Creation and Implementation of Customised Production Scheduling Software in a Processed Cheese Factory

A thesis presented in partial fulfilment of the requirements for the degree of

Master of Technology
in
Manufacturing and Industrial Technology

at Massey University, Palmerston North,
New Zealand

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2000

Abstract

This project investigated creating computer algorithms and friendly software interfaces to assist with the scheduling of single stage operations with sequence dependant set-ups and crew rostering problems across multiple lines.

Various techniques and approaches were investigated for reducing the total solution space including, grouping similar items and orders and bucket scheduling. The principles of the Goldratt Method of Scheduling were used.

A Tabu Search algorithm was implemented to search for solutions where total make-span was minimised and probability of missing orders was taken into account in an unreliable production system.

Microsoft Access and *Microsoft Visual Basic* were used to create a stand alone application that interfaced with an Manufacturing Resource Planning system.

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Chapter 1 – Introduction

1.1 - Overview

This project was initiated by *Pastoral Foods (NZ) Limited* who approached *Massey University's Institute of Technology and Engineering* for assistance in improving their scheduling systems. *Pastoral Foods* saw great benefits from bringing in new scheduling expertise and experience into their production-planning department.

The purpose of this Masters Project from the author's point of view was to investigate the feasibility of creating techniques and systems to improve scheduling in a typical New Zealand manufacturer. This would involve investigation of the overall scheduling processes (including the details of the data management systems used) and to develop the use of better manual scheduling techniques and automatic scheduling systems.

1.2 - The Project's Specific Goals

The overall goal of the project was to use computer technology to assist in the creation of good sequences for manufacture of products through the factories at *Pastoral Foods (NZ) Limited*. Under this goal some specific objectives were created.

The sequencing rules developed were aimed at supporting decision-making to achieve:

1. The maximum production possible in the limited time available by affecting the 'change of run' set-up times and finding the best combinations of products to run together through the multiple production lines.
2. To improve customer service by reducing the number of missed orders to virtually zero.
3. To reduce effective lead-times by better order management and matching of production delivery to required lead-time.

1.3 - Structure of this Report

This report is written to explain the logic of the decisions made in the development of a Computer Scheduling system for a processed cheese factory. The *Next Section* of this Introduction gives a brief description of processed cheese factory *(Pastoral Foods)*. The structure of this report goes through each issue in turn and describes the problems and a variety of techniques for coping with it and then describes in detail the technique chosen and applied to *Pastoral Foods*.

Chapter 2 (Computer Programming Systems) gives an overview of the strategy for the selection of the computer systems on which the project is based.

Chapter 3 (Scheduling Techniques and Systems) gives details of the types strategies and techniques for overcoming scheduling problems in particular the scheduling of single stage operations.

Chapter 4 (Multistage Scheduling Techniques) gives details of some strategies for overcoming multi-stage scheduling problems. This section is by no means exhaustive but give some insight into how a multi-stage scheduling problem may be approached.

In scheduling it is very easy to come up with a single solution, the problem is that the best solution that can be found is more desirable than just the first schedule found. Unfortunately there are many, many possible schedules in all but the simplest situations and as such a search for better schedules must be conducted. *Chapter 5 (Techniques in Searching for Solutions)* describes some techniques for searching for the better solutions.

Scheduling requires large amount of data to be available to the scheduler or scheduling algorithm. *Chapter 6 (Data Collection Methods)* gives some systems and techniques for some of the more time consuming data collection tasks.

In many companies the customer's satisfaction is far more important than the optimisation of the production processes. However optimisation algorithms often do not take this into account effectively enough and as such produce schedules that (in unstable or unreliable

manufacturing processes) may leave the company exposed to dissatisfying the market. *Chapter 7 (Immunity from Disruption)* discusses techniques that can be applied to *Techniques in Searching for Solutions (Chapter 5)* to avoid this possibility.

In some scheduling problems raw material availability is a major issues and must be fully researched before a schedule can be considered. This act can be very time consuming. However sometimes the raw materials are usually available for manufacturing at relatively short notice and so that the scheduler or scheduling algorithm can assume that the materials will be available when required. *Chapter 8 (Raw Material Availability)* discusses this issue.

In Chapter 9 (Optimisation Macros), Chapter 10 (Visual Interfaces) and *Chapter 11 (Over-All Solutions)* a description of the entire system is given and how it is to be used.

Chapter 12 (Discussion and Conclusions) describes the results that came out of this project.

1.4 - Introduction to Pastoral Foods (NZ) Limited

Pastoral Foods (NZ) Limited, which is wholly owned by the *New Zealand Dairy Board*, is the only manufacturer of processed cheeses in New Zealand. *PFL* have markets all over the world including Japan, South East Asia, Libya, South Africa, South America, the Caribbean, the Middle East, Australia and New Zealand.

1.4.1 - Background to the Need for the Project

Previously the *New Zealand Dairy Board* has handled all of *Pastoral Foods* marketing. This has both helped and hindered *Pastoral Foods*. The *New Zealand Dairy Board's* marketing organisation was able to offer the customers a large range of dairy products including processed cheeses from *Pastoral Foods*. In selling a selection of dairy products there were often large amounts of commodity products (such as butter, milk powder and raw cheeses) ordered by customers with a small amount of processed cheese. This meant that *Pastoral Foods* products were not seen as significant to the *New Zealand Dairy Board (NZDB)* or to the customers ordering them and so there was no pressure to improve customer service in terms of shortening lead-times or ensuring on time delivery.

Pastoral Foods (NZ) Limited is entering a new environment where it will no longer deal through the New Zealand Dairy Board for a significant portion of its business. This new situation has already bought competitive pressure onto the business, and heightened awareness of the need for change in the way customer orders are sequenced through their manufacturing processes. It has also become clear that more rapid response from the process will provide a significant competitive edge.

Processed cheese like most food products has a limited life. The agreed residence time of processed cheese in the *Pastoral Foods* stores is only six to eight weeks, even though most of the processed cheeses have lives of one year after manufacture. This is because the customers require the product to be as fresh as possible and will not accept any processed cheese that is older than this agreed limit. In the past *Pastoral Foods* has manufactured all products to confirmed orders from customers and has not attempted to manufacture any product for stock. Even though there are forecasts sent in from the market for up to twelve months for all products, the forecasts are not regarded as accurate enough to confirm for manufacturing. A fast reacting scheduling system is thus seen as imperative in order to allow *Pastoral Foods* to cope with the make-to-order environment.

In a very short space of time the position of the company can change in terms of its production crewing requirements and so the company needs to know as early as possible what the requirements are. When the requirements do change suddenly they need to know the best way to rearrange production schedules so that all orders can be met in the most efficient manner. Hence there is a need for a fast reacting scheduling system.

The scheduling system at *Pastoral Foods* has not changed for years and is quite inefficient. It is a combination of a manual paper tracking system and an MRP-II (Manufacturing Resource Planning) system called *BPCS (Business Planning and Control System)* that tracks customer orders, (planned) manufacturing orders and purchase orders. Any changes that are made to any order are very time consuming and manual to effect. Even if this change is as simple as altering the date of manufacture for an order, there is still manual paper work and adjustments to the MRP-II system to put the change into effect. It is thus a management view that there is significant room for improvement in many facets of the *Pastoral Foods* production scheduling system.

1.4.2 - Manufacturing Facilities and Products

Pastoral Foods (NZ) Limited has only one manufacturing site, located in Eltham, Taranaki, New Zealand. This site has two departments with eight manufacturing lines, making a variety of types of products as listed in *Table 1*. The whole factory usually runs 24 hours a day, five days a week (though all lines cannot run at the same time due to staffing numbers).

Dept.	Production Line	Product Types	Min Run
IWS	KD Line	Individually Wrapped Slices (IWS)	2400 kg
	Retro Line	Individually Wrapped Slices (IWS)	300 kg
SPC	SOS Lines (2 Lines)	Slice On Slice (SOS)	2400 kg
	RDS Line	Cheez Toyz / Bodz	300 kg
		Spreads	300 kg
	Packet Line	250g Packets	300 kg
	Bulk & Block Line	20kg Blocks	300 kg
		2kg Blocks	300 kg
		Skins	300 kg
	Key Ingredients Line	Enzyme Modified Cheese (EMC)	2200 kg
		Pastes and Slurries	300 kg

Table 1 – *Pastoral Foods* - Manufacturing lines and product types.

Within each product type there are a variety of formulations. A formulation is best described as the recipe or mixture of cheeses and additives that go into each product to give the desired characteristics of the cheese (i.e. taste and texture etc.). In addition to this there are also a variety of packing configurations. Packing configurations are the dimensions and weight of cheese portions, the number of portions in each pack and the arrangement of portions in the pack. Each item is wrapped in a specific film and packaged into specific cartons. The two main scheduling characteristics of each product are the formulation and the packing configuration, with the film and carton packaging having only a minor impact on scheduling. A list of all items in each department and their formulation, packaging configuration can be found in *Appendix 1*.

In the manufacture of processed cheese there are six stages that are common to all products. The stages of manufacture can be seen in *Figure 1*. The first stage of manufacture is

blending. Blenders vary in size on different lines at *Pastoral Foods* but they all do the same job and all have a problem with small formulation runs. This is because they require a minimum mass of formulation in a batch in order to be able to mix the blend properly; hence they cannot manufacture runs of formulations below certain defined quantities. *Table 1* shows a list of the minimum formulation masses that can be made for each product type.

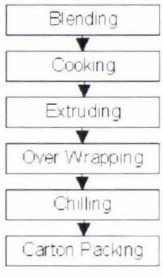


Figure 1 - *Pastoral Foods* Manufacturing Process

For the majority of products, manufacture takes less than ten minutes from the cooking stage to chilling and storage, so we can say that from a scheduling point of view these products are effectively single stage operations. There are however some products that do require special chilling arrangements. These products have to be chilled immediately after manufacture otherwise the temperature of the product remaining from manufacture will cause the cheese to go off at the centre of large blocks. Specifically this is true for 20kg Blocks, 2kg Blocks, Skins and 250g Packets. The 20kg Blocks have their own specialised blast chiller that can hold 300 cartons and this is the maximum quantity that can be manufactured per day. The 2kg Blocks, Skins and 250g Packets all go into another chiller that can hold enough product to allow them time to cool, before the chiller is filled to capacity. This means that *Pastoral Foods* can keep manufacturing these products continuously whilst unloading the chiller at the other end.

Whenever a line stops it will usually take several hours to wash down and several hours to get running properly again. The company wants to do maintenance work on all machines and so the factory lines must all be down at the same time for some periods. This situation lends itself particularly well to the five days per week, twenty-four hours per day operation, which is used by *Pastoral Foods*.

1.4.3 - The Scheduling Problem

Pastoral Foods products and processes have, what are called 'sequence dependent set-ups'. This means that the sequence, in which the products are manufactured, determines the set-up times and therefore the total manufacturing time or Total Make-span of the process. *Pastoral Foods* possesses several kinds of sequence dependent set-up problems in their scheduling. The first and main type of sequence dependent set-up problem involves a variety of formulations with tight restrictions on certain components in the formulations. It is seen as important that these formulations be run in a certain order. For example it is best to run lighter coloured formulations before darker coloured formulations. This is because the effects of cross contamination are minimal and thus the formulations can be run straight after each other without a time consuming clean up. On the other hand if the formulation change is from darker to lighter colours then cross contamination in the pipelines will cause unacceptable dark streaking in the new, lighter coloured, formulation.

The same problem can also exist in some items with particularly strict specifications on certain components. For example low fat products have a very narrow restriction on their fat content and so should be run before high fat content formulations. There are many other examples of this type of sequencing issue and *Pastoral Foods* have worked out the best sequence to run all of their formulations in order to minimise changeover times and minimise out of specification formulations. Sometimes there is no way to adequately arrange the products without creating sequences that produce large amounts of out of specification product. In this case a single full wash up of all equipment involved will be a better alternative and the products will be run in two individually optimal sequences.

The second type of sequence dependent set-up problem involves the variety of packing configurations. After the formulation sequence restrictions have been sorted out the next step is to find the packaging configuration sequence (in light of the formulation sequence) that minimises the packaging configuration changes. For example, if the schedule includes...

Item A - Pale Formulation in 100gram packs
Item B - Pale Formulation in 250gram packs
Item C - Colour Formulation in 500gram packs
Item D - Colour Formulation in 250gram packs

The best sequence will be to run all the pale products together and then the colour products and then within this try to minimise the pack weight changes. This would mean that the best sequence with minimum down time is to run the following sequence...

Item A - Pale Formulation in 100gram packs
Item B - Pale Formulation in 250gram packs
Item D - Colour Formulation in 250gram packs
Item C - Colour Formulation in 500gram packs

This sequence keeps the 250gram items together, whilst keeping the pale to colour formulation sequence.

This sequencing problem cannot be optimised with standard sequences. It must be recalculated and resorted for every sequence that is presented to production. This is because the best arrangement of packing configurations will depend on what item formulations and packing configurations are to be manufactured in the schedule.

In the two departments at *Pastoral Foods* (Individually Wrapped Slices (IWS) and Specialty Processed Cheese (SPC)) there are crewing requirements for the lines to be run. In IWS they have four lines that are capable of manufacturing the same product types. Some lines can manufacture more efficiently than others can. As such IWS must simply look at the total amount of product they have to make and plan accordingly the total crewing requirements.

SPC has a more complex problem. SPC was originally two departments SOS (Slice on Slice) and SP (Specialty Products) that had the crews for lines for RDS (Recombined Dairy Solids), Bulk and Block, 250g Packet and Key Ingredients. Both of these departments had significant problems maintaining a steady level of work for their crews. The market's requirements were quite erratic from month to month. This made it difficult to plan crewing requirements and to know how many temporary workers to hire and for how long. To help cope with this problem *Pastoral Foods* senior management decided to unite these two departments and have all crew members trained up to operate all lines in both departments. This gave the new SPC department more flexibility to handle the ups and downs of required work. SPC has six lines but only enough staff to operate two, three or four (depending on how many staff they have

Chapter 2 - Computer Programming Systems

available) at any one time. Therefore the SPC department has a crew rostering element in its scheduling problem.

1.5 - Scheduling In New Zealand

Pastoral Foods is not untypical of many New Zealand manufacturers, who are quite heavily dominated by natural resource processors. Typically natural material processes involve a small number of raw material items going in to their manufacturing facility and a large number of finished product items going out. These are termed 'V plants', because a map of products will show raw materials going in at the bottom and finished products at the top; hence it forms the 'V' shape. Some raw material processing manufacturers have very few raw materials going in and a huge number of finished products coming out with only one or two stages of the process determining what the majority of finished products will be. These factories are termed 'T plants' again because of the shape formed by the product map.

The majority of New Zealand manufacturers are small companies that have simple operations which effectively only have a few stages that require scheduling. This means that they cannot afford and cannot justify spending large amounts of money on sophisticated scheduling packages that do far more than their factory's scheduling requirements. On the other hand a lot of New Zealand manufacturers have very manual scheduling systems, developed in-house, that are quite inadequate in the new era of the high competition market place with customers demanding short, accurate delivery lead-times. In addition this the task of scheduling is made especially difficult by the fact that many New Zealand manufacturers have large complex ranges of products with some 'oddball' items that are not at all suited to their manufacturing facilities and are very different from their standard products. The author has perceived a need in this manufacturing scene for customisable scheduling systems that fit the simple operations typically found in New Zealand.

Again because of the diverse product ranges and unstable markets some New Zealand companies have multiple production lines of similar machines or have diversified into other manufacturing lines. With multiple lines and erratic demand patterns New Zealand scheduling regularly includes crew rostering as part of the overall problem.

2.1 - Overview

The creation of a scheduling system will require many paper work tasks to be automated and by the nature of planning much information will need to be presented for appraisal by the planner. The production planner will need to make decisions based on the information presented and so the better the information is presented the better the scheduling system will be.

2.2 - Database and Programming Systems

Many database systems available today are applicable to the requirements in this project. The best solution would most likely be the one that was easiest to program and most maintainable. *Microsoft Access* is the most suitable choice because it is familiar to the author and many people at *Pastoral Foods (NZ) Limited* and therefore is likely to create the least resistance for system maintenance etc. *Microsoft Access* has a very large degree of functionality and is very easy to learn and develop new systems in. For these reasons the obvious choice of database system at the moment is *Microsoft Access*. Should any expansion be required Microsoft Access application can be easily adapted to use Microsoft SQL Server and Microsoft Visual Basic which can be used to create faster and more accessible applications.

2.3 - MRP-II Systems and Interfaces

Most major database information systems these days adhere to the ODBC (Open Database Connectivity) standard. This is a great benefit from the point of view of system developers because it essentially means that most major database systems can use and modify the information in most other major database systems. This includes software from both IBM and *Microsoft*. So using the *IBM AS 400* mainframe computer disk operating software that interfaces with the *BPCS* MRP-II software we can have data automatically exchanged between *Microsoft Access*, *Microsoft Visual Basic* and *BPCS*.

Chapter 3 - Scheduling Techniques and Systems

3.1 - Overview

The general principles of 'constraint theory' as depicted by *Eliyahu M. Goldratt* in *The Goal* [4] and *The Haystack Syndrome* [5] are seen as significant components in modern scheduling theory. In these books *Goldratt* discusses the significance of 'the constraint' on scheduling and the profitability of the entire organisation. *Goldratt* argues for global measures over the whole organisation instead of the traditional cost accounting approach of optimising all work centres in the organisation individually. He argues that in many organisations the cost accounting practice of trying to gain maximum production on each and every single machine is detrimental to the total production output of the organisation as a whole. The 'common sense' approach to this problem, is to focus on the one component of the process in the organisation that has least 'effective capacity' relative to its demand in allowing the organisation to generate more money.

If every machine or process in the manufacturing process of the company has more capacity than it needs and the company cannot sell everything it makes (assuming it make the right products) then the company is said to have a market constraint. If the organisation has problems obtaining enough raw materials to make all the products it want to then the organisation is said to have a supplier constraint.

Goldratt [5] argues that in the majority of organisations if the marketing department is vigorous enough and makes enough contacts, then they will be able to sell all the capacity it has. If the company can sell all the capacity it has then the organisation is said to have an internal or capacity constraint. This can usually be traced down to a single machine in the whole factory, or a single machine on each manufacturing line. This project has investigated techniques for dealing with all three-constraint types, but has mainly concentrated on the internal production constraint.

3.2 - Levels of Planning

3.2.1 - Overview

The levels of planning are defined for the purposes they serve and the rank in the hierarchy of the organisation they are associated with. According to *Portugal and Oliver* [3] there could be a level of planning for each level of hierarchy (typically

seven). However, typically organisations only require three levels including the following...

1. Long Range Forecasts and Rough Cut Capacity Planning
2. Master Production Scheduling
3. Shop Floor Control

3.2.2 - Long Range Forecasts and Rough Cut Capacity Planning

This is seen to be associated with the long-term goals of the organisation and may take into account of market 'fashion' trends and analysis of new machinery requirements and major machinery maintenance and replacement. This will typically be done on a month-by-month basis of an entire year or more and in New Zealand is almost always done in accordance with the company's accounting cycles. Senior management has most input to this, because it heavily involves and is based in decisions that relate to the long-term direction of the company.

3.2.3 - Master Production Scheduling

Master Production Scheduling (MPS) is the domain entirely of the planning office and in its most fundamental phase involves the sequencing of finished products (or batch of finished products to be made in a time block) as they are to exit production. This could also be applied to a major stage or constraint of the process of manufacture, instead of the finished product. MPS should deal with all the constraints of the manufacturing process and determine the best sequence or mixtures of production in each time block to achieve maximum throughput for the company as a whole. MPS is executed in time cycles usually of one week. Though the MPS schedule may be for several weeks or even months (typically between four weeks and three months) each cycle of it should be regenerated to reflect the new situation.

According to *Arbita and Elmaghraby* [6], many companies around the world put huge amounts of effort into their long to medium range planning but give little consideration to the short-term day to day scheduling that causes so many of their marketing and profitability problems. Because of this, this project shall focus on the day-to-day scheduling of a factory, especially MPS, though much consideration will be given to Shop Floor Control.

3.2.4 - Shop Floor Control

Shop Floor Control is the day to day running on the factory floor of all operations. This involves scheduling for individual machines and is done in the finest detail necessary for instructions to be carried out on the shop floor. Assuming a realistic MPS has been forwarded to the Shop Floor Control stage of planning, the fine details of the production plan should be met within the due date restrictions supplied in the MPS.

Shop Floor Control is also the stage of the process that makes sure the schedule is being followed. A very common and very significant problem in scheduling is that the MPS is not performed adequately to meet the markets requirements. The causes of these problems vary but many of them include...

- Unpredicted maintenance requirements of unreliable machines.
- Undisciplined supervisors who like to make their own scheduling decisions without planning office consultation.
- A lack of communication of what is in the schedule to the people on the shop floor who are actually supposed to perform it.
- Inaccurate stock keeping of raw material inventories, which causes a lack of availability of raw materials.

Many companies have enormous problems (especially with complex processes) in getting their schedule completed on time. According to Portugal and Oliver it is not uncommon for companies in New Zealand (with high variety production) to have schedule adherence figures around 50%, (though a more common figure may be closer to 70%). This problem must be solved first, before the company looks at improving its scheduling systems. There is no point in producing the best schedules that are possible, if the schedule is not going to be followed as accurately as possible. Solving this problem is very important to the success of any project that is focusing on the scheduling process and although it is beyond the scope of this project, it must be dealt with.

Shop Floor Control also provides feedback to the scheduling office as to the status of the schedule and orders in the schedule. If orders are not going to be met on time or the schedule is going to take longer or shorter than originally expected, then this information needs to be fed back to the MPS stage of planning.

There are two schools of thought on how Shop Floor Control should be run. In many companies the day to day scheduling is performed by the shop floor supervisors, in accordance with a set of restrictions in due dates for the orders. This is done in practice by the scheduler giving the supervisors a 'stack' of orders and telling them to complete them all within a specified time frame in any sequence or manner they choose. The second school of thought is to have central control of all levels of planning and all decisions to be made through the planning office. There are advantages and disadvantages of both systems. Some of the advantages of involving the supervisors in the day to day scheduling include...

- The supervisors have 'buy in' to the schedule because they are involved in its creation and are therefore more motivated to make it work and make sure it is completed on time.
- The production planner cannot be there all day, every day to make all the scheduling decisions when daily issues arise. Involvement, responsibility and authority are given to production supervisors so that the correct decisions can be arrived at when they are needed.
- If the planner is not completely competent and knowledgeable about all aspects of production then he/she cannot expect to make the best decisions about the factory sequencing and as such these details should be left to the direct shop floor supervisors.

Some of the advantages of keeping control of the day to day scheduling in the planning office include...

- If the scheduler has good knowledge of planning requirements and goals and of the factory systems then he/she can make sure that the systems constraints are always fully utilised and the maximum potential is being realised from the factory (i.e. take a more 'global' view to the planning than the supervisors, who are likely to take a very 'localised' view).
- Well trained planning office staff should be the only people who know all the ramifications of many Shop Floor Control decisions from all points of view including marketing, production and the company's profitability.
- A supervisor who is coordinating the scheduling may be seen to favour certain crews or shifts above others and therefore be thought to be arranging for them the easier parts of the schedule. With scheduler unattached from the supervision

staff the planning can seem to be fair and to randomly distribute the 'good' and 'bad' work.

These two schools of thought have both got their good and bad points in all situations. But some situations will lend themselves more heavily to one than the other. In general, if the planner is competent, then it is better to make sure that he/she is in total control of what is being made on all machines (within reason) and has the ability and authority to put the schedule into effect.

Pastoral Foods is attempting to move from factory supervisor control of scheduling, to total control from the planning office.

3.3 - Simplification of Scheduling of Complex Processes

According to *Motron and Pentico* [1], a machine only needs to be scheduled if a queue of more than one job appears in front of it. By this they simply mean that if there are no queues it front of the machine then there are no scheduling decisions to make and the machine should always process the next available job. From this we can assume that any machines with significant percentages of excess capacity can be left unscheduled. The *Goldratt* [5] philosophy of scheduling says this can be taken a step further because we only need to give significant detail of schedule to the production constraints. If we are dealing with a simple process with only a few machines with queues then chances are there will only be one schedule to consider per line.

According to Morton and Pentico [1], this philosophy is common amongst the scheduling software manufacturers including *OPT (Optimised Production Technology)*, *Schedulex* by *Numetrix* and *Q-Control* by *ISE*. These software manufacturers have had their successes with 'V plants' that are common use in process industries. *OPT* was written by *Goldratt* in the 1970's and according to *Morton and Pentico* [1]...

"...to this day *OPT* is still the scheduling software against which the abilities of all others are to be compared."

OPT will be discussed further in *Section 4.3* and *Schedulex* will be discussed further in *Chapter 9*.

3.4 - Scheduling Objective Functions

According to *Motron and Pentico* [1] the three main focuses of scheduling are...

1. Maximise shop throughput over some time period;
2. Satisfy customer desires for quality and promptness; and
3. Minimise current out of pocket costs.

These objectives are based on the principle that we have already decided what orders we are going to manufacture for, given that manufacturing have already promised a delivery date to the marketing people and / or customers. Under these circumstances *Goldratt* [4] has three equivalent statements that an organisation should try to achieve...

1. Maximise Throughput dollars–rate at which the system generates money (sales value – (truly) variable costs);
2. Minimise Inventory (i.e. investment) - the money tied up in the system; and
3. Minimise Operating Expense - the cost of owning the business.

It is easy to see that 1 and 3 from both lists are equivalent. It can also be argued that the purpose of point 2 in *Goldratt's* list is to achieve shorter lead-times and higher quality. So it can be argued that these two lists are essentially trying to achieve the same things. *Goldratt* [4] argues that the current out of pocket costs are largely constant in any organisation. In normal accounting practices, organisations' direct labour costs are considered to be variable, but *Goldratt* argues that these are essentially very static over long periods of time, because they do not change a great deal in relation to the output of Master Production Schedules. With the single (or small number) stage processes we are dealing with in this project, it could be argued that inventories will be small and that the Master Production Schedule will not have a significant effect on this.

We can now state that the main focus of Master Production Scheduling in most New Zealand companies should be to satisfy customer demand and to maximise throughput. From these two qualitative objectives we can define what we want to achieve and can (in some cases) create a mathematical equation that (if we get it right) enables us to quantitatively decide whether one schedule is better or worse than another one. This will enable us to see if any changes we make are an improvement to the schedule. A measurement of the schedule's benefits should be taken over the whole of the schedule rather than any one part of it.

According to *Goldratt* in *The Haystack Syndrome* [5], maximising Throughput Dollars is equivalent to maximising the production output of the constraint. The question of what time period to measure (and try to maximise) the constraints utilisation is important for the overall effectiveness of the scheduling algorithm. It would be desirable to measure the schedule over all orders that are known and planned to be made. This would give the opportunity fir a full optimisation over all orders. However it is not likely that this will give stable solutions because longer term projected requirements are likely to be very changeable as new orders come in and projections of requirements change. It would not be beneficial to measure the schedule with greater penalties for down time in the short-term and less in the long-term. With this the scheduling algorithm would simply force the 'oddball' items out into the future and make the 'run of the mill' items in the short-term. The best solution to this problem is to try to optimise the schedule over a period that all customer orders and projections are judged to be unlikely to change significantly. We should only consider orders that are due for manufacture within this time frame. This can be done equally over the whole time of the schedule by analysing the Total Make-span of all orders in the stable horizon of the schedule. A stable horizon may be typically 4 to 6 weeks. Total Make-span should be measured in hours.

To satisfy all of the company's customers in the best possible way the schedule must make all of their orders on time and in full. Sometimes this may not be possible because the constraints do not have enough capacity to meet all that has been promised. In this case the scheduler should look for a schedule that utilises the constraint to best advantage whilst at the same time satisfying all of the most important customer orders. On the other hand if the factory has enough capacity to meet all of its customer orders then the customer's satisfaction should be paramount and any schedule that allows the company to miss an order should be rejected in favour of a schedule that meets all customer orders.

Manufacturing is a process where many things must occur in the correct quantity, the correct quality and in the correct timing on every item so that a schedule can be produced in full and on time. Disruptions are a regular occurrence and they can lead to significant difficulties in accomplishing a schedule adequately. While we cannot predict when significant disruptions are going to occur we should try to find a way to protect the customer's satisfaction from them. *Goldratt* in *The Haystack Syndrome* [5] suggests some ways of doing this with changes to the buffer management in the manufacturing and scheduling processes. *Goldratt*

advocates a 'finished product shipping buffer time' is added into the production schedule. This means that the schedule should always plan all orders to be finished prior to a finite time before they are due for shipping. This time could be different for each item (depending on how difficult or unpredictable the item is to manufacture), different for each customer or even for each order (depending on how much importance is attributed to the order). A penalty should be placed on any schedule that plans any order to be made some way into this shipping buffer, (measured in days of buffer used).

Taking the *Goldratt* philosophy of buffer management further, it can be argued that if we can predict a high chance of missing an order due to an unplanned breakdown, then we should penalise this schedule. As the predicted probability of missing an order becomes less then we should penalise these schedules less. The method of predicting the probability of missing an order is discussed in *Chapter 7*.

Taking all of these into account we will have an equation that looks something like the following...

Schedule Index = [Total Make-span]

+ Σ ([Penalty for missing an order] * [Days order will be late])

+ Σ ([Penalty for using shipping buffer] * [Days of shipping buffer to be used])

+ Σ ([Penalty for 25% chance of missing an order])

+ Σ ([Penalty for 10% chance of missing an order])

+ Σ ([Penalty for 5% chance of missing an order])

Where:

Schedule Index = Method of comparing one schedule's benefits and costs compared to another.

Σ = Sum of all components (orders).

[Total Make-span] = Total time taken for all orders to be manufactured on the constraint for orders within the current scheduling horizon, measured in hours.

[Penalty for missing an order] = Management assessed cost of missing an order, measured in hours per days late. The amount of constraint time management is prepared to give up in exchange for meeting an order.

[Penalty for using shipping buffer] = Penalty for risking missing an order, measured in hours

per days of shipping buffer used. (<< [Penalty for missing an order])

[Penalty for 25% chance of missing an order] = Penalty for taking a 25% risk in missing an order, measured in hours. (<< [Penalty for missing an order])

[Penalty for 10% chance of missing an order] = Penalty for taking a 10% risk in missing an order, measured in hours. (< [Penalty for 25% chance of missing an order])

[Penalty for 5% chance of missing an order] = Penalty for taking a 5% risk in missing an order, measured in hours. (< [Penalty for 10% chance of missing an order])

These percentages (25%, 10% and 5% are just examples and any probabilities could be chosen. With the exception of Total Make-span (which is generally accepted as the unit of measure by which a schedule cost to benefit can be judged) these measures are all very subjective and there is no hard and fast rule for deciding what values they should have. The best approach for deciding their values would be to try some values and see what works most appropriately. It is dubious as to whether or not the [Penalty for % chance of missing an order] is worth having in the formula. This will require extra calculation time when searching for a good schedule and so it may be more beneficial to look over more schedules than to look at this detail. This subject is covered further in *Chapter 7*.

3.5 - Sequencing

Sequencing involves the actual ordering of items or orders through the machines over a period of time. We may choose to do bucket scheduling (discussed later in *Section 3.10*), in which case in each time lot the scheduler will find the best sequence of manufacture without consideration of the exact due dates. This concept will be discussed further later in *Section 3.6*).

In scheduling there is an obstacle called the 'combinatorial problem'. This problem is at the heart of why scheduling is so difficult. The number of sequences that are possible through only one machine for a number of items is equal to the factorial of the number of items. That is...

n items means n! possible sequences and $n! = n * (n-1) * (n-2) * (n-3) \ldots 3 * 2 * 1$

For small numbers of items n! will remain reasonably small, but it very quickly increases as the number of items increase. If we are to find the absolute best sequence in a set of n orders

then it is necessary to simulate every possible sequence and test its quality of sequence. For sixteen items the number of possible sequences is...

16! = 20 922 789 888 000

It would take a very fast algorithm on a very fast computer approximately two thousand years to calculate, analyse and assess all of them. The most it is practical to do in a useable time frame by searching through every single possible sequence is about twelve items according to *Morton and Pentico* [1]. The best that this project was able to achieve using Visual Basic on an Intel Pentium-II 200 MHz computer was ten items in just over two hours or nine items in less than ten minutes. We are usually trying to schedule many more items than this, so a better way must be used. This issue is discussed further in *Chapter 5*.

3.6 - Sequence Dependant Set-Ups

3.6.1 - Overview

Sequence dependant set-ups are a problem that makes the job of scheduling one or two stage processes much, much harder. Were it not for sequence dependent set-ups then a single stage manufacturing process could be best scheduled by the Earliest Due Date (EDD) method. This is as simple as sequencing the orders in due date succession. If there are significant variations in the average set-up times for changing from product to product then a schedule can be improved by looking for small orders and 'Grouping' them together before the earliest required order is due.

Sequence dependent set-ups are a problem most obvious when sequencing a batch of orders, such as in bucket scheduling (discussed later in *Section 3.10*). Sequence dependant set-ups occur when the sequence in which items are manufactured has significant impact on the Total Make-span of the schedule. Given the combinatorial problem (mentioned previously in *Section 3.5*) finding the most appropriate sequence for a large scheduling problem may be difficult. Sequence dependant set-ups are a very common problem. In general, literature on scheduling tries to avoid this problem and will explain that they are not prevalent. According to *Proud* [7] surveys of manufacturers in the Unit States of America show that more than 70% of manufacturing operations have significant sequence dependant set-ups. They are

commonly found where a single facility carries out several different kinds of tasks and in New Zealand there is likely to be an even higher proportion of companies with this problem.

There are three general types of sequence dependent set-up problems that have been defined in this project, all of which had to be dealt with. They are 'Standard Sequence', 'Conditional Standard Sequence' and 'Trial and Error Calculated Sequence'. Combinations of any two and all three of these are also likely.

3.6.2 - Standard Sequence

Standard sequence is the most simple and easy to deal with of all sequence dependent set-up problems. This involves scheduling items according to a set or standard sequence that is organised to be optimal for minimum Total Make-span. This is common in food manufacturing companies where products are manufactured in a pale to dark style of sequence.

3.6.3 - Conditional Standard Sequence

Conditional Standard Sequence problems are an extension of the Standard Sequence problems. The appropriate sequence can be chosen from a list of alternatives dependent on certain (if-then-else) conditions.

If certain criteria from a list of alternatives are met then the sequence is determined from a list of Standard Sequence alternatives.

3.6.4 - Trial and Error Calculated Sequence

Where there is no standard sequence and the problem's optimal sequence depends on what items have to be made or how much of each item has to be made, then for each proposed sequence the Total Make-span and total objective function must be evaluated. This means that we will have to search for a solution amongst the n! possible sequences. Operations Research Science regards this as the equivalent of the Travelling Sales Person (TSP) problem, where a sales person must travel from one place to another and in the journey visit various cities and various locations within each of these cities. Travelling times between cities are analogous to the changeover times on machines in manufacturing, so to minimise the total distance travelled by

choosing the shortest path around the cities is analogous to minimising the Total Make-span in manufacturing. Road atlases have lists or matrix of distances between major cities. This is analogous to the scheduling requirement of a matrix of the changeover times between items. An example of a 'from item' versus 'to item' matrix where the 'from items' are listed vertically down the left side and the 'to items' are listed horizontally across the top can be seen in *Table 2*.

		To Item										
		Item A	Item B	Item C	Item D	Item E	Item F	Item G	Item H	Item I	Item J	Finish
From Item	Start	20	20	20	20	20	40	20	30	20	20	-
	Item A	-	10	5	5	5	5	10	10	10	15	30
	Item B	20	-	10	15	15	15	20	15	20	25	30
	Item C	30	25	-	20	15	15	25	15	25	25	30
	Item D	15	20	30	-	25	20	20	20	27	25	30
	Item E	30	30	20	20	-	20	25	25	25	25	30
	Item F	40	20	45	25	20	-	25	20	25	30	30
	Item G	60	30	30	20	30	20	-	20	30	32	30
	Item H	120	120	120	120	120	120	120	-	60	60	120
	Item I	120	120	120	120	120	120	120	60	-	60	120
	Item J	120	120	120	120	120	120	120	60	60	-	120

Table 2 – Item versus Item Changeover Times Matrix (Example).

To obtain the changeover time from 'Item D' to 'Item I', look down the left column on the matrix to find the row labelled 'Item D' and then travel across that row to the column labelled 'Item I'. The changeover time from 'Item D' to 'Item I' is 27 minutes. If we are manufacturing a set of items then one row and one column must be chosen of each of the items to be sequenced as well as one item from the start row and one item from the finish column. If we choose the collection of these items with the lowest total then we will have chosen the sequence with minimum Total Make-span. This matrix and how to construct it will be discussed further in *Section 6.3* and finding the best sequence in this matrix will be discussed further in *Chapter 5*.

3.6.5 - Combinations of Sequencing Techniques

In many cases there are 'Groups' that require sequencing by one technique with 'Sub-Groups' (inside these 'Groups') to be sequenced in another technique. These combinations of sequencing techniques can be coped with in an iterative manner, by examining each in turn as required. All of the production lines at *Pastoral Foods* exhibited combinations of standard sequences and trail and error calculated sequences.

3.7 - Grouping Similar Items

When we are manufacturing a diverse range of items then it is quite likely that these items will have sequence dependant set-ups. It is also natural and logical to want to manufacture similar items together instead of breaking them up. If we know we want to manufacture certain items together then there is no point in testing the consequences of manufacturing these items separately. This can be seen to be similar to a travelling sales person, who visits a client in the northern part of Auckland City, travels to central Wellington to visit another client, travels back to Auckland to visit another client in the Southern part of Auckland City and finally travels back to the northern part of Wellington to visit the final client in Porirua. If the salesman's travelling time is considered important and the exact dates for visiting the clients are not so important, then this path is obviously not sensible. A more logical approach would be to visit all the clients in Auckland and then travel to Wellington to visit all of the clients there. It is also better to find the best path around Auckland and Wellington cities. We must find the best path inside each city in light of where the sales person is going to, after all the clients in this city have been visited.

In terms of production scheduling the procedure is as follows

1. First define 'Groups' of items with minimal differences, i.e. products with small changeover times to be separated from items with large changeover times. This will be a judgement call and any experienced production supervisor will be able to distinguish the product list into at most 6 to 10 'Groups' in most factories
2. Define the average changeover times between the 'Groups' and assemble the matrix as described in *Section 6.3*.
3. Find the best sequence of 'Groups' that has the minimum Total Make-span.
4. Within each of the above, defined 'Groups', define 'Sub-Groups' of items with significant differences in changeover times.

5. Define the average changeover times between the 'Sub-Groups' and assemble the matrix as described in *Section 6.3*.
6. Find the best sequence of 'Sub-Groups' (within the sequence of 'Groups') that has the minimum Total Make-span.
7. If necessary repeat steps 4 to 6 in this procedure.

Note: It is important to minimise the number of 'Groups' and if appropriate split the 'Groups' into 'Sub-Groups' and then 'sub-sub-groups' if necessary. This is done to minimise the combinatorial problem as much as possible. If we have too few 'Groups' then we may run items together that are not really suitable and involve significant changeovers. If we have too many 'Groups' then we will still have a significant combinatorial problem to deal with.

Using this procedure the combinatorial problem can be reduced significantly. For example if we have 27 items, calculating these items as a full combinatorial problem, we would need to assess...

27! = 10 888 869 450 418 400 000 000 000 000 possible sequences.

Firstly we shall take those 27 items and divide them into 5 'Groups'. Then we shall take those 5 'Groups' and sub-divide each 'Group' into 4, 3, 4, 2 and 2 'Sub-Groups'. Assuming the sequence of these items within the 'Sub-Groups' does not affect the Total Make-span of the schedule or it can be assessed by a standard sequence, then we could reduce the number of calculations to...

5! + 4! * 3! * 4! * 2! * 2! = 13944 sequences.

This procedure has turned the very large, unwieldy requirements of the combinatorial problem into a small and easy set of calculations.

Grouping similar items can also reduce the solutions space for selecting the week to manufacture orders. If we require two orders that are due at about the same time and are similar in manufacturing requirements (i.e. the same 'Group') then there is no reason why we would want to split them up. We can reduce the number of orders we are dealing with by locking these orders together and treating them as the same order. This will reduce our

solution space significantly. For example if we have 60 orders to be manufactured then we have a solution space of...

$60! = 8.320987 * 10^{81}$ possible solutions.

Reducing this by 'Grouping' similar items may give us as little as seventeen (for example) 'Grouped' orders.

$17! = 3.55687 * 10^{14}$ possible sequences.

This is a significant reduction in the solution space and therefore could be very worthwhile. The problem with this process of is that the detail of an individual customer's on time delivery requirements or other such needs are lost. Because of this loss of detail we should ensure that there are significant gains to be made from 'Grouping' together similar items.

3.8 - Crew Rostering

Where companies own more than one line or more than one set of machines and they don't have the market requirements to make all of their lines work full time, then they may consider trying to multi-skill their workers to be capable of operating more than one production line. This will enable the company to become more flexible and more capable of responding to its market's requirements. This will mean that scheduling will not only have to sequence the production over each line but also work out how many hours each line will have to work and when. An example of this is where a manufacturing operation has five lines (for example) and only enough crews to be able to operate any two of them at any one time. This example can be easily seen in the form of a Gantt chart as in *Figure 2*. From the chart it can be seen that no more than two lines are operating at one time. Gantt Charts will be discussed in more detail in *Section 10.2*.

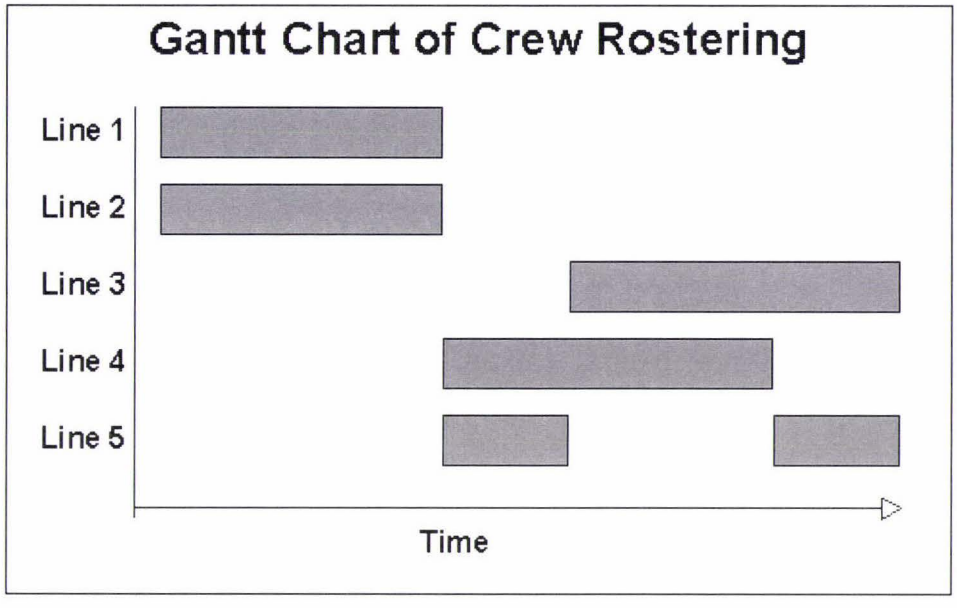


Figure 2 - Crew Rostering Gantt chart (Example)

There are also manufacturing operations where the number of people who are required to operate the lines is not the same or approximately the same across all products/lines. The way to approach this crew rostering problem (both types of problems mentioned above) is to treat them as an extension of the sequencing problem. The *Goldratt* [5] scheduling method (as discussed in *Section 4.1*) says to schedule the constraint first and then schedule the non-constraints. If we assume that the crews are the constraint, then we can attack the problem by assuming that the sequence we are manufacturing in is the sequence the crews are working on each order. We can schedule each order one at a time and place it in the first time slot where we have crews available and an appropriate manufacturing line to make it on. This way we are always using as much of the constraint as possible and the sequence of orders determines the effectiveness of the schedule by examining the Total Make-span of the constraint.

3.9 - Time Management Techniques

3.9.1 - Overview

How to manage time is a probably the single most significant aspect of a scheduling system. There are two basic alternatives to 'attack' time management. The first and most fundamental one is to treat time as a continuous line and the second technique is to use bucket scheduling. Both techniques have been investigated in this project.

3.9.2 - Continuous Time Line Scheduling

Continuous time line scheduling is simply taking each order to be manufactured and placing it on a time line that represents available capacity. This is to be done for each machine to be scheduled and availability of orders that depend on the use of other machines prior to manufacture must be taken into account. This is discussed further in *Chapter 4*. This philosophy can take into account of all possible scenarios and can attempt to see what the possibilities and consequences are for manufacturing in any sequence. The problem with this technique is that it still has to overcome the full combinatorial problem. Any sequence is possible and so it could search through a lot of sequences that are irrelevant and time wasting.

3.9.3 - Bucket Scheduling

Bucket scheduling is the use of discrete time lots to organise production into blocks that are manufactured together. The procedure for bucket scheduling is as follows...

1. Place the orders along the time line in a sequence, (e.g. Earliest Due Date sequence).
2. Divide the time line into discrete time lots or buckets. For example time lots may be a day or a week or half a week depending on what is best for the manufacturing / marketing systems requirements.
3. Sort the orders placed in the first scheduling bucket into an optimal sequence.
4. Check to see that all the orders start in the scheduling bucket being investigated. (If a large order is at the end of the scheduling bucket in the first sequence and the sequence is rearranged, a smaller order at the end may have to be started in the next scheduling bucket and therefore should be included as part of the next scheduling bucket's sequence).
5. If the orders in the current scheduling bucket have changed in step 4, the sequence may need to be re-optimised.
6. Repeat steps 4 and 5 until the orders in the scheduling bucket stay the same.
7. Repeat steps 3 to 6 for each successive required scheduling bucket with the remaining orders.

The advantage of bucket scheduling over continuous time line is that if we are searching for the optimal solution then we have reduced the combinatorial problem significantly. If we use an example of 60 orders, a continuous time line will give...

$60! = 8.320987 * 10^{81}$ possible sequences.

If these 60 orders fit into 6 scheduling buckets and we assume that each scheduling bucket can fit exactly 10 orders and we assume that the 'in bin' sequence does not need to be re-evaluated for each and every possible sequence then the solution space will be as follows...

$^{60}C_{10} * {}^{50}C_{10} * {}^{40}C_{10} * {}^{30}C_{10} * {}^{20}C_{10} * {}^{10}C_{10} = 3.64415 * 10^{42}$ possible solutions.

Where:

$^{n}C_{r}$ = n Combination r

= all possible combinations of r objects selected from a population of n objects.

$= n! / ((n - r)! * r!)$

This is a substantial gain relative to the required calculation time. Alternatively if we assume that the sequence does need to be re-evaluated for each and every possible sequence then the solution space will be as follows...

$^{60}P_{10} * {}^{50}P_{10} * {}^{40}P_{10} * {}^{30}P_{10} * {}^{20}P_{10} * {}^{10}P_{10} = 8.32099 * 10^{81}$ possible solutions.

Where:

$^{n}P_{r}$ = n Permutation r

= all possible combinations and sequences of r objects selected from n possible objects.

$= n! / (n - r)!$

$= {}^{n}C_{r} * n!$

In this case there does not appear to be any reduction in solution space from bucket scheduling. So bucket scheduling should be looked at on a case-by-case basis.

There may be cases where, the comparison of bucket scheduling to continuous time line is favourable to bucket scheduling, but there is concern over the lack of details available in bucket scheduling in terms of the actual due dates. This may cause an increase in lead-times and a decrease in responsiveness to required changes. In this case a smaller scheduling bucket size may be required. The smaller the scheduling bucket's size the larger the solution space and the more calculations will be required, but it may significantly improve the system's responsiveness. The scheduling bucket's size could be defined according to 'insignificant' differences in due date though this may become too expensive in computational time if the scheduling buckets become too small. If the manufacturing system's scheduling buckets sizing is best suited to whole week scheduling buckets (because of light to dark colour - type of sequencing over a whole week), but a better response time is required by marketing, then it may be beneficial to move to half week scheduling buckets, with the allowance that the bucket scheduling system should take into account of the changeover times in between the buckets in the same week. With this we will gain the benefits of better responsiveness, together with some of the benefits of reduced solution space from the use of bucket scheduling.

3.10 - Scheduling Systems with MRP-II

3.10.1 - Overview

An MRP-II system will usually have an automatic scheduling system built into it. Often these are infinite capacity schedulers, which according to *Goldratt* in *The Haystack Syndrome* [5] are not appropriate for the task of scheduling in the majority if organisations. Infinite capacity schedulers, if they work, at best will under utilise the constraint and therefore not generate a schedule that maximises the company's profitability. MRP-II systems do however have systems that take care of a lot of the fundamental information that is required for finite capacity scheduling systems.

To help the scheduling system the MRP-II system has to take a list of customer orders and/or forecasted requirements and on hand stock quantities (from live data), and translate them into a list of required production orders as well as material requirements.

3.10.2 - Master Production Schedule Program

A Master Production Schedule will contain a list of finished goods requirements for production. From this the scheduling system will need to execute the Materials Requirements Planning (MRP) program that will explode through the Bill of Materials (BOM) to create a listing of the required production.

There are many variations on terminology used in companies, in this report the APICS (American Production Inventory Control Society) standard terms shall be used.

The standard system for analysing requirements is MPS. The MPS finished goods requirements list is made up by taking customer orders and forecasts (from the customer), and comparing them to the stock on hand. This enables MPS to generate 'Planned Orders'. Planned Orders are MPS only generated data objects that sit in the MRP-II system advising the scheduling office and purchasing office that there are requirements for particular items on a particular date. The MPS procedure will erase old Planned Orders and generate new Planned Orders each time the program is run on the system. The scheduler can look at the Planned Orders for production and decide whether or not to manufacture them. If the scheduler decides to manufacture a particular Planned Order then he/she will turn the Planned Order into a Firm Planned Order (FPO). A Firm Planned Order is an order that the MPS system will take into account when it generates the list of Planned Orders, but will not change, create or delete them. The Firm Planned Order versus Planned Order arrangement is done so that some stability can be bought to the list of requirements, rather than a continuously changing list of requirements with an assortment of unwelcome surprises and new orders. If the MRP-II system were allowed to change, create or delete Firm Planned Orders then there would be chaos with the planning office trying to balance machine loadings and the purchasing office trying to arrange for on time delivery of raw materials. When the time is right to manufacture a Firm Planned Order, the production planner will run a program that will convert the FPO into a 'Shop Order' (sometimes called a 'Works Order') for manufacture. A Shop Order will contain manufacturing instructions for the item of the original Firm Planned Order. This system can be seen in the procedure diagram in *Figure 3*.

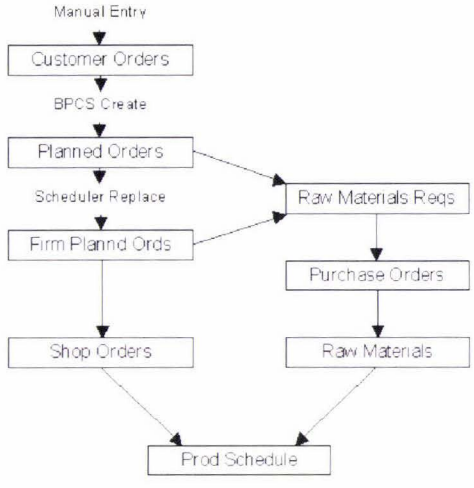


Figure 3 - Master Production Schedule Procedure

The system of automatically generated Planned Orders, manually turned into Firm Planned Orders and then into Shop Orders is good from the point of view of control over manufacturing. However this is cumbersome and unnecessarily complex from the point of view of interfacing a computerised scheduling system with the MRP-II system. It is better to miss out the Planned Orders and Firm Planned Orders step and go straight to the creation of Shop Orders from customer orders and/or forecasts. Planned Orders will be generated by the MRP-II system anyway and this can still be used to flag requirements for purchasing, but production scheduling should have no need for them. This has many advantages including the ability to have the independent planning system determine if parts of forecasts are to be scheduled for manufacture. This is preferable to interfering with the MRP-II Planned Order system, which may have effects on other functions in the system and the company that use Planned Orders.

The scheduling system developed in this project will manipulate the dates of start of manufacture (also known as 'Release Dates') of the Firm Planned Orders and Shop Orders. Most information required for the scheduling systems is stored in the MRP-II system. Some information that may be required and may not be in the MRP-II system include...

- List of standard items with 'Groups' and 'Sub-Groups' (similar item 'Groupings').
- Hours available on machines.
- Matrices of changeover times.

For the scheduling system to work properly it is necessary to have all the information, ready available and always correct.

3.11 - Scheduling Systems without MRP-II

To create a scheduling system in an environment without an MRP-II system will require a great deal more work and extra systems to be built. These could include...

- List of current unfilled orders.
- List of standard items with machines, production rates, 'Groups' and 'Sub-Groups' etc.
- Matrices of changeover times.
- Bill of Materials (BOM).
- List of lines and their capacities.
- Calendar of hours available on machines.

The list of standard items, list of lines and their capacities and calendar of hours available on machines can be solved by using standard databases in *Microsoft Access* or any other database. Matrices of changeover times are discussed further in *Section 6.3*. Bills of Materials are a standard that are very common in most companies that need them, though they are beyond the scope of this project they are discussed in *Chapter 8*.

Scheduling systems require up to date information and in the absence of an MRP-II system there is a need to find a way to keep information up to date. For a busy production planner, the act of keeping the list of current orders up to date, can be very time consuming. A far more time effective and logical way of maintaining the list of current orders is to use an integrated system over the whole company. The people who receive the orders from the customers need to keep track of what orders they have received and what orders are still outstanding. This information could be collected into a central database that can have an interface designed to suit the people using it. This database can also be used for collecting and analysing sales and manufacturing lead-time information. The people who are to dispatch product may be able to use the database to tell them where to dispatch product to and which customers have the highest priority and should receive their product first. This integrated system is relatively easy to set up in the modern world where flexible computer networks are commonplace in businesses.

Chapter 4 - Multistage Scheduling Techniques

4.1 - Overview

There are many methods of scheduling multistage operations. This project has focused on constraint theory, especially the *Goldratt* [5] philosophy.

4.2 - Forecast Myopic Dispatch Method

Morton and Pentico [1] gives a discussion of Forecast Myopic Dispatch, which is an older method of scheduling manufacturing facilities that does not belong directly to the 'Theory of Constraints' as proposed by *Goldratt* [5]. However it does have relevance to the *OPT / Goldratt* Scheduling Method discussed in the *Next Section*. Forecast Myopic Dispatch tries to define a priority list of orders for each machine in order to meet all customer orders, though it does not try to optimise the production schedule to minimise down time. According to *Morton and Pentico* [1] the algorithm for Forecast Myopic Dispatch is described in the following...

1. Take the due date of each order and use this as the due date of the final operation on each order.
2. The total processing time on all successive machines is calculated for each order and some initial estimate of the queuing time throughout the plant is added to this. This gives an estimate of the manufacturing lead-time which is subtracted from final due date to give an estimate of the required start date and time for the first operation on each and every order. The initial estimate of the manufacturing lead-time can be done by any one of a variety of methods including multiplying the processing time on all machines by a scalar (some estimates give 3 to 5 as a starting for this scalar).
3. Each order's first operation is scheduled as early as possible (taking account of other order's processing on that machine) and is sequenced in the priority given by the operation due date and time in step 2.
4. For each order the next most urgent operation (given by step 2) is scheduled as early as possible and this is repeated for all subsequent operations.
5. If this procedure does not give a good schedule first up then we can try using another estimate of the total manufacturing lead-time. Alternatively another method for estimating the total manufacturing lead-time, can be to make an initial run with a 'rough' guess at the overall manufacturing lead-times (using a scalar) and then use the generated schedule's manufacturing lead-times for each order, as the new estimates for use in the second run of the procedure. This can be repeated again if necessary.

This process will not guarantee to make good use of the constraint (it treats all machines with the same importance), but it can be good for processes with market constraints or no consistent constraint.

4.3 - OPT / Goldratt Scheduling Method

According to *Morton and Pentico* [1] *Goldratt's* original involvement in scheduling was to write a scheduling program called *Optimised Production Technology (OPT)*. *OPT* was a very successful scheduling program when it was created in the late 1970's and it is still marketed successfully today. The basic principle used by *OPT* is to make the 'best use' of the constraints of the process.

According to *Morton and Pentico* [1] – 'Many successful scheduling packages use a procedure that is similar to that used by OPT' which *they* [1] describe as follows...

1. Identify the Constraint. This can be done by several methods, the most simple and probably most effective is to analyse the processing time on each machine in the factory, which can be done using current orders, historical data or forecasted demand.
2. Schedule the Bottleneck Resource. The constraint should be scheduled as if it is a stand-alone device. Estimates of the due dates (less a shipping buffer) of orders are given by the actual due date less the estimated lead-time in the factory from the bottleneck to the end of the process (the so-called 'Red Lanes'). The earliest date an item can be manufactured on the constraint is given by an estimate of the lead-time of the 'yet to be completed' operations up to the constraint (this estimate should be a low one to maximise the flexibility on the constraint).
3. Schedule Up To the Constraint. Using the dates and times of manufacturing on the constraint (less a time buffer) as the due date, the schedule should be created for all orders up to the constraint. The Forecast Myopic Dispatch method is a good method to use here and has been used by *OPT*.
4. Re-Schedule the Constraint. Using the dates and times that the orders become available from the preceding processes, re-schedule the constraint. The constraint should be scheduled to minimise down time.
5. Schedule After the Constraint. Scheduling the remainder of the process, after the constraint can also be done by the Forecast Myopic Dispatch method.

Chapter 5 - Techniques in Searching for Solutions

5.1 - Overview

5.1.1 - The Size of the Problem

In the majority of scheduling problems the concept of automatically generating the best solution is an ideal that is difficult to achieve. The number of possible solutions for practical scheduling problems can be enormous due to the factorial problem. If we are to be sure to find the absolute best solution we must search through every single possible schedule and evaluate each one for its advantages and disadvantages in turn. This is usually done by what are called 'exact techniques' like Integer Programming. A typical practical scheduling problem may have so many possible solutions that it will take hundreds of thousands of years to properly evaluate them all, and even then there is considerable debate as to the form of the objective function. This obviously means that we can realistically only evaluate a very small part of the required solutions space and so techniques like Full Integer Programming either have to be simplified so much that the solutions they come up with are impractical, or they will take too long to calculate. Because we can only search a very small part of the possible solution space it is imperative that we use the very best search techniques available to find the best solutions we can in the limited time we have.

Specific 'scheduling heuristics' were not investigated in the project because of the tight time frame. Search methods were chosen over scheduling heuristics because scheduling heuristics were not seen as robust enough to cope with the large amount changes in design of production facilities at Pastoral Foods. In addition Pastoral Foods requested that the scheduling system should be able to cope with the addition of new production lines, which would have required new heuristics to be developed when they arose.

5.1.2 - Techniques Available

There are many types of search techniques available for computer algorithms from the field of operations research and many more will arise in the future. Some of these include...

- Beam Search
- Branch and Bound
- Complete Enumeration
- Dynamic Programming
- Genetic Algorithms
- Integer Programming
- Lagrangian Relaxation
- Myopic Search Techniques
- Partial Dynamic Programming
- Random Pair-Wise Interchange
- Simulated Annealing
- Tabu Search

Complete Enumeration, Pair-Wise Interchange and Branch and Bound are the three simplest of all search techniques available and are more often than not a basis for the other techniques available in the literature. When used in conjunction with other techniques, they can be used to gauge the quality and success of improvements made by the other techniques. Due to the limited time available not all of the search techniques could be investigated in this project. Upon advise from operations research people at Massey University the simplest technique that yields best results would be Tabu Search.

5.1.3 - Effects of Sequence Dependant Set-Ups

Sequence dependant set-ups are a significant cause of problems in production scheduling. Were it not for sequence dependency the best schedules possible on single stage machines would be very similar to the Earliest Due Date sequence. These schedules are the ones that minimise inventory expense and minimise the risks of missing orders.

Using plant models the effects of sequence dependant set-ups were trialed and estimated along with trials of strategies to overcome them. The procedure used in this project can be found in *Appendix 3.1*.

5.1.4 - Visibility Problems

The solutions spaces for scheduling problems are in virtually all cases multi dimensional arenas that are simply enormous and extraordinarily complex. If we could draw a results map or contour map of the solution space we would have a very good tool to help us find better solutions to our scheduling problems. This is not feasible because most scheduling problems will have hundreds of dimensions and are impossible to display or visualise as a map. Because we can't easily visualise a problem it is extremely difficult for the human brain to interpret, or see patterns in the results of some random assortments of trialed solutions. This means we cannot use the pattern recognition ability of the human brain to see where there are likely to be better solutions. These visibility problems are accentuated by the fact that there are often regions where the result maps change very rapidly and are erratic or undulating when only small changes are made to the input solution. The erratic nature of the solutions spaces has the effect that it is also difficult for computer software programs to find good solutions that are not local optima. Tackling this problem is discussed later in *Sections 5.2 to 5.7*.

There are visual techniques available to improve schedules but these usually require a detailed knowledge of the scheduling and manufacturing systems. Some of these systems are discussed in *Chapter 10*.

5.1.5 - Measuring Results

If we want to compare one solution to another we must have an analytical method or procedure for comparison. In the end it would be much simpler for a computer program to assess if this comparison method could boil down to a single number. Accountants would like to express this number in terms of actual costs. It would be of great benefit if it were possible to exactly calculate the actual costs of a schedule, however it is not possible to give accurate information on how much costs will be, as many causes of costs are ambiguous. It is also possible that the least cost solution is not optimal for the company, as the revenue potential for the company may be less for

this solution versus another, which carries higher cost. It is more analytical and beneficial for scheduling to use an arbitrary index that takes into account all factors that are involved and are a good reflection of what we require out of a schedule. *Numetrix* uses a system that is similar to this in their *Schedulex* product. *Goldratt* in *The Haystack Syndrome* [5] argues for use of exact measures that consider Throughput, Inventory and Operating Expense under his definitions, but According to *Noreen, Smith and Mackay* [8] these measures are not commonly used.

With an internal constraint the Total Make-span on the constraint is the best performance measure to tell us the cost/benefit (to manufacturing only) of any particular schedule. Total make span is the total amount of time consumed in the schedule including any down time that is planned. If we analyse this as the main factor in our cost/benefit equations then we will be thoroughly testing the schedules effective use of the constraint. In addition to this we must also take into account of penalties for any orders that we are planning to deliver late. The penalty for this should be quite significant, relative to down time if the company values the customer's business. A detailed review of measuring results can be found in *Section 3.4*.

5.2 - Complete Enumeration

Complete Enumeration is a technique of searching for the very best solution by investigating and evaluating all possible solutions. The advantages of this technique are that, if we give it appropriate measuring criteria, it will always find the best solution. The obvious disadvantages are that it will take far too long to complete and can only be used on very, very small scheduling problems that are extremely rare and can probably be relatively easily solved manually anyway. A procedure flow chart for a Complete Enumeration search algorithm can be found in *Figure 4*. This algorithm simply cycles through each order trying each one in each sequence place.

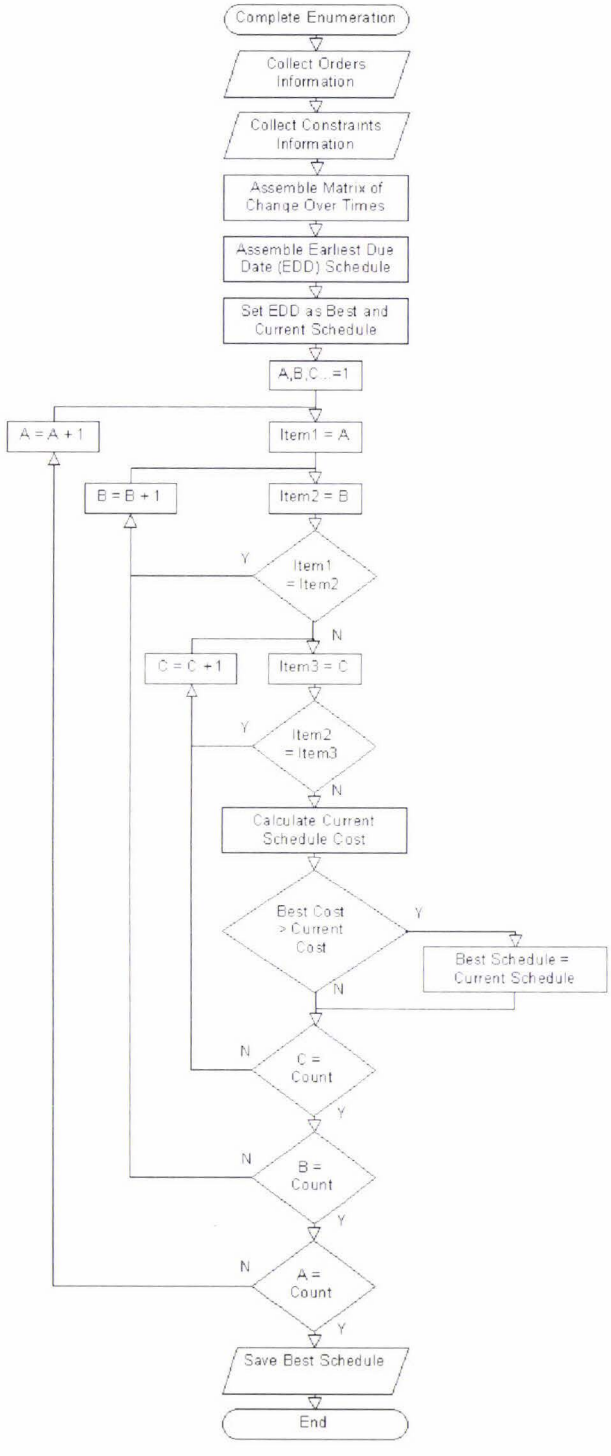


Figure 4 - Procedure Flow Chart - Complete Enumeration

5.3 - Branch and Bound

Branch and Bound is a search technique that systematically hunts thoroughly through a localised area of the solution space and finds the best solution in that local area. This technique is based on the Complete Enumeration but confines itself to local areas, rather than covering the whole solution. *Figure 5* shows a Branch and Bound map of some areas of the solution space for a problem with five orders to be sequenced (A, B, C, D, E.).

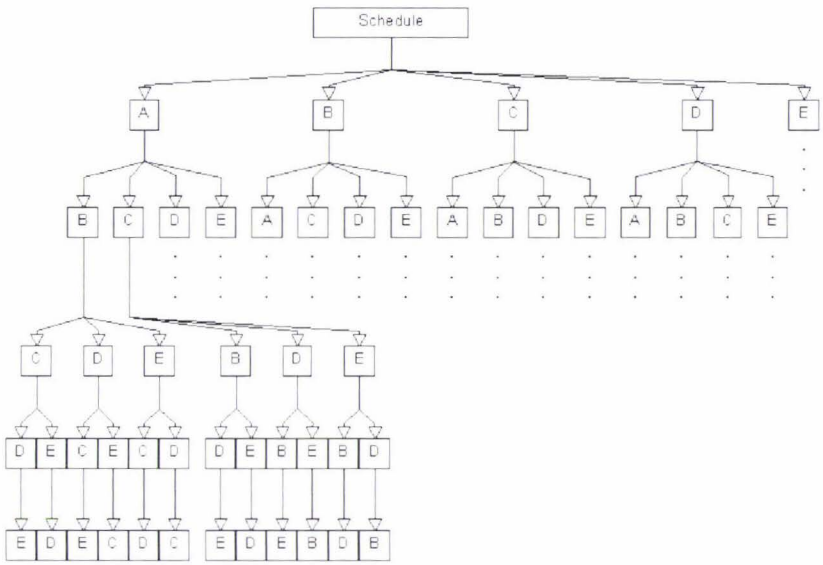


Figure 5 - Procedure Flow Chart Branch and Bound Map

Each line from the top to the bottom of the map is a possible solution and the sequence in which the orders descend on the path gives the sequence of manufacture. The first part of each schedule is systematically generated by the Complete Enumeration technique. To test the effectiveness of the whole schedule the Earliest Due Date method (or some other method that is myopic or greedy) sequences the remainder of the orders.

Whilst the Complete Enumeration technique looks over part of the sequence the results of each schedule are evaluated. As each part of the schedule is evaluated a decision is made as to which part of the schedule is best to continue investigating. The research in this project only considered the evaluation of one path from each point. But the literature on this topic suggests that more technical approaches where several paths of good part schedule results be investigated. As more of the map is covered the areas where results are less promising can be

pruned and paths where the results are more acceptable can be investigated further. A procedure flow chart for a Branch and Bound search algorithm can be seen in *Figure 6*.

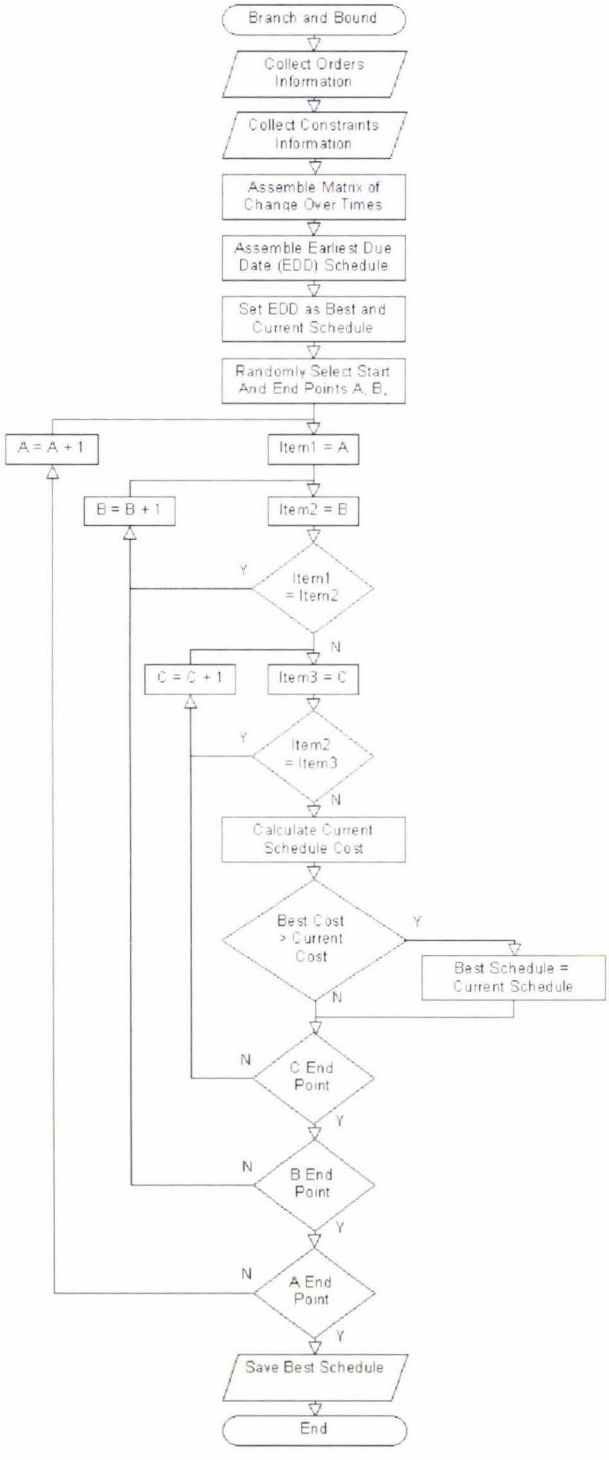


Figure 6 - Procedure Flow Chart - Branch and Bound

A typical result graph against time of the Branch and Bound search procedure investigated in this project can be seen in *Figure 7*.

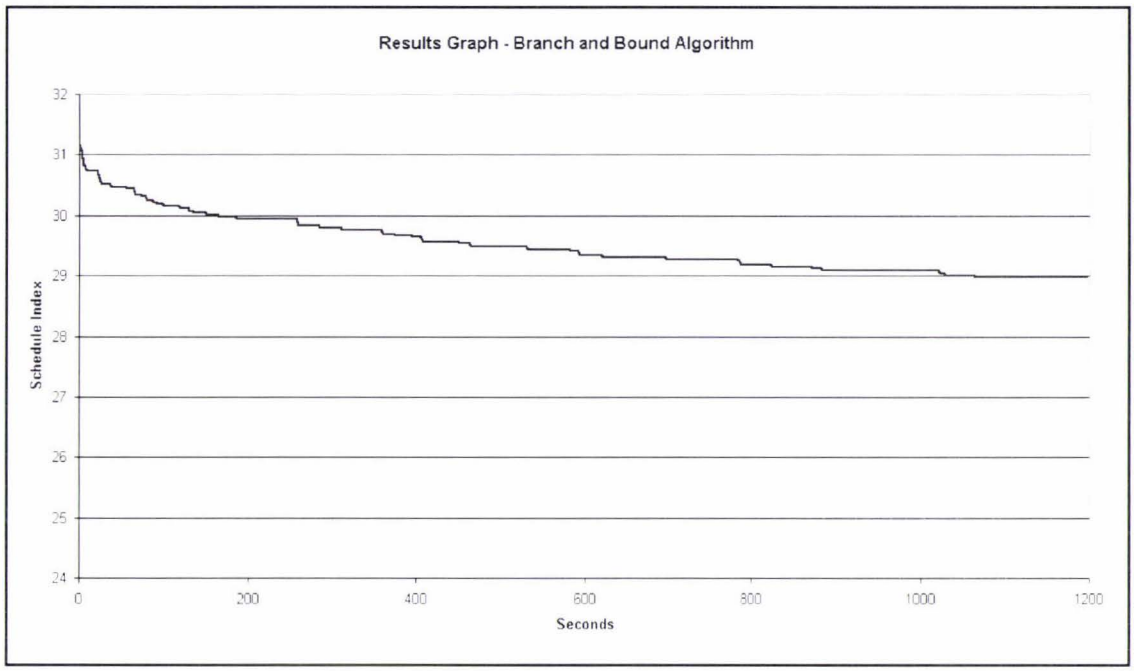


Figure 7 - Graph of Results - Branch and Bound

An example of the results of a Branch and Bound search procedure as applied to the *Pastoral Foods* SOS Production Line can be seen in *Appendix 3.3.1*.

5.4 - Random Pair-Wise Interchange

Random Pair-Wise Interchange is the most basic of all random search procedures. It is essentially an entirely random search that uses only the most primitive search method to find to better solutions. To find better solutions the conventional Pair-Wise Interchange method starts at some good solution (defined by an algorithm, for example Earliest Due Date sequence) and investigates the benefits of moves at random. If the search finds a better solution it will accept it and begin investigating new moves around the new accepted schedule. All moves that are not an improvement are not accepted and the search continues from the same point. It has a fundamental problem in that it will always become stuck in local optima. Unless the search can be made to climb hills there is always the very likely risk that it will only ever find very sub-optimal solutions that are little better than the search's starting point. It is possible to make the search go beyond local optima, by simply allowing it to accept solutions that are less than the current solution. This is still a very primitive

system that will waste a lot of effort in investigating many solutions and is likely to wander off in some fruitless direction (in our multi-dimensional problem) and never find a solution that is better than the start point. A better search method in the same vain as Pair-Wise Interchange, is to take a random selection of starting points and then look for local optima around each starting point. A procedure flow chart for a Pair-Wise Interchange search algorithm can be found in *Figure 8*.

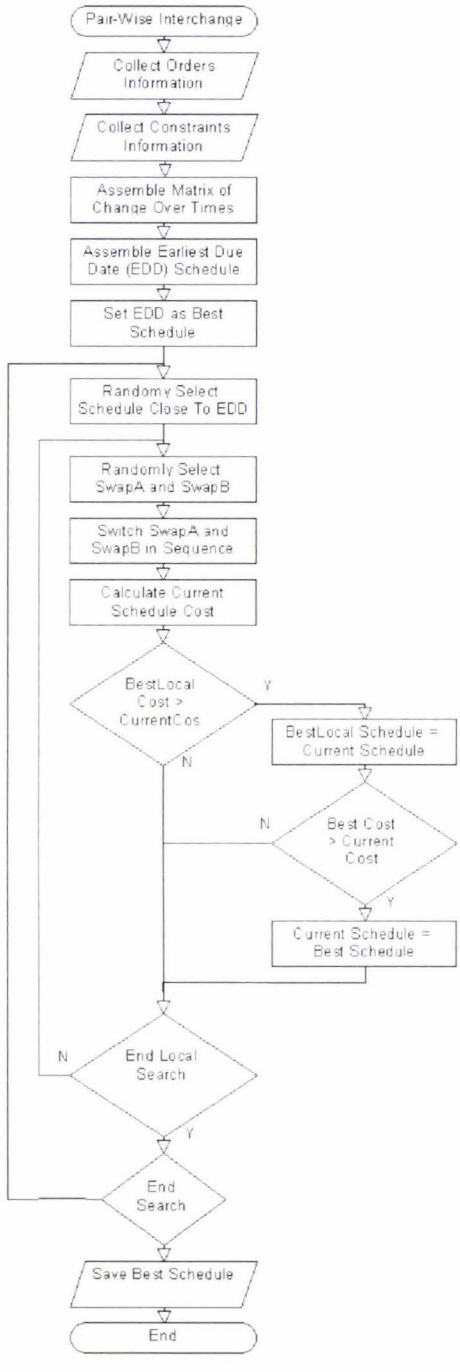


Figure 8 - Procedure Flow Chart - Random Pair-Wise Interchange

The results of the experiments conducted in this project reveal that little or virtually no improvements can be made to Bucket Schedules with 'In Bin' optimisations using Random Pair-wise Interchange. This is due to the fact that the search is more undulating around each search point. The local area around each search point has already found local optima and this

search technique finds it is difficult to climb out of this local area. A typical result graph against time of the Pair-Wise Interchange procedure investigated in this project can be seen in *Figure 9*.

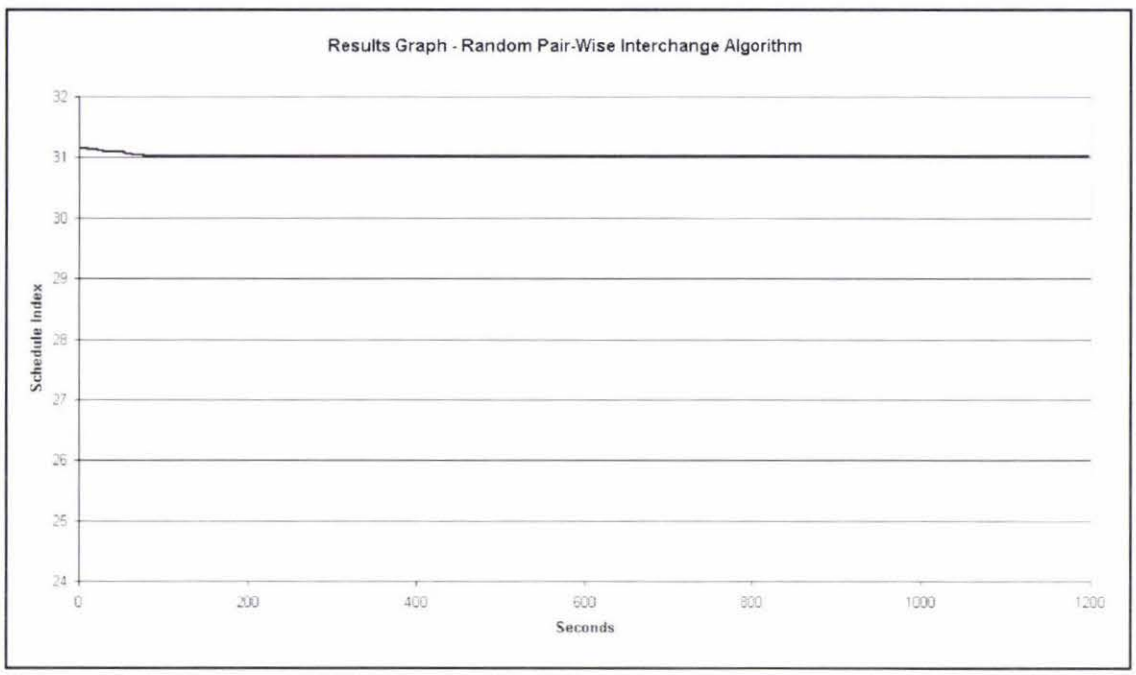


Figure 9 - Graph of Results - Pair-Wise Interchange

The results of this search technique do not show significant improvement over the starting Earliest Due Date schedule. This is as expected as the search gets stuck in local optima. An example of the results of a Pair-Wise Interchange search as applied to the *Pastoral Foods* SOS Production Line can be seen in *Appendix 3.3.2*.

5.5 - Tabu Search

The search algorithms discussed so far have all been simple techniques that are very myopic in their approach. That is, they can only see as far as the next order or next few orders and do not have any memory of the areas of the solution. Tabu search is one of the so-called 'Artificial Intelligence' techniques that has memory capabilities and can learn from its previous results. A general definition of Tabu Search according to *Glover and Laguna* [9] is...

" ... a higher level heuristic procedure for solving optimisation problems, designed to guide other methods (or their component processes) to escape the trap of local optimality."

The 'other method' used in this project was a neighbourhood search, (to be guided by Tabu Search). Neighbourhood search involves a search of the neighbourhood of the current solution. The neighbourhood is all of the solutions within one move (by pair-wise interchange in this case) of the current solution.

Tabu Search can remember the solutions covered previously and based on its interpretations of them decide whether or not to allow further investigation of a proposed solution. The basic format of Tabu Search is a list of solutions or parts of solutions that have been investigated before and are not good enough to be considered further. Hence these solutions are considered 'taboo' (Tabu is the American spelling of Taboo). The Tabu List helps to ensure that the algorithm is always covering new ground and doesn't get into a repetitive and unproductive cycle.

Tabu Search can have two functional types of memory, explicit and implicit. Explicit memory records the whole solution exactly as an entire solution. Implicit memory records characteristics of the solution. Implicit memory can be used to record the common characteristics amongst the better and lesser solutions found so far. This so more solutions involving these can be investigated further or avoided.

Tabu Search can be used for very large complicated problems and the literature shows it to be relatively successful at solving these. These problems require very clever solutions to make the best of their situation. This will require both explicit and implicit memory types to be used. This project has made significant investigations into Tabu Search involving implicit memory, without great success. It was found to be difficult to fine-tune the Tabu Search algorithm in its complicated forms.

According to *Glover and Laguna* [2] Tabu Search has some simpler forms that are useful for looking at small to medium size problems. The technique found to be most successful in this project was one that only involved implicit memory. This technique took each schedule as it was created assessed the solution's entire neighbourhood by Random Pair-wise interchange and choose the best one that was not on the Tabu List. The Tabu List consists of all the entire solutions that have been covered previously in the search.

The problems encountered in this project would have been too large to be solved by this simpler Tabu Search algorithm were it not for the use of bucket scheduling and 'Grouping' of similar items to the reduce the explorable solution space. Bucket scheduling and 'Grouping' also helps the algorithm to cover a great deal of the solution space very quickly.

A procedure flow chart for this simple Tabu Search algorithm can be found in *Figure 10*.

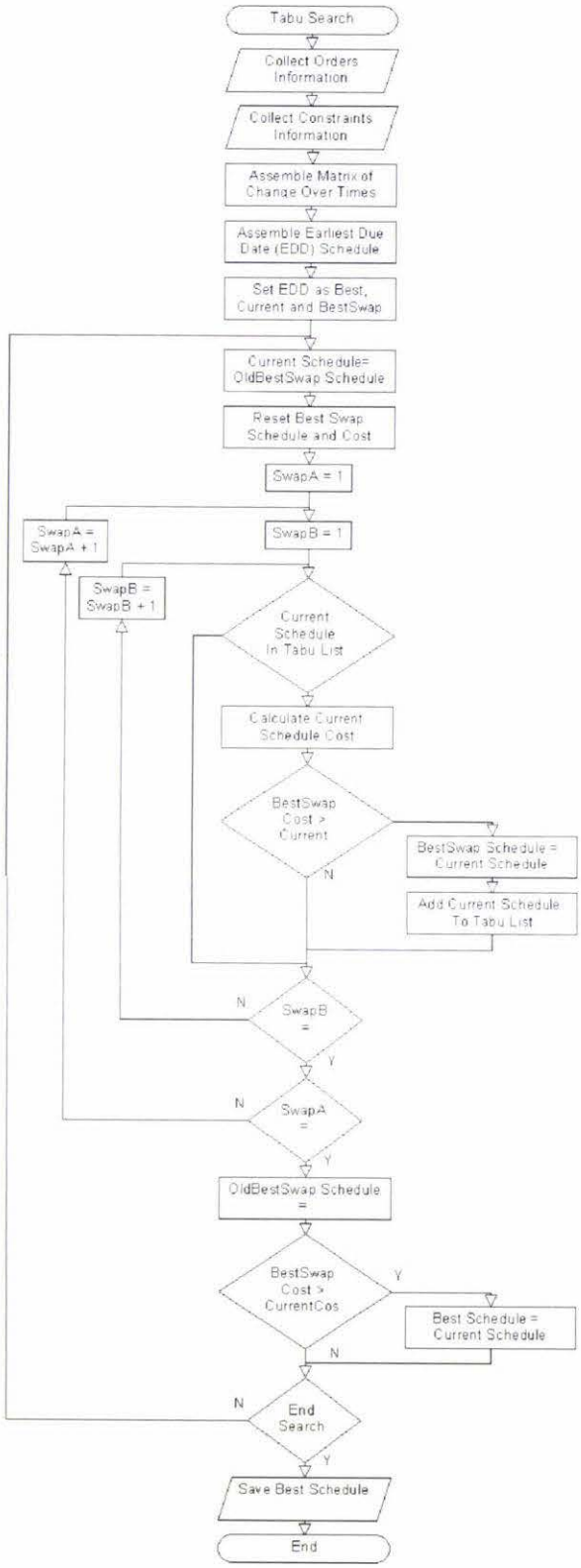


Figure 10 - Procedure Flow Chart - Tabu Search

A typical result graph against time of the Tabu Search procedure investigated in this project can be seen in *Figure 11*.

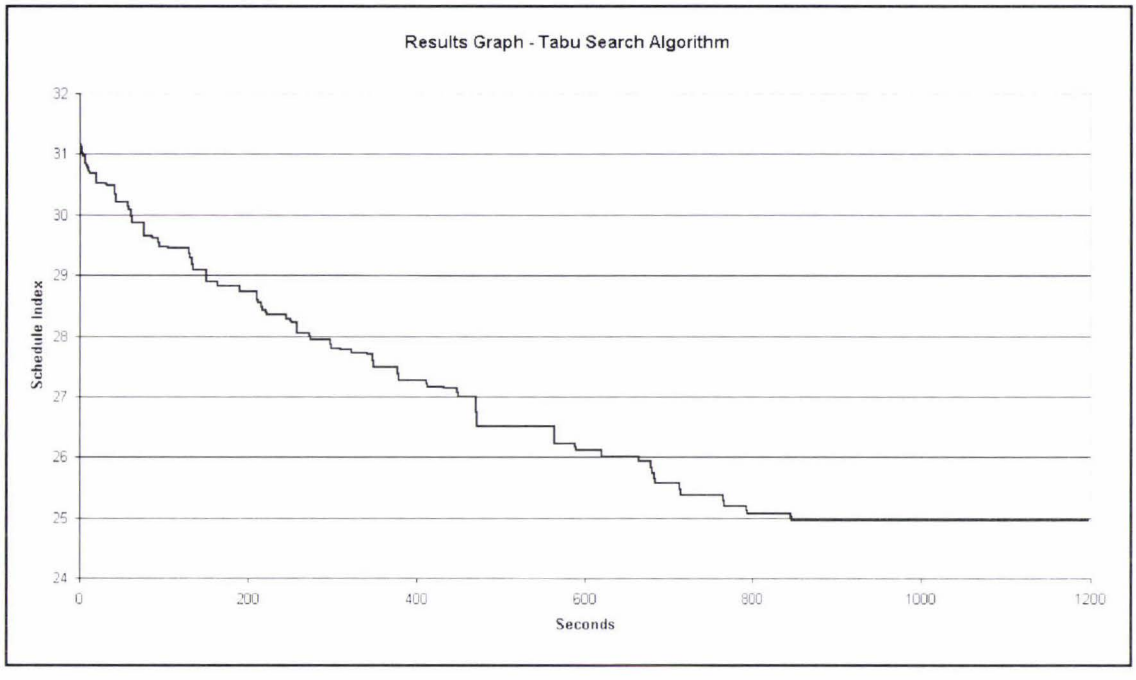


Figure 11 - Graph of Results - Tabu Search

Tabu Search gave consistently good results, though some of the other useable techniques discussed previously studied in this project gave as good or better results in some trials; this was the best overall technique for reliability and consistency of good results. The solutions obtained by this technique were usually not improved further by the algorithm after it had been searching for approximately 30 minutes. Looking at the resulting schedules I cannot see any further improvements to the schedules or see any better schedules. From this I conclude that the search has either reached the optimal solution or something very close. For some schedules this technique would take several of hours to reach a stable and 'probably' optimal solution. Since the search algorithm cannot find any better solutions than this the accountability for the quality of the solution it has found lies in the criteria set in objective function. The objective functions used in this project tend to push the schedules created close to the Due Date Sequence (for the reason of protecting the company from missing due dates) and so it is perhaps not surprising that the search technique finds the optimal solution so easily.

An example of the results of a Tabu Search algorithm as applied to the *Pastoral Foods* SOS Production Line can be seen in *Appendix 3.3.3*.

5.6 - Individual Group Enumeration

As discussed earlier there are many benefits to 'Grouping' together similar items because we know we want to run them together to minimise changeover times. The Pareto principal says that 80% of the products will cause 5% of the down time and 5% of the products will cause 80% of the down time. The significant few items that contribute to down time are usually small in quantity and so take up little of the total production time but contribute significantly to the production down time through changeovers. These items could be described as 'oddball' products.

Whilst these few products may be completely different to the remainder of the products they will usually require significant effort to change to and from the 'run of the mill' products. There are significant benefits to be gained from running these small sets of 'oddball' products together, as they will likely save a number of significant changeovers. Even if there are wide variations within the set of 'oddball' products there can still be benefits gained from treating them separately from the 'run of the mill' products because we can have the opportunity to force them to be run separately or together which ever suits. If we give special attention to these 'oddball' items then we can make significant gains independently from the gains to be made by altering the rest of the schedule. If there are few enough of these 'oddball' items and they make up little enough of the schedule, then we may be able to use Complete Enumeration for these items independently. This would ensure that we are extracting the maximum potential from the scheduling of these items. This process of only operating on the 'oddball' is done whilst taking into account the requirements of the 'run of the mill' items in terms of production capacity, so that they are made on time and in full.

There will possibly be a great deal of potential slack available to move these 'oddball' items around the schedule. If two good schedules have approximately equal planned down time and both schedules meet all orders, then the schedule that sequences the 'oddball' products latest should be chosen. This will give more room for movement of the remainder of items that are unscheduled and therefore more down time minimisation could potentially be achieved when they are scheduled.

5.7 - Combination Individual Group Enumeration and Tabu Search

A combination of techniques can be used to solve different parts of the scheduling problem and the benefits of one technique can be used to solve parts that suit it and others can be used where their greater potential suits. The combination of techniques that was chosen in this project involves Individual Group Complete Enumeration on the 'oddball' items and Tabu Search on the 'run of the mill' items. This was the only combination technique tested and this gave the better results than any of the single techniques tested.

A typical result graph against time of the Combination Individual Group Enumeration and Tabu Search procedure investigated in this project can be seen in *Figure 12*.

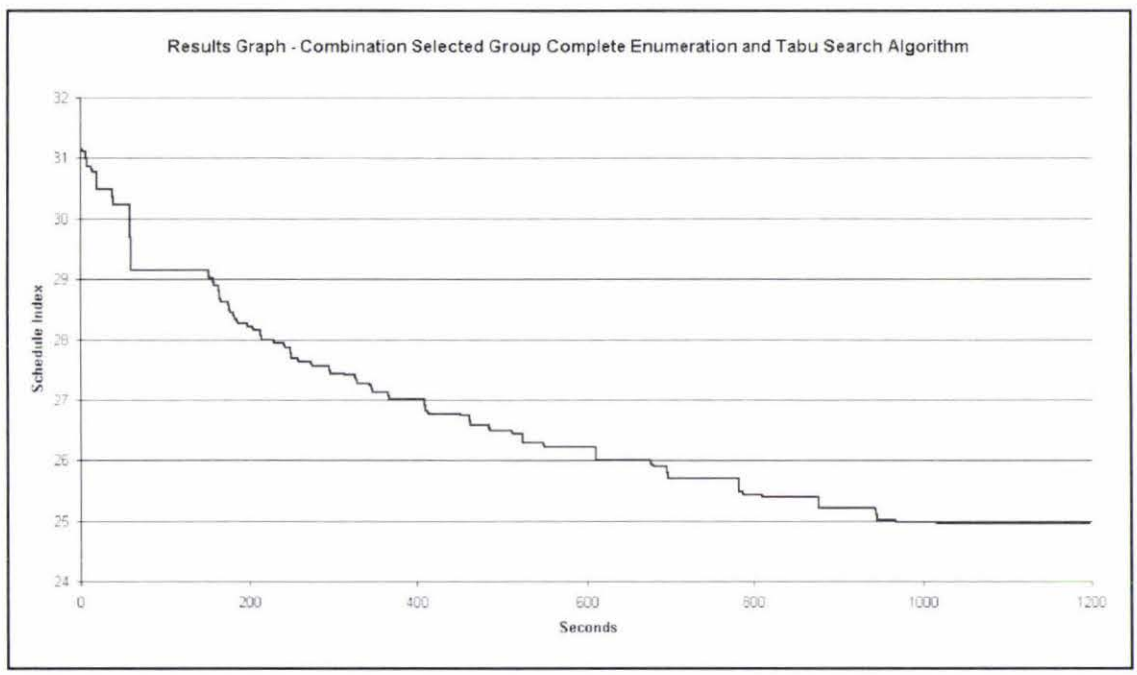


Figure 12 - Graph of Results - Individual Group Enumeration and Tabu Search

An example of the results of a Combination Individual Group Enumeration and Tabu Search algorithm as applied to the *Pastoral Foods* SOS Production Line can be seen in *Appendix 3.3.4*. The results that this algorithm produces are very similar to those produced by the Tabu Search (alone) algorithm. Sometimes this algorithm will find the optimal solution faster than Tabu Search alone after 30 minutes (though this is not always the case). The results of this search were consistently better after only 10 minutes when compared to the Tabu Search (alone) algorithm. This search technique was preferred to Tabu Search (alone) and was

selected for use in this project, because it consistently gave good results in quick time. Often the scheduler will want a solution in a very short time. After the schedule has been adjusted many times (due to disruptions, changes or infeasibility of the schedules produced) this may be understandable and so the option of a 'quick' schedule optimise should be made available.

Chapter 6 - Data Collection Methods

6.1 - Overview

Computer scheduling systems manipulate large amounts of data input. This data must be collected and maintained as accurately as possible. A lot of required information may already be available and maintained in the company. Much of the information may not be kept or at least not kept in a useful form and this data must be collected and arranged so that it is useful. Two major sets of data required are...

1. Average Production Rates.
2. Average Changeover Times.

Both of these sets of data can be very large and highly changeable. If a company has one hundred items that it manufactures as standard then there 100 average production rates that need to be accurately guessed and (100 x 100 =) 10,000 changeover times that need to be guessed. This information may be set up once, but it will be asking a lot of people to get them to maintain it. The people who will have enough knowledge of the process and experience, as well as common sense to be able to figure this data out, are also likely to be too busy to consider it important enough for their time. This is especially true as 100 new pieces of data or more will need to be guessed every time an item is added to the product range. Grouping similar items together can reduce this, but it will still leave a significant amount of data to be collected. This would be easier and more accurate to create and maintain if we could reduce the individual pieces of information required. We can do this by looking at the products characteristics.

For example at *Pastoral Foods* the Slice on Slice production line has eight basic characteristics of its products that are changeable and should be considered in scheduling. Some of these characteristics can be seen in *Figure 13*.

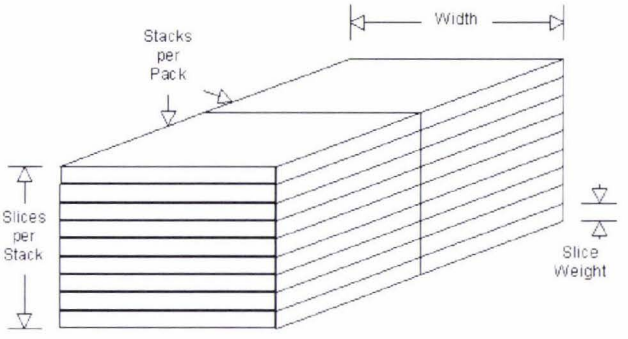


Figure 13 - *Pastoral Foods* SOS Product Characteristics

6.2 - Collecting Production Rates v Machines

By analysing the production rates on individual machines relative to their characteristics, it is possible to build up the production rates of all items with a great deal less collection time of rates of production and a list of each item's characteristics.

For example at *Pastoral Foods* the Slice on Slice production line has four basic characteristics that affect the rate of production of each item. They are as follows...

1. Formulation (Type1, Type2, Type3, Type4)
2. Size of the Slices (76 x 76mm, 90 x 90mm)
3. Number of Slices per Stack (20, 22, 32, 40, 44 slices)
4. Slice Weight (10.25g, 11.25g, 12.9g, 13.5g, 15.0g, 15.5g, 23.5g)
5. Carton Weight (10.8kg, 11.9kg, 12kg, 13kg, 14.4kg, 15.8kg, 17.4kg, 18.2kg)

Each of the following machines has its maximum production rate set by at least one of these product characteristics.

1. Blender (max prod rate set by Carton Weight)
2. Cooker (max prod rate set by Carton Weight)
3. Extruder (max prod rate set by Formulation, Slice Weight, Size of Slices)
4. Stacker Cutter (max prod rate set by Slices per Stack)

By finding the lowest production rate of an item we will find the maximum production rate that the whole line is capable of.

6.3 - Collecting Changeover Times

By analysing item differences in terms of their characteristics we can see the actual causes of the changeover times. If we analyse all possible changes on each machine and recognise which ones have to be done consecutively and which ones can be done at the same time, then we can make up a Critical Path Diagram for the process of all changeovers. If we take two items and we want to know how long it will take to change from one to the other analysis of the Critical Path Diagram, only considering the changes that have to occur (ignoring everything else), gives calculated estimates of the changeover times.

For example at *Pastoral Foods* the Slice on Slice production line has six basic characteristics that affect the time taken to change from one item to another. They are as follows...

1. Formulation Type
2. Formulation
3. Size of the Slices
4. Number of Slices per Stack
5. Number of Stacks per Pack
6. Slice Weight

For each 'change of characteristic' there are a number of 'machine changes' that must occur to effect that change.

1. Formulation Type Change
   a. Pale to Colour or Pale to Flavour
      - Clean Hot-Well (3 mins)
   b. Colour to Pale or Colour to Flavour
      - Full Wash (2 hours)
   c. Flavour to Pale or Flavour to Colour
      - Full Wash (3 hours)
2. Formulation Change
   a. Any Change
      - Blow Line (8 mins)
      - Change Trumpet (8 mins)
3. Size of the Slice Change
   a. Any Change
      - Change Stacker/Cutter (12 mins)

- Change Ribbon Cutters (8 mins)
- Change Natec Width (10 mins)

4. Number of Slices per Stack
   a. Any Change
      - Change Natec Width (10 mins)
5. Number of Stacks per Pack (2, 3, 4 Stacks)
   a. Any Change
      - Change Natec Width (10 mins)
6. Slice Weight (10.25g, 11.25g, 12.9g, 13.5g, 15.0g, 15.5g, 23.5g)
   a. Any Change
      - Slice Weight Adjustment (5 mins)

With a list of all the possible changes that can occur (constructed from the above list) and knowledge of the process of changes, we can construct a Critical Path Diagram with all possible changes that can occur. This Critical Path Diagram for the *Pastoral Foods* SOS Production Line can be seen in *Figure 14*.

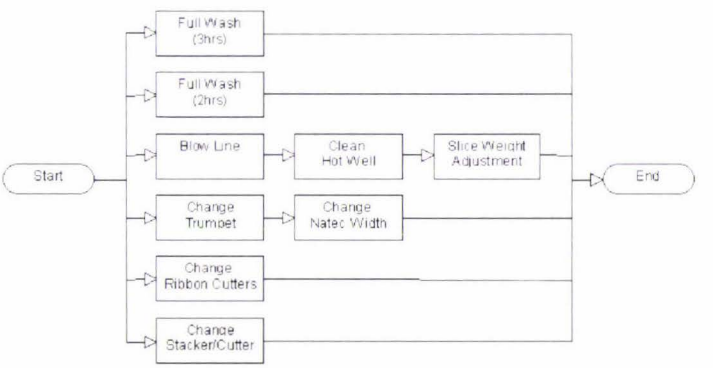


Figure 14 - *Pastoral Foods* SOS Product Change Critical Path Diagram

This treats the activity of changing over from one item to another as a small project and the total changeover time can be calculated as it would on any Critical Path Diagram. To find the changeover times between any two items it is simply a matter of working out what needs to be changed and plugging the number into the Critical Path Diagram and eliminating anything that doesn't need to be done. From here a computer program or a simple spreadsheet can be developed to calculate the total changes between any two sets of product

characteristics. If this technique is applied to all combinations of two items then a matrix of changeover times similar to that in *Figure 2* in *Section 3.6.4* can be made.

Chapter 7 - Immunity from Disruption

7.1 - Overview

Goldratt in *The Haystack Syndrome* [5] says that there are two fundamental principles that all schedules must try to achieve:

1. Schedules must be Realistic: that is, they must be achievable by the manufacturing department in terms of time and resources.
2. Schedules must be 'Immune from Disruption': that is stable, not prone to disaster in the event of a small hiccup.

The first of these two points is obvious and all good production planners try to produce schedules that adhere to this statement. The second of these points is not so obvious and not all production planners take this into account. Despite this, point 2 is almost as important as point 1 and should be treated accordingly.

Whilst creating computer-scheduling algorithms it is very tempting to try to completely optimise the schedule for minimum down time or find the very best schedule that is possible for the criteria selected. This would be a good idea, were it not for the fact that scheduling does not have a hard and fast set of conditions to apply the scheduling algorithms to. In fact scheduling depends on an enormous number of variables, many of which can go wrong at any time. Any one thing going wrong in a fully optimised schedule will cause the schedule to become sub-optimal and may cause a major catastrophe such as missing an important order. The scheduler should try to create schedules that are stable and are not prone to disasters like missing orders.

7.2 - Shipping Buffers

Goldratt has many ideas on ways to 'immunise' against disruption in his book *The Haystack Syndrome* [5]. Specifically *Goldratt* proposes the idea of shipping buffers as a means of preventing the likelihood of missing an order. This is simply the concept that it is better to give a small mount of leeway to allow for any small disruptions in the manufacturing process and production plan, rather than planning the order to be made on the limit of the manufacturing due date.

7.3 - Time and Space Buffers

Time and space buffers are created to stabilise and smooth out disruptions to the schedule. *Goldratt* discusses these in his book *The Haystack Syndrome* [5]. If the constraint is less productive than it can be at any time, then the whole production system will be less productive than it can be. To protect against the loss of productive time, *Goldratt* promotes the use of time and space buffers around the constraint. Time buffers are introduced to prevent loss of time on the constraint, ensuring that disruptions on preceding processes do not affect the up time of the constraint. Space buffers are introduced for similar reasons relating to the processes succeeding the constraint. The space buffer ensures that the constraint can continue working when the later processes are (for some reason) slower than the constraint. This is particularly applicable to JIT or flow process style manufacturing environments.

7.4 - Avoiding Vulnerability to Missing Orders

All processes exhibit variability to some degree, though some more than others. The predictability of the process can be examined by the process's history of reliability. If the process has a very high degree of variability then it will be more difficult to accurately predict the manufacturing date of a particular order. Manufacturing will be judged on their ability to make a schedule in full and on time and as such the variability of the process will make it difficult for them to achieve their schedules. To avoid failing to achieve their targets, manufacturing will often forward very low estimates of how much they think can be made in a small time frame (e.g. a week). Manufacturing will normally be capable of covering their estimated capacity far in excess of their stated ability, however occasionally they will miss their target. Because of this, production requirements will be left to the lower estimate of how much can be made, which will cause productive capacity to be under-utilised in times when capacity is at a premium. This fact may also increase quoted lead-times when the company is struggling to get enough orders to fill its capacity.

The solution is to analyse productive capacity against hours actually worked on a long-term basis and obtain an accurate estimate and a variance of the true capacity of the process. With this long-term data and use of the Central Limit Theorem we can give more accurate estimates of our short-term and long-term manufacturing capability. This will allow us to gain better use of our productive capacity and shorten our effective lead-times. The Central Limit Theorem states that the more samples that are taken the greater accuracy you can

predict the mean of a sample. Therefore the longer the period over which we are planning the more accurately we can predict the productive capacity.

For example, we have an operation that has a variable productive capacity and is also a production constraint. Production will only ever promise up to 90 tonnes per week because they are unsure that they will achieve any more. The long-term data collection shows that the factory's average production capacity is 100 tonnes per week with a standard deviation of 7.8 tonnes per week. This will mean that at 90 tonnes per week the production unit will have on average a 10% chance of not completing a schedule in its entirety and up to 10% of the productive capacity is being thrown away.

If we want to achieve a 95% probability of hitting all orders and then by the use of the Central Limit Theorem and basic statistics we can give the maximum promise-able capacity available. This can be seen in *Table 3*.

Week No	Previous Cumulative Capacity	Average Available Capacity	Cumulative Available Capacity	Capacity Gain	Capacity Gain %
1	90.0	87.2	87.2	-2.8	-3 %
2	180.0	90.9	181.8	1.8	1 %
3	270.0	92.6	277.8	7.8	3 %
4	360.0	93.6	374.3	14.3	4 %
5	450.0	94.3	471.3	21.3	5 %
6	540.0	94.8	568.6	28.6	5 %
7	630.0	95.1	666.0	36.0	6 %
8	720.0	95.5	763.7	43.7	6 %
9	810.0	95.7	861.5	51.5	6 %
10	900.0	95.9	959.4	59.4	7 %

Table 3 - Immunity From Disruption Example

In some circumstances some computer algorithms may find it attractive to bring large amounts of product forward into earlier weeks (than the EDD sequence would place them), so that they can be manufactured together in more economical runs. This may force orders required at earlier dates to be pushed out, close to their manufacture due date. This is fine as

long as the uptime stays high enough to enable all promises to be kept. However if production suffers a bad week then there will be problems meeting all of the requirements. This can be assessed in the iterations of the scheduling search algorithm. When the algorithm produces a schedule, the immunity from disruption of this schedule can be assessed by taking the worst-case scenario (95% Confidence Interval for example) over the first week. By assessing the projected available capacity and order requirements after the first weeks manufacture (in this 95% worst case scenario) the quantity of missed orders can be projected. If the projections are unfavourable, the schedule can be rejected in favour of another one that is safer in ensuring that orders are met. This immunity from disruption procedure prevents the company from using a schedule that may create unnecessary vulnerability to missing orders from long periods of lower than expected production. Just using the *Goldratt* [5] shipping buffer system will only protect the company from small breakdowns.

The *Goldratt* method of scheduling [5] uses a different system to the immunity from disruption technique described above. *Goldratt's* emphasis is on a schedule very close to the 'Earliest Due Date' sequence. His method only moves orders around to avoid missing orders (to reduce Total Make-span by gluing). This will either protect a possible market constraint (if it is a market constraint) from missed orders and/or force a reduction in Total Make-span on a true production constraint. The *Goldratt* philosophy will always protect the company from late orders as much as possible. The philosophy used in this project puts more emphasis on trying to minimise the Total Make-span on a proposed production constraint. This philosophy (unlike *Goldratt*'s) may move orders around so much that the some orders will be planned unnecessarily close to their manufacturing due dates. This is not desirable so the immunity from disruption system introduced above will be beneficial because it will protect the company from this risk.

In the authors belief the *Goldratt* scheduling method is best suited to situations where the short to medium term market forecasts are accurate and orders are stable. The scheduling methods used in this project are built to cope with a future that is changeable and forecasts are not so accurate. In the later situation the company will never know if it has a production constraint until the market makes requests beyond manufacturing's capability. The essentially means that the company must always treat its manufacturing facilities as constraints, to be sure that it can satisfy the markets long-term demands as much as possible.

7.5 - Available to Promise

A major component of any production planner's occupation is to give the delivery lead-times on customer orders. This is always a precarious obligation to perform, as giving shorter lead-times can attract more lucrative business and keep current business in a satisfactory state, whilst giving lead-times which are too short will make manufacturing's task difficult and possibly less economic. This is made more difficult by the unpredictable nature of the manufacturing process. Using the Central Limit Theorem (as explained previously in *Section 7.4*), the capacity that can safely be promised (with 95% confidence) is calculated and cumulated (as in *Table 3*) and subtracted from capacity already promised to orders. This makes the task of promising new order due dates much easier.

Chapter 8 - Raw Material Availability

It is a tendency for many manufacturers to follow the JIT style inventory management practice and minimise all stocks so that they get just as much as they need only when they need it. The task of the MRP systems is to keep a track of inventory and ensure that enough is available at all times for all planned manufacturing.

It is important for a computer algorithm that is trying to optimise scheduling to know what the raw material availability is for all items. In some operations there are very few raw materials and they are always kept in a reasonable supply so that there is minimum impact on scheduling or changes to the schedule. In other systems there are a large number of raw materials and many are ordered only on a JIT basis. This means that any changes to the schedule must consult the Bill of Materials system to check that all materials will be available for the new schedule.

Checking the Bills of Materials (BOM) can be a very time consuming task for a scheduling algorithm. In all cases it is better if the number of raw materials that are checked is kept to a minimum, so that the algorithm can save time and therefore search more iterations. If possible, raw materials checking should be eliminated from the procedure, but this is rarely possible.

In some manufacturing environments the raw materials are almost always available and changes within certain lead-times can normally be accepted. However there is the odd occasion that raw materials have longer than normal lead-times and an automatic scheduling system may violate these restrictions. This can be accounted for without using a full MRP system, but by a simple input table (that the scheduler manually maintains) that states that no more than a certain quantity of a particular item can be manufactured before a particular date. If such a table is possible, this can make the scheduling algorithm much faster and thus much more effective.

Chapter 9 - Optimisation Macros (Automatic Solutions)

An optimisation macro is an automatic procedure for creating good schedules, without a great deal of human intervention. This is created to achieve the scheduling in a fast efficient and effective manner. Optimisation procedures are never capable of understanding the whole scheduling problem because these problems are always too complex to fully program into a procedure, but they can assist as a good starting point.

Scheduling algorithms require a great deal of information and data to be available and correct and as such they also require massive amounts of effort to keep them up to date. An automatic interface with an MRP-II system will assist in maintaining this without too much extra effort. A variety of sources are required as inputs to this system including...

- Bills of Materials requirements for each order
- Inventory levels for every required item
- Purchased material lead-times
- Unfulfilled customer order lists
- Customer order priority lists and/or 'costs indexes' of missing orders
- Average rates of production for items on machines
- Available capacity v 'time bucket' matrix for every 'likely' production constraint
- Changeover time / 'cost index' matrices
- The current schedule

If one of these sets of data is not up to date the scheduling procedure cannot give appropriate results (garbage in, garbage out).

In a system designed to help scheduling, there should be two types of tools.

1. Start up full optimisation macro.
2. Iterative improvement selected criteria macro

The start up, full optimisation macro, should take all the raw information in, to create the best schedule it can, in a reasonable time frame. A reasonable time frame should not be longer than 30 minutes as anything longer than that will be inconvenient to use and possibly will not be used if it has to be run several times to adjust data inputs. The shorter time this procedure can take to run the better. A good compromise may be to allow the user to set the run time.

The iterative improvement macro should be able to be run in just a few seconds or in a time that is set as an input from the user. It will be beneficial if the scheduler could look at a schedule and decide that he/she wants to make adjustments to a particular item, 'Sub-Group', 'Group', or time interval in the schedule. The iterative improvement macro can be integrated into the manual solutions with visual interface, which are discussed in *Chapter 10*.

Chapter 10 - Visual Interfaces (Manual Solutions)

10.1 - Overview

Manual solutions are a 'must have' in scheduling tools, as the automatic solutions cannot solve all of the problems of a schedule. The manual solutions should facilitate the scheduler to be able to see the schedule and emphasise any issues with it.

10.2 - Gantt Charts

Gantt Charting is a tool that has been used in scheduling for a long time and has been very useful for describing complex scheduling problems. Gantt Charts help the scheduler by enabling the pattern recognition ability of the human brain to see where there are opportunities to be gained from adjustments to the schedule. The *Numetrix* scheduling tool (*Schedulex*) has pushes the use of a visual interface in the form of a Gantt chart. *Numetrix* have been very successful as a scheduling company for a long time and their philosophy and scheduling interface have been influential in this project.

Gantt Charts essentially feature a time line that runs across the screen and a list of production lines stacked vertically. As an active computer interface they can be very informative. An example of a Gantt chart interface for the IWS Department at *Pastoral Foods* can be seen in *Figure 15* and a Gantt chart interface for the SPC Department at *Pastoral Foods* can be seen in *Figure 16*. This example is part of the scheduling system developed in this project and is written in *Microsoft Visual Basic*.

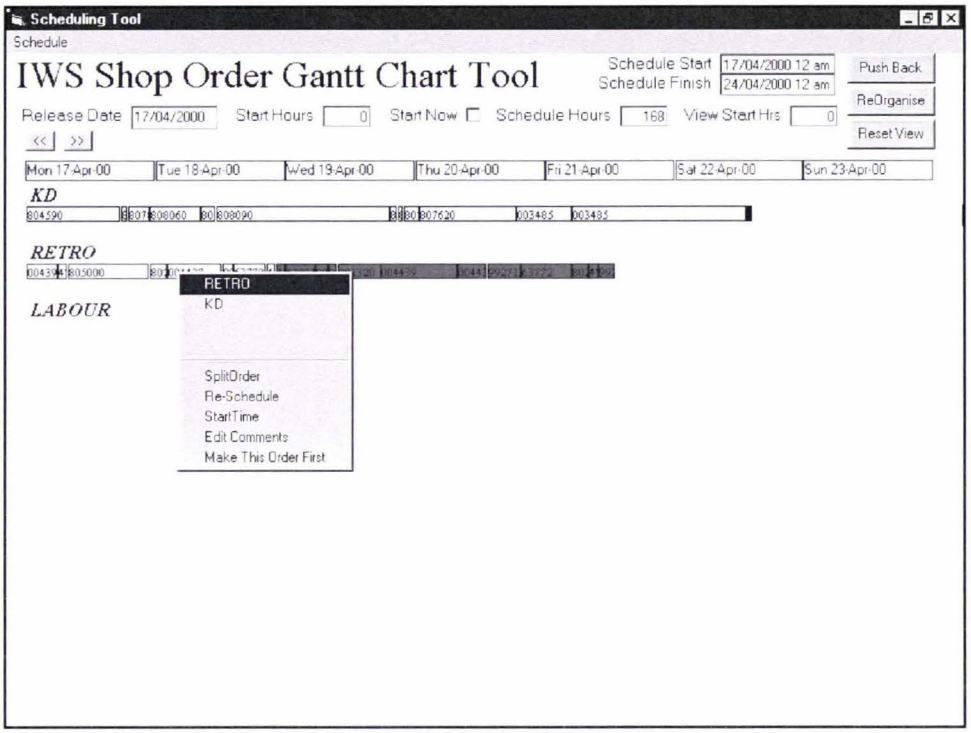


Figure 15 - Gantt chart Interface - *Pastoral Foods* IWS Department

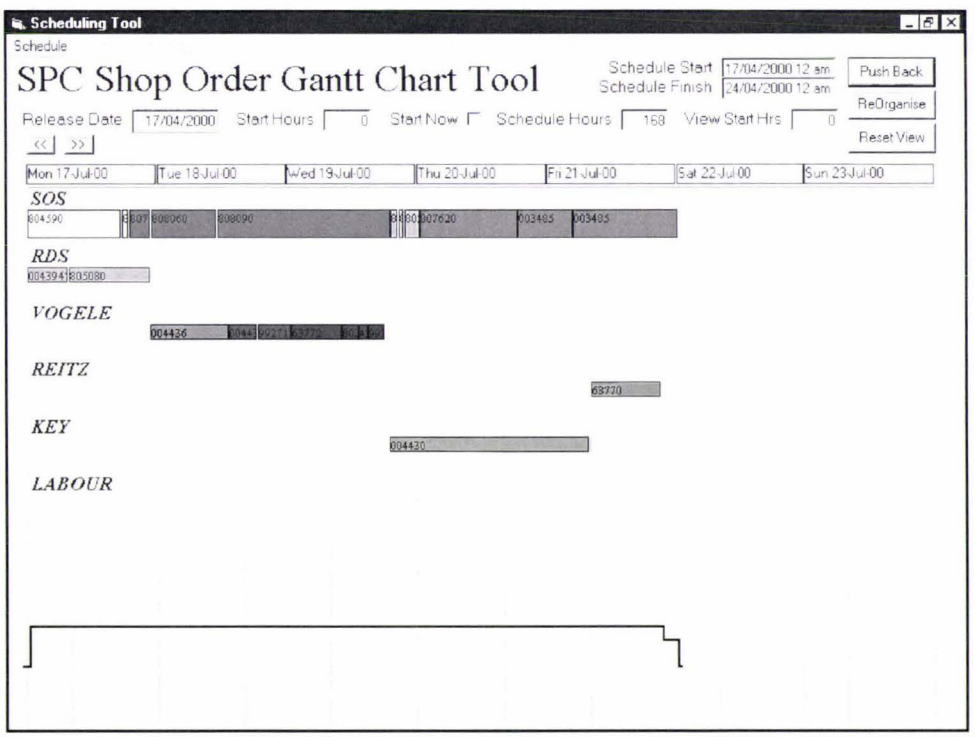


Figure 16 - Gantt chart Interface - *Pastoral Foods* SPC Department

Some of the features of this interface include...

- Automatic optimisation of the production sequence with a given set of rules
- Drag and drop order movement ability. With the mouse any order can be clicked and dragged from one part of the schedule to another.
- Mouse over order descriptions. When the mouse cursor moves over an order a description of the order will appear on the screen, next to the order.
- Mouse - right clicking on any order will give a list of options including...
  - Scheduling the order at a specific start time.
  - Splitting the order into parts to be run separately.
  - Moving the order to a different line.
  - Rescheduling the order to different week.
- Ability to move back and forth across the time line with the click of a button.
- Coloured bars to indicate different types of products or different 'Groups'.
- Symbols used to signify different types of change over times on production lines.

Gantt Charts are most effective for situations where there are multiple stages and dependant events or in crew rostering problems. If the scheduling problem only possesses a single stage then there are fewer gains to be made from Gantt Charts than in other situations. Gantt Charting single stage operations can provide the scheduler with a time map of when operations are going to occur and when and what type of changeover will have to be done in the schedule. Gantt Charting multiple stage operations will give many benefits including the ability to see when down time will occur due to dependant events. There are also great benefits to visualisation of the scheduling of crew rostering problems. In this case the Gantt chart will enable the scheduler to see when there are multiple lines running and when there are crews in excess of the requirements or too many crews are required in the schedule compared to what is available.

10.3 - Adjustable Summary Tables

A good alternative / partner to Gantt Charts are Adjustable Summary Tables. These are tables that display the scheduling data in a text / number format. These can be very helpful and in certain situations can be an effective replacement for Gantt Charts. In single stage operations Gantt Charts can be more cumbersome and time consuming to use than a table that states the projected production time and a sequence number. Using a *Microsoft Access* Form, the scheduling sequence can be manually adjusted and the manufacture times can be automatically projected from this.

A complicated example of an Adjustable Summary Tables is an 'Items and Groups v Time Buckets on Quantities' Table. This was conceptually and programmatically developed in this project and is based on bucket scheduling on a weekly basis. This Adjustable Summary Table for 'Groups' made in *Pastoral Foods* SPC Department can be seen in *Figure 17* and the Adjustable Summary Table for Items made in *Pastoral Foods* SPC Department can be seen in *Figure 18*.

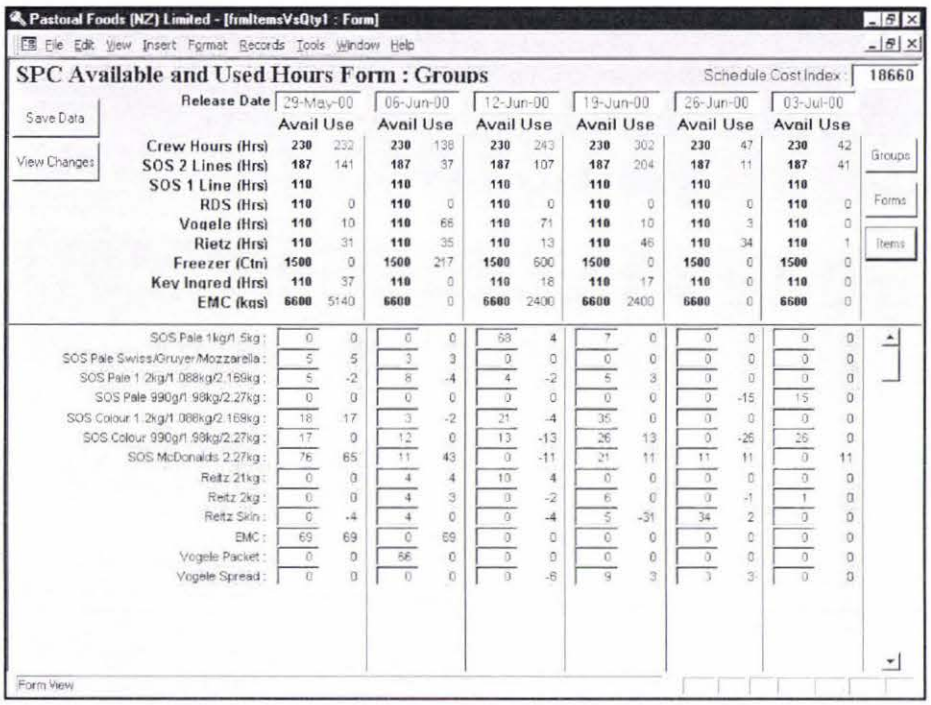
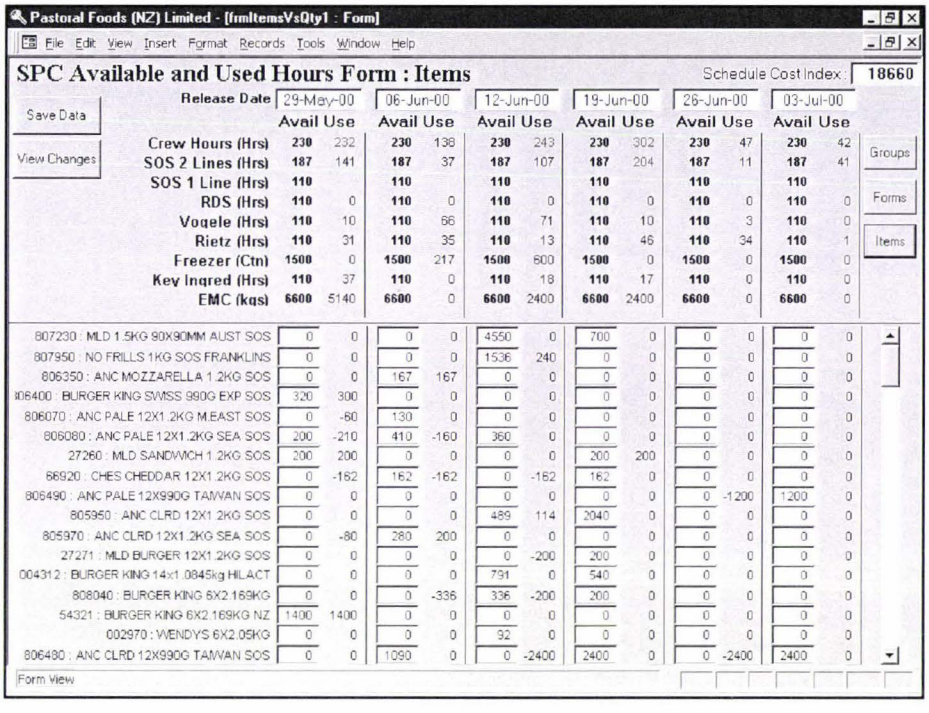


Figure 17 - Groups v Time Buckets on Quantities - *Pastoral Foods* SPC Department



Pastoral Foods (NZ) Limited - [frmItemsVsQty1 : Form]

File Edit View Insert Format Records Tools Window Help

SPC Available and Used Hours Form : Items Schedule Cost Index: 18660

Save Data | View Changes | Groups | Forms | Items

Release Date	29-May-00		06-Jun-00		12-Jun-00		19-Jun-00		26-Jun-00		03-Jul-00	
	Avail	Use	Avail	Use	Avail	Use	Avail	Use	Avail	Use	Avail	Use
Crew Hours (Hrs)	**230**	232	**230**	138	**230**	243	**230**	302	**230**	47	**230**	42
SOS 2 Lines (Hrs)	**187**	141	**187**	37	**187**	107	**187**	204	**187**	11	**187**	41
SOS 1 Line (Hrs)	**110**		**110**		**110**		**110**		**110**		**110**	
RDS (Hrs)	**110**	0	**110**	0	**110**	0	**110**	0	**110**	0	**110**	0
Vogele (Hrs)	**110**	10	**110**	66	**110**	71	**110**	10	**110**	3	**110**	0
Rietz (Hrs)	**110**	31	**110**	35	**110**	13	**110**	46	**110**	34	**110**	1
Freezer (Ctn)	**1500**	0	**1500**	217	**1500**	600	**1500**	0	**1500**	0	**1500**	0
Key Ingred (Hrs)	**110**	37	**110**	0	**110**	18	**110**	17	**110**	0	**110**	0
EMC (kgs)	**6600**	5140	**6600**	0	**6600**	2400	**6600**	2400	**6600**	0	**6600**	0
807230 : MLD 1.5KG 90X90MM AUST SOS	0	0	0	0	4550	0	700	0	0	0	0	0
807950 : NO FRILLS 1KG SOS FRANKLINS	0	0	0	0	1536	240	0	0	0	0	0	0
806350 : ANC MOZZARELLA 1.2KG SOS	0	0	167	167	0	0	0	0	0	0	0	0
806400 : BURGER KING SWISS 990G EXP SOS	320	300	0	0	0	0	0	0	0	0	0	0
806070 : ANC PALE 12X1.2KG M.EAST SOS	0	-60	130	0	0	0	0	0	0	0	0	0
806080 : ANC PALE 12X1.2KG SEA SOS	200	-210	410	-160	360	0	0	0	0	0	0	0
27260 : MLD SANDWICH 1.2KG SOS	200	200	0	0	0	0	200	200	0	0	0	0
66920 : CHES CHEDDAR 12X1.2KG SOS	0	-162	162	-162	0	-162	162	0	0	0	0	0
806490 : ANC PALE 12X990G TAIWAN SOS	0	0	0	0	0	0	0	0	0	-1200	1200	0
805950 : ANC CLRD 12X1.2KG SOS	0	0	0	0	489	114	2040	0	0	0	0	0
805970 : ANC CLRD 12X1.2KG SEA SOS	0	-80	280	200	0	0	0	0	0	0	0	0
27271 : MLD BURGER 12X1.2KG SOS	0	0	0	0	0	-200	200	0	0	0	0	0
004312 : BURGER KING 14x1.0845kg HILACT	0	0	0	0	791	0	540	0	0	0	0	0
808040 : BURGER KING 6X2.169KG	0	0	0	-336	336	-200	200	0	0	0	0	0
54321 : BURGER KING 6X2.169KG NZ	1400	1400	0	0	0	0	0	0	0	0	0	0
002970 : WENDYS 6X2.05KG	0	0	0	0	92	0	0	0	0	0	0	0
806480 : ANC CLRD 12X990G TAIWAN SOS	0	0	1090	0	0	-2400	2400	0	0	-2400	2400	0

Form View

Figure 18 - Items v Time Buckets on Quantities - *Pastoral Foods* SPC Department

This Adjustable Summary Table was created in *Microsoft Access*. The top of the screen features the dates that represent the start date of the buckets (this is titled 'Release Date') and each bucket's information flows down the page from this. From the Release Date row, the screen can be divided into two parts. The top half shows a table of the use and availability of constraints and restrictions in production. The names and units of these constraints and restrictions can be found on the left-hand side of the table. The table itself shows the total constraint or restriction available under the column heading 'Avail' with the quantities in **bold** and the usage of each of these constraints and restrictions under the column heading 'Use'. If the quantities of items planned into any bucket cause the constraint or restriction to be used more than the restriction is available then the used quantity will turn red. This is done to help make problem areas visible to the scheduler. An example of a restriction is the number of hours a machine is available to run in a bucket.

The bottom half of this screen displays a list of items, 'Groups' or 'Sub-Groups' (depending on what choice is made by the user) used in the schedule with the quantities planned and excess quantities available (after the current orders are taken away). This table has the quantities planned in white boxes (as can be seen in *Figures 17 and 18*) and excess quantities available are shown against the grey background. The required quantities are calculated

based on the manufacturing due date of the orders. If the quantity to manufacture is less than the required quantity, then there will be a shortfall of requirements compared to available. This number will show up as a negative in the excess quantities available columns and as this is an important issue, it is coloured red.

The quantities planned can be adjusted simply by typing the new quantities into the white cells of the table. As the planned quantities are adjusted the rest of the screen will automatically change to reflect the new situation. When the 'Save Data' button (in the top left-hand corner) is pressed the data is saved as a new schedule so that it can be written back to the *BPCS* MRP-II system latter at *Pastoral Foods*. This is a big advantage of this screen, as it makes adjustments to the schedule very fast and easy to put into effect. The release dates for production scheduled are written back into the customer orders so that the date an order is going to be manufactured (the release date) can be seen on the customer order.

Another advantage of this screen is that it is able to display the total quantities of 'Groups' and 'Sub-Groups' of items that are planned in any bucket. This will enable the scheduler to see where any economies can be made easily. The 'Groups' are made up of items that are beneficial to run together. The user can swap between these two screens and manipulate the schedule in either 'groups' or items at will.

The benefits of this can be realised with the scheduler matching small runs of items or 'Groups' of items in separate buckets with excess capacities that can be used to run these quantities together. A draw back of this system is that the detail of individual items is lost and some major movements can cause problems with raw material availability. This problem can be over come if a Bill of Materials system is built into the scheduling program so that any issues with raw material quantities can be assessed or displayed and dealt with appropriately.

This system on the whole is very powerful and can be of great benefit to the scheduler.

10.4 - Case Study - Use of Adjustable Summary Table

The Adjustable Summary Tables are a concept that has been developed entirely in this project. They have been and still are used successfully at *Pastoral Foods*. An example of its use was when an item was put on hold for one particular customer. This meant that all planning for this item had to be removed from the schedules, which affected a significant

amount of work (10% of the following week's planned production). Because of a tight scheduling situation with customer wanting more product than *Pastoral Foods* could supply the decision was made to bring forward as much work as possible to fill the void of work. Using the 'Items and Groups v Time Buckets on Quantities' Adjustable Summary Table (similar to those in *Figure 17 and 18*) the production staff were able to see what product was available to be bought forward easily. With this they could decide which items and formulations they wanted to make in that week to get 'good runs' in their plant. After this decision was tentatively made the new schedules are forwarded to procurement so that they could check for raw material availability. Some items could not be made as production had hoped, but the majority of the schedule was accepted and after some minor adjustments the plan went ahead.

Chapter 11 - Over-All Solutions

11.1 - Overview

The system built as a scheduling tool in this project is a *Microsoft Access* database with Visual Basic code controlling it and a Gantt Charting program built as a separate Visual Basic Program. The *Microsoft Access* database and Gantt Charting program are able to exchange information with each other. This provides all information in one concentrated place for convenience and ease of use.

The required output of scheduling algorithms may vary from situation to situation. The possible requirements may include...

- A list of Shop Orders or Firm Planned Orders (or their non MRP-II equivalents) to be processed on each scheduled machine centre with a recommended manufacturing sequence.
- A list of Shop Orders or Firm Planned Orders (or their non MRP-II equivalents) to be processed on each day (specified Release Date) on each scheduled machine centre.
- A list of Shop Orders or Firm Planned Orders (or their non MRP-II equivalents) to be processed in each scheduling bucket on each scheduled machine centre.
- A list of Shop Orders or Firm Planned Orders (or their non MRP-II equivalents) to be done in each scheduling bucket on each scheduled machine centre with a recommended manufacturing sequence.
- A list of items to be made in each scheduling bucket on each scheduled machine centre.
- A list of items to be made in each scheduling bucket on each scheduled machine centre with a recommended manufacturing sequence.

Each Shop Order or Firm Planned Order (or its non MRP-II equivalent) can be linked to a specific Customer Order if required. This may be needed if special instructions for each Customer Order are needed. For example the Customer's Order number or address may need to be printed on the packaging. The system developed in this project can easily be modified to out put any of the above requirements. At *Pastoral Foods* some of the customers require their specific information on each product and so some Shop Orders need to be linked directly to the Customer orders they are being made to satisfy. With this in mind the required output of this project was a list of Shop Orders with a unique sequence number attached for each Release Date and the Release Date to be specified for each Firm Planned Order.

11.2 - Procedure of the System's Operation

The over-all procedure that will be used by operators of this scheduling tool will need to encompass all aspects of the scheduling function, from receiving raw material delivery information from procurement, to setting new customer order shipping dates. The system starts up with the main menu screen as shown in *Figure 19*. This screen gives access to all components of the system including the Gantt Charting Tool.

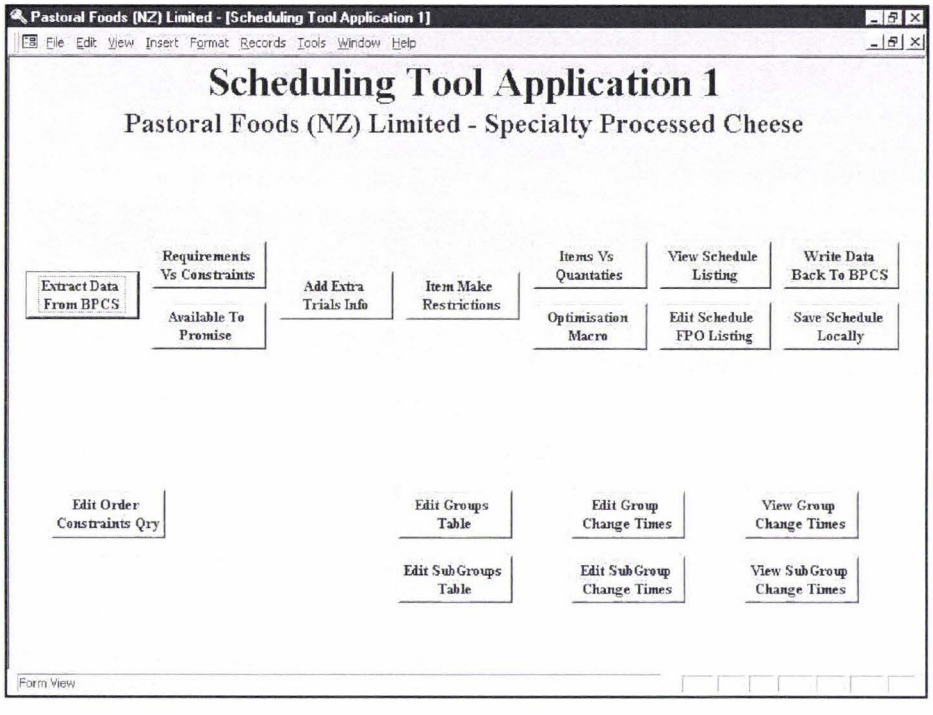


Figure 19 - Scheduling Tool - Main Scheduling Screen

A brief description of a procedure for scheduling with the system developed in this project is as listed below. A more detailed description of each step follows in *Sections 11.2.1 to 11.2.9...*

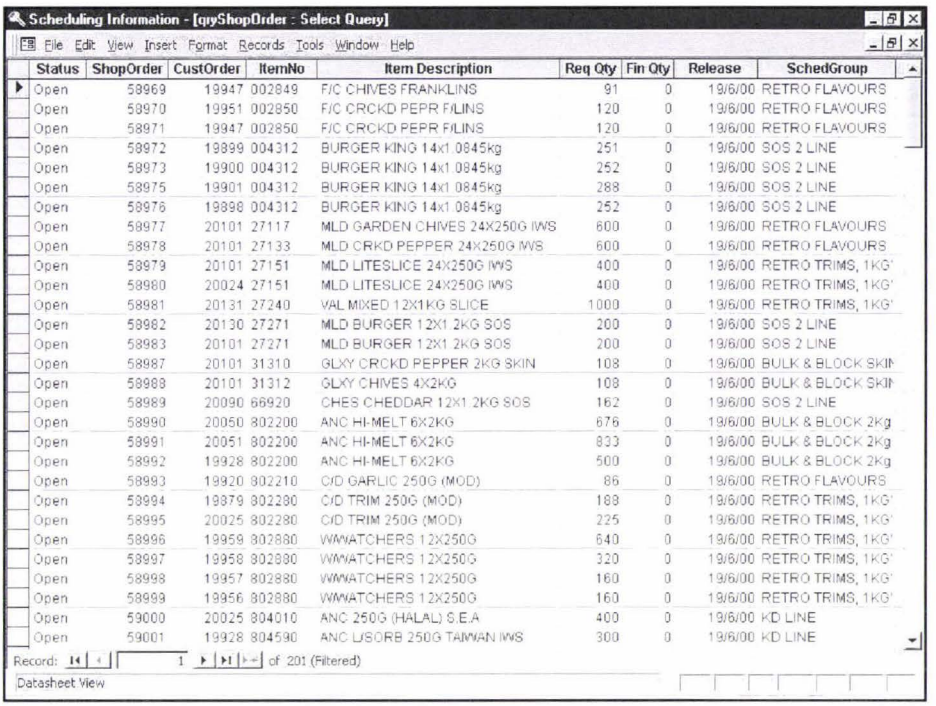
1. Obtain a list of unfilled Customer Orders and the Shop Orders / Firm Planned Orders they match to (automatically done by the system).
2. Display Adjustable Summary Table of 'Capacity Constraints and Restrictions' for each scheduling time bucket.
3. Scheduler adjusts capacity constraints and restrictions for each of the buckets as appropriate and stores the new information for future use.

4. If desired the scheduler can run the 'Automatic Schedule Optimisation Macro' to find the best schedule.
5. The scheduler should inspect and (as appropriate) adjust the schedule using the Gantt chart and 'Items and Groups v Time Buckets on Quantities' Adjustable Summary Table.
6. Procurement to check for raw material availability.
7. The scheduler adjusts the schedule (as appropriate) in light of the information from procurement. This is done using the Gantt chart and 'Items and Groups v Time Buckets on Quantities' Adjustable Summary Table.
8. Feed back of all exceptions to promises already made to marketing.
9. Output of schedule to manufacturing.

11.2.1 - Obtain a Customer Order Listing

The starting point for any scheduling system is always what to make. In this system it is a list of customer orders and stock orders. At *Pastoral Foods* some products are now made to the customer's forecasts and so stock orders are created for these items. These stock orders are a reflection of the customer's net production requirements. *Pastoral Foods* has contracts with its make-to-stock customers to have available for supply the quantities forecasted on certain dates. As these stock orders have a specific date they are requested by and a definite quantity they can be treated the same as true customer orders.

The scheduling system will present the planned manufacturing orders in a form similar to that seen in *Figure 20*. Each Shop Order is matched to a specific Customer Order or forecast.



Scheduling Information - [qryShopOrder : Select Query]

File Edit View Insert Format Records Tools Window Help

Status	ShopOrder	CustOrder	ItemNo	Item Description	Req Qty	Fin Qty	Release	SchedGroup
Open	58969	19947	002849	F/C CHIVES FRANKLINS	91	0	19/6/00	RETRO FLAVOURS
Open	58970	19951	002850	F/C CRCKD PEPR F/LINS	120	0	19/6/00	RETRO FLAVOURS
Open	58971	19947	002850	F/C CRCKD PEPR F/LINS	120	0	19/6/00	RETRO FLAVOURS
Open	58972	19899	004312	BURGER KING 14x1.0845kg	251	0	19/6/00	SOS 2 LINE
Open	58973	19900	004312	BURGER KING 14x1.0845kg	252	0	19/6/00	SOS 2 LINE
Open	58975	19901	004312	BURGER KING 14x1.0845kg	288	0	19/6/00	SOS 2 LINE
Open	58976	19898	004312	BURGER KING 14x1.0845kg	252	0	19/6/00	SOS 2 LINE
Open	58977	20101	27117	MLD GARDEN CHIVES 24X250G IWS	600	0	19/6/00	RETRO FLAVOURS
Open	58978	20101	27133	MLD CRKD PEPPER 24X250G IWS	600	0	19/6/00	RETRO FLAVOURS
Open	58979	20101	27151	MLD LITESLICE 24X250G IWS	400	0	19/6/00	RETRO TRIMS, 1KG
Open	58980	20024	27151	MLD LITESLICE 24X250G IWS	400	0	19/6/00	RETRO TRIMS, 1KG
Open	58981	20131	27240	VAL MIXED 12X1KG SLICE	1000	0	19/6/00	RETRO TRIMS, 1KG
Open	58982	20130	27271	MLD BURGER 12X1.2KG SOS	200	0	19/6/00	SOS 2 LINE
Open	58983	20101	27271	MLD BURGER 12X1.2KG SOS	200	0	19/6/00	SOS 2 LINE
Open	58987	20101	31310	GLXY CRCKD PEPPER 2KG SKIN	108	0	19/6/00	BULK & BLOCK SKIN
Open	58988	20101	31312	GLXY CHIVES 4X2KG	108	0	19/6/00	BULK & BLOCK SKIN
Open	58989	20090	66920	CHES CHEDDAR 12X1.2KG SOS	162	0	19/6/00	SOS 2 LINE
Open	58990	20050	802200	ANC HI-MELT 6X2KG	676	0	19/6/00	BULK & BLOCK 2Kg
Open	58991	20051	802200	ANC HI-MELT 6X2KG	833	0	19/6/00	BULK & BLOCK 2Kg
Open	58992	19928	802200	ANC HI-MELT 6X2KG	500	0	19/6/00	BULK & BLOCK 2Kg
Open	58993	19920	802210	C/D GARLIC 250G (MOD)	86	0	19/6/00	RETRO FLAVOURS
Open	58994	19879	802280	C/D TRIM 250G (MOD)	188	0	19/6/00	RETRO TRIMS, 1KG
Open	58995	20025	802280	C/D TRIM 250G (MOD)	225	0	19/6/00	RETRO TRIMS, 1KG
Open	58996	19959	802880	WWATCHERS 12X250G	640	0	19/6/00	RETRO TRIMS, 1KG
Open	58997	19958	802880	WWATCHERS 12X250G	320	0	19/6/00	RETRO TRIMS, 1KG
Open	58998	19957	802880	WWATCHERS 12X250G	160	0	19/6/00	RETRO TRIMS, 1KG
Open	58999	19956	802880	WWATCHERS 12X250G	160	0	19/6/00	RETRO TRIMS, 1KG
Open	59000	20025	804010	ANC 250G (HALAL) S.E.A	400	0	19/6/00	KD LINE
Open	59001	19928	804590	ANC L/SORB 250G TAIWAN IWS	300	0	19/6/00	KD LINE

Record: 1 of 201 (Filtered)

Datasheet View

Figure 20 - Scheduling Tool - Orders Listing

11.2.2 - Display Capacity Constraints and Restrictions for Each Bucket

A list of the availability of all manufacturing facilities and crews is a very necessary component of planning. In this system this list is reduced to a minimum number that adequately describes the manufacturing constraints and restrictions as well as the requirements for each of them. The scheduling system will present the availability and requirements for each constraint or restriction in a form similar to that seen in *Figure 21*. This is an Adjustable Summary Table that allows the user to directly input the constraint or restriction quantities for each time bucket. This table will calculate the requirements of a Backward Schedule from the manufacturing needs of all orders. The Backward Schedule calculation is not a simple operation as it might appear. Each order must be loaded into the latest bucket it can be manufactured in one at a time. At *Pastoral Foods* some lines will use more staff with high manufacturing quantities in each week and so some quite complex calculations are involved in the Backward Schedule. When there are problems with orders that the required manufacturing quantities are in excess of the available capacity to make them, then the company has a problem. These problems are highlighted in red in the first column or first time bucket. Only the first time bucket turns red because this is the way a Backward

Schedule is calculated. This makes it easy to see exactly how much of an overload there is and where there is available capacity.

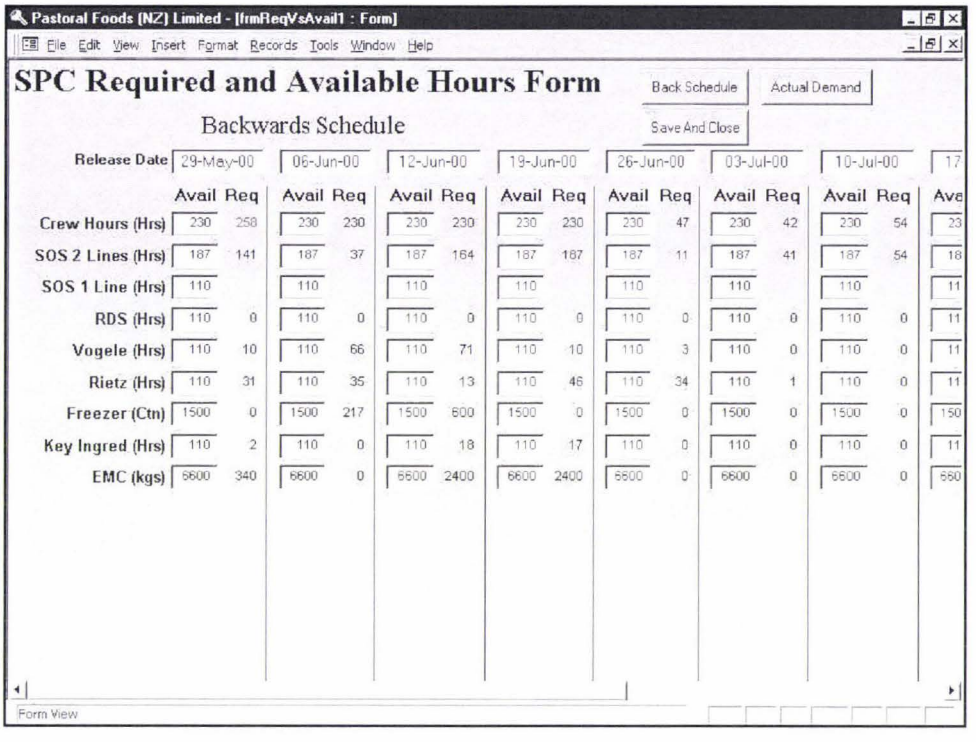


Figure 21 - Capacity Constraints and Restrictions - *Pastoral Foods* SPC Department

11.2.3 - Adjust Capacity Constraints and Restrictions for Each Bucket

If there are issues with the schedule (either too much capacity or too little) then adjustments may be required to the quantities of the restrictions. Extra staff may be bought in, or excess staff laid off, extra maintenance can be planned or planned maintenance could be postponed. Any changes will need to be summarised and the 'Capacity Constraints and Restrictions' Adjustable Summary Table will need to be altered.

11.2.4 - Run the Automatic Schedule Optimisation Macro

A method for improving the schedule is to run the 'Automatic Schedule Optimisation Macro'. This uses the 'Combination Individual Group Enumeration and Tabu Search' algorithm described in *Section 5.7*. It is not compulsory to run this macro, if the

scheduler decides that he/she wants to manipulate the schedule him/her self manually with the aid of other devices in this scheduling tool.

11.2.5 - Inspect and Adjust Schedule

Inspection and adjustment of the schedule can be done manually if desired by the use of two major tools of this project. The Gantt Charting Tool and the 'Items and Groups v Time Buckets on Quantities' Adjustable Summary Table can be used to manipulate the schedule. The features and use of these systems is discussed in detail in *Chapter 10*.

11.2.6 - Check for Raw Material Availability

Any schedule must be checked to see if it can be realistically achieved. The scheduling tool can check for most issues that will normally be constraints or restrictions. But at this stage the scheduling tool produced in this project cannot check if the raw materials will be available. Once the schedule has been produced it must be forwarded to the procurement department so that they can check that they can raise any issues they may have with the schedule. If the schedule has only minor changes to it then rechecking the availability of all items may not be necessary. A list of changes to the schedule, since the last check of raw materials may be all that is needed. The system can produce a list of the recent changes to the schedule so that this can be checked in isolation from the scheduling tool. The list of changes screen can be seen in *Figure 22*.

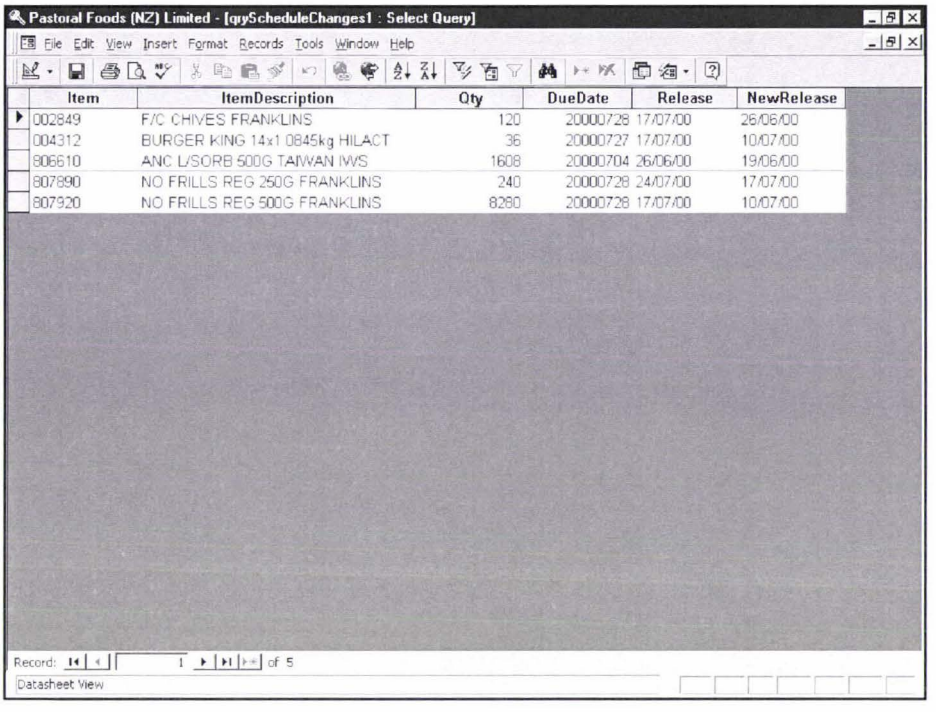


Figure 22 - Scheduling Tool - Recent Schedule Changes

11.2.7 - Adjust Schedule in Accordance with Raw Material Availability

If there are any problems with the schedule with respect to raw materials then these must be adjusted for, possibly using the 'Items and Groups v Time Buckets on Quantities' Adjustable Summary Table and/or The Gantt Charting Tool. These systems are discussed in detail in *Chapter 10*.

11.2.8 - Feed Back Exception Information

If there are changes to the schedule that are likely to impact the customers then this information must be fed back to the marketing department. The system will produce a list of problem orders that may be late or close to being late so that these problems can be highlighted to the scheduler and given to the appropriate people.

11.2.9 - Output the Schedule to Manufacturing

Reports on the schedule can be produced in the form Gantt Charts or Adjustable Summary Tables. The schedule once it has been decided upon can be verified as acceptable or otherwise inside the scheduling system. Once approved the schedule can be written back into the *BPCS* MRP-II system, so that Shop Orders can be issued.

11.3 - Procedure for Accepting New Customer Orders

A procedure for acceptance of and promising dates for new Customer Orders / Forecasted Requirements is as follows. A more detailed description of each step can be seen in *Sections 11.3.1 to 11.3.4*...

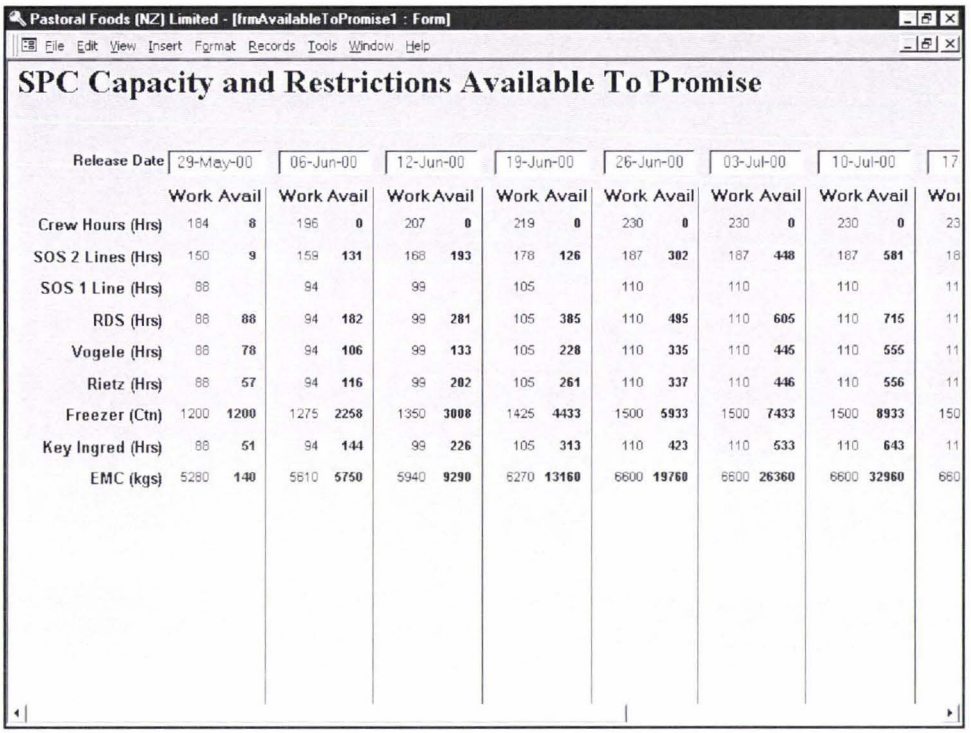
1. Obtain a list of unmatched (without Shop Orders or Firm Planned Orders to cover) Customer Orders (automatically done by the system).
2. Obtain the 'Available to Promise' capacities and restrictions (automatically done by the system).
3. Manually decide what extra orders to plan.
4. Create new Shop Orders and/or Firm Planned Orders and input manually selected 'Release Dates' for them.

11.3.1 - Obtain a List of Unmatched Customer Orders

A list of customer orders and forecasts that are not covered by Shop Orders or Firm Planned Orders can be obtained from the system in isolation from the orders that are covered in the production plan.

11.3.2 - Available to Promise Capacity Constraints and Restrictions

The capacity that is available to promise has to be known to enable delivery dates to be promised on customer orders. The available capacity should be estimated based on the worst-case scenario that can be reasonably expected. This can be done based on a 95 % (for example) Confidence Interval. The Confidence Interval can be calculated using basic statistics as explained in detail in *Sections 7.4 and 7.5*. This available capacity figures (based on the worst case scenario) are displayed in the 'Capacity Constraint and Restrictions Available To Promise' Adjustable Summary Table. An example of this for the *Pastoral Foods* SPC Department can be seen in *Figure 23*.



Release Date	29-May-00		06-Jun-00		12-Jun-00		19-Jun-00		26-Jun-00		03-Jul-00		10-Jul-00		17
	Work	Avail	Work	Avail	Work	Avail	Work	Avail	Work	Avail	Work	Avail	Work	Avail	Wo
Crew Hours (Hrs)	184	8	196	0	207	0	219	0	230	0	230	0	230	0	23
SOS 2 Lines (Hrs)	150	9	159	131	168	193	178	126	187	302	187	448	187	581	18
SOS 1 Line (Hrs)	88		94		99		105		110		110		110		11
RDS (Hrs)	88	88	94	182	99	281	105	385	110	495	110	605	110	715	11
Vogele (Hrs)	88	78	94	106	99	133	105	228	110	335	110	445	110	555	11
Rietz (Hrs)	88	57	94	116	99	202	105	261	110	337	110	446	110	556	11
Freezer (Ctn)	1200	1200	1275	2258	1350	3008	1425	4433	1500	5933	1500	7433	1500	8933	150
Key Ingred (Hrs)	88	51	94	144	99	226	105	313	110	423	110	533	110	643	11
EMC (kgs)	5280	140	5610	5750	5940	9290	6270	13160	6600	19760	6600	26360	6600	32960	660

Figure 23 - Capacity Constraints and Restrictions Available to Promise - *Pastoral Foods* SPC Department

11.3.3 - Decide what Extra Orders to Plan

Using the available to promise capacity the planned manufacture dates for the new requirements can be selected. Each new order will have item number, quantity, due date and planned release date. If the new orders are within the raw material supply lead-time for their raw material components, then procurement should be consulted to see if there is enough materials on hand or in supply to make the new planned quantity in addition to all previously planned orders.

11.3.4 - Create Shop Orders and/or Firm Planned Orders for Orders

Once the extra planned manufacturing has been decided the only task remaining is to create the Shop Orders or Firm Planned Orders. To make this task as easy as possible a form has been created in the database that enables the user to simply type a planned manufacturing date against a new Customer Orders. From this the system can automatically create new Firm Planned Orders, which can be automatically changed to Shop Orders by the *BPCS* MRP-II system.

11.4 - Coping with Changes in Requirements

Modern manufacturing environments are often very changeable and accordingly the requirements of a scheduling tool will also be very changeable. Often a custom built scheduling tool will not be able to cope with significant changes to the scheduling environment, without the need for major time consuming reprogramming of the system. However this is a very desirable aspect of a scheduling tool and considerable effort was put into creating a scheduling package that could cope with change, well. A list of types of changes that the system can cope with is listed as follows.

- Changes to capacities and availability of constraints and restrictions.
- Addition of new items.
- Addition of new 'Groups' and 'Sub-Groups'.
- Changes to crewing and staffing levels of manufacturing departments (crew rostering systems).
- Addition of new manufacturing lines.
- Addition of new manufacturing departments (crew rostering systems).

Changes to the system could be put into effect by making additions to *Microsoft Access* tables and adjusting a *Microsoft Access* table or SQL statement. This could be written and understood by many people who can write SQL statements or use the *Microsoft Access SQL Writer*. The systems developed and specifically developed for *BPCS* at *Pastoral Foods*. However it is not a difficult task to change the data input components of the scheduling tool to read from other places and it could be adapted to read from another type of system provided that all of the same information is available in some form, through the MRP-II system.

The SQL statements for orders listings and usage of constraints and restrictions for *Pastoral Foods* SPC and IWS Departments can be found in *Appendix 2.1 and 2.2*.

11.5 - Future Work

The systems developed in this project cope extremely well with the specific task of scheduling. However they need to be integrated with other aspects and functions that are part of the planning role. A procedure for that would be better and help the scheduler's role significantly is as follows...

1. List unfilled Customer Orders and the Shop Orders / Firm Planned Orders they match to.
2. Display a table of Customer Orders with their planning dates and progress in manufacturing. The scheduler should check this list to make sure that all the orders are appropriate and realistic.
3. Display an exception report that highlights any orders that exceeds customer's forecasts or imposed restrictions.
4. Automatic checking of raw material availability against requirements using the Bill of Materials and available stocks.
5. Display 'Adjustable Summary Table' of 'Capacity Constraints and Restrictions' for each bucket.
6. Scheduler adjusts capacity constraints and restrictions for each of the scheduling time buckets as appropriate and store the new information for future use.
7. If desired the scheduler can run the 'Automatic Schedule Optimisation Macro' to find the best schedule.
8. The scheduler should inspect and as appropriate adjust the schedule using the Gantt Chart and 'Adjustable Summary Table' of 'Items and Groups v Time Buckets on Quantities'.
9. Feed back of all exceptions to promises previously made to marketing.
10. Output of schedule to manufacturing.

A procedure for accepting and promising delivery dates on new customer orders that would help the scheduler's role is as follows...

1. Obtain a list of unmatched (without Shop Orders or Firm Planned Orders to cover) Customer Orders (automatically done by the system).
2. System generated 'Available to Promise' dates of manufacture and availability to the customer taking into account of capacities and restrictions and raw material availability.
3. Automatic updating and acceptance of orders in the system by entering 'Release Dates' against orders and allowing the system to do the rest.

These new procedures will require extra development and new systems to be built and integrated into the scheduling tool. Some of these are in the following...

- Materials Requirements Planning and Bills of Materials.

- Customer order v forecast analysis system.
- Automation of the process of dealing with new Customer Orders.
- Automatic creation of Shop Orders directly from Customer Orders (often part of MRP-II).
- Full integration of the Gantt chart into the scheduling tool (presently it is a separate program).
- Ability to perform a true Backward Schedule.

Other work that could also be of significant benefit to a scheduling package is the integration of 'Routing Files' so that multistage processes can be mapped accurately. This will use the *OPT / Goldratt* Scheduling Method discussed in *Section 4.3*.

Chapter 12 - Discussion and Conclusions

12.1 - Overview

The research in this project has seen systems developed that have made a significant attack on the scheduling problems at *Pastoral Foods* and some of these systems can be applied to the scheduling problems in many other organisations.

Sequence Dependant Set-ups are a significant (and very common) problem in manufacturing, that makes the task of scheduling much more difficult than it otherwise would be. This project developed strategies for coping with Sequence Dependant Set-ups.

This project realised the importance of simplifying the scheduling processes as much as possible. Complex processes can be very difficult to write programs for and if at all possible they should be reduced to single stage operations. Generally a lot of manufacturing process in New Zealand can be reduced to scheduling just 1 or 2 stages. Bucket scheduling is a technique that can be used to reduce the size of the scheduling problem. Grouping similar items together was also used to reduce the size of the scheduling problem.

Tabu Search is an algorithm that can hunt through a large solution space and seek out optimal or good schedules in a realistic time frame. Tabu Search was used to great effect in this project in an 'Automatic Optimisation Macro'. It was found that the quality of the solution found by the Tabu Search algorithm was dependent on the scheduling objective function that was used to define a good schedule. Scheduling objective functions can be used to dictate the solutions optimality in terms of objectives like Total Make-span, or it may force the schedule to be as safe as possible from missing orders. It is a decision to be made by the company as to where in the spectrum (between these two opposing extremes) the scheduling algorithm

should try to aim – safety or optimality. *Pastoral Foods* objectives were very much towards creating safe schedules that would prevent orders being delivered late.

Gantt Charts and Adjustable Summary Tables were created so that the schedules could be easily seen and judged by the scheduler. These also allowed very quick and easy adjustment of the schedules.

12.2 - Operators View

The operator's view of the system is that it is a very powerful scheduling tool that can be used to schedule effectively. It is especially effective at scheduling the factories at *Pastoral Foods* in the medium range of 3 to 6 weeks. This is where the schedule should be stable and this is also where most of schedule rearranging should be done. Changes that occur within the 3-week time horizon are likely to violate the standard procurement lead-times for a significant number of the raw materials. This leaves the schedule changes unconfirmed until they have been passed through procurement. Because of this the scheduling system is less effective than it might otherwise be for scheduling in the short term. These problems can be rectified by further work.

12.3 - Outcomes for Pastoral Foods

During the course of the project *Pastoral Foods* realised its vulnerability to poor or poorly maintained planning systems. On more than one occasion in recent history the scheduling has been done badly and bad information was partially to blame. Because the company's is now pushing itself towards ensuring better customer service, they have decided to purchase a commercial package supported by a large corporation. This will give *Pastoral Foods* a more secure and proven system than could ever be given by a single person developing, supporting and maintaining a whole system, as has been developed in this project.

Pastoral Foods gained a significant amount out of the project in terms of support for the planning function. Many new information tools were developed as sidelines to the main focus of the project. The Gantt Chart Tool was developed and has been used for some time by *Pastoral Foods* to cope with the significant changes to their crew rostering arrangements. Much information on changeover times and production rates was gathered and is available for use in the commercial scheduling package that *Pastoral Foods* has chosen. *Pastoral Foods* now understands its scheduling problem much more effectively because of the work done in this project.

It is difficult to measure exact benefits of the project on Pastoral Foods without a full installation of the systems developed under the same circumstances as before and after the installation. The benefits of this projects have been realised slowly over time at *Pastoral Foods* and have coincided with other changes in the factories operations along with changes in the market's requirements. In order to attempt to measure the exact performance of the project alone, factory simulations were run. These simulations used real historical situations to compare the original schedules with the schedules created by this system. These plans were run through the same uptime and downtime occurrences as what actually happened in the factories. The schedules created with the new systems realised the following improvements over the schedules that were actually issued to the factory.

- Four percent increase in productive capacity averaged over all factories, created by a measurable decrease in downtime due to product changeovers.
- Ten percent decrease in real lead times due to better management of capacity.
- Ninety percent increase in orders 'delivered in full and on time'.

Appendix

Appendix 1 - Pastoral Foods (NZ) Limited List of Items

1.1 - Individually Wrapped Slices - List of Items

Item No	Item Description	Form	Group	Seq	SPR	Weight
002847	F/C PIZZA IWS 250G	F0288	IWS B Flavours	1720	108	6
002848	F/CE SMOKED FRANKLINS	F0232	IWS B Flavours	1580	108	6
002849	F/C CHIVES FRANKLINS	F0282	IWS A Flavours	1250	108	6
002850	F/C CRCKD PEPR F/LINS	F0251	IWS A Flavours	1350	108	6
002922	VAL 250G IWS MIDDLE EAST	F0207	IWS Cheddar	660	125	6
002923	VAL 500G IWS MIDDLE EAST	F0207	IWS Cheddar	690	125	6
003485	MLD CALCIUM ENRICHED 500G	F0279	IWS Cheddar	830	122	6
003486	MLD CALCIUM ENRICHED 250G	F0279	IWS Cheddar	840	122	6
004308	C/D HIGH CALCIUM 250G - SEA	F0279	IWS Cheddar	845	122	6
004310	C/D HIGH CALCIUM 250G - SEA	F0279	IWS Cheddar	840	120	6
004328	HOME BRAND LITE IWS - 500G	F0273	IWS Cheddar	71	125	6
004391	C/D ANLENE 250G IWS -TWN/HK	F0216	IWS Cheddar	0	122	6
004437	C/D TRIM SINGLES 227G IWS	F0214	IWS Cheddar	212	129	5.4
004438	C/D COLOURED 24X227G	F0271	IWS B Flavours	1505	130	5.4
004439	C/D COLOURED SINGLES 454G IWS	F0271	IWS B Flavours	1505	130	5.4
004571	C/D CHEDDAR 14 SLICE ME	F0215H	IWS Cheddar	0	107	7
24764	W/WATCHERS NZ 12X250G	F0214	IWS Cheddar	130	234	3
27112	MLD TASTY 24X250G IWS	F0234	IWS Cheddar	960	125	6
27113	MLD COLBY 24X250G IWS	F0236	IWS Cheddar	900	125	6
27116	MLD FARMHOUSE BACON 24x250G	F0330	IWS B Flavours	1760	117	6
27117	MLD GARDEN CHIVES 24X250G IW	F0282	IWS A Flavours	1260	117	6
27118	MLD THICK & TASTY 250G IWS	F0234	IWS Cheddar	980	117	6
27132	MLD EDAM 250G IWS	F0239	IWS Cheddar	850	125	6
27133	MLD CRKD PEPPER 24X250G IWS	F0251	IWS A Flavours	1360	117	6
27138	MLD SMKD 24X250G IWS	F0232	IWS B Flavours	1590	117	6
27142	MLD CHED 24X250G IWS	F0111	IWS Cheddar	745	125	6
27144	MLD ONION 24X250G IWS	F0233	IWS Cheddar	1110	117	6
27151	MLD LITESLICE 24X250G IWS	F0244	IWS Cheddar	90	120	6
27225	VAL SLICES CHED 500G	F0111	IWS Cheddar	780	125	6
27240	VAL MIXED 12X1KG SLICE	F0111	IWS Cheddar	790	60	12
27250	COWHEAD PLAIN 250g IWS	F0274	IWS Cheddar	550	125	6
27252	COWHEAD PLAIN 500G IWS	F0274	IWS Cheddar	580	125	6
27510	NO FRILLS 12X1KG SLICES	F0111	IWS Cheddar	800	63	12
37119	F/CHOICE REDUCED FAT 250G	F0230	IWS Cheddar	40	115	6
37120	FIRST CHOICE REGULAR 250G NZ	F0275	IWS Cheddar	610	103	6
37121	F/CHOICE PINEAPPLE 250G	F0287	IWS B Flavours	1520	108	6
37122	F/CHOICE SMOKED 250g	F0232	IWS B Flavours	1610	108	6
37123	F/CHOICE CHIVES 250g	F0282	IWS A Flavours	1280	108	6
37124	F/CHOICE CRACK/PEPPER 250g	F0251	IWS A Flavours	1380	108	6
37125	F/C PIZZA IWS 250G	F0288	IWS B Flavours	1720	108	6
37126	F/C SUNDRIED TOMATO F/LINS	F0289	IWS Cheddar	1390	108	6
47150	TARARUA CHED 24X200G IWS	F0111	IWS Cheddar	740	125	4.8
47151	TARARUA TASTY 24X200G IWS	F0234	IWS Cheddar	950	125	4.8
47152	TARARUA LITE CHED 24X200G IW	F0264	IWS Cheddar	80	117	4.8
47153	TARARUA LITE CHIVE 24X200G IWS	F0265	IWS A Flavours	1210	117	4.8
47154	TARARUA P/APPLE 24X200G IWS	F0284	IWS B Flavours	1400	117	4.8
47158	TARARUA COLBY 24X200G IWS	F0236	IWS Cheddar	890	125	4.8
47159	TARARUA BURGER 24X200G IWS	F0330	IWS B Flavours	1750	117	4.8
63763	C/D CHED 24X250G LOC IWS	F0111	IWS Cheddar	760	125	6
63764	C/D COLBY 250G LOC	F0236	IWS Cheddar	920	125	6
63765	C/D TASTY 250G LOC	F0234	IWS Cheddar	1000	125	6
63767	C/D CHIVES 24X250G LOC IWS	F0282	IWS A Flavours	1290	117	6
63769	C/D HRB&GARLIC 24X250G LOC IWS	F0219	IWS A Flavours	1310	120	6
63770	C/D ONION 24X250G LOC IWS	F0233	IWS Cheddar	1130	117	6
63771	C/D P/APPLE 24X250G LOC IWS	F0284	IWS B Flavours	1410	117	6
63772	C/D SMKD 24X250G LOC IWS	F0232	IWS B Flavours	1620	117	6
63774	C/D LIGHT&TRIM 24X250G IWS	F0244	IWS Cheddar	110	120	6
63775	C/D NACHO 250G LOCAL	F0253	IWS B Flavours	1730	117	6
63776	C/D BURGER 250G LOC	F0330	IWS B Flavours	1780	117	6
63777	C/D PIZZA 250G LOC	F0254	IWS Cheddar	552	117	6
63778	C/D EDAM 250G LOC	F0239	IWS Cheddar	870	125	6
63785	C/D 1KG LOC IWS	F0111	IWS Cheddar	810	60	12
800600	ANCCOLOURED 24X250G IWS	F0208	IWS B Flavours	1560	125	6
800990	ANC PLAIN 12X500G IWS	F0207	IWS Cheddar	700	125	6

Item No	Item Description	Form	Group	Seq	SPR	Weight
801320	C/D CHED CLRD 24X250G	F0271	IWS B Flavours	1490	125	6
801560	C/D CHED 12X500G THAILAND	F0280	IWS Cheddar	450	120	6
801810	ANC PLAIN 24X250G IWS	F0206	IWS Cheddar	260	130	6
801890	C/D CHED 24X250G HK/TAIWAN	F0280	IWS Cheddar	380	120	6
801920	C/D TRIM 24X250G THAILAND	F0214	IWS Cheddar	140	120	6
802020	C/D P/APPLE THAILAND IWS	F0284	IWS B Flavours	1430	110	6
802110	MLD SLICED ONES 250G	F0280	IWS Cheddar	390	125	6
802130	MLD SLICED ONES 500G	F0280	IWS Cheddar	460	125	6
802131	MLD SLICED ONES 500G PROMO	F0280	IWS Cheddar	470	122	6
802210	C/D GARLIC 250G (MOD)	F0286	IWS A Flavours	1160	117	6
802270	C/D CHED 250G (MOD)	F0280	IWS Cheddar	400	125	6
802280	C/D TRIM 250G (MOD)	F0214	IWS Cheddar	150	120	6
802290	C/D TRIM 250G (CHINESE)	F0214	IWS Cheddar	160	120	6
802310	C/D P/APPLE 250G (MOD)	F0284	IWS B Flavours	1440	117	6
802320	C/D P/APPLE 250G (CHINESE)	F0284	IWS B Flavours	1450	117	6
802330	C/D ONION 250G (MOD)	F0281	IWS Cheddar	1030	117	6
802340	C/D SMOKED 250G (MOD)	F0285	IWS B Flavours	1650	117	6
802350	C/D CHED 500G (MOD)	F0280	IWS Cheddar	480	125	6
802360	C/D 6 SLICE 125G (MOD)	F0280	IWS Cheddar	360	65	6
802380	VAL CHED 250G (MOD)	F0274	IWS Cheddar	520	125	6
802390	VAL CHED 250G (CHINESE)	F0274	IWS Cheddar	530	125	6
802410	C/D GARLIC 250G (MOD) THAILAND	F0286	IWS A Flavours	1170	113	6
802880	W/WATCHERS 12X250G	F0214	IWS Cheddar	135	234	3
803480	C/D P/APPLE 250G (STD)	F0221	IWS B Flavours	1470	117	6
803490	C/D TRIM 250G (STD)	F0214	IWS Cheddar	180	120	6
803510	C/D GARLIC 250G (H/K)	F0286	IWS A Flavours	1180	113	6
803520	C/D GARLIC 250G (STD)	F0238	IWS A Flavours	1200	117	6
803540	C/D ONION 24X250G TWN IWS	F0281	IWS Cheddar	1040	117	6
803550	C/D SMKD 24X250G TWN IWS	F0285	IWS B Flavours	1660	117	6
803610	C/D COLOURED 24X250G SPAINISH	F0271	IWS B Flavours	1500	125	6
803620	C/D COLOURED 12X500G SPAINISH	F0271	IWS B Flavours	1510	125	6
803630	C/D TRIM 24X250G SPAINISH	F0214	IWS Cheddar	190	120	6
803920	C/D CHED 500G PLAIN NZMPP	F0215	IWS Cheddar	350	125	6
804010	ANC 250G (HALAL) S.E.A	F0206	IWS Cheddar	270	130	6
804020	ANC DUNKIN DONUTS 30X168G IWS	F0206	IWS Cheddar	250	117	5
804290	C/D ONION 24X250G HONG KONG	F0281	IWS Cheddar	1050	117	6
804360	C/D SMKD 24X250G HONG KONG	F0285	IWS B Flavours	1670	117	6
804370	C/D CHED 24X250G THAILAND	F0280	IWS Cheddar	410	120	6
804390	C/D ONION 24X250G THAILAND	F0281	IWS Cheddar	1060	110	6
804410	C/D SMKD 24X250G THAILAND	F0285	IWS B Flavours	1680	117	6
804570	C/D CHED 500G TAIWAN	F0280	IWS Cheddar	490	120	6
804580	C/D GARLIC 250G TAIWAN	F0286	IWS A Flavours	1190	117	6
804590	ANC L/SORB 250G TAIWAN IWS	F0206	IWS Cheddar	280	125	6
804600	ANC ARABIC 24X250G IWS	F0207	IWS Cheddar	670	125	6
804730	ANC L/SORB 24X250G HK/T IWS	F0206	IWS Cheddar	290	125	6
804740	ANC PLAIN 24X250G L/SORB IWS	F0206	IWS Cheddar	300	130	6
804760	ANC L/SORB 12X500G IWS	F0206	IWS Cheddar	310	130	6
804930	C/D CHIVES 24X250G EXPORT IWS	F0226	IWS A Flavours	1220	117	6
804940	C/D SMKD 24X250G EXPORT IWS	F0223	IWS B Flavours	1690	117	6
804950	C/D ONION 24X250G EXPORT IWS	F0218	IWS Cheddar	1070	117	6
804960	C/D CHED 24X250G EXPORT IWS	F0215	IWS Cheddar	330	125	6
805000	ANC LOW FAT 24X250G IWS	F0198	IWS Cheddar	125	120	6
806060	C/D CHED 250G (3X8)	F0280	IWS Cheddar	420	125	6
806610	ANC L/SORB 500G TAIWAN IWS	F0206	IWS Cheddar	320	130	6
807150	C/D CHED 24X250G	F0280	IWS Cheddar	430	125	6
807160	C/D P/APPLE 250G	F0284	IWS B Flavours	1460	117	6
807170	C/D TRIM 250G	F0214	IWS Cheddar	200	120	6
807180	VAL CHED 250G	F0274	IWS Cheddar	540	125	6
807290	C/D PLAIN 24X200G (CIS) IWS	F0280	IWS Cheddar	370	125	4.8
807300	C/D GARLIC 200G (CIS)	F0286	IWS A Flavours	1150	117	4.8
807310	C/D CHIVES 200G (CIS) IWS	F0282	IWS A Flavours	1240	117	4.8
807320	C/D SMKD 200G (CIS)	F0285	IWS B Flavours	1640	117	4.8
807330	C/D ONION 200G (CIS) IWS	F0281	IWS Cheddar	1020	117	4.8
807620	ANC GIANT PACK 1KG IWS	F0207	IWS Cheddar	720	120	6
807660	C/D CHED 250G (3X8)-VIETNAM	F0280	IWS Cheddar	440	125	6
807700	C/D 6 SLICE 113G COLOURED IWS	F0208	IWS B Flavours	1540	67	5.7
807720	C/D 750G MIDDLE EAST	F0207	IWS Cheddar	710	107	6.8
807850	VAL PLAIN 24X200G STH AFRICA	F0274	IWS Cheddar	630	116	4.8
807890	NO FRILLS REG 250G FRANKLINS	F0274	IWS Cheddar	560	135	6
807900	VAL 48X200G 10 SLICE LIBYA	F0114	IWS Cheddar	510	62	9.6

Item No	Item Description	Form	Group	Seq	SPR	Weight
807920	NO FRILLS REG 500G FRANKLINS	F0274	IWS Cheddar	590	135	6
807930	F/C REDUCED FAT 250G	F0230	IWS Cheddar	50	115	6
807940	NO FRILLS LITE 500G FRANKLIN	F0273	IWS Cheddar	70	125	6
807960	FIRST CHOICE REGULAR 250G	F0275	IWS Cheddar	620	103	6
807970	FIRST CHOICE REGULAR 500G FR	F0275	IWS Cheddar	630	120	6
807980	F/C REDUCED FAT 500G	F0230	IWS Cheddar	60	115	6
807990	F/C PINEAPPLE IWS 250G	F0287	IWS B Flavours	1530	108	6
808060	HOME BRAND REG 250G IWS	F0274	IWS Cheddar	570	135	6
808070	MLD SUPER LITE ONES 250G IWS	F0263	IWS Cheddar	10	115	6
808080	MLD SUPER LITE ONES 500G IWS	F0263	IWS Cheddar	20	115	6
808090	HOME BRAND REG 500G IWS	F0274	IWS Cheddar	600	135	6
808110	F/C SUNDRIED TOMATO F/LINS	F0289	IWS Cheddar	1390	113	6
808120	C/D TRIM 24X250G ARABIC	F0214H	IWS Cheddar	220	120	6
808130	C/D ONION 24X250G M/E	F0218	IWS Cheddar	1080	117	6
808140	C/D H&GARLIC 24X250G ARABIC	F0220	IWS A Flavours	1330	117	6
808150	C/D P/APPLE 24X250G ARABIC	F0221	IWS B Flavours	1480	117	6
808160	C/D SMKD 24X250G ARABIC	F0223	IWS B Flavours	1700	117	6
808170	C/D CHED 24x250G	F0215H	IWS Cheddar	640	135	6
808180	C/D CHED 12X500G ARABIC	F0215H	IWS Cheddar	650	130	6
808190	C/D H&GARLIC 24x250G GUATEMA	F0220	IWS A Flavours	1340	117	6
808200	VAL 250G - MALTA	F0111A	IWS Cheddar	500	125	6
808230	TASTEE IWS 24X200G	F0208	IWS B Flavours	1550	120	4.8
808360	C/D CHED 24X250G PACIFIC IWS	F0215	IWS Cheddar	340	100	6
808370	ANC COL 24X250G IWS PACIFIC	F0208	IWS B Flavours	1570	85	6
808380	C/D ONION 24X250G PACIFIC IW	F0218	IWS Cheddar	1090	110	6
808390	C/D SMKD 24X250G PACIFIC IWS	F0223	IWS B Flavours	1710	102	6
808400	C/D CHIVES 24X250G PACIFIC I	F0226	IWS A Flavours	1230	105	6
808420	C/D TRIM 250G (MOD) PACIFIC	F0214	IWS Cheddar	210	105	6
808430	C/D 375G MIDDLE EAST	F0207	IWS Cheddar	680	104	6.8
808470	C/D TRIM 500G MIDDLE EAST	F0214H	IWS Cheddar	230	117	6
99003485	MLD CALCIUM ONES 500G PROMO	F0279	IWS Cheddar	210	136	6
9927112	MLD TASTY 24X250G IWS PROMO	F0234	IWS Cheddar	970	152	6
9927113	MLD COLBY 24X250G IWS PROMO	F0236	IWS Cheddar	910	137	6
9927116	MLD FRMHSE BACON 24x250G PRO	F0330	IWS B Flavours	1770	133	6
9927117	MLD GDN CHVS 24X250G IWS PRO	F0282	IWS A Flavours	1270	136	6
9927118	MLD THICK&TASTY 250G IWS PRO	F0234	IWS Cheddar	990	136	6
9927132	MLD EDAM 250G IWS PROMO	F0239	IWS Cheddar	860	129	6
9927133	MLD CRKD PEP 24X250G IWS PRO	F0251	IWS A Flavours	1370	130	6
9927138	MLD SMKD 24X250G IWS PROMO	F0232	IWS B Flavours	1600	130	6
9927142	MLD CHED 24X250G IWS PROMO	F0111	IWS Cheddar	750	127	6
9927144	MLD ONION 24X250G IWS PROMO	F0233	IWS Cheddar	1120	143	6
9927151	MLD LITESLCE 24X250G IWS PRO	F0244	IWS A Flavours	100	130	6
9963763	C/D CHED 24X250G PROMO PACK	F0111	IWS Cheddar	770	136	6
9963764	C/D COLBY 250G PROMO PACK	F0236	IWS Cheddar	930	137	6
9963765	C/D TASTY 250G PROMO PACK	F0234	IWS Cheddar	1010	137	6
9963767	C/D CHIVES 24X250G PROMO PAC	F0282	IWS A Flavours	1300	136	6
9963769	C/D HRB&GARLIC 24X250G PROMO	F0219	IWS A Flavours	1320	136	6
9963770	C/D ONION 24X250G PROMO PACK	F0233	IWS Cheddar	1140	136	6
9963771	C/D P/APPLE 24X250G PROMO PA	F0284	IWS B Flavours	1420	135	6
9963772	C/D SMKD 24X250G PROMO PACK	F0232	IWS B Flavours	1630	136	6
9963774	C/D LIGHT&TRIM 24X250G PROMO	F0244	IWS A Flavours	120	130	6
9963775	C/D NACHO 250G PROMO PACK	F0253	IWS B Flavours	1740	115	6
9963776	C/D BURGER 250G PROMO PACK	F0330	IWS B Flavours	1790	115	6
9963777	C/D PIZZA 250G LOC PROMO PAC	F0254	IWS Cheddar	552	115	6
9963778	C/D EDAM 250G PROMO PACK	F0239	IWS A Flavours	880	129	6
9963785	Chesdale Cheddar 1kg Promo P	F0111	IWS Cheddar	820	136	12
99807720	C/D 750G MIDDLE EAST Promo	F0207	IWS Cheddar	710	119	6.8
99808080	MLD SUPERLITE ONES 500G PRO	F0263	IWS Cheddar	30	130	6
99808170	C/D CHED 24x250G Promo	F0215H	IWS Cheddar	640	134	6
99808180	C/D CHED 12X500G ARABIC Pro	F0215H	IWS Cheddar	650	141	6

1.2 - Slice on Slice - List of Items

Item No	Item Description	Form	Group	Seq	SPR	Weight
002970	WENDYS 6X2.05KG	F05008	Colour 1.2kg	221	73	12.3
004312	BURGER KING 14x1.0845kg HILACT	F05005	Colour 1.2kg	220	78	15.2
004751	HIMELT 2.436KG	F05025	Hi-Melt	164	36	14.6
27260	MLD SANDWICH 1.2KG SOS	F05010	Pale 1.2kg	139	66	14.4
27266	MLD GRUYERE 12X1.2KG SOS	F05051	Pale Swiss/Moz	169	51	14.4
27271	MLD BURGER 12X1.2KG	F05012	Colour 1.2kg	219	81	14.4
54321	BURGER KING 6X2.05kg NZ	F05005	Colour 1.2kg	229	78	13
63792	WENDY'S 990G LOCAL SOS	F05070	Colour 990g	219	85	11.9
63793	KFC 12X990G LOCAL	F05070	Colour 990g	239	91	11.9
63797	WENDYS 6X2.05kg LOCAL	F05008	Colour 1.2kg	229	74	13
63798	WENDYS SMOKED 6X2.05kg	F05009	Flavour 2.05kg	300	48	13
66920	CHES CHEDDAR 12X1.2KG	F05010	Pale 1.2kg	139	68	14.4
66930	CHES HAMBURGER 12X1.2KG	F05070	Colour 1.2kg	219	68	14.4
805950	ANC CLRD 12X1.2KG	F05012	Colour 1.2kg	210	90	14.4
805970	ANC CLRD 12X1.2KG SEA	F05012	Colour 1.2kg	210	90	14.4
805990	ANC PALE 12X1.2KG	F05010	Pale 1.2kg	130	102	14.4
806070	ANC PALE 12X1.2KG M.EAST SOS	F05010	Pale 1.2kg	130	102	14.4
806080	ANC PALE 12X1.2KG SEA	F05010	Pale 1.2kg	130	102	14.4
806350	ANC MOZZARELLA 1.2KG SOS	F05073	Pale Swiss/Moz	150	57	14.4
806380	AUSTRALIA 990G EXPORT	F05070	Colour 990g	230	90	11.9
806390	BURGER KING 12X990G EXPORT SOS	F05003	Colour 990g	240	83	11.9
806400	BURGER KING SWISS 990G EXP SOS	F05051	Pale Swiss/Moz	160	62	11.9
806440	MEIJI 12X900G	F05014	Meiji 900g	200	55	10.8
806480	ANC CLRD 12X990G TAIWAN	F05012	Colour 990g	210	91	11.9
806490	ANC PALE 12X990G TAIWAN	F05010	Pale 990g	130	80	11.9
806540	MCDONALDS 8x2.27KG SEA SOS	F05002	McD's 2.27kg	260	84	18.2
806850	MCDONALDS 8x2.27kg TAIWAN	F05002	McD's 2.27kg	260	84	18.2
807230	MLD 1.5KG 90X90MM AUST SOS	F05060	Pale 1.5kg	4	104	12
807430	GRAND CHOICE 1.5KG SOS	F05060	Pale 1.5kg	100	104	12
807490	BURGER KING 12X990G JAPAN	F05004	Colour 990g	250	92	11.9
807610	BURGER KING 12X990G M/EAST SOS	F05003	Colour 990g	240	88	11.9
807690	HUNGRY JACK'S CHIVES 2.2KG	F05006	Flavour 2.05kg	310	54	13.2
807870	SUBWAY SWISS 990G EXP	F05051	Pale Swiss/Moz	160	64	11.9
807950	NO FRILLS 1KG FRANKLINS	F05011	Pale 1.5kg	110	63	12
808040	BURGER KING 6X2.05kg	F05005	Colour 1.2kg	220	78	13
808050	BURGER KING PEPPER JACK	F05007	Flavour 2.05kg	320	30	13.2
808210	WENDYS 6X2.05kg	F05008	Colour 1.2kg	220	74	13
808220	WENDYS SMOKED 6X2.05kg	F05009	Flavour 2.05kg	300	85	13
808410	ANC PALE 12X1.2KG PACIFIC	F05010	Pale 1.2kg	130	90	14.4

1.3 - Cheez Toyz/Bodz - List of Items

Item No	Item Description	Form	Group	Seq	SPR	Weight
004319	C/D C/TOYZ ANIMALZ 24x140 S	F0710	RDS Toyz	1	40	3.4
004326	C/D CHEEZ TOYZ ANIMALZ 140g	F0710	RDS Toyz	2	40	3.4
27200	MLD CHEEZ BODZ - FANTASY	F0710	RDS Bodz	2	80	1.7
27205	MLD CHEEZ BODZ - ADVENTURE	F0710	RDS Bodz	3	80	1.7
27210	MLD CHEEZ BODZ - LUNATIC	F0710	RDS Bodz	4	80	1.7
807500	CHES CHEEZ TOYZ 140g SINGAPO	F0710	RDS Toyz	1	40	3.4
807510	CHES CHEEZ TOYZ 140g TAIWAN	F0710	RDS Toyz	1	40	3.4
807520	CHES CHEEZ TOYZ 140g MALAYSI	F0710	RDS Toyz	1	40	3.4
807530	CHES CHEEZ TOYZ 140g INDONES	F0710	RDS Toyz	1	40	3.4
807590	CHES CHEEZ TOYZ 40x140g TAIW	F0710	RDS Toyz	1	24	5.6
807630	MLD CHEEZ BODZ - FANTASY	F0710	RDS Bodz	2	80	1.7
807640	MLD CHEEZ BODZ - ADVENTURE	F0710	RDS Bodz	3	80	1.7
807650	MLD CHEEZ BODZ - LUNATIC	F0710	RDS Bodz	4	80	1.7
807730	CD CHEEZ TOYZ FANTASY SING	F0710	RDS Bodz	2	40	3.4
807740	CD CHEEZ TOYZ ADVENTURE SING	F0710	RDS Bodz	3	40	3.4
808250	CHEEZ TOYZ 140g CHILE	F0710	RDS Toyz	1	24	5.6

1.4 - Cheese Spreads - List of Items

Item No	Item Description	Form	Group	Seq	SPR	Weight
004339	C/D CHEESE SPREAD 200G NZMP	F0700	RDS Spreads	80	83	4.8
12200	MLD FRENCH ONION 200G SPREAD	F0701	RDS Spreads	30	83	2.4
13200	MLD TASTY CHEESE SPREAD 200G	F0700	RDS Spreads	10	83	2.4
14200	MLD SMOKED 200G SPREAD	F0702	RDS Spreads	20	83	2.4
77700	KOROMIKO ONION SPRD 200G	F0701	RDS Spreads	400	83	4.8
77710	KOROMIKO SMOKE SPRD 200G	F0704	RDS Spreads	22	83	4.8
77720	KOROMIKO GARLIC SPRD 200G	F0703	RDS Spreads	405	83	4.8
806910	C/D CHEESE SPRD 24X200G MALA	F0711	RDS Spreads	0	83	4.8
807050	C/D CHEESE SPRD 24X200G TAIW	F0711	RDS Spreads	0	83	4.8
807060	C/D CHEESE SPRD 24X200G SING	F0711	RDS Spreads	0	83	4.8
31121	GLXY FRCH ONION SPRD 12X150G	F0413	Vogele Spread	400	80	1.8
31122	GLXY TASTY SPRD 12X150G	F0414	Vogele Spread	200	80	1.8
31124	GLXY BLUE VEIN SPRD 12X150G	F0410	Vogele Spread	900	60	1.8
31127	GLXY SMOKD SPRD 12X150G	F0411	Vogele Spread	300	80	1.8
31128	GLXY HERB&GARLIC SPRD 12X150G	F0420	Vogele Spread	0	80	1.8

1.5 - Packets (250g) - List of Items

Item No	Item Description	Form	Group	Seq	SPR	Weight
63760	C/D PACKET 24X250G LOCAL	F0608	Vogele Packet	44	76	6
802190	C/D PACKET 2X24X250G PDP ONLY	F0608	Vogele Packet	43	38	12
802770	C/D PACKET 2X24X250 NZMPP FIJI	F0607	Vogele Packet	41	38	12
805100	C/D F/PACK 24X500G EXPORT	F0608	Vogele Packet	46	25	12
806830	C/D PACKETS 24X250G (MOD)	F0607	Vogele Packet	40	76	6
807030	C/D PACKET 2X24X250G MOD	F0607	Vogele Packet	40	38	12

1.6 - Blocks (20kg) - List of Items

Item No	Item Description	Form	Group	Seq	SPR	Weight
001887	KIWI FRUIT CREAM CHEESE	F0601	Reitz 21kg	21	30	20
002181	DICEABLE CREAM CHEESE 1x20KG	F0600	Reitz 21kg	21	45	20
11351	K BASE	F0331	Reitz 21kg	102	900	1
803760	NZ HI-MELT 21KG MOULD	F0320	Reitz 21kg	21	60	21
807470	HI-MELT 21KG TAIWAN	F0602	Reitz 21kg	21	60	21
807480	KFC-HI MELT LOGS 15X1KG	F0320	Reitz 21kg	28	50	15
807710	NZ HI-MELT 21KG for GRATED	F0320	Reitz 21kg	21	60	21
807750	PEPPER JACK BLOCK	F0321	Reitz 21kg	21	30	20

1.7 - Blocks (2kg) - List of Items

Item No	Item Description	Form	Group	Seq	SPR	Weight
63796	HI-MELT 8X2KG (ET)	F0602	Reitz 2kg	12	60	16
802000	ANC COLOURED BLOCK 6X2KG	F0606	Reitz 2kg	31	90	12
802200	ANC HI-MELT 6X2KG	F0602	Reitz 2kg	10	90	12
805910	ANC HI-MELT 6X2KG HI SORB	F0603	Reitz 2kg	10	90	12
808440	ANC HI-MELT 6X2KG (M.EAST)	F0603	Reitz 2kg	10	90	12

1.8 - Skins - List of Items

Item No	Item Description	Form	Group	Seq	SPR	Weight
31310	GLXY CRCKD PEPPER 2KG SKIN	F0303	Reitz Skin	82	60	8
31312	GLXY CHIVES 4X2KG	F0308	Reitz Skin	72	60	8
31313	GLXY SMOKY HAM 4X2KG	F0310	Reitz Skin	111	60	8
31314	GLXY SMOKD 4X2KG	F0307	Reitz Skin	62	60	8
31315	GLXY HERB & GARLIC 4X2KG	F0302	Reitz Skin	102	60	8
63795	HI-MELT SKINS 9X1.5KG (ET)	F0312	Reitz Skin	27	45	13.5
800460	MLD SMOKD 4X2KG	F0307	Reitz Skin	61	60	8
800480	MLD SMOKY HAM 4X2KG	F0310	Reitz Skin	111	60	8
800500	MLD CHIVES 4X2KG	F0308	Reitz Skin	71	60	8
800510	MLD HERB & GARLIC 4X2KG	F0302	Reitz Skin	101	60	8
806720	HIMELT ROUND CHUB 85MM	F0320	Reitz Skin	25	25	12.8
807120	HIMELT ROUND CHUB 75MM	F0320	Reitz Skin	0	60	10

1.9 - Enzyme Modified Cheese - List of Items

Item No	Item Description	Form	Group	Seq	SPR	Weight
001306	EMC FOR EXPORT	F0332	EMC	102	70	1
001360	EMC FOR EXPORT	F0332	EMC	102	70	20
11360	ENZYME MODIFIED CHEESE (EMC)	F0332	EMC	102	70	1

1.10 - Pastes and Slurries - List of Items

Item No	Item Description	Form	Group	Seq	SPR	Weight
31601893	ROMANO CHEESE PASTE	F0353	Key Slurries	0	65	20
31611893	CHEDDAR 'A' PASTE	F0354	Key Slurries	0	65	20
31614861	CHEDDAR 'A' PASTE	F0354	Key Slurries	0	65	10
31621893	AMERICAN PASTE FOR EXPORT	F0345	Key Slurries	0	65	20

Appendix 2 - SQL Statements of Constraints and Restrictions

2.1 - Specialty Processed Cheese Department SQL Statement

```
SELECT DISTINCT qryBPCSFPOs1.FPROD AS ItemNo, tblScheduleItem.ItemDescriptio
n, CDate([qryBPCSFPOs1].[Release]) AS Release, CDate([qryBPCSFPOs1].[DueDate
]) AS DueDate, qryBPCSFPOs1.FQTY AS Qty, [DueDate]-35 AS EarliestMake, IIf([
tblscheduleitem].[Line] Is Null,"",[tblscheduleitem].[Line]) AS Line, IIf([t
blGroups1].[GroupIndex] Is Null,99,[tblGroups1].[GroupIndex]) AS GroupIndex,
 IIf([tblGroups1].[GroupName] Is Null,"",[tblGroups1].[GroupName]) AS GroupN
ame, IIf([tblSubGroups1].[SubGroupIndex] Is Null,199,[tblSubGroups1].[SubGro
upIndex]) AS SubGroupIndex, IIf([tblSubGroups1].[SubGroupName] Is Null,"",[t
blSubGroups1].[SubGroupName]) AS SubGroupName, nz([SchShipDate]-7-IIf(Left([
ShipToName],8)="Mainland",4,IIf(nz([Consolidation],"")="PFL",4,10)),[qryBPCS
FPOs1].[DueDate]) AS ManufDue, IIf([FQTY]/[SPR] Is Null,0,[FQTY]/[SPR]) AS I
temsVsQtyGroupQty, IIf([FQTY]*[CartonWeight] Is Null,0,[FQTY]*[CartonWeight]
) AS ItemsVsQtySubGroupQty, tblScheduleItem.Seq, IIf([IREF01]>="30" And [IRE
F01]<>"51",[Qty]/[SPR],0) AS Constraint1, IIf([IREF01]>="30" And [IREF01]<="
34",[Qty]/[SPR],0) AS Constraint2, IIf([IREF01]>="30" And [IREF01]<="34",[Qt
y]/[SPR],0) AS Constraint3, IIf([IREF01]>="80" And [IREF01]<="82",[Qty]/[SPR
],0) AS Constraint4, IIf([IREF01]>="70" And [IREF01]<="72",[Qty]/[SPR],0) AS
 Constraint5, IIf(([IREF01]>="60" And [IREF01]<="62") Or [IREF01]="73",[Qty]
/[SPR],0) AS Constraint6, IIf([IREF01]="61" Or [IREF01]="73",IIf([cartonweig
ht]>19,[qty],[cartonweight]*[qty]/20),0) AS Constraint7, IIf([IREF01]="50",[
Qty]/[SPR],0)+IIf([IREF01]="51",[Qty]*16/2200,0) AS Constraint8, IIf([IREF01
]="51",[Qty],0) AS Constraint9, 0 AS Constraint10, 0 AS Constraint11, 0 AS C
onstraint12, 0 AS Constraint13, 0 AS Constraint14, 0 AS Constraint15, 0 AS C
onstraint16, 0 AS Constraint17, 0 AS Constraint18, 0 AS Constraint19, 0 AS C
onstraint20, qryBPCSFPOs1.FCLAS, qryBPCSFPOs1.FWHSE, qryBPCSFPOs1.FPBUYC, qr
yBPCSFPOs1.Status FROM (tblSubGroups1 RIGHT JOIN (tblGroups1 RIGHT JOIN (qry
BPCSFPOs1 INNER JOIN tblScheduleItem ON qryBPCSFPOs1.FPROD = tblScheduletem.
Item) ON tblGroups1.GroupIndex = tblScheduleItem.GroupIndex) ON tblSubGroups
1.SubGroupIndex = tblScheduleItem.SubGroupIndex) LEFT JOIN qryCustomerOrders
 ON (qryBPCSFPOs1.FPROD = qryCustomerOrders.ItemCode) AND (qryBPCSFPOs1.DueD
ate = qryCustomerOrders.RequestedDate) WHERE (((qryBPCSFPOs1.Status)<>"Del"
And (qryBPCSFPOs1.Status)<>"New") AND ((IIf([Item]="11111",1,0)+IIf([Item]="
22222",1,0)+IIf([Item]="33333",1,0)+IIf([Item]="44444",1,0)+IIf([Item]="5555
5",1,0)+IIf([Item]="66666",1,0)+IIf([Item]="77777",1,0)+IIf([Item]="88888",1
,0)+IIf([Item]="99999",1,0))=0) AND ((tblScheduleItem.SchedGroup)>"20")) ORD
ER BY CDate([qryBPCSFPOs1].[Release]), CDate([qryBPCSFPOs1].[DueDate]);
```

2.2 - Individually Wrapped Slices Department SQL Statement

```
SELECT DISTINCT qryBPCSFPOs2.FPROD AS ItemNo, tblScheduleItem.ItemDescriptio
n, CDate([qryBPCSFPOs2].[Release]) AS Release, CDate([qryBPCSFPOs2].[DueDate
]) AS DueDate, [DueDate]-35 AS EarliestMake, qryBPCSFPOs2.FQTY AS Qty, IIf([
tblscheduleitem].[Line] Is Null,"",[tblscheduleitem].[Line]) AS Line, IIf([t
blGroups2].[GroupIndex] Is Null,99,[tblGroups2].[GroupIndex]) AS GroupIndex,
 IIf([tblGroups2].[GroupName] Is Null,"",[tblGroups2].[GroupName]) AS GroupN
ame, IIf([tblSubGroups2].[SubGroupIndex] Is Null,199,[tblSubGroups2].[SubGro
upIndex]) AS SubGroupIndex, IIf([tblSubGroups2].[SubGroupName] Is Null,"",[t
blSubGroups2].[SubGroupName]) AS SubGroupName, tblScheduleItem.Formulation A
S Form, nz([SchShipDate]-7-IIf(Left([ShipToName],8)="Mainland",4,IIf(nz([Con
solidation],"")="PFL",4,10)),[DueDate]) AS ManufDue, IIf([FQTY]/[SPR] Is Nul
l,0,[FQTY]/[SPR]) AS ItemsVsQtyGroupQty, IIf([FQTY]*[CartonWeight] Is Null,0
,[FQTY]*[CartonWeight]) AS ItemsVsQtySubGroupQty, tblScheduleItem.Seq, IIf([
IREF01]<="30",[Qty]*[cartonweight]/10,0) AS Constraint1, IIf([Form]="F0263",
[Qty]*[cartonweight]/1000,0)+IIf([Fom]="F0230",[Qty]*[cartonweight]/1000,0)+
IIf([Form]="F0279",[Qty]*[cartonweight]/1000,0) AS Constraint2, IIf([Form]="
F0264",[Qty]*[cartonweight]/1000,0)+IIf([Form]="F0244",[Qty]*[cartonweight]/
1000,0)+IIf([Form]="F0198",[Qty]*[cartonweight]/1000,0)+IIf([Form]="F0214",[
Qty]*[cartonweight]/1000,0)+IIf([Form]="F0214H",[Qty]*[cartonweight]/1000,0)
+IIf([Form]="F0281",[Qty]*[cartonweight]/1000,0)+IIf([Form]="F0218",[Qty]*[c
artonweight]/1000,0)+IIf([Form]="F0233",[Qty]*[cartonweight]/1000,0)+IIf([Fo
rm]="F0286",[Qty]*[cartonweight]/1000,0)+IIf([Form]="F0238",[Qty]*[cartonwei
ght]/1000,0)+IIf([Form]="F0265",[Qty]*[cartonweight]/1000,0)+IIf([Form]="F02
26",[Qty]*[cartonweight]/1000,0)+IIf([Form]="F0282",[Qty]*[cartonweight]/100
0,0)+IIf([Form]="F0219",[Qty]*[cartonweight]/1000,0)+[TempConstraint3] AS Co
nstraint3, IIf([Form]="F0220",[Qty]*[cartonweight]/1000,0)+IIf([Form]="F0251
",[Qty]*[cartonweight]/1000,0)+IIf([Form]="F0289",[Qty]*[cartonweight]/1000,
0)+IIf([Form]="F0284",[Qty]*[cartonweight]/1000,0)+IIf([Form]="F0221",[Qty]*
[cartonweight]/1000,0)+IIf([Form]="F0287",[Qty]*[cartonweight]/1000,0)+IIf([
Form]="F0232",[Qty]*[cartonweight]/1000,0)+IIf([Form]="F0285",[Qty]*[cartonw
eight]/1000,0)+IIf([Form]="F0223",[Qty]*[cartonweight]/1000,0)+IIf([Form]="F
0288",[Qty]*[cartonweight]/1000,0)+IIf([Form]="F0253",[Qty]*[cartonweight]/1
000,0)+IIf([Form]="F0330",[Qty]*[cartonweight]/1000,0) AS TempConstraint3, 0
 AS Constraint4, 0 AS Constraint5, 0 AS Constraint6, 0 AS Constraint7, 0 AS
Constraint8, 0 AS Constraint9, 0 AS Constraint10, 0 AS Constraint11, 0 AS Co
nstraint12, 0 AS Constraint13, 0 AS Constraint14, 0 AS Constraint15, 0 AS Co
nstraint16, 0 AS Constraint17, 0 AS Constraint18, 0 AS Constraint19, 0 AS Co
nstraint20, qryBPCSFPOs2.FCLAS, qryBPCSFPOs2.FWHSE, qryBPCSFPOs2.FPBUYC, qry
BPCSFPOs2.Status FROM (tblSubGroups2 RIGHT JOIN (tblGroups2 RIGHT JOIN (qryB
PCSFPOs2 LEFT JOIN tblScheduleItem ON qryBPCSFPOs2.FPROD = tblScheduleItem.I
tem) ON tblGroups2.GroupIndex = tblScheduleItem.GroupIndex) ON tblSubGroups2
.SubGroupIndex = tblScheduleItem.SubGroupIndex) LEFT JOIN qryCustomerOrders
ON (qryBPCSFPOs2.FPROD = qryCustomerOrders.ItemCode) AND (qryBPCSFPOs2.DueDa
te = qryCustomerOrders.RequestedDate) WHERE (((qryBPCSFPOs2.Status)<>"New" A
nd (qryBPCSFPOs2.Status)<>"Del") AND ((IIf([Item]="11111",1,0)+IIf([Item]="2
2222",1,0)+IIf([Item]="33333",1,0)+IIf([Item]="44444",1,0)+IIf([Item]="55555
",1,0)+IIf([Item]="66666",1,0)+IIf([Item]="77777",1,0)+IIf([Item]="88888",1,
0)+IIf([Item]="99999",1,0))=0) AND ((tblScheduleItem.SchedGroup)<"15")) ORDE
R BY CDate([qryBPCSFPOs2].[Release]), CDate([qryBPCSFPOs2].[DueDate]);
```

Appendix 3 - Trials

3.1 - Procedures for Trials

3.1.1 - Procedure for Trials of Scheduling Strategies

Sequence dependant set-ups are the most significant problem in scheduling at Pastoral Foods (NZ) Limited. It is the most significant contributor to planned down time in the factories and it also has the greatest potential gain. There are many possible schemes for reducing the effects of sequence dependant set-ups. A list of proposed strategies was prepared and the best technique was test for. To test which is the best strategy for reducing the effective changes in Total Make-span each strategy was programmed into a macro and the resulting schedule's were analysed and compared. The list of proposed strategies is as follows...

- Due Date Sequence Only
- Batch Same Items
- Batch Same Formulations
- Batch Same Sizes
- Batch Same Groups
- Batch Same 'Odd Ball' Groups
- Batch Same Groups, Then Same Items
- Batch Same Groups, Then Same Formulations
- Batch Same Groups, Then Same Sizes
- Batch Same 'Odd Ball' Groups, Then Same Items
- Batch Same 'Odd Ball' Groups, Then Same Formulations
- Batch Same 'Odd Ball' Groups, Then Same Sizes

The results of the trials of each of these strategies can be seen in *Appendix 3.2.1 to 3.2.12*.

3.1.2 - Procedure for Trials of Search Techniques

Four basic types of scheduling search algorithms were created in this project. They were as follows...

Branch and Bound

Random Pair-wise Swapping

Tabu Search

Combination Selected Group Complete Enumeration and Tabu Search

Each trial used the same objective function and tried minimise it. The objective function used was as follows...

[Schedule Index (in hours)] =

[Total Make-span (in hours)]

+ 6 (hours) * Σ ([Days order will be late])

+ 2 (hours) * Σ ([Days of shipping buffer to be used])

+ 1 (hours) * Σ ([Penalty for 40% chance of missing an order])

+ 0.5 (hours) * Σ ([Penalty for 30% chance of missing an order])

+ 0.2 (hours) * Σ ([Penalty for 20% chance of missing an order])

Each search technique was trialed and the results analysed for their effectiveness against the criteria chosen. The results of these trials and the schedules created by them can be seen in *Appendix 3.3.1 to 3.3.4*.

3.2 - Trials Results - Strategies Against Sequence Dependant Set-ups

3.2.1 - Due Date Sequence Only

Total Make-span = 478.36

Item No	Item Description	Qty	DueDate	Seq	Bucket	Group Name
807230	Mld 1.5kg 90x90mm Aust SOS	2400	9-Oct	1	1	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	9-Oct	2	1	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	160	9-Oct	3	1	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	23-Oct	4	1	SOS Pale 1.2kg
805990	Anc Pale 12x1.2kg SOS	200	16-Oct	5	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	500	8-Oct	6	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	125	9-Oct	7	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	350	7-Oct	8	1	SOS Pale 1.2kg
806350	Anc Mozzarella 1.2kg SOS	200	9-Oct	9	1	SOS Swiss/Moz
805970	Anc Clrd 12x1.2kg Sea SOS	80	6-Oct	10	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	40	7-Oct	11	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	8-Oct	12	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	9-Oct	13	1	SOS Colour 1.2kg
806380	Australia 990g Export SOS	600	9-Oct	14	1	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	9-Oct	15	1	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	2205	9-Oct	16	1	SOS Colour 990g
806080	Anc Pale 12x1.2kg Sea SOS	120	9-Oct	17	2	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	300	15-Oct	18	2	SOS Pale 1.2kg
805950	Anc Clrd 12x1.2kg SOS	1060	16-Oct	19	2	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	100	16-Oct	20	2	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	1200	16-Oct	21	2	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	9-Oct	22	2	SOS Colour 990g
806390	Burger King 12x990g Export S	350	16-Oct	23	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	8-Oct	24	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	14-Oct	25	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	15-Oct	26	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	16-Oct	27	2	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	16-Oct	28	2	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	2400	23-Oct	29	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	6-Nov	30	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	23-Oct	31	3	SOS Pale 1.5kg
27260	Mld Sandwich 1.2kg SOS	200	30-Oct	32	3	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	220	16-Oct	33	3	SOS Pale 1.2kg
806490	Anc Pale 12x990g Taiwan SOS	240	30-Oct	34	3	SOS Pale 990g
805950	Anc Clrd 12x1.2kg SOS	200	15-Oct	35	3	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	1050	22-Oct	36	3	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	350	23-Oct	37	3	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	120	13-Nov	38	3	SOS Colour 1.2kg
63792	Wendy's 990g Local SOS	216	23-Oct	39	3	SOS Colour 990g
63793	KFC 12x990g Local SOS	324	23-Oct	40	3	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	6-Nov	41	3	SOS Colour 990g
806380	Australia 990g Export SOS	900	23-Oct	42	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	22-Oct	43	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	23-Oct	44	3	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	1800	20-Nov	45	4	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1200	4-Dec	46	4	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	6-Nov	47	4	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	200	6-Nov	48	4	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	13-Nov	49	4	SOS Pale 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	240	29-Oct	50	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	30-Oct	51	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	13-Nov	52	4	SOS Colour 990g
806380	Australia 990g Export SOS	600	6-Nov	53	4	SOS Colour 990g
806390	Burger King 12x990g Export S	240	30-Oct	54	4	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	6-Nov	55	4	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1080	28-Oct	56	4	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	30-Oct	57	4	SOS Colour 990g
807430	Grand Choice 1.5kg SOS	200	20-Nov	58	5	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	4-Dec	59	5	SOS Pale 1.5kg
806380	Australia 990g Export SOS	900	20-Nov	60	5	SOS Colour 990g
806380	Australia 990g Export SOS	900	4-Dec	61	5	SOS Colour 990g
807490	Burger King 12x990g Japan SO	1160	13-Nov	62	5	SOS Colour 990g

3.2.2 - Batch Same Items

Total Make-span = 475.96

Item No	Item Description	Qty	DueDate	Seq	Bucket	Group Name
807230	Mld 1.5kg 90x90mm Aust SOS	2400	9-Oct	1	1	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	2400	23-Oct	2	1	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	6-Nov	3	1	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	9-Oct	4	1	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	23-Oct	5	1	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	160	9-Oct	6	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	500	8-Oct	7	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	125	9-Oct	8	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	350	7-Oct	9	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	9-Oct	10	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	300	15-Oct	11	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	220	16-Oct	12	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	13-Nov	13	1	SOS Pale 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	80	6-Oct	14	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	40	7-Oct	15	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	8-Oct	16	1	SOS Colour 1.2kg
806540	McDonalds 8x2.27kg Sea SOS	900	8-Oct	17	1	SOS Colour 990g
805990	Anc Pale 12x1.2kg SOS	200	16-Oct	18	2	SOS Pale 1.2kg
806350	Anc Mozzarella 1.2kg SOS	200	9-Oct	19	2	SOS Swiss/Moz
805950	Anc Clrd 12x1.2kg SOS	200	16-Oct	20	2	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	1060	16-Oct	21	2	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	9-Oct	22	2	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	100	16-Oct	23	2	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	1200	16-Oct	24	2	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	9-Oct	25	2	SOS Colour 990g
806380	Australia 990g Export SOS	600	9-Oct	26	2	SOS Colour 990g
806380	Australia 990g Export SOS	900	23-Oct	27	2	SOS Colour 990g
806380	Australia 990g Export SOS	600	6-Nov	28	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	9-Oct	29	2	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	2205	9-Oct	30	2	SOS Colour 990g
806380	Australia 990g Export SOS	900	20-Nov	31	3	SOS Colour 990g
806380	Australia 990g Export SOS	900	4-Dec	32	3	SOS Colour 990g
806390	Burger King 12x990g Export S	350	16-Oct	33	3	SOS Colour 990g
806390	Burger King 12x990g Export S	240	30-Oct	34	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	14-Oct	35	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	15-Oct	36	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	16-Oct	37	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	22-Oct	38	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	16-Oct	39	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1080	23-Oct	40	3	SOS Colour 990g
807430	Grand Choice 1.5kg SOS	200	6-Nov	41	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	20-Nov	42	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	4-Dec	43	4	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	200	23-Oct	44	4	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	6-Nov	45	4	SOS Pale 1.2kg
27260	Mld Sandwich 1.2kg SOS	200	30-Oct	46	4	SOS Pale 1.2kg
806490	Anc Pale 12x990g Taiwan SOS	240	30-Oct	47	4	SOS Pale 990g
805950	Anc Clrd 12x1.2kg SOS	1050	22-Oct	48	4	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	350	23-Oct	49	4	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	120	13-Nov	50	4	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	240	29-Oct	51	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	30-Oct	52	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	13-Nov	53	4	SOS Colour 990g
63792	Wendy's 990g Local SOS	216	23-Oct	54	4	SOS Colour 990g
63793	KFC 12x990g Local SOS	324	23-Oct	55	4	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	6-Nov	56	4	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	23-Oct	57	4	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	6-Nov	58	4	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	30-Oct	59	4	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	1800	20-Nov	60	5	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1200	4-Dec	61	5	SOS Pale 1.5kg
807490	Burger King 12x990g Japan SO	1160	13-Nov	62	5	SOS Colour 990g

3.2.3 - Batch Same Formulations

Total Make-span = 476.22

Item No	Item Description	Qty	DueDate	Seq	Bucket	Group Name
807230	Mld 1.5kg 90x90mm Aust SOS	2400	9-Oct	1	1	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	2400	23-Oct	2	1	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	9-Oct	3	1	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	23-Oct	4	1	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	160	9-Oct	5	1	SOS Pale 1.2kg
805990	Anc Pale 12x1.2kg SOS	200	16-Oct	6	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	500	8-Oct	7	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	125	9-Oct	8	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	350	7-Oct	9	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	9-Oct	10	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	300	15-Oct	11	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	220	16-Oct	12	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	13-Nov	13	1	SOS Pale 1.2kg
806350	Anc Mozzarella 1.2kg SOS	200	9-Oct	14	1	SOS Swiss/Moz
805950	Anc Clrd 12x1.2kg SOS	200	15-Oct	15	1	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	1060	16-Oct	16	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	80	6-Oct	17	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	40	7-Oct	18	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	8-Oct	19	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	9-Oct	20	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	100	16-Oct	21	1	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	1200	16-Oct	22	2	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	9-Oct	23	2	SOS Colour 990g
806380	Australia 990g Export SOS	600	9-Oct	24	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	8-Oct	25	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	9-Oct	26	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	14-Oct	27	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	15-Oct	28	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	16-Oct	29	2	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	2205	9-Oct	30	2	SOS Colour 990g
66910	Anc Foods 1.2kg SOS	200	23-Oct	31	3	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	6-Nov	32	3	SOS Pale 1.2kg
27260	Mld Sandwich 1.2kg SOS	200	30-Oct	33	3	SOS Pale 1.2kg
806490	Anc Pale 12x990g Taiwan SOS	240	30-Oct	34	3	SOS Pale 990g
805950	Anc Clrd 12x1.2kg SOS	1050	22-Oct	35	3	SOS Colour 1.2kg
806390	Burger King 12x990g Export S	350	16-Oct	36	3	SOS Colour 990g
806390	Burger King 12x990g Export S	240	30-Oct	37	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	22-Oct	38	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	23-Oct	39	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	6-Nov	40	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	16-Oct	41	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1080	28-Oct	42	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	30-Oct	43	3	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	1800	6-Nov	44	4	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	6-Nov	45	4	SOS Pale 1.5kg
805950	Anc Clrd 12x1.2kg SOS	350	23-Oct	46	4	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	120	13-Nov	47	4	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	240	29-Oct	48	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	30-Oct	49	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	13-Nov	50	4	SOS Colour 990g
63792	Wendy's 990g Local SOS	216	23-Oct	51	4	SOS Colour 990g
63793	KFC 12x990g Local SOS	324	23-Oct	52	4	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	6-Nov	53	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	23-Oct	54	4	SOS Colour 990g
806380	Australia 990g Export SOS	600	6-Nov	55	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	20-Nov	56	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	4-Dec	57	4	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	1800	20-Nov	58	5	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1200	4-Dec	59	5	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	20-Nov	60	5	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	4-Dec	61	5	SOS Pale 1.5kg
807490	Burger King 12x990g Japan SO	1160	13-Nov	62	5	SOS Colour 990g

3.2.4 - Batch Same Sizes

Total Make-span = 473.99

Item No	Item Description	Qty	DueDate	Seq	Bucket	Group Name
807430	Grand Choice 1.5kg SOS	200	9-Oct	2	1	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	160	9-Oct	3	1	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	23-Oct	4	1	SOS Pale 1.2kg
27260	Mld Sandwich 1.2kg SOS	200	30-Oct	5	1	SOS Pale 1.2kg
805990	Anc Pale 12x1.2kg SOS	200	16-Oct	6	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	500	8-Oct	7	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	125	9-Oct	8	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	350	7-Oct	9	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	9-Oct	10	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	300	15-Oct	11	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	220	16-Oct	12	1	SOS Pale 1.2kg
806350	Anc Mozzarella 1.2kg SOS	200	9-Oct	13	1	SOS Swiss/Moz
805950	Anc Clrd 12x1.2kg SOS	1060	16-Oct	14	1	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	200	15-Oct	15	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	80	6-Oct	16	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	40	7-Oct	17	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	8-Oct	18	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	9-Oct	19	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	100	16-Oct	20	1	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	1200	16-Oct	21	1	SOS Colour 990g
806380	Australia 990g Export SOS	600	9-Oct	22	1	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	9-Oct	23	1	SOS Colour 990g
806390	Burger King 12x990g Export S	350	16-Oct	24	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	9-Oct	25	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	8-Oct	26	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	14-Oct	27	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	15-Oct	28	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	16-Oct	29	2	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	2205	9-Oct	30	2	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	16-Oct	31	2	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	2400	23-Oct	32	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	6-Nov	33	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	23-Oct	34	3	SOS Pale 1.5kg
806540	McDonalds 8x2.27kg Sea SOS	1800	22-Oct	35	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	23-Oct	36	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	6-Nov	37	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1080	28-Oct	38	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	30-Oct	39	3	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	1800	20-Nov	40	4	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1200	4-Dec	41	4	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	6-Nov	42	4	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	20-Nov	43	4	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	4-Dec	44	4	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	200	6-Nov	45	4	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	13-Nov	46	4	SOS Pale 1.2kg
806490	Anc Pale 12x990g Taiwan SOS	240	30-Oct	47	4	SOS Pale 990g
805950	Anc Clrd 12x1.2kg SOS	1050	22-Oct	48	4	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	350	23-Oct	49	4	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	120	13-Nov	50	4	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	240	29-Oct	51	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	30-Oct	52	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	13-Nov	53	4	SOS Colour 990g
63792	Wendy's 990g Local SOS	216	23-Oct	54	4	SOS Colour 990g
63793	KFC 12x990g Local SOS	324	23-Oct	55	4	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	6-Nov	56	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	23-Oct	57	4	SOS Colour 990g
806380	Australia 990g Export SOS	600	6-Nov	58	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	20-Nov	59	5	SOS Colour 990g
806380	Australia 990g Export SOS	900	4-Dec	60	5	SOS Colour 990g
806390	Burger King 12x990g Export S	240	30-Oct	61	5	SOS Colour 990g
807490	Burger King 12x990g Japan SO	1160	13-Nov	62	5	SOS Colour 990g

3.2.5 - Batch Same Groups

Total Make-span = 474.52

Item No	Item Description	Qty	DueDate	Seq	Bucket	Group Name
807230	Mld 1.5kg 90x90mm Aust SOS	2400	9-Oct	1	1	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	9-Oct	2	1	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	160	9-Oct	3	1	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	23-Oct	4	1	SOS Pale 1.2kg
27260	Mld Sandwich 1.2kg SOS	200	30-Oct	5	1	SOS Pale 1.2kg
805990	Anc Pale 12x1.2kg SOS	200	16-Oct	6	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	500	8-Oct	7	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	125	9-Oct	8	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	350	7-Oct	9	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	9-Oct	10	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	300	15-Oct	11	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	220	16-Oct	12	1	SOS Pale 1.2kg
806350	Anc Mozzarella 1.2kg SOS	200	9-Oct	13	1	SOS Swiss/Moz
805950	Anc Clrd 12x1.2kg SOS	1060	16-Oct	14	1	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	200	15-Oct	15	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	80	6-Oct	16	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	40	7-Oct	17	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	8-Oct	18	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	9-Oct	19	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	100	16-Oct	20	1	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	1200	16-Oct	21	1	SOS Colour 990g
806380	Australia 990g Export SOS	600	9-Oct	22	1	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	9-Oct	23	1	SOS Colour 990g
806390	Burger King 12x990g Export S	350	16-Oct	24	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	9-Oct	25	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	8-Oct	26	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	14-Oct	27	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	15-Oct	28	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	16-Oct	29	2	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	2205	9-Oct	30	2	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	16-Oct	31	2	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	2400	23-Oct	32	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	6-Nov	33	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	23-Oct	34	3	SOS Pale 1.5kg
806540	McDonalds 8x2.27kg Sea SOS	1800	22-Oct	35	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	23-Oct	36	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	6-Nov	37	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1080	28-Oct	38	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	30-Oct	39	3	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	1800	20-Nov	40	4	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1200	4-Dec	41	4	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	6-Nov	42	4	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	20-Nov	43	4	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	4-Dec	44	4	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	200	6-Nov	45	4	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	13-Nov	46	4	SOS Pale 1.2kg
806490	Anc Pale 12x990g Taiwan SOS	240	30-Oct	47	4	SOS Pale 990g
805950	Anc Clrd 12x1.2kg SOS	1050	22-Oct	48	4	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	350	23-Oct	49	4	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	120	13-Nov	50	4	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	240	29-Oct	51	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	30-Oct	52	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	13-Nov	53	4	SOS Colour 990g
63792	Wendy's 990g Local SOS	216	23-Oct	54	4	SOS Colour 990g
63793	KFC 12x990g Local SOS	324	23-Oct	55	4	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	6-Nov	56	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	23-Oct	57	4	SOS Colour 990g
806380	Australia 990g Export SOS	600	6-Nov	58	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	20-Nov	59	5	SOS Colour 990g
806380	Australia 990g Export SOS	900	4-Dec	60	5	SOS Colour 990g
806390	Burger King 12x990g Export S	240	30-Oct	61	5	SOS Colour 990g
807490	Burger King 12x990g Japan SO	1160	13-Nov	62	5	SOS Colour 990g

3.2.6 - Batch Same Odd Ball Groups

Total Make-span = 474.71

Item No	Item Description	Qty	DueDate	Seq	Bucket	Group Name
807230	Mld 1.5kg 90x90mm Aust SOS	2400	9-Oct	1	1	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	6-Nov	2	1	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	9-Oct	3	1	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	160	9-Oct	4	1	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	23-Oct	5	1	SOS Pale 1.2kg
805990	Anc Pale 12x1.2kg SOS	200	16-Oct	6	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	500	8-Oct	7	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	125	9-Oct	8	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	350	7-Oct	9	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	9-Oct	10	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	300	15-Oct	11	1	SOS Pale 1.2kg
806350	Anc Mozzarella 1.2kg SOS	200	9-Oct	12	1	SOS Swiss/Moz
805950	Anc Clrd 12x1.2kg SOS	1060	16-Oct	13	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	80	6-Oct	14	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	40	7-Oct	15	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	8-Oct	16	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	9-Oct	17	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	100	16-Oct	18	1	SOS Colour 1.2kg
806380	Australia 990g Export SOS	600	9-Oct	19	1	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	16-Oct	20	2	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	9-Oct	21	2	SOS Colour 990g
806390	Burger King 12x990g Export S	350	16-Oct	22	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	9-Oct	23	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	8-Oct	24	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	14-Oct	25	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	15-Oct	26	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	16-Oct	27	2	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	2205	9-Oct	28	2	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	2400	23-Oct	29	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	20-Nov	30	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1200	4-Dec	31	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	6-Nov	32	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	23-Oct	33	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	20-Nov	34	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	4-Dec	35	3	SOS Pale 1.5kg
27260	Mld Sandwich 1.2kg SOS	200	30-Oct	36	3	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	220	16-Oct	37	3	SOS Pale 1.2kg
806490	Anc Pale 12x990g Taiwan SOS	240	30-Oct	38	3	SOS Pale 990g
805950	Anc Clrd 12x1.2kg SOS	200	15-Oct	39	3	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	1050	22-Oct	40	3	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	350	23-Oct	41	3	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	120	13-Nov	42	3	SOS Colour 1.2kg
63792	Wendy's 990g Local SOS	216	23-Oct	43	3	SOS Colour 990g
63793	KFC 12x990g Local SOS	324	23-Oct	44	3	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	6-Nov	45	3	SOS Colour 990g
806380	Australia 990g Export SOS	900	23-Oct	46	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	16-Oct	47	3	SOS Colour 990g
66910	Anc Foods 1.2kg SOS	200	6-Nov	48	4	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	13-Nov	49	4	SOS Pale 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	240	29-Oct	50	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	30-Oct	51	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	13-Nov	52	4	SOS Colour 990g
806380	Australia 990g Export SOS	600	6-Nov	53	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	20-Nov	54	4	SOS Colour 990g
806390	Burger King 12x990g Export S	240	30-Oct	55	4	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	22-Oct	56	4	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	23-Oct	57	4	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	6-Nov	58	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	4-Dec	59	4	SOS Colour 990g
807490	Burger King 12x990g Japan SO	1160	13-Nov	60	5	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1080	28-Oct	61	5	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	30-Oct	62	5	SOS Colour 990g

3.2.7 - Batch Same Groups, Then Same Items

Total Make-span = 474.52

Item No	Item Description	Qty	DueDate	Seq	Bucket	Group Name
807230	Mld 1.5kg 90x90mm Aust SOS	2400	9-Oct	1	1	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	2400	23-Oct	2	1	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	9-Oct	3	1	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	160	9-Oct	4	1	SOS Pale 1.2kg
805990	Anc Pale 12x1.2kg SOS	200	16-Oct	5	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	500	8-Oct	6	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	125	9-Oct	7	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	350	7-Oct	8	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	9-Oct	9	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	300	15-Oct	10	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	220	16-Oct	11	1	SOS Pale 1.2kg
806350	Anc Mozzarella 1.2kg SOS	200	9-Oct	12	1	SOS Swiss/Moz
805970	Anc Clrd 12x1.2kg Sea SOS	80	6-Oct	13	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	40	7-Oct	14	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	8-Oct	15	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	9-Oct	16	1	SOS Colour 1.2kg
63793	KFC 12x990g Local SOS	216	9-Oct	17	1	SOS Colour 990g
806380	Australia 990g Export SOS	600	9-Oct	18	1	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	8-Oct	19	1	SOS Colour 990g
805950	Anc Clrd 12x1.2kg SOS	1060	16-Oct	20	2	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	100	16-Oct	21	2	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	1200	16-Oct	22	2	SOS Colour 990g
806390	Burger King 12x990g Export S	350	16-Oct	23	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	9-Oct	24	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	14-Oct	25	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	15-Oct	26	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	16-Oct	27	2	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	2205	9-Oct	28	2	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	1800	6-Nov	29	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	20-Nov	30	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1200	4-Dec	31	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	23-Oct	32	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	6-Nov	33	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	20-Nov	34	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	4-Dec	35	3	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	200	23-Oct	36	3	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	6-Nov	37	3	SOS Pale 1.2kg
27260	Mld Sandwich 1.2kg SOS	200	30-Oct	38	3	SOS Pale 1.2kg
805950	Anc Clrd 12x1.2kg SOS	1050	22-Oct	39	3	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	350	23-Oct	40	3	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	240	29-Oct	41	3	SOS Colour 990g
63792	Wendy's 990g Local SOS	216	23-Oct	42	3	SOS Colour 990g
63793	KFC 12x990g Local SOS	324	23-Oct	43	3	SOS Colour 990g
806380	Australia 990g Export SOS	900	23-Oct	44	3	SOS Colour 990g
806390	Burger King 12x990g Export S	240	30-Oct	45	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	16-Oct	46	3	SOS Colour 990g
806080	Anc Pale 12x1.2kg Sea SOS	120	13-Nov	47	4	SOS Pale 1.2kg
806490	Anc Pale 12x990g Taiwan SOS	240	30-Oct	48	4	SOS Pale 990g
805950	Anc Clrd 12x1.2kg SOS	200	16-Oct	49	4	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	120	13-Nov	50	4	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	1200	30-Oct	51	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	13-Nov	52	4	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	6-Nov	53	4	SOS Colour 990g
806380	Australia 990g Export SOS	600	6-Nov	54	4	SOS Colour 990g
807490	Burger King 12x990g Japan SO	1160	13-Nov	55	4	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	22-Oct	56	4	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	23-Oct	57	4	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1080	23-Oct	58	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	20-Nov	59	5	SOS Colour 990g
806380	Australia 990g Export SOS	900	4-Dec	60	5	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	6-Nov	61	5	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	30-Oct	62	5	SOS Colour 990g

3.2.8 - Batch Same Groups, Then Same Formulations

Total Make-span = 474.76

Item No	Item Description	Qty	DueDate	Seq	Bucket	Group Name
807230	Mld 1.5kg 90x90mm Aust SOS	2400	9-Oct	1	1	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	6-Nov	2	1	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	9-Oct	3	1	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	160	9-Oct	4	1	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	23-Oct	5	1	SOS Pale 1.2kg
27260	Mld Sandwich 1.2kg SOS	200	30-Oct	6	1	SOS Pale 1.2kg
805990	Anc Pale 12x1.2kg SOS	200	16-Oct	7	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	500	8-Oct	8	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	125	9-Oct	9	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	350	7-Oct	10	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	9-Oct	11	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	300	15-Oct	12	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	220	16-Oct	13	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	13-Nov	14	1	SOS Pale 1.2kg
806350	Anc Mozzarella 1.2kg SOS	200	9-Oct	15	1	SOS Swiss/Moz
806490	Anc Pale 12x990g Taiwan SOS	240	30-Oct	16	1	SOS Pale 990g
805950	Anc Clrd 12x1.2kg SOS	1060	16-Oct	17	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	80	6-Oct	18	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	40	7-Oct	19	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	8-Oct	20	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	9-Oct	21	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	100	16-Oct	22	1	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	1200	16-Oct	23	2	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	9-Oct	24	2	SOS Colour 990g
806380	Australia 990g Export SOS	600	9-Oct	25	2	SOS Colour 990g
806390	Burger King 12x990g Export S	350	16-Oct	26	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	9-Oct	27	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	8-Oct	28	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	14-Oct	29	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	15-Oct	30	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	16-Oct	31	2	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	2205	9-Oct	32	2	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	2400	23-Oct	33	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	20-Nov	34	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1200	4-Dec	35	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	23-Oct	36	3	SOS Pale 1.5kg
805950	Anc Clrd 12x1.2kg SOS	200	15-Oct	37	3	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	1050	22-Oct	38	3	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	350	23-Oct	39	3	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	120	13-Nov	40	3	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	240	29-Oct	41	3	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	30-Oct	42	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	16-Oct	43	3	SOS Colour 990g
807430	Grand Choice 1.5kg SOS	200	6-Nov	44	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	20-Nov	45	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	4-Dec	46	4	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	200	6-Nov	47	4	SOS Pale 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	1200	13-Nov	48	4	SOS Colour 990g
63792	Wendy's 990g Local SOS	216	23-Oct	49	4	SOS Colour 990g
63793	KFC 12x990g Local SOS	324	23-Oct	50	4	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	6-Nov	51	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	23-Oct	52	4	SOS Colour 990g
806380	Australia 990g Export SOS	600	6-Nov	53	4	SOS Colour 990g
806390	Burger King 12x990g Export S	240	30-Oct	54	4	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	22-Oct	55	4	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	23-Oct	56	4	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	6-Nov	57	4	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1080	28-Oct	58	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	20-Nov	59	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	4-Dec	60	5	SOS Colour 990g
807490	Burger King 12x990g Japan SO	1160	13-Nov	61	5	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	30-Oct	62	5	SOS Colour 990g

3.2.9 - Batch Same Groups, Then Same Sizes

Total Make-span = 474.69

Item No	Item Description	Qty	DueDate	Seq	Bucket	Group Name
807230	Mld 1.5kg 90x90mm Aust SOS	2400	9-Oct	1	1	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	6-Nov	2	1	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	9-Oct	3	1	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	160	9-Oct	4	1	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	23-Oct	5	1	SOS Pale 1.2kg
805990	Anc Pale 12x1.2kg SOS	200	16-Oct	6	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	500	8-Oct	7	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	125	9-Oct	8	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	350	7-Oct	9	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	9-Oct	10	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	300	15-Oct	11	1	SOS Pale 1.2kg
806350	Anc Mozzarella 1.2kg SOS	200	9-Oct	12	1	SOS Swiss/Moz
805950	Anc Clrd 12x1.2kg SOS	1060	16-Oct	13	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	80	6-Oct	14	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	40	7-Oct	15	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	8-Oct	16	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	9-Oct	17	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	100	16-Oct	18	1	SOS Colour 1.2kg
806380	Australia 990g Export SOS	600	9-Oct	19	1	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	16-Oct	20	2	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	9-Oct	21	2	SOS Colour 990g
806390	Burger King 12x990g Export S	350	16-Oct	22	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	9-Oct	23	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	8-Oct	24	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	14-Oct	25	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	15-Oct	26	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	16-Oct	27	2	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	2205	9-Oct	28	2	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	2400	23-Oct	29	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	20-Nov	30	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1200	4-Dec	31	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	6-Nov	32	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	23-Oct	33	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	20-Nov	34	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	4-Dec	35	3	SOS Pale 1.5kg
27260	Mld Sandwich 1.2kg SOS	200	30-Oct	36	3	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	220	16-Oct	37	3	SOS Pale 1.2kg
806490	Anc Pale 12x990g Taiwan SOS	240	30-Oct	38	3	SOS Pale 990g
805950	Anc Clrd 12x1.2kg SOS	200	15-Oct	39	3	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	1050	22-Oct	40	3	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	350	23-Oct	41	3	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	120	13-Nov	42	3	SOS Colour 1.2kg
63792	Wendy's 990g Local SOS	216	23-Oct	43	3	SOS Colour 990g
63793	KFC 12x990g Local SOS	324	23-Oct	44	3	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	6-Nov	45	3	SOS Colour 990g
806380	Australia 990g Export SOS	900	23-Oct	46	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	16-Oct	47	3	SOS Colour 990g
66910	Anc Foods 1.2kg SOS	200	6-Nov	48	4	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	13-Nov	49	4	SOS Pale 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	240	29-Oct	50	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	30-Oct	51	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	13-Nov	52	4	SOS Colour 990g
806380	Australia 990g Export SOS	600	6-Nov	53	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	20-Nov	54	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	4-Dec	55	4	SOS Colour 990g
806390	Burger King 12x990g Export S	240	30-Oct	56	4	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	22-Oct	57	4	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	23-Oct	58	4	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	6-Nov	59	4	SOS Colour 990g
807490	Burger King 12x990g Japan SO	1160	13-Nov	60	5	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1080	28-Oct	61	5	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	30-Oct	62	5	SOS Colour 990g

3.2.10 - Batch Same Odd Ball Groups, Then Same Items

Total Make-span = 474.67

Item No	Item Description	Qty	DueDate	Seq	Bucket	Group Name
807230	Mld 1.5kg 90x90mm Aust SOS	2400	9-Oct	1	1	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	2400	23-Oct	2	1	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	9-Oct	3	1	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	160	9-Oct	4	1	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	23-Oct	5	1	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	6-Nov	6	1	SOS Pale 1.2kg
805990	Anc Pale 12x1.2kg SOS	200	16-Oct	7	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	500	8-Oct	8	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	125	9-Oct	9	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	350	7-Oct	10	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	9-Oct	11	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	300	15-Oct	12	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	220	16-Oct	13	1	SOS Pale 1.2kg
806350	Anc Mozzarella 1.2kg SOS	200	9-Oct	14	1	SOS Swiss/Moz
805970	Anc Clrd 12x1.2kg Sea SOS	80	6-Oct	15	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	40	7-Oct	16	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	8-Oct	17	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	9-Oct	18	1	SOS Colour 1.2kg
63793	KFC 12x990g Local SOS	216	9-Oct	19	1	SOS Colour 990g
806380	Australia 990g Export SOS	600	9-Oct	20	1	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	8-Oct	21	1	SOS Colour 990g
805950	Anc Clrd 12x1.2kg SOS	1060	16-Oct	22	2	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	100	16-Oct	23	2	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	1200	16-Oct	24	2	SOS Colour 990g
806390	Burger King 12x990g Export S	350	16-Oct	25	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	9-Oct	26	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	14-Oct	27	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	15-Oct	28	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	16-Oct	29	2	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	2205	9-Oct	30	2	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	1800	6-Nov	31	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	20-Nov	32	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1200	4-Dec	33	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	23-Oct	34	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	6-Nov	35	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	20-Nov	36	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	4-Dec	37	3	SOS Pale 1.5kg
27260	Mld Sandwich 1.2kg SOS	200	30-Oct	38	3	SOS Pale 1.2kg
805950	Anc Clrd 12x1.2kg SOS	1050	22-Oct	39	3	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	350	23-Oct	40	3	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	240	29-Oct	41	3	SOS Colour 990g
63792	Wendy's 990g Local SOS	216	23-Oct	42	3	SOS Colour 990g
63793	KFC 12x990g Local SOS	324	23-Oct	43	3	SOS Colour 990g
806380	Australia 990g Export SOS	900	23-Oct	44	3	SOS Colour 990g
806390	Burger King 12x990g Export S	240	30-Oct	45	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	16-Oct	46	3	SOS Colour 990g
806080	Anc Pale 12x1.2kg Sea SOS	120	13-Nov	47	4	SOS Pale 1.2kg
806490	Anc Pale 12x990g Taiwan SOS	240	30-Oct	48	4	SOS Pale 990g
805950	Anc Clrd 12x1.2kg SOS	200	16-Oct	49	4	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	120	13-Nov	50	4	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	1200	30-Oct	51	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	13-Nov	52	4	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	6-Nov	53	4	SOS Colour 990g
806380	Australia 990g Export SOS	600	6-Nov	54	4	SOS Colour 990g
807490	Burger King 12x990g Japan SO	1160	13-Nov	55	4	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	22-Oct	56	4	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	23-Oct	57	4	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1080	23-Oct	58	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	20-Nov	59	5	SOS Colour 990g
806380	Australia 990g Export SOS	900	4-Dec	60	5	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	6-Nov	61	5	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	30-Oct	62	5	SOS Colour 990g

3.2.11 - Batch Same Odd Ball Groups, Then Same Formulations

Total Make-span = 476.22

Item No	Item Description	Qty	DueDate	Seq	Bucket	Group Name
807230	Mld 1.5kg 90x90mm Aust SOS	2400	9-Oct	1	1	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	2400	23-Oct	2	1	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	9-Oct	3	1	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	23-Oct	4	1	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	160	9-Oct	5	1	SOS Pale 1.2kg
805990	Anc Pale 12x1.2kg SOS	200	16-Oct	6	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	500	8-Oct	7	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	125	9-Oct	8	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	350	7-Oct	9	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	9-Oct	10	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	300	15-Oct	11	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	220	16-Oct	12	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	13-Nov	13	1	SOS Pale 1.2kg
806350	Anc Mozzarella 1.2kg SOS	200	9-Oct	14	1	SOS Swiss/Moz
805950	Anc Clrd 12x1.2kg SOS	200	15-Oct	15	1	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	1060	16-Oct	16	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	80	6-Oct	17	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	40	7-Oct	18	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	8-Oct	19	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	9-Oct	20	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	100	16-Oct	21	1	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	1200	16-Oct	22	2	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	9-Oct	23	2	SOS Colour 990g
806380	Australia 990g Export SOS	600	9-Oct	24	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	8-Oct	25	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	9-Oct	26	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	14-Oct	27	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	15-Oct	28	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	16-Oct	29	2	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	2205	9-Oct	30	2	SOS Colour 990g
66910	Anc Foods 1.2kg SOS	200	23-Oct	31	3	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	6-Nov	32	3	SOS Pale 1.2kg
27260	Mld Sandwich 1.2kg SOS	200	30-Oct	33	3	SOS Pale 1.2kg
806490	Anc Pale 12x990g Taiwan SOS	240	30-Oct	34	3	SOS Pale 990g
805950	Anc Clrd 12x1.2kg SOS	1050	22-Oct	35	3	SOS Colour 1.2kg
806390	Burger King 12x990g Export S	350	16-Oct	36	3	SOS Colour 990g
806390	Burger King 12x990g Export S	240	30-Oct	37	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	22-Oct	38	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	23-Oct	39	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	6-Nov	40	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	16-Oct	41	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1080	28-Oct	42	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	30-Oct	43	3	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	1800	6-Nov	44	4	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	6-Nov	45	4	SOS Pale 1.5kg
805950	Anc Clrd 12x1.2kg SOS	350	23-Oct	46	4	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	120	13-Nov	47	4	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	240	29-Oct	48	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	30-Oct	49	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	13-Nov	50	4	SOS Colour 990g
63792	Wendy's 990g Local SOS	216	23-Oct	51	4	SOS Colour 990g
63793	KFC 12x990g Local SOS	324	23-Oct	52	4	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	6-Nov	53	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	23-Oct	54	4	SOS Colour 990g
806380	Australia 990g Export SOS	600	6-Nov	55	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	20-Nov	56	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	4-Dec	57	4	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	1800	20-Nov	58	5	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1200	4-Dec	59	5	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	20-Nov	60	5	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	4-Dec	61	5	SOS Pale 1.5kg
807490	Burger King 12x990g Japan SO	1160	13-Nov	62	5	SOS Colour 990g

3.2.12 - Batch Same Odd Ball Groups, Then Same Sizes

Total Make-span = 473.99

Item No	Item Description	Qty	DueDate	Seq	Bucket	Group Name
807430	Grand Choice 1.5kg SOS	200	9-Oct	2	1	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	160	9-Oct	3	1	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	23-Oct	4	1	SOS Pale 1.2kg
27260	Mld Sandwich 1.2kg SOS	200	30-Oct	5	1	SOS Pale 1.2kg
805990	Anc Pale 12x1.2kg SOS	200	16-Oct	6	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	500	8-Oct	7	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	125	9-Oct	8	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	350	7-Oct	9	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	9-Oct	10	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	300	15-Oct	11	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	220	16-Oct	12	1	SOS Pale 1.2kg
806350	Anc Mozzarella 1.2kg SOS	200	9-Oct	13	1	SOS Swiss/Moz
805950	Anc Clrd 12x1.2kg SOS	1060	16-Oct	14	1	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	200	15-Oct	15	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	80	6-Oct	16	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	40	7-Oct	17	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	8-Oct	18	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	9-Oct	19	1	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	100	16-Oct	20	1	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	1200	16-Oct	21	1	SOS Colour 990g
806380	Australia 990g Export SOS	600	9-Oct	22	1	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	9-Oct	23	1	SOS Colour 990g
806390	Burger King 12x990g Export S	350	16-Oct	24	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	9-Oct	25	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	8-Oct	26	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	14-Oct	27	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	15-Oct	28	2	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	16-Oct	29	2	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	2205	9-Oct	30	2	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	16-Oct	31	2	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	2400	23-Oct	32	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	6-Nov	33	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	23-Oct	34	3	SOS Pale 1.5kg
806540	McDonalds 8x2.27kg Sea SOS	1800	22-Oct	35	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	23-Oct	36	3	SOS Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	6-Nov	37	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1080	28-Oct	38	3	SOS Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	30-Oct	39	3	SOS Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	1800	20-Nov	40	4	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1200	4-Dec	41	4	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	6-Nov	42	4	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	20-Nov	43	4	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	4-Dec	44	4	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	200	6-Nov	45	4	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	13-Nov	46	4	SOS Pale 1.2kg
806490	Anc Pale 12x990g Taiwan SOS	240	30-Oct	47	4	SOS Pale 990g
805950	Anc Clrd 12x1.2kg SOS	1050	22-Oct	48	4	SOS Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	350	23-Oct	49	4	SOS Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	120	13-Nov	50	4	SOS Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	240	29-Oct	51	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	30-Oct	52	4	SOS Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	13-Nov	53	4	SOS Colour 990g
63792	Wendy's 990g Local SOS	216	23-Oct	54	4	SOS Colour 990g
63793	KFC 12x990g Local SOS	324	23-Oct	55	4	SOS Colour 990g
63793	KFC 12x990g Local SOS	216	6-Nov	56	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	23-Oct	57	4	SOS Colour 990g
806380	Australia 990g Export SOS	600	6-Nov	58	4	SOS Colour 990g
806380	Australia 990g Export SOS	900	20-Nov	59	5	SOS Colour 990g
806380	Australia 990g Export SOS	900	4-Dec	60	5	SOS Colour 990g
806390	Burger King 12x990g Export S	240	30-Oct	61	5	SOS Colour 990g
807490	Burger King 12x990g Japan SO	1160	13-Nov	62	5	SOS Colour 990g

3.3 - Results of Trials of Search Techniques

3.3.1 - Branch and Bound

Schedule Cost Index = 28.99

Item No	Item Description	Qty	DueDate	Seq	Bucket	Group Name
66910	Anc Foods 1.2kg SOS	160	9-Oct	1	1	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	23-Oct	2	1	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	6-Nov	3	1	SOS Pale 1.2kg
27260	Mld Sandwich 1.2kg SOS	200	30-Oct	4	1	SOS Pale 1.2kg
805990	Anc Pale 12x1.2kg SOS	200	16-Oct	5	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	500	8-Oct	6	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	125	9-Oct	7	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	350	7-Oct	8	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	9-Oct	9	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	300	15-Oct	10	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	220	16-Oct	11	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	13-Nov	12	1	SOS Pale 1.2kg
806350	Anc Mozzarella 1.2kg SOS	200	9-Oct	13	1	Swiss/Moz
805950	Anc Clrd 12x1.2kg SOS	200	16-Oct	14	1	Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	1060	16-Oct	15	1	Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	1050	22-Oct	16	1	Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	350	23-Oct	17	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	80	6-Oct	18	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	40	7-Oct	19	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	8-Oct	20	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	9-Oct	21	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	100	16-Oct	22	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	120	13-Nov	23	1	Colour 1.2kg
806540	McDonalds 8x2.27kg Sea SOS	900	8-Oct	24	1	Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	2400	9-Oct	25	2	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	9-Oct	26	2	SOS Pale 1.5kg
63793	KFC 12x990g Local SOS	216	9-Oct	27	2	Colour 990g
806380	Australia 990g Export SOS	600	9-Oct	28	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	9-Oct	29	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	14-Oct	30	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	15-Oct	31	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	16-Oct	32	2	Colour 990g
739007	McDonalds 8x2.27kg Local SOS	2205	9-Oct	33	2	Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	16-Oct	34	2	Colour 990g
806490	Anc Pale 12x990g Taiwan SOS	240	30-Oct	35	3	SOS Pale 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	16-Oct	36	3	Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	240	29-Oct	37	3	Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	13-Nov	38	3	Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	30-Oct	39	3	Colour 990g
63792	Wendy's 990g Local SOS	216	23-Oct	40	3	Colour 990g
63793	KFC 12x990g Local SOS	324	23-Oct	41	3	Colour 990g
63793	KFC 12x990g Local SOS	216	6-Nov	42	3	Colour 990g
806380	Australia 990g Export SOS	900	23-Oct	43	3	Colour 990g
806380	Australia 990g Export SOS	600	6-Nov	44	3	Colour 990g
806380	Australia 990g Export SOS	900	4-Dec	45	3	Colour 990g
806390	Burger King 12x990g Export S	350	16-Oct	46	3	Colour 990g
806390	Burger King 12x990g Export S	240	30-Oct	47	3	Colour 990g
807490	Burger King 12x990g Japan SO	1160	13-Nov	48	3	Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	2400	23-Oct	49	4	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	6-Nov	50	4	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	23-Oct	51	4	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	6-Nov	52	4	SOS Pale 1.5kg
806540	McDonalds 8x2.27kg Sea SOS	1800	22-Oct	53	4	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	23-Oct	54	4	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	6-Nov	55	4	Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1080	23-Oct	56	4	Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	30-Oct	57	4	Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	1800	20-Nov	58	5	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1200	4-Dec	59	5	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	20-Nov	60	5	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	4-Dec	61	5	SOS Pale 1.5kg
806380	Australia 990g Export SOS	900	20-Nov	62	5	Colour 990g

3.3.2 - Random Pair-wise Interchange

Schedule Cost Index = 31.03

Item No	Item Description	Qty	DueDate	Seq	Bucket	Group Name
807230	Mld 1.5kg 90x90mm Aust SOS	2400	9-Oct	1	1	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	9-Oct	2	1	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	160	9-Oct	3	1	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	23-Oct	4	1	SOS Pale 1.2kg
805990	Anc Pale 12x1.2kg SOS	200	16-Oct	5	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	500	8-Oct	6	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	125	9-Oct	7	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	350	7-Oct	8	1	SOS Pale 1.2kg
806350	Anc Mozzarella 1.2kg SOS	200	9-Oct	9	1	Swiss/Moz
805970	Anc Clrd 12x1.2kg Sea SOS	80	6-Oct	10	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	40	7-Oct	11	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	8-Oct	12	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	9-Oct	13	1	Colour 1.2kg
806380	Australia 990g Export SOS	600	9-Oct	14	1	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	9-Oct	15	1	Colour 990g
739007	McDonalds 8x2.27kg Local SOS	2205	9-Oct	16	1	Colour 990g
806080	Anc Pale 12x1.2kg Sea SOS	120	9-Oct	17	2	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	300	15-Oct	18	2	SOS Pale 1.2kg
805950	Anc Clrd 12x1.2kg SOS	1060	16-Oct	19	2	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	100	16-Oct	20	2	Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	1200	16-Oct	21	2	Colour 990g
63793	KFC 12x990g Local SOS	216	9-Oct	22	2	Colour 990g
806390	Burger King 12x990g Export S	350	16-Oct	23	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	8-Oct	24	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	14-Oct	25	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	15-Oct	26	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	16-Oct	27	2	Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	16-Oct	28	2	Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	2400	23-Oct	29	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	6-Nov	30	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	20-Nov	31	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1200	4-Dec	32	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	23-Oct	33	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	6-Nov	34	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	20-Nov	35	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	4-Dec	36	3	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	200	6-Nov	37	3	SOS Pale 1.2kg
27260	Mld Sandwich 1.2kg SOS	200	30-Oct	38	3	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	220	16-Oct	39	3	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	13-Nov	40	3	SOS Pale 1.2kg
806490	Anc Pale 12x990g Taiwan SOS	240	30-Oct	41	3	SOS Pale 990g
805950	Anc Clrd 12x1.2kg SOS	200	15-Oct	42	3	Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	1050	22-Oct	43	3	Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	350	23-Oct	44	3	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	120	13-Nov	45	3	Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	240	29-Oct	46	3	Colour 990g
63792	Wendy's 990g Local SOS	216	23-Oct	47	3	Colour 990g
63793	KFC 12x990g Local SOS	324	23-Oct	48	3	Colour 990g
63793	KFC 12x990g Local SOS	216	6-Nov	49	3	Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	30-Oct	50	4	Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	13-Nov	51	4	Colour 990g
806380	Australia 990g Export SOS	900	23-Oct	52	4	Colour 990g
806380	Australia 990g Export SOS	600	6-Nov	53	4	Colour 990g
806390	Burger King 12x990g Export S	240	30-Oct	54	4	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	22-Oct	55	4	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	23-Oct	56	4	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	6-Nov	57	4	Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1080	28-Oct	58	4	Colour 990g
806380	Australia 990g Export SOS	900	20-Nov	59	5	Colour 990g
806380	Australia 990g Export SOS	900	4-Dec	60	5	Colour 990g
807490	Burger King 12x990g Japan SO	1160	13-Nov	61	5	Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	30-Oct	62	5	Colour 990g

3.3.3 - Tabu Search

Schedule Cost Index = 24.95

Item No	Item Description	Qty	DueDate	Seq	Bucket	Group Name
807230	Mld 1.5kg 90x90mm Aust SOS	2400	9-Oct	1	1	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	9-Oct	2	1	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	160	9-Oct	3	1	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	23-Oct	4	1	SOS Pale 1.2kg
27260	Mld Sandwich 1.2kg SOS	200	30-Oct	5	1	SOS Pale 1.2kg
805990	Anc Pale 12x1.2kg SOS	200	16-Oct	6	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	500	8-Oct	7	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	125	9-Oct	8	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	350	7-Oct	9	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	9-Oct	10	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	300	15-Oct	11	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	220	16-Oct	12	1	SOS Pale 1.2kg
806350	Anc Mozzarella 1.2kg SOS	200	9-Oct	13	1	Swiss/Moz
805950	Anc Clrd 12x1.2kg SOS	1060	16-Oct	14	1	Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	200	15-Oct	15	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	80	6-Oct	16	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	40	7-Oct	17	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	8-Oct	18	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	9-Oct	19	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	100	16-Oct	20	1	Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	1200	16-Oct	21	1	Colour 990g
63793	KFC 12x990g Local SOS	216	9-Oct	22	1	Colour 990g
806380	Australia 990g Export SOS	600	9-Oct	23	1	Colour 990g
806390	Burger King 12x990g Export S	350	16-Oct	24	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	9-Oct	25	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	8-Oct	26	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	14-Oct	27	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	15-Oct	28	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	16-Oct	29	2	Colour 990g
739007	McDonalds 8x2.27kg Local SOS	2205	9-Oct	30	2	Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	16-Oct	31	2	Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	2400	23-Oct	32	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	6-Nov	33	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1200	4-Dec	34	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	20-Nov	35	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	23-Oct	36	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	6-Nov	37	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	20-Nov	38	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	4-Dec	39	3	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	200	6-Nov	40	3	SOS Pale 1.2kg
806490	Anc Pale 12x990g Taiwan SOS	240	30-Oct	41	3	SOS Pale 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	22-Oct	42	3	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	23-Oct	43	3	Colour 990g
806080	Anc Pale 12x1.2kg Sea SOS	120	13-Nov	44	4	SOS Pale 1.2kg
805950	Anc Clrd 12x1.2kg SOS	1050	22-Oct	45	4	Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	350	23-Oct	46	4	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	120	13-Nov	47	4	Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	240	29-Oct	48	4	Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	30-Oct	49	4	Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	13-Nov	50	4	Colour 990g
63792	Wendy's 990g Local SOS	216	23-Oct	51	4	Colour 990g
63793	KFC 12x990g Local SOS	324	23-Oct	52	4	Colour 990g
63793	KFC 12x990g Local SOS	216	6-Nov	53	4	Colour 990g
806380	Australia 990g Export SOS	900	23-Oct	54	4	Colour 990g
806380	Australia 990g Export SOS	600	6-Nov	55	4	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	6-Nov	56	4	Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1080	28-Oct	57	4	Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	30-Oct	58	4	Colour 990g
806380	Australia 990g Export SOS	900	20-Nov	59	5	Colour 990g
806380	Australia 990g Export SOS	900	4-Dec	60	5	Colour 990g
806390	Burger King 12x990g Export S	240	30-Oct	61	5	Colour 990g
807490	Burger King 12x990g Japan SO	1160	13-Nov	62	5	Colour 990g

3.3.4 - Combination Individual Group Complete Enumeration and Tabu Search

Schedule Cost Index = 24.95

Item No	Item Description	Qty	DueDate	Seq	Bucket	Group Name
807230	Mld 1.5kg 90x90mm Aust SOS	2400	9-Oct	1	1	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	9-Oct	2	1	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	160	9-Oct	3	1	SOS Pale 1.2kg
66910	Anc Foods 1.2kg SOS	200	23-Oct	4	1	SOS Pale 1.2kg
27260	Mld Sandwich 1.2kg SOS	200	30-Oct	5	1	SOS Pale 1.2kg
805990	Anc Pale 12x1.2kg SOS	200	16-Oct	6	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	500	8-Oct	7	1	SOS Pale 1.2kg
806070	Anc Pale 12x1.2kg M.East SOS	125	9-Oct	8	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	350	7-Oct	9	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	120	9-Oct	10	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	300	15-Oct	11	1	SOS Pale 1.2kg
806080	Anc Pale 12x1.2kg Sea SOS	220	16-Oct	12	1	SOS Pale 1.2kg
806350	Anc Mozzarella 1.2kg SOS	200	9-Oct	13	1	Swiss/Moz
805950	Anc Clrd 12x1.2kg SOS	1060	16-Oct	14	1	Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	200	15-Oct	15	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	80	6-Oct	16	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	40	7-Oct	17	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	8-Oct	18	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	200	9-Oct	19	1	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	100	16-Oct	20	1	Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	1200	16-Oct	21	1	Colour 990g
63793	KFC 12x990g Local SOS	216	9-Oct	22	1	Colour 990g
806380	Australia 990g Export SOS	600	9-Oct	23	1	Colour 990g
806390	Burger King 12x990g Export S	350	16-Oct	24	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	9-Oct	25	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	8-Oct	26	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	14-Oct	27	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	15-Oct	28	2	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	16-Oct	29	2	Colour 990g
739007	McDonalds 8x2.27kg Local SOS	2205	9-Oct	30	2	Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	16-Oct	31	2	Colour 990g
807230	Mld 1.5kg 90x90mm Aust SOS	2400	23-Oct	32	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	6-Nov	33	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1200	4-Dec	34	3	SOS Pale 1.5kg
807230	Mld 1.5kg 90x90mm Aust SOS	1800	20-Nov	35	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	23-Oct	36	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	6-Nov	37	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	20-Nov	38	3	SOS Pale 1.5kg
807430	Grand Choice 1.5kg SOS	200	4-Dec	39	3	SOS Pale 1.5kg
66910	Anc Foods 1.2kg SOS	200	6-Nov	40	3	SOS Pale 1.2kg
806490	Anc Pale 12x990g Taiwan SOS	240	30-Oct	41	3	SOS Pale 990g
806540	McDonalds 8x2.27kg Sea SOS	1800	22-Oct	42	3	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	23-Oct	43	3	Colour 990g
806080	Anc Pale 12x1.2kg Sea SOS	120	13-Nov	44	4	SOS Pale 1.2kg
805950	Anc Clrd 12x1.2kg SOS	1050	22-Oct	45	4	Colour 1.2kg
805950	Anc Clrd 12x1.2kg SOS	350	23-Oct	46	4	Colour 1.2kg
805970	Anc Clrd 12x1.2kg Sea SOS	120	13-Nov	47	4	Colour 1.2kg
806480	Anc Clrd 12x990g Taiwan SOS	240	29-Oct	48	4	Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	30-Oct	49	4	Colour 990g
806480	Anc Clrd 12x990g Taiwan SOS	1200	13-Nov	50	4	Colour 990g
63792	Wendy's 990g Local SOS	216	23-Oct	51	4	Colour 990g
63793	KFC 12x990g Local SOS	324	23-Oct	52	4	Colour 990g
63793	KFC 12x990g Local SOS	216	6-Nov	53	4	Colour 990g
806380	Australia 990g Export SOS	900	23-Oct	54	4	Colour 990g
806380	Australia 990g Export SOS	600	6-Nov	55	4	Colour 990g
806540	McDonalds 8x2.27kg Sea SOS	900	6-Nov	56	4	Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1080	28-Oct	57	4	Colour 990g
739007	McDonalds 8x2.27kg Local SOS	1035	30-Oct	58	4	Colour 990g
806380	Australia 990g Export SOS	900	20-Nov	59	5	Colour 990g
806380	Australia 990g Export SOS	900	4-Dec	60	5	Colour 990g
806390	Burger King 12x990g Export S	240	30-Oct	61	5	Colour 990g
807490	Burger King 12x990g Japan SO	1160	13-Nov	62	5	Colour 990g

Appendix 4 - Definitions of Terms Used

20kg Blocks: Pastoral Foods product type.
250g Packets: Pastoral Foods product type.
2kg Blocks: Pastoral Foods product type.
American Production Inventory Control Society (APICS): Organisation that promotes production-planning research and education.
APICS: American Production Inventory Control Society.
Available to Promise: Capacity or products that are available to be sold, i.e. the total available that has not yet been promised to other orders.
Backward Schedule: Scheduling technique that performs the requirements of the schedule as late as the factory's capacity will allow. Orders are set down on their manufacturing due dates and then 'bulldozed' or pushed backward (if there is more than one order on a machine at one time) to obtain a realistic schedule.
Beam Search: Search technique.
Bill of Materials (BOM): Listing of quantities of materials that are required in the manufacture or assembly of a product.
BOM: Bill of Materials.
BPCS: Business Planning and Control System.
Branch and Bound: Search technique.
Buffer: Inventory or Time that is strategically placed to prevent small disruptions from causing significant problems or major disruptions.
Bulk & Block Line: Pastoral Foods manufacturing line.
Business Planning and Control System (BPCS): Commercial MRP-II system used at Pastoral Foods.
Carton: Single unit of manufacture and storage. Term used at Pastoral Foods.
Central Limit Theorem: Statistics theory that says that the mean of a sample can be more accurately predicted the larger the sample.
Cheese Spreads: Pastoral Foods product type.
Cheez Bodz: Pastoral Foods product type.
Cheez Toyz: Pastoral Foods product type.
Complete Enumeration: Search technique that evaluates all possible solutions.
Constraint: Something that prevents the company from making more money now and in the future.
Critical Path Diagram: Diagram for displaying and calculating the minimum possible time that a project will take.
Customer Order: Order for a finished product placed on a manufacturing organisation. Must contain item code, quantity required and requested date of delivery. Used in MRP-II systems.
Database Information System: Computer program for storage and fast efficient retrieval of last amounts of related data in tabular form.
Dynamic Programming: Search technique.
Earliest Due Date (EDD): Sequencing algorithm that schedules all items in Earliest Due Date sequence.
EDD: Earliest Due Date.
EMC: Enzyme Modified Cheese. Pastoral Foods product type.
Enzyme Modified Cheese (EMC): Pastoral Foods product type.
Factorial (n!): n! = (n) * (n-1) * (n-2) * (n-3) * (n-4) . . . 5 * 4 * 3 * 2 * 1.

Firm Planned Order (FPO): Order planned to be manufactured by the scheduler only. Must contain item code, quantity required and date of start of manufacture and date it is needed by. Used in MRP-II systems.
Forecast Myopic Dispatch Method: Scheduling algorithm, used in the Goldratt scheduling method.
Formulation: Part of the BOM, the recipe or mixture of cheeses and salts etc, that go into creating a product. Term used at Pastoral Foods.
FPO: Firm Planned Order.
Gantt Chart: A graph that plots the planned usage of one or more machines against time.
Genetic Algorithms: Search technique.
Gluing: Manufacturing similar items together in the same run. This is done to reduce the total make-span by eliminating a change-of-run.
Greedy: Search techniques are greedy or myopic if they look for the best thing in the next move or next few moves. This leads to sub-optimal of local optima schedules.
Group: Term defined and used in and for this project. Similar items that have small changeover-times and are advantages to production to run in consecutively. All items are categorised into their similar item 'Groups' to make scheduling easier.
Individually Wrapped Slices (IWS): Pastoral Foods manufacturing department.
Integer Programming: Search technique.
Internal Constraint: See production constraint.
Inventory: Goldratt term used to define the total investment or value of the money locked up in the manufacturing system.
Item: Single product that has a unique set of characteristics in a product range.
IWS: Individually Wrapped Slices. Pastoral Foods product type, manufacturing line and manufacturing department.
Retro Line: Pastoral Foods manufacturing line.
JIT: Just In Time.
Just In Time (JIT): Manufacturing system that operates with zero or almost zero inventory or work in process between machine centres.
KD Line: Pastoral Foods manufacturing line.
Key Ingredients Line: Pastoral Foods manufacturing line.
Lagrangian Relaxation: Search technique.
Local Optima: Local area of a solution space where all single moves away from the local optima give worse solutions.
Market Constraint: Constraint of the market. The company cannot sell all the capacity it has available. If more sales could be generated revenue would increase.
Master Production Schedule (MPS): Algorithm used in MRP-II systems that will produce the listing of required production orders and raw material purchase order in the form of Planned Orders.
Microsoft Access: Computer database program.
Microsoft Visual Basic: Computer programming language (also used within Microsoft Access).
MPS: Master Production Schedule.
Multi-machine Bottleneck Dynamics: Scheduling algorithm.
Myopic: See Greedy
Myopic Search Technique: Scheduling algorithm.
n!: Factorial, mathematical expression, n! = (n) * (n-1) * (n-2) * (n-3) *. . .4 * 3 * 2 * 1.
Neighbourhood: All solutions within one move of the current solution.
Numetrix: Owner/writer company of Schedulex and other commercial production scheduling packages.
ODBC: Open Database Connectivity.

Oddball Items: A few products that are very different from the majority of products.
Open Database Connectivity (ODBC): Standard used by all major manufacturers of databases. ODBC is a computer protocol for communication between databases of different origins.
Operating Expense: Goldratt term used to define the fixed or non-variable costs of the company.
OPT: Optimised Production Technology.
Optimised Production Technology (OPT): Commercial production scheduling package, first written by Goldratt in the late 1970's.
Packet Line: Pastoral Foods manufacturing line.
Packing Configuration: The number arrangement and mass of cheese potions in a carton used at Pastoral Foods.
Pair-Wise Interchange: Search technique.
Pastes and Slurries: Pastoral Foods product type.
Pastoral Foods (NZ) Limited: Processed cheese manufacturer in Eltham New Zealand.
Planned Order: Order created by the MRP-II system to advise the planner that there are requirements for an item for a certain quantity and required by certain date. Used in MRP-II systems.
Production Constraint: Constraint of the production system. The company can sell all the capacity it has available. More sales would not increase revenue.
Purchase Order: Order planned to be purchased by the purchased officer only. Must contain item code, quantity required and date of date required delivery. Used in MRP-II systems.
Q-Control: Commercial production scheduling package.
Random Pair-Wise Interchange: Simple search technique.
RDS: Recombined Dairy Solids. Pastoral Foods product type and manufacturing line.
Recombined Dairy Solids (RDS): Pastoral Foods product type and manufacturing line.
Red Lanes: Goldratt term, defined as the manufacturing path(s) from the constraint(s) to the end of the process.
Retro Line: Pastoral Foods manufacturing line.
Routing File: File that holds the sequences of machines and machine production rates for multi-stage operations. Used in MRP-II systems.
Run of the mill: Standard products that are typical of the majority of the products made in the factory.
Σ: Sum of everything in the brackets.
Schedulex: Commercial production scheduling package.
Sequence Dependent Set-ups: The set-up time for changeovers between products is dependent on the sequence the products are made..
Shifting Bottleneck Algorithm: Scheduling algorithm.
Shop Order: Order planned to be manufactured by the scheduler only on a FPO and has been released for manufacture. Must contain item code, quantity required and date of start of manufacture and date it is needed by. Often also contains manufacturing instructions and materials to be used. Used in MRP-II systems.
Simulated Annealing: Heuristic search technique.
Skins: Pastoral Foods product type.
SKU: Stock Keeping Unit.
Slice on Slice (SOS): Pastoral Foods product type, manufacturing line and manufacturing department.
Solution Space: The total number of possible solutions. For scheduling problems this is usually very, very large.

SOS: Slice on Slice. Pastoral Foods product type, manufacturing line and manufacturing department.
SP: Specialty Products. Pastoral Foods manufacturing department.
Space Buffer: Space to hold work-in-process that is available that is strategically placed to prevent small disruptions from causing significant problems or major disruptions. Usually placed immediately after a constraint or secondary constraint.
SPC: Specialty Processed Cheese. Pastoral Foods manufacturing department.
Specialty Processed Cheese (SPC): Pastoral Foods manufacturing department.
Specialty Products (SP): Pastoral Foods manufacturing department.
SPR: Standard Production Rate.
SQL: Stated Query Language
Standard Production Rate (SPR): Average rate of production of each item.
Stated Query Language (SQL): Standard language used in most database systems to retrieve information from tables inside the databases.
Stock Keeping Unit (SKU): Single item that has a unique set of characteristics in a product range..
Sub Group: Term defined and used in and for this project. See 'Group'. Similar items are categorised within a 'Group' into 'Sub-Groups'.
Supplier Constraint: Constraint of raw material supply. The company cannot make and sell all the capacity or products it wants to or has available because it cannot obtain enough raw materials.
Tabu List: A list used in Tabu Search that provides the memory of previously studied solutions, or attributes of solutions that the Tabu Search algorithm is forced to avoid.
Tabu Search: Heuristic search technique that uses artificial intelligence and memory, commonly used for scheduling problems.
Throughput: the production output of a manufacturing machine or line.
Throughput dollars: A Goldratt term used to define the absolute money making ability of the organisation. Technical Definition is 'money generated by sales - truly variable costs'. A simple definition is 'money generated by sales - cost of raw materials'.
Time Buffer: Amount of work-in-process inventory calculated in terms of machine processing time. Work-in-process that is strategically pushed to be available so that it prevents small disruptions from causing significant problems or major disruptions. Usually placed immediately before the constraint or secondary constraint so that, that machine does not run out of available work.
Total Make-Span: Total time taken to manufacture a schedule. Usually measured on the constraint alone.
Works Order: Also called 'Shop Order'.

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