A hybrid production planning approach for waste minimisation in convenience food manufacture

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A Hybrid Production Planning Approach for Waste Minimisation in Convenience Food Manufacture

by

Robert Darlington

A Doctoral Thesis
Submitted in Partial Fulfilment of the Requirements
for the Award of Doctor of Philosophy of

Loughborough University

Wolfson School of Mechanical and Manufacturing Engineering

November 2005

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SYNOPSIS

This thesis reports on the research undertaken to minimise wastes from overproduction that are created to meet demanding due dates imposed by retailers in convenience food manufacture. The principle objective of this research is to generate knowledge and generic solutions to minimise the environmental impacts of such wastes through effective production planning and improved processing and supply chain practices.

The research contribution is divided into three major parts. The first part reviews the most relevant publications and legislation, and categorises the contemporary techniques in supply chain management, operations management and production planning. The second part is concerned with three novel concepts of (a) identifying, modelling and analysing the various types of wastes in food industry (b) the systematic support for the improvement of production and supply chain activities through generation of a Responsive Demand Management framework, and (c) the realisation of a hybrid two stage planning approach for minimisation of overproduction wastes. The final part demonstrates the application of these research concepts through a case study for minimisation of overproduction waste within a ready-meal manufacturer.

The hybrid two stage planning approach has been shown to be an effective method by which overproduction wastes can be addressed for products with production lead-times that exceed order lead-times. The responsive demand management framework is a powerful method for the identification and recording of production and supply chain inefficiencies that can be utilised to establish a programme of improvements for further waste reduction. Classification, modelling and analysis of food industry wastes by this research has provided food manufacturing with significant tools to monitor and reduce environmental impacts. The case study has effectively demonstrated the applicability of the research concepts in significantly reducing overproduction waste.

In summary, this research has highlighted the environmental and economic impacts of waste and has underpinned the paramount importance of establishing sustainable manufacturing and supply chain procedures in convenience food sectors.
ABBREVIATIONS

ATO : Assemble To Order
BOB : Budget Own Brand
BOM : Bill Of Materials
CPFR : Collaborative Planning Forecasting and Replenishment
DFMA : Design for Manufacture and Assembly
DMC : Dynamic Material Control
ECM : Environmentally Conscious Manufacturing
EDI : Electronic Data Interchange
EMS : Environmental Management System
ERP : Enterprise Resource Planning
HMR : Home Meal Replacement
IPPC : Integrated Pollution Prevention and Control
JIT : Just In Time
LCA : Life Cycle Analysis
MRP : Material Requirements Planning
MRPII : Manufacturing Resource Planning
MTO : Make To Order
MTS : Make To Stock
OPW : OverProduction Waste
POS : Point Of Sale
PPC : Production Planning and Control
RDC : Regional Distribution Centre
RDM : Responsive Demand Management
RFID : Radio Frequency Identification
RRD : Reduce Recycle Dispose
SCADA : Supervisory Control and Data Acquisition
SCM : Supply Chain Management
SKU : Stock Keeping Unit (as determined by retailer orders)
SMC : Static Material Control
SMED : Single Minute Exchange of Dies
TSP : Two Stage Planning
VSM : Value Stream Mapping
WIP : Work In Progress
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Chapter 1

INTRODUCTION

The widely accepted principle of sustainable development is ‘to meet the needs of today’s generation without jeopardising the ability of future generations being able to provide for themselves’. Environmental considerations are of the utmost importance in all aspects of life, and where production and manufacture are concerned it is clear that an environmentally responsible attitude in addition to economic acumen is necessary for businesses to remain profitable and sustainable in the future. Consumerism has driven manufacture in many developed countries to provide for every desire of their ultimate customers, and within the food industry this has taken many forms, leading to changes in product quality specifications, costs, convenience demands and product availability. This has led to a great diversification of the forms and formats of foods including ready-meals, chilled and fresh prepared foods, sandwiches, salads, snacks, etc. Many of these demands have been met at the expense of the environment, and increasing food production generates greater material, water, energy packaging, and transportation wastes that should be minimised to maintain a truly sustainable food industry.

There are wastes associated with each of the major stages through food production and supply, with the major forms of waste common to each stage indicated in Figure 1.1. One of the major sources of waste is overproduction as a result of unrealistic forecasts to meet the challenging demands placed by increasingly powerful retailers in this sector. OverProduction Wastes (OPW) are those specifically created as a consequence of manufacture beginning before confirmed customer demand is known and are often in the form of finished products that are scrapped through commercial waste channels. Such wastes may be considerable and have been reported to contribute as much as 40% of the total waste costs in convenience food manufacturers.
In manufacturing generally, creating products to meet confirmed orders may be termed Make-To-Order (MTO), while production which creates a reserve of product from which customer orders are met is referred to as Make-To-Stock (MTS). In some volatile markets it is favourable to combine these two approaches in order to benefit from steady production rates of MTS and also to provide responsiveness to changes in customer demand using MTO. However in applications where the start of manufacturing processes cannot be delayed until the orders are confirmed to meet the strict delivery dates, production levels must be based upon forecasted data. In such cases the tendency is to base the production levels on overestimated values as often the consequences of customer dissatisfaction (e.g. contract penalties for late delivery, loss of future orders) is far more significant than the value of waste as a result of overproduction.

The food industry is predominantly led by retailer or supermarket sales, where large numbers of products are held as stock in individual stores for purchase by consumers. The demand for the products held varies considerably, and where demand is most volatile the retailers ‘pull’ orders in from manufacturers at short notice. The short space of time manufacturers have to react to changes in demand would traditionally have been achieved through the application of
a MTS strategy, where large fluctuations in volume were compensated by stock held. In most applications food products have an associated 'shelf-life', a finite amount of time for which they are fit for consumption before spoilage occurs. In some cases a foods shelf-life may be very short, and in these cases it is impossible to hold the product as stock without incurring large amounts of waste through product spoilage.

In addition, it has become common for foods bought by customers to have been increasingly processed, reducing the amount of effort required by the final consumer in preparation. This trend has seen the emergence of ready-meals, prepared meal solutions and other convenience foods etc. and has resulted in manufacturers having to undertake longer processing operations in preparing foods to meet this market demand. As such, these conditions have created a situation where manufacturers have to create products with long preparation times in response to erratic demand volatility with only a very short amount of notice before the products have to be delivered. Further compounding the problem is the issue of shelf-life, which makes it extremely difficult to hold stock to compensate for demand fluctuations.

The research assertion made in this thesis is that in the rapidly growing food manufacturing sector there is a vital need to minimise the waste generated during the supply and manufacturing processes and in particular the waste as a result of overproduction. The overall aim of this thesis is to analyse the underlying reasons for the generation of waste and to investigate a responsive demand management framework to minimise the overproduction waste.

This thesis therefore addresses three major research issues:

i. The generation of a waste model for the analytical consideration of the causes of waste creation due to inefficient operational management

ii. The realisation of a Responsive Demand Management framework to react to the changes in customer demand

iii. The generation of a novel hybrid two stage production planning approach for minimisation of waste as a result of overproduction

This thesis is divided into the following three sections, background review, theoretical and experimental research, and research conclusions as illustrated in Figure 1.2. The background review consists of five chapters and provides the context, objectives and scope of the
research in addition to an appraisal of the relevant research publications and background knowledge to the research. Chapter 1 is the main introduction to the research work and presents the layout of the thesis. Chapter 2 outlines the context of the research and also contains the research objectives, together with a description of the scope of the research. An introduction to the food industry is outlined in the chapter 3, describing market and retailer conditions along with product considerations. Chapter 4 reviews the most relevant environmental, sustainability and waste minimisation literature, and provides an overview of the common tools used when considering waste minimisation projects. Chapter 5 presents a survey of the relevant literature in the areas of planning, lean manufacturing, modelling and simulation and supply chain management. Chapter 6 is the last in the section and describes the research methodology undertaken.

The theoretical research section comprises three chapters which identify novel contributions to research made over the course of the PhD programme. This section commences with Chapter 7 which describes the creation of a waste model to be used for analysis of material flows and waste generation in food production systems. The research issues involved in the development of a structured approach to waste minimisation through convenience food manufacture by consideration of manufacturing and supply chain issues are described in Chapter 8. Chapter 9 describes the development of a novel two stage scheduling approach to address incidences of overproduction arising from order lead-times falling shorter than manufacturing lead-times.

A case study forms the basis of chapter 10, describing the application of the research results to a convenience food (ready-meal) manufacturer to illustrate the benefits of both the novel scheduling approach and the work undertaken to reduce the impacts of long manufacturing lead-times and short order lead-times.

The final section of the thesis, namely research conclusions consists of two chapters. The analysis of a wide range of research issues reported in the thesis from the initial development of the responsive demand management approach to its implementation in case study is presented in Chapter 11 as the concluding discussions. The summary of the conclusions drawn forms the final chapter of the thesis, Chapter 12 providing a list of suggested research ideas for the possible continuation of this research.
Figure 1.2, Thesis Structure
Chapter 2

The Scope and Context of the Research

2.1 Introduction

This chapter describes the scope and context of the research reported in this thesis. The opening section describes the research assertion and provides the context in which the research is placed. The last two sections identify the aims and objectives of the research, together with the specific scope of the work undertaken in meeting each of the objectives.

2.2 Research Assertion

The range and number of products being handled and offered by food retailers has significantly increased meaning many thousands of products are now available to consumers. Products with fresh ingredients, or those that have been prepared and packaged for the purpose of being convenient for the consumer typically have short shelf-lives, similarly short delivery timescales to store, and short demand notification order lead-times. Such products include chilled ready-meals of all varieties, prepared sandwiches and value added products for example sliced cooked meats or bagged salads. These products all experience considerable demand volatility, and in the cases of ready-meals may include ingredients with long manufacturing lead-times.

This research is targeted at ready-meals which are a type of chilled, value-added convenience foods that have a long manufacturing lead-times and typically short order lead-times demanded by the retailers. However it may be argued that the same characteristic principles may apply in many other applications of food manufacture.
In such applications significant waste is generated due to manufacturers overproducing goods to meet demand from retailers where a Make-To-Order (MTO) approach is not possible due to long manufacturing lead-times and shelf-life constraints conflicting with short order lead-times therefore, manufacturers commonly:

i) incur the additional costs related to OPW and creating products retailers do not want,

ii) have to pay for the disposal of the wastes.

In order to simplify production planning and minimise waste, a MTO approach is preferred and in some food production applications this may be achieved by reducing the manufacturing lead-time of products, increasing the amount of time that manufacturers have to respond to demand notification, or a combination of both. However, if this was not possible, then a reactive approach to production planning is required to minimise the wastes created by late notification of demand variation. Hence, the research hypothesis made in this thesis is the need to improve planning and management of supply chain and production activities to enable food manufacturers through the use of appropriate information support tools and intelligent planning approaches to minimise waste created due to overproduction to meet the challenging demands placed upon them by the retailers.

Over the course of the research a series of industrial visits were made to validate the research hypothesis. During these visits a programme of interviews with production planners and managers was undertaken across a range of food industry manufacturers, a report summarising these visits may be found in appendix 1. In preparation for these visits a bespoke questionnaire was developed outlining the research and requesting information regarding production, planning, products, waste and supply chain considerations. The outcome of these interviews provided a clearer indication of the industry’s position relative to the identified shortcomings, and the manner and extent of the overproduction created in meeting order fluctuations. The acknowledgement of these research requirements by industrialists aided in refining the aim, objective and scope of the research, as outlined below.
2.3 Research Aims and Objectives

The overall aim of this research is to minimise production wastes generated in convenience food sectors as a result of inappropriate production processing, management of the supply chain and inefficient production planning approaches through the generation of:

1. A waste model for improved visibility of sources of waste creation in convenience food manufacture,

2. A framework to support a Responsive approach to Demand Management in convenience food manufacture,

3. A novel two stage production planning technique for minimisation of overproduction waste.

To achieve the aforementioned research aims, the following objectives have been defined:

a) To review relevant research work and the state-of-the-art in production planning, waste management and supply chain approaches together with existing industrial practices.

b) To design and specify a waste model for food production based on results of a research review and a survey of industrial practices.

c) To research a novel responsive framework to manage the challenging demands placed upon food manufacturers.

d) To investigate the realisation of two stage reactive planning technique for minimisation of OPW in the food industry.

e) To demonstrate the applicability of the research through a case study.

2.4 Scope of Research

The scope of the research is in line with the research objectives and are listed below, a description of each follows in sections 2.4.1 to 2.4.6.

i. Review relevant research work in associated academic fields,

ii. Design of a waste model for food production,

iii. Structure a framework for minimisation of OPW in the food industry,

iv. Realisation of hybrid two stage production planning model,

v. Demonstrate the validity of the research concept through case study.
2.4.1 Review relevant research work in associated academic fields

In order to effectively place the research within the appropriate academic context, and to take advantage of the knowledge provided by the existing research work, an extensive review of the literature in the fields of food manufacture, waste minimisation and Operations Management will be undertaken.

2.4.2 Design of a waste model for food production

Providing a clear, consistent model for the identification of sources of waste creation in the food industry will aid the benchmarking, accountability and prioritisation for improvement activities needed to make convenience food manufacture sustainable. OverProduction Wastes, waste water (from both processing and cleaning), energy efficiencies and general production wastes etc. can be better monitored, controlled and improved upon, once they have been identified and recorded. The waste model proposed in this research aims to effectively summarise the various sources of waste creation and to provide a visualisation for convenience food manufacturers that can serve as the starting point for a continued waste minimisation programme. In addition this research also investigated the generation of a number of waste analysis methods tailored to the bespoke requirement of convenience food manufacture.

2.4.3 Structure a framework for minimisation of overproduction waste in the food industry

Identification of the production inefficiencies and information flow failures form the basis of an improvement framework that sets out to reduce the impact of conflicting manufacturing lead-times and order lead-time constraints in convenience food manufacturers. This framework provides a structured approach in applying tools and techniques to reduce the effects of long manufacturing times and non-value added time; and to improve communication and technology application in demand notification. The framework in the first place aims to support the move towards a MTO approach where conflicts of manufacturing lead-times and order lead-times had previously rendered this impossible within the constraints of the product’s shelf-life. However, in the cases where such a MTO
approach is infeasible due to a variety of practical restrictions a reactive planning approach is
included in the framework to respond to demand fluctuations.

2.4.4 Realisation of hybrid two stage production planning model

By basing production planning initially upon forecasted data, manufacturing activities may
begin before confirmed order volumes are received. When actual required volumes are
received it is highly unlikely that they will match the forecast data, particularly in highly
volatile food sectors. There is therefore a need to re-adjust the production plans to reflect the
changes required to the initial production plans. These re-adjustments may require additional
resources to be allocated, or determine a course of action for materials already consigned to
manufacture that are no longer required. The research aims to investigate a hybrid reactive
production planning model to take advantage of static scheduling of standard operations
based on forecast and to re-adjust final production plans based on confirmed orders using a
dynamic planning approach. Clearly, in such a reactive production planning model, the
methods for data capture relating to production progress need to be addressed to support the
real-time planning of final production operations.

2.4.5 Demonstrate the validity of the research concept through case study

In order to assess the validity of the research concepts and to highlight the effectiveness of the
responsive framework and hybrid planning model generated in this research, an industrial
based case study is to be identified and undertaken. The company involved in this study
must be sufficiently sized and positioned with the food industry to be facing issues as
described by the research assertions. The outputs from this study will be examined closely to
highlight improvements to production methods and reduction in waste levels, and to
demonstrate the results from the application of the research concepts.
Chapter 3

An Overview of the Food Industry

3.1 Introduction

This chapter presents an overview of the issues related to the production management of the food industry which, as a manufacturing sector has many peculiarities that set it aside from most others. The importance of the industry to its consumers is almost unique, and its supply and retail operations are again distinct. This is in part, due to the nature of the products that comprise foods, having specific requirements for quality, periods of time before spoilage sets in, and hygiene. The immediate factors which contribute to making the food industry so distinct are outlined in addition to the considerations that enterprises within the industry face. The chapter has been divided into three major sections, namely market considerations, food production considerations and major actors in the food supply chain, as outlined in sections 3.2 to 3.4 below.

3.2 Market Considerations

Consumers spent over £57 billion on in-home food consumption in 2004, compared with £44 billion spent in 1994, over this ten year period however convenience foods have demonstrated the highest rise in expenditure- over 40% when inflation is removed (Mintel 2005-b). This growth of UK spend on food and specifically convenience food is displayed in Figure 3.1, a trend which has been described associated to changing consumer time pressures, (Warde 1999), increasing ‘health’ concerns (Shiu et al. 2004), and added value for consumers (Hollingsworth 2001).
Food manufacture involves diverse range of activities, and businesses within the food industry may be classified by the products or operations they are primarily concerned with. There are several systems of classification, however many companies opt to describe themselves by their own terminology leading to a proliferation of sector descriptions in part as each formal system of categorisation has limited flexibility and in some cases broad category descriptions are imposed. For economic and statistical purposes, the food processing industry may be defined by the Standard Industrial Classification (SIC) system, which has been developed, updated and applied in the UK since 1948. Recent versions (since 1992) apply the European Community classification of economic activities entitled NACE (Nomenclature générale des activités économiques dan les Communautés européennes) as closely as possible (UK SIC 2003). Enterprises are allocated to industry groups by their ‘principle product’ with each group having distinctly defined boundaries, and allow for detailed comparison between food industry sectors. Problems arise when considering historical data, due to the change in classifications over the years. The SIC system has since been replaced by the North American Industry Classification System (NAICS) in the U.S., Canada, and Mexico, the countries which jointly developed the system to provide comparable statistics about business activity across the whole of North America (NAICS 2002). Strak and Morgan (1995) suggest further categorisation of food manufacturers into either first-stage processors (for example producing own-label products for retailers) or second-stage processors (manufacturers producing their own branded products). They state that “first-stage processors produce undifferentiated products, with the

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**Figure 3.1**, Consumer spend on food and Convenience food (source: Mintel 2005-b)
majority of their output being sold to intermediate demand, whereas second-stage processors produce differentiated products, the majority of which are sold to final demand”. They go further to imply that first and second stage processors may adopt different competitive strategies, hypothesising that first-stage processors may adopt a bias towards processing innovation, and second-stage processors may lean toward product innovations, which the author has recognised in some cases, but would not apply as a general rule. These means may be useful for broadly pigeonholing and comparing sectors across the board for the purpose of statistics and business, but enterprises often differentiate themselves differently, with the terms chilled, fresh, prepared, ready-meal, recipe-dish and a host of other terms being used by companies within the convenience food sector to suit the manufacturer. Specific issues addressed when manufacturing convenience foods, and in particular ready-meals are further described below.

3.2.1 Convenience foods

Convenience foods as a term describes a wide range of products, ranging from snacks to entire meal replacements, and includes many categories that have differing terminology across the industry. ‘Ready To Cook’ foods describe those products that have been prepared but may still be raw such as portioned or marinated meats, while ‘Home Meal Replacements’ (HMR) substitute entire meals. Costa et al. (2001) provide a further categorisation of HMRs based upon four classes of convenience and a product’s shelf-life, however the term has not been widely recognised in the 9 years since its introduction in the UK by ASDA, one of the major retailers in the UK. Limited consumer demand has meant that some HMRs have been offered hot and chilled from ‘deli’ counters and increasingly as chilled meal bags sold from shelf space, saving on space and labour costs (Mintel 2004-a). As such these HMRs differ from more established UK products such as ready-meals as they have each meal component packaged separately, while ready-meals are typically sold as a single unit. Ready-meals are available as chilled, ambient, and frozen products, with ambient meals representing only a small proportion (estimated around £165 million in 2004) of the market (Mintel 2004-d), and frozen meal sales dropping from £757 million to £719 million in 2003 due to increased price competition from the chilled meals sector (Mintel 2004-b). The chilled meals market almost doubled between 1999 and 2004, reaching an estimated £1.58 billion in 2004 (Mintel 2004-c) while total ready-meal sales were estimated at £2.44 billion, which equates to 14% of the total spend on convenience foods in the UK. These are summarised in Figure 3.2.
Many products have been developed over recent years so as to improve their variety, convenience and availability to the consumer. The social implications resulting from these developments include many considerations as described by Candel (2001) and Jaeger and Meiselman (2003). Warde (1999) outlines the means by which convenience foods have been a response not to labour saving but to time compression, and consumers combining their activities in the same time-space. Harvey (2000) however outlines convenience measures that consumers perceive as adding value, which in terms of products themselves are often designed with the significant thought being given to the perceived convenience of the product. Retailers have had significant influence as to the extent must be made convenient, stipulating the format and material of many forms of packaging so as to present an easily available appearance, and prolong shelf-life such as Modified Atmosphere Packaging (Hart 1997). The extent such convenience measures has on some products is however significant, as in extreme cases products which are processed in a way that imparts a long shelf-life, are further packaged to improve convenience and the result can significantly reduce the shelf-life, and thus flexibility to meet demand fluctuation.

One of the major issues highlighted is waste generation as a drawback to increased consumer convenience, notably the case of increased packaging material wastes for prepared foods.
(Prendergast and Pitt 1996). The wastes generated from food industry production are discussed in chapter 4, including those arising as a result of convenience food manufacture.

3.2.2 Ready-meals

The initial growth of the chilled ready-meal market was based upon convenience factors and new product and recipe introduction which has slowed as consumer demand for the range of cuisines has stabilised. Figure 3.3 shows that the dominant category of ready-meal has been based upon traditional British recipe. The chilled meals have been perceived as the higher quality convenience products and as the market for these new products became more stable, the reduction in prices of the meals by the introduction of ‘value’ or Budget Own Brand (BOB) sectors has sustained growth by attracting consumers previously deterred by prices (Mintel 2004-c). The emergence of such BOB products is in keeping with the market becoming increasingly price conscious, with pressure to cut the costs of meals seeing increased promotional activity by the retailers such as Buy-one-get-one-free offers with such promotions applying pressure to manufacturers and suppliers to operate more efficiently.

![Ready Meal types](image)

**Figure 3.3,** UK Chilled Ready-meal Types (source: Mintel 2004-c)
Chapter 3

3.2.3 Own-label Products

The retailers have sought to differentiate themselves from their competitors on a basis other than price, spending considerable sums in advertising their brand to attract consumer loyalty (Bell et al. 1997). Own-label products are those which bear the branding of the retailer, also referred to as ‘retailer branded’, as opposed to ‘private brands’ or traditionally established products (e.g. tinned beans bearing the retailer’s name versus Heinz branded products). The UK market for own-label foods is valued at £28.5 billion in retail sales, with virtually all of the market growth in the own-label market in the past two years has come from the success of the chilled foods sector (Mintel 2005-a). Supermarkets within the UK have strong brand names and have developed substantial ‘own-label’ brands in competition with established companies in very diverse product sectors. Sectors where retailers have made substantial ground in providing ‘own-label’ goods have been the convenience foods, which are manufactured for the retailers by independent companies that provide complete processing and packaging solutions to deliver retailer-branded goods that are highly convenient for the consumer. The retailers are highly involved in the new product development and specify the requirements to the independent manufacturers based upon their extensive marketing capability. Harvey (2000) describes the nature of food retailing in UK, highlighting criticisms including high mark-ups, barriers to innovation and quasi monopolies. The differences are evident between those products that are marketed as the companies ‘own brand’ and independent manufacturers, in innovation; branded goods producers show relatively few, high investment innovations, own-label manufacturers generate up to a 1000 new products per year each with a short life cycle. This suggests that the independent brands which manufacturers produce lead innovation and that copy-cat products from retailers follow with less success, hence their short life cycle.

3.3 Food Production Considerations

Operational differences inherent to the food industry aside, food products themselves have many characteristics that render them considerably different to traditional engineering products. This section provides brief treatments of shelf-life, flavour, manufacturing lead-times, seasonality, catch-weight, processing and hygiene considerations.
3.3.1 Shelf-lives

Most foods have an expiry date, that is, a period of time after their processing when the product will become unfit for consumption, while the length of this time varies considerably between foods. Pegg (1999) outlines 'the time from production to the point at which the quality of the product becomes unacceptable' as the product's shelf-life, however at the same time acknowledging that many definitions exist. Manufacturers can calculate this period of time with some accuracy however testing methods and approaches vary between foods depending upon their type, the fundamental principle being to ensure that pathogen levels within the food do not become hazardous within the specified time limit (Singh and Cadwallader 2003). There is significant pressure to increase the length of time the product should last after sale with this pressure being the driving force behind manufacturers, distributors and retailers shortening the lengths of time they hold the product. Consumers associate distant expiry dates with fresh produce when shopping and excessively long product shelf-lives with overly processed, and therefore inferior quality foods (Humphrey 1998). Therefore it is desirable for retailers to command as much of the shelf-life of the product as possible, and thus in recent years have placed considerable pressure upon manufacturers to provide a greater proportion of the products shelf-life to the time after delivery to the supermarkets (Harvey 2000). As such this prompts manufacturers to delay production of foods as late before delivery as possible and to minimise as far as is practicable any on-hand stock or work-in-progress.

The shelf-life of a food is dependant upon the processing techniques applied to the product and the preservation methods employed after processing. The purpose of processing and then preserving foods is to prolong the amount of time that the food remains edible and safe, and it is the growth of micro organisms and spoilage that largely limits the length of time that a food can be stored. Other factors do have an impact on shelf-life however, such as naturally acting enzymes within the product (Hutton 2001). The most common means of processing foods is by heat treatment which has the effect of reducing both microbial and enzyme activity. After processing the means by which foods are preserved depends upon the technologies employed, but for most cases this is by either temperature control, the packaging used or both (Hart 1997). At sufficiently low temperatures microbiological and
chemical deterioration is slowed, and many foods are transported, stored and sold at chilled temperatures in order to extend their shelf-life.

3.3.2 Hygiene

Any treatment of the characteristics of food manufacturing would be incomplete without considering hygiene's impact upon what happens during production. Legislation is laid down to ensure that manufacturing procedures are followed to a standard to ensure that all products are safe for consumption (Forsythe and Hayes 1999). This concerns chiefly the means by which foods are produced, but also influences the determination of shelf-lives, the acceptable materials used in packaging foods and temperatures and procedures in place when cooking, storing and transporting foods. Products that have been processed and chilled to prolong shelf-lives must be maintained at temperatures dictated by the legislation. This has led to an extensive chill-chain being developed to ensure the products can be guaranteed to have been kept below given temperatures which Cox et al. (2003) assert to be one of the attributable reasons for the successful growth in the UK of chilled and fresh foods. A number of products from each production run can be tested under lab conditions for the presence of microbiological indicators for fitness for consumption, however given the compressed timescales many of the test products held are only held for traceability purposes should a product recall be required.

3.3.3 Flavour and Ingredient Considerations

The subtle product variations found in many food products also contribute much of the complexity caused in scheduling and production planning. Food products often have similar compositions, though with slight flavour variations, ranging from light to strong. In manufacturing different batches of product use of the same resources through swift changeovers and reduced production downtime is desirable. Only a few tasks are required when changing similar products from a light flavour to a stronger one, though the reverse is often more time consuming on account of product quality and consistency with increased cleaning being required. When changing to a more lightly flavoured product batch, often a lengthy clean up of manufacturing equipment is required to prevent contamination of the more lightly flavoured product by residues of the last batch. Additionally some ingredients must not be present in any amount of the subsequent batch, particularly in the case of
allergens (such as nuts) and after manufacturing products containing allergens, sometimes considerable cleaning of equipment must take place. These considerations contribute significantly to the required planning efforts and the order of production invariably takes account of these factors.

3.3.4 Catch-weight

Catch-weight is a significant issue for manufacturers that implement resource planning software developed for engineering applications, as these software systems have historically been found unable to fit some of the food industry sector needs. The problem comes where products are bought in both numbers of discrete products and weights, for example a whole number of animals and a price by weight for products. The inventory, costing, planning etc. in accounting for these products must, in some cases represent an inverted Bill Of Materials (BOM), with a single entity (for example an animal) at one end and several end products and waste losses at the other. In cases where there is a need to integrate IT systems and planning methods additional complexities may present an impediment to implementation; for example products being bought by weight (e.g. 500 Kg of chicken) and then sold and packed by pieces (2 chicken breasts per pack regardless of weight).

3.3.5 Manufacturing lead-times

The manufacturing lead-time of a product consists the total time spent in preparation, processing, chilling, checking and packaging activities before the product is saleable. The range of make-spans (specifically the required operation times) can vary extremely through the food industry, though the majority are of an order considerably less than found in some of the typical engineering applications. The variation in make-spans of foods can be related to the relatively simple processes that predominate many products combined with much more complicated operations in others, coupled with relatively long cycles over which products undergo essential but time consuming process delays, for example fermentation, chilling or slow cooking.
3.3.6 Seasonality and volatility

Demand for food products varies across the industry. Some foods have a fairly steady, easily predictable demand pattern, meaning that the consumer's demand for the product can be met reasonably accurately, without producing excessive amounts of waste, or disappointing consumers by not meeting their needs. Other products, for example prepared sandwiches, display highly volatile demand, where there may be considerable wastage where demand is over-predicted or consumer dissatisfaction when stock-outs occur. Retailers may attempt to smooth large fluctuations by managing the demand, for example by running various promotional activities to maintain demand for products at a steadier level. The demand management efforts for products are an attempt to compensate for the external driving conditions which create the demand in highly volatile sectors, with such conditions being as diverse as weather conditions, holiday seasons and sporting events. Meeting demand under these conditions presents a considerable challenge, particularly when products have a short shelf-life, which serves to exaggerate the problem. Snack foods, ready prepared foods and meals experience particularly volatile demand, this means that volume of products that consumers wish to buy on a particular day can vary greatly as a proportion of the total volume of products sold. Snack manufacturers can experience huge variation in take up of particular flavour products from one week to the next (Wardle, 2000), and ready-meal manufacturers have historically experienced volatility in terms of product demand associated with the weather. This volatility of products, particularly when in regards of products with short shelf-lives means that manufacturers must try to closely follow demand and also anticipate from historical events anything which may lead to a spike in demand that could not otherwise have been predicted.

3.3.7 Processing

A wide range of processes from cleaning and cutting to cooking are common in food processing, with filling and packing operations within a ready-meal manufacturer being typical for the assembly of final products and HMRs. Terminology varies between companies, however the basic mode of operations remains constant with separate ingredients being added either by manual or mechanical means to a ‘foil’ or tray, which is then sealed, labelled, weighed and checked for contamination by x-ray or metal detection. With these stages completed the foils are packed into cases for despatch. When filling the trays with
ingredients the weight must fall within a specified limit, the manufacturer has a legal obligation to ensure each product contains greater than the specified amount of each ingredient as specified in the UK by the Weights and Measures Act 1985 (revised 2001). However, each addition of ingredient over that limit eventually amounts to a considerable volume of product that is commonly termed ‘giveaway’. The manufacturer anticipates that some volume of ingredient must be planned for ‘giveaways’ when preparing ingredients, though the accuracy of the filling operators/ equipment may mean that this creates some additional waste at the filling stage of production as ingredient planned for giveaway is left at the end of production.

3.4 Major Actors in the food Supply Chain

The main actors of the typical food supply chain may be represented as shown in Figure 3.4 with the arrows in the figure identifying the direction of material flows. These actors can be viewed under four major categories of raw material suppliers, manufacturers, regional distribution centres (RDCs) and retailers which are described below.

3.4.1 Raw material Suppliers

There may be many raw material suppliers for a particular type of product manufactured at a facility, with all types of food ingredient being supplied typically by a separate organisation. By terming them ‘raw material’ suppliers, the inference is automatically made that the material supplied is unprocessed, and while this is the case for some, many products arrive at the manufacturers facility that have already undergone some considerable processing.

![Diagrammatic representation of the common food supply chain actors](image_url)

Figure 3.4, Diagrammatic representation of the common food supply chain actors
Operations such as cleaning, drying, preparation, and packing may be completed before transportation by the supplier, and in the case of products such as meat, undergone considerable other processing at an abattoir. In the context of this research, fresh material suppliers are those that provide vegetables, meat, and sauces while rice, pasta, spices, herbs and prepared additives, such as preservatives are provided by dry ingredient suppliers.

3.4.2 Manufacturers

Convenience food manufacturers upon receiving materials from suppliers cook, mix, prepare and assemble the component parts into a consumer-ready format from which no further processing is required before sale to the consumer. Upon purchase of the product the consumer may be required to undertake additional preparation or cooking depending upon the product, however the manufacturer is the last stage in the supply chain where the foodstuff is handled directly before packaging, and so hygiene within the production facility is paramount. As such, many production facilities are arranged into high care/ low care areas, with appropriate hygiene procedures and requirements within the designated areas of the facility (known as hygienic zoning) (Van Donk and Gaalman 2004). Before final assembly of the product into the saleable format (referred to as ‘filling’ in many sectors), the ingredients are likely to require processing in some form or another. These operations may be cleaning, preparation, cooking, chilling, mixing or other physical manipulation, before product is arranged ready for sale, and grouped by some method for mass transportation. Many of these processing operations will require manual operators, Ilyukhin et al. (2001) describe the results of a survey which showed all the food manufacturers they sampled automated some of their production processes over a ten year period up to 1991, however less than 3% have ‘top-to-bottom’ integration of automation. Depending on the physical size and packaging of the saleable product a range of handling methods are applied for shipment of the products. Most commonly this is the filling cardboard cases with finished goods, then loading finished onto pallets, either standard wooden or plastic. Alternatively, material handling may be completed by loading finished products into wheeled cages and shipping these returnable cages to stores.
3.4.3 Regional Distribution Centres

Regional Distribution Centres (RDCs) accept the shipments from manufacturers and as the name implies are the centre for distribution for a geographical region. It is commonplace for RDCs to be a part of the retailers organisational group, but this is not always the case, as with consolidators such as those described by Collins et al. (1999). An RDC reduces the number of shipments from the manufacturer, simplifying the logistics complication in distributing from one site to all stores within the retailer group. It is however worth noting that the practice of distributing direct to store is the norm in some sectors such as milk production for example. However the majority of food products in the UK are streamed through RDCs and shipped from the manufacturer into one of the 6-12 RDC each of the retailers have located around the country. Upon arriving at the RDC it is common practice for products to be placed within the stores at the site, which can be considerable in size, according to conditions required the store may be temperature controlled for ambient, refrigerated, or frozen goods. The outbound vehicles from the RDC can either take the range of products required directly to a single store, or deliver smaller quantities of goods to a number of stores in a ‘milk round’ style delivery schedule. In addition, crossdocking is a technique specific to distribution centres which has been used where priority products are loaded directly to the waiting vehicle directly after transportation to the distribution centre. This means that the product spends as little time as possible waiting to be delivered to retailer stores, removing the inventory function of the distribution centre, which now acts solely as a consolidation point. With ‘pre-distribution’ crossdocking the outbound logistics are determined when the product leaves the manufacturer while with ‘post-distribution’ the pallets for particular stores are decided at the distribution centre. In either case the information transfer, integration and organisational issues are substantial (more so in the case of pre-distribution) to ensure the outbound vehicles are ready to correspond to the incoming shipments. These policies differ between retailers and products depending upon what is required and considered most economical.

3.4.4 Retailers

A typical out-of-town store offers many fresh products sourced from around the world, and as many as 15-20,000 product lines in total (Hutton 2001) while larger stores may carry 25-
50,000 (Harvey 2000). Tesco, Asda, Sainsbury’s, Morrisons (including Safeway) have a greater market share than their smaller competitors, with these four accounting for 65% of food retailer sales, and the top 10 accounting for 85% (Mintel 2004-e). Within the food industry in the UK the large retailers have the majority of the buyer power in their relationships with their suppliers, as described at length by Hingley (2005), to the extent of threatening the survival of smaller suppliers (Grimsdell 1996; Dobson et al. 2001). The lead in the market by the top retailers has come through developing large hypermarket style stores to drive down their costs through greater distribution network efficiency and bargaining power with suppliers. Retailer stores are often spread throughout the country, each store being an individual site, but fitting closely with the retailer organisation’s template for image, merchandising, product range and pricing, ethics, systems and culture.

The pressures which suppliers face from the retailers is of common concern, and as such the competition commission ruled against further moves to reduce the number of large retailers to less than 4 (Mintel 2004-e). Even so, the large retailers have significantly greater bargaining power over the manufacturers (Robson and Rawnsley 2001) and as such have been able to make demands upon companies that have seen a proportion of shelf-life move out of the factory where it could be used to compensate demand fluctuation and onto supermarket shelves to create an impression of widely available fresh produce. However the consumer’s view of the product will vary considerably from the manufacturers, and that the product’s quality will be judged at consumption, not at the point of sale (Pegg 1999) in which case the retailer’s demands ultimately benefit the manufacturer. However manufacturers in fresh and chilled food sectors often experience delivery due dates for the same day that the order was placed, and even multiple orders being placed for same day delivery which presents a considerable challenge to production, and one that commonly results in substantial waste being created (see chapter 7).

A wide range of issues related to the food industry have been discussed in this chapter which highlights the complexity in particular the operational and Supply Chain Management activities in this sector. These issues have resulted in the generation of significant waste as the result of overproduction to compensate the inefficiencies in planning activities, as will be discussed in the remaining chapters of this thesis. The author’s research aims to identify and analyse factors influencing such waste generation and to develop a framework and hybrid planning approach to minimise such waste.
Chapter 4

Environmental Concern and Waste Creation in the Food Industry

4.1 Introduction

This chapter presents a survey of the literature associated with environmental concerns and waste creation in the food industry. The wider context of sustainable development as a global issue for manufacturers is addressed in addition to pollution prevention and control, with particular regard to the role of waste management as a means of achieving pollution reduction. The current waste issues within convenience food manufacturing are described, highlighting examples of wasteful production and sources of wasted materials and resources, and the chapter concludes by summarising the tools and techniques for reducing the environmental impact of manufacturing.

4.2 Environmentally Conscious Manufacture and Sustainable Development

This section describes sustainable developments as global issues and the methods by which environmental pollution and waste controls may be adopted by manufacturers.

4.2.1 Climate Change and Pollution Controls

It is suggested that the earth’s environment and atmosphere is severely detrimentally impacted by the release of pollutants and the misuse of resources both by industry and through domestic sources. Highly publicised environmental issues such as the depletion of the ozone layer and global warming have been blamed by some on the release of chemical pollutants such as Chlorofluorocarbons (CFC’s) (Rowland 1991) and Carbon Dioxide (CO₂) (Houghton et al. 2001) respectively. It is argued that the release of such chemicals will have
a severe impact on the earth, in particular the climate and atmosphere which will only be reversible, if at all, on exceptionally long time-scales (Rowland 1991).

In the past industrial and economic growth was largely at the expense of the environment, and as a result strictly defined limits regarding the acceptable use of resources and the impact of industrial activities on the surrounding environment are now in place (Byrne and Glover 2002). Typifying this kind of control are ‘clean air’ acts, whereby governments pass laws specifying the maximum outputs of certain damaging chemicals that companies must adhere to or face legal penalties the most obvious examples of which being driven by the Integrated Pollution Prevention and Control (IPPC) measures (Directive 96/61/EC, 1996). In this way all companies must comply with these minimum standards, and their compliance is regularly monitored to ensure environmental impact is sustained below the specified pollution maximums.

Four commonly recognised principles provide a context for environmental management by acknowledging that it is best to avoid creating pollution where possible (European Commission 1999). Where this is unavoidable, the polluter should cover the costs for minimisation and safe disposal; where the full impacts as a result of pollution are not known, it is best to minimise the output of wastes and pollution should be managed in the vicinity of where it is created. The four principles are thus summarised in Table 4.1, below.

<table>
<thead>
<tr>
<th>Principle</th>
<th>Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevention</td>
<td>Minimise creation of pollution by alternative – ‘cleaner’ applications</td>
</tr>
<tr>
<td>Polluter Pays</td>
<td>Those creating pollution cover costs for management and control</td>
</tr>
<tr>
<td>Precautionary</td>
<td>Unforeseen impacts are not excused- all releases must be managed</td>
</tr>
<tr>
<td>Proximity</td>
<td>Pollution should not be transport away from locale</td>
</tr>
</tbody>
</table>

Table 4.1, Pollution principles and the basis upon which the principle works
It has been argued that ‘green’ or environmentally friendly manufacturing strategies and techniques will prove to have a combination of economic and competitive benefits that promote industries to adopt a proactive approach in their adoption (Porter and van der Linde 1995). Were manufacturers to become aware of the benefits of environmentally sound manufacture then it is proposed that their voluntary adoption of the strategies would yield greater benefits to the environment and also company profits, as pollution and wastes would be minimised. This supposition relies on the premise that minimising a company’s production of material wastes and handling of environmentally hazardous materials will increase that company’s profitability. It stands to reason that the waste a company generates adds no value to a company’s products, and may even cost a great deal to dispose of, thereby minimisation of such wastes should be an operational goal of all organisations.

4.2.2 Sustainable Development

The commonly accepted definition of sustainable development comes from the World Commission on Environment and Development (1987) as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’. Wilkinson et al. (2001) go further than this definition for Sustainable Development by acknowledging the ethical ‘fairness’ element of the trade of required between today’s economic pressures and the future environment. There are increasing pressures on manufacturers to develop sustainable products and services, which require commitment to sustainable principles at a strategic level to reassess the environmental impacts of operations, and possible application of clean technologies (Maxwell and van der Vorst 2003).

Sustainable requirements, in conjunction with economic growth and consumerism is acknowledged by the UK governments sustainable development strategy (Department of the Environment, Transport and the Regions 1999), while the link between wasteful production and growth has been identified to be decoupled (Department of the Environment, Transport and the Regions 2000). The interactions between manufacturers, consumers and waste-processors must make most use of the resources available, and where possible take advantage of any resources that may be re-used in another form before being disposed of as waste. A linear type I ecology (as depicted in figure 4.1) demonstrates a single direction flow of material and could only be sustainable should the resources remain infinite (Jelinski et al. 1992).
In most manufacturing conditions resources are only sustained at the expense of other resources and a quasi-cyclic industrial ecosystem has been developed to show how limited resources can be used to their fullest potential before disposal, as shown in figure 4.2. There are several examples of working industrial ecosystems, the development of which have been supported by governments or other institutions (Sarkis 2001) as the linkages between ecosystem components or supply chain members may be financially undesirable. As such initiatives, legal requirements or schemes can be put into place to promote the extraction and re-use of materials rather than disposal as waste. Sustainable manufacturing strategies may be considered from a number of viewpoints, however the author believes that an industrial ecology approach to designing products and process with a view to optimising the materials cycle from virgin material through to final waste provides the clearest view of where sustainable manufacture must be focused.
4.2.3 Environmentally Conscious Manufacturing

The legislative drive to improve industry’s sustainable production and reduce its negative impact upon the environment is in addition to consumer pressures for manufacturers to act in an environmentally conscious manner. Companies with a consistently good reputation for environmentally responsible policies as part of their corporate social responsibility (Piacentini et al. 2000) may find themselves with a significant competitive advantage as suppliers, customers and the public place increasing importance on environmental issues.

![Image](figure4.3.png)

**Figure 4.3.** An overview of environmental concepts and technologies relative to their place in production (adapted from Rahimifard 2004)

A means of classifying the environmental technologies and applications related to elimination and minimisation of wastes and pollution comes by dividing them as either pollution prevention or control, as depicted in figure 4.3, this classification was developed by Rahimifard (2004). The figure also splits classification of technologies and concepts by their point of application, be it before, during, or after production has taken place.

### 4.3 Pollution Control and Prevention

As shown in figure 4.3, environmental technologies and applications may be viewed as either eliminating (preventing) the release of pollutants, such as those approaches described in
4.3.1 Pollution Prevention

Pollution prevention covers many activities including design based changes of products, processes and systems, the adoption of clean technologies and fundamental operational changes to a basic product or primary process in order to provide the best possible environmental performance (Freeman 1995). By actively re-designing, or engineering a process or product so that 'clean' processes may be used that release little or no polluting emissions, parts or bi-products, the environmental impact of manufacturing is substantially improved. However Lillford and Edwards (1997) argue the case for considering the entire food supply chain for clean technologies given the many interdependencies of distribution and disposal on processing methods elsewhere in the food chain. The majority of these changes may be made at the design stage of a product's life cycle, when much of the material and manufacturing decisions are made for a product.

Design has a great deal of influence upon a products life cycle costs, manufacture, environmental impact or ease of assembly and disassembly (Huang 1996). Design for Manufacture and Assembly (DFMA) led to other design methodologies being established, which in some cases lead to the use of Life Cycle Assessment (LCA) such as the eco-design tools described by Kalisvaart and van der Horst (1995). In such considerations the environmental impacts of the products and the materials consumed in production are weighed against alternative or provisional products that may be used instead. Where possible the alternative packaging may contribute no harmful material pollutants or waste to the environment, and as such should always be favoured, provided economic constraints permit the packaging material substitution. Vazquez et al. (2003) describe the packaging design process for food retailers, highlighting the emphasis placed as a “strategic function that delivers brand values to the customer” this importance indicating the conflicts that arise between environmental aspects and aspects of packaging.

Improved supply chain practices may enable pollution to be prevented however, as material handling methods and packaging may be designed in ways that eliminate disposable casings,
pallets and racking that may be used indefinitely or engineered specifically for ease of reclamation and re-cycling (Envirowise 1999; Winder et al. 2001).

4.3.2 Pollution Control

Pollution control should be undertaken wherever a process, product or production cycle cannot be re-designed to eliminate the release of pollutants entirely for either technological or economic reasons. Control of the release of pollutants aims to minimise the impact onto the external environment at all times, firstly by the same principles outlined section 4.3.1 in eliminating the unnecessary actions, materials and releases of waste, and then by managing the environmental aspects of the processes considered to reduce the harm done by any such releases that cannot be eliminated. As such pollution control may begin at the planning stage where the production activities which will potentially result in the creation of wastes and pollution are conceived. The responsible planning of manufacturing activities to minimise the environmental impacts of production is essential, and where possible the redirection, or re-use of materials that had been improperly produced is desirable.

An integrated Environmental Management System (EMS) has been described as a suitable response to legislation and regulations relating to a company's environmental performance (Morrow and Rondinelli 2002; Food and Drink Federation 2002) allowing all activities to be managed and benchmarked against the company's EMS database. An International family of Standards referred to as ISO 14000 (International Organisation for Standardization 2002) provides the framework by which EMSs may be structured, considering auditing, monitoring, analysis and assessment including LCA whereby any potential environmental impacts across a product's life are considered. Some have likened the activity undertaken in an EMS to that of existing manufacturing management systems, such as Total Quality Management (Borri and Boccaletti 1995), while acknowledging the continuous improvement basis upon which EMSs are based as they develop with technological and political advancement (Gupta 1994, Borri and Boccaletti 1995). However there have been criticisms of the ISO 14001 certification procedure, based upon the premise that environmental management is an ongoing requirement, and performance based appraisals lead to improved reduction of environmental risks rather than one-off certification 'events' (Tuberfield 2002).
Waste minimisation clusters, organisations and clubs can be found throughout the UK, set up for most regions, for example Greater Peterborough (En cluster 2005) and have been drivers for the formation of partnerships that have led to considerable waste reduction drives (Phillips et al. 2002). With this kind of initiative manufacturing companies may either competitively or co-operatively work towards implementing an EMS, improve their environmental impact and reduction of wastes in their production systems.

4.3.3 Tools and techniques for Waste Management

A large number of tools and techniques have been developed for the reduction of waste creation and environmental considerations, with Table 4.2 briefly summarising those that the author has classified as being of relevance to this research in areas of environmental management, design, and lean.

<table>
<thead>
<tr>
<th>Tool/Technique</th>
<th>Authors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compliance with</td>
<td>Directive 96/61/EC 1996;</td>
<td>Regulatory measures to promote/ enforce environmental principles (prevention, polluter pays, precautionary, and proximity) to provide context for environmental management</td>
</tr>
<tr>
<td>EU legislation</td>
<td>Directive 04/12/EC 2004;</td>
<td></td>
</tr>
<tr>
<td>Environmental Management Systems</td>
<td>ISO 2002; Morrow and Rondinelli 2002;</td>
<td>The structured management, monitoring and benchmarking of an organisations environmental strategies, these may be assisted and supported by local governments and ISO standards</td>
</tr>
<tr>
<td>Total Quality Environmental Management</td>
<td>Borri and Boccaletti 1995;</td>
<td>Management Philosophy based on Total Quality Management for the development of sustainable manufacturing techniques</td>
</tr>
<tr>
<td>Environmental SWOT</td>
<td>Gupta 1995; North 1992;</td>
<td>A traditional Strengths/ Weaknesses/ Opportunities/ Threats (SWOT) analysis with the primary focus being environmental strengths and weaknesses etc.</td>
</tr>
<tr>
<td>Green Business Strategy</td>
<td>Gupta 1995;</td>
<td>Similar to EMS, structured through Environmental SWOT to drive business toward environmental biased strategy.</td>
</tr>
<tr>
<td>Life Cycle Assessment</td>
<td>Guinee et al. 2002;</td>
<td>Assessment of a particular products environmental impacts- not only on sustainable means, but also with regard it disposal and processing costs across the whole life of the product</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Sustainable product and service development</td>
<td>Maxwell and van der Vorst 2003;</td>
<td>Takes a life cycle viewpoint to sustainable design, based upon the integration of sustainable criteria alongside traditional product requirements</td>
</tr>
<tr>
<td>Design methodology (design for X)</td>
<td>Huang 1996;</td>
<td>Design focus for ensuring eco-efficiency. Many design methodologies have been described, including design for: environment, assembly, disassembly, manufacture</td>
</tr>
<tr>
<td>eco-design</td>
<td>Kalisvaart and van der Horst 1995;</td>
<td>Design of resource and material ecology so that most use is gained from materials before release as wastes</td>
</tr>
<tr>
<td>Lean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toyota Production System</td>
<td>Ohno 1995; Shingo 1995;</td>
<td>Define and identify 7 types of waste and continuously improve production to eliminate sources of the wastes</td>
</tr>
<tr>
<td>Demand Amplification Screen</td>
<td>Jones and Womack 2002; Hines and Rich 1997;</td>
<td>Indication of the incidence of the bullwhip effect on the supply chain considered highlighting ordering inefficiencies and implications for overproduction</td>
</tr>
<tr>
<td>Value Stream Mapping</td>
<td>Tapping et al. 2002; Duggan 2002; Hines et al. 1999;</td>
<td>Mapping process of operations detailing value adding and non-value adding steps, may be extended to Supply chain partners and considers processing and information flows</td>
</tr>
<tr>
<td>SMED</td>
<td>Shingo 1983; McIntosh et al. 2001;</td>
<td>Operational tool to continuously improve operations techniques to minimise offline time</td>
</tr>
</tbody>
</table>

**Table 4.2**, Tools and techniques suitable for waste improvement or minimisation in production.
The tools in Table 4.2 contribute to improving production waste creation in a variety of methods, with several of the techniques associated with environmental management being based around auditing, measuring or the monitoring of waste, and thus indirectly its reduction. A number of the tools consider design techniques, and will impact waste creation by elimination at the design stage, thereby significantly reducing the initial generation of waste, while lean approaches are of use when improving waste creation of production systems.

4.4 Waste In Food Manufacturing

The focus of the research reported in this thesis is the waste created by convenience food manufacture, hence the following review section concentrating on research on waste minimisation in food sectors. This section describes the current forms of waste that are prevalent in the food industry, with particular regard to the convenience food sectors. It is worth remembering at this point that waste may be measured in different ways depending on what is to be considered, and may also be classified relative to a process, or processor. For example wastes from a factory may be measured by weight or at a value-cost, and may be a waste to a producer, while being the raw material to the next stage of processing that the material is passed to (for example waste foods being passed as raw material to a fertilizer producer)

4.4.1 Current Wasteful Practices

Current food industry manufacture has developed from a culture where product losses are inherent to the processes developed, products will typically yield considerably below less than the amount of raw material used. This is due to the physical transformation effect of cooking processes in conjunction with a number of other issues, and as such waste measurement and minimisation have not been undertaken as rigorously as other engineering disciplines. In addition, very few dangerous chemicals and pollutants may be used safely in food manufacture, so the environmental impacts of food wastes have been given little consideration. In fact production wastes may be used for land treatment- with certain production wastes being rich in potassium, phosphorus, and nitrogen, which can be beneficial to replenish soil nutrients, provided the waste application is monitored and managed (Mattsson and Sonesson 2003). One of the most common food industry wastes is in the form
of packaging, which may be primary (sales), secondary (grouped until point of sale) or tertiary (transport packaging) (Mattsson and Sonesson 2003) with much of the primary packaging being polymer based and largely disposed of to landfill after consumption.

4.4.2 Material and Water Wastes

Material wastes in the food industry may be generated from a number of sources. Raw materials may be trimmed, peeled, or prepared in any number of ways that produce some undesirable or unusable material, likewise some raw material may be partly processed before being contaminated, miss-handled, or simply not required and so will be disposed of as waste. Processing itself in some cases produces either losses as foods are reduced, burned, evaporated and in most cases simply yield less final product than the sum of the whole that was inputted. Such wastes are removed from the processing machinery in cleaning operations and are combined with the general wastes from the factory as depicted in Figure 4.4.

Other food industry wastes such as those arising from processing or waste water and effluent are considered under the Integrated Pollution Prevention and Control (IPPC) directive 96/61/EC (1996), earmarked for full implementation in all European Union Member states by October 2007. The IPPC measures were created to prevent, or at least reduce emissions to air, land and water from manufacturing activities whereby companies have to demonstrate that reasonable steps to reduce emissions to acceptable levels are being taken. Water and energy are consumed in great quantities for most food processing applications, and management of these resources is of great importance for food manufacturers.

Figure 4.4, Schematic Material Waste Flows in Typical Food Manufacture
Water is used as a cooking medium as both water and steam, steam may be used to seal packaging, water may even be used under high pressure to cut material, as found in sandwich manufacture, however the greatest uses of water are for cleaning and cooking purposes. Water may be combined with a variety of cleaning agents and is used in great quantities for the purpose of cleaning machinery, containers and facilities to ensure food hygiene standards are maintained. It is used in foods as a raw ingredient and also as a carrier to dispose of wastes from factories and as such is essential for most food manufacturers. The management of a company’s water resources may reap financial benefits as well as significantly reducing the environmental impacts the food manufacturer makes (Holmes 2000; Environment Agency 2001).

Where water is used as a heating medium, such as boiling, sous-vide or cook-chill processing (where foods are processed whilst vacuum packaged (Ghazala 1998)), or steaming, there are significant energy implications as water requires a considerable amount of energy to raise to the required temperatures, and so where possible the thermal insulation, recovery and reuse of the water used for cooking should be considered. In some sous-vide applications for example the water medium is kept entirely isolated from the product and may be re-used for many production runs, whereas water used in direct contact with foods must be used elsewhere or disposed of.

![Figure 4.5](image)

**Figure 4.5**, The increasing cost of water savings by process: highlighting importance of housekeeping and management (adapted from: Holmes 2000)
4.4.3 Packaging

Material wastes created in food supply networks are largely organic and packaging, with the food industry responsible for using over 50% of the total packaging output for the UK (Environment agency 2001). The European Union directives on packaging waste (Directive 94/62/EC 1994; Directive 04/12/EC 2004), indicate the measures and targets that member states must implement. The UK Packaging Regulations (set in 1998 and amended in 2003) based upon these directives require companies handling greater than 50 tonnes of packaging to comply with the legislation and take responsibility for their 'obligation' of packaging waste in order to reduce the environmental impact of such packaging waste (Department of Trade and Industry 2005-a; Department for Environment Food and Rural Affairs 2005). Fernie and Hart (2001) describe how this obligation gave the greater share of the responsibility to retailers, with manufacturers required to recover 9% of packaging, while the actual recovery is often taken care of by third party reprocessors through compliance schemes which issue Packaging Waste Recovery Notes.

4.4.4 Bi-products

Production wastes are in many cases unavoidable with current methods of production. Such wastes may be in the form of material left in processing tanks pipe-work or packaging after emptying during production; product may be disposed of for hygiene reasons after being contaminated and thus be classified unfit for production. Bi-products however are created by the production processes themselves by creating a secondary product when processing the material required. In some cases it is possible for the additional bi-product to be of use in some other way for example the boiling of vegetables produces vegetables as the product, and in addition the cooking water used may be of use as a cooking stock or other ingredient in some cases. Some bi-products are either of no commercial value or are may not be reused by the company and in such cases may simply be re-assigned as wastes.

4.4.5 Production Wastes

Materials that may be wastefully disposed of during production may simply be the products or ingredients themselves or additional materials that are consumed along with the processing of the foods, such as reams, rollers or dispensers that packaging materials are supplied with.
Packaging itself may only be used for intermediate stages within processing, such as temporary plastic sheets to prevent contamination of trays of product, or vacuum packaging meats to cook them, before the used plastic pouches are disposed of.

Resources that generate excessive waste result from processing inefficiencies, such as equipment using more water or electricity than would otherwise be required to process the foods, and in many cases these inefficiencies will be overcome by proactive maintenance or investment in more effective equipment (Envirowise 2001). The design of the processing equipment will dictate the amounts of detergent, water and effort required to clean the equipment and also impact the waste generated in production, as these design elements will influence the amount of material wastes resulting from ingredients being stuck in or to handling equipment and not being used for manufacture.

In food manufacturing at times it is even relatively common for whole product batches to be scrapped and made waste for mistakes in production. Such mistakes may come about as a result of ingredient problems- some spices have variable potency for example; contamination of some kind, either by hazardous materials or allergens; or simply because the batch was not necessary to produce. It is unusual for foods to require rework to correct any problems, though this may occur to improve quality or consistency, or to make better use of any material or produce that has been reclaimed at a subsequent processing step.

This chapter has outlined the various forms of waste associated with the food industry, in particular convenience food manufacture. While there is much legislation and high level research completed in considering the wider implications of waste creation and environmental impacts, there is little research for the reduction of wastes and the improvement of production efficiencies at an operational level. This research aims to provide a consistent theme for the consideration of waste generation in food manufacture, with the primary focus being the minimisation of OverProduction wastes in convenience foods.
Chapter 5

Review of Operations Management Tools and Techniques

5.1 Introduction

The research reported in this thesis has utilised a wide range of contemporary Operations Management tools and techniques to support the structured approach to waste minimisation in convenience food manufacture. This chapter presents a survey of the relevant literature applicable to the research, and is divided into four sections of production planning and control, Supply Chain Management, simulation and modelling, and lean manufacturing.

5.2 Production Planning and Control

Planning essentially determines the production capacity required to meet future demands, while control activities are concerned with the execution of those plans and how capacity may be utilised. The planning of production may be undertaken in a number of different ways, depending on the external drivers around the production system and the tools available to support demand management. The point at which forecasted demands are confirmed as orders, known as the order de-coupling point or order penetration point, contributes greatly (along with the nature of products) to the manufacturing strategy adopted by a company. Make-To-Stock (MTS), Assemble-To-Order (ATO) and Make-To-Order (MTO) are manufacturing strategies that require different planning approaches based on the order decoupling point, while implementing these strategies based on manufacturing lead-times and capacity constraints are among the challenges for production control. Mather (1999) describes industry’s toughest ‘planning dilemma’ as the P:D ratio where P is the production lead-time, while D is the order lead-time. Several solutions are proposed for the condition where production lead-time exceeds order lead-time:

- Over-planning
- Inventories
5.2 Aggregate Planning

Longer term or Aggregate planning is difficult for seasonal and volatile products, as demand levels may be subject to considerable change. Systems have been developed in order to better organise, standardise and report tasks that are completed within the company, for example the early introduction of Materials Requirements Planning (MRP) systems was quickly followed by a number of other approaches which included increasing sophistication to the planning aspects associated with operations. MRP systems have been widely criticised from the food industry as being unsympathetic to many of the considerations as its basis was primarily based around Bill of Materials and simple inventory based analysis. Manufacturing Resource Planning (MRPII) has been implemented into many food manufacturing companies though still experienced many shortcomings in terms of functionality expected by food producers. Enterprise Resource Planning (ERP) considers wider implications of resource planning across the whole of the enterprise, though often by including elements from MRP and MRPII systems. ERP does however allow the engineering of products to be completed in a much more systematic manner. Implementations of ERP systems has been found by many companies to be extremely expensive and sometimes problematic to adapt a standard system to the particular problems faced by the company (Xu et al. 2002). Al-Mashari et al. (2003) describe critical success factors for ERP systems, summarising that the benefits from ERP systems are realised when "a tight link is established between implementation approach and business-wide performance measures". Spring and Sweeting (2002) describe the development of enterprise systems using Advanced Planning Systems (APS). Another novel approach has been proposed by Vandaele and De Boeck (2003) described as Advanced Resource Planning, which sets out to
address aggregate planning and provide lead-time, lot size, service level and delivery times through consideration of stochastic system behaviour and queuing networks.

Aggregate planning of 'perishable' food industry production facilities is described by Tadei et al. (1995), with regard to the annual and short term (monthly) scheduling to minimise conflicting personnel and inventory costs. Jones and Kurse (1999) describe the functioning of an ERP system and basic modules from which it is built, going further to underline some of the shortcomings of ERP, particularly with respect to the food sectors. Suitable ERP packages that support formula and recipe-based product configurations are described by Jones and Kurse (1999). Hare (1999) describes the implementation of ERP system into a dairy manufacturer including the problems faced by the company in terms of demand variability, product variation and compatibility over various lines etc. ERP was implemented alongside existing warehouse management system enabling product tracking throughout the factory. The benefit of the internet to share data across enterprises is described by Davis (2000) who also explains how ERP providers have upgraded systems to have online capability.

5.2.2 Production Scheduling

Production scheduling rules are sets of heuristics or algorithms often referred to as sequencing, or loading rules, which are used to select the next job to be processed, identify that job's route through the production system and to assign the job to appropriate resources. Scheduling rules have been developed to support most production planning and control systems notably flexible manufacturing systems (Aanen et al. 1993; Sabuncuoglu 1998-a; Gamila and Motavalli 2003); however the use of scheduling rules may be applied to off-line and on-line (real time) planning and control, as well as centralised or distributed production environments. Studies into Scheduling practices and perspectives have been undertaken extensively, and several have been outlined by MacCarthy and Wilson (2001), who also describe the growing complexities of schedulers roles in supply chains, and describe in detail a hybrid intelligent production scheduling system. They also describe human decision makers acting as an interface for changing or conflicting goals, applying impartial data and grouping jobs that meet common criteria when applying a software based scheduling system. Basic scheduling rules have been used for many years (Panwalkar and Iskander 1977) as part of the operations research approach to scheduling, with variations utilising many
contemporary techniques including simulation (Rahimifard and Newman 1997), artificial intelligence (Steffen 1986), neural networks (Sabuncuoglu 1998-b) and genetic algorithms (Shaw and Fleming 2000) having been proposed to address industrial scheduling problems.

Scheduling rules may be classified as either static or dynamic rules. Examples of static rules include ‘earliest due date’ and ‘minimum number of operations’ which have performance indices that are independent of time, and therefore are commonly applied prior to production, resulting in a fixed schedule for that production period (Gupta et al. 1989; Vollman et al. 2005). Static scheduling rules are often used in a ‘predictive production planning and control structure’, using off-line planning and control techniques. The utilisation of such static rules enables the sequencing, routing and allocation of jobs to be carried out based on an optimisation process, to satisfy a number of particular manufacturing goals (e.g. minimisation of machine set up times and the number of required tool change over activities). Medium term plans may be commonly generated using an off-line method based on a longer planning horizon, from a month to a week. The length of this planning horizon is influenced by a number of factors such as the average manufacturing lead times of the products, the business requirements, size of the manufacturing system and the length of time for which a reasonably accurate rough cut plan can be generated by the master production scheduling process. However, off-line scheduling can experience difficulties when requirements arise for the frequent update of schedules (i.e. rescheduling) due to changing production conditions within a unpredictable manufacturing environment.

Dynamic scheduling rules such as ‘slack time remaining’ or the ‘machine with the shortest queue’ are time dependent and must be used in conjunction with real time data (Vollman et al. 2005). As a result, the terms ‘real time’ or ‘on-line’ are usually used to refer to planning and control systems with capabilities of incorporating such dynamic rules within a ‘reactive production planning and control structure’. Dynamic scheduling postpones loading decisions thereby preserving routing options for as long as possible in order use the system’s flexibility opportunistically. In this way dynamic scheduling makes routing decisions for a part incrementally as the job completes its operations and therefore the next destination resource for a job at any stage is decided only when its current operation is nearing completion. Short term plans may be developed using an on-line method based on a shorter planning horizon of a day or a shift. The length of this planning horizon depends on a range of issues such as the reliability of the manufacturing system in terms of machine breakdowns,
the frequency with which additional workloads in terms of new jobs are required to be added to existing schedules and other dynamic factors influencing the manufacturing system. Within a real time planning and control system there is a need for integration of a manufacturing system model via a computer network to the physical resources on the shop floor. This model continuously receives information on the progress of previous production instructions and system status through data acquisition systems. This updated information is then used to generate further production instructions and to make appropriate corrective modifications to overcome any possible problems caused by changes through production. As a result, real-time planning and control systems are often used in applications with expensive and modern manufacturing systems with certain levels of automation which can support a fast and responsive information structure.

Scheduling software has aided significantly the process of schedule generation, both speeding up the process, and allowing optimisation of the schedules produced to improve production planning. However Kuo and Hwang (1999) propose the balancing of tasks to remove boring and time consuming tasks to allow human schedulers 'thinking space' as human-computer interactions often require the combination of both to approach complex situations.

The scheduling of production in the food industry has increased importance due to the particular problems posed by the material properties of the food products themselves which limits the extent that caution may be exhibited in scheduling due to wastages resulting from shelf-lives (Nakhla 1995). In its most simple case a food manufacturer may backwards schedule a batch of product from its due-date before applying scheduling rules to ensure that the product is processed as late as possible and hence leave the factory with as great a shelf-life as possible. Further complications are evident however, such as when orders to or shipments of ingredients from suppliers arrive and how this influences the way a schedule is created (Gargouri et al. 2002). Shaw and Fleming (2000) use ready-meal scheduling as a complex example that is subject to forecast volatility, drastic production changes, and often subject to demands of flexible preferences greater than offered by standard rules.
5.2.3 Production Activity Control

Production activity control is described by Browne et al. (1996) as the layer of the Production Management System responsible for the transformation of planning decisions into control commands for the production process. Hierarchical reference models have been developed for the control of modern manufacturing systems, with the most well-known of these models being NBS/NIST and CAM-I models. These models consist of five and four levels respectively, however the control at shop level links offline control (at factory level) to online control (at the work centre level) and is therefore of critical importance. Banerjee (1997) presents the methodology behind designing a production control system through customisation of a number of such reference models for particular applications.

Higgins and Browne (1990) describe effective activity control as being dependent upon real-time data capture and monitoring. Kehoe and Boughton (2001) go further to propose more extensive use of internet technologies to contribute benefits of planning and control across supply chains.

5.3 Supply Chain Management

Supply chain issues have been extensively researched under the banner of Supply Chain Management (SCM). Equally the ranges in different definitions as to what SCM is, vary considerably Metzner (2001) categorises the different definitions as a management philosophy, the implementation of a management philosophy or a set of management processes. The basic descriptions of supply chains vary, though the underlying purpose of SCM activities is to improve the operations across the whole supply chain in order to satisfy the ultimate customer (Quayle 2002) but in particular at the interfaces between companies. Much time and effort has been channelled into negotiating a favourable position for the individual companies in terms of transaction costs, organisational costs, balances of power etc. Hull et al. (1999) go further to discuss the importance of trade-off management – improving overall supply chain performance by one member of the chain ‘losing’. Partnerships may be formed between two or more of the supply network companies, and may take many forms, though all are based on mutually beneficial relationships to reduce uncertainty through improved information flows with the hope of increasing the profitability of the supply chain (Maloni and Benton 1997). Trust issues remain when inter-organisation
activities are undertaken, even where companies working in the same supply chain for many years begin a new improvement initiative. It may be commonplace for companies to set out confidentiality agreements or develop contractual obligations with supply chain partners before sensitive data or particularly co-operative initiatives are set into place. What works best in each case will be subject to negotiation between the companies involved, for example a contemporary practice by large retailers with many ready-meal supplier manufacturer partners is to have employees (planners) from the manufacturers based at their offices to co-ordinate communications and help interpret ordering fluctuations.

Supply chains themselves are simply distribution channels that exist within business and vary considerably in size and complexity, particularly for large companies who are members of many supply chains, such as retailers (Metzner 2001). It has been suggested (Mason-Jones and Towill 1997) that there is a need for a holistic view among supply chain companies, with a single company either becoming a product champion to drive the development of a supply network or supply chain activities, meaning that often networks are built around focal companies. Diagrammatic representations of supply chains also vary considerably, though commonly have a focal company and supplier and customer on either side, (Hvolby and Trienekens 2002) creating large, complicated representations of the systems when all suppliers and customers are included. The modelling and simulation of supply chain behaviour and dynamics has been described (Towill 1996; de Souza et al. 2000), however most representations of supply chains form simple box figures. The extended supply chain shown in Figure 5.1 also indicates companies which, though not directly part of the product or information flows of the channel, also have some level of involvement in SCM, marketing and logistics considerations for example.

Lamming et al. (2000) outline the development of theory and practice with regard to supply chain management, and further into supply networks providing classifications of networks based upon different dimensions.
As such they highlight coordination mechanisms (social, bureaucratic, proprietary); the object of exchange (hard and soft networking of problems, training etc); orientation of the network; integration; and finally network dynamic as dimensions by which networks may be classified. Two distinct types of network are identified, those for innovative-unique products and functional products, they also propose that three aspects of the product to be supplied decide how the network should be managed, namely product innovation, product uniqueness and product complexity. The initial development of supply networks is always different, with a great deal of instability in many cases with regard to relationships and interdependencies between the companies involved (De Toni and Nassimbeni 1995). Hull et al. (1999) describe how organisations should determine strategically which performance metrics a business (or supply chain) will excel in, and in which it will be average; a set of benchmark metrics for comparing competing supply chains is proposed using Kaplan’s scorecard (Kaplan and Norton 2000). Oliver and Delbridge (2002) suggest that successful supply chains share common characteristics, using the automotive industry to establish low inventories, frequent communications and ‘up front’ planning and control as common features. The case can be argued however for companies to ignore the performance of competitors and to strive against a model of perfection, as advocated by Womack and Jones (2003). The performance measures that are used to assess the chain members, and indeed chains themselves, must be carefully selected. Currently accepted measures include inventory turns (measured by sales/inventory value), service (measured by on time shipments % and responsiveness to orders), quality (measured as number of defects as % of products) and unit costs. The best measures for benchmarking promote coordination between managers of upstream and downstream flows (Metzner 2001) which may be achieved through use of the

Figure 5.1, the supply chain extended to include other additional functions that complex supply chains perform (adapted from: Metzner 2001).
performance measures and best practices used in the Supply Chain Operations Reference (SCOR) model developed by the supply chain council (Stephens 2001; Stewart 1997).

Grimsdell (1996) highlights scale of operation, production flexibility and continuity of supply as being fundamental to success for supply chains in the food ingredient sector. Information quality often impairs supply chain performance (Sivadasan 2000) with complexity arising as changes to orders (including quantities, priorities or cancellations), specifications and deliveries. A 'data rich SCM' utilises fast flowing information between its partners. This information must be delivered in a timely manner, in a format that is inherently of use to partners, be passed securely and be of some use on one of a number of levels:

- Within transaction systems (order data, customer inquiry etc)
- Management Control (productivity measurement etc)
- Decision Analysis (Inventory levels, scheduling)
- Strategic Planning (Development and refinement of capabilities and opportunities)

5.3.1 Bullwhip Effects

The bullwhip effect, was first identified by Forrester (1961) and has been extensively investigated since (Metters 1997; de Sousa et al. 2000; Franswoo and Wouters 2000; Johansson et al. 2000; Mason-Jones and Towill 2000; McCullen and Towill 2002; Dejonckheere et al. 2003; Svensson 2003). Mason-Jones and Towill (2000) summarise the bullwhip effect as the following 'law':

*If demand for products is transmitted along a series of inventories using stock control ordering, then the demand variation will increase with each transfer.*

Material and information flows may be considered as continuous processes, carried out through pipelines. The effect of traditional supply chain operations has the effect of amplifying demand uncertainty as shown in Figure 5.2. Its basis is the amplification of demand across a supply chain, to the point of creating seemingly unpredictable demand volatility in suppliers. Additionally, problems occur when one company's actions are reflected across the whole supply chain, so organisations that create demand volatility can increase the complexities and costs across the whole of their supply network.
Demand signal amplification along supply chain

Order fluctuations here are considered to be +/- 20%

Order fluctuations here are considered to be +/- 10%

Order fluctuations here are considered to be +/- 5%

Suppliers → Manufacturer → Large Retailer → Consumers

Material Flow Pipeline → Order Information Flow Pipeline

Figure 5.2, The Bullwhip Effect up the supply chain (adapted from: Mason-Jones and Towill 2000)

The Beer game simulation (developed at Massachusetts Institute of Technology in the 1960's) may be used to describe the amplitude effect up the supply chain (Goodwin and Franklin 1994; Hull et al. 1999; de Sousa et al. 2000; Mason-Jones and Towill 2000) and has been used to identify problems in supply chain communication with regard to demand, and such a view highlights the lack of communication within a supply chain, the lack of knowledge of true demand and any delays in information transfer. This indicates that individual companies attempts to co-ordinate a supply chain will often fail and it is established that old data causes delay, amplifications of demand and overhead. Bolton (1998) describes the impact an organisation itself can have on the demand volatility it perceives in its products and claims that the ways in which company's can contribute to demand volatility are the terms of trade, promotions or pricing, specific company policies (e.g. order quantities) and distribution channel structure. As such, structuring an approach to tackle a company's demand problems should be undertaken, an example of which is provided by Bolton, and is shown diagrammatically in Figure 5.3.
Johansson *et al* (2000) demonstrates a further simulation of the supply chain to emphasise the bullwhip effect, though this is based purely on theory. Several suggested improvements to supply chain performance come about solely through improved information flow (Mason-Jones and Towill 1997; Hull *et al.* 1999) though it is the quality of information passed which is key to improved performance as maintained by Fransoo and Wouters (2000). Supply chain performance has been reported as being significantly improved when Point Of Sale (POS) demand information is passed directly to each member of the chain. Wal-mart (the American retailer) is credited with breaking down many of the barriers to information sharing, and passed it's consumer market data to suppliers for their strategic and tactical use (Mason-Jones and Towill 1997).

Disney and Towill (2003) describe the Bullwhip effect as the combination of the Forrester effect (caused by non-zero lead-times and demand signal processing), the Burbidge effect (caused by order batching for economies), the Houlihan flywheel effect (Houlihan 1987) and the effect of promotions. Disney and Towill (2003) consider a practical approach (Vendor Managed Inventory) to reduce these combined effects, reporting positive improvements, and elimination of a number of underlying effects altogether. The reduction of bullwhip effects have been described as achievable in practice by McCullen and Towill (2002) who describe control system, time compression, information transparency and echelon elimination principles to make the required changes. Elimination of bullwhip effects can improve profitability significantly as suggested by Metters (1997).
5.3.2 Collaborative Planning Forecasting and Replenishment

The basic underlying principles of Collaborative Planning Forecasting and Replenishment (CPFR) are based upon the adoption of a ‘trading partner framework’ to focus the operations on consumers, the mutual development of a single shared forecast of demand for planning across the value chain and then commitment to the shared forecast through removal of supply constraints as defined by the Voluntary Inter-industry Commerce Standards (VICS) (VICS 2002). Barratt and Oliveira (2001) describe CPFR as the evolution of Efficient Consumer Response (ECR) (as described by Sharpe and Hill 1998 and Lowson et al. 1999) with the aim of supporting collaborative undertakings where previous business practices (such as Vendor Managed Inventory (VMI) and Continuous Replenishment) were inadequate. The activities included as part of CPFR have been summarised in Figure 5.4, indicating the many areas in which CPFR focuses collaboration between supply chain members.

Figure 5.4, Collaborative Planning Forecasting and Replenishment (CPFR) (VICS 2004)
The development of a set of standards to maintain the benefits of existing e-commerce standards (such as Electronic Data Interchange) through accessible technologies such as the internet, Value Added Networks etc. has been undertaken and documented by the VICS association (VICS 2002). CPFR standards set out to maintain electronic standards such as EDI when new technology collaboration tools are used to improve supply chain business practices (VICS 1999). The benefits to the supply chain by the development of a CPFR implementation have been described by VICS association as:

- Enhanced relationships between sellers and buyers (manufacturers and retailers)
- Greater sales due to an improved business plan
- Improved Category Management through greater scrutiny
- Improved product offering through collaboration on product opportunities
- Improved order forecasts compared with other approaches
- Greater lead-time for production planning
- Inventory reductions
- Improved technology return on investment

![Figure 5.5](image.jpg)

**Figure 5.5.** An overview of the 9 stages to the generic CPFR process model (adapted from: VICS 2002)
Implementing the CPFR process has often been based around pilot schemes before undertaking a roll-out phase, though every collaborative undertaking will be different, with each supply chain partner having different strengths, competencies and levels of commitment, however the nine major steps of the generic CPFR process model have been outlined in Figure 5.5.

5.3.3 Technology Supporting Supply Communication

Several tools and technologies are available to simplify, speed up and standardise interactions between supply chain partners and to streamline data processing and handling to improve coordination of material handling and replenishment of products.

5.3.3.1 Electronic Data Interchange and the internet

Electronic Data Interchange (EDI) has become well established as a means of improved communication of standard, regular information between supply chain partners (Mentzer 2001). Orders are regularly placed by retailers via EDI methods, which are based on agreed standards and take place through a Value Added Network, an example of a specialist application service provider, a third party through which the supply partners communicate (Lowson et al. 1999; McGuffog 1999; Johnston and Mak 2000). The agreed standards give the rules for the structure of the document and specify which information is required and which is optional. Organisations sending and receiving documents determine what information to send between each other, and are referred to as trading partners, with the greatest benefit coming in scenarios with considerable environmental uncertainty (Maltz and Srivastava 1997). However some larger companies specify the nature and intended use of the information to be exchanged and are often unwilling or unable to change. Owens and Levary (2002) describe a food processing case where EDI potentially reduced raw material ingredient inventory.

5.3.3.2 Point Of Sale Data

Point Of Sale (POS) Data is collected by retailers at the store checkouts electronically by bar code scanning. Each product has a unique code printed on its label which is collected with
each transaction that the retailer makes. The code allows product information pricing or offers to be updated to the bill quickly and easily, and also allows the retailer to gather a great amount of demand information, consumer profiling and correlation for marketing purposes (Lowson et al. 1999). This data is sometimes made available to supply chain partners, notably with Wal-Mart breaking several barriers and supplying manufacturers with POS data (Mason-Jones and Towill 1997; Maltz and. Srivastava 1997; Mason-Jones and Towill 2000; Barratt and Oliveira 2001; Womack and Jones 2003). Where this data is available real-time then planning and forecasting can be substantially impacted, as consumer demand can be responded to accordingly. The availability of POS data amalgamated into monthly reports is provided by some retailers, which is of little benefit to supply chain partners, other than in long term trend forecasting.

5.3.3.3 Radio Frequency Identification

Radio Frequency Identification (RFID) technologies received a great deal of media attention in their introduction to the food industry supply chain for effective tracking through to sale. The technology works on the use of ‘tags’ which are attached to product or cases and passively hold information regarding the product until they are ‘read’ by an antennae as products pass through that antennae’s field of operation (Finkenzeller 2003). The tags draw energy from the radio frequencies transmitted by the antennae, and then pass a unique information code back through to the information system which is tracking the product. Where manual checking of containers and products has been undertaken in the past, even by electronic barcode systems, RFID presents significant time savings in that as soon as a container passes out of the factory it may be automatically located without the need of a human operator searching out the product and scanning it. Current drawbacks to the technology are the cost of the tags (at around $0.25-$0.35 each in 2004- with predictions prices will fall to around $0.05 (Jones et al. 2005)), consumer concern over privacy invasion and the lack of appropriate global RFID standards (Woodland 2005). Benefits of using RFID through the supply chain have focused around traceability of products and the reduction in the number of out of stocks given the improved visibility of supply fulfilment (Jones et al. 2005).
5.3.3.4 Supervisory Control and Data Acquisitions

Supervisory Control and Data Acquisitions (SCADA) systems provide the opportunity for communications from the production environment to be regulated and control of activities to be placed further into the hands of the production supervisors. Such systems cover a wide range of techniques and technologies at the most sophisticated end providing full process automation and control (Boyer 1999). Simpler cases involve the collection of production data for use when making management decisions, active and passive devices can either automatically relay data to an IT system or provide production operators with the means to input data relating to production conditions (Hurst 2001).

5.4 Simulation

There are several forms of simulation, depending on the focus of what is being modelled. Dynamic simulations are models that are influenced by time (Gogg and Mott 1993) while discrete event simulations are driven by instantaneous actions that occur at points in time and are widely used for manufacturing applications (Robinson 1994). Aspects of simulation software may incorporate graphical features, such as Visual Interactive Simulation (VIS), which has been available since the late 1970s (Bell and O'Keefe 1987; Robinson 1994). Software packages of this type incorporate an animated display of some aspect of the system and an interaction between the user with the capability to check function validity to give a greater understanding and appreciation of results (Hurrion 1986; Bell and O'Keefe 1987; Robinson 1994). More effective communications between the user and the simulation analyst so that both have an improved understanding of the problem was a key reason in developing VIS (Hurrion 1986) which is the underlying communication aid that Alabastro et al. (1995) recognise as being crucial when dealing with large teams or when presenting a concept.

Simulation projects generally follow a common set of steps (Law 1986; Askin and Standridge 1993; Gogg and Mott 1993; Seila 1995; Lung 1998). Despite similarities, most papers emphasise different aspects in applying simulation; Law (1986) outlines model elements and where simulation may be applied while Gogg and Mott (1993) provide a view of simulation as a planning and problem-solving tool that must be set against a justification of costs (i.e. compare against financial analysis, Internal Rate of Return, cash flow analysis
etc.). Askin and Standridge (1993) however emphasise the difference between efficient and effective model building and that common practice within projects is the poor generation of formal documentation (also shown by Schormann & Perera 1998). Seila (1995) details the steps in simulation and provides a modelling methodology while Lung (1998) advocates the use of systematic templates for projects and the development of a consultancy database. Other articles introducing simulation address issues such as the importance of problem solving elements in simulation tools, rather than data processing (Ramsell and Rasch 1989). Sterman (1996) focuses on the limitations of various modelling approaches, Salt (1993), however argues the case for building simpler models, allowing for easier changes and disposal of models in favour of newly released technology. Sources that indicate that most simulation projects follow a similar form are generally in agreement in terms of the major steps that define the work. These key elements are outlined in Table 5.1 (Law 1986; Musselman 1993; Gogg & Mott, 1993; Seila 1995; Lung 1998; Liyanage and Perera 1998;) the approximate proportions indicated for each stage of individual projects having been described by (Liyanage & Perera 1998).

There are a wide variety of software packages available to perform simulation though these can be broadly classified as either a simulation language or a simulator (Banks 1991; Robinson 1994). Simulation languages can be used for accurate simulation of complex systems, though the extensive learning and training required to model with such a package effectively is extensive. Simulators can be utilised by those most closely linked with the problem, who have a greater understanding of the nature of the problem, without the need for expert level understanding required for efficient simulation language use (Robinson 1994).

Almodovar (1988) stresses that expert simulation personnel may be better employed to use simulators and use the time saved to learn in more detail the specific system being modelled. This ensures that a working model is produced that will be subject to vigorous analysis; however there is still the danger that the root of the problem will be missed and the wrong solution supplied as the modeller will not be as well aquatinted with the intricacies of the problem.
### Project Task | Definition | Approximate Project time
---|---|---
Problem Definition and Analysis | A written statement of the problem-solving objectives, understood by all involved, and it is the problem that needs solving | ~10% each
Data Gathering and Validation | The models input parameters are specified and data collected relative to the model detail. The data is checked to ensure it is both appropriate and representative | ~10 to 40%
Model Construction | The model is built from either a simulation language or a simulator, it should be a simplified representation of reality, though including enough detail to provide a good approximation remembering that this will be used for problem solving | ~10 to 40%
Verification and Validation | Verification determines whether a model correctly performs as intended, and validation establishes the credibility of the model, ensuring there is a correspondence between the real system and the model—typically by collecting and comparing data from both | ~10%
Experimentation | Experiments are planned to efficiently produce meaningful output data from experimental test runs. The conditions that produce a change in results can be altered and contrasts between alternatives highlighted | ~10 to 20%
Analysis of Results | Statistical procedures should be implemented to measure performance, including estimates of errors where possible | ~10%
Recommendations | Documentation of the model is good practise to avoid any duplication of effort, assumptions made in the model should be noted and if suitable, the model should be implemented | ~5%

**Table 5.1.** Typical stages comprising a simulation project

Examples of simulation models used for performance improvement support or cost/benefit analysis undertaken within the food industry as a whole are rare, even in areas of vague relevance to a ready-meal manufacturer, with Woollen (2001) introducing the concept of simulation software for use in the food industry.

#### 5.5 Lean Manufacturing Philosophy

There are a range of methods that are available for effective management of production systems one of the most widely recognised of which is lean manufacturing. The concepts and mindset associated with lean manufacturing was developed under a philosophy first conceived within the Toyota Production System (TPS) as reported by Womack *et al.* (1990). The TPS was developed by engineers working at Toyota, notably Taiichi Ohno to be customer focused and aimed to eliminate all stages through production that added costs but no value, in other words waste. Muda is translated from the Japanese for waste, with muda being a cornerstone of the lean philosophy (Womack and Jones 2003). Ohno (1988) identified the seven original wastes identified as overproduction, waiting, transportation,
inappropriate processing, unnecessary inventory, unnecessary motions and defects. A further seven wastes have been claimed to exist (Bicheno 2000), covering environmental, human potential, inappropriate systems and customer service related sources of wastes. The production system developed by Toyota Motor Corporation to provide best quality, lowest cost, and shortest lead time through the elimination of waste comprised of two pillars, Just-in-Time and jidoka (Ohno 1988), and may be represented as shown in Figure 5.6. Just In Time (JIT) pulls the flow of production from the customer rather than pushing from production, and is based around as series of signals or Kanbans to indicate when production processes should make the next part (Huang and Kusiak 1996). JIT works best with a level demand, as reflected through the takt time calculated for production cells (Feld 2000; Simons and Zokaei 2005) to facilitate the lean philosophy heijunka which deals with efforts to flatten the demand for products (Womack and Jones 2003).

Standardised work throughout the facility for stability is another prerequisite of the philosophy, along with the application of kaizen, or ‘continuous improvement’ whereby processes systems or products are deconstructed and put back together better (Bicheno 2000). Jidoka has several meanings in English, but can refer to ‘automation with human intelligence’ (autonomation) (Ohno 1988) and also stopping a manual production line when something goes wrong.

![Figure 5.6, Toyota Production System (adapted from Gemba 2005)](image-url)
As such jidoka contributes greatly to continuous improvement activities, and ties in with the idea of poka-yoke, or mistake-proofing (Shingo 1995). Many lean implementations fail, as the philosophy requires a mindset change and for cultural underpinnings of the company to be sympathetic to the changes that lean manufacture demands. Although there have been recent suggestions (Womack 2005) of the application of ‘fractal’ lean concepts to points of production where flow and waste reduction can be most benefited without entire production systems undergoing the move towards lean manufacture.

5.5.1 Tools and Techniques to aid lean thinking

The many tools used to highlight lean manufacture may be grouped to consider either analysis and mapping, or production system tactics and a range will be outlined here.

5.5.1.1 Lead-time mapping

One of the most simple analysis tools is lead-time mapping, which tracks, quantifies and prioritises the steps which contribute the total lead time. The concept behind the mapping is to highlight the main causes of delay in the products lead time by arranging the production steps which are commonly displayed chronologically in a Gantt chart format, into a Pareto format (Bicheno 2000). By severing the process step dependencies and focusing on the lead-times, those process steps which may contribute the greatest time savings can be focused upon, as shown in Figure 5.7.
5.5.1.2 Process Activity Mapping

Process Activity Mapping is a name given to the process analysis style of mapping which originated in industrial engineering (Hines and Rich 1997) which may be summarised thus:

i) The study of the flow of processes

ii) The identification of waste

iii) Consideration of whether the process can be rearranged in a more efficient sequence

iv) Consideration of a better flow pattern, involving different flow layout or routing

v) Consideration of whether everything happening at each stage is necessary and the result should superfluous tasks be removed

Studies of process activities has been undertaken within industrial engineering to analyse process performance and to plan for improvements through waste elimination (Ishiwata 1997), however the mappings described here directly relate to the activity types, distances moved and the elimination of those activities that are unnecessary or wasteful. An example of a simple Process Activity Mapping is shown in table 5.2.
Table 5.2, Example Process Activity Mapping

5.5.1.3 Value Stream Mapping

Value Stream Mapping (VSM) is a lean tool, and like all lean tools has as its underlying motive the elimination of waste. VSM serves to identify sources of waste by creating visualisations of the flows (or ‘value streams’) of product through to final consumer from raw materials and tracking which processing steps add value and which do not. VSM provides a visualisation of the physical and information flows through a particular value chain (Tapping et al. 2002). The physical flows through a supply chain concern the movement and processing of products and components from raw material right through to delivery of finished goods. By information flows, all communications of information between supply chain members and also departments within a company which have regard to order placement and processing, stock availability and confirmations of orders goods received. In short, the process of VSM may be described as (Rother and Shook 1998, Duggan 2002) selecting a product family, creating a current-state map then creating a future-state map using lean techniques, creating an implementation plan for the future state and then implementing the future state through structured continuous improvement activity.

By selecting a product family, operational issues for each set of individual products are separated, simplifying problems so that they may be acted upon more easily. The choice of product family has no strict ruling, though it is of most use to identify products with similar if
not identical processing routes as viewed from the furthest point downstream (towards customer) in the value chain. Alternative means of selecting product families (where many products run to similar process routes) have been demonstrated such as considering products with different demand and revenue profiles according to a Pareto split (Hines et al. 1999). The primary drawback of the VSM process is its product-focused nature, which makes each mapping very specific to a small number of products dependant upon the product families determined at this stage of the VSM process. In order to gain a balanced view of the performance, product families and their mappings should be decided carefully to be representative of the supply chains product portfolio.

After deciding which particular product family will be the subject of the mapping activity all the production steps, wasted time, inventory, product movements and shipments are logged to describe the total time from start of value stream to end. The boundaries of the value stream are identified to begin with, usually focused within one particular enterprise from the shipments of raw materials received and finishing with despatched products, though this may be extended to consider supply chain partners as described by Jones and Womack (2002). The application of extended value streams have been described as useful for raising the awareness of lean issues across supply chain partnerships to drive improvements (Womack and Jones 2003). The typical data required to perform the initial steps in creating the ‘current state’ value stream map have been described as relating to (Duggan 2002) the process steps, cycle times for processing, changeover times between production runs, machine uptime, number of operators. This required information may be collected simply by observation. It is however emphasised that the data is best collected by spending time within the production facility considered and following product flows and witnessing first hand production activity. Creating a current state map has traditionally been completed manually on paper, drafting the outline of the map using standard symbols and linking these symbols in a standardised way, with data relating to process steps and information flows being included at the relevant positions on the map. Once the current state map has been created improvements to the mapping based on lean principles to improve flow, smooth ‘pull’ through the value stream and remove wasteful steps can be made. VSM utilises several other additional tools such as the quality and delivery screen for identifying percentages of defective deliveries and defects per part per million and decision point analysis (as shown in Figure 5.8) which provides a representation of the dislocation point of customer pull and supplier push.
This identifies where manufacture is based upon actual demand and to what extent production must be based upon forecast driven data. The knowledge of where decision points lie in a supply chain allows strategic partnership/benchmarking targets to be set in order that decision points may be moved.

5.5.1.4 Demand Amplification Screen

One of the Lean tools the author recognises as providing considerable benefit to the research is the Demand Amplification screen, as described by Jones and Womack (2002). This analytical tool simplifies the demand amplification data collected at each site across the extended value chain and provides an indication of the incidence of the bullwhip effect on the supply chain considered (Hines and Rich 1997; Hines et al. 1999; Hines and Taylor 2000). When combining the demand amplification diagrams across the value chain, the result is shown in Figure 5.9 (Jones and Womack 2002). This screen can then be used to show demand across the supply chain and aid decision support for value stream restructuring and reduction (and benchmarking) of demand volatility (Jones et al. 1997).
5.5.1.5 Product Family Analysis

Product family (also known as product/quantity) analysis provides emphasis to the products that require the primary focus of the manufacturer. A simple means of undertaking such analysis is to arrange products based upon sales volume (Feld 2000). The different products may then be grouped relative to their volume of sales for the supply network and it is claimed that many manufacturers experience a breakdown of products and volumes as shown in Table 5.3 (Glenday 2005).

<table>
<thead>
<tr>
<th>Cumulative Volume</th>
<th>Cumulative % of products</th>
<th>Grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>50%</td>
<td>6%</td>
<td>1</td>
</tr>
<tr>
<td>95%</td>
<td>50%</td>
<td>2</td>
</tr>
<tr>
<td>99%</td>
<td>70%</td>
<td>3</td>
</tr>
<tr>
<td>100%</td>
<td>100%</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 5.3, breakdown of products and associated volumes (adapted from: Glenday 2005)
In this way, it is inferred that the split of products to corresponding volume roughly follow a Pareto breakdown (Michalski 1998) which then allows alternative processing arrangements to be considered (Charney 1991). Feld (2000) breaks the split of products into 3 groups, termed 'runners, repeaters and strangers', based on the demand levels and order frequency. It is suggested that by organising production so that high volume products are levelled, either by manufacturing them together on separate equipment, or in specified level blocks that throughput can be substantially improved through improved utilisation of capacity, while focus on changeovers for the lower volume products can maintain their throughputs by reducing waiting times (Glenday 2005).

5.5.1.6 Supply Chain Response Matrix

The Supply Chain Response Matrix is also known as 'time based process mapping' however these mappings each aim to represent the critical lead-time constraints associated with processes (Hines and Rich 1997; Jones et al. 1997). This straightforward representation aids in identifying the bottlenecks in production which contribute greatest to lead-time delays (plotted on the horizontal axis); and points to those steps though supply where inventory builds up and subsequent waste/costs are created. Cumulative inventory is plotted on the vertical axis, showing the amount of working day's material held in the system, with the total lead time and inventory time calculated to give a 'response' time (Hines and Rich 1997).

5.5.1.7 Production Variety Funnel

The Production Variety Funnel outlines the number of product variants through the various stages of production, mapping the number of physically different product units at each stage against the average process lead-time (Bicheno 2000). The number of part variants is plotted on the vertical axis while the lead-time for the processes is indicated along the horizontal axis, as outlined in the simplified view in Figure 5.10. The Production Variety Funnel is similar to the IVAT analysis (Hines and Rich 1997) which classifies the operations within a company as demonstrating an 'I', 'V', 'A' or 'T' shape. Convenience food manufacture commonly displays the I shape, as shown in Figure 5.10, where many ingredients undergo similar processing before being assembled into many final products.
This tool is of use in widening understanding of how the firm operates and the accompanying complexities to be managed (such as targeting inventories for reduction and processing priorities), while at the same time highlighting similarities with other industries (for example the convenience food funnel in figure 5.10 is the same shape as many generic chemical plants) (Hines and Rich 1997; Jones et al. 1997).

5.5.1.8 Single Minute Exchange of Dies

The concept of Single Minute Exchange of Dies (SMED) came about from large processing industry, where forming equipment underwent lengthy changeover operations when changing between products. Drastic improvements were achieved, with a changeover of dies taking four hours reduced to three minutes, largely through the conversion of processes from ‘internal’ set-ups to ‘external’ (Shingo 1995). Through detailed work study, analysis of handling procedures, improved equipment design, increased offline (‘external’) preparation for changeovers and training, the enormous reductions in changeover times were achieved (Feld 2000). The principles that drove SMED improvements may be applied to the simplification of changeovers of any process, with the goal of eliminating production down
time due to anticipated changeovers not simply focused upon equipment interchange (McIntosh et al. 2001).

5.5.2 Lean concepts applied to the food industry

There are a number of examples of lean manufacturing within the food industry, with Womack and Jones (2003) describing the supply improvements in cola cans for Tesco supermarkets, while Ohno (1988) was first inspired to develop the Just-In-Time system based upon the modern American supermarket. Simons and Zokaei (2005) report case studies from red meat processing, comparing facilities utilising takt time with 'traditional' processing lines, concluding that improved line balancing reduces overproduction waste and requires 25 percent less labour. Womack and Jones (2003) suggest the future for lean food supply as being e-commerce driven supported by collaborative replenishment systems, citing the potential benefits being shopper time and total costs being reduced were 'direct to consumer' shipments made from distribution centres.
Chapter 6

RESEARCH METHODOLOGY

6.1 Introduction

This chapter describes the research methodology used in undertaking the research reported in this thesis. The formulation of the research hypothesis, data collection methods used over the course of the research, the refinement of research concepts and activities and the use of a case study to demonstrate those concepts are described in detail as the methodological approach is outlined.

6.2 Research Methodology

The research methodology is based on an approach beginning with the definition of the research hypothesis, followed by the review and survey of relevant academic research and industrial practice, definition of research aims and objectives, the undertaking of research activities together with experimentation and demonstration of research concepts through a case study and analysis of research results. This research methodology is depicted in figure 6.1.

The research hypothesis (defined in Chapter 2) was initially formulated through the author's previous experience at undergraduate project level whilst undertaking simulation project at a convenience food manufacturer. This hypothesis was refined and its validity confirmed through an initial round of industrial visits across a range of convenience food manufacturers at the start of the research, which was undertaken in conjunction with a survey of literature in the food industry domain together with publications in operations management and environmental conscious manufacturing subjects.
It became apparent at the data collection and verification stage that a combination of quantitative and qualitative information would be required which may require direct measurement (such as product manufacturing lead-times). The author found that a standard questionnaire method of data collection for such requirements was unsatisfactory given the reliance on respondent comprehension and accuracy, and the potential poor reliability and quality of data that may be returned. Therefore, a system of semi-structured interviews was devised whereby a number of manufacturers in convenience food sectors were identified and an initial round of letters was sent out with an indication of question areas and a request for corresponding visits. This method received a 63% positive response rate, where manufacturers were willing to participate in the visits and provide data to the research. The author was able to use a predefined list of questions to structure the visits ensuring the specified data was collected in each case, and provision was made to allow considerable scope to include supplementary information.

The healthcheck and process modelling stages together with the definition of the waste model benefited from subsequent industrial visits to refine the knowledge and information collected and to support an iterative process of improvement. The waste model was initially drafted through flow charts, however the combination of requirements for process and material flow modelling meant that the waste model was particularly well presented through IDEF0 representation, as shown in section 7.2. In addition, the Responsive Demand Management Framework was initially specified using IDEF0 methods, which was further simplified and improved upon as shown in section 8.2.

The research concepts were demonstrated through application of each of the research activities to an industrial case study that was selected from the convenience manufacturers visited at the initial data collection stage. This case study started by definition of a waste model for the selected company followed by application of three stages of the RDM framework. Research conclusions were drawn from these applications based on the analytical assessment of the improvements proposed and achieved in production planning, supply chain, and waste minimisation.
Research aims and objectives, hypothesis and scope

Prior knowledge and background experience

Definition of Initial Research Hypothesis

Refinement of Research Hypothesis

Survey of Literature

Intensive initial undertaking with maintained over course of research

Data collection and verification

Programme of Industrial Visits

Semi-Structured Interviews

Structured questionnaire template

Specification of waste types and waste sources through production

Research activities

Return Industrial Visits

Waste Model

Definition of Waste Model

Waste Analysis

RDM Framework

Health Check and Process Modelling

Production and order lead-time improvements

Two Stage Planning

Experimentation

Selection of Case Study Company

Case Study Waste Model and Analysis

Case Study Data and Process Modelling

Case Study Production and order lead-time improvements

Two Stage Planning of Case Study Production

Research Conclusion

Analytical assessment of research result

Figure 6.1, Outline Research Methodology and Research Concept Refinement
Chapter 7

Modelling Waste in Convenience Food Production

7.1 Introduction

This chapter presents the investigation into the modelling of waste generated along the production and supply chain within the convenience food sector (CFS). Initial sections of the chapter outline the various types of waste created in CFS with the main sections of the chapter describe the various manufacturing processes and their associated waste types. The main focus in line with research objectives is to identify the processes during which the overproduction waste are generated. The chapter concludes by analysis of the environmental impact and the costs of these wastes.

7.2 Waste Model

One of the major objectives of the author’s research is the minimisation of waste in the CFS to support a sustainable approach to food manufacture. The model proposed in this chapter aims to provide a visualisation of waste in convenience food manufacturers and serves as the starting point for realisation of a framework for waste minimisation. The waste model has been generated and subsequently refined based on information collected/obtained over the course of a comprehensive programme of industrial visits and interviews as described in chapter 6. The visits included two ready-meal manufacturers, two sandwich manufacturers, two prepared meat manufacturers and one dairy producer, as summarised in Table 7.1 the reports from each manufacturer visit are available in greater detail in appendix 1. In addition, the publicly available data by government sources on the range and amount of waste generated by food manufacturers are used to complement the information gathered during the industrial visits and are included in the waste model. These include information obtained from Department of Trade and Industry (Department of Trade and Industry 2005-b) sources, the Environment Agency and Envirowise website (Envirowise 2005) which promotes the economic incentives of waste reduction.
The range of wastes created across the convenience food supply chain was briefly mentioned in Chapter 1 and is shown in Figure 7.1. These include waste generated during ingredient supply, manufacture, distribution, retail, final consumption and disposal. Ingredient supply activities in this research refers to the range of processes involved in gathering, preparing and transporting materials to a production facilities. In a similar manner, any process undertaken to prepare, cook and package the foods are considered in the Manufacturing stage, which is the predominant focus of waste minimisation in this research. The following step ‘Retail and Distribution’ brings together sources of waste in the downstream supply chain, from despatch at the manufacturer facility, through Regional Distribution Centres (RDC’s) to individual stores where product is stocked on shelves for sale to consumers. The final stage in this categorisation of waste in the food supply is the end consumption of the product while wastes created at this stage constitute excess food (organic wastes) and packaging wastes that are largely disposed of to landfill. IDEF0 representation which is one of the most popular modelling methods has been utilised to generate the waste model, the IDEF methodology is a structured modelling technique initially developed by the US air force and has been used extensively since for modelling systems (Kusiak 2002). IDEF0 representations are easy to comprehend with boxes representing functions and arrows representing input, output, control and mechanism interfaces while their hierarchical approach has the ability to model a system in many levels of detail (Dorador and Young 2000).
Figure 7.1, broad description of wastes across the food supply chain

Figure 7.2 presents an IDEF0 representation of various stage identified in the food supply chain and their associated waste types. These various types of waste are described below.

7.2.1 Bulk Wastes

These wastes are associated with the preparation of ingredients and may include inedible parts of the ingredient, such as stems, leaves, bones, excess animal fat etc; contaminated material or ingredients, such as outer layers of vegetables that are spoiled; and even soil or debris on the ingredients which needs to be removed by washing or mechanical means. The costs of these wastes are low, the mechanisms by which they are collected being their primary expense, and provided they are disposed of responsibly present little environmental hazard, being almost wholly organic material.
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7.2.2 Water Wastes

Water is used in large quantities in food processing, predominantly in the preparation, cleaning and cooking stages of the product's life cycle, as indicated in Figure 7.2. Water may form an ingredient for many products, but the waste water as described in this context is the water reclaimed at the end of the process either as a carrier for dirt and contamination or a bi-product from cooking or processing operations. To expand upon this, water (along with detergents) is the primary method for cleaning machinery and facilities of food deposits and contaminants, and large volumes of fresh clean water are used daily for this process. In addition water may be the medium by which cooking operations are completed, with many processes based upon the use of steam or boiling water to cook, and blanching or chilling using cold water. In some cases it may be possible to recycle the water after filtration, for example in Sous-vide manufacturing (see section 4.4.2), where the product is not in contact with the water throughout processing. However most applications result in the water having

Figure 7.2, IDEF0 representation of the Waste Model through life cycle
Chapter 7

the bulkiest debris filtered out and the contaminated water being disposed of to the drain or groundwater.

7.2.3 Processing Wastes

Processing wastes as considered here may be due to a number of different sources, and may be further described as being due to poor housekeeping procedures, process inherent losses or poor conformity.

7.2.3.1 Poor housekeeping

Spillages, damages and contamination of product may be caused by operator neglect or poor handling procedures, forming equipment making improper seals on packs etc. The creation of such wastes will largely result in waste product being spilt to the floor which will be disposed of as either bulk wastes or as trade effluent when the equipments and production areas are cleaned. In more unusual cases where housekeeping issues result in considerable waste being created these will be disposed of to bulk wastes.

7.2.3.2 Process inherent losses

Such losses are anticipated for imperfect processes for example as product yields are subject to variability and may result in wastes where a batch of ingredients yields greater amount of product than was planned for. Similarly, where ingredients under-yield, the other ingredients they were to be combined with may end up as bulk waste if they cannot be used for other products before their shelf-life expires. Bi-products in this context are materials that are created by the manufacturing process but have little or no value and cannot be used elsewhere, they may be well anticipated in production such as estimated volumes of juices or animal fats created with product which are removed and disposed of to give the desired product quality or consistency. Although not in a strict sense a waste, a number of product units must be kept from each production run for traceability and microbiological testing. These test products are kept in chilled conditions until such time that they are tested and passed or expire, at which time they are added to the facility's commercial waste. ‘Giveaways’ of product to ensure each individual product foil is above the specified weight is not considered a waste as part of this research, rather a cost to the manufacturer from ineffective process control. However should weight measurements be completed more accurately then is planned for (i.e. operators weighing closer than anticipated to the specified
limit) then excess ingredient may be left-over and made waste at the end of a production run as a result of less “giveaway” than planned, however the reduction of such giveaways is beyond the remit of this research.

7.2.3.3 Poor conformity
Wastes may be created at any time for any ingredient or product failing to adequately conform to specifications, with all final products being tested for quality, consistency, appearance, flavour and aroma etc. Rejected products may be packaged foils and be added to standard refuse waste or may be batches of sauces, meat or pasta for example that can be added to bulk organic wastes.

7.2.4 Packaging Wastes

Packaging wastes are widespread in the food industry to prevent contamination or spoilage of foods they are often packaged to protect them from their immediate environment. Packaging can vary from large paper based sacks for bulk ingredients to various plastic bags sheets and pouches depending on the product and situation. Some ingredients are packaged specifically for a processing operation and then have to be removed from that packaging for subsequent processing, (e.g. vacuum packaged meats) the material properties and specific nature of the packaging used being engineered for each application, though they are all disposed of in similar manner- to commercial waste disposal.

7.2.5 OverProduction Wastes (OPW)

OverProduction Wastes constitute significant cost to the company as materials and resources in manufacturing are wasted given that the product no-longer has an end customer. OPW may be used to describe batches of ingredients that have been prepared before order confirmation decreases in volume and cannot be re-directed before expiry. In such cases the ingredients will typically be scrapped to commercial waste and landfill as many own label manufacturers cannot re-direct the product to different customers in keeping with their agreements with the Retailers. It may be possible to reduce the impact both commercially and environmentally of OPW by the authorised extension of the products shelf-life by a companies technical department for those products to be sold at cost prices in the staff shop.
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Such practices are not always feasible, and it is the authors contention that a structured route to reducing incidences of OPW must be sought.

7.3 Waste in the Manufacturing Stage

The main focus of the research reported in this thesis are the wastes from production that will be described in greater detail in the remaining sections of this chapter. When considering manufacturing wastes, we must first establish the production processes undertaken to produce each product. Ready-meals and convenience foods are often varied in their form and format, and as such the processing of each product likewise varies. Nonetheless a generic process route has been defined and used as the basis for this waste model, encompassing activities common to most products. Figure 7.3 is an IDEF representation of these production processes within the manufacturing stage. This represents a breakdown of the activities in the manufacturing phase (box A2 in Figure 7.2 above) which are described in greater detail in sections 7.3.1 to 7.3.6.

Figure 7.3, An IDEF0 Diagram to develop a Waste Model for Production Processes in Convenience Food Manufacture
7.3.1 Goods Inwards

Raw materials arrive in bulk to the manufacturing facility and are typically checked upon or shortly after arrival for quality and fitness as required by the company's specified standards. It is unusual for ingredients to be found unfit at this stage, however any obvious damages or leakages that have occurred in transit can be quickly isolated to the commercial or bulk waste. Packing material is also created at this stage as ingredients are broken down into easier to handle trays or trolleys.

7.3.2 Ingredient Preparation

Preparation of ingredients may include washing, trimming inedible or excess parts, pre-measuring and weighing ingredients for a recipe, removing material from the packing cases or bags, storing or sealing ingredients into bags or pouches prior to processing or simply holding the product in the chilled 'Prep' area until it reaches the required temperature. As such the wastes created by the initial product preparations will include packaging material wastes, bulk wastes and waste water.

7.3.3 Cooking/Process Steps

Processing wastes as described in section 7.2.3 predominate in the cooking stages of convenience food manufacture with each of the three forms of processing waste being possible to create on virtually any equipment for any cooking process. That is not to say that process improvements and control cannot eradicate such wastes, in fact the reason for the distinction between bulk wastes and processing wastes is in order that such wastes be measured and improved upon. However, the establishment is that processing wastes are common in this form of manufacturing and can be generated at almost any stage of the cooking phase.

7.3.4 Pre-Fill Preparation

The simplest stage following cooking in most cases may be a cooling period where the cooked product must be held in a blast chiller to ensure its temperature is within a specified
limit. For cooking processes that have used bagged ingredients, the cooked product may need to be recovered, either manually or automatically from the packing, which will generate more plastic packaging wastes. It is at this stage (i.e. once cooking cycles have been completed) that OPW may be created by products becoming unnecessary as order volumes are confirmed. In such cases the production planner will typically try to balance schedules and make use of the ingredients before their shelf-lives expire, however should this prove impractical the OPW will be disposed of as bulk waste.

7.3.5 Filling and Packing

Filling refers to the assembly operation of adding cooked ingredients and materials to a tray which is sealed and then subsequently packed ready for shipment. Filling operations are typically undertaken on an assembly line using manual labour, supported by some automated processes, for example products having valuable ingredients being manually weighed before having sauce deposited into the tray which is sealed, weighed, labelled and x-rayed automatically. Some processing machinery inherently creates greater processing waste through poor reliability (notably seal formers) or the excess product they are unable to deliver to the line (such as sauce depositors that do not fully empty) creating wastes which are disposed of during the cleaning stages after production. As before, considerable waste water is generated in cleaning the assembly line and OPW (of packaged ready to ship products) can be generated as volumes are confirmed, however at this stage packaged product is no longer able to enter the bulk waste stream as easily and may more commonly be disposed of as commercial waste.

7.3.6 Despatch

Once the product has been packed into cases at the filling and packing phase described previously no further processing is required, however the exact quantities required for transportation to each RDC may highlight the OPW wastes that were not identified by the filling operators, or alternatively the order volumes may only be confirmed at this stage. In either case the finished packaged product may then be disposed of to general commercial waste should the demand have been over-estimated.
7.4 Analysis of Wastes from Convenience Food Manufacture

Three analysis methods have been used to identify the most appropriate approach for minimisation of waste in CFS, these methods being Waste Inventory analysis, Cost versus Environmental impact analysis and Reduce Re-cycle Disposal (RRD) Analysis. Each of these techniques of analysis are described in the following sections.

7.4.1 Waste Inventory Analysis

In order to assist in the consideration of wastes generated through convenience food manufacture and supply, this research has designed and proposed a systematic procedure for highlighting the wastes identified through manufacture in section 7.3. The aim of waste inventory analysis is to effectively summarise and highlight the data collected which aids in identifying means by which waste creation may be reduced.

Figure 7.4, Example Waste mapping for Convenience Food Manufacturer

Summarising the sources of waste through production is achieved through creation of a Waste Inventory diagram, which summarised the data available relating to wastes created at each stage, as illustrated for an example product in Figure 7.4. Each step of the mapping draws upon the associated wastes indicated from section 7.3, highlighting the salient waste creation data created at that stage, summarising the volumes generated for each classification of waste outlined in section 7.2. This Waste Inventory analysis provides a high degree of flexibility as to its form and construction, with little rigidity required in the type of data.
collected, as the inventory serves to indicate only rough-cut volumes of waste created at the various stages of production. In addition, the inventory analysis diagram provides a powerful tool to undertake a benchmarking activity so that manufacturers may measure their environmental performance, and as such may include varying metrics of weight, volume or products, even costs of wastes created. Reduction of wastes in some cases requires significant changes to the way in which current production processes are undertaken, with investment or redesign necessary in many cases. The construction of the Waste Inventory diagram presents the case for those situations where simple changes may account for significant waste reductions through heightened awareness from the measurement of wastes. Finally, the waste inventory diagram could be used to prioritise the required investment and improvements.

7.4.2 Cost versus Environmental Impact Analysis

As described in Chapter 4, waste may be measured as a financial loss to the manufacturer, and as such may be an economic driver for change; or may be accounted for by a physical measure of weight or volume with associated environmental implications for landfill and disposal. Whilst it is intuitive that a weight of waste is the simplest and quickest measure to obtain, in practice manufacturers may prefer to collect information relating to the costs of materials that are being disposed of and as such ‘costings’ have been found to be more readily available than weights and volumes of waste created. Estimated volumes of product ingredients are recorded by some manufacturers from which cost of wastes can be calculated.

The form of the waste must also be considered when analysing the material being disposed of in production, for instance the environmental consequences of disposing of a large amount of biodegradable organic matter and a relatively small amount of hazardous or non-biodegradable material will have a considerably different impacts. Similarly, the cost calculation undertaken by manufacturers will reflect these differences as large volumes of bulk wastes such as trimmings have little or no value. However, disposing of finished products that have been subject to lengthy cooking cycles and packaged in plastic before being disposed have an appropriately higher associated cost, taking into consideration the resources and materials consumed in manufacturing the product.
In order to further demonstrate this difference between the cost of wastes and the volumes of products Figure 7.5 shows the relative compositions of wastes created for a period of one month production at a ready-meal manufacturer. Cost against volume graphs can be generated to illustrate the relationship between cost and volume. By considering Bi-products which incur low cost, yet are created in high volumes contrasted against OverProduction Wastes which account for a considerable proportion of the cost of waste created, while only contributing approximately 14% of the volume of waste created. The correlation between the costing a company assigns to wastes and the environmental impact of waste however requires further consideration, as methods of calculation differ between manufacturers, and no generic link between the economic drivers of food manufacturers and the environmental impacts of associated wastes has as yet been established.
However the author contends that in the general case OverProduction Wastes (having a high cost impact for the manufacturer) also contribute the greatest environmental impact through consumed resources, materials, water, energy and wasted packaging materials. OverProduction Wastes impact several other forms of waste that may be easily identified by ready-meal manufacturers, including ingredient expiry and oversupply. Identifying such wastes as being attributable to sources other than OPW disguises the extent of overproduction and the actual costs caused by OPW, which is already one of the biggest waste costs for convenience food manufacturers, running at 40-50% in some cases. OPWs are commonly only measured where product has completed manufacture and has been packaged ready for despatch and sale. Disposing of product at this stage directly to commercial waste streams (which is common practice) is extremely wasteful, however some manufacturers prefer this solution to the relatively more costly method of separating the organic matter from the plastic packaging to different waste streams, particularly where large volumes of products would require such separation.

Planning errors and OPW contribute greatly to the amounts of waste created by convenience food manufacturers, thus analysis of a company’s wastes to determine precisely how many of those wastes may be attributable to OPW as described in this thesis, is required to establish the extent of improvements that may be made. Costs associated with the creation of OPW will maintain manufacturer focus on waste reduction, while the environmental impacts of such wastes will be benefited whether the exact implications for the environment are calculated or not.

7.4.3 Reduce - Recycle - Disposal Analysis

The following Reduce - Recycle - Disposal (RRD) analyses have been designed and proposed by the author’s research as a method of simultaneously considering three activities of reduce, recycle and disposal for each of the waste types identified in section 7.2. These approaches are considered in a hierarchy, with the reduction of the sources of wastes being followed by the re-cycling of materials where possible in order to minimise the amount of waste that must be disposed. Figure 7.6 represents a Reduce - Recycle – Disposal Diagram
which are used to summarise the inputs and outputs to waste model, with inputs corresponding to the production and supply activities and the outputs to systematic suggested steps in reducing, recycling and safe disposal of the waste type being considered. In some cases a number of techniques are available to reduce the creation of wastes, and as such each is identified and may be implemented concurrently. The RRD diagram for OPW is the major focus of this research, and is depicted in Figure 7.7, while the RRD diagrams for the other waste types are included in Appendix 2.

Entire elimination of wastes at any stage will be highly unusual, realistically only the point of waste creation will be shifted for most instances, although substantial changes to business practices or technological investment may yield clean processes. As such the primary focus of the RRD analysis is to minimise the creation of any wastes and thus the impacts to the environment those wastes could make. Such changes include lessening the volumes of wastes created through more accurate or efficient manufacture and supply, ideally aiming to eliminate the wastes entirely. Recycling as part of the RRD analysis considers all opportunities for re-use of materials through production and also the preferential sorting of materials to separate waste or re-use streams to maximise the environmental benefit reaped from each product or component in keeping with the industrial ecology concepts described in section 4.2.2. Landfill and incineration are the disposal options in each case with the exception of waste water. These are the common waste disposal streams for industrial and household waste, with incineration being preferred in most cases, provided the calorific content of the waste is such that significant amounts of energy can be generated from the wastes.
Overproduction Wastes are created late in the production sequence, either by latter stages of manufacture, or through the Distribution channels as demand fluctuates. As indicated in Figure 7.7, the reduction of such wastes would be greatest from accurate forecasts upon which manufacture could be based, followed by the changes to lead-times to enable products to be manufactured to order. Improved planning flexibility will result in faster turnaround of production plans which again will reduce the volumes of OPW created. Methods by which OPW may be reused comes through the re-direction of ingredients to alternative products to follow demand, the offloading of finished products to alternative customers or ultimately the separation of completed products to separate waste streams (i.e. plastics and organic matter rather than commercial waste).

7.5 Summary of the analytical results

The result of these analysis activities all indicate that OPW is the most concerning type of waste as this results in high inventory wastes, costs and environmental impacts. The RRD analysis has shown that the most effective approach to deal with OPW is through reduction of production and order lead-times and the improvement of planning flexibility. This has been investigated through the Responsive Demand Management (RDM) framework as outlined in chapter 8.
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Responsive Demand Management Framework to Minimise OverProduction Waste

8.1 Introduction

This chapter describes the Responsive Demand Management (RDM) framework that has been generated to provide a systematic approach to minimise OverProduction Waste (OPW) for convenience food sectors. The chapter begins by identifying the OPW related to the manufacturing and order lead-times. The main sections of the chapter describe the RDM framework and its three stages, namely health-check, production and order lead-time improvement and reactive production planning. The chapter concludes by considering issues related to implementation of RDM framework.

8.2 Manufacturing Lead-time and Order Lead-time

OPW are created in part as a reaction to planning complexities that are created by the intrinsic pressures of the convenience food sectors as outlined in chapter 7. The creation of OPW hinges around the combination of a number of factors which constrain the supply system. This research has tackled this situation by the methods outlined in this framework under the provision that:

- Demand for convenience foods, notably ready-meals will remain volatile
- Product shelf-lives will remain short, given consumers demands for fresh foods, free from most preservatives
- Processing times will remain high, given the convenient nature of the product

Shelf-life constraints when combined with volatile consumer demands, retailer ordering policy, lengthy processing and capacity constraints result in production plans being based upon forecasts and subsequently substantial wastes being created. Two such factors contributing to this complex planning problem are the long manufacturing lead-times and
short order lead-times associated with convenience foods. These two factors are considered
in the initial stages of the RDM framework with the aim of improving (reducing) the
manufacturing lead-times and increasing the given order lead-time to manufacturers. By
improvement of these lead-times the author reasons that the situation will more closely
approximate to a Make-To-Order system with simplified scheduling requirements. Figure
8.1 depicts the major goal of the RDM framework that is to reduce manufacturing lead-times
and maximise the order lead-time available to manufacturers, as illustrated in part c) of the
Figure. The RDM framework aims to identify the underlying conditions that serve to create
long manufacturing lead-times and short order lead-times and to improve these lead-times so
that a Make-To-Order approach becomes feasible (i.e. order lead-time exceeds
manufacturing lead-time). However if these improvements do not allow a Make-To-Order
approach to be adopted, a hybrid two-stage planning approach has been investigated as part
of this research to minimise OPW.

Figure 8.1, Relationships between Manufacturing lead-time and Order lead-time for Food
Industry Manufacture
This two-stage planning is based on classifying the production processes into two categories of standard and specialised operations where standard operation refers to common processes required by a range of products, and specialised operations deliver the product’s identity, such as assembly or packaging. The two-stage planning method utilises a hybrid approach based on static and dynamic planning in which standard operations are planned based on forecasts and standard scheduling rules and specialised operations are finalised as plans after confirmation of demand using a dynamic approach. The details of activities in the two-stage planning has been described in chapter 9, the remaining sections of this chapter describe the various stages of the RDM framework.

8.3 Responsive Demand Management Framework

The Responsive Demand Management (RDM) framework consists of a number of distinct stages which are linked as shown in Figure 8.2, these stages were initially drafted using IDEF tools as described in chapter 7, however for clarity the framework has been outlined as shown in Figure 8.2. In this way data gathering, process modelling; the operational improvement tools and techniques, and planning procedures are considered sequentially within each stage of the RDM framework. The author would like to state that although applications of the health-check, process modelling, simulation and VSM are not unique to this research, the sequential use of these techniques as suggested by the RDM framework provides a novel optimisation approach for production and supply chain activities prior to application of two stage planning. Furthermore, while it is acknowledged that this framework could be expanded upon to reduce other forms of waste as identified in the Waste Model (see chapter 7) OPW is maintained as the primary focus of improvement procedures within the RDM framework.

The principle means of collecting information relevant to the RDM framework is completed by two complementary elements of the initial stage, namely a health-check for ready-meal manufacture and process modelling. The health-check gathers information concerning supply chain practices, information flows (which are difficult to obtain by direct measurement) through a questionnaire, with detailed production data being gathered through process modelling. The health-check also serves to highlight and provide context to the current practices and inefficiencies currently in place.
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The process modelling stage requires information from the health-check and in addition requires considerable data to be collected by means of observation of current production and material handling practices. The current state of the supply chain is considered as part of the process modelling activity, and further serves to outline the ineffectiveness of current practices undertaken and serves as the baseline against which improvements may be compared. The data collected at this initial stage is then communicated to the remaining stages which consider the improvement of production processing and Supply Chain procedures that impact production and order lead-times. Figure 8.3 illustrates the application of the RDM Framework, indicating the points at which changes and improved performance will impact the production system. It is at these points that the changes made could potentially allow manufacture to begin after confirmed orders (i.e. a Make-To-Order approach) have been placed, provided sufficient scope for improvement has been found.
8.3.1 RDM Framework Functional Stages

The three stages of the OPW Minimisation Framework (see Figure 8.2) are briefly described below and are discussed in more detail in the remaining sections of this chapter.

i. Health-check and Process Modelling
The consideration of efficiencies of the manufacturers and associated supply chain forms the focus of the health-check, which benchmarks the effectiveness of the information flows

Figure 8.3, Flow chart representation of RDM Framework indicating interrelationships and decision points.
across production and supply chain processes. Process modelling of the production system of the manufacturer is based on collected data and provides visualisation of ‘current state’ for use in latter stages of the RDM framework, as outlined in section 8.4.

ii. Improvements to Production and Supply Chain Processes
This stage of the framework aims to reduce production processing lead-time by compressing the time taken to manufacture products as far as is physically possible. In addition, the information flows and other contributing factors in delaying the communication of consumer demand data to the manufacturers are analysed to improve order lead-times. The improvement methods arising from this stage of the framework are described further in section 8.5.

iii. Reactive Production Planning
A reactive approach to planning of the manufacture of ready-meals is applied in this stage of RDM framework to cope with the late confirmation of orders and demand fluctuations, in order to minimise wastes as a result of overproduction. Chapter 9 describes the functionality of this novel planning approach based on OPW minimisation in detail, with a brief overview included in section 8.6.

8.4 Health-check and Process Modelling

The primary stage of the framework requires the collection of various forms of information and as such two different methods of collecting different forms of data have been designed. The required information may be broadly classified into general information (production, supply chain, waste and planning) and specific processing and manufacturing data. The health-check questionnaire is primarily concerned with the collection of information relating to the supply network, waste creation and planning information. This information is gathered via template based questionnaire and made available to the process modelling activities and the further stages of the RDM Framework. Process modelling of a production facility collects specific production data and aims to model material flows through the company, providing a ‘current state’ representation of the manufacturing activities.
8.4.1 Health-check

The term health-check has been coined by this research in recognition of the work undertaken in considering production performance and supply network ‘health’, and the means by which it allows manufacturers to critically assess their role and position within their supply chain. The health-check has been compiled with the intention of collecting the information required for completion of the analyses regarding supply chain reaction notification. The data identified by the questionnaire is largely required from those personnel working with direct experience of the supply network and communication channels and may require the input from several staff from different departments and companies. The information identified to be collected within the health-check can be summarised as:-

i) Manufacturing and Order lead-times  
ii) Processing routes  
iii) Supply Chain Dimensions  
iv) Supply Chain Mechanisms  
v) Demand Management  
vi) Production Planning and Control  
vii) Waste

Under each of these seven sections that form the health-check questionnaire, Sections i)-v) are specific to particular products, and require ranges of data while sections vi) and vii) will remain constant across most products considered. A sample from the health-check questionnaire is included in Table 8.1, with the following questions underpinning the generation of the questionnaire:

i) To what extent do manufacturing lead-times conflict with order lead-times times?  
ii) What is the shortest theoretical manufacturing lead-time when running near full capacity; how can this be further reduced, and made easier to attain under normal operating conditions?  
iii) How is the supply chain structured from a material flow point of view from suppliers through to distribution and retail?  
iv) How is information communicated through the Supply network, with particular emphasis on the order processing cycles?  
v) How swiftly and to what effect is demand data communicated upstream through the supply network?
### Health-check

<table>
<thead>
<tr>
<th></th>
<th>Production and Order-lead times</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>What are current order lead-times (in hours?)</td>
</tr>
<tr>
<td></td>
<td>Longest order lead-time</td>
</tr>
<tr>
<td></td>
<td>Shortest order lead-time</td>
</tr>
<tr>
<td>b)</td>
<td>Identify the ranges of production lead-times (in hours, the total time for all manufacturing operations)</td>
</tr>
<tr>
<td></td>
<td>Production lead time: Hours (product: )</td>
</tr>
<tr>
<td></td>
<td>Production Lead-time Hours (product: )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>What are the range of Shelf-lives of products manufactured, what is average shelf-life?</td>
</tr>
<tr>
<td></td>
<td>Longest:</td>
</tr>
<tr>
<td></td>
<td>Average:</td>
</tr>
<tr>
<td>b)</td>
<td>What are the typical ranges of changeover between product runs?</td>
</tr>
<tr>
<td>c)</td>
<td>How many products does the company produce? How many component ingredients are required?</td>
</tr>
<tr>
<td>d)</td>
<td>Do products require dedicated tooling or operators due to process/ part etc? If so identify the processing routes affected.</td>
</tr>
</tbody>
</table>

**Table 8.1** Sample page of health-check questionnaire

vi) How is production currently planned; what is given priority when jobs are scheduled?  
vii) What environmental wastes does the supply chain create; are these wastes managed and can they be improved upon?

The data that is gathered may in some cases require ranges of values typically with the maximum and minimum expected values being collected. This health-check information
may be compared against leading supply chains in the same sectors, as part of a benchmarking exercise to demonstrate the current state of production and supply chain. The data collected under the health-check relating to the creation of waste and the company’s environmental impacts serve to highlight the areas for improvement, with particular regard to OPW for the supply chain. Each form of waste identified in Chapter 7 can be scrutinised at the supplier, manufacturer and distributor levels, and where such wastes exist, the health-check gathers information regarding whether the waste is disposed of, recycled or reused in some way.

8.4.2 Process Modelling

This section outlines the modelling of physical and information flows which is achieved by utilisation of Value Stream Mapping methods, as described previously in section 5.5.1.3. The inputs to the modelling process require collection by simple observation and measurement which is completed using a set of templates for data input by the process modeller. A number of open templates for data collection were constructed, examples of which are found in appendix 3 covering each of the identified input data elements required. A form of process activity modelling was used to identify each of the production processing steps as shown in Table 8.2. Mapping of value streams was completed using eVSM software (GumshoeKI Inc 2005) to provide an easily communicable layout, which is outlined in Figure 8.4.

![Figure 8.4, Value Stream Mapping of critical path in ready-meal manufacture presented in eVSM software](image-url)
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### Detailed Process steps Value Creating Steps

<table>
<thead>
<tr>
<th>Steps</th>
<th>Total Time (minutes)</th>
<th>Value Creating Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transport Link 1</strong></td>
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<td></td>
</tr>
<tr>
<td>Direct shipment (50 miles)</td>
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<td></td>
</tr>
<tr>
<td><strong>Manufacturer</strong></td>
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<td></td>
</tr>
<tr>
<td>Receive and storage placement</td>
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<td></td>
</tr>
<tr>
<td>Held in storage</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Transport to preparation (prep) area</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Waiting in prep area</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Cut prepared</td>
<td>1 1 45 seconds</td>
<td></td>
</tr>
<tr>
<td>Loaded into vacuum package</td>
<td>10 seconds</td>
<td></td>
</tr>
<tr>
<td>Vacuum packaged</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Waiting in prep area</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Transport to cookhouse</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Held in cookhouse prior to loading</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Loaded into mould and automated system</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Cook/cool/chill and unload</td>
<td>2 420 360</td>
<td></td>
</tr>
<tr>
<td>Waiting in cookhouse</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Transported to blast chiller</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Held in blast chiller</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Transported to prep area (assembly line)</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Held in prep area</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Debaged/portioned and added to tray</td>
<td>45 seconds</td>
<td></td>
</tr>
<tr>
<td>Held in tray in prep area</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Transported to line</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Waiting with operator</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Weighed, added to tray and put on line</td>
<td>3 20 seconds</td>
<td>20 seconds</td>
</tr>
<tr>
<td>Line filled, checked, sealed, sleeved</td>
<td>4 1</td>
<td>20 seconds</td>
</tr>
<tr>
<td>Waiting in despatch to be boxed</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Boxed and stacked on pallet</td>
<td>30 seconds</td>
<td></td>
</tr>
<tr>
<td>Waiting on pallet until despatch</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>Loading onto truck</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>Transport Link 2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct ship to RDC (100 miles)</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td><strong>Regional Distribution Centre</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unload truck</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Store awaiting full truck</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Reload truck for daily shipment</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>Transport link 3</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ship via multi-drop route (75miles)</td>
<td>240</td>
<td></td>
</tr>
<tr>
<td><strong>Retailer Store</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accept and unload into store</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

Table 8.2, Production Processing steps on critical path of ready-meal for an extended value stream (based upon: Womack and Jones 2002)
The data boxes associated with each process step may be configured to display any information deemed appropriate to the process, capacity and uptime being used in this example. The main measurement from the mapping is production time which is shown along the bottom of the figure in the ‘lead-time ladder’. This ‘lead-time ladder’ identifies the time taken for all stages of production and summarises the Value Adding and Non Value Adding steps. The visual representation of the mapping provides a record of the information channel structure and inefficiencies. The material flow element of the representation gives immediate indication of the wasted time in a production facility and provides straightforward starting point for improvement activities, based upon priority elimination of time-wasting steps. In addition to the regular mappings, this stage of the RDM framework combines VSMs of component ingredients onto single mappings by neglecting the associated information flows (which are largely similar for each value stream). This summary of component ingredients provides an overall view of each product, which despite staggering lead-time ladders, provides a useful overview of processing. The Physical Actions for the above example are summarised in Table 8.3, the main processing activity in this example is a long cooking cycle of 360 minutes, which is a major element of the value adding processes in production.

### 8.5 Production Processing and Supply Chain Improvements

The data related to information and material flow gathered in the first stage of the RDM framework is utilised to improve manufacturing and order lead-times. A number of contemporary techniques have been utilised in a bespoke sequence identified by this research based upon products, processes, resources and layouts in order to achieve this goal, as described below.

#### 8.5.1 Production Processing Improvements

The specific food industry requirements that have been identified as significantly contributing to manufacturing lead-times are:-
Hygiene delays are most noticeable at changeovers, when equipment requires rigorous cleaning between production runs. Where production consists of many small volume product runs, there may be many changeovers, and thus the time for cleaning equipment, rather than processing, may be long. Additional constraints on the production system come where processing operations or ingredients may be specific to particular products requiring specialist personnel or equipment to be processed, placing great importance on the resources being well managed. Cooking operations may be lengthy, with some techniques taking many hours to complete. Similarly, chilling products down to an acceptably low temperature may also take a number of hours, where the processed ingredients are held in ‘chillers’ before the next stage of processing. Such constraints on production may be process inherent and only possible to eradicate under significant technological investment. In addition to the relatively lengthy manufacturing lead-times the capacity of the production system will contribute to the overall lead-time of orders, particularly when the system is working near capacity. The flexibility of processing equipment and personnel to manufacture products on alternative production lines when available capacity is low will aid in reducing bottlenecks and delays in manufacture that contribute to lengthening an order’s manufacturing lead-time. The range of tools and techniques used for improvement of production processes are described in the following sections.

8.5.2 Tools and Techniques used for reducing manufacturing lead-times

The tools and techniques used to reduce manufacturing lead-times are grouped into Product Processes Resources and Layout as outlined in Table 8.4. Although these techniques may be applied to certain elements of the production system, their impacts may reach out into other aspects, for example product family analysis will promote changes that will impact which products are manufactured where and when, with subsequent implication for scheduling and organisation of work, such as line balancing and changeover practices. A simulation model is used to test and validate the suggested changes made through application of each of these four groups of tools and techniques as illustrated in figure 8.5.
<table>
<thead>
<tr>
<th>Product</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product family analysis</td>
<td>line balancing, scheduling, changeovers</td>
</tr>
<tr>
<td>Design for Manufacture, Design for Assembly</td>
<td>Product features and commonalities; resource requirements etc.</td>
</tr>
<tr>
<td>Process</td>
<td>Waste, production flow</td>
</tr>
<tr>
<td>Lean tools</td>
<td>Work In Progress (WIP), Lead-time, bottlenecks</td>
</tr>
<tr>
<td>Supply Chain Response matrix</td>
<td></td>
</tr>
<tr>
<td>Production Variety funnel</td>
<td>Component/ feature design aspects, product families</td>
</tr>
<tr>
<td>Technological Benchmarking</td>
<td>Processing lead-times, capacities, scheduling</td>
</tr>
<tr>
<td>Resource</td>
<td>Throughput, efficiencies waste creation</td>
</tr>
<tr>
<td>Equipment design analysis</td>
<td>Changeovers, Scheduling priorities</td>
</tr>
<tr>
<td>Single Minute Exchange Dies (SMED)</td>
<td>Production layouts, routings</td>
</tr>
<tr>
<td>Process activity mapping</td>
<td>Material handling, WIP,</td>
</tr>
<tr>
<td>Material Flow Analysis</td>
<td></td>
</tr>
</tbody>
</table>

Table 8.4. Lead-time reduction tools and techniques array

![Diagram](image.png)

Figure 8.5, Manufacturing lead-time reduction tools and the application of simulation to support improvements.
8.5.2.1 Product focused techniques

This includes the application of *product family analysis* (see section 5.5.1.5) which focuses the attention of the manufacturer on those products with the greatest volume so that routing and resources may be utilised based around the different manufacturing priorities of those products. Product analysis in this way is not a route to processing time improvement, however when used in conjunction with other techniques such as SMED etc. it can enable better organisation of manufacturing and utilisation of resources.

In addition, consideration is given to the application of *Design For Manufacture and Assembly (DFMA)* (as described in section 4.3.1) to the products that the company manufactures. Design based product features have large implications on the overall cost of the product, and the extent to which improvements to manufacturing process may be made. Certain design features are demanded by the customer, however, it is in the interests of the manufacturer to standardise as many parts of the products as possible to ensure minimisation of changeovers and simplify part substitution etc. A sample of considerations of such design features include:

- **Interchange-ability of components and ingredients**- how many products contain ingredients that are not used in any other products?
- **Packaging constraints**- of all packaging used across the products what differences are evident between the different types? Can packaging features eradicate any differences so that production resources may manufacture different packs?

8.5.2.2 Process based techniques

The process based tools lend themselves to the identification of wastes and the development of sustainable improvements in the manufacturing environment.

This includes the *Supply Chain Response matrix* (see section 5.5.1.6) which represents by means of a simple diagram the cumulative manufacturing lead-times and inventory through supply. This research author has suggested the generation of a modified matrix based upon the original response matrix (shown in Figure 8.6 part (1)) to better fit the needs of the convenience food sectors. This is achieved by replacing inventory with a measure of capacity on the vertical axis as shown in Figure 8.6 part (2).
This novel adoption of response matrix based on capacity availability is of greater use in the food industry given the short shelf-lives of products limiting inventory held, and the capacity restraints of the production system being poorly recognised and recorded. As such the theoretically calculated capacity of a resource (commonly available) may be directly compared to the levels typically experienced for specific products.

The second tool considered in the process based improvement is the Production Variety Funnel (PVF) (as described in section 5.5.1.7) which highlights the sources of complexity and variety through production. As depicted by Figure 8.7, the funnel highlights the product variants and where they appear in the production sequence. In this example a small number of cooking processes (boiling, grilling and baking) are common to many products that have many variations based upon combinations of ingredients. This research has proposed the generation of PVF representations by mapping processes along the horizontal axis, with the boundary of each process step indicating the cumulative lead-time to that point in the production processing stage. The number of part variants at each boundary are indicated up the vertical axis, and the whole mapping then mirrored in the lead-time axis. An example of this PVF mapping process is provided in Figure 8.7, which displays the basic mapping of processes prior to being mirrored in the x-axis.
The final analytical tool used to improve processes in this stage of the RUM framework is the *Technological Benchmarking* of techniques to determine the following:

- What are the techniques currently employed by the manufacturer to achieve the desired outcomes from a particular process?
- What are the predominant factors when concentrating on a particular process? Consider the following to be adopted as metrics: total cost of ownership, throughput/processing time, additional processing required/removed, waste creation, product quality, process reliability.
- What are the possible alternative means that may deliver the desired outcomes from a process?
- By how do these alternative techniques compare with the incumbent processes over the selected metrics?

The diverse range of processes and technologies available in preparing, cooking, filling and packing convenience foods, in addition to the regular development of alternative processing indicates that the benchmarking exercise should be undertaken periodically to identify possible alternative techniques and technologies suitable for a particular application.

### 8.5.2.3 Resource Based Techniques

The resource based techniques aim to analyse and improve various resources by focused consideration of resources and their effectiveness in production. *Equipment design analysis*
involves the consideration of any processes or actions that have been highlighted in areas for production improvement, typically focused around a particular piece of equipment or machine identified at an earlier stage of the framework. Through detailed analysis of the precise actions, events, resources and equipment used in processing, the effectiveness of the current processing method may be scrutinised. Once the identified process has been studied in detail the following questions are to be considered and improvements met through a drive to implement the most effective techniques for comparable processes:

- What are the current performance levels of the process for optimum throughput, waste creation, changeovers, operational reliability, resource utilisation, costs, and typical production throughput achieved?
- What alternative methods may be employed to achieve the same manufacturing results?
- Between the incumbent system and the alternatives, which results in the shortest production processing time per item?
- Additional considerations must be taken into account when comparing existing system with alternatives, what are the implications for: total costs, operational reliability, changeovers, resource utilisation, training or specific needs, changes to hygiene mechanisms, changes to handling methods
- What are the organisational constraints to implementing alternative processes? (for example costs, space, resource availability)

Single Minute Exchange of Dies (SMED) methodology (as described in section 5.5.1.8) is considered for the reduction in impact of changeovers themselves. The simplification of movements and equipment used during changeovers is emphasised, with priority going to those resources indicated during equipment analysis that experienced problematic changeovers. Significant resource changeovers (such as tool or head changes) are evaluated and improved upon using common techniques from the SMED methodology.

8.5.2.4 Layout Based Techniques

Process Activity Mapping (as described in section 5.5.1.2) consists of a tabulation of processes essentially the same as outlined in Table 8.2, but includes categorisations of the steps, indications about resources and distances travelled. The availability of the data from the process mapping undertaken (as described in section 8.4.2) are used for the further analyses completed when considering production layouts. Food manufacturing facilities have many specific requirements regarding the layout and physical structure of the
processing plant (as described in section 3.4.2). Layout analysis will yield the greatest benefits where facilities have been adapted over many years, with production lines being moved or added particularly where product flow has now become a complicated series of movements between processes.

Building upon Process Activity Mapping, material movements can be investigated utilising Material Flow Analysis of the production system, whereby the handling of products and ingredients throughout production are studied. The following examples indicate the situations through manufacture where material flows are examined and may be improved upon, through modifications to facility layouts, facilities and handling practices:

- Distances and lengths of time in transporting materials between process steps
- Points where material waits, or is consolidated before moving to next stage
- Congestion points or bottlenecks within the facility (such as elevators, corridors, chillers and refrigerators)

These investigations may be completed through straightforward consideration and intuitive changes to flows, or within simulation software mapping the material flows through a facility and highlighting the problem routes, as shown in an example in Figure 8.9.

8.5.3 Simulation

Simulation has been identified as a tool to be utilised in order to gain an insight, test and validate the identified improvements to the production system in light of proposed changes by various aforementioned tools and techniques before such changes are implemented within actual production system.

This research proposes the application of focused simulation projects as described in Figure 8.8. The performance improvements of the production system may be better understood and justified from a cost/benefit viewpoint within such simulation experiments. The activities, workstations, and production areas that the simulation project considers may be varied, and applied to any part of the production system that has been highlighted for improvement, and may be based around:
- Changeover reduction
- WIP levels
- Operational efficiency (due to down time/breakdowns, waiting times etc)
- Total lead-time
- Technology/operating method comparisons

SIMUL8 simulation software (Simul8 corporation 2001), a Microsoft windows visual simulator, has been utilised to generate simulation models and to analyse improvements suggested by techniques in the RDM framework. Figure 8.9 provides an animation from one such a simulation project that considered material flows through a ready-meal production facility through cook stations to assembly lines.

The operational efficiencies of two service lifts were compared in the simulation in Figure 8.9; with changes suggested through resource based equipment improvements (in this case uptime gains on service lift 2) being tested and outputted through SIMUL8 as shown in Figure 8.10. The experimentation with such simulation models may then be used to validate and prioritise the suggested changes by the tools described, before implementation.
Figure 8.9 Example Simulation Project based around ready-meal production layout

Figure 8.10, Graphical outputs from Layout Simulation Project
8.5.4 Supply Chain Improvements

The communication of demand data from retailers to other supply chain members in an accurate and timely manner aids to eradicate some forecast uncertainty, while increasing the time manufacturers have to react to demand fluctuations. This has the potential to significantly impact the levels of waste, operational efficiencies and service levels. Timely use of consumer demand data can enable manufacturers to readjust production volumes and plans and avoid creating waste. Techniques including Supply Chain Management (SCM) and e-commerce technologies must be implemented and managed effectively to maximise the responsiveness, productivity and profitability of the supply chain. The use of the term “supply chain management”, and in particular the associated supply chain tools applied within this research relates directly to those techniques which have bearing upon order lead-times. The tools and techniques that the author believes to be of greatest use in reducing order lead-times have been described in section 8.5.5 of this thesis.

8.1 Tools and Techniques used to maximise order lead-time

The tools that were determined of greatest use when considering the reduction of order processing lead-times, information flow streamlining and improvement of supply chain practices are divided into three categories as shown in Table 8.6. The impacts of these techniques are also broadly summarised in Table 8.6, for example supply chain management may have bearing on virtually any stage of product supply and inter-relationships between organisations. Value Stream Mapping has been applied at this stage of the RDM framework in order to provide visualisations of the changes to the information flows and demand communication channels which are proposed through these supply chain tools and techniques, as illustrated in Figure 8.11.

<table>
<thead>
<tr>
<th>Supply Chain Tools</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Chain Management (SCM) -Partnerships</td>
<td>Any supply issue once strategic relationships develop through network</td>
</tr>
<tr>
<td>Network Benchmarking</td>
<td>Service levels, quality, supply streamlining</td>
</tr>
<tr>
<td>Decision point analysis</td>
<td>Strategic Planning- supplier/ customer relationship</td>
</tr>
</tbody>
</table>
8.1.1 Supply Chain Tools

Supply chain tools firstly considers Supply Chain Management (SCM) which comprises a wide range of tools, techniques, applications and philosophies all of which are concerned with making the supply network operate more effectively, or to a higher degree of efficiency.
The nature of SCM requires the input and collaborative effort of more than one supply chain member. For this reason, improvement activities in the supply chain may be difficult to realise in practice, for they rely on the co-operation of multiple chain members, some of whom may not realise the benefit of any changes, or believe the undertakings unnecessary. Such a situation may require one of the supply chain members to take a leading role and act as a ‘channel captain’ driving the SCM activities forward, fostering chain partnerships and promoting the benefits of collaborative efforts. At this stage of the framework, the relationships with suppliers and customers are to be strategically evaluated regarding levels of trust, information sharing, technology compatibility and long term plans etc. to generate an ‘as is’ model of the supply chain and to establish how relationships between partners can be further developed.

The author believes that *Network Benchmarking* provides the opportunity to establish both the company’s market position (against other companies) and potential for growth and improvements (against a set of ideals). Where supply chain members are involved in a collaborative cluster, then benchmarking may be easier to implement as the availability of willing participants will be higher, however in some cases a leading supply chain actor could not be identified against whom to benchmark a specific manufacturer. In such cases the manufacturer must establish the theoretical limits of what may be achieved in each area of performance and use these values as the benchmark based on which the long-term objectives must be defined (described in section 5.3 as striving for ‘perfection’).

The remaining tools for order lead-time improvement in the supply chain practices category are used for strategic analysis of the supply chain’s demand and order structures. *Decision point analysis* is used at this stage of the framework to highlight the dislocation point of customer pull and supplier push, identifying the extent to which production must be based upon forecast driven data. This analysis builds upon the earlier mapping of value streams to provide knowledge of where decision points lie in a supply chain between manufacturers and retailers, and aids in strategic target setting in order that decision points may be moved jointly to a mutually beneficial stage of production and delivery.

*Demand amplification* may be represented in the form of a ‘screen’, (see section 5.5.1.4) and is used in the RDM framework to summarise the patterns of demand variation that are experienced along the supply chain. It is an aim of the whole supply chain to reduce uncertainties and hence product costs, so by highlighting the extent of the demand
amplification, better co-ordination and co-operation practices may be negotiated with supply chain members, which will in turn improve forecast accuracies. In addition, periodic reviews of the demand amplification screen for the supply chain will provide the each partner with clear feedback of order accuracy performance improvements, or the existence of any ‘bullwhip’ remaining within the chain.

8.5.5.2 Communication Streamlining Tools

*Collaborative Planning Forecasting and Replenishment* has potential to provide the greatest benefit to communication streamlining and to eliminate demand amplification (bullwhip) effects within the supply chain as described in section 5.3.2. At this stage of the RDM framework the adoption of CPFR is to be explored by suppliers, manufacturers and retailers as the means by which information flows may be overhauled to eradicate uncertainties in forecasting and ordering between members of the same supply chain. The implementation stages and standards to be adopted must be considered strategically, and agreed upon under new collaborative working relationships that have the potential to reduce supply chain (and product) wastes, costs and order lead-times.

The development of *Communications Technologies* provides supply chain members with the opportunity to simplify, speed up and standardise their interactions, particularly with regard to ordering and procurement transactions. The RDM Framework has proposed to utilise contemporary communication technologies to provide earlier warning to suppliers and reduce order lead-times by replacing incumbent techniques with more efficient methods of communication. Traditional order mechanisms and basic EDI should be reviewed based upon their effectiveness with regard to the time that is spent in each order cycle in processing orders. A hierarchy of communication technologies has been identified by this research, as depicted in Figure 8.12, which needs to be considered by supply chain members in conjunction with financial and IT infrastructure constraints that provide a barrier to moving between technologies.
Chapter 8

Figure 8.12, Communication Technology Hierarchy

The practice of making available Point Of Sale data to manufacturers and suppliers is proposed at this stage of the RDM Framework to improve forecast accuracy and to reduce the time manufacturers require to interpret retailer orders. The list below represents the range of existing POS options. There is a requirement for supply chain members to consider the cost and IT requirements of various options against the potential benefits obtained through implementation of the POS provision.

i. Real-time, demand POS data available web-based
ii. Daily updated EDI/Web POS data
iii. Weekly-Monthly POS Summary
iv. Weekly-Monthly Demand Data Summary
v. No demand data or POS data communicated

8.5.5.3 Technology Applications for Supply Chain

The initial technology application proposed by the RDM framework is crossdocking, which should be reviewed and implemented in some form to shorten product waiting times at distribution centres, hence reducing delivery lead-times. Pre-distribution crossdocking (where store destination is determined at the manufacturer) is preferred, though information integration issues are to be considered, particularly in cases where substantial changes to the existing infrastructure are required.

In the context of the streamlining of supply, Radio Frequency Identification presents several timesaving aspects that will improve the material handling times and tracking through delivery to store, reducing delivery lead-times through the supply chain. The potential of
RFID to increase material tracking accuracy will also improve order lead-times through greater knowledge of material availability in planning manufacture and for this reason is to be considered at this stage of the RDM framework. The costs of RFID systems and those entailed with the integration of the associated information systems, which may be significant, must be weighed against the benefit RFID presents in streamlining the replenishment system.

Feedback of production conditions and progress to support management decisions in a timely and convenient manner is desirable for production planning and scheduling of jobs, particularly in a dynamic environment. Production monitoring systems and Supervisory Control and Data Acquisition systems provide means by which such feedback can be achieved hence the inclusion of SCADA systems at this stage of the RDM framework. Where order processing and production planning efforts are to be minimised, knowing the exact manufacturing conditions at that time simplifies the process. Many convenience food manufacturing processes are heavily dependant upon manual labour, and as such control aspects of such systems may be unworkable, with report generation at the supervisory and management levels being the outcomes of any implementation. Even the simple communication of orders status (waiting, completed or underway) and available capacity via straightforward readily available means will allow planning decisions to be made more effectively to respond to changes in demand, and as such it is proposed that investment in such systems are to be investigated at this stage of the framework.

8.5.6 Value Stream Mapping

The Value Stream Mapping of supply chain and information flow improvements at this stage of the RDM framework, representing the 'future state' diagram, allows comparison to be made with the 'current state' value stream map generated in the initial process modelling stage to provide implementation benchmarks for production system and supply chain. In addition, the changes to physical flows can be highlighted in the new mappings, particularly where the number of processing steps has been changed, or where non-processing times have been significantly reduced. To further support the comparison between 'current' and 'future' state maps the outputs from eVSM software (GumshoeKI 2005) as indicated in Figure 8.13 may be used to summarise the performance metrics to be used when comparing the changes to production systems. In addition, the visual representation of the improved communication flows and information channels quickly establishes whether the demand data is passed through the supply chain more effectively.
8.6 Reactive Production Planning

The techniques outlined in sections 8.5, have as their goal a production system where constraints no longer maintain manufacturing lead-times longer than order lead-times. Where manufacturing lead-times still exceed order lead-times, either from prohibitively expensive technologies or techniques, ineffective implementation of changes, or excessively stringent demands on production, then an alternative planning approach is required to minimise the creation of OPW. This research has investigated a two stage reactive planning approach based on the static planning of standard operations and the dynamic planning of specialised or product identity delivering operations.

The outline view of this scheduling approach is shown diagrammatically in Figure 8.14, where standard operations are preparation or cooking activities and specialised operations comprise the product filling and packing.
Chapter 8

Figure 8.14, Overview of Two Stage Planning method

Figure 8.15, outlines the typical scheduling characteristics that are obtained via the two stage planning approach. The development and detailed explanation of the two stage planning approach is described in chapter 8, along with an outline of the software implementation.

Figure 8.15, A two stage planning approach to planning of convenience food manufacture
Chapter 9

A Hybrid Two Stage Reactive Production Planning Approach

9.1 Introduction

This chapter presents the research undertaken in designing, specifying and prototyping a reactive production planning model to cope with the late confirmation of demand. Such a planning approach is required in convenience food manufacturing sectors where the application of the Responsive Demand Management (RDM) framework outlined in chapter 8 have not created a situation where Make-To-Order production can be adopted. The chapter begins by outlining two common production scheduling approaches which are used in this hybrid Two-Stage Planning (TSP) while the main sections of the chapter outline the steps involved in the application of TSP. The chapter also includes a computational viewpoint of the TSP approach using a commercially available scheduling software, namely PREACTOR.

9.2 Scheduling Approaches

Static and dynamic scheduling are commonly adopted for the sequencing of production, with each being based on different requirements and having different goals. As part of the TSP a hybrid approach based on both scheduling methods are investigated, with static planning undertaken prior to the start of production and dynamic scheduling being utilised once orders are confirmed. Static and dynamic scheduling are briefly described below.

9.2.1 Static Scheduling

Static Scheduling is carried out before the production cycle begins, and is described as static because of the manner in which the schedule is prepared based on forecast volumes which are available (but unreliable) days before production must begin. An important consideration
when undertaking static scheduling is that the generated schedules are likely to be subject to change due to demand volatility. With this knowledge, static scheduling as considered by this research may be summarised as follows:

- Based upon forecast data,
- Order volumes will be subject to change,
- A set of Standard operations (see section 9.3.1.1) for each product type are used to create a static schedule,
- Schedules are created and released before the start of production,
- To reduce waste priority is given to products with lowest forecast volatility, and those with ingredients used in the greatest number of other products,
- Shelf-lives, customer priorities, capacity constraints, changeovers are also considered as secondary constraints in scheduling at this stage,
- Static schedules will require re-scheduling due to changes in demand or production system status.

9.2.2 Dynamic Scheduling

Dynamic scheduling is undertaken relatively late in the production cycle and has been termed dynamic due to the rapid, responsive nature by which it is undertaken. Dynamic planning is based upon confirmed volume demands as they become available from Retailers, typically using real-time data, though where this is technically infeasible, readily available timely data is essential. The dynamic schedules must be created and released as quickly as possible to production to minimise wastes and ensure orders are met, with primary consideration being implications of considerable changes from the forecasted volumes, and how the production system can respond to these changes. The characteristics of dynamic planning may therefore be summarised as:

- Based on confirmed order volumes,
- Requires data from the production system relating to ingredients and products processed,
- Dynamic Schedule and work-to-lists will be released to the production environment as soon as they are generated,
- In order to minimise waste those over forecasted volume jobs must be cancelled and where possible ingredients re-directed to other products,
In order to maintain customer service levels additional jobs may need to be scheduled in order to accommodate under-forecasted demand for products.

9.3 A Hybrid Two Stage Planning approach

Two Stage Planning (TSP) utilises the static and dynamic planning techniques in two separate stages. Manufacturing operations are similarly divided into those that process ingredients (which in some cases may be used in several products) and those that impart a product's identity. The TSP approach focuses on planning of the ingredient processing at the static stage and the dynamic scheduling of particular products once order demand has been confirmed. It is anticipated that the RDM framework will impact the underlying conditions that serve to create long manufacturing lead-times and prolong the order lead-times, however it may not be possible to reduce the impact of these conditions to a point where Make-To-Order manufacture may be achievable. In these cases, an intelligent application of hybrid planning activities is required to minimise the waste from overproduced volumes of short-life products. In order that the TSP system may achieve these aims, the following assumptions about the production system have been made:

- Products are comprised of well documented ingredients and processing operations that may be divided into Standard and Specialised (characteristic imparting) tasks,
- Product ingredients are common components allowing interchange between products to fit demand,
- Production begins before the required order volumes are confirmed to allow adequate processing time,
- Forecasting methods and the consideration of historical data and seasonal trends can be applied to initial production plans,
- Confirmed customer orders can be read into the planning system in a format that allows their swift processing,
- Data can be captured and applied relating to current volumes during the production cycle,
- The confirmed volumes can be attained (minimising the amount of waste created) by adjustment of the forecasted production plans with the release of an updated set of schedules.
At the point of determining the exact quantities to be prepared for despatch, the volumes of each component ingredient must be tallied against the required volumes for the products. As described previously, the two stages of the planning method proposed by this research are based on static and dynamic scheduling of jobs, with each stage outputting schedules to the production facility that are either Soft (liable to change) or Hard (fixed based on orders) as indicated in Figure 9.1.

9.3.1 Production process categorisation in Two Stage Planning

In order to easier facilitate the planning and scheduling goals of the Two Stage Planning approach, a categorisation of production processes has been proposed by this research based around the principle that many food products manufactured in convenience sectors often share common ingredients (e.g. rice, sauces etc.). The features that distinguish a distinct product are delivered either through the specific combination of ingredients or the product’s packaging, which are typically carried out late in the production cycle.

![Diagram of Two Stage Planning](image)

**Figure 9.1**, the Two Stage Planning approach to static and dynamic planning of late ordered products
9.3.1.1 Standard operations

Standard operations are production processes which are common in several products, typically time consuming operations undertaken in preparing ingredients included in one of several final products. Provided demand across a mix of products is reasonably balanced, then standard operations can be planned based on initial forecasts for total product demand.

9.3.1.2 Specialised operations

Specialised operations are production processes that provide distinct product characteristics, either by ingredient configuration, assembly, or other operation that imparts specific product identity to the materials. These operations are typically short and among the last operations to be completed. The exact demand for individual products must be known before specialised operations may be planned.

9.3.2 Production Scheduling in Two Stage Planning

Production schedules may take the form of visual representations of the jobs designated to resources (such as Gantt charts of the orders to be completed) or be the simple listing of operations to be completed on a resource (typically referred to as work-to-lists). Both forms are used in the TSP approach, and the production planning activities depicted in Figure 9.1 output either Gantt charts or work-to-lists depending upon whether they are generated as Soft or Hard schedules.

9.3.2.1 Soft Schedules

Soft schedules are generated in the static planning stage which are the guide for production until the Hard schedules are released. The Soft schedules are in Gantt chart form and indicate the schedule for the production operators for each line of processing equipment right through to final production, should all orders have been accurately forecasted. Soft Schedules are released to the production environment through a variety of channels and formats depending upon the manufacturers IT and control infrastructures.
9.3.2.2 Hard Schedules

Hard schedules are generated in the dynamic scheduling phase of TSP and are based on the confirmed order volumes. In their most basic form, Hard schedules can form a simple 'work-to-list' of products and the volume that must be filled for each order to be satisfied. The generation of these lists is only feasible where orders have not substantially deviated from forecasts. In such circumstances, a bespoke job card system can be used to issue the work-to lists to each resource. Whether Hard schedules are released via electronic or paper means, the speed with which they are made available to production is crucial. Where demand has fluctuated greatly from the forecasted Soft schedule, there may be a requirement for rescheduling of standard operations to plan for changeover and line balancing issues that are required to meet the new demand volumes.

9.3.3 Analysis of Production Levels against Confirmed Orders

At the point of order confirmation, there are four possible outcomes for products, determined by first comparing confirmed volumes against forecasts, and then against current production volumes, as shown in Figure 9.2. The orders that a retailer places may be exactly the quantity that had been forecasted, be higher than anticipated, or lower than the forecasted volumes. Where confirmed orders exactly match forecasts, all of the required ingredients will be in place, orders will be met and no product will be wasted. Where orders are higher than forecasts then there is a requirement to quickly process extra products to meet the higher than anticipated demand. Additional ingredients may be required with limited available material, and the re-scheduling of standard operations may be required to free capacity for additional processing tasks. This scenario presents several conundrums for the production planner, who must consider the following:

- Has any other product been over-estimated compared with the actual demand? If so are there sufficient ingredients available to meet the additional volumes required for the particular product?
- Are adequate raw materials on hand to meet the additional demand?
- Is capacity available within the production system for the additional processing required?
• Does the processing lead-time of the product’s additional volume allow manufacture to be completed before delivery?

When orders are below the forecast volume, the most updated status of production must be quickly ascertained, and where applicable, unnecessary standard operations called to a halt. The production planner has the opportunity at this point to eliminate OPW arising from WIP, given the possibility of prepared ingredients having suitable interchange-ability. It is intended that through improving the forecast method used as part of static scheduling undertaken will mean such situations will be minimised, though ingredients that have been prepared must be redirected to alternative products unless a significant shelf-life means that the components will not immediately become OPW. Given these potential outcomes, swift feedback to production is required regarding those specialised operations that have been over-forecasted and are in danger of creating OPW. This has been achieved through the application of a heuristic to establish the shortages and OverProduction Wastes of products, based on the newly confirmed order volumes and current-state manufacturing data, as shown in Figure 9.3.

Figure 9.2, Scenarios at order confirmation point for Order volume
The various steps in the TSP heuristic to establish the ingredient requirements across the production range is outlined in Figure 9.4, and for the purposes of describing the course of action to be followed when confirmed orders arrive late, the figure is accompanied by a list of definitions. The boundary condition for these heuristics regarding redirection of ingredients takes the position that once ingredients have been combined into a final product, they cannot be redirected to another product, i.e. no products are differentiated by product packaging alone, and products assembled in excess of confirmed orders constitute OverProduction Waste.

The first stage of the heuristic considers the confirmed volume for each particular product, for the purposes of this explanation product n is identified. The order volume is then compared to the forecast volume to which product n began manufacture, the outcome from this comparison is to assign product n to either being exactly as forecasted, or having an order greater than or less than forecasted. Most straightforwardly those products being correctly forecasted \( O_n = F_n \) need no further action, the targets set for production through the Soft schedule may remain and no wastage will be generated.
Figure 9.4, Heuristic for the determination of immediate production support and rough-cut ingredient requirements
The next stage of the heuristic utilises production system data in order to differentiate between those orders that are below forecasted volumes and above production \((O_n > P_n)\) and those that are also below the current production volumes \((O_n < P_n)\). At this point a number of orders to the production facility are executed either to stop production immediately (for cases where \(O_n < P_n\) to prevent further waste, or where new production targets are required \((O_n > P_n)\) so that production can work until the order volume is attained. The ‘available ingredients’ are calculated differently as ingredients already committed to specific products \((O_n < P_n)\) are no longer available to other products. This stage also identifies the shortfall of ingredients to fulfil orders that have exceeded forecasts (where \(O_n > F_n\)). The final stage of the heuristic is used to balance ingredients between the shortages created and the available ingredients leftover when manufacture runs to lower order volumes. The calculation of shortage products to negative values aids in the balancing method, a simplified example of which is demonstrated in table 9.1, where product ‘C’ has been under forecasted by 50 units, with production a further 50 products behind completing the original forecasted volume (hence creating a shortage of -100).

The focus of this redirection of ingredients to minimise the waste of their overproduction, it is worth noting therefore that ‘product a’ (an example of \(O_n < P_n\)) generates 200 ‘available’ ingredients, as identified in the table. The manufacture of ‘product a’ has already generated an additional 100 units of finished product in excess of the order. As such, 100 of each ingredient in ‘product a’ are no longer available for redirection to other products and must be dealt with as OverProduction Wastes (OPW), and therefore are not considered through this ingredient rebalancing process. In this example, no further ingredients are required to be prepared, the shortages identified for ‘product c’ can be transferred from the over forecasted products (‘a’ and ‘b’).

<table>
<thead>
<tr>
<th></th>
<th>(F_n)</th>
<th>(O_n)</th>
<th>(P_n)</th>
<th>(S_n)</th>
<th>(A_n)</th>
<th>Ingredient BOM for Products a, b and c</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ingredient 1</td>
<td>ingredient 2</td>
<td>ingredient 3</td>
<td>ingredient 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product A</td>
<td>600</td>
<td>300</td>
<td>400</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Product B</td>
<td>900</td>
<td>800</td>
<td>600</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Product C</td>
<td>420</td>
<td>470</td>
<td>370</td>
<td>-100</td>
<td>-100</td>
<td>-100</td>
</tr>
<tr>
<td>Ingredient availability for reallocation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

Table 9.1, balancing of “shortage” and “available” ingredients
9.3.4 TSP application issues

Hard and Soft schedules as outlined in TSP may be released to the production environment in one of two ways: electronically, with the schedules displayed in similar fashion to those developed by the planner, or paper based plans, listing products and product details, along with volumes and resource sequence. Similarly, when information is required from the production environment by the planner, a number of means are possible, which may be formal (or standardised) and informal (or non standard) channels. Formal planning meetings at set times each day may allow face to face standard communication of what production is ongoing and has been completed prior to orders being received. Informal means of communication may be achieved ad hoc. when the planner requires a specific piece of information and contacts the production environment by phone, email, or simply visiting. The application of Supervisory Control and Data Acquisition systems has been described in section 5.3.4.4, with the benefits of standardisation of communications from the production environment quickly streamlining the most commonly required data direct to the planner. Drawbacks of this IT system for food industry manufacturers have been reported as the expense of implementation and hostile environment for electronic equipment in the high-care facility for data collection. Listed below are the preferred forms of data communication, while the common practice within the sector is to base communications around a paper based set of production plans released to production at fixed intervals.

- Integrated electronic control of production and data capture by planning
- Electronic communication of plans to production environment
- Face to face meetings and communication of plans and production information usually combined with paper based plans generated for production environment:
  - Delivered to operators,
  - Collected by operators.

The following methods of data collection may be employed by production planners to gather the necessary information relating to the state of production when orders are confirmed:

- Automated data capture provided in real-time electronically to planners,
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- Traditional communication methods for collection of production information (telephone, e-mail etc.).

9.4 Computational Viewpoint of TSP

The TSP concept investigated as part of this research has been realised in a commercially available planning and scheduling software PREACTOR, the basic functioning of which is outlined in section 9.4.1. The detail of how the functionality of this software has been enhanced to realise the Two Stage Planning approach is provided in section 9.4.2.

9.4.1 PREACTOR Software

PREACTOR is a highly configurable finite capacity planning system using graphical interfaces and menu based navigation (Figure 9.5) for ease of use and rapid access to information, having a modular structure of functionality with the base modules named PREACTOR 100, 200, 300, 400, 500 and APS. PREACTOR 100, through 500 are for Finite Capacity Scheduling (FCS), each version incrementally adding increased functionality while PREACTOR Advanced Planning and Scheduling (APS) having additional features and functionality over the PREACTOR FCS versions (Preactor International 2002).

Additional scheduling techniques within APS (event and resource focused), allow selection and creation of bespoke scheduling rules, and it has features enabling the addition of material constraints based on 'Bill Of Materials' data supplied to it from an ERP/MRP system. The way in which products are defined in the standard PREACTOR APS is based upon a relational database structure. Manufacturing data is entered into PREACTOR through various fields, grouped to cover products, resources, resource groups and additional considerations as detailed in the menu in Figure 9.5. The addition of specific manufacturing data to a product is achieved via additional dialogue boxes (an example of which is shown in Figure 9.7) that are prompted from the products database as shown in Figure 9.6.

In order to outline the BOM structure in the FCS versions of PREACTOR, each additional operation must have an 'assembly level' and 'assembly key' specified, in addition to the operation number. Operations on the same key follow the operation number order, whereas assembly levels indicate that all keys must be completed before the operation on the next assembly level may begin as depicted in Figure 9.9.
Orders are specified within the standard versions of PREACTOR through a schedule generator as shown in Figure 9.8. Details regarding customers, order numbers and the product required are entered, along with the due date that the order is required on, and the quantity of product requested which enters the order as jobs to be scheduled. The generation of schedules is completed in Gantt format with jobs being represented by icons (prior to sequencing) and coloured bars for the position of the job in the production schedule, both of these identifiers being specified in the products database. Scheduling rules may be applied to load the ordered operations into the 'sequence overview' area, or alternatively manual dragging and dropping icons from the list of orders into the sequencer as required. An example schedule generation for a small number of products is shown in Figure 9.8, note that two operations are still to be allocated (square icons in the unallocated job queue) onto resources in the sequence overview window (panel at the bottom of the screen).

Figure 9.5, Menu Based view of PREACTOR software
Figure 9.6, Preactor APS Products Database Editor

Figure 9.7, Inputting Product data for processing operations- Parent data and levels and keys
There are two expansions to the PREACTOR APS module named Static Material Control (SMC) and Dynamic Material Control (DMC), which are aimed at applications where WIP has high value and shelf-lives of products are of greater importance. The typical applications of the material control modules within the scheduler has been where materials that are required for a particular product will over-run their allocated shelf-lives if the production schedule is not modified to allow for earlier final processing.
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The way in which these modules differ from other versions of PREACTOR is their system of 'Sales orders' and 'Works orders'. Data is required in a form of BOM relating to each material or ingredient), which allows the products to be defined according to which materials are 'used by' which products. This data may be imported from MRP or ERP systems via an Excel spreadsheet With Sales orders used in place of a strictly defined parent product and the interaction between Works orders and Sales orders being described as two queues. In Figure 9.10 Sales orders (possibly for different customers) each require a different number of the same product. The works orders in Figure 9.10 represent four batches of the same product, following the default rule in SMC, the two works order batches at the bottom of the producing queue are used to meet the first Sales order.

The difference between SMC and DMC lies in the DMC module dynamically reallocating materials while the schedule is being built, whereas the SMC module is a pre-process completed prior to scheduling. The DMC module can allocate materials from a late finishing batch to another to minimise WIP wastes. The SMC and DMC versions of PREACTOR have been used to develop the TSP PREACTOR model as described below.

9.4.2 Two Stage Planning PREACTOR Model

The PREACTOR software system has been utilised to develop a computational viewpoint of TSP as shown in Figure 9.11. The realisation of Two Stage Planning as described in section
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9.3, could not be achieved using standard scheduling applications of the standard PREACTOR software. Hence the functionality of PREACTOR APS SMC (Advanced Planning System with the Static Material Control functionality) has been enhanced to enable jobs to be scheduled without attaching materials to specific orders. This enhancement included time based modifications to the PREACTOR table definition file (.prtdf) so that orders may be specified for particular times of day, rather than midnight of the due date, which was constraining over such short production lead-times. The increased complexity of SMC scheduling also meant that product information, operation data, display specification and BOM structure no longer could be supported or maintained through the product database and so considerable data structuring was required to support the TSP scheduler. This data was transferred into PREACTOR through the standard data transfer menu for orders and products. Resource and resource grouping data of the TSP model is held in the standard PREACTOR database as described in section 9.4.1. Figure 9.12 outlines the data transfer through the PREACTOR schedule generator within the TSP approach.

Figure 9.11, TSP Configuration in PREACTOR APS with SMC functionality
Input of order and product data was achieved from external Excel files which simulate the uploading of EDI data to the scheduler and are kept within the configuration system folder with three particular files (‘productsin’, ‘ordersin’ and ‘BoMdata’) being required for the loading of product and order data. The ‘productsin’ file is shown in Figure 9.13 holds all of the information that would otherwise be inputted into the PREACTOR products database relating to each product’s operations, the display information associated with each, set-up and processing times, resources etc.

Input of forecast order data is achieved in the same way, with data referring to parts, customers, quantities required and due dates all being assigned to a particular order number, as shown in Figure 9.14. Bill of Material data is read in from the ‘BoMdata’ file as shown in Figure 9.15, which identifies the component parts required to manufacture a single unit of each product, as identified by order numbers. In this way the order data is not tied to a particular product, rather the component ingredients for each order being specified. This additional complexity enables the flexibility required in PREACTOR to dissociate ingredients from specific products.
Figure 9.13, Product database outlining product and component data

Figure 9.14, Forecast Order data, note that materials generate separate orders
Static planning of production is undertaken offline and in order to meet the requirements outlined in section 9.2.1 focuses on a number of priorities when considering the product volumes that are released to production on schedules. The anticipation of product demand is achieved by the formulation of forecast orders by retailers which give to some extent an indication of the demand which may be expected. Planners have traditionally made use of historical data in order to refine forecasts combining weekly trends, seasonal variations and holiday behaviours etc with information regarding current conditions. Knowledge of current retailer promotions, (and their on-shelf availability), upcoming special events or weather forecasts are of use to the planner in order to try and anticipate variations from the historical data that may be attributable to these conditions. The focus therefore falls to the consideration of standard operations, the planning of which under the TSP framework should be logged with the historical data and used to map the component ingredient requirements-both planned and confirmed along with the overall confirmed orders and forecasts. In this way the planning of standard operations will be refined with the aid of this historical data so that the consequences of prioritising the manufacture of ingredients used in the greatest number of products, or those with the lowest forecast volatility be known. For each product

Figure 9.15, Bill Of Material Data for each ‘order’ (column A indicating ingredients by part number)
in each order cycle the following data is to be recorded for consideration of future static planning:

- Retailer Forecast and Confirmed demands,
- Ingredient volumes used for both soft and hard schedules,
- OPW ingredient/products,
- Customer service shortfall (number products short on order),
- Notes regarding any unusual circumstance (Special events, promotions, weather).

The release of Soft schedules also consider shelf-lives, capacity constraints, resource availability and changeovers at that stage. Given these complexities the support provided by historical data simplifies the scheduling process. Soft schedules are created and released shortly before production must begin to take advantage of updated forecast or Point Of Sale data where it is available. An example of the Soft schedule is represented in Figure 9.16, identifying the order of operations, ingredients, volumes and operational details required for groups of resources as found in the production environment. Confirmed orders are received via EDI or other such communication and are presented to the decision heuristic for ingredient re-balancing and dynamic planning before material requirements and adjusted order volumes are passed to the schedule generator.

Figure 9.16, Soft Schedule Generated in PREACTOR sequencer
The application of the TSP Heuristic generated as part of this research establishes the ingredient requirements for dynamic planning through the consideration of forecast (planned) volumes, confirmed orders, BOM data and production data. The Heuristic was realised in Microsoft EXCEL software, example visualisations of which are shown in Figures 9.17 and 9.18. Each of the digits used for the product codes in this example represents a shortened form of the BOM, with the first digit representing the meat component, the second representing the Sauce ingredient etc. Figure 9.17 shows the worksheet where Order, forecast and Production data are amalgamated after being uploaded (possibly from EDI etc.) into the format shown. The breakdown of ingredient requirements is generated through the tables shown in Figure 9.18 while the BOM data held for all products as shown in Figure 9.19 is used to generate separate ingredient requirements for various products. These adjusted ingredient requirements (as shown from the form in Figure 9.20) are re-loaded into the schedule generator for dynamic planning of specialised operations.

![Figure 9.17, amalgamation of Forecast, Confirmed Order and Production Data](image-url)
Figure 9.18, Heuristic Excel Worksheet calculating ingredient requirements for second stage dynamic scheduling

<table>
<thead>
<tr>
<th>Product Code</th>
<th>Confirmed Order Volume (On)</th>
<th>Forecast</th>
<th>Shortages</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1510</td>
<td>564</td>
<td>500</td>
<td>2</td>
</tr>
<tr>
<td>A3110</td>
<td>1073</td>
<td>900</td>
<td>1</td>
</tr>
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</tr>
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<td>1600</td>
<td>2</td>
</tr>
<tr>
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<td>1000</td>
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</tr>
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<td>1300</td>
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</tr>
<tr>
<td>C3132</td>
<td>530</td>
<td>500</td>
<td>0</td>
</tr>
</tbody>
</table>

Wastages above confirmed volumes: the ingredients required to be redirected to avoid CFW.

<table>
<thead>
<tr>
<th>Product Code</th>
<th>Confirmed Order Volume (On)</th>
<th>Forecast</th>
<th>Wastages</th>
<th>Ingredients already committed</th>
<th>Sum of Waste Ingredients</th>
<th>Implication on ingredient</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1510</td>
<td>564</td>
<td>500</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
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</tr>
</tbody>
</table>

Figure 9.19, The BOM data for the products considered in the RDM Framework
Dynamic scheduling based on confirmed orders is achieved within PREACTOR which generates Hard schedules for the production environment. Standard operations are locked to resources as they have been planned in the static planning stage, allowing specialised operations to be planned using Dynamic scheduling. Dynamic Scheduling of specialised operations may be achieved in two ways:

i. Using Dynamic Material Control (DMC) within TSP PREACTOR with real-time data and schedule release made through IT infrastructure,

ii. Manual 'Drag and Drop' of jobs into the sequencer based on planners discretion, with job information updated by planner in real-time.

The sequencing environment, as shown in Figure 9.21 will continually update on the availability of real-time data, whereby the use of DMC dynamically reallocates materials to resources taking into account changes of production data presented by the real-time data.

Figure 9.20, Output from Heuristic indicating confirmed orders and Material requirements
The second method of Dynamic scheduling requires planners to manually allocate jobs to the resources represented in the sequencing environment as production data is communicated or becomes available. In this way schedules may be built dynamically with jobs allocated to resources in real-time. The author asserts that in the absence of real-time data being available, improvements will still be made to planning in the face of the challenges described in this thesis through the utilisation of TSP through PREACTOR SMC similarly modified to release updated job cards to production.

9.4.3 Application of TSP PREACTOR Model

There are three possible methods by which schedules may be released to the production system, including both electronic and hard copy means. Route and job cards may be produced to provide processing information for specific jobs, while work-to-lists may be generated for resources. The PREACTOR scheduling software can generate electronic reports which can either be passed directly to production or printed hard copies. An example route card for confirmed production volumes generated from the PREACTOR sequencer when dynamically scheduling is shown in Figure 9.23.
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Figure 9.22. Release of sequences and job cards to production facility

Figure 9.23. Job cards released from PREACTOR for each order to fill the confirmed volume
Chapter 10

Case Study

10.1 Introduction

This chapter provides a case study demonstration of the research concepts described in this thesis which involved a ready-meal manufacturer producing own label products for a large retailer. A background to the company is outlined in section 10.2, describing the products, supply chain issues and manufacturing considerations that relate to the company. The main section of this chapter address the application of the RDM Framework and the improvement programme for production processes and order processing before outlining changes to production planning. The chapter concludes by analysing the results and reflecting on the improvement activities undertaken at the case study company.

10.2 Company Background - Oscar Mayer

The company selected for involvement in the research as a case study was Oscar Mayer, and an outline of the company is provided in this section. The Hygrade group of which Oscar Mayer is a part, is made up of three separate businesses located across the UK, producing in excess of two million ready-meals a week. The company was visited in the initial stages of the research and was involved until the very end, over which time substantial changes within the company had taken place. Oscar Mayer is a privately owned business established in 1985 manufacturing chilled prepared meals for sale through one of the largest UK food retailers referred to in this thesis as ‘retailer X’. The production facility is based in Chard in Somerset and is staffed by 1000 personnel, operating 24 hours a day, 7 days per week, though night work mainly consists of hygiene teams and cook cycles. The main facility is split over three floors (designated as OM1, OM2 and OM3), each of which manufactures a different family of products. Each floor consists of ‘low risk’ preparation and cooking areas which are separate to the ‘high risk’ filling area, which in turn is separated again from another low risk area for packing and despatch. These separate areas prevent personnel and equipment from
easily moving between low and high risk zones of the factory without passing through the necessary hygiene procedures. The flexibility of the equipment used on each floor means that several products can often be assembled on the lines on other floors, should demand require it. Some products must be manufactured on specific filling lines where ingredients demand that specific processing equipment be used, for example those ready-meals including sheet pasta require to be processed on one of three lines in OM2, while mashed potato dishes require the filling lines in OM3.

10.2.1 Products

Oscar Mayer currently manufacture 130 of retailer X’s own label products, 80 of which were described as core lines, having greater demand accordingly. Table 10.1 indicates a small range of the products manufactured on each floor of the factory.

<table>
<thead>
<tr>
<th>Product code</th>
<th>Product Description</th>
<th>Factory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z01503701</td>
<td>SMOKED SALMON RISOTTO</td>
<td>OM1</td>
</tr>
<tr>
<td>Z01500901</td>
<td>LAMB SHANKS</td>
<td>OM1</td>
</tr>
<tr>
<td>Z25380601</td>
<td>CHICKEN TIKKA 400G</td>
<td>OM1</td>
</tr>
<tr>
<td>Z01513501</td>
<td>LEBONÉSE LAMB</td>
<td>OM1</td>
</tr>
<tr>
<td>Z01516001</td>
<td>CHICKEN RISOTTO</td>
<td>OM1</td>
</tr>
<tr>
<td>Z16404101</td>
<td>MINCED BEEF COBBLER</td>
<td>OM1</td>
</tr>
<tr>
<td>Z01504001</td>
<td>Cauli &amp; Camembert Bake</td>
<td>OM2</td>
</tr>
<tr>
<td>Z01500301</td>
<td>Meat Lasagne 450g</td>
<td>OM2</td>
</tr>
<tr>
<td>Z01504601</td>
<td>Meat Lasagne 700g</td>
<td>OM2</td>
</tr>
<tr>
<td>Z16416701</td>
<td>Beef in Red Wine</td>
<td>OM2</td>
</tr>
<tr>
<td>Z01508801</td>
<td>Moussaka</td>
<td>OM2</td>
</tr>
<tr>
<td>Z16422601</td>
<td>Lamb &amp; Redcurrant Casserole</td>
<td>OM2</td>
</tr>
<tr>
<td>Z16404401</td>
<td>Beef in Ale</td>
<td>OM2</td>
</tr>
<tr>
<td>Z01514601</td>
<td>Premium Lasagne</td>
<td>OM2</td>
</tr>
<tr>
<td>Z05820001</td>
<td>Chicken Broccoli Pesto</td>
<td>OM2</td>
</tr>
<tr>
<td>Z05820101</td>
<td>Chicken Sundried Tomato</td>
<td>OM2</td>
</tr>
<tr>
<td>ZTRIAL2009</td>
<td>Chicken &amp; Sundried Tomatoes</td>
<td>OM2</td>
</tr>
<tr>
<td>Z05818701</td>
<td>Tag Lemon Chicken</td>
<td>OM2</td>
</tr>
<tr>
<td>Z16404001</td>
<td>Chicken &amp; Bacon Gratin</td>
<td>OM2</td>
</tr>
<tr>
<td>Z16402301</td>
<td>Irish Stew</td>
<td>OM2</td>
</tr>
<tr>
<td>Z05900901</td>
<td>Mini Liver &amp; Bacon</td>
<td>OM2</td>
</tr>
<tr>
<td>Z05931201</td>
<td>Mini Fruity Chicken Curry</td>
<td>OM2</td>
</tr>
<tr>
<td>Z05931301</td>
<td>Mini Chicken Casserole</td>
<td>OM2</td>
</tr>
<tr>
<td>Z16401101</td>
<td>Pork &amp; Apple Meatballs</td>
<td>OM3</td>
</tr>
<tr>
<td>Z16447301</td>
<td>Braised steak and mash</td>
<td>OM3</td>
</tr>
<tr>
<td>Z16404201</td>
<td>Liver &amp; bacon</td>
<td>OM3</td>
</tr>
<tr>
<td>Z16404301</td>
<td>Sausage &amp; mash</td>
<td>OM3</td>
</tr>
<tr>
<td>Z05813001</td>
<td>Beef chasseur</td>
<td>OM3</td>
</tr>
</tbody>
</table>

Table 10.1, Sample product ranges manufactured at Case Study company
Trial products are often tested in the production facility, either to new recipes generated by the product development team, or to refine existing recipes, for example to reduce salt content (e.g. product ZTRIAL2009 in table 10.1). The manufacturing lead-times of products vary considerably, from a few hours for very simple products to several days for products requiring long cook or marinade cycles. Some ingredients have a reasonably long shelf-life for Oscar Mayer to use prior to final assembly, and as such products with large variances on the day production may be held over for the following days products where such shelf-lives allow. Retailer X aims for a 'minimum life on receipt' of 75%, whereby a product with 10 days shelf-life after cooking must be received by retailer X with 7.5 (rounded to 8) days remaining before expiry.

10.2.2 Customer

As mentioned previously, the company works for a single retailer, providing own-label branded products for a number of the retailer's brand ranges. These ranges consist of products emphasising either health, 'value' (low cost products), or premium quality, with Oscar Mayer manufacturing a number of products in each range. Orders for all products are placed at 9 am each day, which frequently differ to the forecast demand available from the Retailer X's PDS (Performance Data Site) website on a rolling basis for 10 days ahead. The orders placed at 9 am are for despatch to Regional Distribution Centres (RDCs) at the earliest 19:00 hours on the same day through to 12:00 on the following day. 10 RDCs are served in this way, the geographically furthest away from Oscar Mayer requires despatch at 19:00, while the closer RDCs have their despatch times delayed until later in the order cycle. Once products are completed in the main factory they are transported to a separate despatch facility from which shipments to the RDCs are organised.

10.2.3 Supplier Network

Oscar Mayer is served by approximately 150 suppliers, including many international companies, with low costs being reported as the main driver for competition on ingredients, provided adequate standards of quality, shelf-life and consistency are met by the various suppliers. Transport times thus vary considerably between the different suppliers, and so should increased frequencies of deliveries be required the limited responsiveness that
overseas suppliers can deliver may impact the levels of service they may be able to offer, and at times outweighing their economic advantages. Many of these suppliers provide a number of different ingredients, and for the most important ingredients Oscar Mayer will source from several suppliers to drive competition, ensure availability and maintain quality standards. This does however mean that some inspection is undertaken of the raw materials at the intake area (located in OM1) to ensure consistency between suppliers.

10.2.4 Manufacturing

As previously described the production facility is split over three floors, as outlined in Figure 10.1. The filling and cooklines are indicated in the figure, and it can be seen that each of the floors may be considered a distinct food ‘factory’ each with an initial ingredient preparation area and then separate processing equipment and ‘high risk’ areas on each floor. Ingredients may be processed on a number of floors, for example meats being cooked in the bulk oven in OM1 being passed to the chillers in OM2 and OM3 for further processing.

![Figure 10.1, Overview of Oscar Mayer Production Facility](image-url)
A detailed breakdown of the resources available on each floor is provided in section 10.3.1 as was undertaken in mapping the production activities at Oscar Mayer. Each of the prep areas on each floor is staffed by an operator that ‘kits’ together the required materials for each production run, grouping the materials close to the cooklines prior to processing. Each of these prep rooms contains some small processing equipment (grouped in Figure 10.4 as ‘meat prep’) specific to the ingredients that the cooklines require. Marinated ingredients for example are prepared in tumblers, bagged meats are sealed in this prep area, frozen meats may be defrosted while other materials may need to be chilled.

An obvious inefficiency comes where product is transported to a local warehouse with trucks transporting crates from the factory making around 15 trips per day, this transportation alone costing around £3000 each month. Sorting of products prior to despatch is undertaken at the warehouse, with the individual store allocations being specified for crossdocking at the distribution centre simply due to shortages of available space in the despatch areas in OM2 and OM3 as outlined in Figure 10.2. The product that is consolidated at the warehouse each day accounts for around £500,000, which presents a significant overhead to the company. In addition Oscar Mayer has identified difficulties in production control and also product routings through the factory, and problems from operators on individual floors prioritising their own production runs ahead of products from other floors that need to use their capacity. As such these problems have come about from the operators own autonomy in sequencing production, working simply from order-volume lists as provided by the planners.
The planning and scheduling of production was completed manually via a system of spreadsheets (with one planner responsible for each floor) at the time of the initial research visit and data gathering. The planning efforts took 12 man-hours daily, with production runs confirmed at 13:00 each day (and often later, sometimes 16:00-17:00), after orders were received at 9:00 as outlined in Figure 10.3. The cooking cycles to prepare sauces and meats for production typically began 48 hours before despatch (in some cases meats were in production for 6 days for defrosting, preparation and cooking). Considerable time was spent determining whether there was enough material available on-hand to meet the orders, which could be easily completed through use of an MRP system. Orders were manually converted to filling-plans, with intervention by the planners being highlighted as the primary indicator of any large variances in demand, prompting action from the planner. Order variances from the retailer were substantial, some products having confirmed orders 200% above the forecasts. Across the product ranges around a third of products experienced low variances (below 10%), with a similar proportion varying from forecasts by greater than 25%. Implications for production were greatest where demand under-estimations had been made for products requiring use of the same manufacturing equipment, thus causing capacity problems. Estimated processing times which did not realistically reflect the actual production performance were being used to plan production, while operator priorities in sequencing production and resisting manufacturing change hindered operating improvement. Oscar Mayer aims to achieve 99.5% customer service levels as a performance target, with actual levels achieved reaching 98.7%, while waste generation is given lower priority in order to achieve this goal, as outlined below.

![Figure 10.3, Order placement and 3-day production overview at Oscar Mayer](image-url)
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10.2.6 Waste Creation

Waste creation at the case study company was not measured and recorded when first visited, however there was acknowledgement that a great deal of waste was created by Oscar Mayer and inefficiently dealt with. Sources of waste creation were identified as those associated with:

- Traceability requirements and product testing,
- Process inefficiencies, product giveaways and yield losses,
- Substantial volumes of waste created through overproduction.

Traceability and product giveaways are accepted as necessary and of low volume (only 3-5 products are kept from each product run for testing), while process inherent inefficiencies produced greater volumes of waste that were either bi-products or otherwise unusable to other processes. Overproduction wastes on the filling and packing lines represented considerable costs to Oscar Mayer, with some finished products being made available through the staff shop as ‘authorised extensions’ by members of the technical department. Overproduction wastes on the cooklines were largely through calls from the planning department to cancel cooks which meant that pre-mixed bagged ingredients were disposed of, unless the ingredients had already been processed, which resulted in more costly disposal of the prepared batches.

10.3 Application of Responsive Demand Management Framework

The following section outlines the work undertaken as part of this research in applying the Responsive Demand Management (RDM) Framework to the case study company. In keeping with the structure maintained in chapter 8, the health-check is addressed in section 10.3.1, before the improvement issues for manufacturing and order lead-times are outlined in section 10.3.2. Two Stage Planning of production for the case study company is described in section 10.3.3, before the chapter concludes with a discussion of results.
10.3.1 Health-check and Process Modelling activities

10.3.1.1 Questionnaire

The initial stage of the framework sets out to compile the available data regarding manufacture and supply, utilising various methods of collection. The Health-check questionnaire was completed initially, as outlined in appendix 3, however the following summary indicates the highlighted points to arise from completing the questionnaire:

- Many products will be able to be processed within the order lead-times, while a subset of products have substantially greater manufacturing lead-time,
- Variations in processing times, changeovers etc. are considerable, and poorly monitored by manufacturer,
- The single customer has great power in relationship reflected through ordering, forecasting and even product development,
- Several forms of communication and information processing are utilised, with considerable manual input of data and face-to-face communications (planning meetings),
- Although retailer provides promotion information, improvements may still be made regarding demand communication,
- Scheduling is not undertaken by the planning team, (who monitor and control material availabilities) with production sequencing is carried out by operators,
- Waste generation is considerable, with little knowledge of the causes and volumes of waste creation or the implications and costs associated with wasteful production being available.

In addition to the questionnaire, a number of data collection and production measurement activities were organised and undertaken, with the results being used to support the questionnaire in providing quantitative data for process modelling. The templates used for this data collection are provided in appendix 3, with sample data for one of the cooklines measured being presented in the format developed for detailed consideration of the changeovers.
10.3.1.2 Process Modelling

Process Modelling of the case study manufacturer was undertaken utilising Value Stream Mapping techniques. In order to map the production flows the resources in use at Oscar Mayer were grouped as outlined in Figure 10.4. Each resource was placed in a group relative to a floor in the production facility with the exception of the meat prep resources which are located relative to the processing lines they are used with. Grouping the meat prep resources in this way has been done as the implications for process routings are alike each of these resources. Other processing activities include preparation and chilling operations which require no specific resources apart from the approximate area in which they are undertaken in most cases, in this way, capacity restrictions for these operations is based upon operators and the constraints of the physical location.

Figure 10.4, Groupings of resources throughout Oscar Mayer production facility
Process Mapping began with the identification of the major product families manufactured by the company, and the selection of those products within each family that demonstrated the main features of the value stream for mapping, as mapping every component of all 130 products was infeasible. Table 10.2 contains an example of the initial activity mapping which details the processing steps for a particular component’s value stream. The information flows of each Value Stream Mapping remains largely the same, and to clarify the mappings as much as possible, after an extended VSM was completed for the suppliers and distribution centres, (as shown in Figure 10.5) each subsequent mapping focused simply on the manufacturing processes and physical flows (as shown in Figure 10.6). As can be seen in Figure 10.6, the combination of material flows (in the absence of information flows) was undertaken for whole product configurations.

<table>
<thead>
<tr>
<th>Detailed Process steps</th>
<th>Value Creating Steps</th>
<th>Total Time (minutes)</th>
<th>Value Creating Time (sec)</th>
<th>Distance (approx metre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>De-bagging of Raw materials (cheese mix)</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheese loaded into trays and held in prep area</td>
<td>90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trays passed through Stein Cooker</td>
<td>1</td>
<td>25</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>Trays transported to OM3 potato prep area</td>
<td>5</td>
<td></td>
<td></td>
<td>28m (to OM1 lift) + 54m OM3</td>
</tr>
<tr>
<td>Trays held prior to processing</td>
<td></td>
<td>55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ingredients added to Flavour Masher</td>
<td>2</td>
<td>7</td>
<td>210</td>
<td>5</td>
</tr>
<tr>
<td>Mash ingredient transported to blast chiller</td>
<td>0.5</td>
<td></td>
<td></td>
<td>47</td>
</tr>
<tr>
<td>Held in blast chiller</td>
<td></td>
<td>340</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transported to production line prior to filling</td>
<td>0.5</td>
<td></td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Waiting to be added to product</td>
<td></td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Addition of mash to fish pie assembly</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(flow line through grill, cryo-freezer, check weigh and metal detect)</td>
<td>3</td>
<td>2</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Flow line</td>
<td></td>
<td>1</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Addition of sleeve to product, packing to case</td>
<td>4</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Moved to despatch area before loading</td>
<td></td>
<td>90</td>
<td></td>
<td>45</td>
</tr>
</tbody>
</table>

Table 10.2, detail of processing steps for cheese mix/mash component of 600g fish pie
Figure 10.5, Value Stream Mapping indicating information channels and communication flows at Oscar Mayer

Figure 10.6, Value Stream Mapping of material flows for luxury fish pie 600g
10.3.1.3 Waste Inventory for facility

The wastes created at the case study company have been recorded as part of a new system of measurement which requires operators to record each instance when materials are disposed of to waste (termed 'isolations') reporting back the following information to the planning and purchasing departments:

- Product or ingredient concerned,
- Reasons for 'isolation',
- Quantity rejected (number of foils or weight),
- Who decided the isolation,
- Any corrective action taken.

The data collected however was used to create a waste inventory as described in section 7.4.1, in order to further highlight the incidences of waste for when the obvious cost-driven improvements have been implemented. As can be seen from Figure 10.7, the wastes which did not contribute directly to product costs from the manufacturer's point of view (water and packaging costs) have not been recorded as part of the waste measurement completed thus far.

Figure 10.7, Waste mapping for OM3 production areas over one month's manufacture.
10.3.2 Manufacturing and Order Lead-time improvements

The following section describes the work undertaken in applying the tools used in the second stage of the RDM framework for improvements of production process and supply chain activities to the case study company.

10.3.2.1 Product based techniques

*Product family analysis* was undertaken initially, the split over four groups as shown in Table 10.3, with the products manufactured by the case study company considered relative to their volume. The breakdown of the volumes of products revealed that, contrary to what the company had described initially, there were a small number of higher volume products while most products contributed similar volumes. This means that Oscar Mayer’s product portfolio has a greater balance of product volumes, with 23% of the products constituting half the volume of production. In addition, the number of products constituting very low production volumes was lower than anticipated and as such the elimination of smaller volume products was not considered an option for the case study company. This analysis has shown that Oscar Mayer’s products do not fit the ‘runner, repeater and stranger’ model of product variety described in section 5.5.1.5, which the author believes is due to the frequent new product introductions and retailer focus on high demand products. Oscar Mayer has already balanced volumes of production across OM1, OM2 and OM3, with those that share common ingredients or resource requirements, for example the larger volume potato ingredient products being processed in the same areas as the other smaller volume runs.

<table>
<thead>
<tr>
<th>Cumulative Volume</th>
<th>Cumulative % of products</th>
<th>Suggested Grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>50%</td>
<td>23%</td>
<td>1</td>
</tr>
<tr>
<td>95%</td>
<td>85%</td>
<td>2</td>
</tr>
<tr>
<td>99%</td>
<td>96%</td>
<td>3</td>
</tr>
<tr>
<td>100%</td>
<td>100%</td>
<td>4</td>
</tr>
</tbody>
</table>

*Table 10.3, Volume consideration of Products*
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The other product based improvement techniques included in the framework consisted of design considerations. In the case of Oscar Mayer, products are all specified by the retailer, with decisions regarding foil design, ingredient components, shelf-life determinations etc being strictly specified by the retailer, with limited opportunity for modification or substitution given the consistency demanded. This means that ingredient interchange-ability is restricted as the processing of all products is to the retailers specifications, and there is little scope to standardise ingredients. The application of design methodologies by retailer X has been pressed by Oscar Mayer, and as such collaborative efforts have been undertaken in 2005 to make modifications to design aspects of the products to improve manufacturing considerations.

10.3.2.2 Process based techniques

The Supply Chain Response matrix was used in its modified form as developed by this research to map capacity against lead-time for the common product routings, using average capacity data. An example mapping is shown in Figure 10.8, with the processing capability of several resources (abco masher and stein cooker) being able to process at considerably higher rates. However it can be seen from Figure 10.8 that the majority of the manufacturing lead-time is spent in blast chillers where product must reach a specified temperature before subsequent processing which represent variable process delays that may take around 6 hours to complete.

![Figure 10.8, Supply Chain Capacity Mapping of Mash Component of Fish Pie Product](image-url)
As such, Oscar Mayer has begun a program of investigation to ‘maximise chill capacity’ available through production in order to reduce the temperature of materials in less time, and also to identify with greater accuracy the lengths of time specific products must be chilled for.

The use of the *Production Variety Funnel* as shown in simplified form (before being mirrored in the x-axis) in Figure 10.9. Figure 10.9 indicated the substantial number of ingredient variants and the small number of processing methods to produce a significant number of different products, displaying the same basic “I” shape described in section 5.5.1.7, with however a far larger number of ingredient variants than anticipated. This indicated that very few products shared the same base components, such as sauces, which would impact the adoption of a system of standard and specialised operations.

![Figure 10.9, Production Variety Funnel for Case Study Manufacturer](image)
Considerable data collection was undertaken within the case study manufacturer with a number of processing methods being highlighted as particularly labour intensive, wasteful and time consuming. *Technological benchmarking* of the manufacturers current production methods determined several opportunities for improved processing.

<table>
<thead>
<tr>
<th></th>
<th>Manual Lid Seal</th>
<th>Multi Headed M/C</th>
<th>Single Headed M/C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Throughput (foils/h)</td>
<td>2520</td>
<td>1680</td>
<td>2280</td>
</tr>
<tr>
<td>Typical Throughput (foils/h)</td>
<td>1680</td>
<td>1350</td>
<td>2100</td>
</tr>
<tr>
<td>Changeover Time (min)</td>
<td>~16-20 (2 sealer)</td>
<td>~20</td>
<td>~15-20</td>
</tr>
<tr>
<td>% total line downtime</td>
<td>19%</td>
<td>22%</td>
<td>16%</td>
</tr>
<tr>
<td>Operator expertise rqd</td>
<td>very low</td>
<td>moderate</td>
<td>moderate</td>
</tr>
<tr>
<td>Average line personnel</td>
<td>10.4</td>
<td>7.6</td>
<td>7.1</td>
</tr>
<tr>
<td>Total Cost Ownership</td>
<td>moderate</td>
<td>high</td>
<td>moderate</td>
</tr>
<tr>
<td>Investment Required</td>
<td>very low</td>
<td>moderate</td>
<td>high</td>
</tr>
</tbody>
</table>

**Table 10.4.** Comparison of the sealing machines for resource improvement

An illustrative example of this step of the framework came in consideration of OM2’s pasta filling lidding and sealing operations before the meals pass through a chiller into the packing area. Lines 1 and 3 were heavily labour dependant for these operations, with operators adding lids to trays and hand crimping the foil trays to form a seal. Line 2 had for some time been operating using a multi-headed (processing 4-8 foils at a time) sealer which added lids to the trays and sealed them automatically at the end of the filling line. Operators had complained of the multi-headed sealer’s reliability, which regularly miss-fed trays into the sealer, which then required the line to be stopped while spoiled product was removed (often to floor waste). The improved processing time and reduced labour requirement of the multi-header were measured against additional consideration of waste creation and process reliability when looking to alternative processing resources. A single headed lidding and sealing machine operating at higher throughput times was identified as providing improvement to both current processing resources by means of simulation, with a simple model being constructed to compare the performances of the different resources. Processing line 1 was trialled with a single lidding machine, which demonstrated higher reliability over the first month of its use than the multi-header, with other considerations as outlined in Table 10.4.

These process based techniques highlighted the importance of minimising the process delays through production (from the supply chain response matrix), a wide range of production inefficiencies which may be improved upon through investment in processing equipment (by
technological benchmarking) and demonstrated the extent to which products are comprised of distinct ingredients (through the production variety funnel).

10.3.2.3 Resource based techniques

*Equipment design analysis* was completed for several areas of production, in particular for those processing operations where considerable time was spent in changeovers between products as identified at the data collection stage of the health-check. Improvements to changeover processes were prioritised, with *Single Minute Exchange of Die* simplifications to processing operations identified in a number of resources considered within the equipment design analysis. A key example of which came through the cookline kettles in OM2 where the Fairfield (large batch) processors are good examples of effective processing, while the smaller kettles require significantly greater labour levels, and the process of emptying the kettles generates considerable waste which is inherent to the process. The Fairfield kettles are filled from above and then emptied automatically through pipe work at the base of the tank to depositors ready for use on the filling lines. The small batch kettles however are emptied manually over the wall separating ‘low risk’ and ‘high risk’ by scooping sauce or other ingredients from the kettle into trays which are used to serve the filling lines. The modification to the production area so that the small kettles could be drained to depositors or trays in a similar manner to the larger kettles would eliminate considerable spillage and floor wastes, in addition to decreasing changeover time and labour requirement. The cumbersome production techniques highlighted through this stage of the framework were noted by Oscar Mayer for further investigation.

These resource based techniques were focused primarily on product changeovers and as such highlighted several processing inefficiencies caused by poor utilisation of the available resource. The technology required to implement such processing improvements was already in place at the manufacturer and the author believes the reductions of waste and improved process control will offset the financial investment required.

10.3.2.4 Layout based techniques

The *Process Activity Mappings* were completed in the format shown in Table 10.2, with resource detail indicated in the left hand column. Example mappings were created for
products through manufacture from detailed facility plans, and in addition several product lines had the flows through goods inwards through to final despatch to RDC mapped. As seen in Table 10.2, considerable movement of product occurs around the facility, particularly where ingredients are prepared on one floor and then transported to another level of the facility. Although there are numerous occasions where a product's lead-time can be improved by alternative flow layouts, this simultaneously detrimentally increases other product's lead-times.

Based upon material flow analysis this research considered two major layout changes to be of primary importance. Firstly the movement of products to the separate despatch warehouse as described in section 10.2.4 was seen to add labour costs, planning and logistic complexity and additional lead-time substantially impacting every product. The company has invested in some building conversion work in 2005 and is currently modifying some cold storage space (used for bulk storage of long shelf-life ingredients) into additional despatch area to reduce the need to move material to the warehouse. Secondly the ingredient intake area and the despatch areas are located at the same end of the factory. OM1 runs contra to the flow of production through the facility, meaning that both finished products have longer transit times through to the despatch area (which is located in OM2 and OM3) and ingredients have to travel further in OM2 and OM3 to reach the start of production. Ideally despatch should be completed at the opposite end of the factory, with all floors flowing production in the same direction, however Oscar Mayer has considered this but deemed the costs of such structural changes and disruption to production as infeasible.

The layout based techniques have highlighted the material routing problems that are evident at the case study company and through detailed product activity mapping provide a quantifiable means of comparison of various production layouts. The significant changes identified by this research have been acknowledged by Oscar Mayer for consideration in the future.

10.3.2.5 Supply Chain Tools

Suppliers to Oscar Mayer have been able to co-operate in improving supply chain management methods by delivering materials on the same day that they are ordered, significantly streamlining goods inwards operations at the same time simplifying
communications. This improvement by suppliers has increased flow through the factory and reduced goods inwards material holding. This has however created further complexity when raw material supplied has failed to meet specification, meaning there is greater reliance on suppliers providing materials of sufficient quality. Should consignments of raw materials have to be scrapped then significant numbers of other materials will have to be cancelled for that day’s production, wherein the past substantially more material was held which could be used in production. In addition Oscar Mayer took part in a scheme implemented by the retailer in which employees (planners) from the ready-meal supplier manufacturers were placed at the retailer head offices to co-ordinate communications and help order placement. This has significantly clarified drivers behind some order fluctuations from the retailer, and has enabled the manufacturer to collate greater information regarding planned promotions and product launches.

*Network benchmarking* has not been possible against a suitably similar supply chain, and as such Oscar Mayer has considered its position relative to a set of ‘ideals’ by which inbound and outbound logistics are streamlined, data exchange is made in real-time to all supply chain partners and service levels to customers and on-shelf availability of in-store products is 100%. *Decision point analysis* of the supply chain confirmed that retailer order ‘pull’ comes too late in the production cycle for products to be made to order. The *demand amplification screen* for the case-study supply chain is based upon manufacturer demand volatility experienced from retailer orders. The visualisation provided in Figure 10.10, demonstrates the level at which the case study manufacturer was experiencing demand volatility on the forecast order volumes received, which has been further shown in Figure 10.11 for a sample of 7 products.

The supply chain considerations have improved flows of material from suppliers and information regarding promotions and new product launches is used by the case study company with greater reliability due to the improved working relationship that has been fostered through the planner placement.
Figure 10.10, Demand Amplification Screen for Oscar Mayer Order volumes

Figure 10.11, levels of order variance from forecasts for 7 products over 84 orders
10.3.2.6 Communication Streamlining

The adoption of Collaborative Planning Forecasting and Replenishment requires involvement by each member of the supply chain, but this proved to be infeasible over the course of this research. However, by consideration of the principle aims of CPFR, an ideal future state case for the information flows in the case-study supply chain was generated as shown in Figure 10.12. The benefits this would present to the manufacturer in terms of order lead-time would be considerable, given the swifter availability of real-time order data and the inclusion of suppliers and manufacturers in the forecasting considerations. This availability of data may in turn mean that supply of products from Oscar Mayer may be more streamlined through more frequent shipments of smaller volumes as orders are completed. The view in Figure 10.12 of the future value stream focuses on the simplification of the ordering process and does not include the required changes to replenishment, which could also significantly improve the way in which retailer store demand is satisfied.

The utilisation of external communication technologies have remained unchanged over the course of this research between the manufacturer and retailer X, so to improve responsiveness to order confirmation and material availability problems that arise through production, improved internal communications have been developed.

![Image](image.png)

Figure 10.12, future state Value Stream Mapping based upon Collaborative Forecasting and Planning
Greater responsibility has been placed on the production supervisors both to anticipate and communicate ingredient shortages to the planners and also to quickly react to the production changes required immediately after order volumes have been confirmed. In this way the case study company has become more flexible to changes, making better use of the time they have available, and creating more time to respond to fluctuations in production volumes.

Demand data is made available to Oscar Mayer from the retailer only through periodic summaries, while orders are accumulated and provided via Electronic Data Interchange daily, in a single transfer of orders. This availability may be improved upon through the provision of daily or even real-time Point of Sale data updated over EDI, or through other e-commerce methods. In addition, the retailer’s ordering procedures contribute significantly to delays in data flows, as order volume communications are delayed until data for all products is available for transfer (standardised to 9am). As such, considerable improvement to order lead-time can be made through changes in keeping with initiatives under the Efficient Consumer Response approaches.

Information flows have been improved internally within the case study company, while the most appropriate communication methods have been identified with regards to order placement, availability of demand data and the use of collaborative practices to reduce information flow complexity as part of this stage of the framework. In addition, the use of Value Stream Mapping at this stage has provided a ‘future state’ of supply chain towards which each supply chain member can work to foster the alliance required for CPFR implementations.

10.3.2.7 Technology for Supply Chains

Pre-distribution cross-docking is used for the supply chain, with crates of product sorted for particular stores at the warehouse prior to despatch to the distribution centres. This means that communication management and integration costs are greater however this means that less material handling time is required at the RDC, further reducing the delivery time through to store. There have been a range of reports and press statements regarding the trials retailer X undertook using Radio Frequency Identification for ready-meals through one of its distribution centres. This trial lasted two years, and ended in 2000 (Sharp 1999; security at work 2005). The outcomes of this trial was for the retailer to plan implementation across all
stores and products, however it has been seen from the case-study manufacturer that there has not been a complete roll-out of RFID across all the retailer's suppliers. The costs of RFID systems have reduced substantially since the trial was undertaken, however the costs per chip have still been considered too high, preventing adoption of the technology as standard.

Considerable improvements have been made to promote communication of material shortages from the production facility as problems arise. This involved improving awareness to production supervisors of the importance of timely information regarding shortages of ingredients and the timing of planning meetings for supervisors to report back progress from production. The application of production monitoring systems and Supervisory Control and Data Acquisition systems were determined as prohibitively expensive for the company to invest in over the course of this research. The informal existing information channels were established in a more standardised way, with regular meetings to communicate production progress and a culture shift by operators to communicate difficulties and delays to production planners in a timely fashion. The benefits of an automated data capture system, or a means by which production information may be made available to planning electronically were acknowledged by Oscar Mayer, however justification of the costs of such a change were still to be finalised.

10.3.3 Two Stage Planning of Oscar Mayer Production

The realisation of Two Stage Planning of the case study company's product ranges was undertaken in PREACTOR software as described in chapter 9, and is outlined in this section.

10.3.3.1 Data inputs and Database set-ups

The TSP realisation of Oscar Mayer's production system was structured in keeping with the TSP PREACTOR model. The resource and resource grouping databases within PREACTOR were set up to reflect the production facility as illustrated in Figure 10.4. The resources and resource groupings databases are depicted in Figure 10.13 (showing the population of the OM1 cookline resource group). Modifications were also required throughout the other PREACTOR databases to reflect production at Oscar Mayer, for example the shift calendars were modified to reflect the differences in working time on cook and filling lines. The three
major input files described in section 9.4.2 were used in the same format to load product, order and Bill of Material data into the TSP PREACTOR environment, as shown in Figures 10.14 and 10.15.

Figure 10.13, Resources and Resource Groupings within the PREACTOR database
Chapter 10

Figure 10.14, Oscar Mayer Product list

Figure 10.15, Oscar Mayer Bill of Materials
10.3.3.2 Specialised and Standard operations

The product structures found in Oscar Mayer varied considerably from the model previously described where relatively small numbers of ingredients were assembled into a wide range of products. As seen from the Production Variety funnel in Figure 10.9, there are a large number of ingredients used and processed through a relatively small number of different processing methods (around 18) to create a very large number of final products. The number of final components is equally large, with only a few common sauces etc. used in several products. This is in part due to the demands of the retailer in specifying the nature and form of the ingredients to be used and thus creates a possible improvement consideration for the retailer and manufacturer in new product development process to consider the component inter-changeability for manufacturing. In the context of the TSP approach, the large number of product-specific ingredients presents a considerable challenge to waste minimisation, given that components can only be redirected to a very small number of alternative products. The extent of this challenge is highlighted in Figure 10.16, which indicates part of the Bill of Materials for Oscar Mayer’s products, taken from the TSP Heuristic which demonstrates the very small number of common ingredients.

Figure 10.16, Sample of Bill Of Materials for Oscar Mayer Products
10.3.3.3 Planning of Production

The challenge for production planning therefore was to minimise wastes without the allowance in allocating ingredients to different final products when demand fluctuates. The generation of soft schedules, and making the best use of the available capacity were both prioritised to meet this challenge in addition to the goals of TSP. In addition, a small number of ingredients had a limited shelf-life which was available to be used through production allowing those ingredients to be used for the next shift before they had to be disposed of, this flexibility was included in considering static scheduling.

10.3.3.4 Soft Schedules

Static scheduling of production for the purpose of Soft schedule generation was highlighted as being critical as to the volumes of waste created, as ingredients committed to production at the Soft schedule stage were likely to generate OPW when demand for those products was overestimated. Figure 10.17 provides a Soft schedule Gantt chart view of the cookline resources for Oscar Mayer.

![Sequence Overview](image)

Figure 10.17, Soft Schedule Gantt chart of Oscar Mayer Production Schedule in TSP

PREACTOR overview
The systematic collection, analysis and application of historical data was instigated to support the generation of Soft schedules, which allowed improved estimates as to the final confirmed order to be generated. These improved estimates limited the extent of wastes created in some cases. The application of historical data was used to refine the expected volatility, with the provision of maximum and minimum experienced forecast and order volumes (along with soft and hard schedule volumes and OPW incurred) for each particular product relative to previous seasonal, holiday and weekly trends. Plans of promotions led by the retailer were made available in advance by the latter stages of the research, with information relating to the duration of promotions, details of the offers (percentage savings, buy one get one free, etc) and new product launches being provided for each product up to 15 weeks in advance. The improved confidence in knowing the extremes of order fluctuations for each product enabled initial commitment of ingredients to be completed more consistently to levels below the confirmed orders. This strategy was only possible for those products with short production lead-times that could have small volumes of ingredients prepared quickly to the known volumes required. The products with manufacturing lead-times that were in excess of the time available were then prioritised for waste minimisation through lead time reduction and consideration of shelf-life maximisation. Those ingredients that required long processing times (as identified through earlier stages of the RDM framework described in sections 10.3.1.2, 10.3.2.2 and 10.3.2.4) were scrutinised as to the exact shelf-life demands of those ingredients and with support from the technical department it was found that the majority of these ingredients could be used within 48 hours of processing. This extension to shelf-life availability meant that it was possible to utilise the previous production cycle’s ingredients but this required consideration of the previous day’s hard schedule and on-hand material availability.

10.3.3.5 Hard Schedules

Production volumes are loaded into the TSP heuristic to determine the production requirements for ingredients and to provide instant feedback for those instances where demand has been over-predicted. Figures 10.18 and 10.19 show the TSP heuristic populated with OM data which outlines the waste ingredients identified (Figure 10.18) and the shortages of specific ingredients relative to the current production volumes across all products (Figure 10.19). The uploading of ingredient requirements is completed from the
heuristic (as shown in the format in Figure 10.20) directly into the Oscar Mayer TSP PREACTOR configuration, from which the hard schedules are generated.

Figure 10.18, Waste Identification for Oscar Mayer Products

Figure 10.19, Ingredient requirement calculation through TSP heuristic
Responsive Demand Management (RDM)

Figure 10.20, Output product and ingredient requirements from the TSP Heuristic

Figure 10.21, Example Hard Schedule report outputted from Oscar Mayer TSP PREACTOR configuration
Hard schedules are generated in TSP PREACTOR by the planner using the aforementioned drag and drop process. The hard schedule is released in the form of job cards to the production environment indicating sequences of special operations to be carried out (as shown in Figure 10.21) and in the most extreme cases this may be a stop order to prevent the creation of further OPW. The IT infrastructure at Oscar Mayer does not support the electronic transmission of data to the production environment so the standardisation practice of formal planning meetings needed to be extended to include the provision of hard schedules.

10.4 Results

As a result of the application of RDM, the following improvements have been noted within the case study company, described over the following four sections, addressing manufacturing lead-time, supply chain, planning issues and waste minimisation.

10.4.1 Improvements to Manufacturing Lead Times

The application of lean tools to the manufacturer was undertaken through a number of different stages, with small projects being implemented through the despatch areas (notably OM1). The investment in less labour intensive technology resources also improved manufacturing lead-times, with subsequent resource upgrades planned to supplement the changes described in section 10.2.3.2 on filling lines 1 and 2 in OM2. The large number of other improvements highlighted through the analysis undertaken in the RDM framework were deemed to require too much capital to implement instantly, but they have been noted and are considered for stepwise implementation. The priority improvement that was identified by the research involved eliminating the movement of product to the despatch warehouse due to lack of available space in the main factory. This was acted upon through building conversion to increase floor space in the despatch area to for product holding prior to despatch.
10.4.2 Supply Chain Changes

Retailer X has maintained a policy of late ordering, and as such the development of collaborative supply chain practices have not been possible, with improvements to communications and technology applications being limited due to these changes being beyond Oscar Mayer’s influence and control. The changes that have been achieved involved closer co-ordination with suppliers and the increased functionality of the MRP system (system 21) to organise production as well as generating the order volumes. These changes are shown via VSM in Figure 10.22, with prep and cook plans being based on forecasts, while fill and despatch plans are generated based on confirmed orders. Suppliers responding to Oscar Mayer’s change in procurement procedures have enabled less inventory to be held and reduced waste, while at the same time improved flow through the facility. These changes have still presented a number of problems including examples where sub-quality ingredients have been delivered resulting in entire product orders being scrapped and the retailer being poorly served.

Figure 10.22, Current state of Oscar Mayer information flows
The author believes that the retailer's demands for late confirmation of product volumes are unlikely to change, in keeping with other retailer's Top Up Fresh Foods schemes, and as such the CPFR approach described in section 10.3.2.6 is the best route to minimising OPW and effective supply. This approach, like the other supply chain tools requires co-operation from the retailer, and until that is possible the improvements within the manufacturer to streamline data collection by technologies such as SCADA should be undertaken.

10.4.3 Planning Improvements

Improvements to production planning methods were severely affected by the absence of a suitable planning tool such as PREACTOR used in the development of the TSP production planning model. Reasons for the lack of such a tool were identified as financial and the lack of availability of a suitable tool to integrate effectively with the incumbent MRP system. As such the TSP method has been compared against production which continues to be planned based on product volumes with no sequencing of jobs, with operators determining the production sequence. Priority orders are highlighted to production, but material availability is still dependant upon operators indicating when there are shortages. Forecasting has been significantly improved, with a steady order state being used as the starting point for each production cycle, which is subject to change on order confirmation. Performance measurement undertaken as part of the health-check has served to improve the processing and changeover times used in the MRP system, which were inadequate on its initial implementation, providing unrealistically small production capacity. Oscar Mayer continues to work towards the implementation of a visual planning system for production sequencing and improved operator support, while the possibilities highlighted through this research have demonstrated the cost savings, lead-time improvements, layout implications and waste reductions possible through the TSP approach.

10.4.4 Waste Minimisation

By far the most marked improvement in Oscar Mayer's operations came through the reduction of manufacturing wastes, where substantial financial savings were realised as described in section 10.3.1.3. The implementation of a scheme of waste measurement was driven throughout the factory and has resulted in significant cost reduction as shown in Figure 10.23. This trend for reduction of waste costs has been affected on two occasions, as
represented by spikes (1) and (2) in Figure 10.23. Spike (1) represents wastes associated with Christmas, which traditionally experiences unpredictable demand. Spike (2) in Figure 10.23 shows waste costs associated with the withdrawal of products and ingredients contaminated with ‘Sudan 1’ in February 2005, £15,000 of which is estimated to have been directly caused by the withdrawal.

These improvements were driven initially by the monitoring of the costs of the wastes being created, the better use of the MRP system and with preventative measures targeted at waste minimisation. Cultural issues relating to the collection of data were difficult to overcome, however the closer monitoring of production wastes led quickly to considerable reductions which quickly reduced weekly waste costs to around £15-£20,000. The wastes generated by Oscar Mayer may still be substantially improved upon, as the savings described were initially ascribed to the greater accountability of operators in disposing of product and ingredients. The application of the RDM framework and further improvements to planning that may still be achieved will significantly reduce creation of OPW, which has remained a major contributor to the overall created wastes throughout the case study.

Figure 10.23, Total waste costs for the factory, calculated weekly over the 12 months leading up to 5/3/2005
Chapter 11

Concluding Discussion

11.1 Introduction

The discussions provided in this chapter are based upon the research contributions reported in this thesis and bring together the major research issues in order that a set of conclusions may be formulated. The initial part of the chapter provides an overview of research contributions and outlines the broad food industry considerations that provided the context for the work. The remaining sections of the chapter draws together the points of discussion using the structure defined for the research scope in chapter 2.

11.2 Research Contributions

The author has identified the following to be the major contributions to this research subject:

i) Generation of a comprehensive waste model that can be used to identify types and sources of waste and also the factors contributing to waste creation in food manufacture,

ii) Definition of a number of waste analysis methods, namely waste inventory analysis, cost versus environmental impact analysis and Reduce-Recycle-Disposal analysis which can be utilised to identify the most effective means of waste minimisation,

iii) Construction of a formal health-check procedure through design of a bespoke questionnaire to ascertain the current state of production and supply chain activities in a company and to collect required data to be used for subsequent modelling and improvement tasks,

iv) The generation of a framework for Responsive Demand Management to improve manufacturing and supply chain management activities in convenience food sectors based on a systematic program for consideration of products, processes, resources, layout, supply chain management, and demand communication technologies,
v) Generation of a reactive hybrid two stage production planning based on the advantages offered both by static and dynamic planning to minimise overproduction wastes.

11.3 Concluding Discussions

The remainder of this chapter uses the structure of the scope to outline the points of discussion arising from the research.

11.3.1 Food Industry Considerations

The growth in the demand for convenience foods and ready-meals in the UK has been driven by changes in lifestyle and available leisure-time with people prepared to spend less time in preparing foods, and convenience foods now established as a significant food sector. One of the fastest growing convenience foods has been ready-meals, which have been described as having lengthy processing times due to the value added nature of the meals, and being demanded in highly volatile quantities due to the consumer's demands and requirements for fresh preparation which resulted in short shelf-lives and consequently produced considerable OverProduction Waste. These consumer preferences mean that production of ready-meals is tightly constrained while the dominance of the UK retailers means that ready-meal manufacturers are pressured into a highly wasteful production procedures in order to meet demands. The dominance of the retailers in their buyer-supplier relationships is due to the aggressive brand building of own-label products that has coincided with the proliferation of convenience foods. The establishment of retailer brands as leaders in ready-meal sectors has meant that the profitability of ingredient producers, farmers and manufacturers has been significantly impacted. However, the most concerning trend was the volume and cost of overproduction waste generated as a result of inappropriate planning and supply chain management procedures as evidence in the companies visited during this research. This highlighted the requirements and possible timely benefits that can be gained by the application of the research concepts investigated by this research

11.3.2 Environmentally conscious manufacturing in the food sector

There is concern among manufacturers related to the increasing legislation and consumer pressures regarding environmentally sound manufacturing practices and sustainable
production. Simple disposal of wastes to landfill is no longer acceptable through significant economic, environmental and also ethical issues and thus greater consideration must be given to both the costs and volumes of wastes created by manufacturers and how they are dealt with. In cases of OverProduction Wastes, significant water, energy and material resources are consumed, and despite the costs these represent to manufacturers, considerable wastes have been generated in the past in order to meet the demands imposed by the retailers. The current focus of improvement methods on waste water and packaging highlights the requirement for the consideration of other environmental impacts throughout production, as has been addressed by this research.

11.3.3 Operational Management tools and Techniques for food manufacture

There has been a long-standing shortage of literature relating to planning of food manufacture, with the bulk of research interest in the food industry traditionally being targeted at the fields of food science, generic operations and supply chain management issues. The contemporary techniques described as part of this research have considerable potential to improve manufacture and supply chain issues within the food industry, particularly where combinations of these techniques are applied. The challenging demands by both the consumer and retailer necessitate more sophisticated computerised approaches to operations management and production planning which have often been developed for applications in manufacturing industries other than those concerned with food production. Software applications in use in the food industry therefore have been modified or required additional modules, with very few IT tools being developed primarily for use in the food sector and addressing the inherent requirements described in this thesis. As such the current operational and supply chain management tools developed for engineering applications are not suitable for application in food sector. The research concepts investigated in this thesis provide support for the development of the bespoke tools tailored to the bespoke requirements of food manufacturing sectors, in order to effectively manage the supply and production planning challenges they face.

11.3.4 OverProduction Waste in the food industry

The study of factors influencing OverProduction Waste creation highlights that the relationship between manufacturers and retailers is one of the drives and possibly the greatest
contributor to the generation of OPW. The volatility of demand on combinations of products and the lack of formal communications technology to provide early warning for manufacturers has prompted manufacturers to over-produce. Food industry waste has been largely considered as consumer landfill waste and as such manufacturing wastes have been such low priority that wasteful production has been thought of as acceptable to meet consumer demands. Further classification of wastes by this research allows for the separation of wastes filtered at source in production to different end processing or disposal that the author contends will lead to considerably more effective waste control and reduce environmental impacts.

When considering food manufacturing in a broader sense, it is the author’s belief that a consistent structured approach to waste prevention through the food supply chain has been lacking, providing the impetus for the generation of the waste model described in this thesis. Although many initiatives are in place locally under particular producers, processors and retailers, there should be a common goal for all food supply actors to ensure that a truly sustainable food production industry provides for all as required whilst minimising the impacts of consumer demands upon the environment.

11.3.5 Responsive Demand Management Framework

It became evident in the early stages of this research that there was a general acceptance of waste creation and the ineffectual planning procedures in place, however there was also considerable lack of awareness of the tools and techniques by which this situation could be improved. The specific case of OPW that the research set out to address was a dynamic composite of several considerations across supply chains, manufacturing and production planning with a complex set of inter-relationships between each. The author believes that this situation requires a systematic improvement approach and therefore a framework has been proposed as a suitable tool. The application of the Responsive Demand Management framework enabled the most apt tools available to be utilised in support of the reduction of manufacturing lead-times and maximisation of order lead-times to allow adoption of a Make-To-Order approach. However it was acknowledged that Make-To-Order in some cases would be exceedingly difficult to attain, and so the establishment of a Two Stage Planning method has been investigated to improve responsiveness to late demand changes.
A further point about the RDM framework is that health-check and improvement processes were supported by the author throughout the case study however it is feasible to automate these stages of the framework through development of a case tool which would support all three stages of the RDM framework. This has been suggested by the author as one avenue of further work in chapter 12.

11.3.6 Production planning approach based on Two Stage Planning

Contemporary planning tools provide significant capability to store, manage and define complex planning and scheduling rules. The novel approach defined by this research has taken advantage of such capability through Two Stage Planning (TSP) of standard and special operations to minimise OPW. The proactive approach to planning based on both static and dynamic scheduling allows OPWs to be minimised through reallocation of material at the order confirmation point. The author would like to highlight the difference between the TSP approach and postponement approaches suggested and adopted in a number of engineering applications, which separates production into two independent stages based on Make-To-Stock and Assemble-To-Order. The TSP approach considers production as a single activity planned in two stages as components in production cannot be held as stock and will create wastes if production is not balanced for ingredients over every order cycle due to the short shelf-life of ingredients. A commercial planning tool was selected and utilised to provide a computational viewpoint for the TSP model, but this required enhancement in its functionality. This highlighted the flexibility offered by contemporary manufacturing software that can effectively be utilised to achieve a very complex scheduling rules which can potentially provide significant cost saving and waste minimisation.

11.3.7 Demonstration of the validity of the research concept through case study

A number of potential industrial case study companies were visited as part of this research, however time availability meant that detailed consideration was limited and Oscar Mayer was selected based upon commitment, interest in and support of research, in addition to availability and access to waste data, planning and production activities. The initial health-check highlighted a range of planning and supply chain issues and provided mapping and visualisations of the improvement areas. The improvement procedures identified through the application of the RDM framework required further cost/benefit analysis to justify
modifications to production (and layouts) while successful improvement of network relationships enabled the streamlining of deliveries. The author was particularly encouraged by the reduction of waste volumes and costs demonstrated at Oscar Mayer, with the greatest benefits achieved through the implementation of the simple measurement controls. Two Stage Planning of Oscar Mayer’s production facility was demonstrated using PREACTOR software which demonstrated the applicability of the research concept to the company, and is now being considered as part of their IT and manufacturing planning improvements.
Chapter 12

Conclusions and Further Work

12.1 Introduction

This chapter provides conclusions drawn from the research and suggestions for further work areas based upon the research issues reported in this thesis.

12.2 Conclusions

The conclusions drawn from this research are as follows:

i) The convenience food sector in the UK has expanded significantly, and is now established to account for around one third of the total spend on food, while this research has shown that the effective planning of production and supply chain relationships of convenience food manufacturers requires significant investigation given considerations which are particular to this sector.

ii) The increased prominence of environmental issues and consumer pressures necessitate an environmentally conscious manufacturing approach to be adopted in food manufacturing. This research has identified that waste from overproduction is considerable in the convenience food sectors, particularly in the volatile markets where unpredictable demands and short shelf-lives have led to the use of overproduction tactics in order to meet very tight due dates imposed by increasingly powerful retailers.

iii) The creation of OverProduction Waste is a priority for elimination from environmental, ethical and economic points of view, because this is considered as the most wasteful use of resources. Therefore the underlying factors contributing to the
iv) The majority of planning and manufacturing software tools in food manufacturing have been developed for engineering applications and as such are unsympathetic to the demands of food production systems and constraints, with most food manufacturing systems modifying existing software systems to the 'best fit' of their needs. New bespoke planning and IT support tools are required for food manufacturing and must be investigated to support the specific goals of the food sectors.

v) The application of planning and supply chain tools and techniques structured in such a way that allows sequential combinations of improvements to be considered as identified by this research within the Responsive Demand Management framework has shown to provide an effective systematic approach to the minimisation of OPW. Production improvements sequenced into categories of product, process, resource and layouts presented a powerful approach to improving manufacturing performance within the production system. Supply chain improvements similarly structured to categorise supply chain management and demand communication technology provided strong support for network co-ordination and order lead-time reduction.

vi) The hybrid planning approach described as part of this research has been investigated in response to the situation in convenience food manufacture where a Make-To-Order is not possible. This intelligent two stage consideration of production volumes is based upon knowledge that orders will be received late and thus production plans need to proactively be updated. This novel two stage planning approach has shown to provide advantages offered by both static planning through efficient management of standard operations and dynamic planning through the ability to react to changes in demand for minimisation of overproduction waste.

vii) The case study considered within the context of convenience food OverProduction Waste minimisation has effectively demonstrated the applicability and significance of the research concepts. The application of the waste analyses and the RDM Framework have resulted in environmental and economic benefits, while the
implementation of the Oscar Mayer TSP PREACTOR configuration has demonstrated that the hybrid two stage production planning approach provides a powerful tool for reduction of OPW in convenience food manufacture.

viii) The significant contributions made by this research has highlighted the gains possible in reducing waste creation through convenience food sectors. However, as the challenges in convenience food sectors become more complex, through retailers becoming increasingly powerful, greater consumer demands for product variety, freshness (reducing available shelf-life), and convenience which may further shorten order lead-times; further development of bespoke tools to support food manufacturers in the face of these new challenges will be required.

12.3 Further Work

The author recognises the following areas for further work arising as a result of this research:-

12.3.1 Implementation of TSP within ERP

As stated, the TSP production planning model has been implemented using a bespoke commercial scheduling system. The interoperability of production schedulers and traditional MRP systems has been questioned over the course of this research in addition to the limitations in the development of systems without considerable investment and vendor support to provide modified planning systems. However, current ERP systems used by increasing numbers of major food manufacturers and retailers have production scheduling incorporated as part of overall system capability. Therefore implementation of the TSP approach within ERP systems to provide seamless adoption of such novel concepts without the requirement for purchasing and installation of another third party software system.

12.3.2 Cost/benefit analysis wastes

As indicated in chapter 6, the wastes from certain processes in food manufacture may be considered the raw materials for entirely different producers or industries. This point was illustrated by reclaimed bulk organic wastes being used in composting or fertilizer when
made available to farmers (or even manufacturer's suppliers) or alternatively being incinerated on site to provide some renewable energy to the manufacturer. A cost benefit analysis of the best course of action for each waste stream identified by this research is required in order to support business decisions as to what to do with wastes created. Such decision support is of increasing importance as legislation regarding the environmental performance of food manufacturers becomes more widespread, and robust environmental justification for disposal, recycling and minimisation of wastes being demanded.

12.3.3 Development of a CASE tool to support Responsive Demand Management Framework

This research has provided an effective systematic approach for consideration of production and supply chain issues that create overproduction wastes in the form of the Responsive Demand Management Framework. There are a range of techniques and methods applied to improve production planning and scheduling, and these can benefit from the design and development of a Computer Aided Software Engineering (CASE) tool to support the various stages of RDM. In addition, such software support will reduce the extent to which the framework is expert-driven. The development of such a CASE tool specifically designed to simplify, direct and support the improvement activities within each stage of the RDM framework will prove a valuable extension to this research.
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Appendix 1

INDUSTRIAL VISIT REPORTS AND INTERVIEW DOCUMENTATION

A1.1 Introduction

This appendix outlines the industrial visits undertaken as part of this research, indicating the main manufacturing activities, information flows, order and production lead-times, product shelf-lives and other relevant issues discussed with each company. The reports generated resulting from these visits presented as listed below:

A1.2 X Dairies,
A1.3 G Bakery (sandwiches),
A1.4 U Prepared Foods (sandwiches),
A1.5 A Prepared Meats,
A1.6 O Ready-meals,
A1.7 R Foods (prepared meats),
A1.8 G Ready-meals.
A1.2 X Dairies (15/4/03)

A1.2.1 Company Background

X Dairies have a number of processing facilities across the UK, with the midlands facility being the focus of this visit report which employs around 230, the company dates back to the 1920s.

A1.2.2 Products

X produces milk for five retailers under own label product categories, in each of the milk product variants (standard, semi and skimmed) and in 4 sizes. The shelf-life demands are the day of manufacture plus eleven days before expiry for the retailer to use or pass on to consumer. Demand for X’s products may be described as steady, with a regular pattern in the product take-up over the course of the week with variations in demand most noticeable around holiday periods when consumer buying habits are skewed.

A1.2.3 Order Lead-time

Production for the site is generally based on orders received, though historical data for demand variations are used in order to plan for departures from the regular buy-habits (for example in the weeks before a national holiday) in order to ensure the required capacity can be met. A retailer’s orders for the following day is aggregated and placed at a fixed time (for example, for one retailer this may be 5 am, another 7 am) for delivery the next day. Although the orders for particular retailers are lumped together, the distribution for each store is carried out individually, and staggered throughout the day to suit delivery schedules suiting both X and the store involved. Orders are placed via Electronic data interchange (EDI, in this case AS400 from IBM) and then confirmed and inputted to ScheduleX (a scheduling software by Numetrix) by the Telesales Department, see figure A1.1, below

A1.2.4 Manufacturing Lead-times

The raw material (milk) is brought to the facility and held in storage tanks prior to processing, each of these tanks is cleaned every 24 hours, so no product is held in the storage for any more than this. The pasteurization process is completed within a short period of time, and the make-span to take the raw milk through processing, chilling and filling of bottles is considerably lower than the reaction time to produce a batch of product for dispatch.

A1.2.5 Additional Information

ScheduleX has been used for the purpose of short interval scheduling, to maximise throughput to balance with sales, to reduce inventory and to synchronise with production flow as shown in Figure A1.1.
The planning manager applies his experience to the task of arranging the orders inputted into ScheduleX on the planning board into an arrangement that will meet the demand subject to the following constraints:

- Two main customers have priority and their orders are scheduled first
- Shortages to be met are prioritised
- The delivery schedule is considered (today or next day despatch)
- The milk type to manufacture
- The pack type to be used (bottle size and cap colour)
- The shelf-life retailer constraints are considered
- Labour availability

The planning board is manipulated manually, having a line for each flow line, and a different colour and code for each milk type and customer. The process of inputting and manipulating the customer orders takes the planning manager roughly 30 minutes each day, and the data interpreted from the scheduler is downloaded into the Management Information System.
Information System (MIS) from where several sources access the information held. Where there is an apparent shortcoming in the production capacity for the day the planning manager is able to liaise with other X Sites and add to their orders for the day to meet demand. The processing plant uses the data within the MIS to give a breakdown of how much milk is required for the day's production in terms of volume of product. Communication outside of the information system is common, with shortage data being passed between the chilled store and the planner regularly, in addition to a nightly audit or stock check in the chilled store to confirm the actual on hand product available to the stores. Additionally communication between the processing plant and the planner is supplemented through informal channels to ensure the storage tanks have enough capacity to meet the demand faced. Currently information is passed down to the production lines via the MIS that the line operators access and manually input product codes displayed. This process is due to be updated as the MIS in X is due to be upgraded and opportunities for operator error reduced, in line with one of the large customers supplier policy. Operational efficiency, waste, stoppages and other performance data are collected in real-time in the MIS from each of the production lines, and each individual case of downtime is reported back into the system to aid diagnosis of areas in need of improvement. The information collected is stored in an Oracle database, though reporting is typically done through Excel or similar program. The software in place has been customised by each vendor company to meet X's requirements (numetrix, orbe and marex) support contracts from software vendors have been criticised as expensive in the past.

A1.2.6 Other Issues

The scheduling complexity in servicing all stores rather than a small number of RDCs makes this the most extreme case faced in scheduling production to meet a series of despatch times from lumped order placement.

A1.3 G Bakery (sandwiches) (7/5/03)

A1.3.1 Company Background

G has existed as a company since 1948, and is now a part of a large food group comprising a number of separate companies operating in many different sectors throughout the UK. A smaller bakery only site is run by the company in the area, which has been used to prototype different products and also equipment and software (notably PREACTOR).

A1.3.2 Products

The site employs around 1400 people, and the production facility is split fairly evenly between chilled products (virtually all of which form sandwiches to supply one high street retailer) and bakery products. G services 6 RDCs at fixed times everyday with around 55 product variations, though these products are subject to seasonal variations, and, in fact 25% of the current products have been in production for less than 12 months. Although some ingredients have long shelf lives (25% being delivered at intervals greater than 1 month), post processing chilled products have 2 days shelf-life, and in the most extreme product cases 1 day before expiry.
A1.3.3 Order Lead-time

Confirmed order volumes are received the night prior to production, on hand resources have been identified as a problem, given that additional labour is kept available to meet demand uptake, however the demand level isn’t confirmed until late, so often personnel are waiting to provide the peak capacity that is periodically required. The handling of customer orders is described broadly as shown in the Figure A1.2.

![Figure A1.2, Representation of Order processing through scheduling for Chilled Products at G Bakery](image)

A1.3.4 Manufacturing Lead-time

Despite high volumes of throughput possible in assembly, value-adding steps for example cooking and massaging ingredients amount to roughly 24 hours. Production of the chilled products is completed over 10 assembly lines each with up to 30 operators operating on it depending on the product, with a dedicated prep-room and cookhouse elsewhere on site. Production is currently manually carried out, though automation has been prototyped.

A1.3.5 Additional Information

The company is currently exploring means by which software systems for order handling and production scheduling may be implemented, SAP R3 is already part implemented as the ERP system (completed October 2004). Around 180-ingredient suppliers work with the company, roughly half being UK based, a further 30% being European, with the remainder of suppliers being sourced from around the world. 50% of suppliers deliver to the facility at least once per week, with 12% delivering daily and 18% delivering twice weekly.
A1.4 U Prepared Foods (sandwiches) (8/5/03)

A1.4.1 Company Background

U prepared foods has supplied a high street retailer since 1989 with production at the midlands site being split between deli products and sandwich type chilled products. The company, which was originally formed in 1926 now commands a 45% share of the retailer’s convenient prepared food own brand.

A1.4.2 Products

Roughly 60 product variations (some variations are based solely on the base-card placed in the packaging) are manufactured, though 5 represent 30% of total production. Manufacture is completed over 11 production lines, 2 of which are fully automated (leader lines) and handle the company’s core products over extended product runs. Shelf-lives of the product are typically production plus 2 (expiry two days after despatch), though some products are suitable to be frozen, and then have 2 day shelf life after being defrosted. This potentially is a means of smoothing demand against demand volatility, though the exact number of product this is feasible with, or any effect on product quality is unclear.

A1.4.3 Order Lead-times

The final confirmed order is placed at 6am (often then to be changed at 8am) for a 1pm-8pm despatch, depending on the RDC. Some 250 suppliers service the site, which again supplies to a small number of RDCs at specific despatch times via a third party Logistics (3PL) handler. Orders are received into Kewill systems EDI, and then the relevant information dropped into Excel spreadsheets for the purposes of scheduling. Various reports are then generated by the production planning manager for each line supervisor detailing product type, volumes and times to be met, in order for the day’s production to be completed.

A1.4.4 Manufacturing Lead-times

Some preparations can take as long as 48 hours, with changeovers for the automated lines take roughly 45 minutes, whereas the manual production lines, though being much more labour intensive are flexible enough to perform short changeovers and thus run shorter batch sizes. The minimum run of any product handled by the company are around 120 products, and frequent daily runs of around 16-17000 products are common.

A1.4.5 Additional Information

The company is about to undergo alteration of production layout in order to better facilitate production flow.
A1.5 A Prepared Meats (7/6/03)

A1.5.1 Background

'A' was established as a company in 1908 and now spans a number of sites in the East midlands producing sausages, cooked meats and pastries to a number of (including the largest) retailers. Manufacture of sliced meats is completed at a new facility with room for expansion on either side, should demand require it.

A1.5.2 Products

Around 10% of the products manufactured by A are own-brand produce, with around 56 product variations. The ranges of shelf-lives are typically P+30 for sliced ham, P+16 for beef and as much as 16 weeks on some products, with A having typically 4 days (2 for beef products) before despatch. A holds no more than 3 days finished goods stock, with around 4 weeks worth of material on hand through production (used to ride price fluctuations).

A1.5.3 Order Lead-times

Processing of raw meat is completed to stock, with finished good on hand being used to meet orders almost exactly. A weekly forecast is received, followed by pre-finals (3-4 days before due date) and then orders are received 2 days prior to due dates. Orders are received via EDI, however this is still inputted manually to plans, with an MRP system currently being piloted to remove this step.

A1.5.4 Manufacturing Lead-times

Standard products are held for 4 weeks after cooking (in a chiller wind tunnel) before being debagged and brought to temperature for 12 hours, from which slicing and despatch take a few minutes. Changeovers take around 5 minutes, with production capable of slicing 15000 products per 8 hour shift, cleandowns occur every four hours.

A1.5.5 Additional Information

Orders for ingredients are made daily, with suppliers coming from a range of areas, though all are approved by the retailers first.

A1.6 O Ready-meals (13/5/03)

A1.6.1 Background

The company was established in 1985 as a privately owned company in order to supply ready meals. The production facility is staffed by 1000 personnel, operating 24hours a day, 7days per week, though night work mainly consists of hygiene teams and cook cycles. The main facility is split over three floors, each of which manufactures a different base of products, one for Italian dishes, one for traditional English dishes and another for ethnic foods.
A1.6.2 Products

Currently manufactures 130 of a retailer's own label products, 80 of which are described as core lines, and have greater demand accordingly.

A1.6.3 Order Lead-times

Orders placed at 9 am each day, which are frequently considerably different to the forecast demand available for the immediate 7 days from the retailer's (PDS - Performance Data Site) website. The orders placed at 9 am are for despatch to RDCs at the earliest 19:00 hours that day, through to 12:00 the following day. The planning and scheduling effort is completed manually via a system of spreadsheets (with one planer responsible for each floor), and runs to 21 man-hours daily, with production runs being scheduled and confirmed at 13:00 each day. Manual intervention of the orders by data input was highlighted as the first indication that the company has to react to large variances in the demand forecasted.

A1.6.4 Manufacturing Lead-times

The make-spans of products vary from a few hours to several days for products requiring long cook or marinade cycles for example. Products are moved to a separate despatch facility from where 10 RDCs are serviced for retailer's. Some ingredients have a certain amount of shelf life available for O to use, and as such products with large variances on the days production may be held as stockholdings for the following days products.

A1.6.5 Additional Information

The company has identified difficulties in production control and also product routings through the factory, and have expressed an interest in the application of simulation to improve operations in these areas. Problems have arisen in the factory when operators on individual floors prioritise their own production runs ahead of products from other floors that need to use their capacity. Production control and overcoming a legacy company culture have been identified as priorities before effort is expended in improving the companies scheduling efforts. Even so, the company aims for 99.5% customer service levels, with actual levels achieved reaching 98.7%. The day of the company visit for example, overall variance from the estimate was up 14.3% on all products. This unexpected demand variance was particularly highlighted in a small number of products, with several having around 50% uptake in demand, and one product line's confirmed order value being 84% greater than estimated the day previously by the retailer. Other problems identified on the day of the visit included large demand variances for products requiring use of the same manufacturing equipment, thus causing problems in capacity.

A1.7 R Foods (prepared meats) (26/8/03)

A1.7.1 Background

R foods was formed in the 1960's and is now part of a group with two other companies. R foods has several sites in Southern England, manufacturing bacon and other value added meats.
A1.7.2 Products

The main site manufactures around 50 different product variations for around 12 major customers, and the main site can produce 500 tonnes of product every 5 days. The main products are all based around the same basic format, varying value cuts of meat are processed to small size, massaged and thermally processed as 'logs', which are chilled and then sliced in any one of a number of ways and packed. Additionally the site thermally processes bacon for the MacDonald's chain of fast food outlets.

Around 30 suppliers of raw material service the factory, though product is bought on the world market, from an international supplier base. The facility has been custom built, with many features and technologies to smooth product flow and material handling, though much of the packing and loading of sealed product is still completed using manual labour. There are 16 lines in the main filling area, two of which are more highly dedicated, with automatic packing machines 'through the wall' in low-care packing. The thermal processing methods undertaken means that the company claims product can be maintained fresh for far longer than the 21 days that the retailers insist upon. Some products however have a shelf life of just 3 days from processing.

A1.7.3 Order Lead-times

Many orders are received via EDI and automatically uploaded into the companies Intranet, however, two customers still fax through a daily order that must be forwarded to the production planner.

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[Diagram: Figure A1.3, Representation of Order processing R Foods]
A1.7.4 Manufacturing Lead-times

Manufacturing lead-time varies considerably from product to product—some having 12-hour cool cycle alone. The temperature of product is closely monitored to maintain product quality in slicing operations, in this way additional time is added into the manufacturing lead-time to ensure the product is at optimal temperature.

![Diagram of manufacturing processes](image)

**Figure A1.4**, Manufacturing processes through R foods

A1.8 G Ready-meals (9/2/04)

A1.8.1 Background

The G company originated from the field of horticulture during the late 1800s. The site was opened in 1964 as a banana ripening and packing centre. The prepared foods business was transferred there in 1978. The first ready meal factory opened on the site in 1988 and the first soups and sauces facilities in 1993. It is now G’s largest site, where nearly 1000 fresh prepared food products are made.

A1.8.2 Products

The site now comprises a number of distinct factories of which the recipe dish and soups and sauces represents some of the most volatile demand and short run products. 95% of products manufactured in the recipe dish side of the factory are for a big retailer’s own-label produce. Shelf-life for products is tracked using the P+ system, with an internal shelf-life defined by the retailer of 2 days. Additionally, product is tracked using the Stock Keeping Unit system (SKU) with 6.2 product turns per week being typical.
A1.8.3 Order Lead-times

The site runs to the retailer's TUFF (Top-Up Fresh Food) scheme, where a portion of the days production is held in reserve for the following day. Typically around 60-70% of the days production is specified at 6 a.m. for distribution throughout that day to distribution centres. The remaining 30-40% is specified the following morning for distribution at short notice - each of these order placements is subject to considerable (10%) variation when the final confirmation comes through. Orders are manually inputted from the EDI, there have been reports that the lanner EDI has tendencies to crash.

A1.8.4 Manufacturing Lead-times

The company reports lead times of around 48 hours, when kitting of products begins, through to the day of production where there is typically a ten hour processing time, beginning in the day prior to despatch.

A1.8.5 Additional Information

When a product is selling well, the retailer quite happily orders above agreed capacity and the lack of capping of order volumes leads to serious problems within the site.
Appendix 2

REDUCE-RECYCLE- DISPOSAL ANALYSES FOR CONVENIENCE FOOD MANUFACTURING WASTES

A2.1 Introduction

Support representations for each form of waste identified from chapter 6 are presented in this appendix, each being based on Reduce-Recycle-Disposal described in chapter 6.

A2.2 Reduce-Recycle-Disposal Analysis

These are the common waste streams for industrial and household disposal, landfill and incineration are the disposal options in each case with the exception of waste water. Incineration is generally preferred, provided the calorific content of the waste is such that some energy can be reclaimed from the wastes, which can be completed on site, or at a central incineration facility. Bulk Organic Wastes (BOW) are somewhat inevitable when processing foods that are harvested along with inedible parts. The organic nature of these wastes however mean that they can have useful application in other fields- literally in the case of composting the waste, or in some cases the BOW may be processed in order to be fed to livestock (Feeds).

![Figure A2.1, Bulk Organic Waste (BOW) sources and Re-use Hierarchy](image)
As shown in Figure A2.1, opportunities for reduction of the creation of BOW comes from earlier processing of the raw materials—removing husks, shells, bones, leaves etc at the supplier. This has the effect of reducing the amount of material handled through the supply chain, and in many cases this will be closer to the point of application of any BOW that are reclaimed for use as fertilizers or feeds. The means by which these changes may be implemented include tighter product specification from manufacturers and appropriate re-location of equipment and work from the manufacturer site upstream to the suppliers in the supply network.

Waste Water has considerable implications for industry and there is a great deal of support available for manufacturers, particularly food industry manufacturers, in undertaking environmental projects to reduce the amounts of water required by industry. Capital is available through government agencies (Envirowise described in section 6.2) to offset the cost of investment in new technology to reduce water wastes, and such technology covers the monitoring and control of water use, automated systems (such as Cleaning In Place (CIP) and pigging equipment (where crushed ice is used to clear pipework for changeovers in place of large volumes of water). As indicated in Figure A2.2, straightforward housekeeping measures add considerably to the efforts to reduce consumption of water, and many example initiatives and case projects are documented through the government agencies. The possibility to re-claim and recycle the water a company uses in house requires considerable investment, and will not be feasible for many companies requiring a very high quality of fresh water in the food industry, however end-of-pipe solutions that reclaim much of the food wastes collected in cleaning operations will allow considerably more BOW to be sent for re-processing to fertilizer or feed as previously described, alleviating additional burden on re-processing plants that treat the trade effluent.
When considering Packaging Waste, manufacturing organisations also benefit from considerable support and financial incentive from government agencies to instigate improvement projects to reduce the amount of packaging inherent to the products. Reduction of packaging associated with a particular product requires redesign of either the packaging itself, or the accompanying handling procedures to produce those products as shown in Figure A2.3. Expert support is available for free in undertaking such re-design projects for packaging minimisation, again through the government agencies listed earlier. The most common methods by which these improvements may be made come in the form of elimination of the need for intermediary packaging, and double packaging of products and components; and there numerous examples of such improvement projects. Separation plastics from general wastes in manufacturing facilities will significantly ease the subsequent processing in collecting wastes for re-cycling from the general waste streams, increasing the cost efficiency of such operations.
Process Wastes are all sourced directly from manufacturing as indicated in Figure A2.4 and may be best improved by redesign methods already described and modifications to handling methods, both aimed at reducing incidences of product being accidentally lost in production by process inefficiency. More costly investment in improved processing machinery will yield better improvements still, though the economic cost savings balanced against the environmental benefits will vary greatly from product and process.

![Figure A2.5, OverProduction Waste sources and Re-use Hierarchy](image_url)

Overproduction Wastes are created late in the production sequence, either by latter stages of manufacture, or through the distribution channels as demand fluctuates. Compared with the other forms waste described here there is no support or advice available through government agencies to help specifically the reduction of these wastes, which addressed in Chapters 7 while the application of novel planning methods to better enable the re-use of components will be described in Chapter 8.
Appendix 3

HEALTH-CHECK QUESTIONNAIRE AND DATA COLLECTION TEMPLATES FOR CASE STUDY

A3.1 Introduction

This appendix provides sample data collected from the case study company in the health-check and data collection phase of the process modelling stage of the Responsive Demand Management (RDM) framework. Section A3.2 contains the questionnaire filled out for Oscar Mayer at the initial visit, while section A3.3 comprises a sample of the data collection templates used within the production facility.

Section A3.3 contains an example of the open (work measurement) templates used to initially record operational performance for several product runs (as shown in Table A3.3.1) and the more specific Kettle templates used for more extended consideration of individual product processing and downtime as detailed in Tables A3.3.2 and A3.3.3.
### A3.2 Health-check Questionnaire

<table>
<thead>
<tr>
<th>Health-check</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Production and Order-lead times</strong></td>
<td></td>
</tr>
<tr>
<td>a) What are current order lead-times (in hours?)</td>
<td></td>
</tr>
<tr>
<td>Longest order lead-time</td>
<td><strong>23 Hours</strong></td>
</tr>
<tr>
<td>Shortest order lead-time</td>
<td><strong>6 Hours</strong></td>
</tr>
<tr>
<td>b) Identify the ranges of production lead-times (in hours, the total time for all manufacturing operations)</td>
<td></td>
</tr>
<tr>
<td>Production lead time:</td>
<td><strong>120 Hours</strong> (product: steak and kidney casserole)</td>
</tr>
<tr>
<td>Production Lead-time</td>
<td><strong>1.2 Hours</strong> (product: pilau rice)</td>
</tr>
</tbody>
</table>

**Processing**

<table>
<thead>
<tr>
<th>2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a) What are the range of Shelf-lives of products manufactured, what is average shelf-life?</td>
<td></td>
</tr>
<tr>
<td>Longest: <strong>12 days from cook- 9 days into depot</strong> (OM has 3 days shelf-life)</td>
<td></td>
</tr>
<tr>
<td>Average: <strong>7 days from cook- 5 days into depot</strong> (OM has 18-24 hours self life)</td>
<td></td>
</tr>
<tr>
<td>b) What are the typical ranges of changeover between product runs?</td>
<td></td>
</tr>
<tr>
<td><strong>10 – 15 minutes</strong> is typical and planned for. Frequently found to be less than this and around <strong>5 minutes</strong>.</td>
<td></td>
</tr>
<tr>
<td>Large equipment changeovers can take <strong>20 minutes</strong></td>
<td></td>
</tr>
<tr>
<td>c) How many products does the company produce? How many component ingredients are required?</td>
<td></td>
</tr>
<tr>
<td><strong>Around 120 products, new introductions (modifications or genuine new products) are frequent</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Around 100 ingredients this also changes substantially through suppliers</strong></td>
<td></td>
</tr>
<tr>
<td>d) Do products require dedicated tooling or operators due to process/ part etc? if so identify the processing routes affected.</td>
<td></td>
</tr>
<tr>
<td><strong>Pasta/potato products must be processed on pasta/potato lines (dedicated filling machines)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Steam products require steam filling line</strong></td>
<td></td>
</tr>
<tr>
<td>e) How much variation is there in the duration of the required processing tasks?</td>
<td></td>
</tr>
</tbody>
</table>
Considerable variation-process and product specific, operators can vary processing times for identical products and delays in chillers etc can result in similar batches being considerably longer in the factory.

No products are more than 48 hours through production however.

<table>
<thead>
<tr>
<th>f)</th>
<th>What are typical hatch sizes/ production runs?</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 kg cooks are common up to 2-3 ton maximum for sauces</td>
<td>Filling runs average around 300 up to around 3000 products</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>g)</th>
<th>Do current production flows or product routings cause any problems?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where ingredients are processed on one floor and filled on another handling and movement through facility is required</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3</th>
<th>Supply Chain Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>How Many Customers does the Manufacturer serve?</td>
</tr>
</tbody>
</table>

**Single Customer only**

<table>
<thead>
<tr>
<th>b)</th>
<th>How many shipments are made daily from manufacturer? Are these to stores directly or a number of Distribution centres?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Stores: none</td>
<td>Number of RDCs: ten</td>
</tr>
</tbody>
</table>

Timings of daily shipments:

<table>
<thead>
<tr>
<th>to each RDC:</th>
<th>to each Store:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 RDC at 7pm</td>
<td>1 RDC at 12pm</td>
</tr>
<tr>
<td>5RDCs at 8am</td>
<td>3 RDCs at 10.30am</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>c)</th>
<th>How many Raw Material Suppliers are there to the Company?</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>d)</th>
<th>What is the range of transit times for ingredient/product delivery between supply chain actors?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longest delivery time: many international suppliers, vary considerably</td>
<td>Shortest delivery time: 45 minutes</td>
</tr>
</tbody>
</table>

| e) | Map out the supply network, following the below conventions, indicating suppliers, RDCs, transit time and frequency of delivery. |
4 Supply Chain Mechanisms

a) To what department are orders placed by customers (Retailers)? How are orders placed?
Order placement to:

Sales Department only
Sales Department and Production Planning Dept. simultaneously

Manufacturer is non traditional; Vendor Managed Inventory (VMI) etc.

Orders are placed by EDI or other online mechanism? EDI

By telephone, fax, or similar?

b) By what means and to what department are orders placed by: manufacturer to suppliers?

EDI to sales and/or production planning

c) How frequently does Manufacturer order from suppliers?

Daily, with the exception of spices and bulk frozen ingredients

How is information communicated between production, procurement and sales departments?

Email, telephone face to face and internal server

Which ERP/MRP/EDI packages are used in the company? Are incoming orders integrated with Production planning or Procurement?

IT systems:

Geac System 21 MRP (part implemented), AS400 EDI

System Integration:

Planning undertaken in isolation via spreadsheet

5 Demand Management
a) Is Point of Sale (POS) data made available to manufacturer?

Yes, in real time

Yes, after Analysis by Retailer, consolidated weekly or monthly

Partly, when concerned with promotions or similar

No, Not at all

b) What is the maximum length of time ahead of today's manufacture is forecast data worked to? Is this forecast data provided by retailers or generated in-house? Please fill in each column below accordingly.

<table>
<thead>
<tr>
<th></th>
<th>(a) Maximum time ahead data is forecasted</th>
<th>(b) Manufacturer Generated?</th>
<th>(c) Retailer Provided?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual forecasts</td>
<td>Available</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>Available</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monthly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekly</td>
<td>Maximum for detailed volumes</td>
<td>Based on retailer</td>
<td>Available</td>
</tr>
<tr>
<td>2-3 days</td>
<td></td>
<td>Based on retailer</td>
<td>Available</td>
</tr>
</tbody>
</table>

c) What is the average and maximum deviation from forecasted volumes compared with the actual orders placed daily?

<table>
<thead>
<tr>
<th></th>
<th>(a) Maximum deviation in orders (% change on predicted)</th>
<th>(b) Average deviation in orders (% change on predicted)</th>
<th>Not Tracked</th>
</tr>
</thead>
<tbody>
<tr>
<td>At Retailer</td>
<td></td>
<td></td>
<td>Unknown</td>
</tr>
<tr>
<td>At Manufacturer</td>
<td>250%</td>
<td>26%</td>
<td>known</td>
</tr>
<tr>
<td>At Supplier</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

d) Are manufacturers and suppliers notified and involved in planned promotions/offers in stores impacting demand?

Yes, all promotions as they are planned

Yes, in advance of store release

Partly, expected increases in demand are identified

No, Not at all

6 Production Planning and Control

a) What software package is used to create production schedules?

Microsoft Excel

b) At what point do customer orders encounter planner intervention? How do orders enter the production plan?
EDI orders are manually inputted to production scheduling spreadsheet - this enables planners to check for large variances that require action

c) Are Gantt charts/work to list made available to production via electronic or hard copy means? How is data collected/reported back to production

Spreadsheet copies are printed for each production area, no means of electronic comms into the factory.
Any problems in material availability etc. is reported to planners by supervisors phoning

d) How is production sequenced? What are the priorities in sequencing jobs?

Priority for that day's delivery, each line then prioritises based on tray size, products etc.

e) Does the current method of planning create any problems?

Spreadsheets require regular updating and are time consuming to fill out daily

<table>
<thead>
<tr>
<th>Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Does separation of wastes occur through supply?</td>
</tr>
<tr>
<td>Plastic: No</td>
</tr>
<tr>
<td>No, only Commercial Wastes are disposed of</td>
</tr>
</tbody>
</table>

b) Are volumes/costs calculated for these wastes? Please provide ranges (over shortest timescale available)

<table>
<thead>
<tr>
<th>Manufacturers- Goods Inwards: Costs</th>
<th>Weekly/Monthly/Annual figures: Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>Max</td>
</tr>
<tr>
<td>Paper</td>
<td>£</td>
</tr>
<tr>
<td>Organic</td>
<td>£</td>
</tr>
<tr>
<td>Water</td>
<td>£</td>
</tr>
<tr>
<td>OPW</td>
<td>£</td>
</tr>
<tr>
<td>Commercial</td>
<td>£</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Manufacturers- Prep Areas: Costs</th>
<th>Weekly/Monthly/Annual figures: Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>Max</td>
</tr>
<tr>
<td>Paper</td>
<td>£</td>
</tr>
<tr>
<td>Organic</td>
<td>£</td>
</tr>
<tr>
<td>Water</td>
<td>£</td>
</tr>
<tr>
<td>OPW</td>
<td>£</td>
</tr>
<tr>
<td>Commercial</td>
<td>£</td>
</tr>
</tbody>
</table>
### Manufacturers - Cooking:

<table>
<thead>
<tr>
<th></th>
<th>Costs</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>Plastic</td>
<td>£</td>
<td>£</td>
</tr>
<tr>
<td>Paper</td>
<td>£</td>
<td>£</td>
</tr>
<tr>
<td>Organic</td>
<td>£</td>
<td>£</td>
</tr>
<tr>
<td>Water</td>
<td>£</td>
<td>£</td>
</tr>
<tr>
<td>OPW</td>
<td>£</td>
<td>£</td>
</tr>
<tr>
<td>Commercial</td>
<td>£</td>
<td>£</td>
</tr>
</tbody>
</table>

### Manufacturers - Fill/Assembly:

<table>
<thead>
<tr>
<th></th>
<th>Costs</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>Plastic</td>
<td>£</td>
<td>£</td>
</tr>
<tr>
<td>Paper</td>
<td>£</td>
<td>£</td>
</tr>
<tr>
<td>Organic</td>
<td>£</td>
<td>£</td>
</tr>
<tr>
<td>Water</td>
<td>£</td>
<td>£</td>
</tr>
<tr>
<td>OPW</td>
<td>£</td>
<td>£</td>
</tr>
<tr>
<td>Commercial</td>
<td>£</td>
<td>£</td>
</tr>
</tbody>
</table>

### Manufacturers - Despatch:

<table>
<thead>
<tr>
<th></th>
<th>Costs</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>Plastic</td>
<td>£</td>
<td>£</td>
</tr>
<tr>
<td>Paper</td>
<td>£</td>
<td>£</td>
</tr>
<tr>
<td>Organic</td>
<td>£</td>
<td>£</td>
</tr>
<tr>
<td>Water</td>
<td>£</td>
<td>£</td>
</tr>
<tr>
<td>OPW</td>
<td>£</td>
<td>£</td>
</tr>
<tr>
<td>Commercial</td>
<td>£</td>
<td>£</td>
</tr>
</tbody>
</table>

### Weekly/Monthly/Annual figures:

<table>
<thead>
<tr>
<th></th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
</tr>
<tr>
<td>Kg</td>
<td>Kg</td>
</tr>
<tr>
<td>Kg</td>
<td>Kg</td>
</tr>
<tr>
<td>Kg</td>
<td>Kg</td>
</tr>
<tr>
<td>Kg</td>
<td>Kg</td>
</tr>
<tr>
<td>Kg</td>
<td>Kg</td>
</tr>
</tbody>
</table>

### Questions:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>c) Are the reasons for waste creation recorded?</td>
<td>No</td>
</tr>
<tr>
<td>d) Are customers and suppliers participants in compliance scheme for packaging wastes?</td>
<td>No</td>
</tr>
<tr>
<td>e) Are Environmental Management Schemes (EMS) in use throughout Supply network?</td>
<td>No</td>
</tr>
<tr>
<td>f) What Waste Minimisation/reduction tactics are already in place?</td>
<td>Part of packaging compliance scheme</td>
</tr>
</tbody>
</table>

### Part of packaging compliance scheme

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>g) What proportion of the wastes go to the following: (where known)</td>
<td>Animal feed: Recycling:</td>
</tr>
<tr>
<td>Landfill: 90% ? Animal feed: Fertilizer/Compost: Glass: Paper:</td>
<td></td>
</tr>
<tr>
<td>Incineration:</td>
<td></td>
</tr>
</tbody>
</table>

Plastics: unknown proportion reclaimed
### A3.3.1 Work Measurement Cookline

**Factory:** OM1 Cookline  
**Equipment Detail:** Kettle 7  
**Measurement Start Time:** (1.05pm) 00  
**Measurement End Time:** (3.35pm) 2.35.11  
**Date/ Time:** 29/3/05

<table>
<thead>
<tr>
<th>Product and Operation Detail (breaks/downtime/changeover)</th>
<th>Volume/cycle time (p/min)</th>
<th>Time Complete (m)</th>
<th>Notes (defects/crew size etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filling ingredients delayed while requirement is established</td>
<td></td>
<td>4.19</td>
<td>Cook and supervisor</td>
</tr>
<tr>
<td>ZPILAUNEW (520Kg rqd)</td>
<td>173kg</td>
<td></td>
<td>Cook 1 of 3</td>
</tr>
<tr>
<td>Filling of Kettle begins (water)</td>
<td></td>
<td>14.55</td>
<td>1 cook</td>
</tr>
<tr>
<td>Ingredients added</td>
<td></td>
<td>16.05</td>
<td></td>
</tr>
<tr>
<td>Rice Added</td>
<td></td>
<td>36.39</td>
<td></td>
</tr>
<tr>
<td>Manual fill begins</td>
<td></td>
<td>60.00</td>
<td>1 Fill</td>
</tr>
<tr>
<td>Fill complete (kettle empty)</td>
<td></td>
<td>63.50</td>
<td>1 Cook</td>
</tr>
<tr>
<td>Hygiene operation complete</td>
<td></td>
<td>64.30</td>
<td></td>
</tr>
<tr>
<td>ZPILAUNEW</td>
<td>173kg</td>
<td></td>
<td>Cook 2 of 3</td>
</tr>
<tr>
<td>Filling of kettle begins</td>
<td></td>
<td>64.40</td>
<td></td>
</tr>
<tr>
<td>Heat off/ downtime for break</td>
<td></td>
<td>80.20</td>
<td></td>
</tr>
<tr>
<td>Cook resumed</td>
<td></td>
<td>125.30</td>
<td></td>
</tr>
<tr>
<td>Rice added</td>
<td></td>
<td>129.20</td>
<td></td>
</tr>
<tr>
<td>Manual fill begins</td>
<td></td>
<td>148.10</td>
<td>1 fill</td>
</tr>
<tr>
<td>Fill complete (kettle empty)</td>
<td></td>
<td>150.35</td>
<td></td>
</tr>
<tr>
<td>Hygiene Cleandown complete</td>
<td></td>
<td>155.11</td>
<td>1 cook</td>
</tr>
</tbody>
</table>

Next product : ZSA1273Cook
A3.3.2 Process timing Measurement- OM Cook Line

Templates

The following templates were used for process measurement on OM Cook Line equipment in order that more accurate timings for cook cycles, changeovers and hygiene cleandowns may be recorded. These timings will be held on the MRP system used for planning the factory's capacity and replace the existing timings that are currently used as a baseline for production. The Potato Mashers and Pasta Lines have not been considered at this stage as their bulk throughput is considered on a volume basis rather than timed batches.

Timings

Measurements are to be recorded specific to a particular product, regardless of the equipment it is produced on, and as such each template records a single cook cycle and associated filling and hygiene operations. It should prove possible to record multiple products being processed simultaneously across a number of kettles, with all operations recorded being referenced back to start time of the initial cook.

Processes

In considering cook cycles on Kettles (numbered 4-7 in OM1; 4-10 in OM2 and 1-7 in OM3) the following process steps have been highlighted:

| Cook Start time begins with the first ingredient added to the kettle—typically oil or water being brought up to temperature | Cook finish time is often determined by a member of the crew (high-risk) emptying the kettle contents into ingredient trays | Hygiene operations begin after final tray has been filled and duration depends on product and in some cases subsequent product. May be difficult to determine if equipment is idle or still awaiting final cleaning operations |

Downtime

During or in-between the phases identified above the following delays may be observed and are to be recorded in the relevant space on the template:

- Scheduled breaks
- Crew Unavailable (completing other task)
- Equipment Idle (waiting for crew for next operation to begin)

In addition, space has been provided for details relating to crew size, defect rate etc, where information is available and may be recorded in the notes section.
### A3.3.2 Kettle Measurement Template

<table>
<thead>
<tr>
<th>Product/Item Code: ZBA1273RICE</th>
<th>Factory Number: OM1</th>
<th>Kettle Number: (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date/Time: 29/3/05</td>
<td>Volume: 140Kg</td>
<td>Cook: 1/1</td>
</tr>
</tbody>
</table>

#### Cook Phase

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Duration</th>
<th>Notes (crew/defects)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.19</td>
<td></td>
<td>1 cook operator</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Projected Duration</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>55 min</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Finish Time</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>40.30</td>
<td></td>
</tr>
</tbody>
</table>

#### Fill Operation

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Duration</th>
<th>Notes (crew/defects)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40.30</td>
<td></td>
<td>1 cook operator</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Finish Time</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>44.36</td>
<td></td>
</tr>
</tbody>
</table>

#### Hygiene Cleandown

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Duration</th>
<th>Notes (crew/defects)</th>
</tr>
</thead>
<tbody>
<tr>
<td>44.36</td>
<td></td>
<td>1 cook operator</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Finish Time</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>48.16</td>
<td></td>
</tr>
</tbody>
</table>

#### Next Product

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Duration</th>
<th>Notes (crew/defects)</th>
</tr>
</thead>
<tbody>
<tr>
<td>49.19</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Code: ZLEBONRI CE</th>
<th></th>
</tr>
</thead>
</table>

#### Summary

<table>
<thead>
<tr>
<th>Cook Duration: 40 min 17s</th>
<th>Crew Low Risk: 1</th>
<th>Total Breaks: none</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variance from Plan: -14 min 40s</td>
<td>Crew High Risk: 1</td>
<td>Total Downtime none</td>
</tr>
</tbody>
</table>
### A3.3.3 Kettle Measurement Template

<table>
<thead>
<tr>
<th>Product/Item Code:</th>
<th>Factory Number: OM1</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZLEBONRICE</td>
<td>Kettle Number: (4)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date/Time:</th>
<th>Volume:</th>
<th>Cook:</th>
</tr>
</thead>
<tbody>
<tr>
<td>29/3/05</td>
<td>104Kg</td>
<td>1/1</td>
</tr>
</tbody>
</table>

#### Cook Phase

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Duration</th>
<th>Notes (crew/defects)</th>
</tr>
</thead>
<tbody>
<tr>
<td>49.19</td>
<td></td>
<td>1 cook operator</td>
</tr>
</tbody>
</table>

| Projected Duration | 105 |
| Finish Time       | 83.07 |

#### Fill Operation

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Duration</th>
<th>Notes (crew/defects)</th>
</tr>
</thead>
<tbody>
<tr>
<td>83.07</td>
<td></td>
<td>1 fill operator</td>
</tr>
</tbody>
</table>

| Finish time | 86.40 |

#### Hygiene Cleandown

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Duration</th>
<th>Notes (crew/defects)</th>
</tr>
</thead>
<tbody>
<tr>
<td>86.40</td>
<td></td>
<td>1 cook operator</td>
</tr>
</tbody>
</table>

| Finish time | 119.30 |

- **Break**: 86.40 - 111.20
- **Fill op begins**: 111.20
- **Cook begins**: 117.20

#### Next Product

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Duration</th>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>120.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Code: ZSA1269C OOK |

- Fill operator began cleandown while waiting for cook operator to return from break, cook operator completed cleandown (which took in total only 8 mins 10 secs; rather than the 34 minutes between product runs) Cook time was substantially shorter than planned.

#### Summary

<table>
<thead>
<tr>
<th>Cook Duration:</th>
<th>Crew Low Risk:</th>
<th>Total Breaks:</th>
<th>Total Downtime</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 min 48s</td>
<td>1</td>
<td>1</td>
<td>24.30</td>
</tr>
<tr>
<td>-75 min 48s</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

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Appendix 4

RESPONSIVE DEMAND MANAGEMENT WITHIN THE FOOD INDUSTRY

A4.1 Introduction

This paper is from the proceedings of the International Federation of Automatic Control (IFAC) Conference on Manufacturing Modelling, Management and Control (IFAC_MIM'04), held in Athens, Greece (Darlington and Rahimifard 2004). This Appendix describes the development of the Responsive Demand Management (RDM) Framework and the elements comprising it.
RESPONSIVE DEMAND MANAGEMENT WITHIN THE FOOD INDUSTRY

Rob Darlington and Shahin Rahimifard

Advanced Manufacturing Systems and Technology Centre, Loughborough University, UK

Abstract: There has been a proliferation of advances within the processed foods sectors, resulting in increasing availability of value-added and convenience foods. This is due to consumer demands for foods that can easily and quickly be prepared and has resulted in significant increase in product variety and their related preparation, cooking and packaging processes. The research reported in this paper investigates particular applications where long make-spans resulting from the increased processing and preparation requirements for convenience foods and short notification of reaction times demanded by retailers creates considerable wastage in the form of over-production to ensure order fulfilment. Copyright © 2004 IFAC

Keywords: food processing, planning, production control, performance analysis, optimization

1. INTRODUCTION

The food industry is bounded by a number of constraining factors that have created a unique production ethos which make it distinct from many other manufacturing sectors. The volatility of demand for food products can be extreme; dependant on a diverse range of factors while the products themselves often have relatively short shelf life which limits the possibility of holding a safety stock to guard against demand fluctuations. In addition, food manufacturers are often given very short reaction times by increasingly powerful global food retailers while the software support which would otherwise aid manufacturing in such responsive environments is largely adapted from other sectors and is ill-equipped to deal with food industry requirements. The growth of convenience foods has been steady and well defined, with many new products being introduced at regular intervals providing labour saving meal accompaniment or solution. Product sectors such as fresh foods and ready-meals have grown from small beginnings to have strong prominent positions in supermarkets, as a result of popularity with consumers seeking time saving products who are prepared to pay a premium for this convenience. The grocery supply chain in the UK is predominantly through a small number of large retailers, who thanks to the economies of scale offer "own label" products branded with the supermarket chains own name which has been manufactured on their behalf to their specifications.

In this paper, the authors discuss the issues involved in the development of a structured approach to combating the long make-span and short reaction time constraints in order that a responsive planning framework to reduce overproduction wastes may be realised. The following section of this paper provides a review of the previous research work relating to this aim. The remaining sections of the paper describe the research concepts related to the development of a responsive demand management framework for the food industry.
2. RESEARCH BACKGROUND

The structure of food retailing in the UK is based around a small number of retail chains, with a heavy bias for large out of town stores, where the majority of groceries are sold (Bell et al., 1997). The relationships between these retailers and their suppliers need to be effective for consumer demands to be met, however it is considered that the retailers dominate in their dealings and inter-organisation cooperation is lacking (Robson and Rawnsley, 2001).

Demand for food products varies across the industry. Some foods have a fairly steady, easily predictable demand pattern, meaning that the consumer demand for the product can be met accurately, without wasteful overproduction, or disappointing consumers by not meeting their needs. Other products, for example prepared sandwiches, display highly volatile demand, for which there may be considerable wastage when demand is overpredicted or consumer dissatisfaction when stock-outs occur. Retailers may attempt to smooth large fluctuations by managing the demand, for example by running various promotional activities to maintain demand for products at a steadier level. The demand management efforts for products are merely an attempt to compensate for the external driving conditions such as weather conditions, holiday seasons and sporting events which contribute to the demand in highly volatile sectors.

In this context, the bullwhip effect was first identified by Forrester in the early 1960s, and has been investigated thoroughly since (Towill, 1996; Metters, 1997). Its basis is the amplification of demand across a supply chain, to the point of creating seemingly unpredictable demand volatility in suppliers. Additional problems occur when one companies actions are reflected across the whole supply chain, so organisations that create demand volatility can increase the complexities and costs across the whole of their supply network.

This is a clear indication that old data causes delay, amplifications of demand and overhead. Wal-mart (an American retailer) broke barriers with an innovative approach of introducing Point Of Sale (POS) data, made available to each level of supply chain, making actual demand much clearer across the companies (Mason-Jones, 2000). In this approach the inventory levels at retail point may be directly linked to suppliers for instant notification of product demand.

One of the primary considerations when dealing with food industry manufacturing is the Shelf Life of the ingredients and final products being processed. The times over which foods are fit for consumption may be accurately predicted, dependant on storage conditions.

In general food quality degrades with chemical changes and micro-organism growth over the time it is held until the shelf life expires (Pegg, 1999). Retailers aim to provide consumers with as much of the available shelf life possible, limiting the time that manufacturers have to hold produce.

When it comes to the scheduling of the production of convenience foods a number of considerations must be borne in mind; hygiene is of paramount importance and regular, intensive "clean-downs" of the processing equipment must be scheduled into the production schedule which may take as long as an hour per assembly line, typically occurring every 24 hours. In terms of planning production there are further restrictions as to the order of products to be processed dependant on flavour and allergen content (for nut-free products for example). Production schedules must take into account the order that products must follow in keeping with constraints such as flavours as described in detail by Nakhla (1995).

The 'rules of thumb' and constraints that must be imposed by the production planner are also poorly defined, rarely recorded, and it is often the case that it is only the planner or scheduler that knows when and where to apply these rules (Van Donk and Van Dam, 1998). This places great responsibility upon the production planner, and a formalised system of identifying these constraints will clearly be of benefit in times of staff illness or turnover, and will aid dissemination of vital production knowledge across the enterprise.

Further scheduling complications are evident based on the highly dynamic nature of the food industry (Gargouri et al., 2002) such as when shipments of ingredients from suppliers arrive relative to when orders are placed and how this influences the way a schedule is created. Additionally, changes to the production plan from confirmed orders that had been forecasted create considerable complexity to the scheduling effort, particularly when the scheduling is being completed on such a compressed timeline, i.e. for orders which must be completed in a number of hours. Scheduling software has aided significantly the process of schedule generation, both speeding up the process, and allowing optimisation of the schedules produced to improve production planning. Some systems even potentially enable scheduling of jobs on the production plan to be integrated directly with the Manufacturing Execution System (MES) to take out all manual intervention, though the sophistication of such systems in dealing with food and drink industry problems is unclear, and certainly is at this stage unproven.

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3. DEMAND MANAGEMENT IN THE FOOD INDUSTRY

Traditionally operational planning within the food industry has been based on a predictive make-to-stock approach, which utilised a number of forecasts for various product demands as a basis for production levels. However in recent years there has been greater pressure to adopt a more reactive make-to-order approach, similar to that adopted by the discrete parts manufacturing companies in the engineering sector. The make-to-order format of production is represented in Figure 1a, where the overall reaction time allowed for production is greater than the processing time of products. The implementation of such reactive customer order driven systems has proved to be more feasible in the engineering sector where such reaction times are allowed for the given make-spans. In this research, reaction time is taken to be the length of time from when customer orders are confirmed until the finished products are despatched. In convenience food sectors such as chilled ready-meals and sandwiches, there is greater complexity where the make span of products often represents a significantly longer time period than the reaction time required by the customer. This means that the production processes must be started before the exact levels of customer demands are known. This is represented diagrammatically in Figure 1b, where production starts before the orders have been placed, and thus order quantities must initially be predicted through some means of forecasting activity. This basing of production volumes upon forecasting methods inevitably introduces inaccuracies in the production plans, creating waste due to the difficulty in accurately predicting the customer orders to be met. In addition, further complexities are created in this current state of manufacturing convenience foods by the volatile pattern of customer orders due to seasonal promotions/marketing activities and the limited shelf life of raw material and finished goods as mentioned previously which prevents products being made to stock. It may be considered that the problem of long make-span and short reaction time overlap may be resolved by separate focus on the two distinct dimensions of this problem, namely minimising the production make-span and maximising the reaction time as outlined in Figure 1c. While there are many potential improvements that may be made in tackling the problem, the changes required may take some time to implement, and in some cases may yield only slight improvements to the overlap of make-span and reaction time. In these cases there is a requirement for improved planning activities to reduce the impact of late notification of demand volatility.

The research reported in this paper has developed a structure for sandwich and ready-meal production to be improved with regard to the situation described earlier by adoption of a systematic approach as outlined in the IDEF0 diagram in Figure 2. This approach is based on four major activities namely health check, product/process optimisation, supply network optimisation and a novel two stage production planning. The Health Check aims to provide the appropriate information related to production processes, supply chain and production planning activities through a structured modelling activity.

![Diagram of Relationships between Make-span and Reaction Time for Food Industry Manufacture](image-url)
Fig. 2. IDEF0 Representation of the RDM Framework

The principal tool considered for this modelling has been Value Stream Mapping (VSM), which allows for simple and insightful mapping of both process and information flows along a supply chain. This mapping process provides the required information and knowledge to undertake the subsequent three activities as outlined in the following sections.

3.1 Product/Process Optimisation

In focusing upon reducing the overall production lead-time for the manufacture of convenience foods, it may be seen that non value-adding steps in production may be quickly identified, leaving only the time required for the processing of tasks that are essential for manufacture. This requires the make-span of the products themselves be reduced, which may be achieved by only a limited number of means. Considering each of the essential processes in terms of the product's requirements, and the technology and resources reasonable to achieve those requirements, it may be infeasible to reduce the make-span of many products significantly without considerable technological development or resource investment. As such, the effort in "minimising make-span" encompasses considerable work in reducing the time-based wastes in the production system by the application of Lean techniques, and the careful consideration of how current practices may be improved upon to reduce the incumbent value-adding processes.

The Lean tools initially considered as being of most use when undertaking improvement of convenience food manufacture include Layout redesigns, Single Minute Exchange of Dies (SMED) philosophies applied to changeovers and set-ups and Work In Progress (WIP) reduction. The preferred method of determining the potential impacts of changes to production processes is Simulation. Small scale models focused on particular aspects of the process being considered for improvement are used for initial data relating to the applied techniques. A commercial simulation software package, namely Simul8 has been used for this purpose. The details of this research work is the subject of further publication and is beyond the scope of this overview paper.

3.2 Supply Network Optimisation

The aspects of the problem related to the reaction time are considered under Supply Network Optimisation. This includes order processing at both retailer and manufacturer, point of sale data processing and information flows between supply chain members. The significant improvements that may be made in reducing the demand notifications will not be limited to the manufacturer. In order that the best improvements may be made, it is likely that all members of the supply chain are involved and it is to that end in part the health-check was devised in order to promote collaboration between members of the chain. The positive dissemination of Point of Sale (POS) data across the supply chain has been successfully exploited by only a small number of retailers, and would substantially reduce the bullwhip effect described in section 2 which may be mapped across supply chains using the Demand Amplification Screen as applied in VSM.
The application of new e-commerce technologies to better enable information flows in this way will reduce the time spent in order placement and processing, and the mapping of such flows, as undertaken in VSM will outline where specific improvements may be made. A simple value stream mapping for a ready-meal production facility undertaken in electronic (eVSM) form is outlined in Figure 3. Further integration of planning activities via Advanced Planning Systems (APS) will also impact upon the overall lead time allowed for convenience foods.

3.3 Two Stage Planning

Once the activity concerning the optimisation of make-span and reaction time have been undertaken, focus must then be placed upon production planning activities. In this context, the research has developed a two stage planning framework based on a hybrid approach of utilisation of static and dynamic production scheduling rules. In this approach, operations are divided into two categories of standard and special operations. Standard operations are those which do not give the product identity and are shared among many products. Special operations are those that give identity to a product. The main principle of the two stage planning is to use static planning for the standard operations based on traditional forecasting approach in the first stage to generate a soft schedule, and to utilise a dynamic (real time) approach for special operations. The second stage is initiated when customer orders are confirmed. The confirmed production levels will be used to re-adjust the batch sizes for special operations to produce...
a hard schedule indicating that this final work-plan based on confirmed orders.

In this two stage planning framework, the processing of standard operations are initiated based on the soft schedule. The processing of special operations are however subject to change, dependant upon the confirmed orders and shop-floor data indicating the current state of production as shown in figure 4.

A commercial software scheduling system, namely PREACTOR has been adopted to implement the two stage planning. PREACTOR is a highly configurable finite capacity planning system, and utilises graphical user interfaces for ease of use and rapid access to information. It has modular structure of functionality, named PREACTOR 100, 200, 300 and APS, and among these PREACTOR 300 and APS enable users to create their own scheduling rules using Visual Basic programming. In order to develop the two stage planning system, the functionality of the standard PREACTOR software has been extensively enhanced to include custom scheduling routines, custom import and export scripts and specially designed user interfaces to support the real time planning of special operations. A simple schedule for a ready-meal production facility generated in PREACTOR is shown in Figure 5.

The research reported in this paper considers a sector of products, namely convenience foods where the product make-spans exceed the reaction times that manufacturers are given to meet these demands. This has led to a situation where much waste is generated through overproduction to ensure retailer orders are met. As a result a responsive demand management framework has been proposed which utilises a number of contemporary process modelling and manufacturing planning tools to eliminate this wasteful overproduction. With the ever-increasing trend in variety of convenience foods and the large production volumes which are forecasted to rapidly increase, the adoption of such responsive demand management framework will not only provide significant financial benefit, but also support a sustainable approach to food production through reduction/elimination of waste.

4. CONCLUSION

Food industry manufacturers face production conditions that demand the application of specialist tools, techniques and software owing to the nature of, and the volatile demand for, these products. This highlights a need for increased use of IT tools, especially within small enterprises for effective production in the face of:

- Large volumes and varieties of product
- Relatively short production lead times
- Short shelf lives of product ingredients
- Short Product Life-cycles

5. REFERENCES


Appendix 5

A RESPONSIVE DEMAND MANAGEMENT FRAMEWORK FOR THE MINIMISATION OF WASTE IN CONVENIENCE FOOD MANUFACTURE

A5.1 Introduction

The paper contained in this appendix has been accepted for publication by the International Journal of Computer Integrated Manufacturing and details the wastes created through convenience food manufacture and the application of the Responsive Demand Management (RDM) framework in reducing the impacts of these wastes.
Appendix 5

A Responsive demand management framework for the minimisation of waste in convenience food manufacture

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Convenience food manufacture generates considerable waste through poor planning of production. This problem is particularly acute for products that have a very short shelf life and will be disposed of as waste should their shelf life expire. Chilled ready-meals are convenience foods with relatively short shelf lives and volatile consumer demands; their manufacture is based on forecasted volumes and when demand has been over-predicted, considerable wastes are created. This is referred to as OverProduction Waste which typically sees finished product disposed of through commercial waste channels due to lack of demand. The research reported in this paper has investigated the generation of a responsive demand management framework for the reduction of overproduction wastes.

Keywords: Waste Minimisation; Reactive Planning; Food Manufacture

1. Introduction

The widely accepted principle behind sustainable development is “to meet the needs of today’s generation without jeopardising the ability of future generations being able to provide for themselves”. Environmental considerations are of the utmost importance in all aspects of life, and where production and manufacture are concerned it is clear that an environmentally responsible attitude in addition to economic acumen is necessary for businesses to remain profitable and sustainable in the future. One of the issues of environmentally conscious manufacturing is the minimisation of waste during the production stage. In food manufacture a significant proportion of this waste is due to the short shelf life of both the ingredients and products and is often generated as a result of overproduction to meet retailer demands.

Convenience foods provide consumers with value-added products that save preparation time and are available in a range of formats from fresh to frozen snacks, meal accompaniments or even meal solutions. The research reported in this paper focused on chilled ready-meals which typically have a very short shelf life due to their fresh nature and are subject to large volatility in demand, in part due to consumer’s tendency to purchase these products on impulse. The retailer’s own label branded goods have the prominent market share, with the manufacture of these products usually being outsourced to independent manufacturers, several of whom may be subcontracted to provide the same product, to demanding specifications required by the retailer. In this sector, the retailers often hold significant buying power which influences their relationships with supplier manufacturers. In this
relationship, the retailers focus on minimising stock holding while fulfilling consumer demand which has led to a situation where late confirmation of order volumes is commonplace. This confirmation of the required volumes shortly before the products must be shipped presents several planning complexities for manufacturers and often results in creation of large amounts of overproduction waste.

One of the major research objectives has been to develop a responsive framework to deal with volatile demands of products in this sector and to minimise the wastes as a result of overproduction based on unreliable forecasted values. The initial sections of the paper provide an overview of relevant research and legislation in this area and a waste model developed for convenience food manufacture. The main sections of the paper outline and illustrate through a case study the various stages within the Responsive Demand Management (RDM) framework which has been generated to minimise OverProduction Waste (OPW).

2. Review of relevant legislation

Concern with regard to the environment, and manufacturing’s impact upon it, is such that improvement in environmental performance has not been left to the economic incentive of cost savings, but enforced through compliance with legislation. Such coercion has reportedly resulted in more effective means of business performance being adopted (Sarkis 2001; Maxwell 2003). Material wastes created in food supply networks are largely either organic or resultant from packaging processes, with the food industry responsible for using over 50% of the total packaging output for the UK (Environment agency 2001). The European Union directives on packaging waste (Directive 94/62/EC 1994; Directive 04/12/EC 2004), indicate the measures and targets that member states must implement with each target being periodically reviewed. The UK Packaging Regulations first introduced in 1998 is based upon these directives and require companies handling greater than 50 tonnes of packaging to comply with the legislation and take responsibility for their ‘obligation’ of packaging waste in order to reduce the environmental impact of such packaging waste. Fernie and Hart (2001) describe how this obligation gave the greater share of the responsibility to Retailers, with manufacturers required to recover only 9% of packaging. The actual recovery is often undertaken by third party reprocessors through compliance schemes. Other food industry wastes such as material wastes, those arising from processing or waste water and effluent are considered under the Integrated Pollution Prevention and Control (IPPC) directive 96/61/EC (1996), which is to be fully implemented by October 2007. The IPPC measures were created to prevent, or at least reduce emissions to air, land and water from manufacturing activities whereby companies have to demonstrate that reasonable steps to reduce emissions to acceptable levels are being taken.

An integrated Environmental Management System (EMS) has been described as a suitable response to legislation and regulations relating to a companies Environmental performance (Lillford 1997) allowing all activities to be managed and benchmarked against the companies EMS database. A family of International Standards referred to as ISO 14000 provides the framework by which an EMS may be structured (ISO14001) considering auditing, monitoring, analysis and assessment including Life Cycle Assessment (LCA) whereby any potential environmental impacts across a products life are considered. The activity undertaken in an EMS has been compared to that of existing manufacturing management systems, such as Total Quality Management (Borri1995), while acknowledging the continuous improvement basis upon which EMS’s are based as they develop with technological and political advancement (Gupta 1994; Borri 1995).
3. Waste Model for Convenience Food Supply

Wastes are created in the food industry often through process inefficiencies, planning complexities, improper use of materials and sometimes simply from not using the ingredients before spoilage. In most cases, food quality degrades with chemical changes and micro-organism growth over the time it is held until the shelf life expires and the food becomes unfit for consumption (Pegg 1999). Shelf life is measured in days for most convenience foods and can be the cause of consumer created wastes; retailer created waste from overstocked shelves; and manufacturer/supplier wastes where both the finished product and their ingredients have not been used in the delivery window. The shelf life demands on the convenience food supply network means that products cannot effectively be made to stock, creating planning difficulties to meet the volatile demand. Wastes in food industry may be generated through any stage of preparation, manufacture, supply or consumption as shown in Figure 1; however the main focus for this research has been the OverProduction Wastes which typically account for the biggest proportion of the manufacturer’s wastes constituting as much as 40% of total cost of wastes.

Several convenience food manufacturers contributed to a series of exploratory interviews used as the basis of the work in creating the waste model. IDEF0 representations (Dorador and Young 2000) have been utilised to model and demonstrate the relationships between each stage and the sources of particular types of waste. The IDEF0 representation for the broad stages of food supply through a products life is shown in figure 2. The wastes identified across this representation are described in sections 3.1 - 3.5.

<table>
<thead>
<tr>
<th>Ingredient Supply</th>
<th>Manufacture</th>
<th>Distribution and Retail</th>
<th>Use and Disposal</th>
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<tr>
<td>Material Wastes</td>
<td>Production Wastes</td>
<td>Product Wastes</td>
<td>Consumer Wastes</td>
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<td>Organic Material</td>
<td>Processing</td>
<td>Failure in Supply</td>
<td>Plastic and Packaging</td>
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<td>• Losses grading</td>
<td>• Housekeeping</td>
<td>• Damage or loss</td>
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<td>Plastic and Packaging</td>
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<td>In-Store disposal</td>
<td>Shelf Life and Spoilages</td>
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<td>• Hygiene</td>
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<td>• Overestimate of requirement</td>
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<tr>
<td>• Handling</td>
<td>• Hygiene</td>
<td>• Shelf Life expiry</td>
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OverProduction Waste (OPW)

• Late Notification
• Planning Errors

Figure 1, Waste Creation through life cycle of Convenience Food Supply
3.1 Bulk organic wastes

These wastes are associated with the preparation of ingredients and may include inedible parts of the ingredient, such as stems, leaves, bones, excess animal fat and contaminated materials, such as outer layers of vegetables that are spoiled.

3.2 Water wastes

Water is used in large quantities in food processing, predominantly in the preparation and cooking stages of the product's life cycle, as indicated in figure 2. Water may form an ingredient for many products, though it may be a waste described in this context as the water reclaimed at the end of the process either as a carrier for waste and contamination or a byproduct from cooking or processing operations. In addition, water and detergents are the primary method for cleaning machinery and facilities of food deposits and contaminants, and large volumes of fresh clean water are used daily for this process. The Environment Agency (2001) reports that the UK food and drink industry used 6600 Million litres per day in 1997/98 accounting for around 10% of the non household public water supply and direct abstraction of water by primary industry.

3.3 Processing wastes

Processing wastes may be created by a number of different sources, often resultant due to poor processes and housekeeping, process inherent losses or poor conformity. This could include spillages, damages and contamination of product caused by poor handling procedures
Appendix 5

and operator neglect or poor processes, e.g. forming equipment making improper seals on packs etc. The creation of such wastes will largely result in waste product being spilt to the floor which will be disposed of as bulk organic wastes when the equipments and production areas are cleaned. Bi-products in this context are materials that are created by the manufacturing process but have little or no value and cannot be used elsewhere. They may be well anticipated in production such as estimated volumes of juices or animal fats created with product which are removed and disposed of to give the desired product quality or consistency. Wastes may be created at any time for any ingredient or product failing to adequately conform to specifications, with all final products being tested for quality, consistency, appearance, flavour and aroma etc. Rejected products may be final packaged products and be added to standard refuse waste or may be batches of sauces, meat or pasta for example that can be added to bulk organic wastes.

3.4 Packaging wastes

Packaging wastes are widespread in the food industry, due to the essential requirements for preventing contamination or spoilage of foods by their immediate environment. Packaging can vary from large paper sacks for ingredients to various plastic bags sheets and pouches depending on the product and packaging requirements. In some cases ingredients are packaged specifically for a processing operation and then have to be removed from that packaging for subsequent processing e.g. vacuum packaging of meats for cooking processes. The material properties and specific nature of the packaging used in each application are considered in conjunction with marketing, logistics issues and environmental concerns (Prendergast and Pitt 1996). Typically packing materials are all disposed of in similar manner to commercial waste disposal.

3.5 OverProduction Wastes

OverProduction Wastes constitute significant cost to the company as materials, energy and production capacity in manufacturing are wasted given that the product no-longer has an end customer. OPW may also be used to describe batches of ingredients that have been prepared before order confirmation decreases in volume and cannot be re-used before expiry. In such cases the ingredients will typically be scrapped to commercial waste and sent to landfill as many own label manufacturers cannot re-direct the product to different customers in keeping with their agreements with the retailers. It may be possible to reduce the impact both commercially and environmentally of OPW by the authorised extension of the products shelf life by a company's technical department for those products to be sold at cost prices, for example in the staff shop. Such practices are not always feasible and therefore the authors argue that a more structured route to reducing incidences of OPW must be sought. When considering where manufacturing wastes are generated we must first establish the manufacturing processes and production steps that must be undertaken to create each product. Ready-meals and convenience foods are varied in their form and format, and as such the processing of each product likewise varies. However, a typical generic process route has been presented in figure 3, and used as the basis for a more detailed waste model, encompassing activities common to most ready-meal products. It should be noted that figure 3 details the activities identified in the manufacturing phase as outlined in figure 2.
4. Minimisation of Wastes due to Overproduction

The Environment Agency and Envirowise (formerly the Environmental Technology Best Practice Programme) in the UK have waste minimisation clubs, projects and guidelines demonstrating the scope for businesses to make substantial cost savings in making environmental improvement activities in their operations. This view of the economic incentive of waste reduction promotes companies to investigate the costs of the wastes they create and thus reduce those costs. The costs of bulk organic wastes as described in the waste model in section 3 are low, the mechanisms by which they are collected being their primary expense, and provided they are disposed of responsibly present little environmental hazard. For the convenience foods considered in this research, volumes of bulk organic waste represented a small proportion of both the costs and volumes of wastes created. However OPW typically constitute over 40% of the costs of wastes and accounts for at least 20% and as much as 50% of the volume of waste.

One of the major reasons for the generation of OPW is that in these applications production volumes are often based on forecasted values as the adoption of a Make-To-Order approach is not feasible due to the required order lead-times being significantly shorter than the manufacturing lead-time of the product. As mentioned earlier this is often caused by the late confirmation of the required order volumes by the Retailers. This presents a substantial challenge to production planning, where overproduction results in significant waste and to the detriment of the company’s profitability. In order to effectively reduce the amounts of
OPW and promote greater manufacturing sustainability, the factors influencing and aggravating these planning issues must be identified and carefully considered. The research reported in this paper has identified three main methods of reducing the impact from the impact of long manufacturing lead-time versus short order lead-time:

1. Reduce manufacturing lead-time through improved production processes and technology
2. Increase order lead-times through more effective management of supply chain activities
3. Utilisation of an intelligent reactive production planning approach

Based on these, a framework for Responsive Demand Management (RDM) has been proposed which aims to reduce the Overproduction Waste. This framework utilises a number of contemporary modelling and analysis techniques, such as simulation and Value Stream Mapping, to achieve its objectives. Figure 4 depicts the major goal of the RDM framework which is to minimise the overlap between the manufacturing lead-time and order lead-time (Darlington and Rahimifard 2004).

Figure 4, Relationships between Manufacturing lead-time and Order lead-time for Food Industry Manufacture

In some cases, the reduction of manufacturing lead-time and increase of order lead-time could result in a Make-To-Order approach being feasible (i.e. order lead-time is longer than the manufacturing lead-time). However in most applications the improvement of manufacturing lead-time and order lead-time will still not enable a Make-to-Order approach to be adopted (i.e. the manufacturing lead-time is still longer than the required order lead-time). In these cases, a hybrid production planning approach based on the use of both static

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and dynamic scheduling rules can be adopted to minimise the overproduction waste as outlined in the remaining sections of this paper.

4.1 A Responsive Demand Management Framework for convenience food manufacture

The RDM framework consists of three stages as outlined in figure 5, which are briefly described below and are further discussed and illustrated with the aid of a case study in the remaining sections of this paper.

i. Health Check

The review and analysis of the effectiveness and efficiencies of the manufacturing activities and associated supply chain processes forms the focus of the health-check to be carried out in the first stage of the RDM framework. Such a health-check aims to benchmark the fitness of both the material and information flows along with the company’s environmental performance.

Figure 5, Activities in RDM Framework for Waste Minimisation in convenience food manufacture

The subsequent process modelling in this first stage provides a visualisation of the 'current state' of manufacturing and supply chain activities and is based on information collected through the health-check process.

ii. Improvements to Production and Supply Chain Processes
This stage of the RDM framework examines the various existing production technologies and aims to identify inefficiencies or the use of more up-to-date techniques to reduce the overall required manufacturing lead-times of the product. In addition, analysis of the supply chain activities to identify opportunities for closer integration of information flows and greater availability of consumer demand data to the manufacturers and suppliers is undertaken.

### iii. Reactive Production Planning

The final stage of the RDM framework adopts a hybrid planning method based on static scheduling of standard operations (i.e. operations that are common among many products and do not impart product identification, e.g. cleaning meats, cooking operations) and a real-time approach to the planning of special operations (i.e. operations that provide product identification e.g. adding specific sauce or packaging).

### 5. Case Study

The various stages of the RDM framework have been applied in a convenience food manufacturer which produces a range of fresh ready-meals for one of the major retailers in the UK, under the retailer's own brand. In the case of this particular food manufacturer, the order confirmations from these retailers are received within 24 hours of required delivery times. However the average manufacturing lead times are 36 hours and hence traditionally the production levels in this company has been based on forecasted values. As part of this research, the three stages of the RDM framework have been applied to identify possible improvements in production processes and supply chain activities to be able to adopt a Make-To-Order approach for production planning. In addition the Two Stage Planning approach has been implemented to be able to utilise a real-time planning of special operations, hence minimising the OverProduction Waste. These three stages are described below.

#### 5.1. Health Check and Process Modelling

The process of health check for the company was based on completing a questionnaire through a set of interviews with key decision makers and providing feedback which serves to highlight the context to the current practices and inefficiencies that are in place. The sources of waste identified for the case study manufacturer were consistent with the stages of production as outlined in figure 3. The current state of manufacturing processes and supply chain activities were recreated utilising Value Stream Mapping (VSM) and based on information from the health check as illustrated in figure 6 (Hines and Rich 1997). In addition a considerable amount of data was not historically recorded by the company and hence had to be collected by means of observation of current production and material handling practices.
The ability of Value Stream maps to highlight complexities of communication channels, timings, methods and frequency of contact makes them a useful tool to identify the improvements in manufacturing and supply chain activities. The modelling of the information and physical flows related to products between production processes, through to finished goods store and distribution centres, highlighted a number of non-value adding processes. This provided an immediate benefit for the company to focus on a range of improvement initiatives targeted at these non-value adding processes and resulted in the investment by the company to integrate their MRP system with their Electronic Data Interchange used by the retailers.

5.2 Production and Supply Chain Improvement

In order to improve the production lead-time within the company a systematic approach based on consideration of the product, processes, resources, and layouts was adopted. A number of contemporary optimisation techniques, as outlined in figure 7 were utilised to analyse and improve the product family groupings, the process set-ups, the range of resources and the layout with which they are positioned in the production system. The company's production system is typified by 'Human Centred Manufacturing System' and this provided the flexibility of utilising processes and personnel on alternative production lines to reduce bottlenecks and delays in manufacturing that contributed to a lengthening of production lead-times.
The analysis of production layouts in the company identified a number of potential methods for reduction of production lead-time through re-grouping of product families, processes, and their related resources. These potential optimisation scenarios were subjected to a what-if analysis through development of a simulation model.

The simulation model utilised for this project required a high degree of flexibility to examine a large number of what-if scenarios related to these potential optimisation methods. SIMUL8 simulation software (Simul8 corporation 2001), has been utilised for this simulation project. The straightforward user interface and accessibility of the visual simulator enabled significant number of simulation experiments to be carried out. Figure 8 provides an animation of the simulation model of the company production system, in which nine filling lines were serviced by two elevators, each separately providing meat and sauce components to 9 filling lines. The simulation project was able to provide comparative data relating to ingredient queues due to elevator availability and breakdown with the analysis undertaken offline and without disruption to production.
In order to improve the order lead-time within the company a review of Supply Chain practices, data flow and communication streamlining and adopted technology and applications was undertaken. A number of contemporary Supply Chain Management techniques as outlined in figure 9 were utilised to identify potential improvements in supply chain activities with the retailer. This review indicated that the greatest improvement to be obtained by streamlining communication between the company and the retailers. This allows the timely use of consumer demand data, enabling manufacturers to respond more quickly to variability, and adjust production volumes and plans appropriately. One of the most effective techniques for such communication streamlining is based on the adoption of e-commerce technologies which was considered by the company for future development.
In addition, the case study company took part in a scheme implemented by the retailer in which employees (planners) from ready-meal supplier manufacturers were placed at the retailer head offices to co-ordinate communications and help order placement. This has significantly improved order placement resulting in an increase in reaction time for the manufacturers to fulfil retailer’s demands. In addition, the utilisation of high tech IT based tracking processes have been investigated through a two year trial within one of the retailer’s distribution centres. The early results from this trial indicated significant improvements can be achieved across supply chain replenishment through increased visibility of product requirement and availability.

5.3 Reactive Production Planning

The activities described in the beginning of sections 5.1 and 5.2 resulted in significant improvements in manufacturing lead-time and order lead-time. However these improvements have not enabled the company to adopt a Make-To-Order approach and although the volume of waste as a result of OverProduction was reduced due to better manufacturing and supply chain activities there was still a need for a reactive production planning approach that can respond to the late changes in product demands. The final stage of the RDM Framework is based on the application of a two stage hybrid production planning approach, as outlined in figure 10.

![Two Stage Planning Diagram](image)

Figure 10, Outline of the Two stage Planning Approach

In this Two Stage Planning (TSP) approach, operations are divided into two categories of standard and special operations. Standard operations are those which do not give the product identity and are shared among many products. Special operations are those that give identity
to a product. The main principle of the two stage planning is to use forecasts to plan for standard operations in the first stage to generate a soft schedule, and then to utilise a dynamic (real time) approach for the planning of special operations in the second stage, when orders are confirmed. The confirmed production levels will be used to re-adjust the batch sizes for special operations to produce a hard schedule for the final work-plan based on confirmed orders. The PREACTOR software scheduling system (Precator International 2002) was adopted in this case-study to implement the TSP model. PREACTOR is a highly configurable finite capacity planning system using graphical interfaces for ease of use and rapid access to information. The recent development in PREACTOR Advanced Planning System (APS) based upon Static Material Control (SMC) and Dynamic Material Control (DMC), enabled the implementation of the TSP model. A simple example of a soft and a hard schedule developed for a sub-set of orders in the case-study company is depicted in Figure 11.

![Figure 11, Examples of Soft and Hard schedules in PREACTOR](image)

In this example, the soft schedule contained a range of standard operations namely cleaning processes, preparation, cooking meat, etc. and the hard schedule mainly included the special operations in the assembly lines (e.g. adding sauces and packaging). The application of this hybrid planning approach enabled the company to significantly reduce their OPW through proactive consideration of common ingredient requirements and postponement of planning decisions for special operations until after order confirmation.

6. Conclusions

OPW presents a considerable source of waste for convenience food manufacturers in terms of both cost and volumes of physical wastes generated. The underlying causes of overproduction waste creation in food manufacture are due to the nature of products themselves and the supply chain relationship inefficiencies that creates a planning challenge that has traditionally been addressed by Over-Production tactics. Legislation raising the
profile of environmental considerations has led to best practice guidelines and recommendations for product and packaging designs and reactive waste management processes. The authors argue that long term environmental benefits are to be obtained through a proactive approach to waste minimisation by reconsidering entire production and supply systems. The research presented in this paper sets out to address convenience food planning challenges through the application of a Responsive Demand Management framework, which aims to apply contemporary techniques to improve manufacturing lead-time and order lead-time in addition to the use of hybrid planning to reduce wastes resulting from Over-Production. The continued drive to consumer service and on-shelf product availability pressures manufacturers to meet ever shorter order lead-times, which in the future will be a challenge to be met through efficient manufacturing, collaborative planning and effective supply.

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Appendix 5


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