categorized under assembly group have been working closely with its suppliers by adopting long-term contracts and reduced supply base concepts. These food and drink plants have been observed to be more integrated with their suppliers. Case 12 and case 14 have been receiving their main raw materials on a daily basis, which is quite close to JIT delivery, though true JIT delivery is still a dream due to the large economic transport size. Case 12 has been engaged in the majority of lean supply practices (active information exchange, supplier development activities etc).

6.3 Summary

This chapter elaborated on various issues pertaining to the adoption of lean thinking in the food industry. All cases were compared and classified on the basis of products, processes and market characteristics. Each case study was analysed so as to identify specific inhibitors and enablers for the adoption of lean manufacturing principles and practices.

It is found that practices relating to aligning production with demand are not evident in the majority of the food plants. Wide demand variability, limited shelf life, variable process yield, variable raw material quality, food safety issues, point of discretisation (POD), position of decoupling point (POD) and prices and service as order winning criterion have restricted the food industry to align its production with demand. These factors, which are not present in the automotive industry, have added new dimensions to the complexity of food production systems. A majority of the food plants employ either temporary labour or variable working hours to cope with demand fluctuations. Although this policy works well to deal with the demand uncertainty, it does not create an environment where these temporary employees can be involved effectively to improve the production system.

Chapter 7

Lean approach for the food & drink industry

Lean manufacturing provides an approach to do more with less manpower, less equipment, less time and less space. It can improve the performance of a food supply chain by offering customers exactly what they need by just focussing on the value adding elements in the process. This manufacturing approach, based on the practices evolved in the Japanese motor industry, has been around for some time. It has been well known in the discrete manufacturing industry and has led to some spectacular improvements. Lean manufacturing has been lately applied to other sectors including construction, healthcare and shipbuilding.

The food & drink industry is not one industry, but incorporates diverse types of industries offering commodity products such as oil and sugar to customised/differentiated products such as convenience meals and sandwiches using a variety of transformation systems. The distinction between different food & drink industries has not been well understood. This fact has led to the segregation of the food & drink industry on the basis of its different transformation characteristics. Subsequently, three types of the food & drink industry (continuous, batch and assembly) have been suggested.

It was observed during the field research that the food & drink industry under these groups displayed different levels of lean adoption. The reasons for this can be attributed to the differences in the product, process and market characteristics & managerial practices.

Based on discussions with the plant managers and observations during the plant tours, the lean model widely adopted in a discrete manufacturing environment, particularly automotive, is not applicable as such in the food & drink sector. The environment within which a discrete manufacturing industry, such as automotive, electronic and aerospace, operates is quite different from the food & drink industry environment. The products offered by the food & drink industry have a very low product cost compared to products produced by a discrete manufacturing industry. On the other hand, work-in-progress (WIP) and manufacturing lead-time in the automotive and the aerospace industry are quite high when compared to the food & drink industry. This means that the value of WIP is quite high in the automotive and the aerospace industry whereas the value of WIP in the food & drink industry is not very significant (Table 7.1).

Industry	Product cost	Product volume	Work in Progress	Manufacturing Lead time
Automotive	Very High	Moderate	High	High
Electronic	High	High	High	Moderate
Aerospace	Very high	Low	Very high	High
Food industry	Low	Very high	Low	Low

Table 7.1: Typical characteristics of industry environment

Although the assembly type of food & drink industry is quite similar to the discrete manufacturing industry, the adoption of a lean manufacturing model has found to be limited. The field research suggests that the food & drink industry require a specific lean approach. Moreover the lean approach should be specific to each category of the food & drink industry.

7.1 Lean approach for a continuous type of food & drink industry

The food & drink industries categorised under this group use continuous manufacturing where the raw materials flow without any interruption through highly automated and specialised equipment. It requires a high level of capital intensity and offers little product variety. These industries are more likely to deal with commodity type products and emphasise process innovation rather than product innovation in their competitive strategy. The main raw materials are the produce of agriculture where, their availability and quality depends on the vagaries of nature.

The continuous type food & drink industry typically represents the characteristics of a process industry and presents great difficulty in the adoption of all lean principles and practices which are widely embraced by the automotive industry. The lean principle and practices for this group has been suggested in Table 7.2.

Lean principles	Lean practices	Potential lean vision
Elimination of waste	Good house keeping/5S Visual control Standardisation Total productive maintenance Food safety and hygiene Process mapping Quality systems	Reduce cost and improve quality
Employee involvement for continuous improvement	Suggestion scheme Continuous improvement programme Job rotation	Improve quality & productivity
Alignment of production with demand	Collaborative forecasting system	Reduce cost and improve customer responsiveness
Supplier integration	Long term contract Supplier audit Supplier reduction policy Exchange of information electronically	Improve quality

Table 7.2: Lean principles and practices for the continuous type food & drink industry

7.1.1 Elimination of waste

The food & drink industries (beer, milk, sugar, etc) under this group have to manage a few raw materials which are quite often seasonal. The availability and quality of the raw materials depends on the vagaries of the weather which disrupts the rhythm of the production line.

The plants under the continuous group are capital intensive, produce low unit cost products and depend on high volumes. The plants are assessed solely on the basis of capacity utilisation, which demands an uninterrupted supply of raw materials. The availability of raw materials is ensured by building a greater level of raw materials stock due to the fact that a number of raw materials are seasonal and in some cases suppliers are geographically dispersed. The emphasis on achieving high capacity utilisation due to the high capital investment also leads to the creation of a large finished goods stock.

The majority of the food & drink plants in this category use a product layout which means that the material flows in a fixed route without backtracking and thus, wastage in material handling is limited. Moreover, the maximum work-in-progress (WIP) is already fixed and is limited to the size of the vessels or tanks. Short manufacturing lead-times also leads to a lower level of WIP. There are a few exceptions, such as the beer plant which requires more WIP than any other plant due to the slow fermentation process. For the rest of the food & drink plants, controlling WIP is not a major issue.

It is observed that waste in a continuous type food and drink industry is mainly due to overproduction, the high raw materials inventory, plant down time and variable process yield. A few of the lean tools can make it possible to reduce these wastes. The applicability of various lean tools is discussed below.

One of the important lean practices, quick changeover poses a problem for this category of plants. A changeover can only take place at the end of a shift, as the plant has to be cleaned for hygiene reasons. Sometimes quick changeovers can induce mixing of flavours due to the mixing of different ingredients, though quick changeovers can be possible at the packing stage.

Practices such as cellular manufacturing will not be useful due to the low product variety and the use of continuous manufacturing. Moreover the flow of material follows the most efficient path. These types of plants will benefit the most from lean practices such as preventive maintenance that can reduce plant downtime and increase overall equipment effectiveness. Practices such as 5S/good house keeping, visual control, quality systems, and standardisation are universal in nature and can be adopted without too much difficulty.

7.1.2 Employee involvement & empowerment for continuous improvement:

In the past, continuous type food & drink plants have not focused on involving their employees creatively for continuous improvement due to the low level of manpower cost when compared to the raw material cost and fixed cost. The plants under this group are typically characterised by the high level of capital intensity and continuous manufacturing which require few direct production employees. The majority of the production employees are required at the packing stage. The job at the packaging stage is relatively simple, but monotonous, which creates an opportunity for the job rotation.

Discussion with the operation managers and plant managers revealed that although employee involvement and empowerment to improve the work place have not been practised, it can help in improving the plant utilisation. As a few employees manage these plants harnessing the potential of these employees can lead to improved plant utilisation. Suggestion schemes, continuous improvement programmes, job rotation can very well be adopted, but this requires top management commitment.

7.1.3 Alignment of production with demand

These types of plants mainly produce commodity type food products and offer little product variety. The commodity products are sold in large volumes to several customers, which justifies significant capital investment. These capital-intensive plants have to run continuously to utilise the principle of economy of scale and require the continuous availability of the raw materials, which are mostly seasonal, leading to a greater level of raw material stock. Sometimes these raw materials are procured from overseas which cannot be delivered on a just-in-time basis. If the raw materials have a short shelf life then these cannot be stored for a longer duration. Such plants will either have to process perishable raw materials and store them in a controlled environment or convert the raw materials into a form which has a longer shelf life.

The continuous type food & drink industry also faces the problem of demand seasonality due to changing weather conditions and social occasions. The high capital investment, together with inconsistent raw materials and demand seasonality, have not motivated the industry in the past to look into the possibility of adopting a pull system, but the success of pull systems in other industries has now generated a renewed interest.

It is observed that due to the use of continuous manufacturing, there are a very few locations for the decoupling point (DP)

- the stock at the raw materials storage stage
- the stock before the packing stage
- the stock after the packing stage

Most often the location of the DP is at the 'stock after the processing stage' or just before the packaging stage due to the inflexible and continuous operations. It is hard to move the DP to the 'stock at the raw material storage stage' due to the capital-intensive equipment, continuous manufacturing and long sequence dependent changeovers. There is only one location where the DP can be shifted upstream and that is at the 'stock before the processing stage', which can then offer an opportunity to use an MTO/MTS process strategy. An MTO can be served from the 'stock before the processing stage' and the stock can be replenished using an MTS strategy. This option also means that the concept of pull production can be applied downstream of the packaging stage.

Lean practices such as mixed model production and one-piece flow are practically impossible to practise before the packaging stage due to non-discrete flow, continuous manufacturing and long sequence dependent set-up times.

7.1.4 Supplier integration

It has been observed that the plants under this group have shown a remarkably low level of supplier integration. A few suppliers were connected electronically and relationships with suppliers had been very delicate.

The plants under this group mainly require commodity type of raw materials. These raw materials do not pose a problem with regard to identifying a supplier but restricts their continuous availability due to their seasonal nature. The large capital investment required in the plant necessitated the continuous availability of raw materials in order to achieve the high plant utilisation. The availability of the raw material is ensured by building a safety stock that can offset the effects of seasonality.

However, in some plants such as dairy plant, perishability is a major issue due to food hygiene and safety reasons which drives the industry to produce and deliver along the whole supply chain quickly. This also implies that there should be a close link between the suppliers and the food manufacturers so as to efficiently manage the shelf life of the raw materials.

With a few exceptions, most lean practices can be adopted without much difficulty in these types of food & drink plants. Supplier participation in product development, exchange of information electronically, emphasis on restricting the number of suppliers for ingredients which are purchased locally, supplier audit/accreditation and long-term contracts can be adopted but JIT delivery for ingredients purchased from distant and global suppliers is difficult to implement.

It is difficult to envisage that the extent of diffusion of supplier integration in these plants will be at par with the automotive industry. The suppliers of an automotive plant mainly supply to a very few automotive plants. The product is complex having high unit cost and is customer specific which drives the automotive plant to develop and foster a close relationship with its suppliers.

7.2 Lean approach for the batch type of food & drink industry

Food & drink plants such as biscuit, bakery, confectionery, and snacks are categorised under this group. These plants are characterised by a moderate product variety and a mix of continuous and intermittent production systems. The product becomes discrete at the packaging stage where non-discrete material is packed in various pack sizes and labels. The plants under this group are more likely to adopt lean principles and practices then the plants under continuous type. Table (7.3) presents the lean principles and practices relevant for these types of plants.

7.2.1 Elimination of waste

The plants under this group use continuous manufacturing as well as intermittent manufacturing in their production systems. The packing stage generally involves continuous manufacturing with or without automation whereas the processing stages often follow intermittent as well as continuous manufacturing. A continuous-intermittent manufacturing interface is achieved by keeping a buffer stock. It is observed that these types of plants keep a large finished goods inventory and a relatively low raw material inventory. Unnecessary inventory and defects are the most prominent waste in these types of food & drink plants.

Most of the lean practices pertaining to the elimination of waste such as preventive maintenance, 5S, visual control, SPC, mistake proofing, and standard operating procedure are equally relevant and applicable. It has been observed that there is a great emphasis on the implementation of 5S, food safety and hygiene and HACCP, due to the food regulations imposed by the government.

Lean principles	Lean practices	Potential lean vision
Elimination of waste	Good house keeping/5S Visual control Standardisation Preventive maintenance Food safety and hygiene SPC Quality systems Mistake proofing	Reduce cost and improve quality
Employee involvement & empowerment for continuous improvement	Suggestion scheme Job rotation Continuous improvement program Quality circle Team based problem solving Autonomation	Improve quality & productivity
Alignment of production with demand	Pull production Levelled production	Reduce cost and improve customer responsiveness
Supplier integration	Long term contract Supplier reduction Exchange of information electronically Supplier participation in new product development Supplier development activities	Improve quality

Table 7.3: Lean principles & practices for the batch type food & drink industry

Applicability of quick change over is limited as the processing stages require cleaning due to health and safety regulations which cannot be performed quickly. However, quick changeover is possible at the packing stage. Scope for cellular manufacturing is also very limited due to the fact that the majority of the products follow a fixed route and the product variety is mostly due to the large number of pack sizes and labels.

7.2.2 Employee involvement and empowerment for continuous improvement

The batch type food & drink plants employ more manpower on the shop floor due to having a greater product variety, large volume and the use of intermittent processes. An increased product variety and large volume are managed by installing a large number of packing lines. The majority of the manpower is employed at the packing lines with the jobs being relatively simple but repetitive which creates scope for job rotation.

Although a very few lean practices aimed at employee involvement and empowerment have been pursued, there are no reasons why they cannot be implemented in the batch type food & drink plants. Suggestion schemes, quality circles, autonomation, team based problem solving and continuous improvement programmes can equally be adopted. The product, process and market characteristics of the batch type food & drink plants do not pose a big problem except that during seasons of high demand, temporary labour is employed to increase the production thus limiting the scope for involvement of the workforce in a process of continuous improvement.

7.2.3 Aligning production with demand:

The batch type food & drink plants have been faced with a wide demand fluctuation due to the seasonal nature of demand, promotional schemes regularly launched by retailers, and unpredictable weather conditions. Forecasting is particularly difficult for products such as meat, ice cream and soft drinks that are affected by weather conditions. It was observed that the orders are often changed at short notice, which causes problems for the suppliers who may need to supply large quantities at a very short notice. The demand fluctuations due to special promotional schemes are the most difficult to forecast accurately and competitor's promotions also have a major effect on sales. This has made it difficult for the food plant to plan its production in advance and also to communicate any changes in the delivery schedule to its suppliers in time.

The more reliable the sales forecast, the less is the need to hold safety stocks which can be reduced by building trust and visibility. The high safety stock is a result of mistrust and sharing of little information among trading partners. Accurate sales forecasts are another protection against demand amplification.

The plants also experience raw material variability which also gives rise to process variability. Process variability results in unpredictability of throughput that makes it difficult to align production with demand.

Compared to a continuous type food & drink plant, batch type food plants have more locations for the decoupling point (DP), as the flow of goods is not purely continuous. Most often non-discrete material becomes discrete at the packing stage. The processes before the processing stage use both intermittent as well as continuous production. The probable locations of the DP can be identified as,

1. The stock of raw material
2. The stock before the intermittent production stage
3. The stock before the continuous production stage
4. The stock before the packing stage
5. The stock after the packing stage

Most of the batch-type food plants have made 'the stock after the packing stage' as the decoupling point due to the high service level demanded by the customers, wide demand fluctuations and low value additions. Improving physical and information visibility can shift the location of the DP upstream. Batch type food plants have more chance to adopt a pull production due to a higher number of potential locations of the DP. The mixed model production and one piece flow will be harder to implement due to the sequence dependent set up time and the fear of mixing of flavours. However, levelled production can be adopted if the set up time can be reduced.

7.2.4 Supplier integration

Batch-type food plants deal with relatively more number of raw materials due to high product variety and a high number of ingredients required in making a complete product. These materials are mostly commodity items which are procured locally as well as globally. The selection of suppliers for the commodity item is primarily based on the price, hence a close relationship with the suppliers is difficult to achieve.

Although the implementation of lean practices to make the suppliers an integral part of an organisation has been found to be limited, the majority of lean practices such as supplier development activities, supplier reduction, long-term contracts and active information exchange with the suppliers can be adopted without much difficulty. Suppliers supplying perishable items need to deliver the materials quickly and frequently and this requires a close relationship with the suppliers. JIT deliveries are also possible for the local suppliers but this depends on the economic transport size due to low value to weight ratio.

7.3 Lean approach for assembly type food & drink industry

The industries producing convenience meals, sandwiches, pizzas etc. are categorised under the assembly type of food & drink industry. These industries are quite similar to a discrete industry and mainly assemble various ingredients on an assembly line which can be manual as well as highly automated. A few food & drink plants also cook their own sauce/gravy which is then added on the assembly line whereas other food & drink plants procure the sauce or gravy from suppliers. The assembly type of food & drink industry not only offers a high product variety but also produces in large volume. The high product variety coupled with high volume is managed by installing a large number of parallel assembly lines. The case studies of convenience meals, frozen meals and sandwich plants portray that lean principles and practices are more appropriate to an assembly type food & drink industry. Table 7.4 summarises lean principles and practices for the assembly type food & drink industry.

Lean principles	Lean practices	Potential lean vision
Elimination of waste	Good house keeping/5S Visual control Standardisation Preventive maintenance Food safety and hygiene Process mapping SPC Mistake proofing Quality systems Cellular manufacturing	Reduce cost and improve quality
Employee involvement & empowerment for continuous improvement	Suggestion scheme Job rotation Continuous improvement programme Team based problem solving Quality circle	Improve quality & productivity
Alignment of production with demand	Pull production Mixed model production Levelled production One-piece flow	Reduce cost and improve customer responsiveness
Supplier integration	Long term contract Supplier reduction Exchange of information electronically Supplier participation in new product development Supplier development activities	Improve quality and reduce cost

Table 7.4: Lean principles and practices for assembly type food & drink industries

7.3.1 Elimination of waste

It was observed that the raw materials stock as well as work-in-progress is relatively low, compared to finished goods stock in the assembly type food & drink industry producing relatively long shelf life products. Whereas the assembly type food & drink industries producing the short shelf life products cannot store products for a longer duration. This also means that the industry has to manage the shelf life efficiently in order to minimise waste. The short shelf life of the products should drive the industry to become leaner.

The majority of lean practices aimed at the elimination of waste have been practised on the shop floor. Lean practices such as 5S, standard operations, visual control, statistical process control, quick changeover, quality system and mistake proofing are relevant and can help in the elimination of various types of waste.

7.3.2 Employee involvement and empowerment for continuous improvement

Despite the large manpower required in the assembly type food & drink industry, it has not been able to effectively utilise its workforce to continuously improve the work systems. Moreover this industry employs a large number of temporary labour to cope with demand during seasons of high demand. This temporary labour fills the gap of demand and supply and does not become part of the regular workforce.

Though lean practices pertaining to this lean principle has not been embraced by the majority of the assembly type food & drink industry, there is no reason why it cannot be adopted. Practices such as quality circles, suggestion schemes, team-based problem solving and job rotation are very much relevant and beneficial.

7.3.3 Aligning production with demand

The assembly type food & drink industry, which resembles a discrete industry, is characterised by high volume and high product variety. A few powerful retailers dominate this industry and demand a high service level, short delivery time and low cost. The majority of the food & drink industries fulfill customer demand through a make-to-stock (MTS) policy, but it has been observed that a number of assembly type food & drink plants have successfully developed a make-to-order policy also. Plants producing short shelf life products will be more likely to embrace an MTO policy and will be able to better align their production with customer demand. Being close to discrete industry, there are more opportunities to adopt lean practices such as pull production, mixed model production, leveled production and one-piece flow. Until now this industry has not been able to embrace pull production due to inaccurate demand forecasts, high service level and promotional schemes. With the advent of ECR and CPFR initiatives this industry can take advantage of a pull production.

7.3.4 Supplier integration

The assembly type food & drink industry has to manage a comparatively large number of raw materials due to the large product variety as well as the large number of ingredients required to make a complete product, which calls for a closer coordination with suppliers.

It was observed that this type of industry deals with a few suppliers for each raw material and have been following the practice of awarding business on a long-term contract basis. The suppliers supply the materials at least once a week and in a few cases, particularly with perishable items, they supply twice a day.

The economic transport size limits how frequently the supplier can deliver the raw materials. On the other hand the shelf life of the product will influence how fast it can be delivered. The issue of shelf life has been managed by using temperature controlled logistic systems, though it has increased the product cost.

The case studies have revealed that a version of just-in-time delivery is possible for those items which can be procured from local suppliers. Despite long-term contracts with the suppliers, emphasis on reduction of suppliers and frequent supply of raw materials, the industry has not been able to move further to establish collaborative relationships. Supplier development activities, supplier involvement in new product development and active information exchange have not become part of a daily routine.

7.4 Summary

A lean approach has been developed for each category of the food & drink industry. The assembly type food & drink industry can embrace more lean initiatives when compared to continuous and batch type food & drink industry. Table 7.5 summarises feasible lean initiatives for each category of food & drink industry.

Food industry classification	Food & drink products	Feasible lean initiatives
Continuous	Beer, edible oil, sugar, pasteurised milk, salt, wheat flour	Supplier reduction policy, Suggestion scheme Continuous improvement programme Visual control Standardisation Total Productive maintenance
Batch	Biscuits, pasta, processed meat, confectionery, cornflakes	Pull production, Levelled production Supplier reduction Supplier development activities Supplier participation in new product development Quality circle Suggestion scheme Team based problem solving Continuous improvement programme Visual control Standardisation
Assembly	Sandwiches, convenience meals, frozen pizzas	Pull production, Levelled production, One-piece flow, Mixed model production, Supplier reduction policy, Supplier development activities Supplier participation in new product development, Quality circle Suggestion scheme Team based problem solving Continuous improvement programme Visual control Standardisation Cellular manufacturing Preventive maintenance

Table 7.5: Feasible lean initiatives and the food industry

Figure 7.1 displays current lean initiatives in the fourteen food plants. Though the adoption of lean paradigm in the food industry is limited but the industry can very well embrace a high number of lean initiatives. Figure 7.2 portrays feasible lean adoption in the food plants.

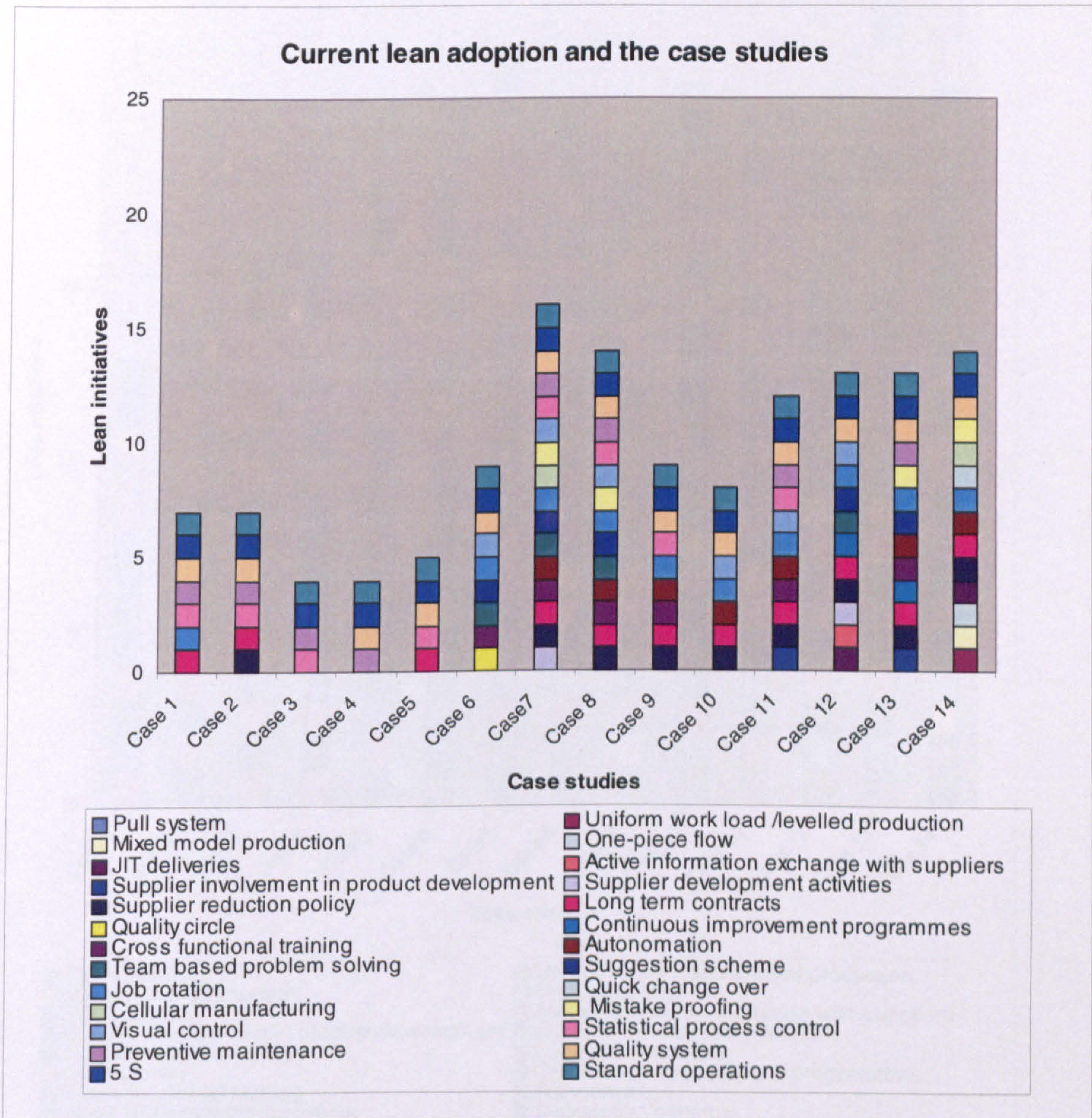

Figure 7.1: Current lean adoption and the case studies

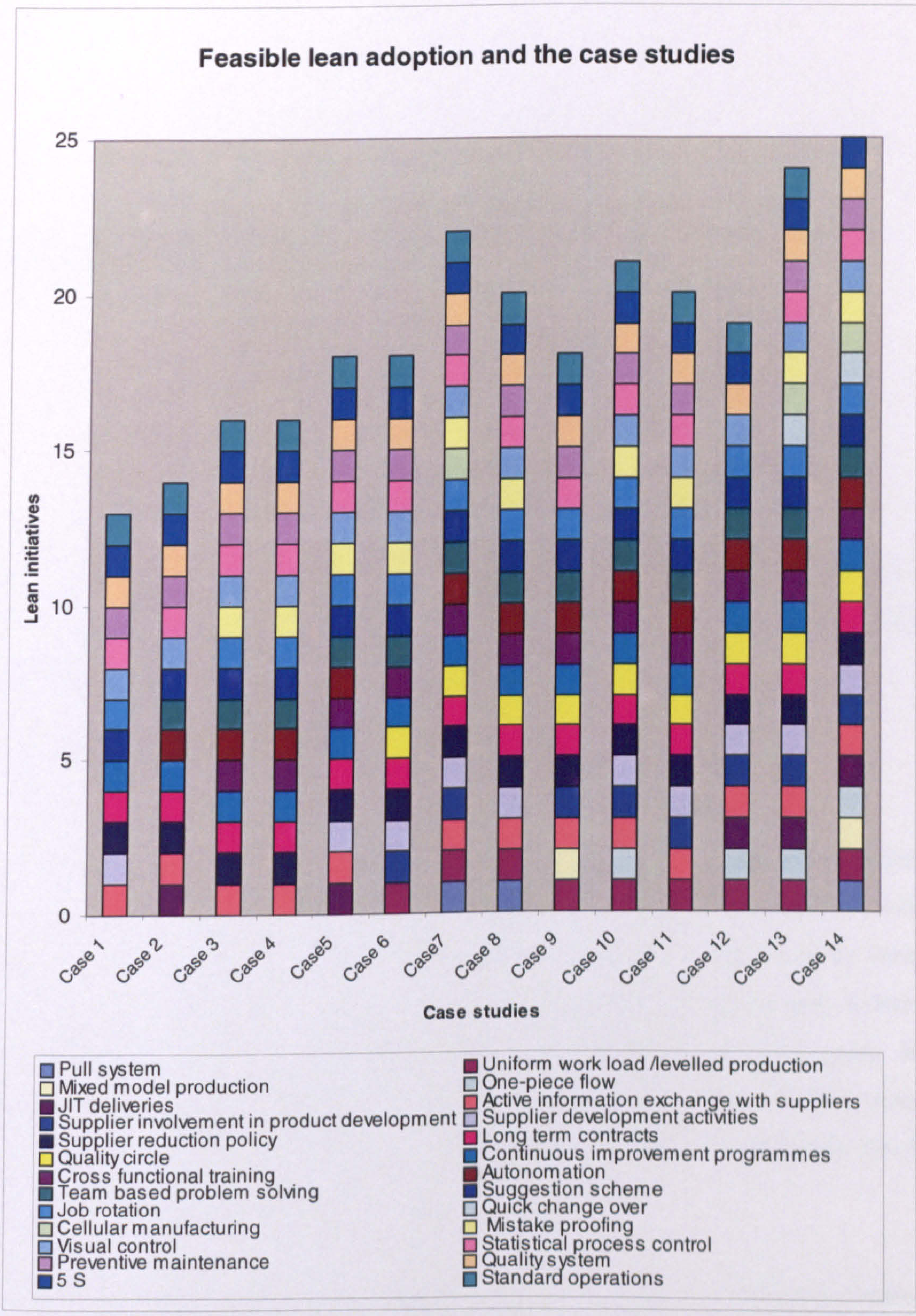

Figure 7.2: Feasible lean adoption and case studies

Chapter 8

Summary and conclusions

In this chapter, the key aspects of the research are summarised and conclusions are derived. The contributions of this research are highlighted and future directions are offered for further work.

8.1 Summary of the research

Lean manufacturing as an operational initiative has undergone a significant evolution beyond its roots in the automotive industry. Therefore, the first task of this research was to develop a lean manufacturing framework encompassing the work undertaken by various researchers and practitioners. On the basis of the available literature and industrial production models, a lean manufacturing framework consisting of lean goals, lean principles and lean practices has been suggested. This lean framework was then used to assess the status of lean in the food industry. The framework has also been used to develop a suitable lean approach for the food industry.

The review of the literature also revealed that there has not been any attempt to develop a classification for the food industry transformation system. Considering that the food industry is not one industry but a collection of several types of industry producing a diverse range of products and employing a varied range of processes, a food industry classification system has been proposed on the basis of visits to various food plants and the available literature in order to categorise the food industry into distinguishable groups. This classification helps to understand the scope of lean manufacturing in the food industry. In general the classification system provides a starting point for planning lean implementation in the food sector

To investigate specific issues pertaining to the adoption of lean concepts in the food industry, a multiple case study research strategy approach was selected for the research investigation. A total of fifteen cases were selected for the study. There were fourteen case studies representing the food sector and a single case study representing the automotive sector. Each case study has been described with regard to product, market, raw materials and process aspects of a plant. Subsequently the case studies have been assessed in order to understand the degree of leanness by examining the status of lean practices.

Next stage involved mapping of the characteristics of the food manufacturing plants on the food industry classification scheme to identify specific food industry types of each food plants. Following mapping of the case studies on the food industry classification system, all cases were compared and classified on the basis of products, processes and market characteristics. Issues pertaining to the adoption of lean thinking concepts have been further elaborated.

Subsequently a lean approach consisting of lean principles, lean practices and potential lean vision for the food industry has been suggested which would enable food plant managers to make the plant lean and stay competitive.

8.2 Conclusions

The main goal of the dissertation was to investigate the use & applicability of lean thinking concepts in the food industry & to develop a strategy for the productive adoption of lean thinking in the food industry. This goal was addressed through a number of specific objectives as highlighted in Chapter 1.

1. The first objective was to undertake a literature review of operational initiatives in the food industry. Chapter 2 presents a comprehensive literature review incorporating characteristics of the food industry, business & manufacturing challenges, operational improvement initiatives (vendor managed inventory, efficient consumer response, collaborative planning forecasting & replenishment and lean manufacturing) in the food

industry. It was found that operational initiatives such as vendor managed inventory (VMI), efficient consumer response (ECR) and collaborative planning, forecasting and replenishment (CPFR), primarily instituted by the large retailers, have focused mainly on the downstream side of the supply chain from producer to customer and have not had much influence on the upstream side of the food supply chain.

The prime focus of the research investigation was on the use and application of lean manufacturing in the food industry so a review of lean manufacturing has been presented. The review of literature shows that the majority of food industry companies have not been able to enjoy the benefits of operational improvement initiatives, such as lean manufacturing, which has evolved and developed in the automotive industry. The literature, whilst highlighting many examples of successful implementation of lean within various industries, also provided limited evidence of its application within the food industry. Though few lean practices such as 5S, standardised work, suggestion schemes, and teamwork have been adopted and practised by the food industry, lean thinking as a holistic operations approach has not yet reached a stage of adoption where it is any way conspicuous as an improvement initiative within the food sector.

2. The second objective of the research was to develop an appropriate lean manufacturing framework incorporating the work of academics and practitioners. The literature review revealed a number of lean models comprising of principles, tools and techniques. Despite a number of lean manufacturing models available in the literature, there has not been a unanimous agreement amongst scholars with regard to its various principles and elements. More than 70 scholarly articles were rigorously reviewed to arrive at a common agreed set of lean manufacturing principles and practices. On the basis of the literature and available industrial production models, a lean manufacturing framework consisting of lean goal, lean principles and lean practices has been suggested. Four lean principles (elimination of waste, employee involvement and empowerment for continuous improvement, supplier integration and aligning production with demand) have been identified and twenty-six lean practices were categorised with regard to these lean principles.

3. The third objective was to develop a food industry classification based on the transformation system characteristics. The visits to a number of food plants as well as the

literature review suggest that the food industry can be segregated into three groups from a production system point of view. These groups are organised by *how products are manufactured* and not by the *specific end product*. The food industry groups present a continuum from continuous, to intermittent types of production systems. These three groups were termed as continuous, batch and assembly. These industry types were differentiated on the basis of 11characteristics pertaining to product and process aspects of the food industry. This classification differs from the current "standard industrial classification system". The purpose of the classification was to demonstrate that the food industry is a very general term and that each industry within the food sector has its own distinguishing characteristics.

4. The fourth objective was to assess the status of lean manufacturing in the food industry and benchmark with the automotive industry. A multiple case study research was undertaken to investigate the use and application of lean manufacturing in the food industry. A case study research strategy was selected for this research investigation as the intent was not to test the hypothesis, but to investigate specific issues pertaining to the adoption of lean concepts in the food industry. A multiple data collection method comprising of a plant tour together with interviews, documentation and a questionnaire, was considered for the case study investigation to increase validity. A total of fifteen cases (fourteen food and drink cases and one vehicle assembly case) were selected for the study. The case of a vehicle assembly plant was considered to benchmark the automotive industry with the food industry with regard to the extent of implementation of lean manufacturing concepts. The adoption of a lean manufacturing paradigm in the food plants studied has been limited.

5. The fifth objective was to compare the UK/Indian food industry. Out of fourteen food plants selected for the study, six food plants were located in India and the rest of the food plants were based in the UK. Six Indian food plants produced pasteurised milk, UHT milk, beer, butter, sweet biscuit and Mayonnaise & salad dressing. The eight UK food plants produced edible oil, savoury biscuit, sliced meat, snack food, tea bag, convenience meals, frozen food and sandwiches. Except for the sweet biscuit plants located in India, the rest of the Indian food plants did not show evidence of lean manufacturing as an operational initiative. On the other hand a few of the UK food plants have started using

lean principles and practices, though the principle of aligning production with demand has still not been embraced by the UK food industry.

6. The sixth objective was to map the food industry on to the food industry classification system. All the cases pertaining to the food industry were mapped on the food industry classification scheme to identify specific food industry types of each of the food plants. Based on the 11 transformation characteristics all the food case studies were categorised as continuous or batch or assembly type food industry.

It was further observed during the field research that the food industry under continuous, batch and assembly groups showed different levels of lean adoption. The continuous type of food industry typically represents the characteristics of a process industry and presents great difficulty in the adoption of all lean principles and practices which are widely embraced by the automotive industry. The food plants categorised as assembly types were noticed to be leaner than the other food plants. These industries are quite similar to a discrete industry and mainly assemble various ingredients on an assembly line which can be manual as well as highly automated.

7. The seventh objective was to identify the key inhibitors and enablers of lean manufacturing in the food & drink industry. A number of inhibitors and enablers were observed during visits to the food plants. Except for quick changeover, the majority of lean practices pertaining to " the elimination of waste" are being practised by the majority of food plants considered. A major cause of the large finished goods inventory in any plant is the long changeover time. It is observed that stringent hygienic demands necessitated frequent cleaning. Cleaning between the production of different products also contributed to long change over times.

It is found that practices relating to aligning production with demand are not evident in the majority of the food plants. Wide demand variability, limited shelf life, variable process yield, variable raw material quality and food safety issues have restricted the food industry to align its production with demand. These factors, which are not present in the automotive industry, have added new dimensions to the complexity of food production systems. The demand pattern is the main critical factor in aligning production with customer demand; make too much and there is a wastage problem due to the limited product shelf life, make too little and there is a loss of sales plus potential lost customers. Throughput uncertainty generated due to variable process yield and variable raw material quality, which is not an issue in the vehicle assembly plant, has forced the food plants to create time buffers or physical buffers. The problems of variable process yield and variable raw material quality are more prominent in the continuous food industries because they use the raw materials which are a produce of agriculture.

Most of the lean practices (pull system, mixed model production, one piece flow etc) pertaining to the alignment of production with demand have evolved in the automotive sector, which operates in a discrete environment. Hence these lean practices will have more relevance in the discrete part of the food plants. The food industry such as the sandwich plant, that become discrete relatively early in the process, would be a good candidate for lean practices pertaining to aligning production with demand. In all the food plants, except the assembly type of food plants, the point of discretisation (POD), where non-discrete unit becomes discrete, is relatively late in the process. It is also observed, particularly with the continuous type of food plants, that all the processes before the POD are tightly coupled and involve mostly continuous operations. This fact imposes a restriction on the depth of customer order penetration. The point of discretisation (POD) in the assembly type of food plants is at the beginning of the assembly stage, which means a pull system, one–piece flow, and mixed model production can be applied after the POD.

It has been observed that the position of the decoupling point determines how much a plant can align its production with demand. If the location of the DP is upstream, it means that the plant can respond to the customer demand more effectively. Unpredictable demand, high service level, short delivery time, variable process yield, long set-up times, reliable and frequent deliveries have a downstream effect on the DP whereas a short shelf life has an upstream effect on the DP. Most of the continuous type of food plants are characterised by tightly coupled processes,. long changeover times and low value added which restricts the possibility of locating the DP at the stock of raw materials. The batch and assembly food plants have a better chance of shifting the DP to the upstream of the finished goods storage.

A majority of the food plants employ either temporary labour or variable working hours to cope with demand fluctuations. Although this policy works well to deal with the demand uncertainty, it does not create an environment where these temporary employees can be involved effectively to improve the production system.

The supply chain is relatively simple in the food sector and for the majority of the food plants the order-winning criterion is price. Hence, there is little drive for the food plants to establish long-term relationships with their suppliers. Moreover, if the supply chain activities are geographically dispersed, fast flow of information and goods along the supply chain required to make the food industry lean, will be costly as well as complex.

8. The eighth objective was to develop a lean approach specific for the food industry. The research outlined that the food industry shares characteristics with discrete industries that make it possible to implement lean principles and practices, but in varying degrees depending on the industry environment. It was found that the lean model widely adopted in a discrete manufacturing environment, particularly automotive, is not applicable as such in the food sector. Therefore, a lean approach consisting of lean principles, lean practices and lean vision has been suggested for continuous, batch and assembly type of the food industry. This lean approach also identified the applicability of lean practices for each category of the food plants.

Continuous types of food plants will benefit the most from lean practices such as preventive maintenance that can reduce plant downtime and increase overall equipment effectiveness. Practices such as 5C/good house keeping, visual control, quality systems, and standardisation are universal in nature and can be adopted without too much difficulty by all categories of the food industry. Suggestion schemes, continuous improvement programmes and job rotation can very well be adopted by the majority of the food industry, but this requires top management commitment. Lean practices such as mixed model production and one-piece flow are practically impossible to practise by the continuous type of food industry before the packaging stage due to non-discrete flow, continuous manufacturing and long sequence dependent set-up times. Supplier participation in product development, exchange of information electronically, emphasis on restricting the number of suppliers for ingredients which are purchased locally, supplier audit/accreditation and long-term contracts can be adopted but JIT delivery for ingredients purchased from distant and global suppliers is difficult to implement.

The batch type of food industry has more chance to adopt a pull production due to a higher number of potential locations of the DP. The mixed model production and one piece flow will be harder to implement due to the sequence dependent set up time and the fear of mixing of flavours. However, levelled production can be adopted if the set up time can be reduced. Although the implementation of lean practices to make the suppliers an integral part of an organisation has been found to be limited, the majority of lean practices such as supplier development activities, supplier reduction, long-term contracts and active information exchange with the suppliers can be adopted without much difficulty.

The assembly type food industry can embrace more lean initiatives when compared to continuous and batch type of food industry. The case studies of convenience meals, frozen meals and sandwich plants portray that lean principles and practices are more appropriate to an assembly type food industry. Plants producing short shelf life products will be more likely to embrace an MTO policy and will be able to better align their production with customer demand. Being close to discrete industry, there are more opportunities to adopt lean practices such as pull production, mixed model production, levelled production and one-piece flow.

8.3 Research contribution and future directions

Applied research such as this often provides both theoretical and managerial contributions. The major contribution of this research is the development of a lean manufacturing framework consisting of goals, principles and practices which can be used to assess the leanness of any manufacturing plant. This framework provides future researchers a standard by which to compare and benchmark companies. For managers, this framework provides a holistic approach to developing an integrated operations strategy for the company.

The review of literature shows that the food industries have been clubbed together. Consequently the distinctions between different food industries are not well understood. This research has addressed this issue and proposed a classification system for the food industry which would help researchers and managers to better understand the specificity of the production systems.

Previous research has addressed the issue of lean manufacturing in discrete manufacturing and has been limited in examining the implementation of lean manufacturing in the food industry. This research has attempted to investigate issues pertaining to the use and applicability of lean manufacturing in the food industry. The primary idea of the research is to help the food industry take advantage of operational improvement initiatives such as lean manufacturing to stay competitive in today's global market.

This research showed that the same lean model widely adopted in a discrete manufacturing environment, particularly automotive, is not applicable as such in the food sector. The environment within which a discrete manufacturing industry, such as automotive, electronic and aerospace, operates is quite different from the food industry environment. A lean approach for the food industry has been suggested which would enable the managers to transform their plants into lean plants. The identification of which lean practices are applicable and where and when they should be applied are the main contributions to new knowledge.

The classification which is based on the available literature and visits to food plants, presented in this paper is a "proposed" classification because this study was not designed to provide conclusive evidence of the actual taxonomy itself, but rather to provide evidence that a food industry transformation system classification exists. This classification needs to be further tested empirically with a larger sample size.

The case studies selected for the study were mainly from the UK and India. The study has not taken into account the differences in the UK and Indian industrial practices. India being a developing country lags behind the UK with regard to infrastructure and market sophistication. Today the structure of the food market in the UK is characterised by the emergence of the major retailers and their own brands, bigger store size, greater retailer concentration, demand for one stop shopping, increased retailer access to information via electronic point of sale (EpoS), introduction of loyalty cards and a huge proliferation of choices. A few powerful retailers have replaced the manufacturer's dominance in the food market. Independent grocers, green grocers and butchers have declined sharply in numbers with the increase in supermarket opening hours. From the food and drink industry point of view, the linkage with customer is only possible through the retailers who control and regulate the market. On the other hand, structure of the food market in India is characterized by a larger number of retailers, smaller retailer size, greater manufacturer's dominance and limited product variety. The study has not incorporated the impact of market structure on the leanness of the food plant. This limitation can be taken care of in the future research.

This research is based on multiple case study research strategy. For each of the food category, at least three case studies were undertaken, It is felt that each category of the food industry needs to be examined for the application of a lean approach with more number of case studies in order to improve generalization.

The lean approach suggested in this research needs to be further tested empirically. It would be interesting to know the impact of this lean approach on the performance of food plants.

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Appendix I: Lean manufacturing research articles and their contributions

Author (Year)	Methodology	Region studied	Major contribution for academicians and practitioners
Billesbach et al. (1991)	Survey [99 manufacturing firms]	UK and US	Provided a comparative analysis of U.S. and U.K. firms with regard to managerial practices and perception, which have led to differing approaches in the implementation of lean philosophises.
Mehra and Inman (1992)	Survey [550 manufacturer]	US	Identified the elements of lean implementation that are required to ensure successful implementation. Proposed 19 elements required during a lean implementation process which were grouped into four broader elements.
Bartezzaghi et al. (1992)	Survey [173 manufacturing firms]	Italy	Explored elements, benefits, costs and problems involved with JIT adoption related to some context factors such as size and type of firms & specific manufacturing strategies.
Womack and Jones (1994)	Case study [2 Auto-component and 2 car plant]	UK and U.S.	Proposed a new organisation model 'the lean enterprise' which consists of individual, functions and legally separate but operationally synchronized companies.
Oliver et al. (1994)	Survey [18 autocomponent plants]	Japan and UK	Examined the performance and management practices of 18 autocomponent plants, nine of which were located in the UK and nine in Japan.
Sohal and Egglestone (1994)	Survey [51 companies]	Australia	Investigated the extent to which lean practices (JIT, kanban, kaizen, TQM, group technology, flexible manufacturing system, quality circle, supplier reduction) have been implemented; Studied the structural changes taking place as a result of implementation of lean practices.
Zhu et al. (1994)	Secondary research method	-	Presented an overall picture of lean implementation process and summarized the most recently published lean implementation article that would help practitioners improve the likelihood of a successful implementation.

Author (Year)	Methodology	Region studied	Major contribution for academicians and practitioners
Ramarapu et al. (1995)	Discussion	-	Carried out a comprehensive review of the lean implementation literature which integrates the critical elements that have been cited in the earlier research
Billesbach (1994)	Case study [One textile plant]	US	Shared the experience of a process facility, which has adopted some of lean principles.
Mould and king (1995)	Case study (6 electronics manufacturer)	UK	Examined the process and extent of JIT implementation; looked at management's interpretation of JIT practices, surveying the extent of the application of JIT practices.
Hum and Ng (1995)	Survey [69 companies]	Singapore	Examined pre-implementation and implementation experiences of lean companies; assessed the reason for and the benefits associated with their adoption of lean.
Kosonen and Buhanist (1995)	Case study [One elevator company]	Finland	Discusses the change process in converting a factory in a lean organisation.
Lawrence and Hottenstein (1995)	Survey [504 repetitive manufacturing plants]	Mexico	Examined the relationship between lean manufacturing and performance. Four dimensions of performance were measured: productivity, quality, lead-time and customer service.
Spencer and Guide (1995)	Survey [101 repetitive manufacturing industry] and One case study	US	Identified elements that are critical to lean success through literature, consequently elements identified were examined using a survey instrument. Same survey was also administered at an air-conditioner manufacturing company in order to improve the understanding of the elements identified as critical and their relationships.
Dong (1995)	Case [Single automotive company]	China	Studied the results achieved in an automotive company due to implementation of lean production.
Warnecke and Huser (1995)	Discussion	Germany	Presented a lean manufacturing model consisting of product development, chain of supply, shop floor management and after sales service.

Author (Year)	Methodology	Region studied	Major contribution for academicians and practitioners
Womack and Jones (1996)	Case study [One wrapping machine manufacturer]	US	Described application of lean thinking in small size industry and its impact on the business results.
Burcher et al. (1996)	Discussion	-	Proposed a methodology to support traditional repetitive batch manufacturers in the adoption of the lean manufacturing principles by highlighting those areas where change would bring the greatest benefits; modelled the effect of proposed changes and quantified the benefits that could be gained through implementing the proposed changes.
Boyer (1996)	Survey [202 metal working industries]	US	Focused on the degree to which lean manufacturing elements (JIT, TQM) are aided by investments in the supporting manufacturing infrastructure of the firm; examined four types of investment in the manufacturing infrastructure: quality leadership on the part of management, the use of small groups or teams for problem solving, training, and worker empowerment.
Engstrom et al. (1996)	Case study [Single automotive industry]	Sweden	Discussed production models for final assembly in the automotive industry and also reported on the performance of one final assembly plant representing an innovative production model, namely the Volvo Uddevalla plant; considered important issues and problems of current production model.
Lamming (1996)	Discussion	-	Concept of lean supply characterised as "beyond partnership" has been examined by comparing the techniques, which constitute lean supply with those contained in supply chain management, partnership sourcing, and strategic purchasing.

Author (Year)	Methodology	Region studied	Major contribution for academicians and practitioners
Forza (1996)	Survey [43 plants]	Italy	Proposed a framework linking work organization and lean production practices. Study outlined that lean production plants seem to use more teams for problem solving, to take employees' suggestions more seriously, to rely more heavily on quality feedback both for workers and supervisors, to document production procedures more carefully and to have employees able to perform a greater variety of tasks including statistical process control.
Katayama and Bennet (1996)	Case study [Automotive plant, PCB plant, refrigerator plant, air-conditioner plant]	Japan	Discussed the recent trend in Japanese manufacturing; explained how Japan's recent recession due to the factors relating to the external and internal environment has influenced the viability of lean production within Japan's emerging competitive climate; proposed the concept of adaptable production as an approach which can accommodate to greater changes in demand than lean production
Oliver et al. (1996)	Survey, [71automotive component plant]	France, Germany, Italy, Japan, Mexico, Spain and UK	Investigated the relationship between lean production and performance using data from a benchmarking study of 71 plants in the international automotive components industry.
Toni and Tonchia (1996)	Case study [One domestic appliance company]	Switzerland	Outlined that the pursuit of excellence and the organizational change required by lean production leads to a management-by-process organization, and that management by process influences the performance measurement system (PMS). Provides a detailed analysis of the organizational change and its effects on performance measurement.

Author (Year)	Methodology	Region studied	Major contribution for academicians and practitioners
Sohal (1996)	Case study [One automotive plant]	Australia	Studied the experience of an Australian automotive parts manufacturer over the ten-year period from 1984-1994 as it adopted lean production methods and new work organisation structures. Outlines the activities undertaken as part of a just in time programme during the second half of the 1980s and discusses the benefits achieved.
Hallihan et al. (1997)	Case study [Seven manufacturing firms]]	UK	Developed a lean model founded on the basis of elimination of the seven waste and has three levels namely support levers (managerial actions), waste elimination technique and performance measure.
Karlsson and Ahlstrom (1997)	Case study [One office equipment company]	Sweden	Addressed the question of whether the lean enterprise concept would be applicable to small and medium-sized firms; the implications of the lean enterprise framework for the smaller firm were summarized .
McLachlin (1997)	Cast study [6 manufacturing plants]	Canada	Examined significance of management initiative on the implementation of lean manufacturing; considered six management initiative, out of which four (promotion of employee responsibility, provision of training, promotion of team work, demonstration of visible commitment) were found essential for the implementation
Plonka (1997)	Discussion	US	Discussed the demands that lean and agile manufacturing initiatives would place on the workforce; the issues of worker selection, continuous skill development, workplace design, equipment maintenance, process improvement, mistake proofing for new products were discussed from a human factors perspective.

Author (Year)	Methodology	Region studied	Major contribution for academicians and practitioners
James-Moore and Gibbons (1997)	Survey [Aerospace]	UK	Proposed a methodology for enabling an examination of the degree of relevance of lean manufacturing to such products, using a model of a typical lean high-volume automotive producer as a base, comparing the drivers faced, the practices adopted to respond and the type of measures used to assess effectiveness. Lean model used consists of the characteristics in five areas, namely: flexibility, waste elimination, and optimisation process control and people utilization.
Levy (1997)	Case study [One personal computer company]	US, Europe and Japan	Examined the implementation of lean production in an international value chain; study outlined that the rapid flow of goods and information required by lean manufacturing would be costly and difficult to achieve in international context.
Jones et al. (1997)	Case study [One distribution company]	U.K.	Laid out an alternative approach 'lean logistics' to designing and managing a logistics system; also raised a number of key questions for the academic community in terms of future research and applications within the broad area of lean logistics
Hines and Rich (1997)	Discussion	-	Developed a new value stream or supply-chain mapping typology. This seven-map typology was based on the different wastes inherent in value streams; described each tool briefly and gave a simple mechanism for choosing which would be most appropriate to contingent situations.
Sakakibara et al. (1997)	Survey [41 manufacturing plants]	U.S.	Developed a lean framework that included JIT practices and infrastructure practices. Subsequently an empirical analysis of lean manufacturing was carried out to find out the impact of both JIT practices and their supporting practices on manufacturing performance

Author (Year)	Methodology	Region studied	Major contribution for academicians and practitioners
Jina et al. (1997)	Case study [One aerospace manufacturer and one specialist machinery manufacturer]	UK	Presented some of the major organizational and technological barrier which need to be overcome in applying lean principles in high volume and low variety(HVLV) sector; proposed approached to implement lean manufacturing principles within HVLV situation
Kinnie et al. (1998)	Discussion	-	Discussed how downsizing had been associated with the move towards lean working in organisations and with having negative consequences for employees; considered the extent to which downsizing would be lean and mean drawing on an extensive review of the available literature
Scarbrough and Terry (1998)	Case study [Two automotive industry]	UK	Discussed the "Japanization" of British industry with empirical evidence from established car producers in that industry. Investigated the relevance of the two major theoretical models of workplace change in the motor industry - the "diffusion" and the "bolt-on" models of change.
Panizzolo (1998)	Case study [27 manufacturing firms]	Italy	Studied the way the lean production model has been adopted by the organisation. Developed a lean production model consisting of a number of improvement programmes in different area of the company.
Chandra and Kodali (1998)	Discussion	India	Presented the AHP methodology for justification of JIT for Indian industries with out reference to any company.
Hines et al (1998)	Case study [One distributor of electronic, electrical and mechanical components)	UK	Studied the application of lean logistic approach to the development of supplier network, which involved mapping the activities of the firm, identifying opportunities for improvement and then undertaking an improvement programme with the firm.

Author (Year)	Methodology	Region studied	Major contribution for academicians and practitioners
Ahlstrom (1998)	Case study [One office equipment firm]	Sweden	Examined whether any sequence of manufacturing improvement initiative exist and what these sequences are
Oliver et al (1998)	Survey [21 autocomponent plants]	UK, Japan	Studied 12 UK and nine Japanese automotive component plants with a view to compare productivity, quality and work structure aspects.
Wafa and Yasin (1998)	Survey [130 manufacturing plants]	US	Identified factors that impede the implementation success of lean philosophy in manufacturing environments.
Michaels (1999)	Case study [One aerospace machined parts supplier]	US	Presented the application of lean principles to created lean supply chains; analysed business practices, cultural, and behavioural factors that contributed to successes and failures.
Naylor et al (1999)	Case study [One PC supply chain]	UK	Compared the lean and agile manufacturing paradigm; Suggested that neither of these two paradigm should be considered in progression or isolation; use of either paradigm had to be combined with a total supply chain strategy considering market knowledge and positioning of the decoupling point as agile manufacturing would be best suited to fluctuating demand conditions and lean manufacturing would require a level schedule.
Storch and Lim (1999)	Discussion	-	Explored the application of lean principles to the shipbuilding industry; proposed a metrics by which to measure how close to ideal flow a shipbuilding system would be.
Katayama and Bennett (1999)	Survey [182 companies]	Japan	The concepts of agile manufacturing, adaptable production and lean production were explored through a number of questions concerned with strategy, action programme and performance measures.
White et al. (1999)	Survey [454 manufacturers]	US	Examined lean implementation differences between small and large U.S. manufacturers

Author (Year)	Methodology	Region studied	Major contribution for academicians and practitioners
Bamber and Dale (2000)	Case study, [One aerospace manufacturing organisation]	UK	Discussed the application of lean manufacturing methods to a traditional aerospace manufacturing organisation.
Yingling et al. (2000)	Discussion	-	Presented lean manufacturing potential for application in the mining industry; some of the lean practices such as standardised work, TPM, flexible workforce, set-up reduction, continuous improvement could be implemented in the mining industry but technique designed for flow would be difficult to transfer from manufacturing to mining.
Lewis (2000)	Case study [Three auto-component plants]	UK, Belgium and France	Sought to establish what impact lean manufacturing had had on the overall competitiveness of the adopter firms.
Perez and Sanchez (2000)	Survey [28 automotive plants]	Spain	Produced empirical evidences of some lean manufacturing practices in the supplier automotive industry.
Mathaisel and Comm (2000)	Survey [25 aerospace companies]	US	Investigated the value and the relevance of the lean manufacturing concept in US defence launch vehicle, spacecraft and space industries.
White and Prybutok (2001)	Survey [Manufacturing organisation]	US	Studied JIT implementation in US manufacturers particularly association between the JIT practices implemented and type of production system. It showed that JIT manufacturing is utilized by both nonrepetitive and repetitive production system but it differs in terms of rate of implementation of JIT practices.
McIvor (2001)	Case study [One electronics equipment manufacturer and its key supplier]	Northern Ireland	Studied the presence of the lean supply model between an OEM and its key suppliers; the research focused on supplier involvement in customer design activities and joint buyer- supplier cost reduction issue.

Author (Year)	Methodology	Region studied	Major contribution for academicians and practitioners
Arkader (2001)	Case study [Four car assembler and nine auto parts supplier]	Brazil	The paper dealt with advances and barriers to renewed buyer-supplier relations under lean production practices.
Fullerton and McWatters (2001)	Survey [95 manufacturing firms]	US	Examined the benefits from the adoption of lean practices and the dependence of these benefits upon the level of commitment in adopting lean practices.
Yusuf and Adeleye (2002)	Survey [107 companies]	UK	Presented a comparative study of lean and agile manufacturing with a related-survey of current practices in the UK; explored the threats to lean and the drivers of agile manufacturing.
Soriano-Meier and Forrester (2002)	Survey [30 ceramic tableware firm]	UK	Proposed a research instrument for measuring the degree of leanness and applied to a new table ware sector of the ceramic industry, characterised by craftsmanship type of production; main aim was to assess the applicability of lean manufacturing to craft production sector.
Scaffede (2002)	Case study [Automotive component supplier]	Holland	Described the experience of lean implementation journey in the company and developed their own lean model
Cooney (2002)	Case study [Two automotive component manufacturing company]	Australia	Investigated the claim made in the lean manufacturing literature that the lean manufacturing system is universally applicable.
Shah and Ward (2003)	Survey [1748 manufacturing manager]	US	Examined the effects of three contextual factors, plant size, plant age and unionis ation status on the likelihood of implementing 22 lean manufacturing practices; Proposed four bundles of interrelated practices (JIT, TQM, TPM and HRM) and investigated its effect on operational performance.

Author (Year)	**Methodology**	**Region studied**	**Major contribution for academicians and practitioners**
Pavnaskar et al (2003)	Discussion	-	Proposed a classification scheme to serve as a link between manufacturing waste problems and lean manufacturing tools.
Motwani (2003)	Case study [One automotive industry]	US	Studied the critical factors involved in the implementation of lean manufacturing utilising a business process framework
Fullerton et al. (2003)	Survey [253 manufacturing firms]	US	Investigated relationship between measures of profitability and the degree of specific lean practices used.
Kojima and Kaplinsky (2004)	Survey [50 autocomponent plants]	South Africa	Developed lean manufacturing index for measuring the degree of progress in the adoption of lean production; addressed the analysis of factors determining adoption of lean manufacturing principles.
Haque (2003)	Case studies [3 aerospace industries]	UK	Described application of lean principles in the aerospace industry at three different level of engineering organisation
Crute et al. (2003)	Case studies [2 Aerospace industries]	UK	Studied the key drivers for lean implementation in the Aerospace industries; identified the challenges faced by individual companies through primary data collected from two sites.
Wu Y C (2003)	Survey [194 auto component suppliers]	America	Examined the connection between lean production and logistics system and further compared to find whether significant performance differences exist between lean suppliers and non-lean suppliers.
Ballard et al. (2003)	Case study, [One pre-cast concrete fabrication company]	UK	Described the application of lean concepts to structural precast concrete fabrication; lean implementation resulted in shop cycle time and lead time reduction, increase throughput rate, and improved productivity.
Dhandapani et al. (2004)	Case study [One steel plant]	India	Principles of lean thinking was applied in a steel plant and the cost and benefits were quantified.

Author (Year)	Methodology	Region studied	Major contribution for academicians and practitioners
Hines et al. (2004)	Discussion	-	Summarised the lean evolution and provided a framework for understanding the evolution of lean as well as its implementation within an organisation.
Benders and Morita (2004)	Case studies [Automotive]	Japan	Describes the changes such as line segmentation, the use of inter-segment buffers and high-tech automation in the Toyota production system (TPS) and reported continuous evolving TPS.
Womack and Jones (2005)	Discussion	-	Applied lean thinking approach to the processes of consumption, which would provide the full value that consumers desire from their goods and services with the greatest efficiency and least pain
Simons and Zokaei (2005)	Case studies [Red meat processing plant]	UK	Applied few lean principles (Takt time and standardised work) to red meat industry and reported benefits of lean principles in one manufacturing area, the cutting room where meat is split down from a carcass into retail cuts of meat.

Appendix- II
Lean Assessment Questionnaire

Company name:

Company address:

1. General Information

1.1 Annual sales turnover :

1.2 Unit production (number of yearly production units) :
(tonnes per year/ tonnes per week/ packs per week/packs per year)

1.3 Product shelf life (number of weeks/days) :

1.4 Number of Stock Keeping Unit (SKU) :

1.5 Number of different products manufactured :

1.6 Number of production employees :

1.7 Number of production shifts :

1.8 Number of raw materials :

1.9 Average number of ingredients per product :

1.10 Number of value adding operations: :

1.10 Average run time :

2. Inventory Profile

2.1 Average main raw material inventory(days / weeks) :

2.2 Work-in-progress(pipeline) inventory(days/weeks) :

2.3 Finished goods inventory(days/weeks) :

3 Lean vision

3.1 Is cost your main order winner? Yes/No

3.2 Do you consider product quality to be order qualifier? Yes/No

3.2 Do your customers demand a high service level? Yes/No

3.3 Do your customer demand frequent delivery of the items? Yes/No

3.4 Do your customers amend their orders frequently? Yes/No

3.5 Do you operate in an environment where there are few powerful customers? Yes/No

3.6 Do you fulfil customer orders from stock? Yes/No

3.7 Do your customers demand high product variety? Yes/No

4 Lean principles and practices

4.1 Elimination of waste

	Questions	Answer
4.1.1	**Quick Changeover**	
4.1.1.1	Are changeovers scheduled in advance and are all workers informed on the team?	**Yes/No**
4.1.1.2	Have changeover teams received training on change over time reduction procedure?	**Yes/No**
4.1.1.3	Are changeovers done frequently?	**Once per shift Twice per shift Thrice per shift More than three per shift**
4.1.1.4	Do changeovers take less than 10 minutes?	**Yes/No**
4.1.1.5	Are changeover procedures standardised?	**Yes/No**
4.1.2	**Visual control:**	
4.1.2.1	Are display boards containing job training, safety, operation measurable, production data and quality problem visible at each process and are updated regularly?	**Yes/No**
4.1.2.2	Are check sheets and tracking the quality defects posted at each process?	**Yes/No**
4.1.2.3	Are equipment and processes equipped with call (andon) lights or signals that bring attention to situation requiring assistance with a problem?	**Yes/No**
4.1.3	**5S(House keeping):**	
4.1.3.1	Has the floor lined that identify work areas, paths and material handling aisles?	**Yes/No**
4.1.3.2	Are all employees aware of good housekeeping practices?	**Yes/No**
4.1.3.3	Is every needed item, tool, and material container labelled and easy to find?	**Yes/No**
4.14	**Preventive maintenance**	
4.1.4.1	What is the overall average availability of plant equipment?	**0-60% 60-80% 80-90% 90% and more**
4.1.4.2	Have maintenance team and workers been trained in the basics of preventive maintenance?	**Yes/No**
4.1.4.3	Are preventive maintenance activity lists posted in work areas?	**Yes/No**
4.1.4.4	Are preventive maintenance responsibilities defined for both maintenance and production workers?	**Yes/No**
4.1.4.5	Is time allocated in the daily production schedule for workers to perform their preventive maintenance and cleaning duties?	**Yes/No**

4.1.5	**Standard operations**	
4.1.5.1	Have standard operating procedures (SOP) been developed for each process or cell and are used to train employees?	**Yes/No**
4.1.5.2	Has every process its SOP posted within view of the worker performing the operation?	**Yes/No**
4.1.5.3	Are SOP's audited periodically?	**Yes/No**
4.1.6	**Mistake proofing/Poka-Yoke**	
4.1.6.1	Have employees been trained in the basics of mistake proofing?	**Yes/No**
4.1.6.2	Does Equipment stop working as soon as it detects defective parts?	**Yes/No**
4.1.6.3	Have manual processes or tasks been equipped with mechanical checks to aid human judgement whenever possible?	**Yes/No**
4.1.7	**Statistical Process control**	
4.1.7.1	Are statistical techniques (Bar charts, check sheets, Pareto diagram) used to check the process and to identify a problem?	**Yes/No**
4.1.7.2	What portion of operations is controlled with statistical process control (SPC)?	**0%** **0-25%** **25-50%** **50-75%** **75-100%**
4.1.8	**Quality system**	
4.1.8.1	Do you have ISO 9000 certification?	**Yes/No**
4.1.8.2	Do your plant HACCP certified?	**Yes/No**
4.1.8.3	Do you audit your quality system regularly	**Yes/No**
4.1.8.4	Do you pursue zero defect policy	**Yes/No**

4.2 Alignment of production with Demand

S.N.	Questions	Answers
4.2.1	**Pull system**	
4.2.1.1	Is production schedule not related to customer demand?	**Yes/No**
4.2.1.2	Are items produced to forecasted demand and stocked until sold?	**Yes/No**
4.2.1.3	If production plan is made on the basis of demand forecast, how much forecast error do you experience?	**0-5%** **6-10%** **10-20%** **20% and more**
4.2.1.4	Are downstream processes pulling material from upstream processes?	**Yes/No**
4.2.1.5	Are production supervisors and operators motivated to produce no more parts than the subsequent process requires.	**Yes/No**
4.2.1.6	Are processes capable of adapting to (+/- 20%) changes in customer demand	**Yes/No**
4.2.1.7	Is change over in production made to support the concept of running to demand for all products, and not to support long production runs or emergencies?	**Yes/No**
4.2.1.8	When do you freeze your master production schedule?	**1 day before production** **2-7 days** **1-2 week** **more than 2 week**
4.2.1.9	After freezing the master production schedule, do you change/amend it frequently?	**Yes/No**
4.2.1.10	Is kanban used to assist production scheduling?	**Yes/No**
4.2.2	**Mixed model production**	
4.2.2.1	How many different product each production line can produce?	**1** **1-5** **5-10** **10-20** **20 and more**
4.2.2.2	How many different products are manufactured in one shift?	**1** **1-5** **5-10** **10-20** **20 and more**
4.2.3	**Levelled production**	
4.2.3.1	Is there a fixed and level schedule?	**Yes/No**
4.2.3.2	Are production line levelled to meet daily demand?	**Yes/No**
4.2.3.3	Do you produce the same mix of end items or families each day	**Yes/No**
4.2.4	**One-piece flow**	
4.2.4.1	Do you manufacture in large batches?	**Yes/No**
4.2.4.2	Do you employ kanban and takt time to achieve one-piece flow?	**Yes/No**

4.3 Employee involvement and empowerment for continuous improvement

S.N.	Question	Answer
4.3.1	Are goals or performance results are published and posted for all employees to see?	**Yes/No**
4.3.2	Have employees been trained in continuous improvement methods?	**Yes/No**
4.3.3	Do employees know the seven wastes? Are they actively involved in identifying wastes in their processes?	**Yes/No**
4.3.4	Are Kaizen projects (continuous improvement programme) planned and implemented?	**Yes/No**
4.3.5	Are employees given formal training before doing a job on their own?	**Yes/No**
4.3.6	Are employees cross-trained and able to do the work at each workstation?	**Yes/No**
4.3.7	Do operators work on more than one workstation each day?	**Yes/No**
4.3.8	Is there a formal suggestion process in place to solicit ideas for improvements from all employees and to recognise their participation?	**Yes/No**
4.3.9	What percentage of personnel are active member of work teams, quality teams or problem solving teams?	**less than 5%** **6-25%** **26-50%** **51-75%,** **76% and more)**
4.3.10	Are many problems being solved through small group activities	
4.3.11	Are operators empowered to stop the line when a defective unit is found?	**Yes/No**
4.3.12	Is there a team responsible for analyzing process defects and identifying mistake proofing opportunities?	**Yes/No**
4.3.13	Do employees develop new and better standard operating methods	**Yes/No**
4.3.14	How many quality circles are there in your plant?	**0-10** **11-20** **21-50** **more than 50**
4.3.15	Is control of production in the hands of worker?	**Yes/No**

4.4 Supplier Integration

S.N.	Question	Answer
4.4.1	What percentage of suppliers do you have a LTA (Long term agreement) with?	**0%** **<25%** **25-50%** **50-75%** **>75%**
4.4.2	What percentage of items are purchased under long term agreement(LTA)?	**0%** **<25%** **25-50%** **50-75%** **>75%**
4.4.3	What is the average number of supplier for each raw material or purchased item?	**1** **2-3** **3-5** **5 and more**
4.4.4	Do you receive daily shipments from most suppliers	**Yes/No**
4.4.5	What percentage of raw material and purchased parts is delivered more than once per week?	**0%** **<25%** **25-50%** **50-75%** **>75%**
4.4.6	Do your suppliers have a long-term schedule but deliver according to pull signals.	**Yes/No**
4.4.7	Do you give equal weightage to quality, cost, and delivery in the selection of supplier?	**Yes/No**
4.4.8	Do you rely on small number of high quality suppliers?	**Yes/No**
4.4.9	Is there any system in place to measure supplier performance?	**Yes/No**
4.4.10	Are suppliers involved in the new product development process?	**Yes/No**
4.4.11	Do you share your production plan with the suppliers?	**Yes/No**
4.4.12	What percentage of raw material is delivered directly on the point of use without incoming inspection or storage?	**0%** **<25%** **25-50%** **50-75%** **>75%**
4.4.13	Do you exchange information through EDI with suppliers?	**Yes/No**
4.4.15	If you exchange information through EDI what is the percentage of documents interchanged with supplier through EDI or Intranets?	**0%** **<25%** **25-50%** **50-75%** **>75%**
4.4.16	What portions of raw material come from qualified/certified suppliers?	**0%** **<25%** **25-50%** **50-75%** **>75%**
4.4.17	Does shop floor personnel coordinate directly with suppliers for delivery?	**Yes/No**
4.4.18	Are most suppliers in proximity	
4.4.19	Is there active supplier audit and certification program	**Yes/No**
4.4.20	Do you have a policy to reduce the number of suppliers?	**Yes/No**