THE IMPROVEMENT OF CAPACITY & MATERIAL UTILISATION THROUGH EFFECTIVE NESTING & BATCHING PROCESSES

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EXECUTIVE SUMMARY

The main aim of this project was to improve the capacity & material utilisation through the design and implementation of effective nesting and batching processes. This led to an improved production planning and control process, through the reduction of material wastage and off-cut production. The improvement of these processes was necessary due to the fact that the previous nesting and batching processes were insufficient and in some instances non-existing. The lack of planning between the different job orders made the material assignment and control virtually impossible. This resulted in the waste of material, labour hours and money. A further area of concern was the lack of inventory control that existed in the various shops.

The improvement of the material utilisation was done through the effective use of batching and nesting techniques, algorithms and software. All the necessary software was already available; the updated versions were re-installed, uploaded and implemented at The UCW Partnership plant in Nigel. Inventory control was also used to determine the length of the production window that will be opened. This was used as a direct measure of the batch sizes and Production Order List's time span. The reduced floor space and storage area available were also deciding factors in determining the batching rules and batch sizes. This together with the management of Shop-Floor control tools that will be implemented will greatly reduce the levels of inventory of both the material and the work in process (WIP). Various reports and GANTT Charts will also be used to measure the adherence to plan and serve as key performance indicators (KPIs). The *"Dynamic Conservatism"* method was used to manage the change in the materials purchasing, production planning and scheduling methods. This method was preferred because of the nature of the area of change implementation

This project greatly improved the capacity and material utilisation through the design, implementation and use of improved nesting and batching methods and processes. This was mainly achieved by the reduction of set-up and material handling times. The production of off cuts was also minimised which in turn lead to a reduction of wastage produced and money lost.

The optimal solution is a reachable goal, which will be reached with constant, gradual improvement and constant positive changes.

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1 INTRODUCTION & BACKGROUND

1.1 Company Background

Union Carriage & Wagon Co. (Pty) Ltd was formed in 1957 and has designed and produced more than 13 000 new electric locomotives, diesel electric/diesel hydraulic locomotives, inter-city passenger coaches, electric multiple units, railcars and all purpose freight wagons.

The UCW Partnership was formed in 2003 and is a joint initiative between the Murray & Roberts subsidiary, Union Carriage & Wagon Co. (Pty) Ltd, and a consortium led by the J&J Group. The UCW Partnership is currently situated at a 37 hectare facility in Nigel, Gauteng.

As a broad-based empowerment enterprise, The UCW Partnership provides innovative rail transport solutions to South Africa and some other key export markets. Refurbishing and upgrading of rolling stock is a significant element of the partnership's growth strategy and they are currently busy with a general overhauling project on old motor coaches and trailers for The South African Railway Commuter Corporation (SARCC). (Mbabake, Summer 2008)

This commitment is reinforced by an expert engineering and design team satisfying the requirements of the most exacting customers. The company offers a full spectrum of services, including conceptual studies, estimating, procurement, project management, cost control, production management, commissioning and systems integration of all rolling stock components. All the designs are constantly reviewed and updated in order to meet the latest demands.

The facility is purpose built and designed for the manufacture, refurbishment and overhauling of all types of rolling stock. Extensive testing facilities exist for static and dynamic testing, ensuring maximum reliability and customer satisfaction. (webmaster@murrob.com, 2009)

The UCW Partnership is currently busy with five different contracts.

These include:

- 9 New generation 10M4-S2 train sets consisting of 12 passenger coaches each
- 110 New class 19E locomotives for the Coal Link Corridor between Ermelo and Richards Bay
- 44 New class 15E locomotives to haul iron ore from Sishen to Saldanah Bay in the Western Cape
- The assembly of 81 Gautrain rolling stock vehicles

1.2 Background to shop M9 (Parts Manufacturing Shop)

Shop M9 is the primary parts manufacturing shop of The UCW Partnership.

Stakeholders in M9 include:

Foremen:

- Johan Meyer
- Solly Motsogae

Suppliers:

- Outside suppliers
- Stores

Customers:

- Sub-assembly shops
- Assembly shops
- Paint shops

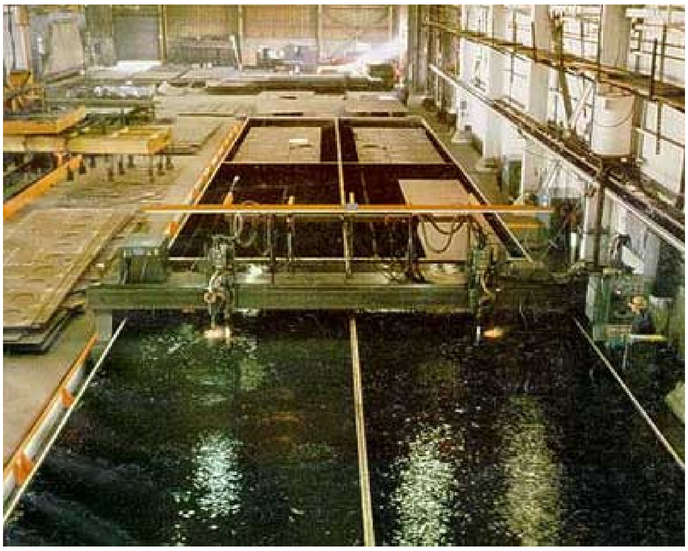


Figure 1 - M9 Plasma Cutter

All the parts and components that are made at M9 are manufactured from stock metal which is bought from steel suppliers. Sheet metal, metal bars and metal tubes are mostly used. Material types include; mild-steel, which is a softer steel, stainless steel (CR-12) which is harder and more frequently used and aluminium. All of the above mentioned types of steel are bought in sheets of different sizes and thicknesses.

The M9 shop supply components for the GO, 10M, 15E and 19E projects. Basically all the processes start off by cutting the sheet metal to the required sizes on the different guillotines. There are two types of guillotines that are being used. The first type shears metals with a thicknesses ranging between 1-3mm and the second, bigger type shears metal with thicknesses of between 5-12mm. After the sheets have gone through the shearing process on the different guillotines, the plates have to be de-burred to remove the sharp edges which could result in future injuries. The de-burred sheets are then sent to the various cutting and bending processes.

These processes are again followed by a de-burring stage after which the parts are sent to the bending, drilling and milling machines, depending on the tasks that the PO requires. Some of the cut-outs can only be made after bending because of the structural qualities required by the parts.

The milling machines in M9 are mainly used to cut chamfers on the edges that will be welded in S9SA. This will ensure better structural qualities through v-groove and double v-groove welds.

Other machines in M9 include: a lathe, various drilling machines and a profile cutter. Each machine in the shop has an assigned number that refers to that specific machine, for example: M9-47 refers to the plasma cutter. These numbers are used to assign each job to specific machines during planning.

1.3 Stakeholders

Murray & Roberts	–	The Majority Share Holders
The UCW Partnership	–	The Company
Chris van Schoor	–	Supply Chain Executive
Isak Pretorius	–	Systems Expert

Jozine Botha	–	Project Leader
Liet Searle	–	Production Control Manager
Mary Fryer	–	Materials Handler
Paddy Whelan	–	Production Control Scheduler
Eugene Radley	–	Production Controller (M9)
Seun Posthumus	–	CNC Programmer
Johan Meyer	–	Foreman (M9)

1.4 Problem statement

The previous nesting and batching processes were insufficient and in some instances non-existing. The lack of planning between the different job orders made the material assignment and control almost impossible. This resulted in the waste of material, labour hours and money.

The main reason for the material being wasted or scrapped was excessive off-cuts that were produced due to insufficient nesting methods and techniques. Workers were forced to do their own on-the-floor nesting and they constantly had to search for off cuts. These off cuts were then used to manufacture parts for which the required material had already been assigned. The off cuts weren't stored in any specific order. They were also just thrown onto different heaps and in different bins for the various types of materials and their respective thicknesses.

There existed a huge communication gap between the material issuers, the foreman, designers, planning and production control. This resulted in the planning being done on non-standard sheets, unnecessary off-cuts being made and material getting lost and wasted. A further concern was the level of communication and control between the different workshops. Parts were lost between the component shop, paint shop and the sub-assembly shop.

One last area of concern was the lack of inventory control that was applied in the shops. Some excess parts were made to minimise off cuts but these parts were not uploaded onto the system. This caused a part that has already been made to be re-ordered and these parts were re-made instead of the finished inventory being used.

1.5 Project Aim

The main aim of this project was to improve the capacity & material utilisation through the design and implementation of effective nesting and batching processes. This led to an improved production planning and control process, through the reduction of material wastage, off-cuts and set-up times.

1.6 Project Scope

1.6.1 The following project approach was followed:

- Analysed the current component manufacturing processes, materials inputs and materials flow. (Define *As-Is* Production Life Cycle)

- Analysed Machine operation times and set-up times. Used this data to batch according to specific groups of production. (CNC trump, Bending Machines, Plasma Cutters and Profile Cutters)

- Analysed the Production Scheduling and Job Order processes, including: Job Clocking, Production Order and Nesting software, their capabilities and utilisation.

- Determined the scope of the input materials used in M9.

- Did a literature study on the different batching, nesting, material handling and production planning methods and techniques. This literature study focused on *Batching in Job Shops* & *2D Nesting* and included the best practises, case studies & benchmarking.

- Determined problems, limitations and constraints in the planning, nesting and batching processes.

- Completed a SigmaNEST software analysis.

- Developed and implemented an improved *Production Planning Process* including the implementation of SigmaNEST software. This included an implementation plan, a training manual, licensing needs, Workflow Manual and a scheduled approach.

- Determined batching rules and batch sizes according to the operation and set-up times, design changes, design stability, etc.

- Analysed current material handling methods and improvement possibilities.

- Developed an implementation plan for the new batching and nesting methods and processes.

1.6.2 *Project Approach Diagram*

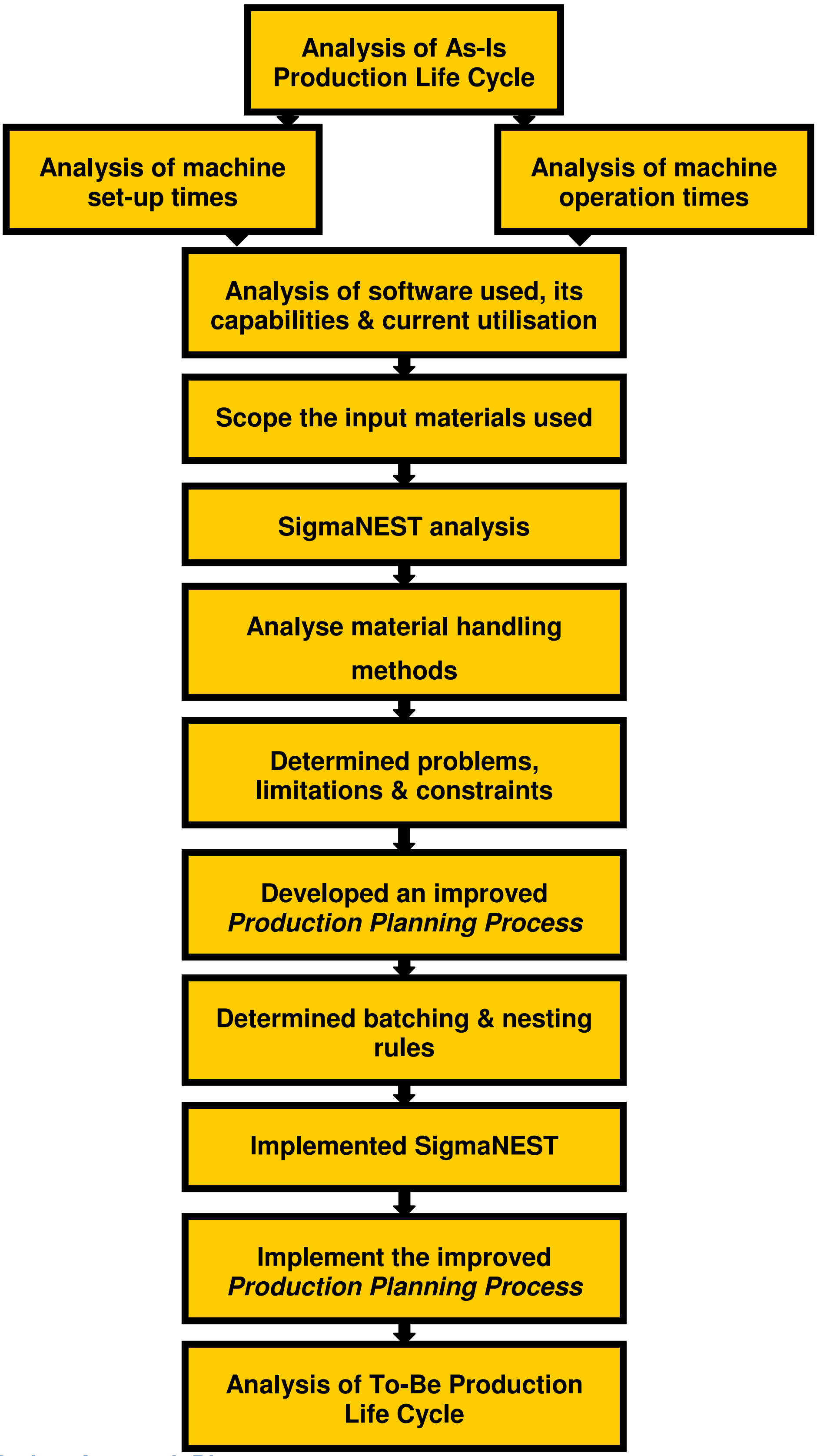


Figure 2 - Project Approach Diagram

1.7 Deliverables

- Group products according to process flow
- As-Is Business Process Flow including inputs and outputs and the interaction between the different software systems including:
  - Controlware
  - Preactor
  - Syspro
  - SigmaNEST
- Literature Study Report
- Implementation & Integration of SigmaNEST
- Evaluation of Dynamic and Static nesting process
- Improved Production Control Process
- Batching Laws
- Implementation of Batching Rules including an action plan
- SigmaNEST Manual
- SigmaNEST Workflow and Process Manual
- Final report and presentation to management

1.8 Resources

The main resource for this project was the people working at The UCW Partnership. This included various people from management to shop floor level. The necessary parties have been interviewed and the data gathered was used to define the As-*Is* picture. Further resources included the internet, software descriptions, software manuals and previous project reports on projects that were done on this specific shop, M9. More resources were also used during the literature study that was done on the different batching and nesting techniques and methods available. These resources included journal articles and readings, internet resources and textbooks on the applicable techniques and methods. A study on material requirements planning and scheduling methods has also been conducted.

2 LITERATURE REVIEW

2.1 Introduction

The literature review was done to identify and investigate industrial engineering principles and methods that could aid in the completion of this project. Research was also done on the different process approaches and applicable software systems that are used at The UCW Partnership. A quick overview of the different process control software systems has been compiled.

2.2 Process control software currently used at The UCW Partnership

2.2.1 SYSPRO

SYSPRO is a business process platform and provides enterprise business solutions. SYSPRO was formed in 1978 and was one of the first vendors that developed an enterprise resource planning (ERP) solution software.

The company’s main mission is to develop remarkable software that simplifies operational effectiveness on a continuous basis and keeps the customers in control of their own businesses. (Syspro, 2006)

2.2.2 Controlware

Controlware does the same work as a control engineer. Controlware imports the planned times per activity from Syspro and then compares it to the actual time per task completed. This information is then fed to Preactor. Preactor uses the new, updated times to refine its schedules and production planning.

Controlware can also be used for batching and scheduling of tasks, but this is not its main purpose. Controlware can batch the tasks according to dates, set up times, type of material required and machine used for manufacturing. (Controlware, 2006)

2.2.3 Preactor

Preactor is a world leader in the Production Planning and Scheduling software market. There are currently more than 2 500 companies, in 65 countries that are using this product to streamline their planning and scheduling needs.

The software has a large array of functions that assist the production planners and schedulers in assigning different tasks to different work centres and shops. (Preactor, 2007)

These functions include:

- Automatic resource selection
- Capable to Promise (CTP) enquiries
- Finite and infinite resource capabilities
- Resource efficiency enquiries
- Breakdowns and planned maintenance incorporation
- Process run time and reports
- Single/multiple resource constraints per operation
- Automatic schedule repair
- Cost calculation by order
- Rule building functions

2.3 Nesting

Nesting is the process of efficiently planning and manufacturing parts out of raw, flat material, like sheet metal. Algorithms are developed to fit the highest possible number of parts into one sheet of metal and therefore maximising the material utilisation.

The manufacturing processes of these parts include; water jet cutting, plasma cutting, laser cutting, blanking, shearing, ultrasonic cutters and guillotines. Nesting software is used to implement the algorithms and minimise scrap and therefore increasing material utilisation. These algorithms determine the best orientation of the different parts, to enable the shop to produce the required number of parts, on a specific machine and at a specific time, while reducing material wastage.

There are a large variety of software programs available and their functionality and ability varies a lot. The least expensive and most basic options only do nesting of rectangular shapes. The other more complex options have a number of nesting algorithm possibilities and odd and complex shapes can be nested to further increase material utilisation. The software imports the part drawings from the applicable CAD software and then determines the optimal layout of the nest.

Nesting software must take machining limitations and features, which are associated with the applicable manufacturing technologies used, into account.

These include:

- Material wastage due to clamping
- Width of the punch tool when using punching technology
- Shearing limitations
- Guillotines can only cut in a straight line and they also cut through the entire sheet
- Rotation angles of the material and process used (i.e. laser cutters cut in any rotation and punches only at right angles)
- Direction constraints on the applicable materials

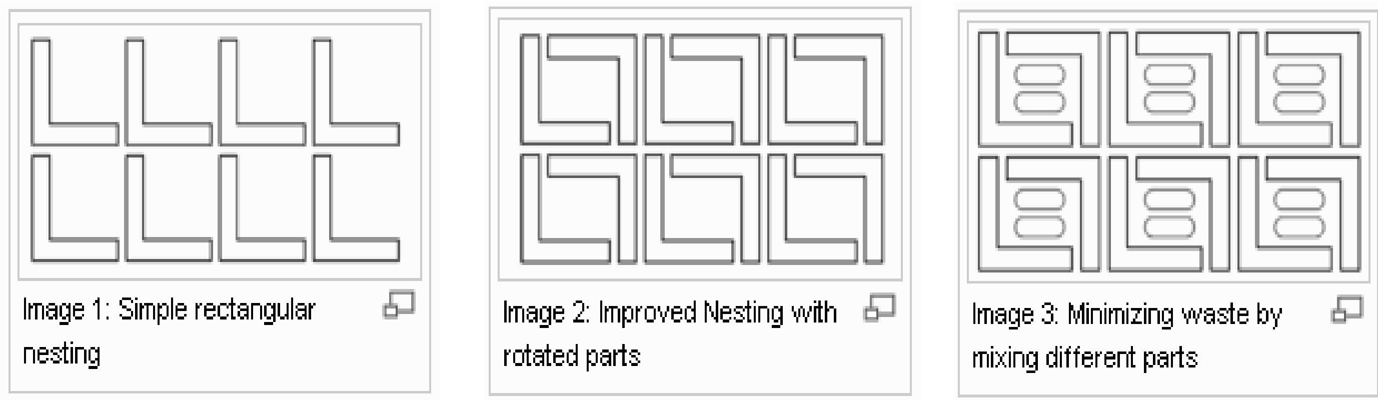


Figure 3 - Maximising material utilisation through effective nesting methods (JETCAM International, 2009))

2.4 Off-the-Shelf Nesting Software Packages

2.4.1 SigmaNEST

SigmaNEST is an integrated nesting, profile cutting and punching CAD system. SigmaNEST also interfaces with most CAD programs. SigmaNEST uses an advanced automatic nesting algorithm. The algorithm is feature-based enabling it to accommodate arbitrarily shaped parts while recognising inside contours and geometric irregularities.

Optimal material utilisation is ensured by making use of automatic "parts-in-parts" nesting algorithms. (Sigmatek, 2003)

SigmaNEST enhances productivity through:

- Reducing scrap material through improved utilisation
- Saving time in profile cutting activities
- Improving parts quality and accuracy
- Dynamic auto tooling in punching operations
- Advanced repositioning algorithms
- Inspection of parts
- Advanced auto tabbing algorithms
- Estimating more accurate and competitive quotes based on computer generated material (SigmaTEK, 2004)

2.4.2 ProNest

ProNest is a powerful nesting software system that is easy to learn and simple to use. ProNest software gives the user superior material utilisation, without compromising on machine and nesting times. ProNest has the advanced option of *"Nesting System Optimisation"* that allow the user to evaluate between different nesting possibilities regarding the sheet sizes, material inventory and different nesting strategies. ProNest converts uploaded CAD drawings into nest-ready parts and a variety of reports can be drawn from the system.

ProNest's *"claim-to-fame"* is the fact that the time it takes to learn to use the software is only a quarter of that of its competitors. (MTC, 2007)

Standard features of ProNest include:

- Automatic CAD imports and material assignment
- Variable part creation and advanced *"Drag-and-Drop"* nesting methods
- Detection of part interfaces
- Part and clamp interference detection
- Automatic and interactive sheet cropping
- Animated cutting sequence animations
- CNC Post-Processor (MTC, 2007)

2.5 Nesting Methods (Dynamic vs. Static nesting)

2.5.1 Dynamic nesting

Definition

Dynamic nesting is the continuous nesting of different parts on different sheets of material, depending on the production orders and the material inventory. This results in continuous process where a new nest is done for every batch of production orders. It is also known as *"ever changing"* nests. Dynamic nesting is therefore better suited to projects and job shops where the flow of material and parts manufactured are inconsistent. It is also of great advantage to batch processing systems, if the batches differ in quantity and types of parts to be manufactured. (Taylor & Francis, 2000)

Advantages of Dynamic Nesting

The main advantages of dynamic nesting are its ability to change over time and to adapt to specific needs at a specific point in time. It therefore gives you the optimal material utilisation for the required parts, for every batch of products ordered.

Disadvantages of Dynamic Nesting

Dynamic nesting is time consuming; this is mainly because it has to be done on a continuous, ongoing basis. The required parts have to be imported into the software and new nests have to be calculated according to the material available in the inventory.

2.5.2 Static nesting

Definition

Static nesting is the once-of nesting of different ordered parts on standard sheets of material. This results in standard, static production orders that can be implemented for long term use. These static production orders are effective because the various nests are only made once for an entire production lifecycle. This makes static nesting more suited to batch processing and continuous manufacturing systems. (Taylor & Francis, 2000)

Advantages of Static Nesting

The main advantage of static nesting is the cost and time effectiveness of the nests. This is due to the once-off nature of this method. The production orders and batch sizes will remain constant and will therefore enable the production managers to complete only a single nest.

Disadvantages of Static Nesting

The main advantage can also be the main disadvantage. The fact that the nest is only done once and then used for the entire production lifecycle, limits the production orders to constant batches. The main problem with this method arises when design changes occur and re-work on parts has to be done. This will force the production managers to either re-nest their production orders or to manufacture unnecessary parts that are not ordered.

2.6 Manufacturing Scheduling and Planning

2.6.1 Types of Manufacturing Processes and Scheduling Approaches

TYPE	PRODUCT	CHARACTERISTICS	SCHEDULING APPROACH
Continuous	Chemicals, wire, cables, liquids, etc.	Full automation, one facility dedicated to only a few products	Forward scheduling (Finite), limited to machine/demand capabilities
High-volume	Automobiles, textiles, telephones, etc.	Semi-Automated, assembly lines & little/no handling	JIT & Kanban systems, production pull schedule
Mid-volume	Industrial parts, consumer products.	Mini factories, highly specialised, automation varies	Forward scheduling (Infinite), limited to labour & due dates
Low-volume	Custom designs, prototypes & specialized products	High labour, long set up times, large variety of products, high material handling	Forward scheduling (Finite), limited to labour/machines & due dates

Table 1 – Types of manufacturing Processes and Scheduling Approaches (Richard B. Chase, F. Robert Jacobs, Nicholas J. Aquilano, 2007)

2.6.2 Scheduling and Control Functions

Functions performed for scheduling and controlling operations:

- Allocated orders, equipment and man hours to the different work centres and other locations. (Short-run capacity planning)
- Determined order performance and order sequence. (Establishing job priorities)
- Performance initiation of scheduled work. (Order dispatching)
- Control of the shop floor through:
    i. Reviewing the order progress and status control
    ii. Expediting late and critical orders (Richard B. Chase, F. Robert Jacobs, Nicholas J. Aquilano, 2007, p. 666)

2.6.3 Operations Scheduling – Shop-floor Control

Definition

"A system for utilising data from the shop floor as well as data processing files to maintain and communicate status information on shop orders and work centres." – R Chase

Major Functions

The major functions of shop-floor control include:

i. Assigning priority to each shop order
ii. Maintaining work-in-progress (WIP) information
iii. Communication between shop-floor and management offices
iv. Providing actual output data
v. Providing quantity per location shop information
vi. Measuring efficiency, utilisation and productivity of capacity

(Richard B. Chase, F. Robert Jacobs, Nicholas J. Aquilano, 2007, p. 675)

Shop-Floor Control tools

The basic tools for shop-floor control include:

1. A daily dispatch list, this list will tell the supervisor, foremen and managers which jobs to run, when to run them and the planned time to complete the various jobs.
2. Various reports, including status and exception reports, including:
   i. Anticipated/forecasted delay reports, this will affect the master schedule.
   ii. Scrap reports, including reasons.
   iii. Rework reports, including reasons.
   iv. Detailed and summarised performance reports.
   v. Shortage lists.
   vi. Updated bill of materials
3. GANTT Charts
4. Input vs. Output Control (Richard B. Chase, F. Robert Jacobs, Nicholas J. Aquilano, 2007, pp. 675-676)

2.6.4 Change Management

Different models and theories

Unfreeze-Change-Refreeze

This is on of the earliest models of change management and was developed and later edited by Kurt Lewin. He defined the three-stage process, consisting of:

1. Unfreezing – Mainly consisting of overcoming the existing mindset and narrow mindedness.
2. Change – This is the stage where the physical change occurs through a period of confusion and transition.
3. Freezing/Refreezing – New methods and techniques becomes the norm and the previous comfort levels and acceptance are again reached.

This model is also known as the *"Exit-Transit-Entry"* method. (Lewin, 1952, p. 187)

People Centered Implementation (PCI)

This is a technique to manage change and was developed by *Changefirst.* This method has gone through continuous improvements and has been rephrased a number of times.

The six crucial success factors of the PCI Method include:

1. Shared change policy
2. Effective change leadership
3. Powerful Engagement Processes
4. Committed local sponsors
5. Strong personal connection
6. Sustained personal performance (Hiatt, 2006)

Dynamic conservatism

This is a model developed by Donald Schön and is more focussed on change in an organisation or company. It explores the inherent nature to be conservative and reluctant to constant change that is found in most organisations. Schön recognised the specific need for consistent and continuous change and implementation of flexibility in the modern global market environment.

This method includes:

1. Implementing a *"learning"* process and organisation
2. "Reflection-in-action" techniques
3. Process mapping and tracking (Schön, 1974, pp. 201-203)

2.7 Material Handling

2.7.1 Definition

Material Handling concerns the movement, storage, protection and control of different materials, goods and products throughout the manufacturing process. This process includes; distribution, consumption and disposal. The focus is mainly on the different methods, mechanical equipment, systems and related controls used to achieve the required functions.

- *"Material handling is concerned with the*
    - *Movement*
    - *Storage, and*
    - *Control*

  Of material in a process" – Logistics System Design: Material Handling Systems; (Marc Goetschalckx; 2003)

- *"Material Handling refers to activities, equipment, and procedures related to the moving, storing, protecting and controlling of materials in a system." - Facilities Planning*, (Tompkins, White, Bozer, Frazelle, Tanchoco, Trevino, 1996)

- *"Material Handling means providing the right amount; of the right material; at the right place; at the right time; in the right position and in the right sequence for the right cost." - Factory Physics*, (Hopp and Spearman, 2003)

2.8 Conclusion

The literature study was completed across various applicable industrial engineering methods and techniques. The various software systems, nesting methods, scheduling and planning, change management systems, material handling and shop-floor control methods have also been analysed and their applications determined where applicable.

The information gathered was used in the final decisions made during this projects and formed part of the final design and solutions of this project.

3 AS-IS ANALYSIS AND METHODS TO BE USED IN M9

3.1 Introduction

The only applicable data that was gathered for this project was the information on the different types of material purchased and used in the M9 Workshop. The large variety of different types of steel and the numerous different sheet sizes made this information very important. The data acquired was used to determine effective batch sizes and the different nesting procedures and parameters.

3.2 Types of steel used

3CR12

CR-Mild Steel

HR-Mild Steel

300WA

50C-Plate

Aluminium Vastrap

AL2S

3.3 Additional material information

There are 234 different types of steel sheets that can be bought from various steel suppliers. This is such a large number because the sheets are available in a large array of different thicknesses and sheet sizes. Sheets range between 1mm and 120mm in thickness and the sizes vary from (1m x 1m) to (10m x 2.4m).

This in itself is created a big materials management and storage problem. All the different types of steel have to be stored in different, allocated areas and within these areas the different sheet sizes had to be separated. The ordering processes and levels of planning control that the MRP required was becoming a huge supply chain challenge.

The average lead time on steel orders are 6.218 days with a minimum of 0 days and a maximum of 40 days. These however differ according to the market requirements and the suppliers used.

3.4 Industry benchmark

3.4.1 Introduction

Kulungile Metals Group is a material and parts supplier that acts mainly as an outsourcing company for The UCW Partnership. They manufacture a large array of parts from various material types and thicknesses. The large variation in parts, the volume of Kulungile's contracts and the way in which they manage manufacturing make them a perfect benchmark for the sheet metal manufacturing industry.

A questionnaire was compiled and sent to the managers of Kulungile. They had time to review the questionnaire and advise The UCW Partnership on their various manufacturing procedures and approaches. The production manager and the head of the drawing office were also interviewed and explained their procedures and methods in detail. Some of the representatives of The UCW Partnership were also allowed to complete a site visit at Kulungile's plant in Spartan.

The following report was completed once the site visit and the questionnaires was completed.

3.4.2 Kulungile Metals Group - SigmaNEST Report

Kulungile is a metal component supplier that manufactures parts as ordered by their various clients. They deal with a wide variety of parts and inconsistent orders due to the nature of their business. This high level of variation complicates production planning and material control. It is therefore of utmost importance to minimise off cuts and material inventory. The large quantity of material in inventory is mainly due to the high volume of off cuts and the large array of different material types and thicknesses used.

Kulungile therefore uses SigmaNEST to nest the ordered parts on available sheets and off cuts. This nesting is done in the drawing office. SigmaNEST is used by the draftsmen, production schedulers, material managers and production planners. Off cuts are also uploaded into the system and are shown on the available materials list. Off cuts are stored in an upright position to minimise the floor space occupied. This upright storage method also enables the workers in the workshop to identify specific plates and stock codes. This greatly reduces the time spent looking for material and the material handling time. The required sheet will never be at the bottom of a pile of sheets.

Kulungile’s Cape Town office also uses the quotation capabilities of SigmaNEST to add mark ups to their material usage and guide their sales teams to complete quotes for their customers. This results in very accurate cost estimations due to the fact that material, labour, energy and machine costs are taken into account. SigmaNEST uses cost per pierce and running cost per millimetre to complete the production quotes.

Drawings are imported into SigmaNEST from the various CAD software packages that are used by the draftsmen. The drawing can only be uploaded onto SigmaNEST if the applicable CAD software programs are also running on the same network or PC. It is therefore very important to have a dedicated network port available and the draftsmen may be required to manually upload the drawings in to SigmaNEST. These drawing formats include: CDL, DXF, ICS, DWG, IGES, SAT, Step, Solid Works, Solid Edge, Pro-E, Autodesk Inventor, Unigraphics, Unfolder, Catia, Think 3 and NC.

Part drawings are imported as a total document including the applicable notes, drawing sheet and dimensions. This is important for the control checks between drawings and job orders. This unnecessary information should however be removed before the final nesting is done. By removing all the unnecessary information, the extracting step in the nesting process is completed.

A further positive function from SigmaNEST is that it picks up drawing errors and immediately enables the user to correct these errors. The software indicates to the user where the drawing error occurs and thus reduces the time spent on correcting the drawings. The corrected SigmaNEST drawing should then be saved to the correct file path. This will clean up the data base and result in once-off fixing of the nesting drawings. The revision number can also be included in the 2D part drawing. This is also very important for controlling and managing purposes, especially in a manufacturing environment where design changes occur regularly.

Kulungile only use dynamic nesting because of the high variation in parts ordered as well as the time between orders. Parts from various orders are nested together to ensure better material utilisation and reduction of off cuts produced. Once the parameters have been set and the nests completed, the “Auto NC” function is used to code the required production process. These programs are then sent to the various operating machines via a wireless network. This ensures that the required codes are available when the material reaches the production floor.

There are no control loops present in Kulungile's production processes; this is mainly due to the fact that they are an outsourcing company that receive the drawings from outside companies. It is therefore important that their customers send them the correct drawings including the required information and manufacturing parameters. Some of the SigmaNEST input parameters include: The number of nest tries, nesting strategy used, clearance gap between parts, lead in clearance, priority (which to cut first), check lead-ins and shear or cutting nesting. The various strategies determine in which direction sheets are filled.

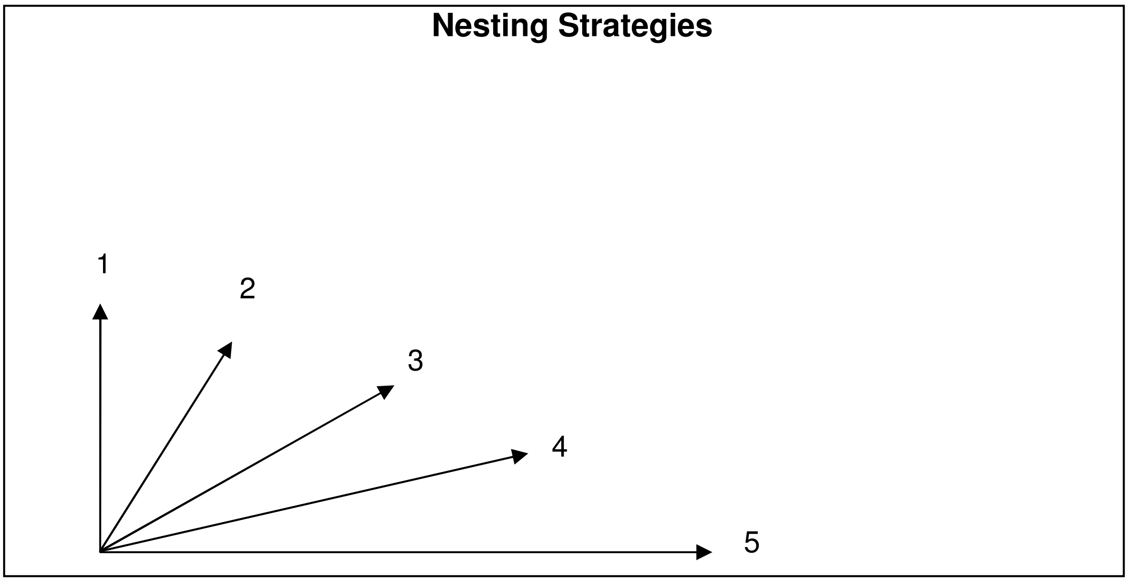


Figure 4 - Nesting Strategies

3.5 Component Rejections

3.5.1 Introduction

Defective parts and component rejections are a far too common sight at The UCW Partnership. These defects cover a wide array of types and reasons but remain unacceptable practise as it causes a lot of time, material and money wastage. More than half of all the rejections are due to incorrect dimensions, which include geometric dimensions and incorrect hole positions.

3.5.2 Types of Defects

- Incorrect dimension & hole errors
- Bending errors and inaccuracies
- Material Defects
- Wrong shape and shape variations
- Unprocessed parts and material

3.5.3 Reasons for Defects

- Different revisions used at different stages of the production cycle. This leads to miss fittings and manufacturing errors. The revisions are not sent to all the departments and stages. In some instances the components are already manufactured before the final revisions are received and they fail to reproduce the ordered parts.
- Poor cutting procedures & incorrect dies used.
- Defective equipment used. This can be due to unplanned break downs, machine defects and incorrect and insufficient maintenance.
- Incorrect and unnecessary handling of material and parts. The more handling the material and parts has to undergo, the greater is the probability that they can be mishandled and damaged. It is therefore very import to minimise handling and to apply the necessary care and correct procedures and use the correct equipment when parts and materials are handled.

3.6 Conclusion

The large quantity of different sheet types and sizes are a complicating factor in the production of parts at The UCW Partnership. The UCW Partnership is advised to reduce the number of different sheets purchased. This reduction will lower material inventory levels and increase material planning and control. This data will also be used to assist in future material purchasing, material requirements and material stock management.

After visiting The Kulungile Metals Group and seeing how they utilise their nesting software, The UCW Partnership decided to train various personnel in the SigmaNEST software package and obtained an extra SigmaNEST operating license. An audit and upgrades were also done on SigmaNEST, the operating systems and the various software packages. A relationship between Kulungile Metals Group and The UCW Partnership was established. The customer and supplier will, in future, work together to obtain the best possible manufacturing methods and techniques. The upright storage methods and off cut numbering and control methods will also be investigated and applied where applicable in future. Research will also have to be done on the type of clamping and cranes used at Kulungile's Isando plant as the safety precautions involved with upright material storage is of a much higher standard than that of flat storage methods.

There seem to be limited awareness concerning quality in the workshop. The root cause analysis is lacking and results in the same defects occurring repetitively. Incorrect drawings are also contributing to the amount of defective parts produced. The storage and handling of material and parts are also creating a problem because of parts and materials being mishandled or lost. It is also advisable to implement a self inspection and accountability procedure in the production process. Management will have to make a strategic decision to increase the level of quality awareness and accountability throughout the entire plant and all of its operations. The clocking disciplines and adherence to rules and manufacturing procedures will play an integral part in the continuous improvement process.

4 DESIGN AND SOLUTIONS

4.1 Introduction

The designed solution was to fully install, implement and utilise the SigmaNEST software and the required user and system interfaces. The system interfaces included the internal relationships between Syspro, ControlWare, Preactor and SigmaNEST. SigmaNEST will now nest parts and batches through automatic nesting algorithms and according to the methods and processes described in this report.

4.2 Batching Rules

Batch parts according to:

- Date required
- Type of material used
- Thickness of the material used
- Machine used for manufacturing (Plasma cutter, Profile cutter or guillotines)

This is a major improvement, because previously only the date required was used to batch parts. The batched production orders will then be sent to the nester.

4.3 Software used at The UCW Partnership

SigmaNEST nesting software was used, because The UCW Partnership had already attained several licenses to use this software and some of the employees have received training in the software. Additional licenses had a much smaller cost implication compared to the purchasing, installation and implementation of the ProNest software. Implementation of ProNest would have had additional training and implementation costs as well as system downtime due to the upload of data and synchronisation with the operating system. SigmaNEST was also a better fit for the specific problems at The UCW Partnership, because of its dynamic auto tooling and parts-programming features.

Although SigmaNEST has been more complex to master, it was seen as a long term investment and the dividends are endless. The required user manuals and interfaces were available at The UCW Partnership and a relationship with the software distributor already existed. This minimised the complexity of further training, which was required.

A further advantage is that The UCW Partnership has previously used SigmaNEST to do some of the planning of their CNC processes and therefore some of the employees had experience in the software usage.

4.4 Nesting method used at The UCW Partnership

The more stable, static nesting method would have been preferred in a perfect, theoretical environment. This is mainly due to the fact that batch production is applied and that more than one of the same type of product are manufactured. The fact however remains that design changes and subsequent re-work, forms part of the daily existence of The UCW Partnership, and therefore makes static nesting less attractive. The large array of different parts manufactured at shop M9, further complicated the nesting methods and procedures.

The amount of parts manufactured makes it a very high risk move to implement static nesting. The uncertainty of the future contacts and the order book adds more weight behind the dynamic nesting argument. It will be a huge financial risk to implement a static nesting procedure and produce parts for trains and locomotives that have not been ordered yet. The nature of the industry and contracts signed, forces the use of dynamic nesting in stead of static nesting.

It was therefore more profitable to start with a dynamic nesting procedure. This enabled the production planners to run a nest for a specific batch of production orders and incorporated the material inventory in the optimal nesting solution. This greatly aided the then, current situation, where lots of off-cut material and random sheets were available on the manufacturing floor. The production planner is now able to upload an available sheet size into the nesting software, draw the required batch of production orders from the database and determine the optimal layout to maximise material utilisation.

It is also strongly advised to reduce off cuts where applicable by trying to fill sheet with required or ordered parts. It is therefore of utmost importance to keep track of all the parts manufactured and to update all these parts on the system.

4.5 Further Industrial Engineering Tools and Techniques Used

The UCW Partnership and its factories are treated as a *"High Volume"*, manufacturing factory and assembly line. This helped to categorise the different methods and structures that will be implemented in the future. This also indicated that batch production cycles and accurate forecasting is part of the production planning and control systems at The UCW Partnership. Additional sequencing and production control features are irrelevant as long as the current state of affairs continue. This will however be looked at and modified once the capacity and material utilisation has been improved.

The *"Dynamic Conservatism"* method was used to manage the change in the materials purchasing, production planning and scheduling methods at The UCW Partnership. This method was preferred because of the nature of the area of change implementation. The Dynamic Conservatism method is more suited to organisational structures and areas where change is treated as an unknown and untouched enemy. The UCW Partnership has lots of employees that have literally been working at the same factory for decades and the same methods and communication channels have been used for years on end. The old methods have been working for years and that is why the employees will be tentative not to change anything, but the global market, including their competitors has changed and adapted over the years. It was therefore very important to implement a mindset of change and continuous improvement in the company.

A stable manufacturing system and schedule will trigger a lot of further improvement possibilities. These will include line and load balancing, capacity planning by using forward load techniques and the implementation of issuing through kitting methods and procedures. Stock will be issued, in pre-packed kits, to the specific births where it is required. These kits will consist of all the parts, materials, fixings and consumables that are needed at the specific workstation. The kitting methods and procedures will work on a Just-in-time basis and will dramatically reduce inventory levels and increase material and inventory management and control.

4.6 SigmaNEST Implementation

4.6.1 Action Plan

1. Compile a parts list for all the Plasma Cutter operations per contract for:
    - 16 mm
    - 20 mm

2. Import drawings to SigmaNEST, in the correct format and do corrections where necessary. These corrections may include:
    - Openings on corners
    - Incorrect information and material specifications
    - Differences between the drawings and the POs

3. Determine static nesting parameters including:
    - Number of contracts per batch
    - Inventory levels allowed

4. Optimize nesting methods including optimum plate sizes as material inputs.

5. Synchronise the Syspro and SigmaNEST software packages to control the materials issued and remnant stock available.

6. Determine and control safety stock levels to act as a buffer.

7. Correct planning through implementing and managing feedback loops.

8. Assign the responsibility to do a stock-take and clean out inventory where applicable by implementing dynamic nesting procedures and methods.

9. Install Network Points at the various processing machines.

4.6.2 Action Plan Diagram for Static Nesting

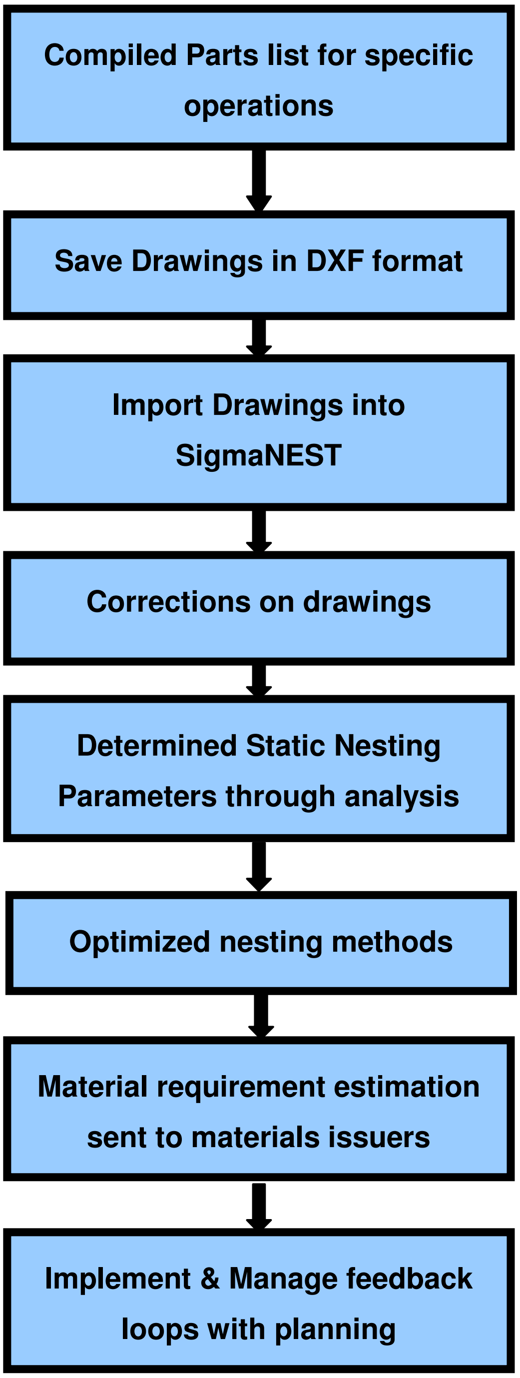


Figure 5 - Action Plan Diagram for Static Nesting

4.6.3 Process Flow for Static Nesting

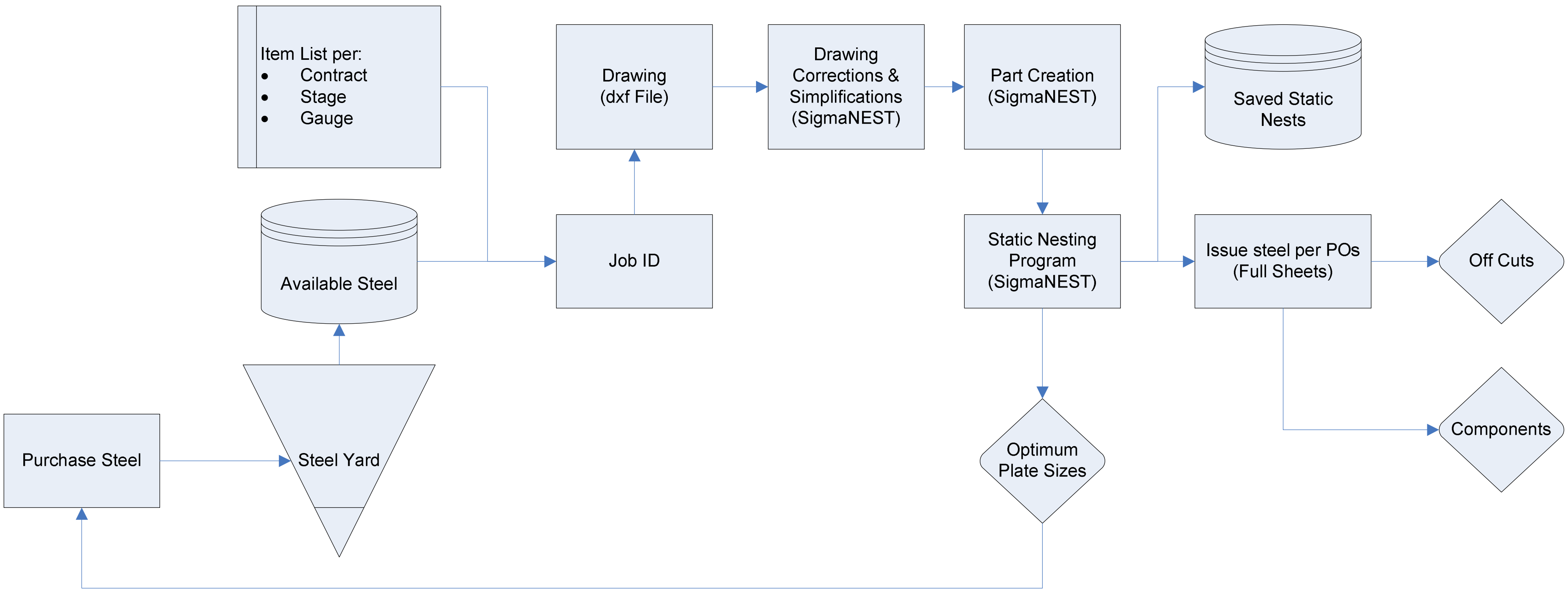


Figure 6 - Process Flow for Static Nesting

The static nest will only be used for materials planning and purchasing. The static nests will aid both of these departments in establishing a better estimation of the materials used per contract on the various projects. The material will however be issued according to the dynamic nesting parameters as will be discussed later in this report.

The static nesting procedure will start of by compiling the parts lists for the various material types, thicknesses and processes used. The drawings will be saved in a dxf. format after which it will be imported into SigmaNEST where the necessary corrections will be done and the parts created and stored on the data base. The static nesting parameters will then be implemented and the applicable plate sizes and quantities to be issued will be determined through an analysis procedure. These estimated material usage guides will then be sent to both the material issuing and material purchasing departments. This will greatly aid in the material issuing and usage management.

A further advantage of implementing this method will be the negative flow back control system that will aid the purchasers in deciding on the correct sheets and quantities to buy in the future.

4.6.4 Action Plan Diagram for Dynamic Nesting

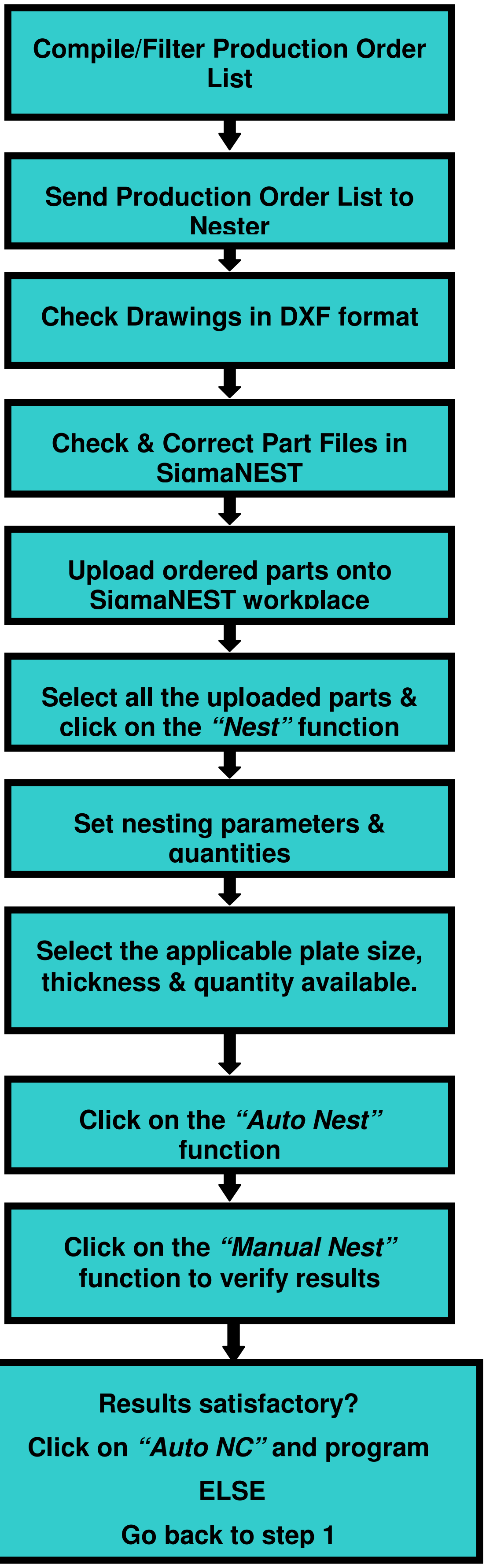


Figure 7 - Action Plan Diagram for Dynamic Nesting

4.6.5 *Process Flow for Dynamic Nesting*

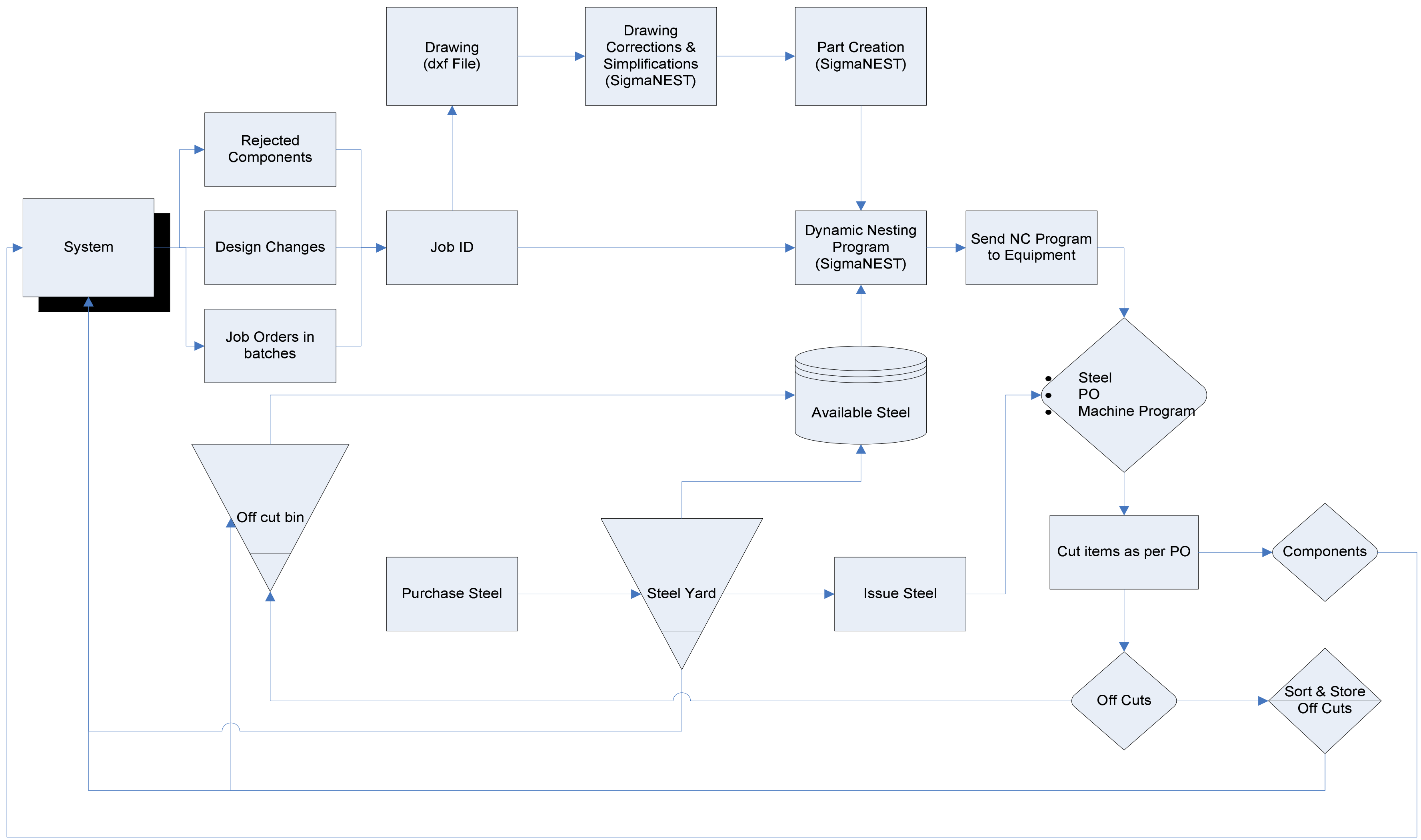


Figure 8 - Process Flow for Dynamic Nesting

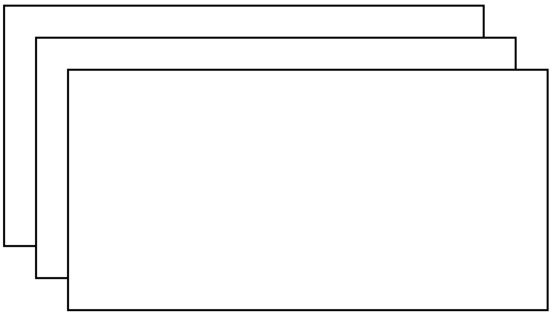
The dynamic nesting procedure will be used for physical plate/sheet nesting and will greatly aid the workshop to reduce their off cuts and wastage production. Material will be utilised in full sheets and this will also reduce set-up and material handling times.

The nesting software will be synchronised with Syspro to enable the nester to only nest on available plates/sheets of material. The parts to be nested will also be drawn from the system and will reduce the time it will take to fill up the nested plates. The synchronisation will also aid in the production control and management of parts in inventory that has already been manufactured.

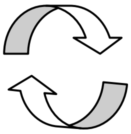
The parts to be manufactured will be batched according to the dates required, material type and thickness to be used and the starting process of manufacturing. This will enable the nester to nest on full, available plates for a specific production process. The drawings will also have to be saved in dxf. format if it has not yet been done. Thereafter the drawings will be imported into SigmaNEST, corrections completed on the drawings and parts created, if the required parts are not yet on the data base. The quantity of parts ordered and the task parameters must be checked before the final nest is completed. The available sheets and off cuts will be visible in SigmaNEST and the nester will be requested to nest full sheets. This will only be possible through an open production order window and the batching being done for up to two weeks at a time. Once the sheets have been filled, the *Auto NC* function will be used to complete the programming for the ordered parts.

After the NC programming has been completed; the parts list together with the *Production Orders*, the physical issued sheets and the NC program will be sent to the shop floor for production. The parts produced will be updated on the system and the off cuts will be sent to the applicable storage areas.

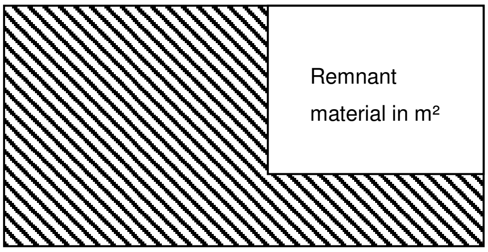
4.6.6 System Update Procedures



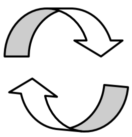
Material available to issue – [Syspro stock Code X] (EA) – Full sheets only



Synchronise raw materials with SigmaNEST (Full sheets only)



1. Manually issue full sheets to jobs as required per nests done.
2. Do a manual negative issue of remnant m² to job. [Stock Code XR (m²)]



Synchronise raw materials with SigmaNEST (Full sheets only)

Figure 9 - System Update Procedures

4.7 Nesting Parameters

- Nesting will be done on full plates to reduce off cuts and increase material utilisation, this will also reduce set up times and material handling times.
- Off cuts produced will be updated back onto the system to enable the programmers to us them for future dynamic nests.
- Parts from different projects will be mixed to increase material utilisation.
- All the parts on the filtered Production Order List must be nested for the specified production period.

4.8 Cost comparison

A cost comparison was done on the different costs of the alternative solutions and the estimated costs of the current manufacturing system. The current costs were compiled by using square, guillotine type nesting. This is however a better method than the current practise, but sufficient due to the lack of any current costs or control measures. The saving indicated will therefore be a very conservative, minimum value that will be greatly exceeded once the total new system is up and running.

Money Saved per material type

3CR12 - 16mm	3232.82
3CR12 - 20mm	4624.50
300WA - 16mm	1575.87
300WA - 20mm	0.00
TOTAL:	9433.19

Table 2 - Money saved per material type

The new improved nesting and batching system will therefore save the UCW Partnership a minimum of R9 433.19 per manufacturing heart-beat on the 16mm & 20mm, plasma cutter parts alone. The 16mm and 20mm parts only makes up a very small amount of all the parts manufactured at The UCW Partnership.

4.9 Material handling

4.9.1 Background

Materials and off cuts are currently stored on different heaps in and around the M9 workshop. These heaps contain either full, new sheets or off cut materials. A grouping structure is implemented in the off-cut bins and the steel yards. These plates are however only stored according to the type of material and the sheet thickness, plate size is not taken into account. It will be of an advantage to the company to implement a well defined grouping structure were plate sizes are sorted in different categories. This will encourage the workers to go and look for off-cuts to use, because it will require less effort of them.

It is also advisable to update the off cut inventory on the system. This can either be updated onto the Syspro material inventory or the SigmaNEST available materials library. SigmaNEST has a function called "*Crop Rem*" that was designed specifically with this requirement in mind. The off cut produced is calculated after the nest is completed and the operator is given the option to update the specific off cut back into the system for future use.

4.9.2 Flat storage

Flat storage of metal sheets are widely accepted and used as the safest and most common way of storing material sheets. It is however not the optimal solution because of the large floor space required and the long material handling times. These material handling times are becoming a problem due to the fact that sheets are not where they supposed to be. They are either on the wrong heap or at the bottom of a heap that will require the material handler to firstly lift all the sheets on top of the required one. These sheets will then, afterwards also have to be placed back onto the heap to reduce the amount of floor space occupied. Flat storage is however the safer option because the plates cannot fall over and the handling and grips are a lot safer and easier to use.

4.9.3 Upright storage

Upright storage methods and applications, including the material handing methods and tools have been researched and investigated. The applicable methods and techniques are very important, especially for the thicker plates where safety becomes the deciding factor. These plates can weigh up to 6 tons each. It is however possible to store all the plates upright in a safe and secure manor. The UCW Partnership's suppliers are already using these upright storage methods. These methods will reduce the floor space occupied by the material stored on the shop floor. It will also reduce the time spent looking for specific sheets and material, if the material tags and information are visible. The required sheet will never be lost or at the bottom of a heap of off cuts.

The upright storage method however requires more intense safety precautions and material handling equipment. The material handling equipment and grips for upright storage handling will have to be investigated and purchased. The material handlers will also have to be trained to use the new equipment and methods.

4.10 Additional project hurdles

- Drawing formats from planning and design due to the use of various CAD software programs. Save files in dxf format. Complete drawing corrections and simplifications in SigmaNEST before the parts are created.

- System updates, synchronisation and control is of utmost importance regarding nesting done, parts made and designs changed. The newly created off cuts, their sizes and drawings will be updated on the SigmaNEST materials library.

- Updating old programs and creating new programs to accommodate design changes and static nests. Store both the nested and the single part programs.

- It is very important to back up the NC programs, both on the user's machine and on a dedicated server.

4.11 Handling of Exceptions

Use dynamic nesting to handle exceptions. The proper processes and methods have to be followed and the necessary documentation and sign offs completed. This will enable the planners and material issuers to complete the required documents and release the new Production Orders. The Production Orders will be used to do new dynamic nests. These nests will preferably be done on off cut materials which will be uploaded onto the system. It will be the programmer's first task to find a suitable off cut to manufacture the required part. If however, there are no off cuts available or if the sizes and shapes of the off cuts are incompatible, full plates can be used to complete the additional work. The new off cuts that will be manufactured will have to be uploaded onto the SigmaNEST system to enable it to be used in future.

A further aspect within the handling of exceptions is to implement a control loop to eliminate further manufacturing defects and continually increase the material utilisation and control within the workshop. The root cause of the defects have to be found, reported and fixed. This will ultimately reduce the overall number of exceptions occurring and enable the planners to plan according to a stable, recurring manufacturing heartbeat.

4.12 Assigned Responsibility

- Software Interfacing & System Co-ordination – System Expert
  (Isak Pretorius)

- Production Planning & Scheduling – Production Scheduler
  (Paddy Whelan)

- Physical Nesting Procedures – Programmer
  (Seun Posthumus)

- Nesting & Programming – Programmer
  (Seun Posthumus)

- Nesting & Programming Back Up – Back Up Programmer
  (Keith Botha)

- Material Issuing – Steel Planner
  (Mary Fryer)

4.13 Future Tasks

- Finish all the design changes
- Implement a stable production system
- Full utilisation of static nesting methods for material purchasing and planning
- Implement upright storage methods

4.14 Conclusion

The improved solution was to introduce continuous dynamic nesting into the system, this minimised the total cost of material purchases and manufacturing set-up times. Continuous dynamic nesting will also assist the production schedulers and planners in knowing what parts to manufacture where and when. This will however only be improved once all the design changes had been completed and a stable manufacturing system is introduced. Design changes are one of the major enemies of a stable production schedule and are also one of the main reasons for not using static nesting methods and procedures. The parts that have already been cleared of any further design changes were static nested as a pilot project and the nests were completed on the preferred sheet sizes.

It was however concluded, after a thorough analysis, that static nesting was not the answer for this specific manufacturing environment. This was mainly due to the high volume of rework and the number of design changes that are made. The risk involved in a static nesting system will be too high and the cost implications could be disastrous. A further aspect in favour of the dynamic nesting method was the lack of future contracts being secured. Contracts are now signed for only a limited number of trains to be produced with the option of increasing the number of trains or locomotives ordered. Static nesting will increase the level of inventory and can lead to the production of parts that will not be used and will eventually have to be scrapped.

The completed static nests however aided the materials purchasing departments, who are now able to control and measure the amount of material issued. They now issue material according to a specific batch and nested sheets. This will greatly reduce the costs incurred by the materials purchasing and materials control departments.

The current material handling methods and techniques will be kept and the possible changes and improvements will only be made once the nesting and batching projects have been fully implemented and adapted.

5 CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The improvement of the material utilisation is possible through the effective and efficient use of batching and nesting techniques and software. The applicable software is already available, installed, and updated. The further improved nesting procedures should be implemented as soon as possible.

The UCW Partnership has decided to train various personnel in the SigmaNEST software package. This training has been completed and an additional SigmaNEST operating license has been purchased. An audit was also done on SigmaNEST, the operating systems and the various software packages. The newest version of SigmaNEST has since been acquired and the licences renewed.

The lack of planning and control disciplines are still an area of concern and the following requirements must be attended to:

1. A complete, integrated planning and control system
2. A valid master production schedule
3. Accurate data and planning times
4. Qualified people
5. Effective management to plan, execute and control

It is also advisable to implement a self inspection and accountability procedure in the production process. Management will have to make a strategic decision to increase the level of quality awareness and accountability throughout the entire plant and all of its operations. The clocking disciplines and adherence to rules and manufacturing procedures will play an integral part in the continuous improvement process.

5.2 Industrial Engineering Tools and Techniques Used

The UCW Partnership and its factories are treated as a *"High Volume"*, manufacturing factory and assembly line. This helped categorise the different methods and structures that will be implemented in the future. High volume manufacturing also indicated that batch production cycles and accurate forecasting are part of the production planning and control systems at The UCW Partnership. This will however only be looked at and modified once the capacity and material utilisation have been improved.

The nesting methods and algorithms used will greatly aid the production planning and management departments. These algorithms have been defined and tested over a large array of applications and over a long time. It is therefore of utmost importance to set the parameters and strategies used to optimally aid the company in their various production processes and planning.

Inventory control was also used to determine the length of the production window that will be opened. This was used as a direct measure of the batch sizes and lengths. The reduced floor space and storage area available were also deciding factors in the batching rules and sizes. This together with the management of Shop-Floor control tools that will be implemented will greatly reduce the levels of inventory of both the material and the work in process (WIP). A daily dispatch list with production orders will be handed to the foremen of the various shops. This will enable them to plan their productions process according to the parts required and level of capacity available for both machine times and material. Various reports and GANTT Charts will also be used to measure the adherence to plan and serve as key performance indicators (KPIs).

The *"Dynamic Conservatism"* method was used to manage the change in the materials purchasing, production planning and scheduling methods at The UCW Partnership. This method was preferred because of the nature of the area of change implementation. The Dynamic Conservatism method is more suited to organisational structures and areas where change is treated as an unknown and untouched enemy. The UCW Partnership has lots of employees that have literally been working at the same factory for decades and the same methods and communication channels have been used for years on end. The old methods have been working and that is why the employees will not want to change anything. The global market, including their competitors has changed and adapted over the years, it was therefore very important to implement a mindset of change and improvement in the company.

5.3 Optimal Solution

The optimal solution was to introduce continuous dynamic nesting into the system, this will minimise the total cost and will assist with the production scheduling and planning. This will be further improved and fine-tuned once all the design changes have been completed and a stable manufacturing system is introduced. The static nest will only be used for materials planning and purchasing. The static nests will aid both of these departments in establishing a better estimation of the materials used per contract on the various projects. The material will however be issued according to the dynamic nesting parameters. The dynamic nesting procedure will be used for physical plate/sheet nesting and will greatly aid the workshop to reduce their off cuts and wastage production. Material will be utilised in full sheets and this will also reduce set-up as well as material handling times.

The nesting software will be synchronised with Syspro to enable the nester to only nest on available plates/sheets of material. The parts to be nested will also be drawn from the system and will reduce the time it will take to fill up the nested plates. The synchronisation will also aid in the production control and management of parts in inventory that has already been manufactured.

The parts that have already been cleared of any further design changes were first in the static nests done on the preferred sheet sizes. The nests were done according to the prescribed parameters and used for material planning purposes. The static nests also aided the materials purchasing departments, who are now able to control and measure the amount of material issued. The material can now be issued according to the specific batch requirements and parts are nested on full plates. This will greatly reduce the costs incurred by the materials purchasing and control departments.

Dynamic nests will be completed according to the specified batching rules. These batching rules include:

- Date required
- Type of material used
- Thickness of the material used
- Operations used for manufacturing (M9-Code)

This is a major improvement, because previously only the date required was used to batch parts. Dynamic nesting will be used by the programmer/nester and the parts that need to be re-made, because of various occurrences, will be included in the nests.

Man hours, machine hours, money and material will be saved through the implementation of an ever changing and continuous environment within the company. This will enable the workers to come up with innovative ideas and enable engineers to run projects that will bear fruit for all involved.

5.4 Material Handling

The current material handling methods and techniques will be kept and the possible changes and improvements will only be made once the nesting and batching projects have been fully implemented and adapted. There are lots of areas for improvement within the material handling and storage procedures at The UCW Partnership. This will however only be completed on a later stage as an additional add-on project.

Upright storage methods and techniques will form the main parts of this project, with additional material handling techniques and storage layouts as an alternative solution.

5.5 Final Conclusion

This project greatly improved the capacity and material utilisation through the design, implementation and use of improved nesting and batching methods and processes. This was mainly achieved by the reduction of set-up and material handling times. The production of off cuts was also minimised which in turn lead to a reduction of waste produced and money lost.

The final optimal solution is a reachable goal that will be achieved by positive changes and continuous improvement of the newly implemented system.

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APPENDIX A

SigmaNEST Drawing List – 16 mm

Contract 19 = 15E, 15 = 19E, 17 = 10M Motors, 18 = 10M Trailers
WorkCentre M9-47... PlasmaCutter

Job	Item	Item Description	Contract	Stage	SubStage	Qty	Material	Material Description	Qty (m2)	Cutting Length	Cutting Width
1069773	8487078-0-M	TAPPING PAD	15	03	75	8.00	S-3CR12-16	3CR12-16MM	0.001	40.00	25.00
1907628	8487078-0-M	TAPPING PAD	19	06	20	16.00	S-3CR12-16	3CR12-16MM	0.001	40.00	25.00
1629760	8487078-0-M	TAPPING PAD	15	03	75	4.00	S-3CR12-16	3CR12-16MM	0.001	40.00	25.00
1907540	8487078-0-M	TAPPING PAD	15	03	75	4.00	S-3CR12-16	3CR12-16MM	0.001	40.00	25.00
1519836	2587891-0-M	DC ARRESTOR PAD	15	21	10	1.00	S-3CR12-16	3CR12-16MM	0.1104	460.00	240.00
1519832	2587883-0-M	EXTERNAL PAD INNER PLT.	15	21	10	7.00	S-3CR12-16	3CR12-16MM	0.0256	160.00	160.00
1520884	2587883-0-M	EXTERNAL PAD INNER PLT.	15	22	10	6.00	S-3CR12-16	3CR12-16MM	0.0256	160.00	160.00
1521205	2587883-0-M	EXTERNAL PAD INNER PLT.	15	23	10	1.00	S-3CR12-16	3CR12-16MM	0.0256	160.00	160.00
1521233	2587884-0-M	GRAB HANDEL MOUNTING PAD	15	23	10	2.00	S-3CR12-16	3CR12-16MM	0.012	300.00	40.00
1027266	7792135-0-M	SUPPORT BAR, INDUCTIVE SHUNT C	17	31	07	1.00	S-3CR12-16	3CR12-16MM	0.0545	778.00	70.00
1028014	7792138-0-M	SUPPORT BAR, INDUCTIVE SHUNT C	17	31	07	1.00	S-3CR12-16	3CR12-16MM	0.0678	848.00	80.00
1492679	2191032-1-M	PLATE	17	30	02	1.00	S-3CR12-16	3CR12-16MM	0.4824	2622.00	184.00
1898099	0391955-0-M	SPACER BRAKET	17	03	06	6.00	S-3CR12-16	3CR12-16MM	0.0015	60.00	25.00
927378	3391198-0-M	TAPPING PAD	17	31	02	3.00	S-3CR12-16	3CR12-16MM	0.003	60.00	50.00
927381	3391198-0-M	TAPPING PAD	17	31	02	2.00	S-3CR12-16	3CR12-16MM	0.003	60.00	50.00
927382	3391198-0-M	TAPPING PAD	17	31	02	1.00	S-3CR12-16	3CR12-16MM	0.003	60.00	50.00
598347	0391205-0-M	PLATE	18	03	08	12.00	S-3CR12-16	3CR12-16MM	0.0028	80.00	35.00
598398	0391206-0-M	PAD FIXING	18	03	08	3.00	S-3CR12-16	3CR12-16MM	0.005	125.00	40.00
598399	0391207-0-M	PAD FIXING	18	03	08	2.00	S-3CR12-16	3CR12-16MM	0.0082	205.00	40.00
913712	0391744-2-M	BOTTOM GUSSET BOLSTER	18	03	04	2.00	S-3CR12-16	3CR12-16MM	0.5186	787.00	659.00
1199320	0893098-0-M	TAPPING PAD	19	31	10	1.00	S-3CR12-16	3CR12-16MM	0.0372	600.00	62.00
1668144	0393400-1-M	ANGLE	19	05	10	1.00	S-3CR12-16	3CR12-16MM	0.4244	2070.00	205.00
1293389	0393400-1-M	ANGLE	19	03	30	1.00	S-3CR12-16	3CR12-16MM	0.4244	2070.00	205.00
1293481	2593221-2-M	POTENTIAL TRANSFORMER TAPPING	19	22	10	1.00	S-3CR12-16	3CR12-16MM	0.16	400.00	400.00
1294975	2593309-1-M	PANTO AIR THRU BUSH TAPPING PA	19	22	10	1.00	S-3CR12-16	3CR12-16MM	0.0625	250.00	250.00
1404388	2593220-1-M	SURGE ARRESTOR TAPPING PAD	19	22	10	1.00	S-3CR12-16	3CR12-16MM	0.09	300.00	300.00
1404407	2593526-3-M	VCB TAPPING PAD	19	22	10	1.00	S-3CR12-16	3CR12-16MM	0.5885	1070.00	550.00
1404428	2593527-0-M	EARTH SWITCH MOUNTING PLATE	19	22	10	1.00	S-3CR12-16	3CR12-16MM	0.1856	1280.00	145.00
1604540	0893190-0-M	TAPPING PAD	19	31	10	1.00	S-3CR12-16	3CR12-16MM	0.1301	2099.00	62.00
1865891	8993161-0-M	SUPPORT BLOCK	19	06	20	1.00	S-3CR12-16	3CR12-16MM	0.0016	40.00	40.00
1866165	8993161-0-M	SUPPORT BLOCK	19	06	20	1.00	S-3CR12-16	3CR12-16MM	0.0016	40.00	40.00
1905515	2593599-0-M	TAPPING PAD	19	06	12	4.00	S-3CR12-16	3CR12-16MM	0.0006	25.00	25.00

Job	Item	Item Description	Contract	Stage	SubStage	Qty	Material	Material Description	Qty (m2)	Cutting Length	Cutting Width
1285428	2593135-2-M	CAPTIVE PAD	19	24	10	26.00	S-U4-16.0	BLUE/Y200/E20/C.5	0.002	65.00	30.00
1286212	2593135-2-M	CAPTIVE PAD	19	24	50	6.00	S-U4-16.0	BLUE/Y200/E20/C.5	0.002	65.00	30.00
1478154	4693015-0-M	TOILET ADAPTOR PLATE	19	04	30	1.00	S-U4-16.0	BLUE/Y200/E20/C.5	0.81	900.00	900.00
1855828	4693015-1-M	TOILET BASE PLATE	19	04	30	1.00	S-U4-16.0	BLUE/Y200/E20/C.5	0.81	900.00	900.00

Job	Item	Item Description	Contract	Stage	SubStage	Qty	Material	Material Description	Qty (m2)	Cutting Length	Cutting Width
1029302	0893006-0-M	REAR COLUMN	19	31	10	1.00	S-U2-16.0	YELLOW/Y300/E20/C.5	0.9471	1868.00	507.00
1029642	0893008-0-M	REAR COLUMN	19	31	10	1.00	S-U2-16.0	YELLOW/Y300/E20/C.5	0.8798	1868.00	471.00
1044646	0893032-0-M	REAR COLUMN	19	32	10	1.00	S-U2-16.0	YELLOW/Y300/E20/C.5	0.8014	1868.00	429.00
1044649	0893031-0-M	REAR COLUMN	19	32	10	1.00	S-U2-16.0	YELLOW/Y300/E20/C.5	0.9545	1868.00	511.00
1175835	0893097-0-M	SIDE PANEL TAPPING PAD	19	32	10	6.00	S-U2-16.0	YELLOW/Y300/E20/C.5	0.0187	260.00	72.00
1175836	0893097-0-M	SIDE PANEL TAPPING PAD	19	31	10	6.00	S-U2-16.0	YELLOW/Y300/E20/C.5	0.0187	260.00	72.00

SigmaNEST Drawing List – 20 mm

Contract 19 = 15E, 15 = 19E, 17 = 10M Motors, 18 = 10M Trailers
WorkCentre M9-47... PlasmaCutter

Job	Item	Item Description	Contract	Stage	SubStage	Qty	Material	Material Description	Qty (m2)	Cutting Length	Cutting Width
1069759	8487033-0-M	END PLATE	15	03	75	4.00	S-3CR12-20.0	3CR12-20MM	0.0079	89.00	89.00
1069931	8487033-0-M	END PLATE	15	03	75	2.00	S-3CR12-20.0	3CR12-20MM	0.0079	89.00	89.00
1517299	2587778-0-M	ROOF FIXING BLOCK	15	24	10	2.00	S-3CR12-20.0	3CR12-20MM	0.0015	50.00	30.00
1518548	2587765-0-M	ROOF FIXING BLOCK	15	24	10	1.00	S-3CR12-20.0	3CR12-20MM	0.003	100.00	30.00
1519880	2587886-0-M	THRU BUSHING MOUNTING PAD	15	21	10	1.00	S-3CR12-20.0	3CR12-20MM	0.0864	294.00	294.00
1521230	2587886-0-M	THRU BUSHING MOUNTING PAD	15	23	10	1.00	S-3CR12-20.0	3CR12-20MM	0.0864	294.00	294.00
1609989	8487033-0-M	END PLATE	15	03	75	2.00	S-3CR12-20.0	3CR12-20MM	0.0079	89.00	89.00
1886382	2587974-1-M	LV TRAY MOUNTING PAD	15	24	10	1.00	S-3CR12-20.0	3CR12-20MM	0.0465	620.00	75.00
1886383	2587976-0-M	MOUNTING PAD EXTENSION DUCT	15	24	10	2.00	S-3CR12-20.0	3CR12-20MM	0.002	50.00	40.00
1080772	8091420-0-M	TAPPING PAD	17	27	02	2.00	S-3CR12-20.0	3CR12-20MM	0.004	80.00	50.00
873596	0391876-0-M	PLATE	17	03	06	1.00	S-3CR12-20.0	3CR12-20MM	0.314	1000.00	314.00
873616	0391186-0-M	PLATE	17	03	06	1.00	S-3CR12-20.0	3CR12-20MM	0.314	1000.00	314.00
1086003	8493028-0-M	TAPPING PAD	19	06	20	16.00	S-3CR12-20.0	3CR12-20MM	0.0184	306.00	60.00
1086468	8493009-0-M	END PLATE	19	06	20	8.00	S-3CR12-20.0	3CR12-20MM	0.0079	89.00	89.00
1161748	8793043-0-M	TAPPING PAD	19	62	91	8.00	S-3CR12-20.0	3CR12-20MM	0.0064	80.00	80.00
1161797	8793043-0-M	TAPPING PAD	19	62	91	8.00	S-3CR12-20.0	3CR12-20MM	0.0064	80.00	80.00
1285866	2593183-2-M	TAPPING PAD	19	24	10	1.00	S-3CR12-20.0	3CR12-20MM	0.0235	240.00	98.00
1285867	2593186-2-M	TAPPING PAD	19	24	10	1.00	S-3CR12-20.0	3CR12-20MM	0.0343	286.00	120.00
1389695	7893045-1-M	TAPPING PAD_BOX	19	04	30	2.00	S-3CR12-20.0	3CR12-20MM	0.0608	608.00	100.00
1404406	2593509-0-M	PANTO TAPPING PAD	19	22	10	4.00	S-3CR12-20.0	3CR12-20MM	0.04	200.00	200.00

Job	Item	Item Description	Contract	Stage	SubStage	Qty	Material	Material Description	Qty (m2)	Cutting Length	Cutting Width
1343156	0391099-0-M	BRACKET LUG-STEP	17	04	04	1.00	S-U4-20.0	BLUE/Y200/E20/C.5	0.0038	76.00	50.00
1343275	0391099-0-M	BRACKET LUG-STEP	17	04	04	1.00	S-U4-20.0	BLUE/Y200/E20/C.5	0.0038	76.00	50.00
1343283	0391099-0-M	BRACKET LUG-STEP	17	04	04	1.00	S-U4-20.0	BLUE/Y200/E20/C.5	0.0038	76.00	50.00
1343285	0391099-0-M	BRACKET LUG-STEP	17	04	04	1.00	S-U4-20.0	BLUE/Y200/E20/C.5	0.0038	76.00	50.00
1343286	0391102-0-M	BRACKET-STEP	17	04	04	1.00	S-U4-20.0	BLUE/Y200/E20/C.5	0.0122	152.00	80.00
1343277	0391102-0-M	BRACKET-STEP	17	04	04	1.00	S-U4-20.0	BLUE/Y200/E20/C.5	0.0122	152.00	80.00
1462811	2193331-0-M	SPACER PLATE	19	55	18	1.00	S-U4-20.0	BLUE/Y200/E20/C.5	0.4038	1346.00	300.00

Job	Item	Item Description	Contract	Stage	SubStage	Qty	Material	Material Description	Qty (m2)	Cutting Length	Cutting Width
1449663	0391098-0-M	BRACKET-STEP	17	04	04	1.00	S-U2-20.0	YELLOW/Y300/E20/C.5	0.026	520.00	50.00
1449670	0391101-0-M	STEP BRACKET	17	04	04	1.00	S-U2-20.0	YELLOW/Y300/E20/C.5	0.0267	533.00	50.00
1042910	0893079-3-M	BODY SIDE SKIN	19	32	10	1.00	S-U2-20.0	YELLOW/Y300/E20/C.5	3.4837	1930.00	1805.00
1116922	2193275-0-M	SUPPORT PLATE	19	55	15	1.00	S-U2-20.0	YELLOW/Y300/E20/C.5	0.034	485.00	70.00
975263	2193002-7-M	CAB REAR WALL SKIN	19	61	10	1.00	S-U2-20.0	YELLOW/Y300/E20/C.5	5.2218	2700.00	1934.00

APPENDIX B

Kulungile Metals Group - SigmaNEST Questionnaire

- What do you use SigmaNEST for? (Description of functions and applications.)

- What other software packages interfaces with SigmaNEST? How?
  Formats of CAD imports?

- Procedure for handling drawing errors?

- How are the final manufacturing code (programs) sent to the various machines?

- Are there any designs changes present in your operations? How are they handled?

- Do you use Static or Dynamic nesting methods? Guillotine or physical parts nesting?

- Who uses SigmaNEST at your company? (Job titles and descriptions of functions.)

- Are there control loops present in the planning, purchasing and manufacturing processes? (These control loops can improve the input material optimization and remove design and planning errors.)

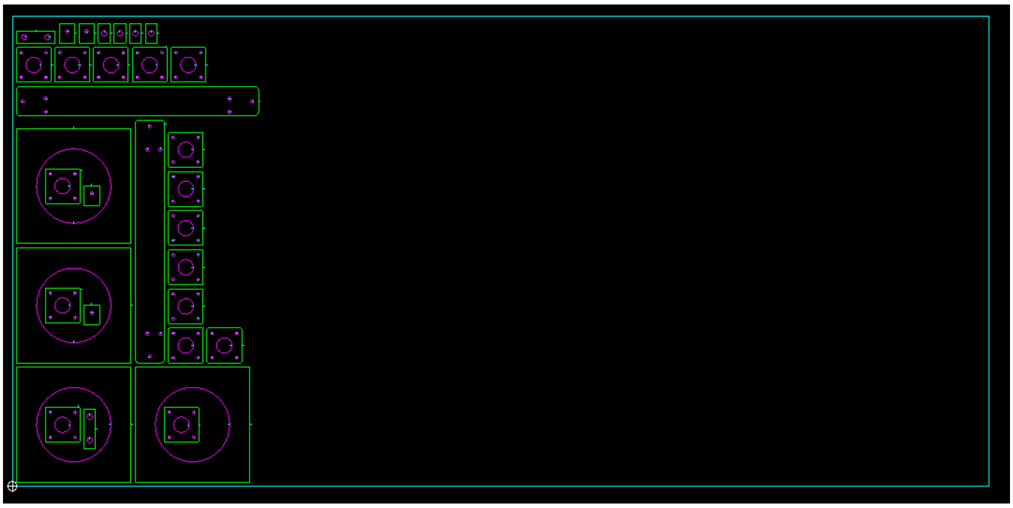
- Are there any off-cuts? How are they handled and prevented?

APPENDIX C

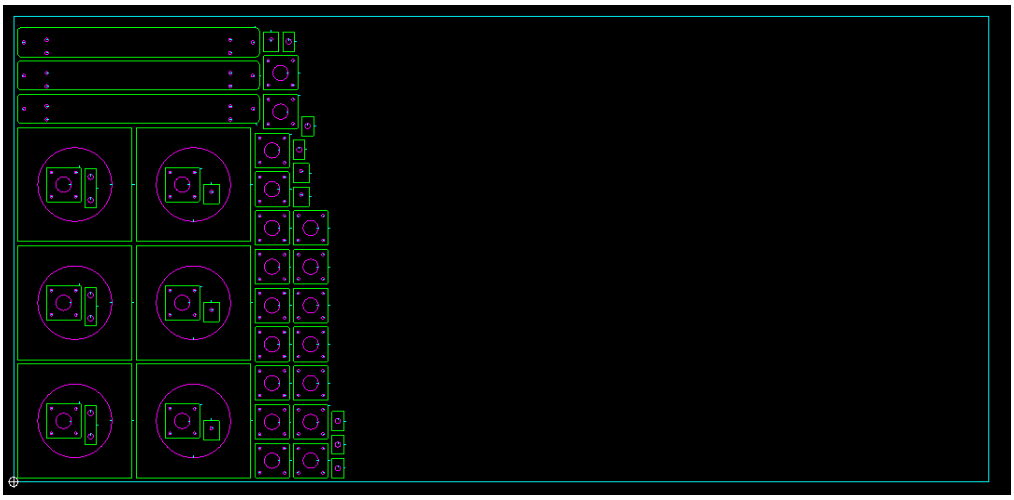
Nesting Pictures

20mm 3CR 12 (2.5m x 1.2m) – 19E Project - 1 Contract

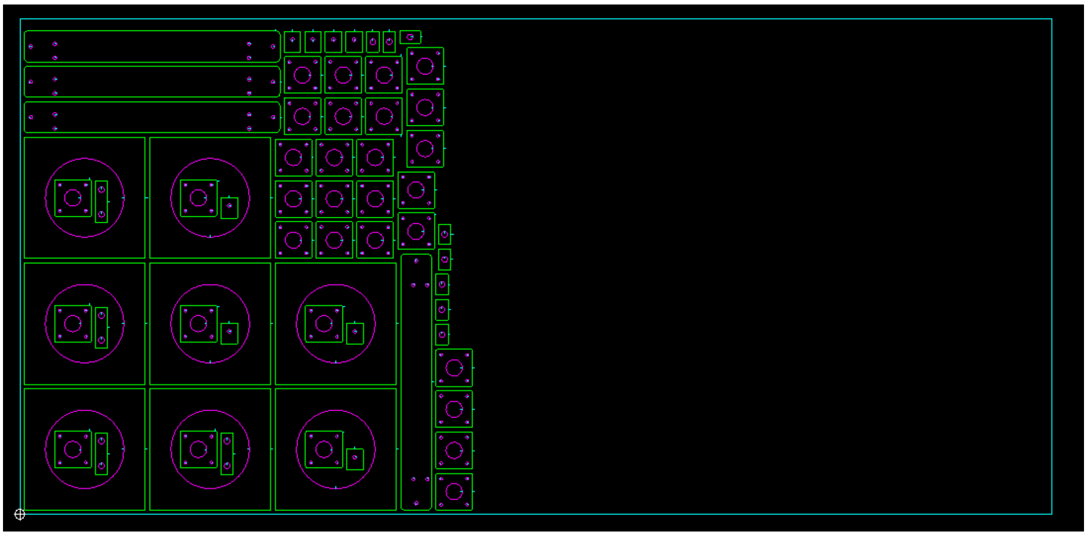
20mm 3CR 12 (2.5m x 1.2m) – 19E Project - 2 Contracts



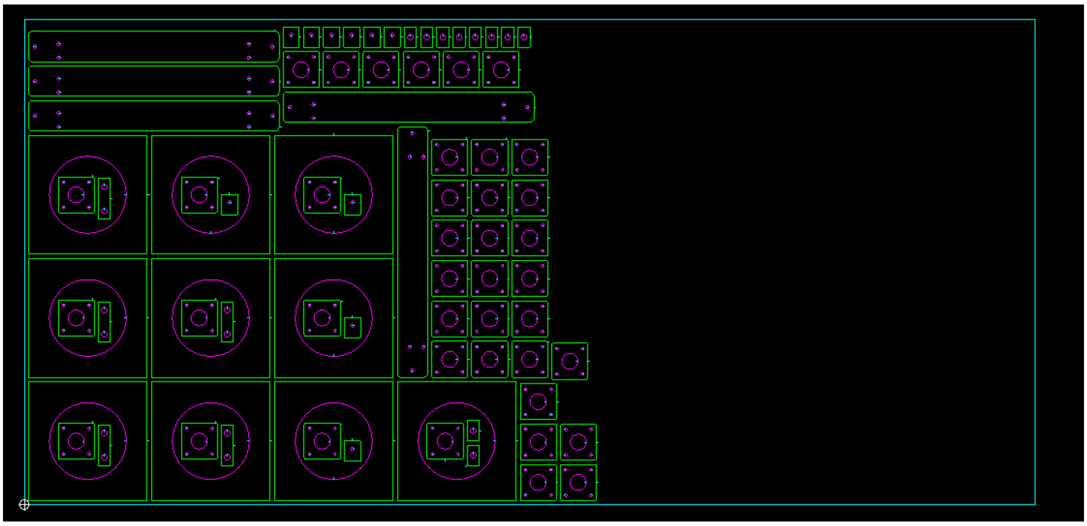
20mm 3CR 12 (2.5m x 1.2m) – 19E Project - 3 Contracts



20mm 3CR 12 (2.5m x 1.2m) – 19E Project - 4 Contracts



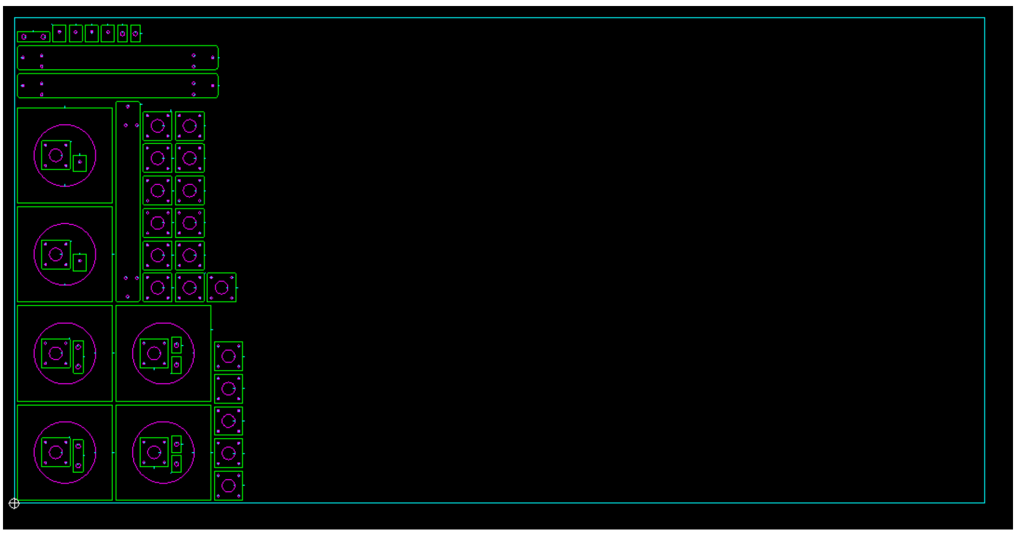
20mm 3CR 12 (2.5m x 1.2m) – 19E Project – 5 Contracts



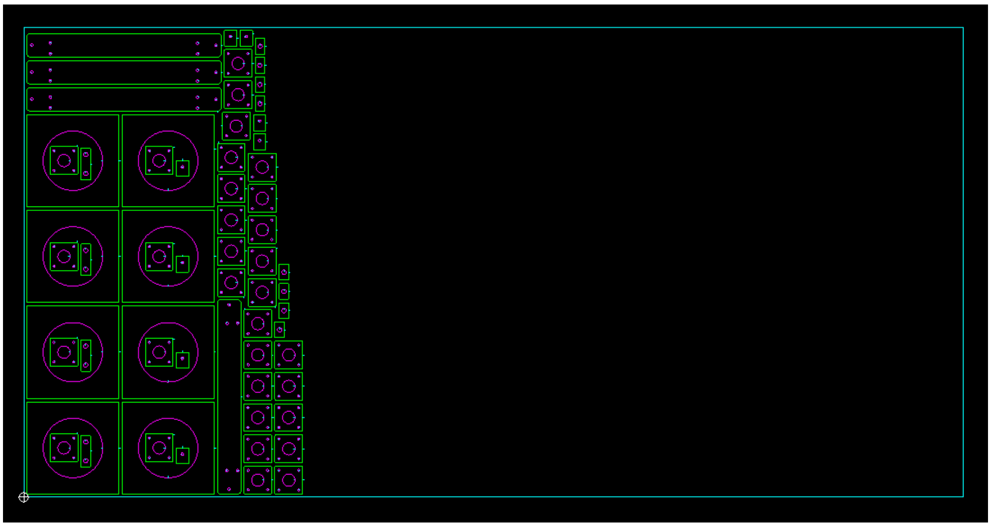
20mm 300WA (3m x 1.5m) – 19E Project – 1 Contract

20mm 300WA (3m x 1.5m) – 19E Project – 2 Contracts

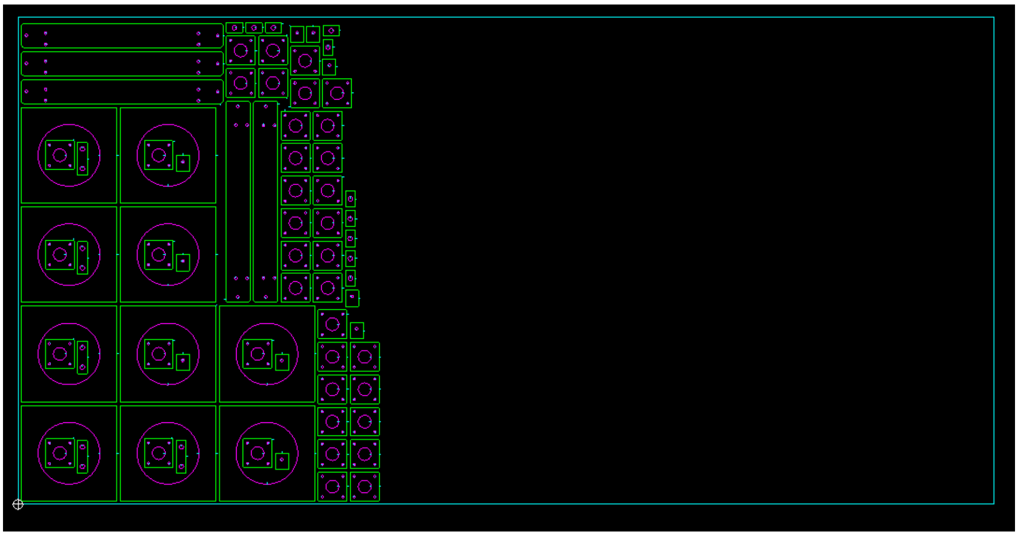
20mm 300WA (3m x 1.5m) – 19E Project – 3 Contracts



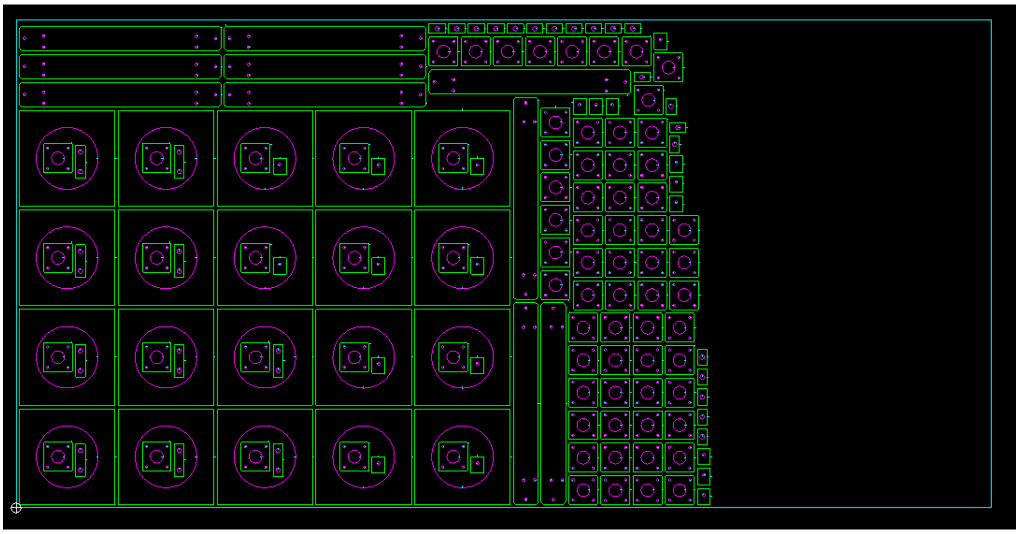
20mm 300WA (3m x 1.5m) – 19E Project – 4 Contracts



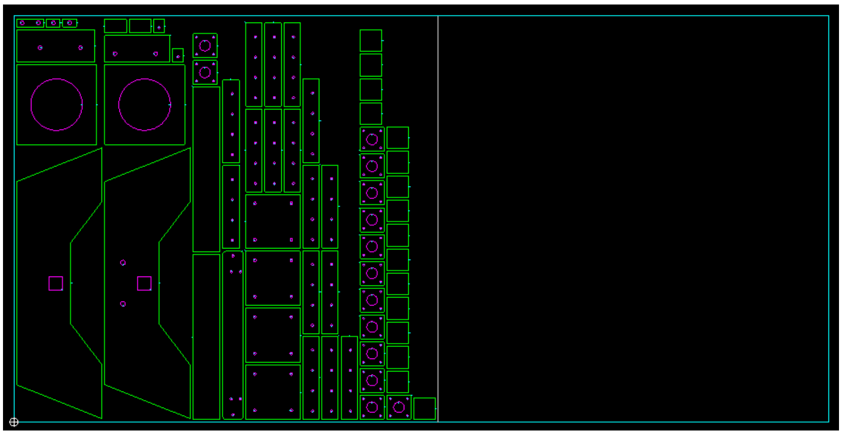
20mm 300WA (3m x 1.5m) – 19E Project – 5 Contracts



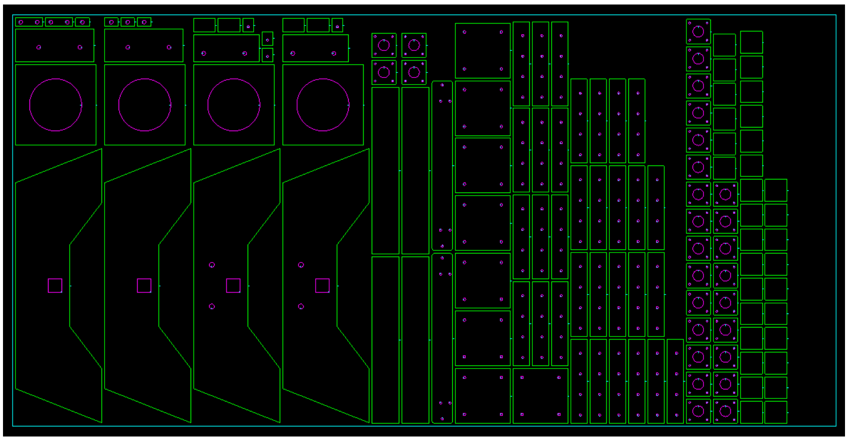
20mm 300WA (3m x 1.5m) – 19E Project – 10 Contracts



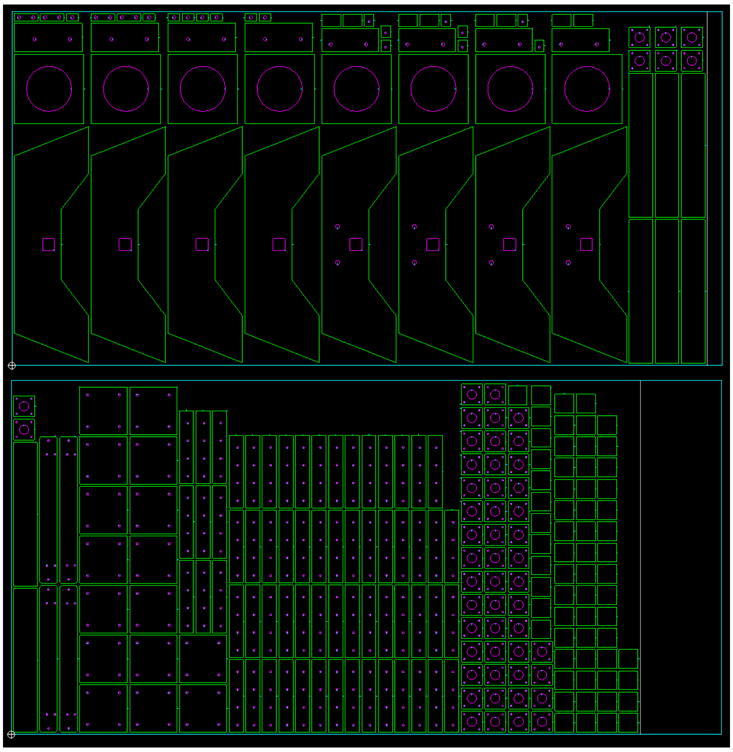
20mm 3Cr12 (2m x 1.5m) – All Projects – 1 Contract each



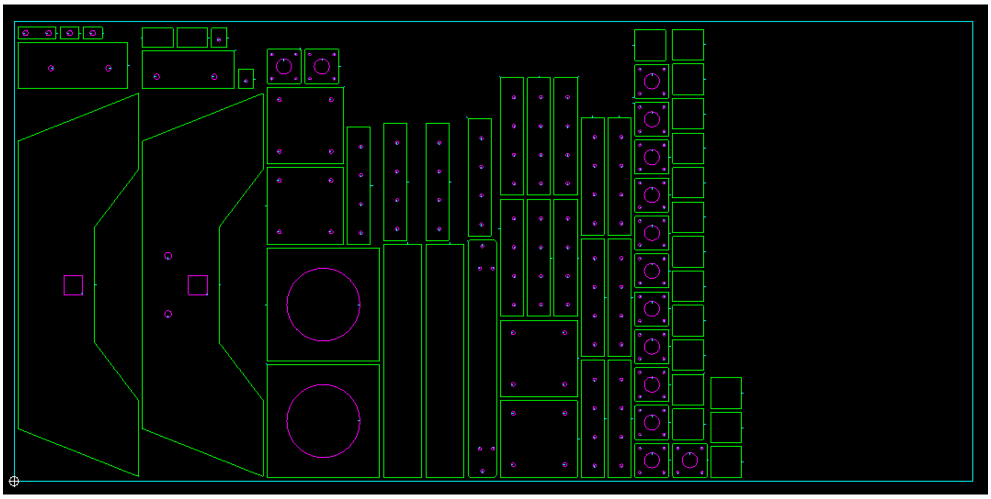
20mm 3Cr12 (2m x 1.5m) – All Projects – 2 Contracts each



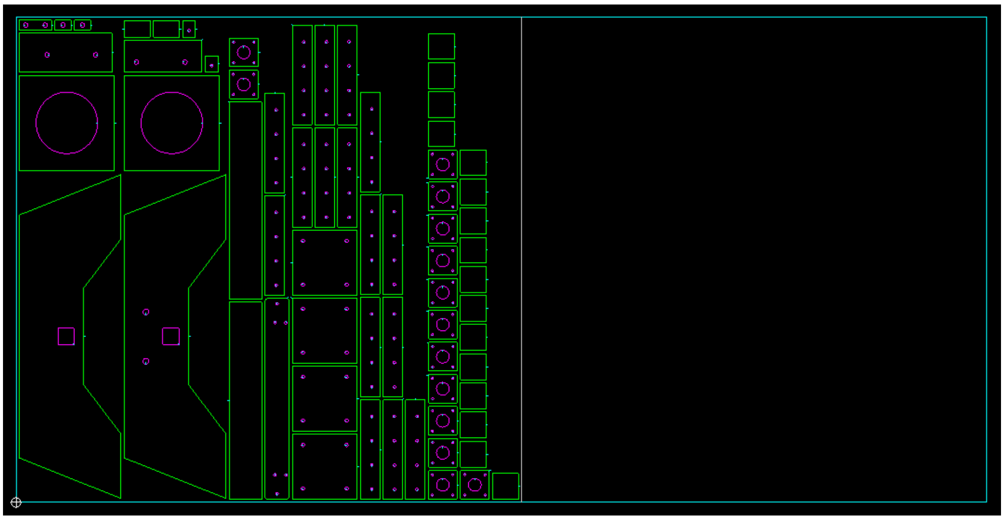
20mm 3Cr12 (2m x 1.5m) – All Projects – 4 Contracts each



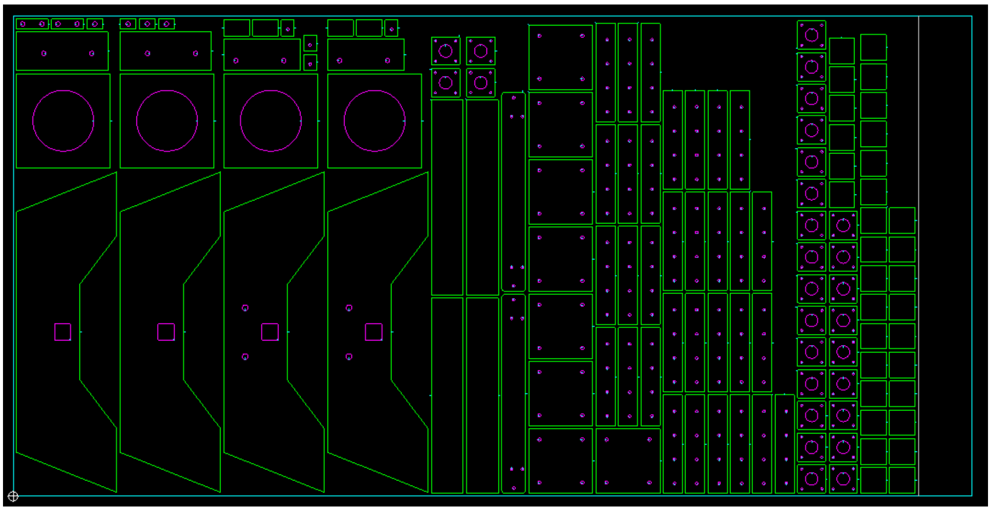
20mm 3Cr12 (2.5m x 1.2m) – All Projects – 1 Contract each



20mm 3Cr12 (3m x 1.5m) – All Projects – 1 Contract each



20mm 3Cr12 (3m x 1.5m) – All Projects – 2 Contracts each



APPENDIX D

Nesting Comparisons (3CR12 – 16mm)

16 mm

Project	Number of cars per nest	Sheet size	Number of sheets used	Scrap
19E	1	2.5X1.25	1	83.92%
19E	2	2.5X1.25	1	67.84%
19E	3	2.5X1.25	1	51.77%
19E	4	2.5X1.25	1	35.69%
19E	5	2.5X1.25	1	19.61%
19E	6	2.5X1.25	2	51.77%
19E	7	2.5X1.25	2	43.73%
19E	8	2.5X1.25	2	35.69%
19E	9	2.5X1.25	2	27.65%
19E	10	2.5X1.25	2	19.61%
19E	1	3X1.5	1	88.83%
19E	2	3X1.5	1	77.67%
19E	3	3X1.5	1	66.50%
19E	4	3X1.5	1	55.34%
19E	5	3X1.5	1	44.17%
19E	6	3x1.5	1	33.01%
19E	7	3X1.5	1	21.84%
19E	8	3X1.5	2	55.34%
19E	9	3X1.5	2	49.76%
19E	10	3X1.5	2	44.17%

Project	Number of cars per nest	Sheet size	Number of sheets used	Scrap
10M-M	1	2.5X1.25	N/A	N/A
10M-M	2	2.5X1.25	N/A	N/A
10M-M	3	2.5X1.25	N/A	N/A
10M-M	4	2.5X1.25	N/A	N/A
10M-M	5	2.5X1.25	N/A	N/A
10M-M	6	2.5X1.25	N/A	N/A
10M-M	7	2.5X1.25	N/A	N/A
10M-M	8	2.5X1.25	N/A	N/A
10M-M	9	2.5X1.25	N/A	N/A
10M-M	10	2.5X1.25	N/A	N/A
10M-M	1	3X1.5	1	87.73%
10M-M	2	3X1.5	1	75.47%
10M-M	3	3X1.5	1	63.20%
10M-M	4	3X1.5	1	50.94%
10M-M	5	3X1.5	1	38.67%
10M-M	6	3x1.5	1	26.41%
10M-M	7	3X1.5	2	57.08%
10M-M	8	3X1.5	2	50.94%
10M-M	9	3X1.5	2	44.81%
10M-M	10	3X1.5	2	38.68%

Project	Number of cars per nest	Sheet size	Number of sheets used	Scrap
10M-T	1	2.5X1.25	1	65.97%
10M-T	2	2.5X1.25	2	65.97%
10M-T	3	2.5X1.25	2	51.95%
10M-T	4	2.5X1.25	3	54.63%
10M-T	5	2.5X1.25	4	57.46%
10M-T	6	2.5X1.25	4	48.95%
10M-T	7	2.5X1.25	5	52.37%
10M-T	8	2.5X1.25	6	54.62%
10M-T	9	2.5X1.25	6	48.95%
10M-T	10	2.5X1.25	7	51.38%
10M-T	1	3X1.5	1	76.37%
10M-T	2	3X1.5	1	52.73%
10M-T	3	3X1.5	1	29.10%
10M-T	4	3X1.5	2	52.74%
10M-T	5	3X1.5	2	40.92%
10M-T	6	3x1.5	2	29.10%
10M-T	7	3X1.5	2	17.29%
10M-T	8	3X1.5	3	36.98%
10M-T	9	3X1.5	3	29.10%
10M-T	10	3X1.5	3	21.22%

Project	Number of cars per nest	Sheet size	Number of sheets used	Scrap
15E	1	2.5X1.25	2	73.91%
15E	2	2.5X1.25	2	47.82%
15E	3	2.5X1.25	3	47.82%
15E	4	2.5X1.25	4	47.82%
15E	5	2.5X1.25	5	59.77%
15E	6	2.5X1.25	5	37.38%
15E	7	2.5X1.25	6	39.12%
15E	8	2.5X1.25	7	40.37%
15E	9	2.5X1.25	7	32.91%
15E	10	2.5X1.25	8	35.52%
15E	1	3X1.5	1	63.76%
15E	2	3X1.5	2	63.76%
15E	3	3X1.5	2	45.65%
15E	4	3X1.5	3	51.68%
15E	5	3X1.5	3	39.61%
15E	6	3x1.5	4	65.00%
15E	7	3X1.5	5	49.27%
15E	8	3X1.5	5	42.02%
15E	9	3X1.5	5	34.77%
15E	10	3X1.5	6	39.61%

Project	Number of cars per nest	Sheet size	Number of sheets used	Scrap
10M-M; 10M-T; 15E & 19E	1	2.5X1.25	N/A	N/A
10M-M; 10M-T; 15E & 19E	2	2.5X1.25	N/A	N/A
10M-M; 10M-T; 15E & 19E	3	2.5X1.25	N/A	N/A
10M-M; 10M-T; 15E & 19E	4	2.5X1.25	N/A	N/A
10M-M; 10M-T; 15E & 19E	5	2.5X1.25	N/A	N/A
10M-M; 10M-T; 15E & 19E	1	3X1.5	2	58.47%
10M-M; 10M-T; 15E & 19E	2	3X1.5	3	44.62%
10M-M; 10M-T; 15E & 19E	3	3X1.5	3	16.93%
10M-M; 10M-T; 15E & 19E	4	3X1.5	4	16.93%
10M-M; 10M-T; 15E & 19E	5	3X1.5	5	16.93%

Nesting Comparisons (3CR12 – 20mm)

20 mm

Project	Number of cars per nest	Sheet size	Number of sheets used	Scrap
19E	1	2X1.5	1	92.54%
19E	2	2X1.5	1	85.09%
19E	3	2X1.5	1	77.63%
19E	4	2X1.5	1	70.17%
19E	5	2X1.5	1	62.72%
19E	10	2X1.5	2	62.72%
19E	1	3X1.5	1	95.03%
19E	2	3X1.5	1	90.06%
19E	3	3X1.5	1	85.09%
19E	4	3X1.5	1	80.12%
19E	5	3X1.5	1	75.14%
19E	10	3x1.5	1	50.29%
19E	1	2.5X1.2	1	92.54%
19E	2	2.5X1.2	1	85.09%
19E	3	2.5X1.2	1	77.63%
19E	4	2.5X1.2	1	70.17%
19E	5	2.5X1.2	1	62.72%
19E	10	2.5X1.2	2	62.72%

Project	Number of cars per nest	Sheet size	Number of sheets used	Scrap
10M-M	1	2X1.5	1	85.03%
10M-M	2	2X1.5	1	70.07%
10M-M	3	2X1.5	1	55.09%
10M-M	4	2X1.5	2	70.06%
10M-M	5	2X1.5	2	62.58%
10M-M	10	2X1.5	2	50.10%
10M-M	1	3X1.5	1	90.02%
10M-M	2	3X1.5	1	80.04%
10M-M	3	3X1.5	1	70.06%
10M-M	4	3X1.5	1	60.08%
10M-M	5	3X1.5	1	50.10%
10M-M	10	3x1.5	2	50.10%
10M-M	1	2.5X1.2	1	85.03%
10M-M	2	2.5X1.2	1	70.06%
10M-M	3	2.5X1.2	1	55.09%
10M-M	4	2.5X1.2	2	70.06%
10M-M	5	2.5X1.2	2	62.58%
10M-M	10	2.5X1.2	2	50.10%

Project	Number of cars per nest	Sheet size	Number of sheets used	Scrap
15E	1	2X1.5	1	73.91%
15E	2	2X1.5	1	47.82%
15E	3	2X1.5	2	60.87%
15E	4	2X1.5	2	47.82%
15E	5	2X1.5	2	34.78%
15E	6	2X1.5	2	21.74%
15E	7	2X1.5	3	39.13%
15E	8	2X1.5	3	30.43%
15E	9	2X1.5	3	21.73%
15E	10	2X1.5	4	37.78%
15E	1	3X1.5	1	82.61%
15E	2	3X1.5	1	65.21%
15E	3	3X1.5	1	47.82%
15E	4	3X1.5	1	30.43%
15E	5	3X1.5	2	56.52%
15E	6	3x1.5	2	47.82%
15E	7	3X1.5	2	39.13%
15E	8	3X1.5	2	30.43%
15E	9	3X1.5	2	21.74%
15E	10	3X1.5	3	42.02%
15E	1	2.5X1.2	1	73.91%
15E	2	2.5X1.2	1	47.82%
15E	3	2.5X1.2	2	60.87%
15E	4	2.5X1.2	2	47.82%
15E	5	2.5X1.2	2	34.78%
15E	6	2.5X1.2	2	21.73%
15E	7	2.5X1.2	3	39.13%
15E	8	2.5X1.2	3	30.43%
15E	9	2.5X1.2	3	21.73%
15E	10	2.5X1.2	4	34.78%

Project	Number of cars per nest	Sheet size	Number of sheets used	Scrap
10M-M; 15E & 19E	1	2X1.5	1	51.92%
10M-M; 15E & 19E	2	2X1.5	2	51.92%
10M-M; 15E & 19E	3	2X1.5	2	27.88%
10M-M; 15E & 19E	4	2X1.5	3	35.89%
10M-M; 15E & 19E	5	2X1.5	4	39.90%
10M-M; 15E & 19E	1	3X1.5	1	59.39%
10M-M; 15E & 19E	2	3X1.5	1	35.90%
10M-M; 15E & 19E	3	3X1.5	2	51.92%
10M-M; 15E & 19E	4	3X1.5	2	35.90%
10M-M; 15E & 19E	5	3X1.5	3	46.57%
10M-M; 15E & 19E	1	2.5X1.2	1	51.92%
10M-M; 15E & 19E	2	2.5X1.2	2	51.92%
10M-M; 15E & 19E	3	2.5X1.2	2	27.88%
10M-M; 15E & 19E	4	2.5X1.2	3	35.89%
10M-M; 15E & 19E	5	2.5X1.2	4	39.90%

Nesting Comparisons (300WA – 16mm)

16 mm

Project	Number of cars per nest	Sheet size	Number of sheets used	Scrap
15E	1	2.5x1.2	3	40.67%
15E	2	2.5x1.2	6	39.67%
15E	3	2.5x1.2	9	39.67%
15E	4	2.5x1.2	12	39.67%
15E	5	2.5x1.2	15	39.67%
15E	10	2.5x1.2	30	39.67%
15E	1	3x2.4	1	24.59%
15E	2	3x2.4	2	24.59%
15E	3	3x2.4	3	24.59%
15E	4	3x2.4	4	24.59%
15E	5	3x2.4	5	24.59%
15E	6	3x2.4	10	24.59%
15E	1	4x2	1	32.13%
15E	2	4x2	2	32.13%
15E	3	4x2	3	32.13%
15E	4	4x2	4	32.13%
15E	5	4x2	4	15.16%
15E	6	4x2	5	18.55%
15E	7	4x2	6	20.82%
15E	8	4x2	7	22.43%
15E	9	4x2	7	12.73%
15E	10	4x2	8	15.16%

Nesting Comparisons (300WA – 20mm)

20 mm

Project	Number of cars per nest	Sheet size	Number of sheets used	Scrap
10M-M	1	2.5X1.2	N/A	N/A
10M-M	2	2.5X1.2	N/A	N/A
10M-M	3	2.5X1.2	N/A	N/A
10M-M	4	2.5X1.2	N/A	N/A
10M-M	5	2.5X1.2	N/A	N/A
10M-M	10	2.5X1.2	N/A	N/A
10M-M	1	3x1.5	N/A	N/A
10M-M	2	3x1.5	N/A	N/A
10M-M	3	3x1.5	N/A	N/A
10M-M	4	3x1.5	N/A	N/A
10M-M	5	3x1.5	N/A	N/A
10M-M	10	3x1.5	N/A	N/A
10M-M	1	4x2	2	61.72%
10M-M	2	4x2	3	48.96%
10M-M	3	4x2	5	54.06%
10M-M	4	4x2	7	41.96%
10M-M	5	4x2	8	52.15%
10M-M	10	4x2	15	48.96%
10M-M	1	4x2.4	2	68.10%
10M-M	2	4x2.4	3	57.47%
10M-M	3	4x2.4	5	61.72%
10M-M	4	4x2.4	6	57.47%
10M-M	5	4x2.4	8	60.13%
10M-M	10	4x2.4	15	57.67%

Project	Number of cars per nest	Sheet size	Number of sheets used	Scrap
15E	1	2.5X1.2	1	97.02%
15E	2	2.5X1.2	1	94.04%
15E	3	2.5X1.2	1	91.05%
15E	4	2.5X1.2	1	88.07%
15E	5	2.5X1.2	1	85.09%
15E	6	2.5X1.2	1	82.11%
15E	7	2.5X1.2	1	71.93%
15E	8	2.5X1.2	1	76.14%
15E	9	2.5X1.2	1	73.16%
15E	10	2.5X1.2	1	70.18%
15E	1	3x1.5	1	98.01%
15E	2	3x1.5	1	96.02%
15E	3	3x1.5	1	94.04%
15E	4	3x1.5	1	92.05%
15E	5	3x1.5	1	90.06%
15E	6	3x1.5	1	88.07%
15E	7	3x1.5	1	86.08%
15E	8	3x1.5	1	84.10%
15E	9	3x1.5	1	82.11%
15E	10	3x1.5	1	80.12%

15E	1	4x2	1	98.88%
15E	2	4x2	1	97.76%
15E	3	4x2	1	96.65%
15E	4	4x2	1	95.53%
15E	5	4x2	1	94.41%
15E	6	4x2	1	93.29%
15E	7	4x2	1	92.17%
15E	8	4x2	1	91.05%
15E	9	4x2	1	89.94%
15E	10	4x2	1	88.82%
15E	1	4x2.4	1	99.07%
15E	2	4x2.4	1	98.14%
15E	3	4x2.4	1	97.20%
15E	4	4x2.4	1	96.27%
15E	5	4x2.4	1	95.34%
15E	6	4x2.4	1	94.41%
15E	7	4x2.4	1	93.48%
15E	8	4x2.4	1	92.54%
15E	9	4x2.4	1	91.61%
15E	10	4x2.4	1	90.68%

Project	Number of cars per nest	Sheet size	Number of sheets used	Scrap
10M-M & 15E	1	2.5X1.2	N/A	N/A
10M-M & 15E	2	2.5X1.2	N/A	N/A
10M-M & 15E	3	2.5X1.2	N/A	N/A
10M-M & 15E	4	2.5X1.2	N/A	N/A
10M-M & 15E	5	2.5X1.2	N/A	N/A
10M-M & 15E	6	2.5X1.2	N/A	N/A
10M-M & 15E	7	2.5X1.2	N/A	N/A
10M-M & 15E	8	2.5X1.2	N/A	N/A
10M-M & 15E	9	2.5X1.2	N/A	N/A
10M-M & 15E	10	2.5X1.2	N/A	N/A
10M-M & 15E	1	3x1.5	N/A	N/A
10M-M & 15E	2	3x1.5	N/A	N/A
10M-M & 15E	3	3x1.5	N/A	N/A
10M-M & 15E	4	3x1.5	N/A	N/A
10M-M & 15E	5	3x1.5	N/A	N/A
10M-M & 15E	6	3x1.5	N/A	N/A
10M-M & 15E	7	3x1.5	N/A	N/A
10M-M & 15E	8	3x1.5	N/A	N/A
10M-M & 15E	9	3x1.5	N/A	N/A
10M-M & 15E	10	3x1.5	N/A	N/A
10M-M & 15E	1	4x2	2	61.16%
10M-M & 15E	2	4x2	3	48.21%
10M-M & 15E	3	4x2	5	53.39%
10M-M & 15E	4	4x2	6	49.38%
10M-M & 15E	5	4x2	8	51.45%
10M-M & 15E	1	4x2.4	2	67.63%
10M-M & 15E	2	4x2.4	3	56.85%
10M-M & 15E	3	4x2.4	5	61.16%
10M-M & 15E	4	4x2.4	6	56.85%
10M-M & 15E	5	4x2.4	8	66.79%

APPENDIX E

Nesting Cost Comparisons (3CR12)

3CR12 - 16 mm (3mx1.5m)	Sheets used	Wastage percentage	Cost per sheet	Wastage cost
Old method (1)	3	72.31%	9697.5	21036.79
SigmaNEST - Single Project (1)	4	79.17%	9697.5	30710.04
SigmaNEST - Mixed Projects (1)	2	58.47%	9697.5	11340.26
Old method (2)	4	58.47%	9697.5	22680.51
SigmaNEST - Single Project (2)	5	53.93%	9697.5	26149.31
SigmaNEST - Mixed Projects (2)	3	44.62%	9697.5	12981.07
Old method (3)	4	37.70%	9697.5	14623.83
SigmaNEST - Single Project (3)	6	56.83%	9697.5	33066.54
SigmaNEST - Mixed Projects (3)	3	16.93%	9697.5	4925.36
Old method (Lowest - 3)	4	37.70%	9697.5	14623.83
SigmaNEST - Single Project (Lowest - 3)	6	56.83%	9697.5	33066.54
SigmaNEST - Mixed Projects (Lowest - 3)	3	16.93%	9697.5	4925.36

3CR12 - 20 mm (2mx1.5m)	Sheets used	Wastage percentage	Cost per sheet	Wastage cost
Old method (1)	1	51.92%	9249	4802.08
SigmaNEST - Single Project (1)	3	83.83%	9249	23260.31
SigmaNEST - Mixed Projects (1)	1	51.92%	9249	4802.08
Old method (2)	2	51.92%	9249	9604.16
SigmaNEST - Single Project (2)	3	67.66%	9249	18773.62
SigmaNEST - Mixed Projects (2)	2	51.92%	9249	9604.16
Old method (3)	3	51.92%	9249	14406.24
SigmaNEST - Single Project (3)	4	64.53%	9249	23873.52
SigmaNEST - Mixed Projects (3)	2	27.88%	9249	5157.24
Old method (Lowest - 3)	3	51.92%	9249	14406.24
SigmaNEST - Single Project (Lowest - 3)	4	64.53%	9249	23873.52
SigmaNEST - Mixed Projects (Lowest - 3)	2	27.88%	9249	5157.24

3CR12 - 20 mm (3mx1.5m)	Sheets used	Wastage percentage	Cost per sheet	Wastage cost
Old method (1)	1	67.95%	13873.5	9427.04
SigmaNEST - Single Project (1)	3	89.22%	13873.5	37133.81
SigmaNEST - Mixed Projects (1)	1	67.95%	13873.5	9427.04
Old method (2)	1	35.90%	13873.5	4980.59
SigmaNEST - Single Project (2)	3	78.44%	13873.5	32647.12
SigmaNEST - Mixed Projects (2)	1	35.90%	13873.5	4980.59
Old method (3)	2	51.92%	13873.5	14406.24
SigmaNEST - Single Project (3)	3	67.66%	13873.5	28160.43
SigmaNEST - Mixed Projects (3)	2	51.92%	13873.5	14406.24
Old method (Lowest - 2)	2	35.90%	13873.5	9961.17
SigmaNEST - Single Project (Lowest - 2)	3	78.44%	13873.5	32647.12
SigmaNEST - Mixed Projects (Lowest - 2)	2	35.90%	13873.5	9961.17

3CR12 - 20 mm (2.5mx1.2m)	Sheets used	Wastage percentage	Cost per sheet	Wastage cost
Old method (1)	1	51.92%	9249	4802.08
SigmaNEST - Single Project (1)	3	83.83%	9249	23260.31
SigmaNEST - Mixed Projects (1)	1	51.92%	9249	4802.08
Old method (2)	2	51.92%	9249	9604.16
SigmaNEST - Single Project (2)	3	67.65%	9249	18770.85
SigmaNEST - Mixed Projects (2)	2	51.92%	9249	9604.16
Old method (3)	3	51.92%	9249	14406.24
SigmaNEST - Single Project (3)	4	64.53%	9249	23873.52
SigmaNEST - Mixed Projects (3)	2	27.88%	9249	5157.24
Old method (Lowest - 2)	3	51.92%	9249	14406.24
SigmaNEST - Single Project (Lowest - 2)	4	64.53%	9249	23873.52
SigmaNEST - Mixed Projects (Lowest - 2)	2	27.88%	9249	5157.24

Nesting Cost Comparisons (300WA)

300WA - 16 mm (2.5mx1.2m)	Sheets used	Wastage percentage	Cost per sheet	Wastage cost
Old method (1)	4	47.50%	3300	6270.00
SigmaNEST - Single Project (1)	3	40.67%	3300	4026.33
SigmaNEST - Mixed Projects (1)	3	40.67%	3300	4026.33
Old method (2)	7	40.00%	3300	9240.00
SigmaNEST - Single Project (2)	7	40.00%	3300	9240.00
SigmaNEST - Mixed Projects (2)	7	40.00%	3300	9240.00
Old method (3)	11	42.73%	3300	15510.99
SigmaNEST - Single Project (3)	9	39.67%	3300	11781.99
SigmaNEST - Mixed Projects (3)	9	39.67%	3300	11781.99
Old method (Lowest - 3)	4	42.73%	3300	5640.36
SigmaNEST - Single Project (Lowest - 3)	6	39.67%	3300	7854.66
SigmaNEST - Mixed Projects (Lowest - 3)	3	39.67%	3300	3927.33

300WA - 16 mm (3mx2.4m)	Sheets used	Wastage percentage	Cost per sheet	Wastage cost
Old method (1)	1	24.59%	7920	1947.53
SigmaNEST - Single Project (1)	1	24.59%	7920	1947.53
SigmaNEST - Mixed Projects (1)	1	24.59%	7920	1947.53
Old method (2)	3	41.67%	7920	9900.79
SigmaNEST - Single Project (2)	2	24.59%	7920	3895.06
SigmaNEST - Mixed Projects (2)	2	24.59%	7920	3895.06
Old method (3)	4	34.38%	7920	10891.58
SigmaNEST - Single Project (3)	3	24.59%	7920	5842.58
SigmaNEST - Mixed Projects (3)	3	24.59%	7920	5842.58
Old method (Lowest - 1)	2	24.59%	7920	3895.06
SigmaNEST - Single Project (Lowest - 1)	3	24.59%	7920	5842.58
SigmaNEST - Mixed Projects (Lowest - 1)	2	24.59%	7920	3895.06

300WA - 16 mm (4mx2m)	Sheets used	Wastage percentage	Cost per sheet	Wastage cost
Old method (1)	1	21.26%	8800	1870.88
SigmaNEST - Single Project (1)	1	21.26%	8800	1870.88
SigmaNEST - Mixed Projects (1)	1	21.26%	8800	1870.88
Old method (2)	2	21.26%	8800	3741.76
SigmaNEST - Single Project (2)	2	21.26%	8800	3741.76
SigmaNEST - Mixed Projects (2)	2	21.26%	8800	3741.76
Old method (3)	3	21.26%	8800	5612.64
SigmaNEST - Single Project (3)	3	21.26%	8800	5612.64
SigmaNEST - Mixed Projects (3)	3	21.26%	8800	5612.64
Old method (Lowest - 9)	9	21.26%	13873.5	26545.55
SigmaNEST - Single Project (Lowest - 9)	7	12.73%	13873.5	12362.68
SigmaNEST - Mixed Projects (Lowest - 9)	7	12.73%	13873.5	12362.68

300WA - 20 mm (4mx2m)	Sheets used	Wastage percentage	Cost per sheet	Wastage cost
Old method (1)	2	61.16%	10400	12721.28
SigmaNEST - Single Project (1)	3	80.30%	10400	25053.60
SigmaNEST - Mixed Projects (1)	2	61.16%	10400	12721.28
Old method (2)	3	48.21%	10400	15041.52
SigmaNEST - Single Project (2)	4	73.36%	10400	30517.76
SigmaNEST - Mixed Projects (2)	3	48.21%	10400	15041.52
Old method (3)	5	53.39%	10400	27762.80
SigmaNEST - Single Project (3)	6	53.39%	10400	33315.36
SigmaNEST - Mixed Projects (3)	5	53.39%	10400	27762.80
Old method (Lowest - 2)	3	48.21%	10400	15041.52
SigmaNEST - Single Project (Lowest - 2)	4	73.36%	10400	30517.76
SigmaNEST - Mixed Projects (Lowest - 2)	3	48.21%	10400	15041.52

300WA - 20 mm (4mx2.4m)	Sheets used	Wastage percentage	Cost per sheet	Wastage cost
Old method (1)	2	67.63%	12480	16880.45
SigmaNEST - Single Project (1)	3	83.59%	12480	31296.10
SigmaNEST - Mixed Projects (1)	2	67.63%	12480	16880.45
Old method (2)	3	56.85%	12480	21284.64
SigmaNEST - Single Project (2)	4	77.81%	12480	38842.75
SigmaNEST - Mixed Projects (2)	3	56.85%	12480	21284.64
Old method (3)	5	61.16%	12480	38163.84
SigmaNEST - Single Project (3)	6	79.46%	12480	59499.65
SigmaNEST - Mixed Projects (3)	5	61.16%	12480	38163.84
Old method (Lowest - 2)	3	56.85%	12480	21284.64
SigmaNEST - Single Project (Lowest - 2)	4	77.81%	12480	38842.75
SigmaNEST - Mixed Projects (Lowest - 2)	3	56.85%	12480	21284.64

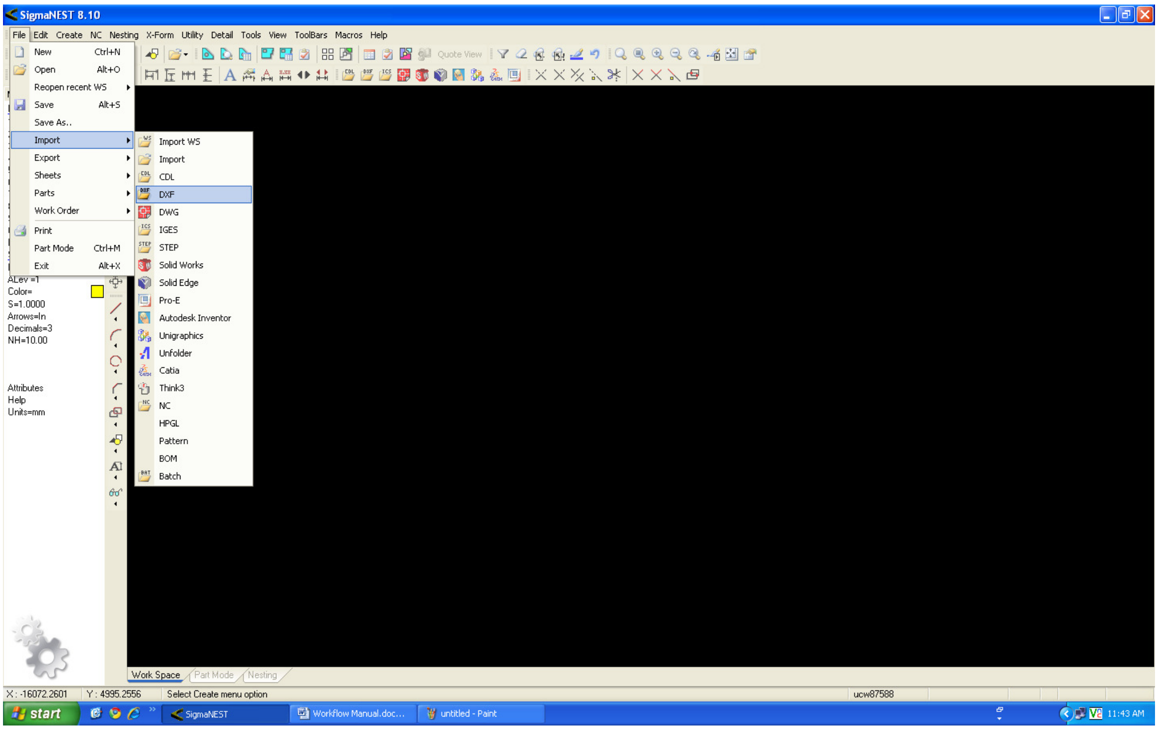
APPENDIX F

Workflow Manual

Steps to Batch, Nest and Program Production Orders

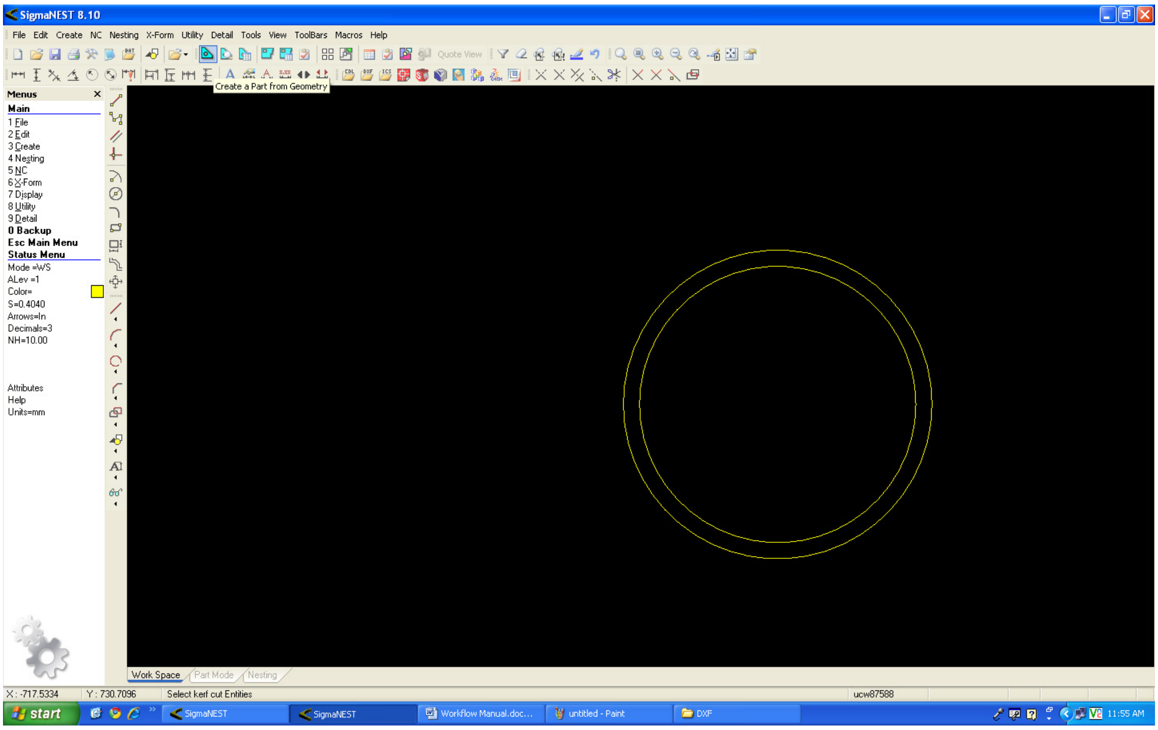
1. Filter the Production Orders of one week according to; type of material to be used, thickness of the material to be used and the production centre of the first process. Release these Production Orders and send the Scheduled Production Order List to the nester.

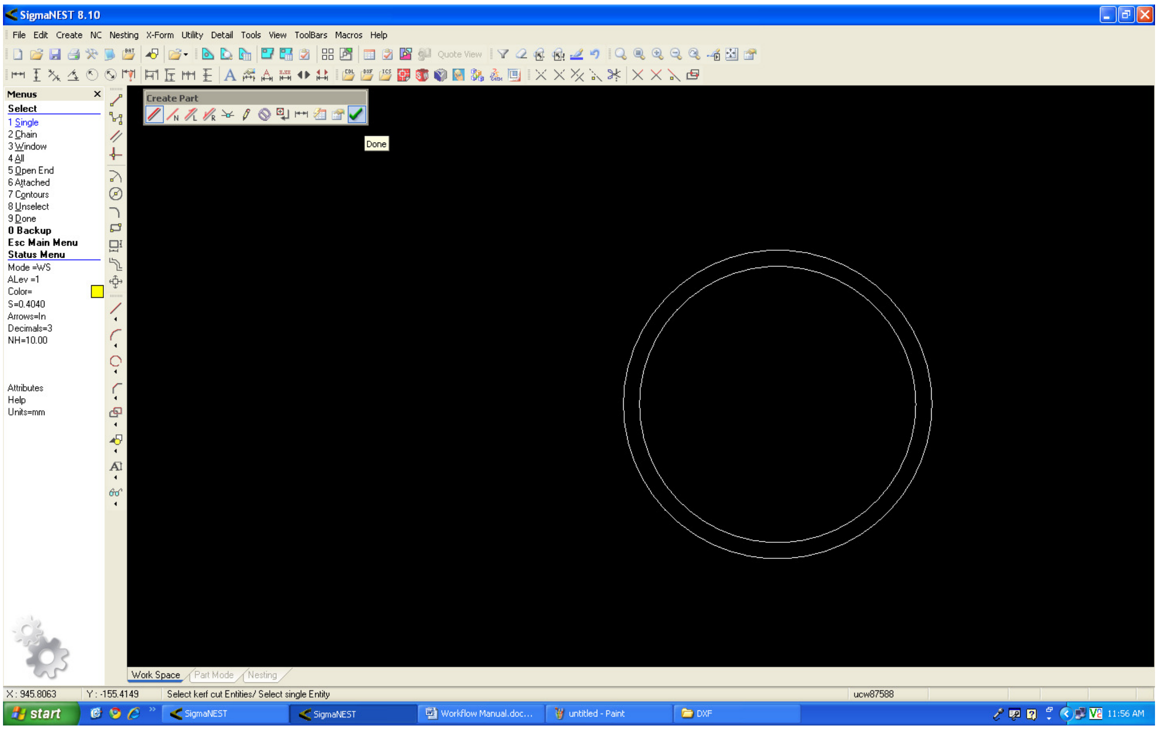
2. Check that all the drawings of the required Production Orders are available, updated and saved in a dxf.-format.



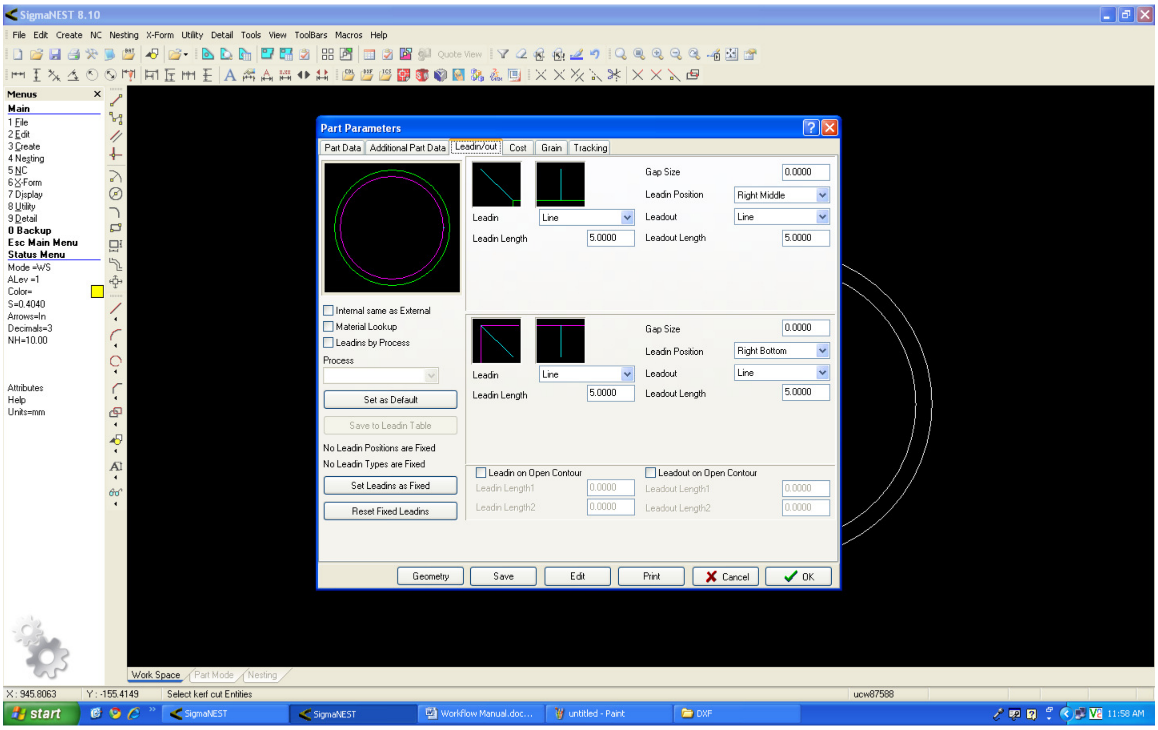
3. Check that all the part files of the required Production Orders are available on SigmaNEST and updated according to the latest revisions. The part files must also be adjusted and corrected to enable immediate nesting of the parts if the newest revisions are not saved as new, updated parts.

"Create Part" from drawing

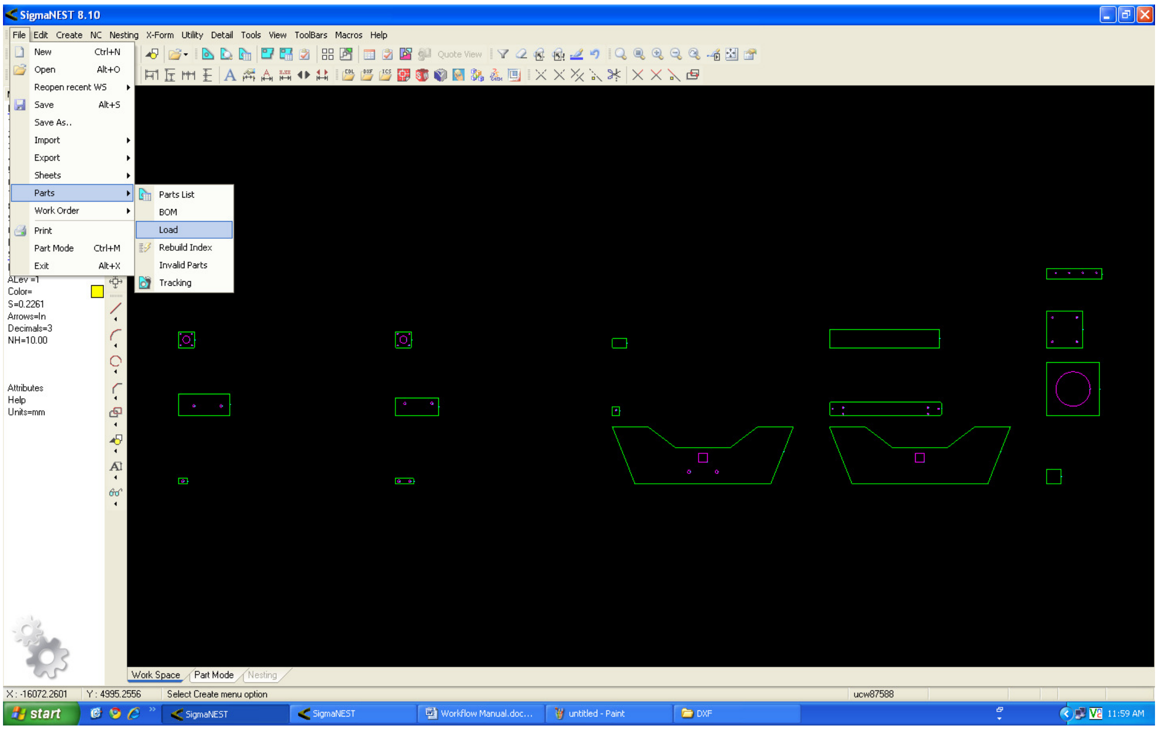


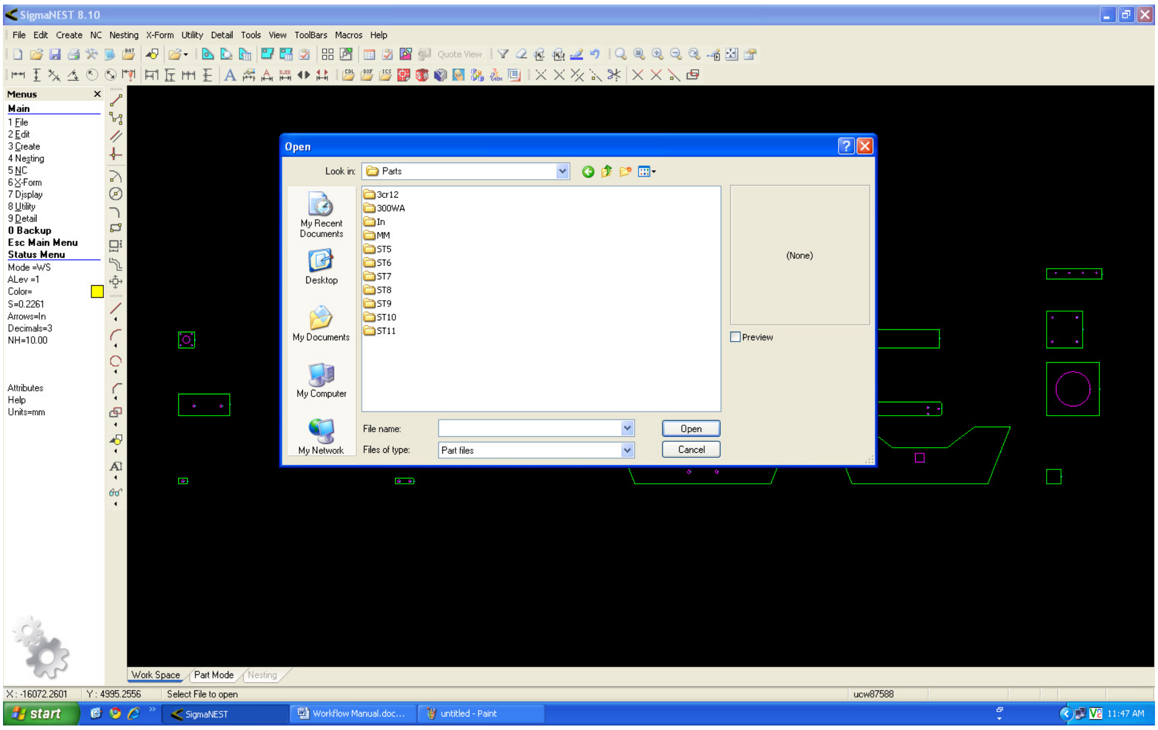


Set *"Part Parameters"*

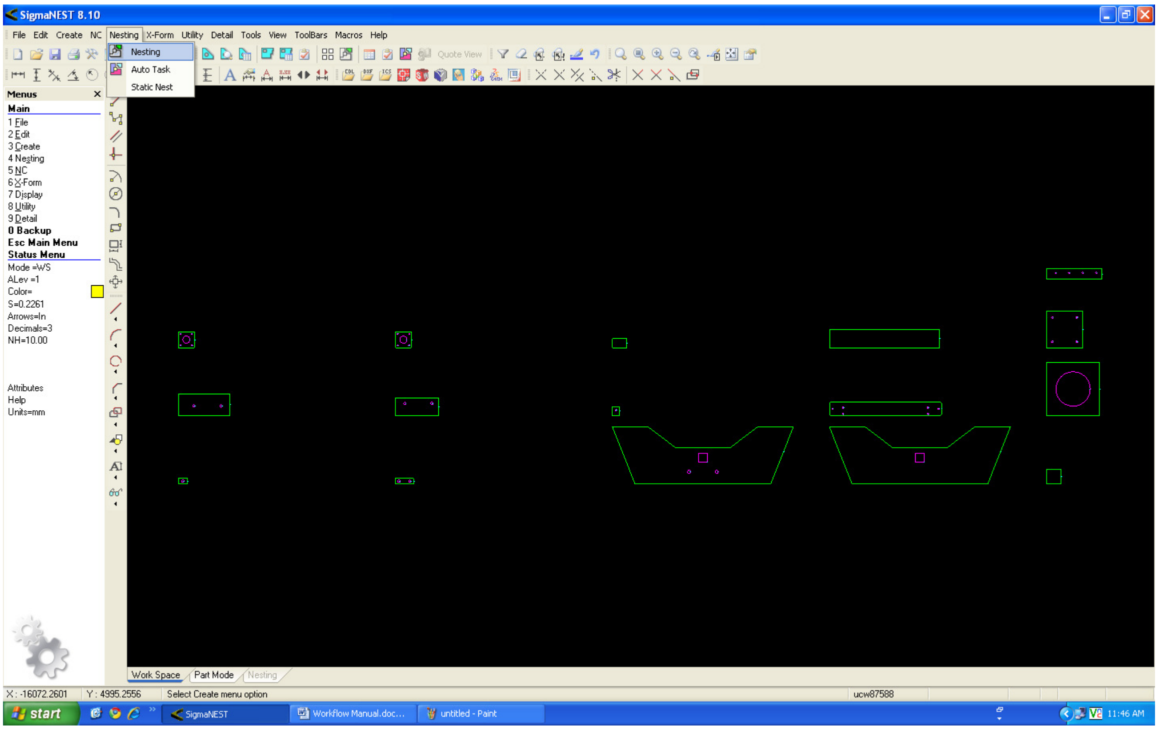


4. Upload all the parts as per Production Order Scheduled List onto the SigmaNEST workplace.

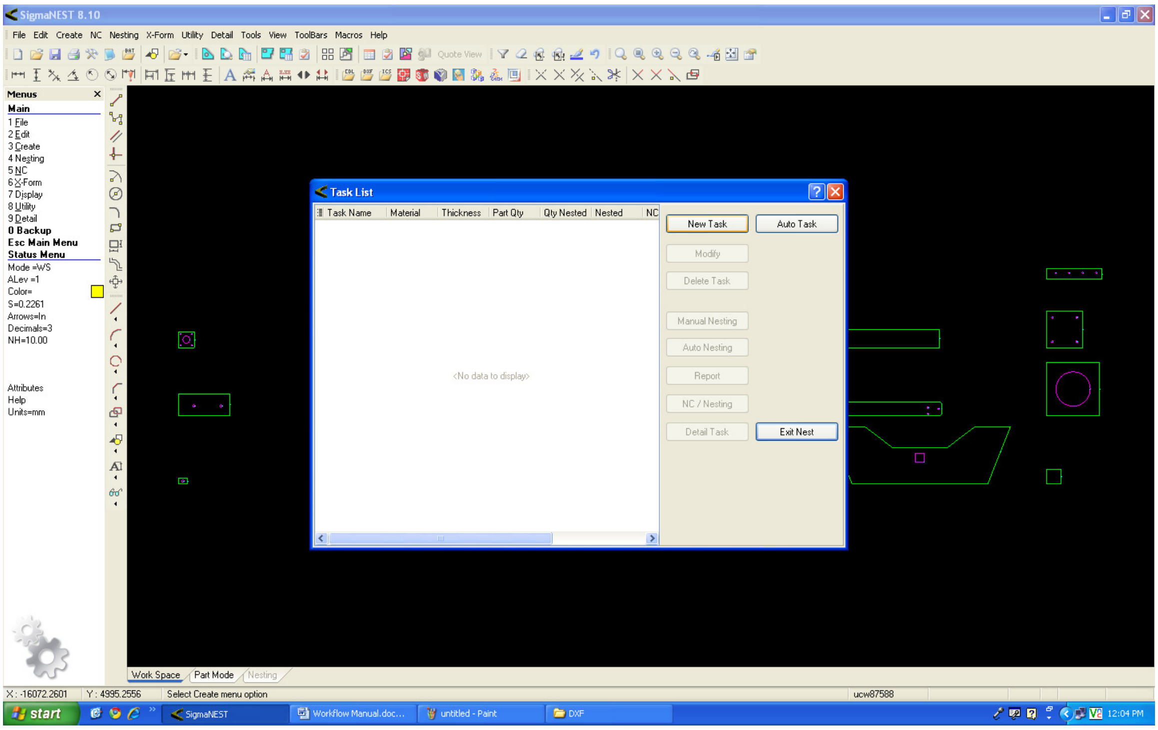




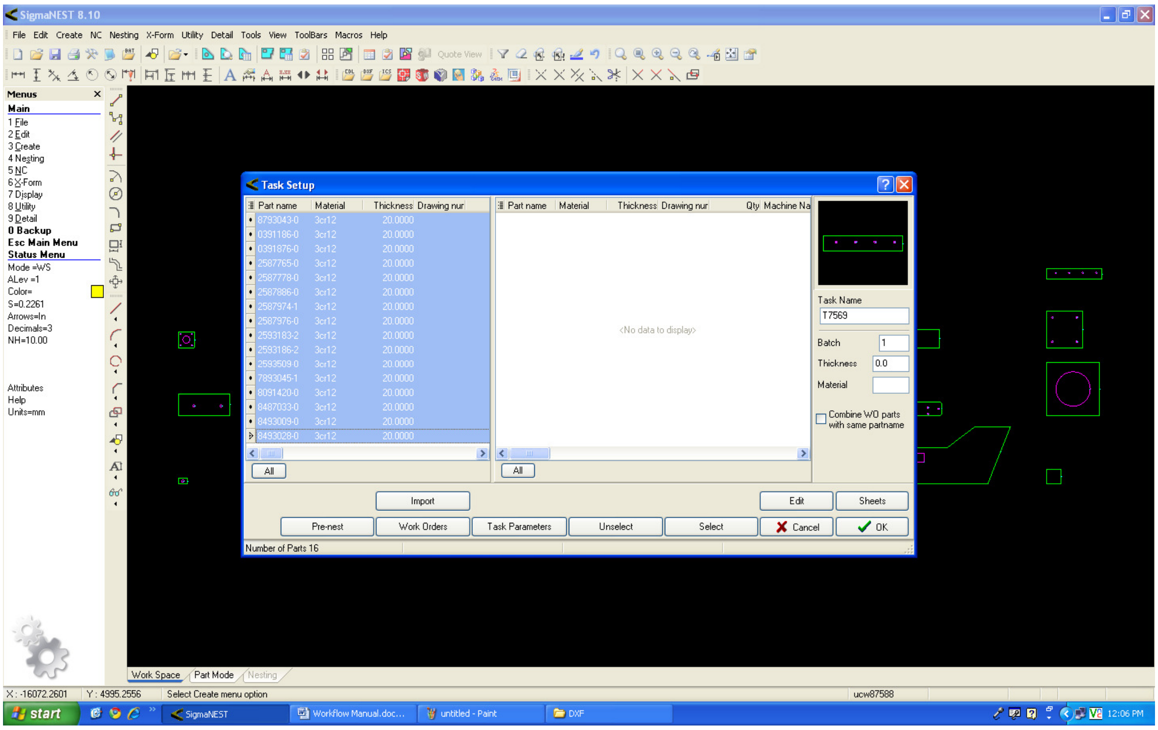
5. Select all the loaded parts and click on the Nest function.



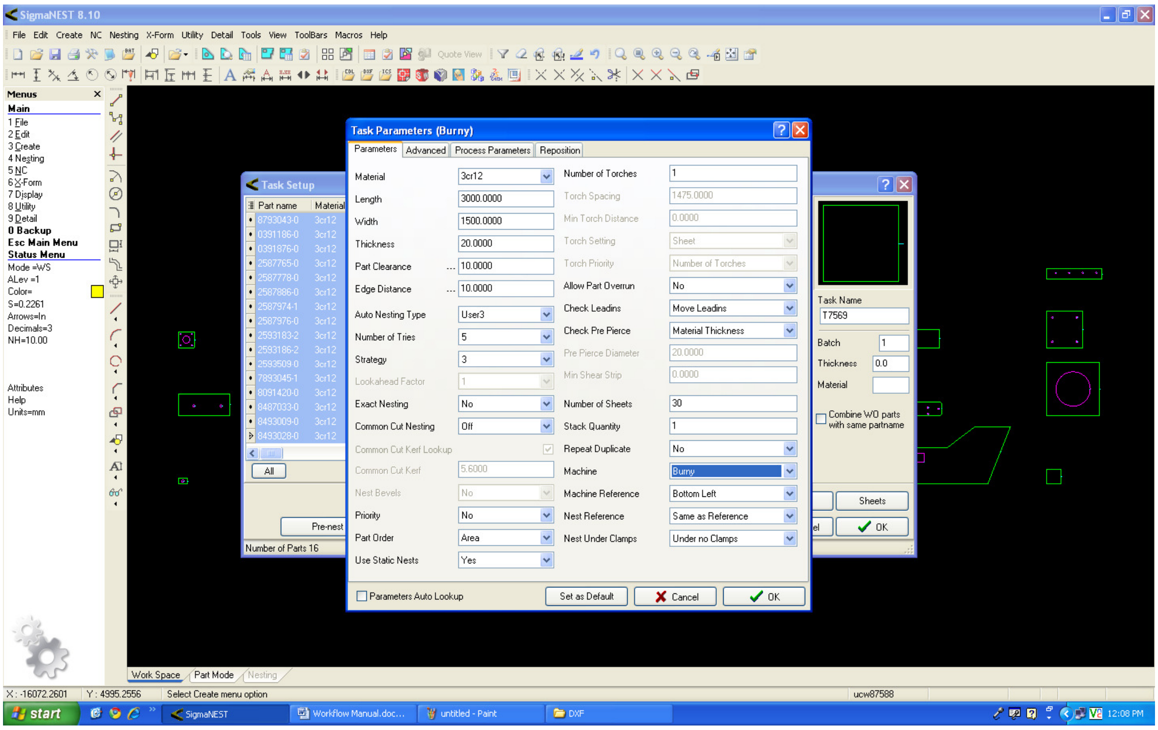
6. Select the *“New Task”* option.



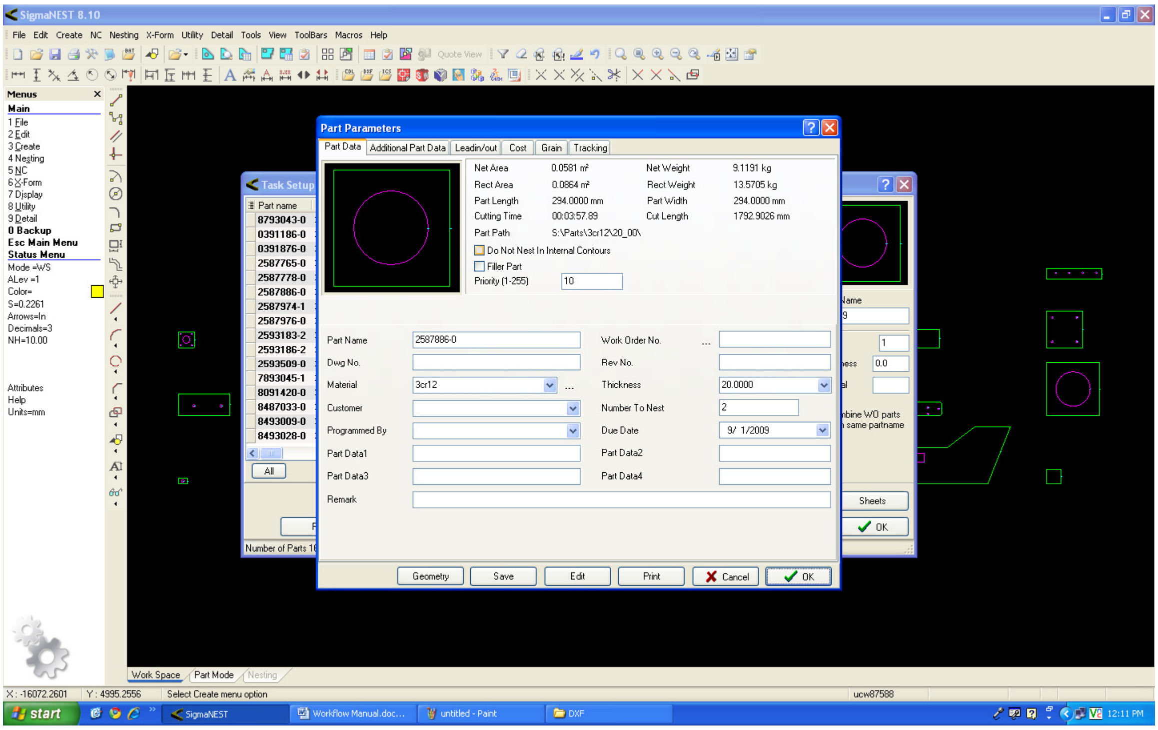
7. Select the parts and quantities to be nested. Set nesting parameters according to the specific process and machine that will be used. This is done by selecting the *“Task Parameter”* option.



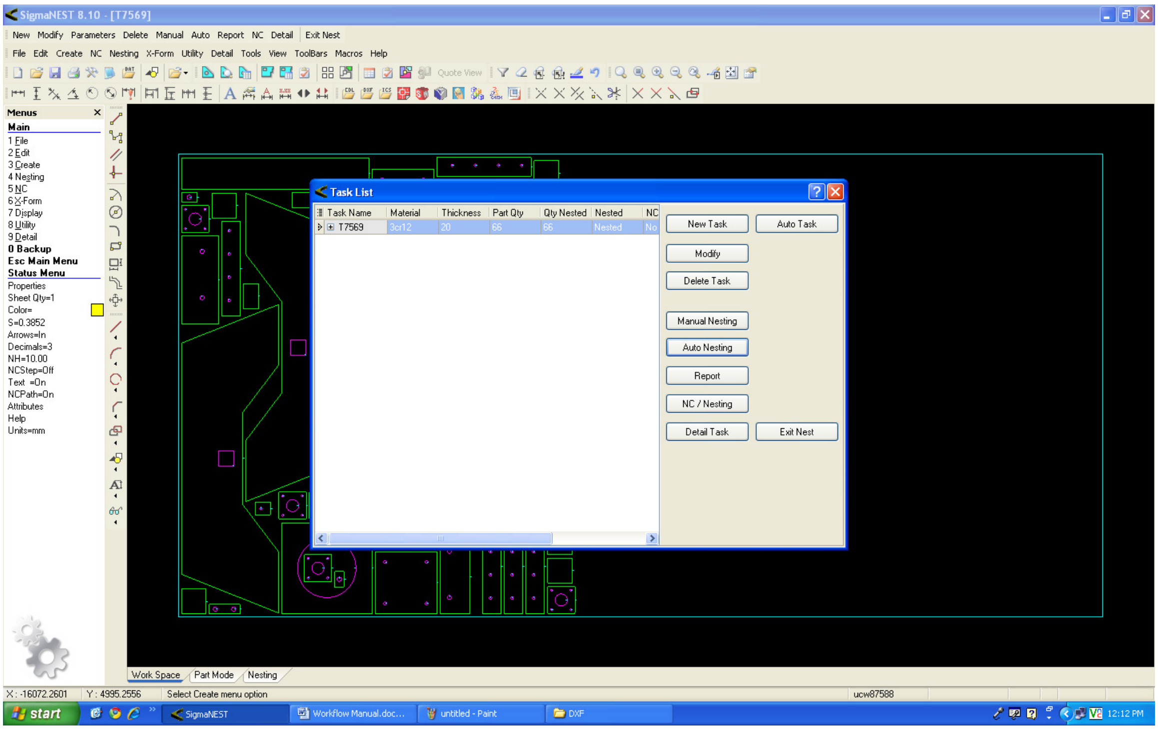
Select the applicable plate type, size and quantity to nest the parts on.



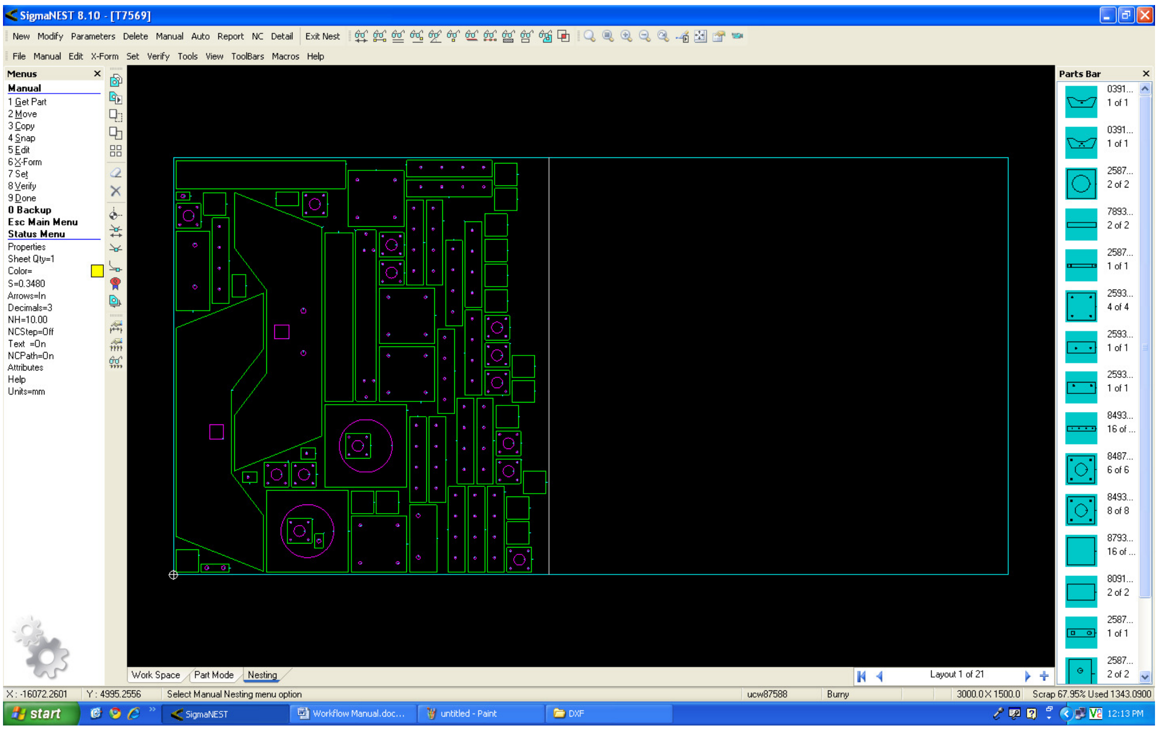
Check the parameters of every part for the specific machine and processes that will be used by double clicking on the specific part.



8. *“Auto Nest”* the parts once all the parameters have been set.

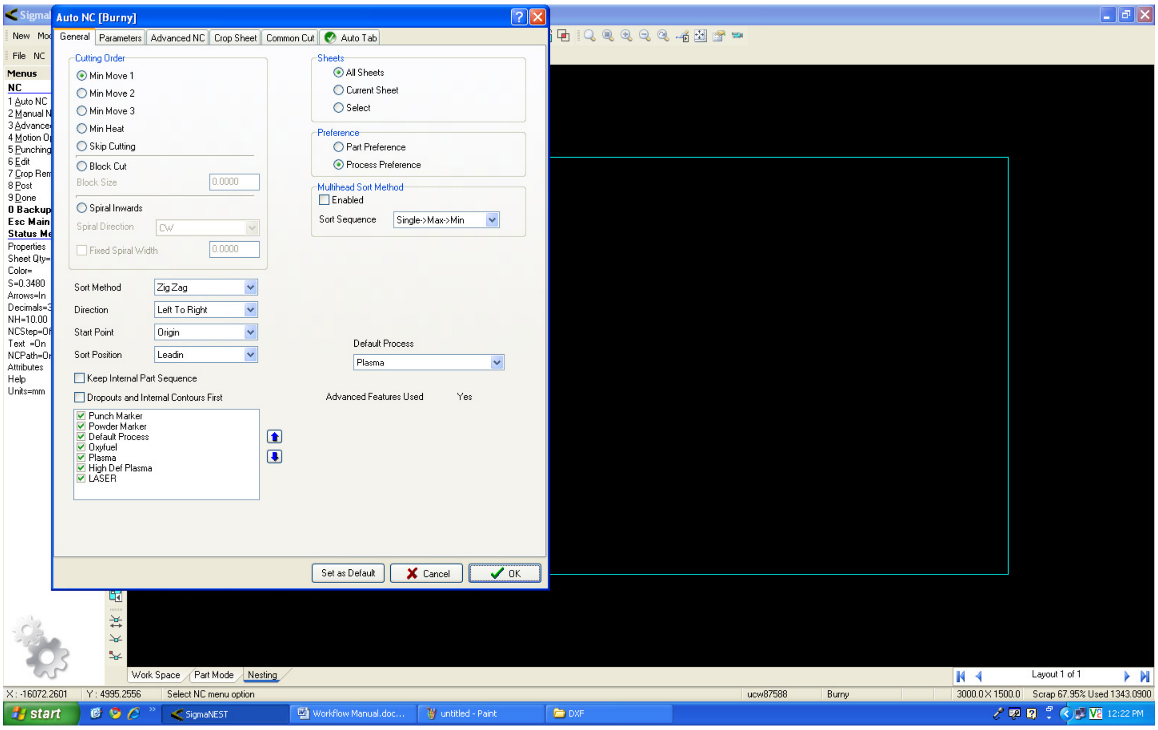


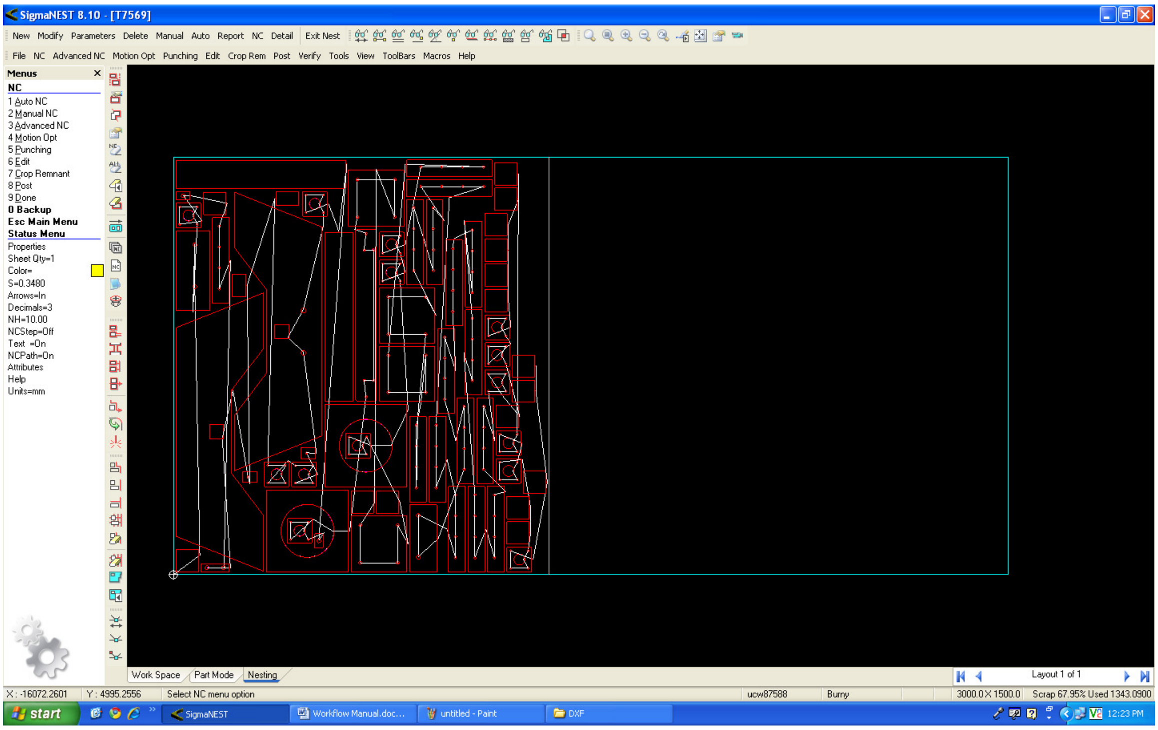
9. C lick on *“Manual Nest”* to check the nest results.



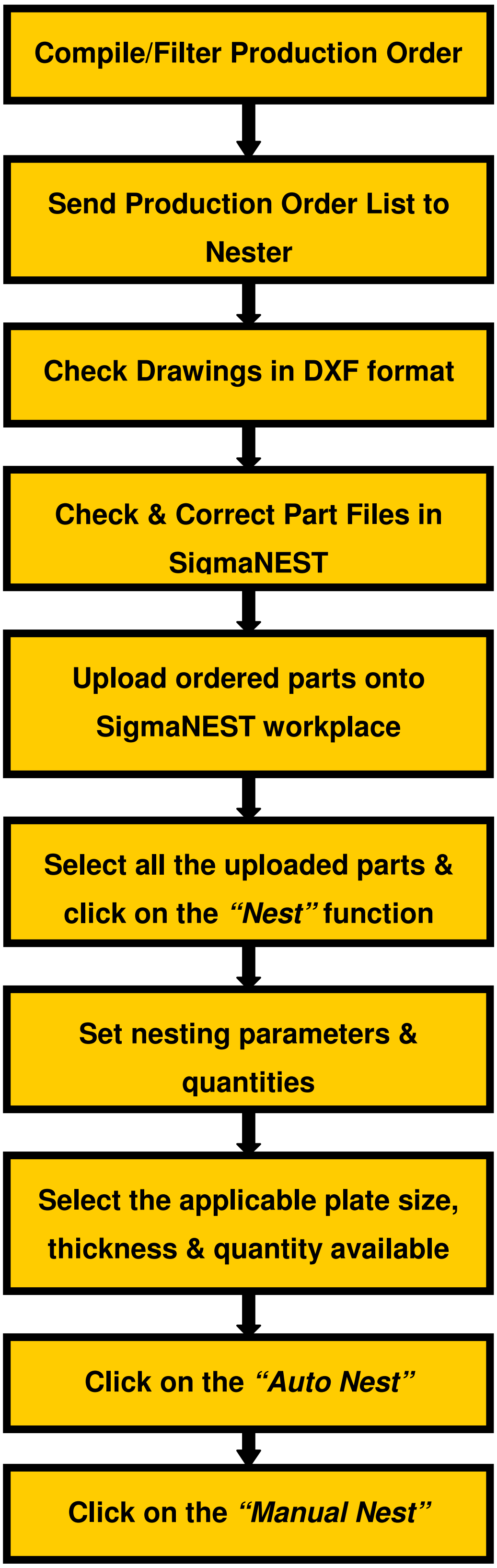
10. If the results are not satisfactory, go back to Step 1 and increase the window opening.

11. If the results are satisfactory; click on *"Auto NC"* to set the *"Program Parameters"* for the current nest.





Batching and Nesting Workflow



APPENDIX G

Budget

Project Steps	Level of Effort (hours)	Unit Cost	Total (Ex Vat)
Project Background	40	19.39	775.6
Problem Identification and Composing of Problem Statement	45	19.39	872.55
Project Planning	40	19.39	775.6
Literature Study on Batching & Nesting Techniques	20	19.39	387.8
Development and implementation of an improved Production Planning Process	100	37.61	3761
Software Training	4	700	2800
Purchase of additional Software licences	N/A	45 000	45 000
Development & implementation of Batching Rules including an action plan and a SigmaNEST manual	80	37.61	3008.8
Installation of Network points	N/A	80 000	80 000
Final report and presentation to management	80	37.61	3008.8
TOTAL:	**405**		**140 390.15**

The total cost included in this project included the wages paid to the student, additional software licenses and software and the installation of network points at various shop floor machines. The wages was paid on a per hour rate that was pre-determined and stipulated in the contract between the student and The UCW Partnership.