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Prioritised Improvement Plan – Basic Quality Tools

Quality and Business Improvement ACMA4004

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1 Introduction

1.1 Aims

This technical report aims to inform the reader how effective the use of appropriate basic quality tools can help to improve processes in the workplace.

Additionally, the report will specifically focus on how the use of Check Sheets and Pareto Analysis significantly reduce variation/defects in the rapid prototyping of Visijet Wax Jewel Red wax models at the Diamond Centre of Wales Limited.

1.2 Objectives

One of the main objectives is to identify causes of defects in Visijet Wax Jewel Red wax models using Root Cause Analysis tools.

Another objective is to successfully create a Prioritised Improvement Plan for the Diamond Centre Wales, to decrease the number of defects in the rapid prototyping process for sending wax models to an external company for precious metal casting.

2 Literature Review

2.1 Rapid Prototyping at the Diamond Centre of Wales Limited

At the Diamond Centre of Wales, a vital role in the whole bespoke manufacturing process is the rapid prototyping of wax models. The design team give the Computer Aided Designers a brief after an appointment with clients, in which they need to create bespoke jewellery items using computational software called 3Design – a bespoke jewellery design package.



Figure 1 - Digital rendering of 18 carat white gold earrings with a central London blue topaz, surrounded by round white diamonds and marquise white diamonds. Created in 3Design and rendered in Keyshot.

Once the clients receive and approve the images that they receive, the jewellery items need to be prepared in 3Design for 3-dimensional printing on a Projet 2500W 3D printer. This process involves applying sprues to the items, before exporting them as stereolithography (STL) files. These files are then uploaded to slicing software called 3DSprint. Once the models are prepared on 3DSprint, they are sent to the Projet2500W 3D printer via the network for 3D printing.



Figure 3 - 9 carat white and yellow gold bangle with round sapphires and diamonds in bezel settings. Created in 3Design and rendered in Keyshot.



Figure 2 - The bangle in Figure 2 shown in 3Design split into separate parts for 3D printing and precious metal casting.

Once the printer has successfully completed the print, the models are removed by slightly melting the support material to remove from the print bed and are placed into an isopropanol bath to remove the excess support material. These models are then dried with an air-compressor. Before being bagged up to send to Weston Beamor (precious metal casters at the Birmingham Jewellery Quarter), some models require stones to be checked in the settings to ensure that they fit nicely for setting at a later stage. As well as this, some of the models contain mechanisms which need to be checked for functionality before sending for precious metal casting.

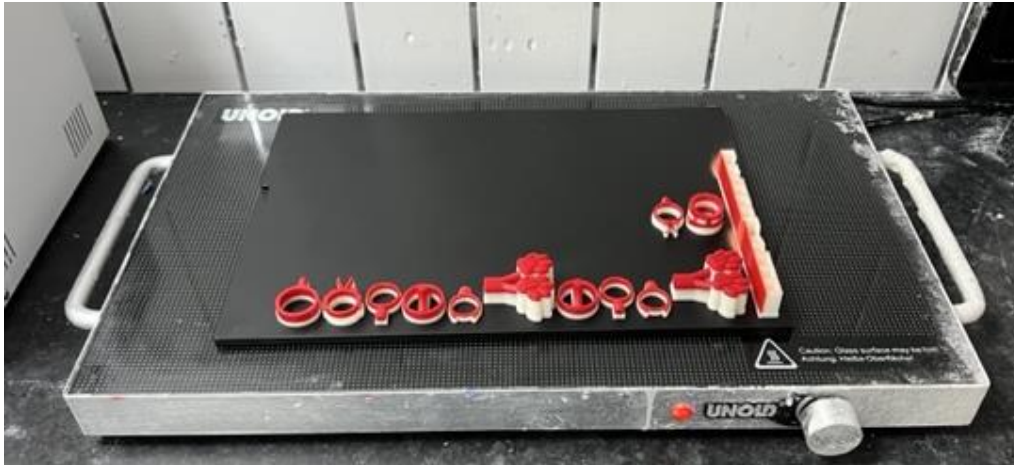


Figure 4 - Visijet Wax Jewel Red support material being slightly melted on a hot plate to remove from the print bed.

When the models are confirmed to be appropriate for precious metal casting, they are sent to the precious metal casters to undergo a highly skilled process. The wax models are attached to a casting tree via a sprue before entering the investment stage. The investment stage involves the wax trees being coated in special material which forms a casting mould. These moulds are then left to dry and harden to be put into an oven which vaporises the original wax material. The completion of this step leaves a negative impression of the jewellery design left in the mould.

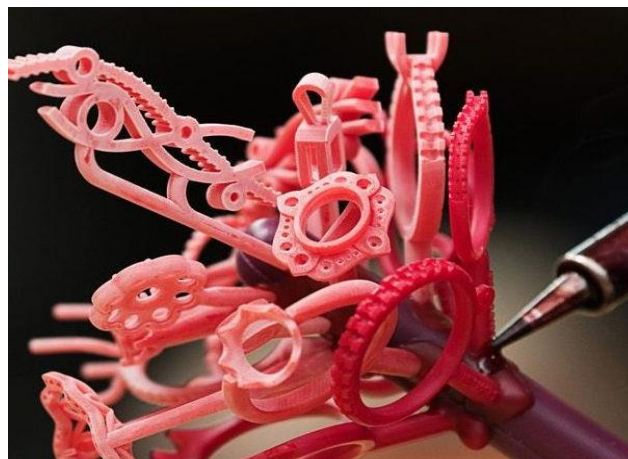


Figure 5 - Image of Visijet Wax Jewel Red models being carefully attached to a casting tree. (Weston Beamor 2023)

After the Lost-Wax process is finished, molten metal replaces the void that is left through a very special casting process. The tree, which was once a wax tree, is now a precious metal tree. The precious metal pieces are then carefully cut away from the tree, and if required, are sent for hallmarking at the Birmingham Assay Office. **(Morris and Watson – Date unknown)**.



Figure 6 - A yellow gold casting tree. (Morris and Watson)

The precious metal items are returned to the Diamond Centre of Wales for a quality control and are processed into the workshop for finishing. It is vital that the wax models are of a high quality with no defects.

2.2 The 7 Basic Quality Tools

The 7 basic quality tools are Pareto Analysis, Histograms, Scatter Diagrams, Control Charts, Process Flow Charts, Ishikawa Diagrams (also known as Fishbone Diagrams) and Check Sheets. These tools were created by a Japanese engineering professor in the 1950s. The reason he created these 7 basic quality tools was to help employees to implement effective quality control measures into the workplace. **(Lucid Content Team, 2019)**

2.3 Root Cause Analysis

Root Cause Analysis is a process that is applied in an array of industries to identify the root cause of defects within a particular process. The whole aim of Root Cause Analysis is to completely eradicate issues rather than just simply making them better. The initial goal in performing Root Cause Analysis is to identify the root cause of the problem. The next goal is to figure out how to fix the problem, and the final goal is to use the knowledge learned from finding out the root cause to ensure that further issues are not repeated. **(Graupp, P. 2022)**

The first step to a Root Cause Analysis is to clearly identify the problem before gathering relative data to the problem. The following step is to identify the possible causes to the issue at hand. Later in this paper, you will see 2 of the basic quality tools used to gather data related to defects in Visijet Wax Jewel Red models which helps to define the causes of the defects. These tools help to highlight the root causes, which allows for the creation of a prioritised improvement plan to help eradicate the root causes. **(MindTools, 2023)**

Root cause analysis is a vital process, especially in the manufacturing industry where errors easily creep into processes. The use of tools such as the Failure Modes and Effects Analysis are integral to improving quality in products/processes which leads to higher customer satisfaction and increased profits.

2.4 Check Sheets

Check Sheets are a great way to track defects in a product/process. Check Sheets record information like cause of defects, frequency of those causes and the location of those causes. **(QualityGurus – Date Unknown)**

To create a Check Sheet, you need to firstly determine what information you want to collect data for. The next step is to create the Check Sheet form which needs to include information such as the operator of the form, the date and time, the location and the categories. **(PV, T.H, Ramana 2013)**

After this, data needs to be recorded over time. For example, a jewellery manufacturer wants to find out the root cause of defects to wax models, so, they create a Check Sheet to input data for the causes of defects. The frequency of the specific defect categories will be recorded over a set period to be used in a Pareto Analysis diagram potentially. This helps to determine the root causes of defects and allows resources to be focused on the vital problems, rather than the trivial many.

2.5 Pareto Analysis

The Pareto principle, also commonly known as the '80/20 Rule', was created in 1906 by an Italian economist called Vilfredo Pareto. Vilfredo Pareto discovered that 80% of the land in Italy was owned by 20% of the population. This is where the name came from. **(Laoyan, S. 2021)**

The Pareto principle states that roughly 80% of effects happen due to 20% of causes. This is applied in multiple industries and is a vital tool in quality control of products, processes and services. In the Diamond Centre of Wales, roughly 80% of the money earned comes from 20% of high-spending clients. Due to this, the Diamond Centre of Wales created a special club called 'Club 58' which gives these clients early insights to new design projects etc. **(Guy-Evans, O. 2022)**

The first step of Pareto Analysis is to identify issues, make a list of the potential defects and score the problems by frequency of occurrence for example. A Check Sheet provides a great resource to perform Pareto Analysis. Create a Pareto Chart as seen later in this paper, which will highlight the 20% of defects that are causing 80% of problems. The 20% causing the problems can then have resources prioritised to them to try and solve the problems. This is a lot more effective than wasting resources on the trivial many.

3 Methodology

3.1 Use of a Check Sheet to identify defects

At the Diamond Centre of Wales, a Check Sheet was created by a member of the Computer Aided Design department to identify the root causes of defects in wax models printed on the Projet2500W 3D printer.



Figure 7 - Projet2500W 3D printer

A list of defect causes was created and every time one of these caused a defect to a wax model, a mark would be added to the Check Sheet for that week. This was carried out over 7 weeks – the marks from all the weeks were added up to give the frequency of the defect causes.



Figure 8 - A collection of defected Visijet Wax Jewel Red models about to be put into the wax GY (graveyard)



Figure 9 - Visijet Wax Jewel Red model deformed by being dropped on the floor

4 Combined Results and Analysis

4.1 Check Sheet Results

Table 1 Check Sheet created at the Diamond Centre of Wales for monitoring frequency of defect causes in wax models.

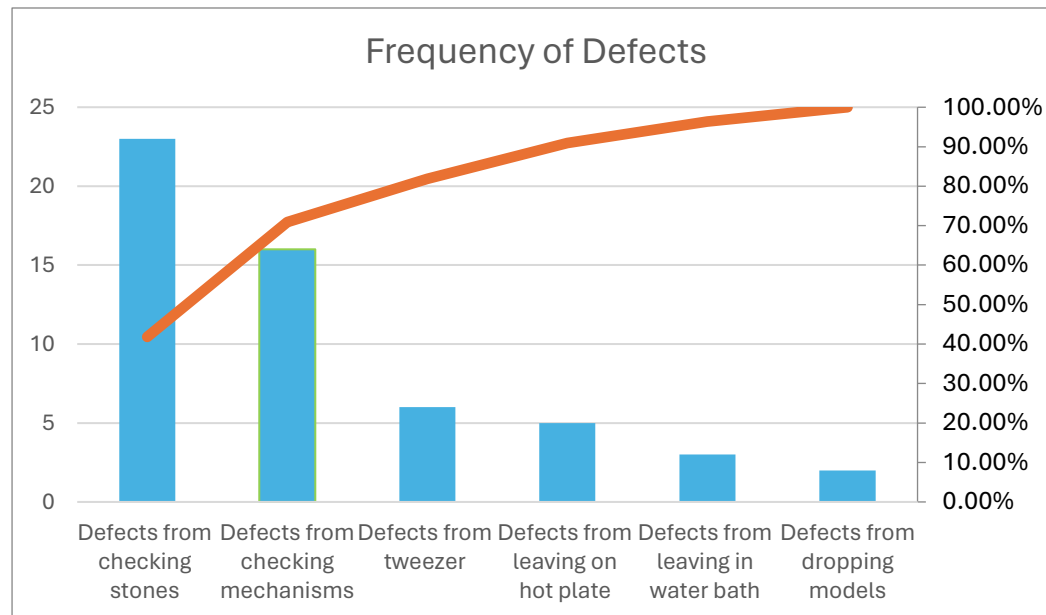
Diamond Centre of Wales Check Sheet - CAD Department								
Defects to Visijet Wax Jewel Red Models								
Recorded by Meuryn Nelson Dates: 02/01/24 - 20/02/24								
Defect Types	Weeks							Total
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	
Defects from checking stones	III	IIII	II	III	III	I	III	23
Defects from checking mechanisms	I	II	III		III	I	II	16
Defects from dropping models			II					2
Defects from tweezer	I	I	II		I		I	6
Defects from leaving on hot plate		I		IIII				5
Defects from leaving in water bath						III		3
Total	7	9	11	8	11	5	6	

The results from the Check Sheet show that over the 7 weeks, a total of 55 wax models had defects which stopped them from being sent for precious metal casting. These all had to be reprinted.

4.2 Use of Pareto Analysis to analyse defects

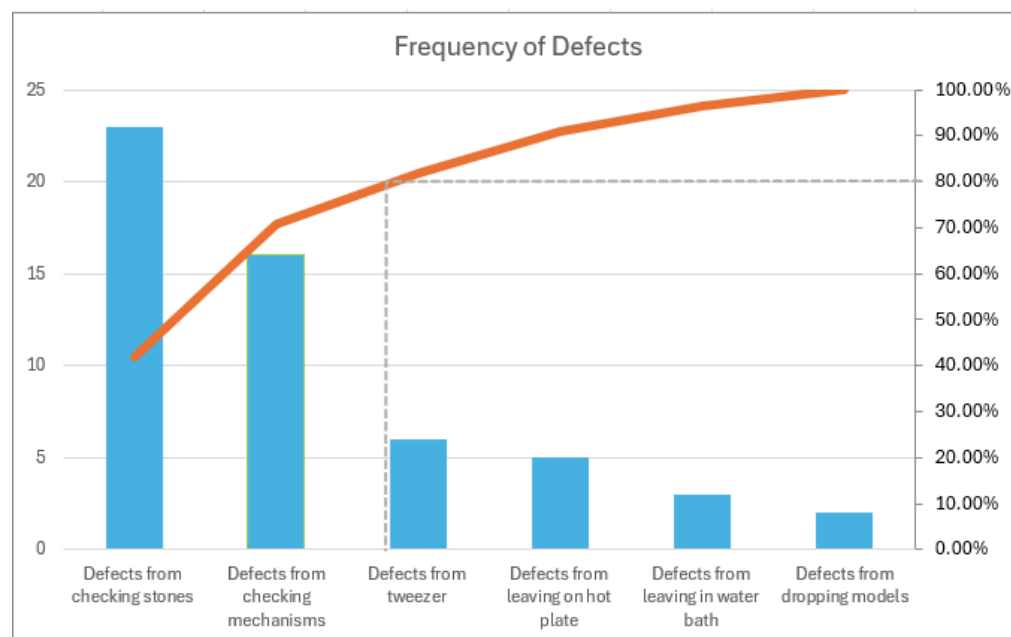
The data gathered from the Check Sheet enabled the creation of a Pareto Analysis Diagram to further emphasise the root causes for the high number of defects occurring to the wax models.

Table 2 - A Pareto Analysis Chart created at the Diamond Centre of Wales to show the frequency of defect causes with the wax models.



The next step after creating the Pareto Analysis diagram is to place the 80% markers to identify the vital few and the trivial many.

Table 3 - The same as Table 2 but with a dotted line showing the 80% line to divide the 'Trivial Many' and the 'Vital Few'.



By using the Pareto principle, it has highlighted that the 2 largest causes of defects to the Visjet Wax Jewel Red models are the checking of stones and mechanisms with the wax models. These are known as the vital few. The remaining causes of defects are the trivial many. The vital few are the defects to improve or eradicate completely.

5 Discussion

5.1 Prioritised Improvement Plan

When checking stones in the wax models, damage easily occurs to them due to the extreme fragility of the waxes. The same happens regularly when checking if mechanisms, like hinges and clasps in bangles, will work. This causes delays to the manufacturing process which ultimately can lead to customer dissatisfaction, whilst this also costs the company financially due to the number of reprints that are needed.

The Check Sheet identified that over the course of 7 weeks, a total of **55** wax models had defects out of 492 models printed. That is **11.22%** of the models printed that ended up having defects.

Table 4 - Table showing figures related to the number of wax models printed at the Diamond Centre of Wales.

No. of models printed over 7 weeks	No. of models that needed a reprint	% Of reprinted models
490	55	11.22%

39 of the defected wax models were caused by the vital many that was deciphered using Pareto Analysis. The vital few make up **7.96%** of the defected models – if the cause of the defects was to be eradicated, then the % would drop down to **3.26%**.

Table 5 - Table showing the amount of models that needed reprinting over 7 weeks.

No. of models that needed a reprint from the vital few	% Of models that needed a reprint from the vital few
39	7.96%

The Visijet Wax Jewel Red material cartridges used for the Projet2500W printer are costly. Roughly 4 of the wax material cartridges are purchased along with 4 of the support material cartridges annually. The cost of these combined comes to a large sum of £3880.00 per/annum.

	Cost of material cartridges	Quantity over 12 months	Total Cost of cartridges per year
VisiJet Wax Jewel Red	£675.00	4	£2,700.00
VisiJet Wax Jewel Support	£295.00	4	£1,180.00
TOTAL £ SPENT ON PROJET 2500W MATERIALS ANNUALLY			£3,880.00

<https://shop.3drp.co.uk/product-page/visijet-m2-jewel-red-wax-1-5kg>

<https://shop.3drp.co.uk/product-page/visijet-m2-suw-support-1-6kg>

If **11.22%** of wax models are being reprinted, then that is **£435.336** a year that goes to waste. Over the span of 5 years that is **£2176.68**. If the vital few are eradicated, then the wastage per year reduces to **£126.488**. Over 5 years that equates to just **£632.44**. Saving the company **£1544.24**.

To eradicate the vital few defects, a Anycubic Photon Mono 2 is to be purchased. This is a 3D printer which allows printing in resin material which is extremely durable. For the jewellery waxes that need stones to be checked in and mechanisms tested; a prototype will be printed on the Anycubic Printer using Anycubic Water Washable 3D Printer Resin. All stones can be checked in these resin models with no issues due to their durability, and the same goes for the mechanisms. Once the CAD department employees are happy with the items in question, they can then be printed on the Projet2500W and will be in prime condition to send for precious metal casting.

<https://uk.anycubic.com/products/photon-mono-2> The plan is for the CAD department to purchase this machine by 15/03/2024 as the Anycubic Photon Mono 2 is discounted from the official site at £169.00. The Anycubic Resin is to be purchased from Amazon at just £29.99 per 1kg of material. Using the Pareto 80/20 rule, 20% of items will require printing on the Anycubic for checking.

No. of printed models over 7 weeks	Average No. of models printed weekly	Average No. of models printed annually
490	70	3640

20% of the annual 3640 items printed annually equals to 728 items annually. The author's own knowledge of 3D printing jewellery states that roughly 3 grams of material is used per item. 3 grams multiplied by 728 items means just over 2KG of material will be used per annum. That equates to 10.92KG over 5 years. Over 5 years, just 11 bottles of Anycubic resin purchased which would cost **£329.89** at today's prices. That added to the **£169.00** for the 3D printer means **£498.89** spent over 5 years.

Take that figure away from the **£1544.24** saved by removing the vital many problems, then the company saves **£1045.35**.

Additional benefits include that clients will be able to try wax versions of rings on their fingers without the models breaking and the CAD team can experiment with new mechanisms without being weary of wasting material like with the Visijet Wax Jewel Red material. The Anycubic is also very fast at printing.

There are cost benefits, time benefits and customer benefits. The downside to the Anycubic resin is that it can't print in as fine detail as the Visijet material, so, clients may be disappointed when viewing wax models for fine detail. In this case, the Visijet material would need to be used. Another potential barrier going forwards with this plan is that the CAD team aren't trained up to use this printer. To mitigate this, the team have already sourced training via YouTube which shows how simple it is to use.

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