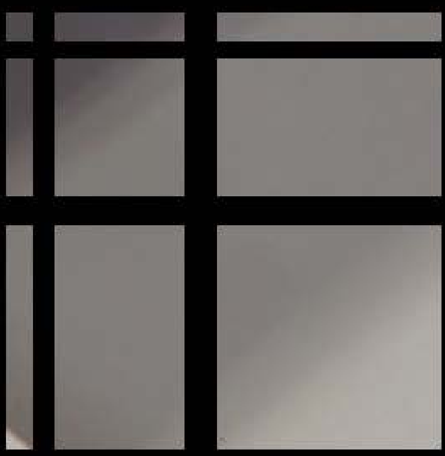
Future proofing the mold making process for Royal Delft ceramics



Master Thesis

J. F Heesakkers

2021

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Master Thesis
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Abstract

This graduation report presents a new mold making approach for Royal Delft. The traditional production trajectory starts with a positive model and pouring plaster mold parts onto it one by one, producing a negative casting mold for one shape. This new proposal takes the plaster mold parts as a starting point, combining them into a modular system that can be modified continuously in order to produce many variations of a shape without starting from scratch for every new shape. The benefit of this approach is that shapes such as plates, vases and boxes can be quickly tailored to individual customers, changing elements, adding personal texts and creating custom vector reliefs.

Keywords
Ceramic; slip casting; mold; industry 4.0; digital manufacturing; craftsmanship; knowledge management; personalization; 3D-printing;

Abbreviations

FDM-printing	Fused Deposition Modelling
SLA-printing	Stereolithography Printing
SLS-printing	Selective Laser Sintering
CNC-milling	Computer Numeric Controlled Milling
ÙSP's	Unique Selling Points

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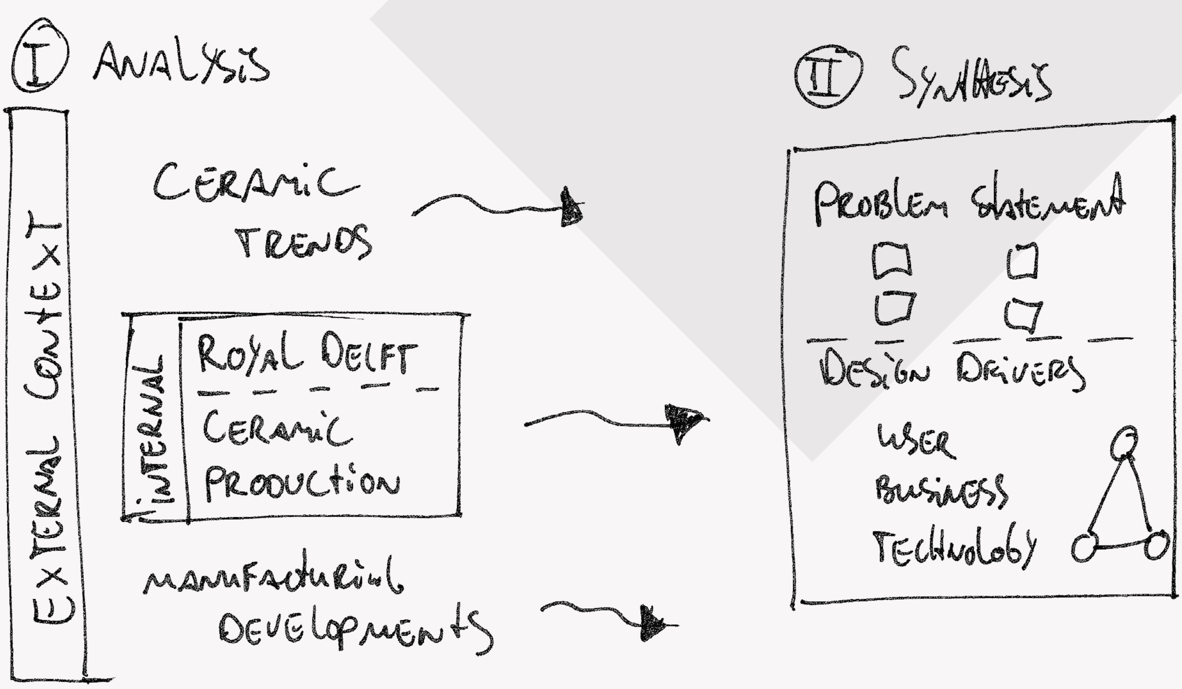

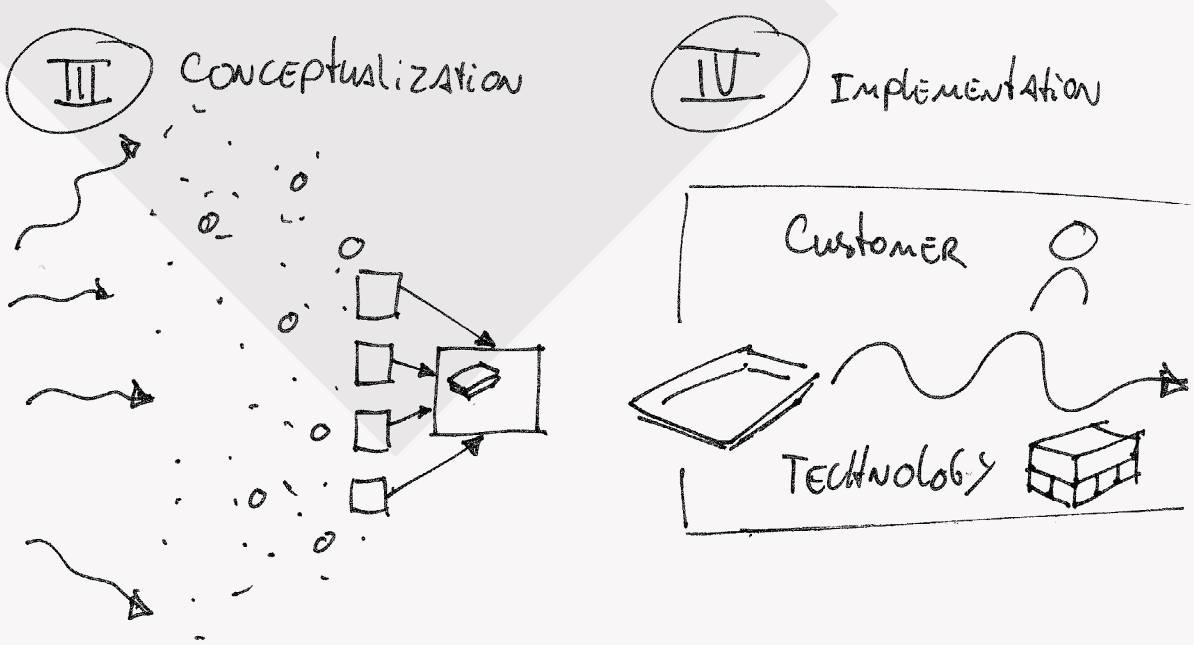

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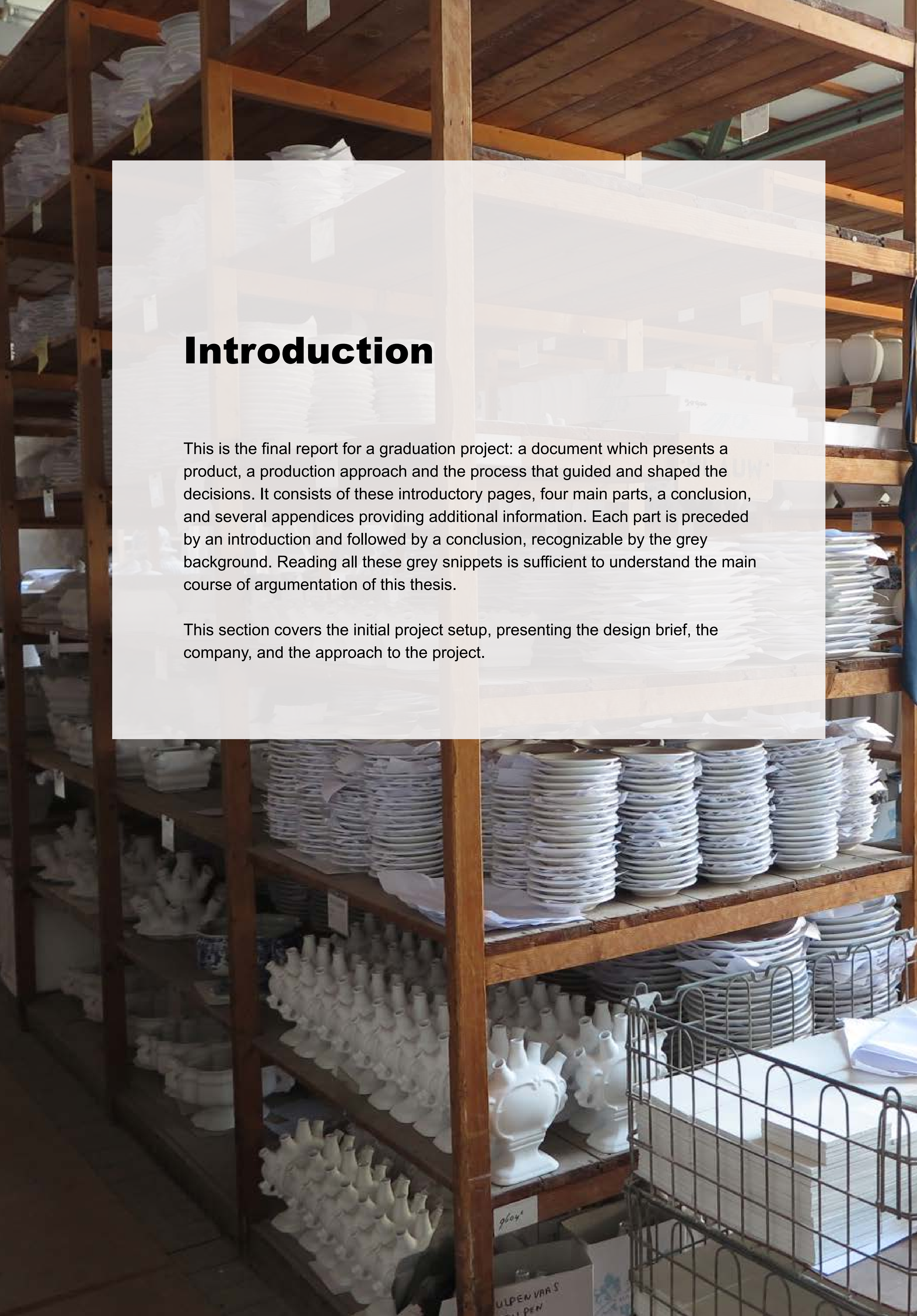


Introduction

This is the final report for a graduation project: a document which presents a product, a production approach and the process that guided and shaped the decisions. It consists of these introductory pages, four main parts, a conclusion, and several appendices providing additional information. Each part is preceded by an introduction and followed by a conclusion, recognizable by the grey background. Reading all these grey snippets is sufficient to understand the main course of argumentation of this thesis.

This section covers the initial project setup, presenting the design brief, the company, and the approach to the project.

Introduction

Initial brief

The initial assignment as formulated by Royal Delft is stated as follows:

> *"Analyze the mold making process and transform it into the future Royal Delft approach to mold making, including implementation of the innovated process."*

This is a sensible start, especially when briefly elaborating on the three stages: 'analyse', 'transform' and 'implement'.

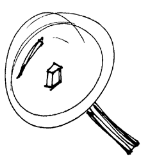
Analyze

The analysis of the mold making process is required to get an outsider (me) acquainted with the production process and the company in order to propose a made-to-measure solution. Additionally, the insights from an analysis-phase are often valuable in themselves, as they present a new perspective on existing friction points, or identify external opportunities and possibilities for the client. The analysis and its insights are covered in Part I.

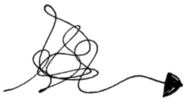
Transform

The transformation of the process raises numerous questions:

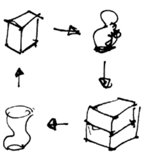
- *Why is there a need to transform the process?*
- *What aspects of mold making need to be transformed?*
- *What transformations are desirable?*
- *On what time scale does the transformation take place?*
- *What value can be brought by transformation?*
- *How radical needs the transformation to be?'*
- *What transformations are possible?*
- *Does everyone desire the same transformation?*



1. Analyze



2. Transform



3. Implement

The relevant questions need to be identified and answered, after which the imagining and generation of a sensible transformation can be started. These steps are covered in part II and part III.

Implement

The implementation of the transformed mold making process is better understood as a call to feasibility and to a sense of reality than a rigid demand from the client (especially considering the limited time of a graduation project and the amount of tasks as described above). This can be described in two points:

1. The proposed production approach is proven to be implementable, meaning that the project has been executed including the 'embodiment' part of the design process. Material tests, prototypes, cost-comparisons and scenario's demonstrate that the proposal is well thought-out and realistic.

2. The proposal comes with a description of concrete steps to take for Royal Delft in order to realise this production approach, including an overview of activities and a road-map sketching out possible future developments.

This is covered in part IV.

1. Various stages in the production process of the 3D shape - source Royal Delft

Context

The aim of the project is in itself rather abstract, its context makes it understandable and alive. This section presents the main circumstantial factors in which the project took place.

Client and workspace

The client for this project is Royal Delft, the only factory that produces hand-painted ceramics since 1653 in Delft, which will be elaborated on in a later chapter. Setting-wise it is good to note that luckily I was allowed to work for 3 days a week at their facility, commuting from the office to the factory and back. Working at location is highly advisable when doing an embodiment project for a specific client, but after a year of studying from home it was also an immense relief to be at a physical workspace with people again.

2. *Both names visible on the facade: De Porceleyne Fles and Royal Delft*

Industry 4.0

The aim of the project is to innovate a centuries-old production method with modern techniques. Concepts like industry 4.0, smart revolution, and advanced manufacturing will be mentioned and explored as a means to generate ideas to realise the innovation.

For Royal Delft implementing industry 4.0 is not a goal in itself, but for the sake of academic contribution to the field (however small) innovation is most interesting when done in a modern way.

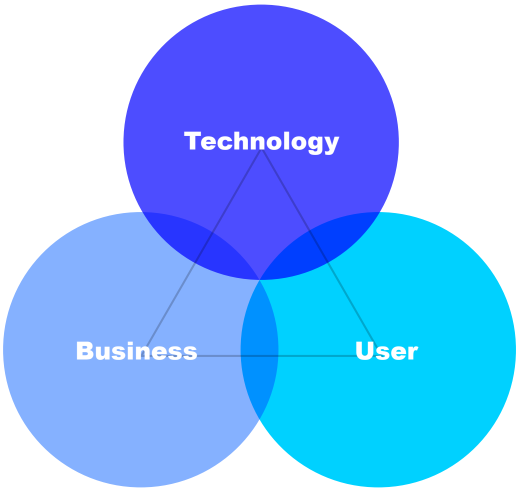
Learning Objectives

This ties in to one of my personal motivations for this project, which is to get acquainted with advanced manufacturing techniques and implement them in a real-life setting. While all learning objectives can be found in appendix C, I want to mention here that a curiosity for ceramics, an omnipresent yet unfamiliar industrial product-group, was another main reason for this choice.

Integration

New technical manipulations of ceramics were explored, however not as an independent, academic material test but always in context of Royal Delft. This frame guided the research-directions, and pushed the project forward into an actual application for real users with a decent business-case.

This means that the project grew over time into a better integrated whole, doing justice to the three pillars of our faculty: user, business, technology, where the specific IPD master adresses all three aspects in harmony.



Approach

From the above it becomes clear that this project embodies the desire for a technological development of a rather traditional company. This vision sets the scene for the general approach of the project.

The task that lies ahead can be phrased as: “To innovate with care” - meaning that a thorough understanding of the company is required, as well as a free view on possible futures. The diagram displays the project planning, following the well-known double diamond method of discover, define, develop, deliver, as described in the Delft Design Guide (Boeijen, 2013). I translated this methodology to the following reasoning steps:

I. An analysis phase is required to understand the company and the outer context.
II. Based on this analysis problems are distilled and design drivers are formulated.
III. Ideas and concepts are generated as a response to these design goals.
IV. The most promising concept is further developed, to deliver a tangible plan for realising a feasible product.


BLAUW

Section Summary

The aim of the project can be phrased as:

“Innovate the future mold making approach for Royal Delft”

This makes the project a combination of production design with a showcase product. The production method, business activities and brand identity of Royal Delft will be analysed. Then opportunities from trends and advanced manufacturing techniques will be explored. A generation phase will yield different concepts, of which the most promising and relevant one will be developed into manufacturing. The feasibility and viability will be evaluated and a roadmap for future implementation of this showcase product will be the final deliverable to the client.

Part I: Analysis

The first part breaks down the company, technology and broader context. This analysis is first performed internally, covering the history, production process and business model of Royal Delft. Knowledge was gathered by reading volumes from the Royal Delft library, examining in detail a vast number of molds, models and clay shapes, literature studies into knowledge management, and interviewing two mold makers, the technologist, and several employees from retail, sales and design. The insights from this chapter are complemented with an external analysis, looking into other ceramic manufacturing approaches and industry 4.0 developments.

By identifying the main regions of improvement for Royal Delft, and combining these with the opportunities in advanced manufacturing and design trends, the design drivers are defined to further shape the project. It consists of the following chapters:

Ch. 1 Internal - Company

Ch. 2 Internal - Technology

Ch. 3 External Context

1. Internal - Company

1.1 History

Being a centuries-old, royally acknowledged and globally known company it is relevant to elaborate on the history of De Porceleyne Fles. This helps understand the context, but also highlights some radical changes in the past: a company must innovate and evolve to remain viable for multiple centuries.

Founded in 1653

Hand-painted earthenware in China blue style became popular in the Netherlands in the middle of the 17th century, resulting in 32 production companies of delftware in Delft (Van Erkel, 2013). The delftware produced in this period was made from brown Dutch clay, covered in white glaze and hand-painted. A century later this type of delftware was outcompeted by higher quality products in Germany and Brittain which led to the closing of all Delft-based producers, except for De Porceleyne Fles.

Revival

A century later Joost Thooft, Adolf le Comte and Abel Labouchere initiated the revival of delftware, improving both the painting technology and artistic direction This method is best known as 'underglaze', referring to the fact that the paint is applied directly onto the biscuit (the fired clay body), and glazed and fired again afterwards. The artistic and technological revival stimulated many developments and innovations of different sorts, for example polychromous decors and the production of building ceramics in the 1900's.

3. *Brown clayware with white glazing from 1665*

4. *Polychrome plate*

Current status

In 2008 De Porceleyne Fles fused with Royal Van Kempen & Begeer and Royal Leerdam Crystal into the Royal Delft group. Since then a more contemporary design direction is taken, reflected by the design label Blue D1653, collections co-created with Dutch designers, collaborations with artists like Henk Schiffmacher or products made to order for different companies. 25 years ago the company museum and factory were opened to the public, since then providing revenue from entree tickets and sales to visitors.

5. Decorative building ceramics

6. Blue D1653 collection - Source: Dezeen

7. Collaboration with Moooi design

1.2 Business Models

Among other things Royal Delft is a production facility, a museum, a purveyor to the royal household ('hofleverancier'), and an event location. To get an understanding of how these roles co-exist and influence each other, this chapter covers the different business activities of Royal Delft.

Overview of activities

Royal Delft's core business has always been the production and sales of ceramics, mainly to consumers, occasionally to the court, and sometimes to other businesses (see diagram 9). It should be noted that the sales cannot be completely detached from the 140.000 yearly visitors to the factory (pre covidium), of which many buy products in the shop. This leads to the fact that 65% of revenue is made on the terrain in Delft, the other 35% consists of online sales and sales in other stores. In 2019, 78% of the visitors were foreign tourists, rendering this a potentially interesting target group.

Core Values

As mentioned earlier, defining and modernizing Royal Delft's brand identity has been an important theme in recent years. Royal Delft wants to stay close to their history, but also show that delftware is not necessarily old-fashioned by demonstrating their strength as a modern high-quality production facility. Their core competences can be summarized in the following list:

- High quality ceramics
- Hand painted
- Delft heritage
- Iconic visual style
- Luxury segment
- Small to mid-range capacity

These qualities are the most common motivators for companies or designers to collaborate with Royal Delft.

8. Royal Delft's revenue streams

Production costs

As most products are sold directly to consumers, the ratio between production costs and sales price (commonly '1:4', see diagram) is crucial for implementing a viable product. For this reason, collaborations with external designers, artists or companies are sometimes sold in-house (Schiffmacher, Blue D1653) and otherwise via the partner (Moooi, Supreme, Lord Lou).

9. *Price ratio: factory, to retailer, to consumer*

10. *Supreme collaboration*

Ocasionally ceramics are produced by Royal Delft, and sold under by a distinct company, for example the "When Objects Work" bowls. A fourth category is products that are (partially) outsourced to other ceramic producers. This mainly occurs for mass produced functional items with a boundary price: kitchenware and souvenirs have a consensus price ceiling, which is not the case for emotional, decorative objects. Usually the molds and transfers are produced in Delft, and then sent to the other facility in China, Indonesia or Morocco, in order to keep control of the quality of the end-product.

12. *When Objects Work bowls*

11. *Schiffmacher plate*

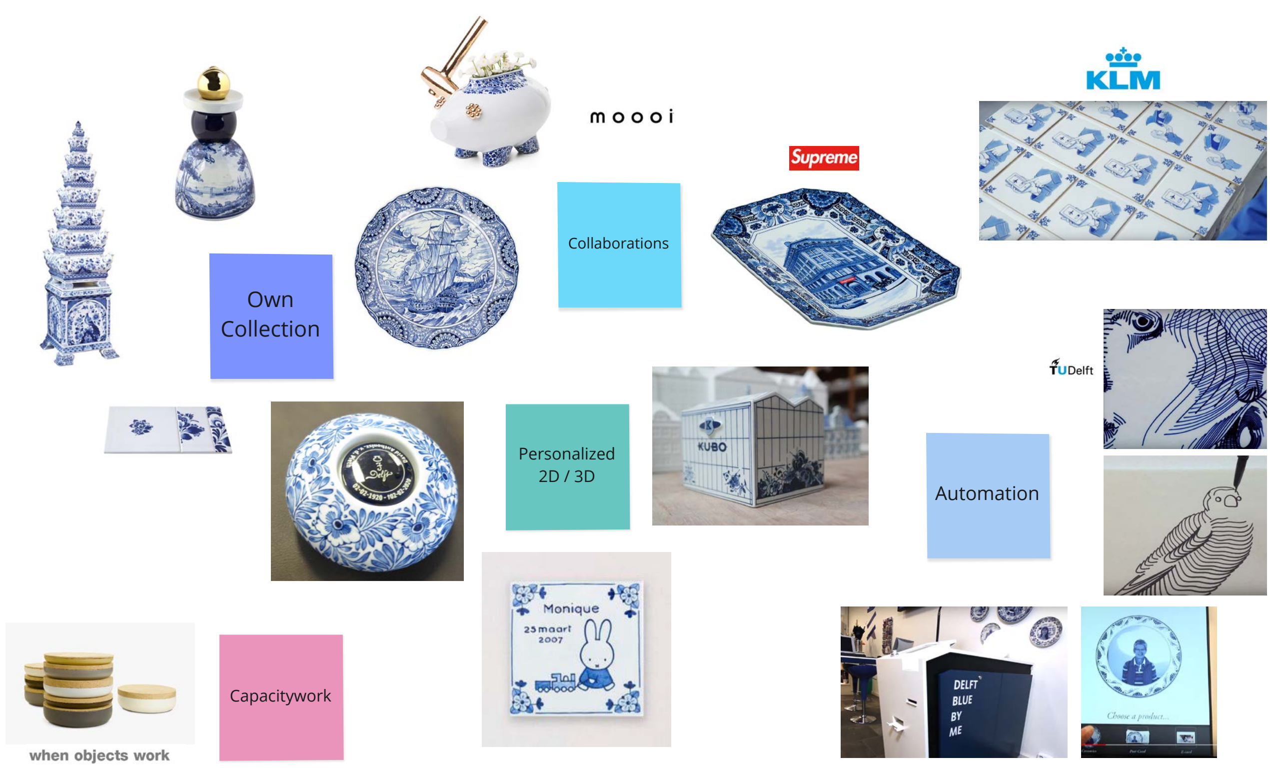
1.3 Ceramic Products

Looking at the company on a product-level, Royal Delft produces objects ranging from traditional in-house ceramics to collaborations with modern designers to custom orders. This section displays the current production variety and recent developments in modern innovations.

Collections

A first distinction can be made between conventional, traditional Delft blue products, and more modern lines. These modern product lines, such as Miffy (Nijntje), Blue D1653, and the Schiffmacher line are often collaborations with external designers and artists. Products are either hand-painted or produced with a transfer-technique, to keep the tradition and craft alive but also to offer delftware at a price that appeals to more consumers.

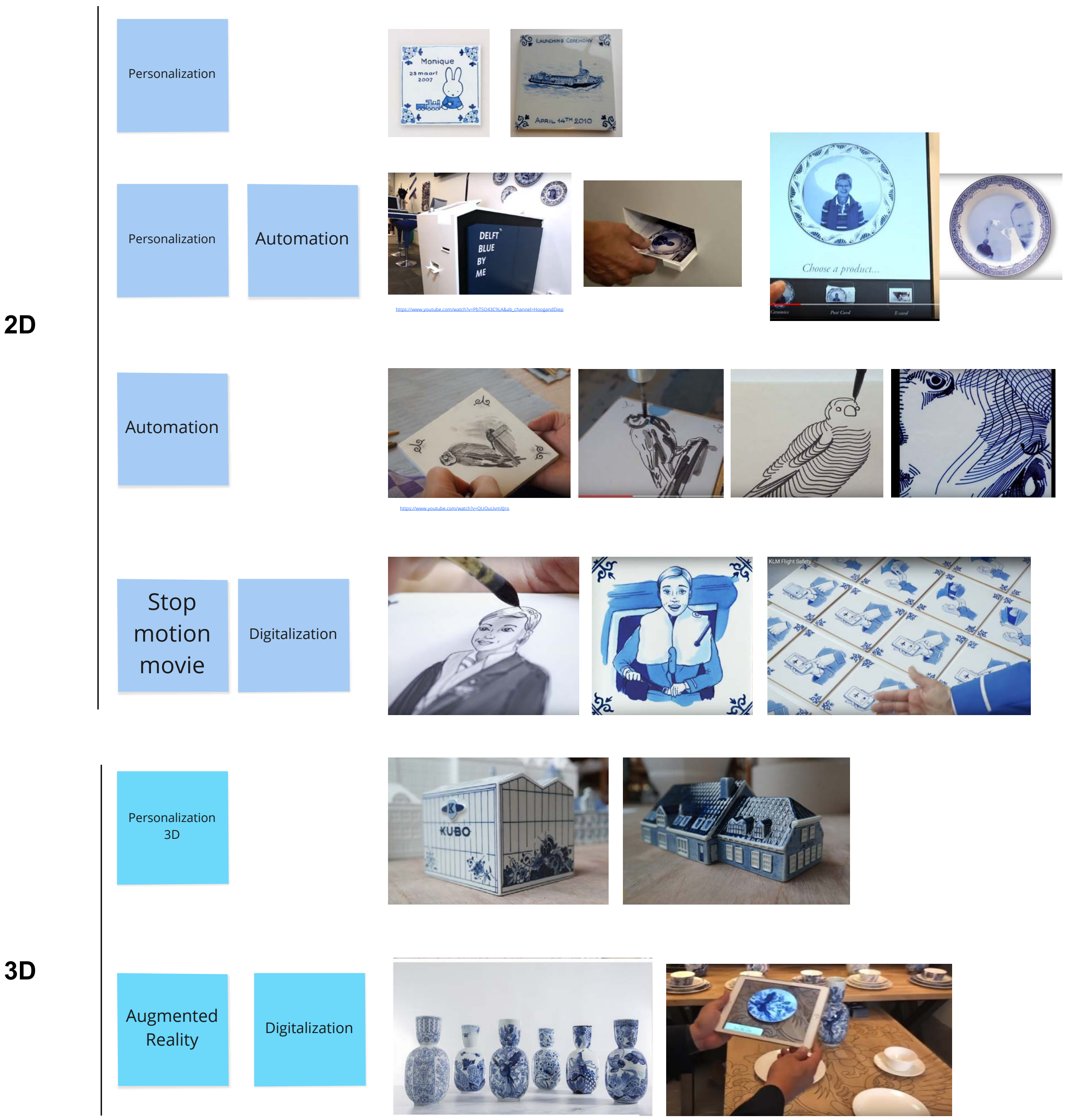
Royal Delft also offers custom, one-off pieces. The simplest and most affordable way of doing so is a custom paint decoration, for example a name or a company logo on an anniversary plate. If a customer desires a 3D-object, for example their own miniature house, this object has to be modelled, and a multi-part slip casting mold has to be produced from scratch. This makes a new slip cast product time-consuming and expensive to develop, but this production method does allow for a higher level of customization.



13. Overview of different production domains in which Royal Delft is active

Innovation

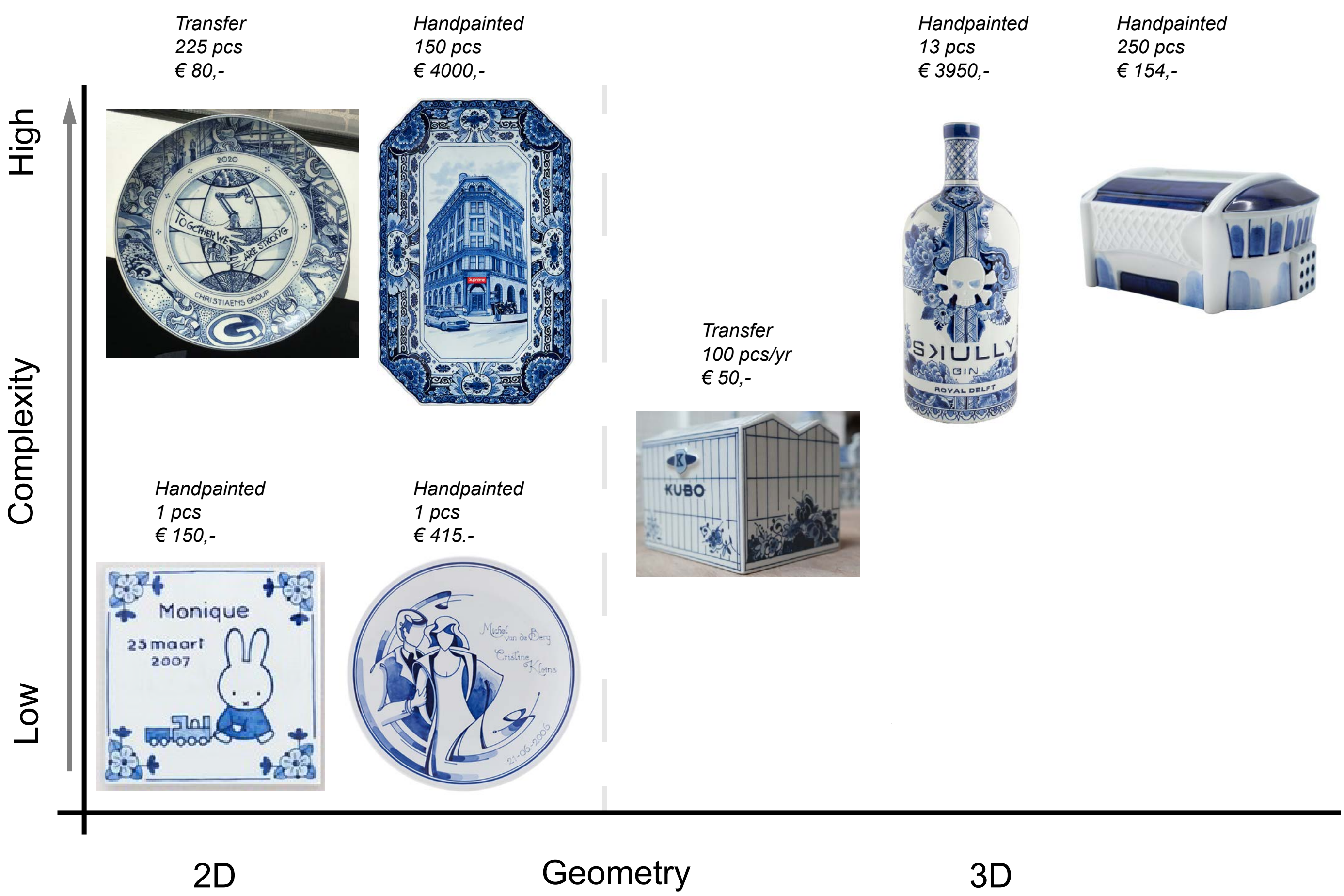
These painted plates or personalized buildings are the most known examples of diverse innovative projects that were run over the past years (see overview below). Experiments and functioning prototypes with selfie-transfers, robotized painting and augmented reality demonstrate Royal Delfts innovative character, their desire and actions to develop.



14. Overview of contemporary production explorations (some implemented and sold, others showcasing possibilities) that touch elements of industry 4.0

Custom Work

A special category of products that has been produced since the first Chin de Commande reached europe are custom invoices. The simplest variation is adding a personal text on a known plate design, which is usually sold to individuals. Companies often demand more personalization, which can be realised as an elaborate painting design or a personalized shape.



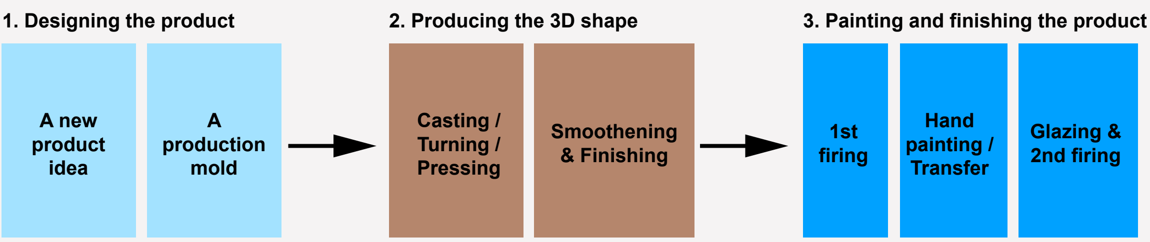
15. Customwork: different complexity levels for geometry types

For this category the final design is a dialogue between the artist and the mold maker, finding a balance between producibility and trueness to the design. This category of products consumes a lot of time and money, as models and mold parts are updated iteratively and communication takes place between different stakeholders: the artist, the mold maker, the design department, and often some external toolmaker 3D printing the model. As all these costs need to be covered with a limited amount of products, naturally the price per product for a custom shape increases rapidly with a small series size.

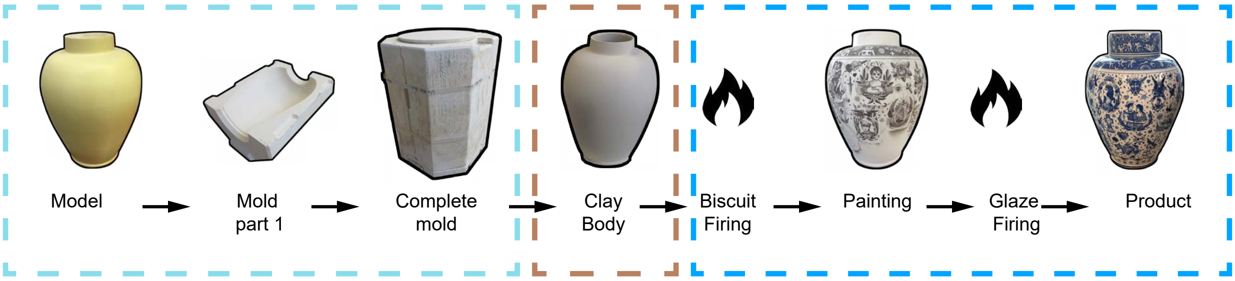
2. Internal - Technology

2.1 Ceramic Production at Royal Delft

This chapter presents an overview of the ceramic production process at Royal Delft. A distinction between 3 stages is made, covering respectively the iterative process of creating a new product; the making of the 3D ceramic object and the decoration of this object in the traditional Delft blue fashion. The first stage will be elaborated on most, as this is the stage where mold production takes place.



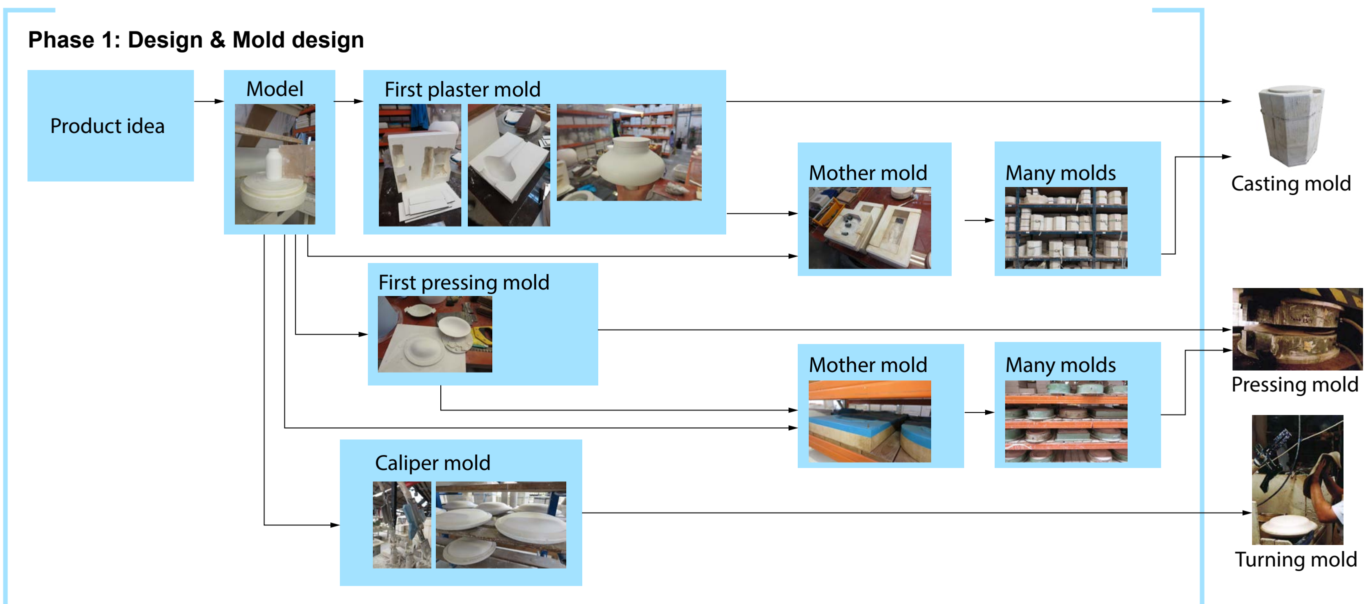
The diagram below displays visually the briefest summary of the production process. A positive model slightly bigger than the final shape is used to produce a plaster casting mold. Then, a clay body is cast in this mold, dried and sponged. Finally this clay body is fired, painted, glazed and fired again to become a handpainted Delft blue vase. The next chapters will cover these three stages in-depth.



16. Ceramic production process for a Schiffmacher Vase (height: 56cm; sales price: €7.999,-)

Stage 1: Shape Design

- Mold production for slip casting will be discussed in more detail in chapter 3.2 -

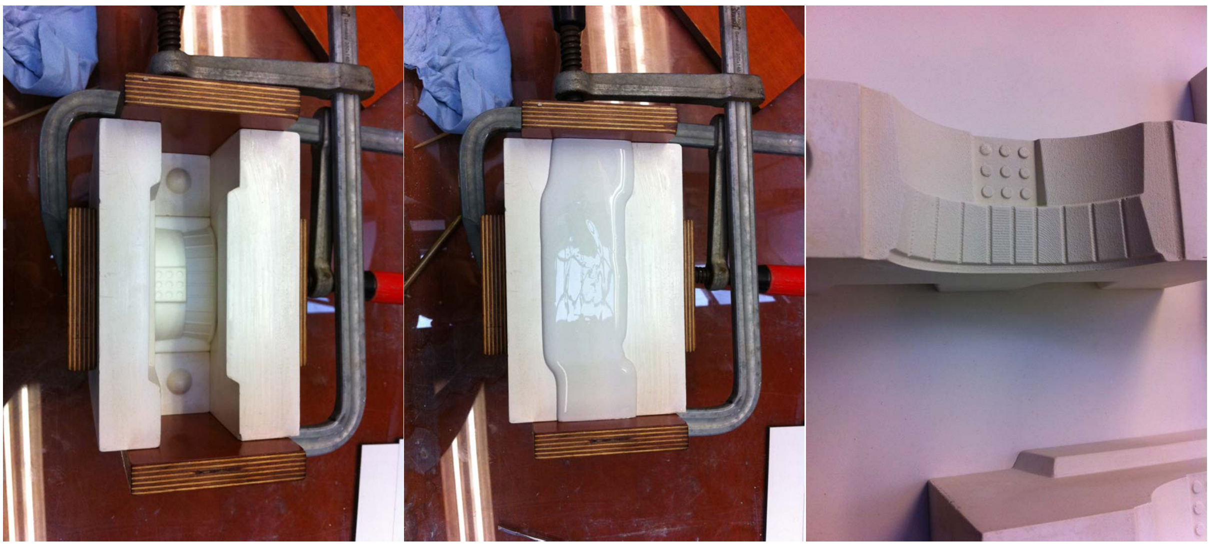


17. Overview Design & Mold design production steps

After a product idea is developed, a model is made: the first physical positive of the shape. Then, mold parts are cast one by one onto the model, and onto the other mold parts, using wooden planks and clay to create formworks and fill holes (fig. 18).

At Royal Delft, three types of production molds are made, namely those for casting, pressing and turning. Sponging is a necessary treatment by hand of every clay body: cast, pressed or jollied. These molds are made for different product geometries, series sizes and costs (fig. 19).

It should be mentioned here that for some shapes, especially those that are produced year in year out, a mother-mold is made: a multi-piece mold with which the casting mold can be reproduced over and over again (see diagram on the left page). For small series or custom work this is unnecessary and costly.



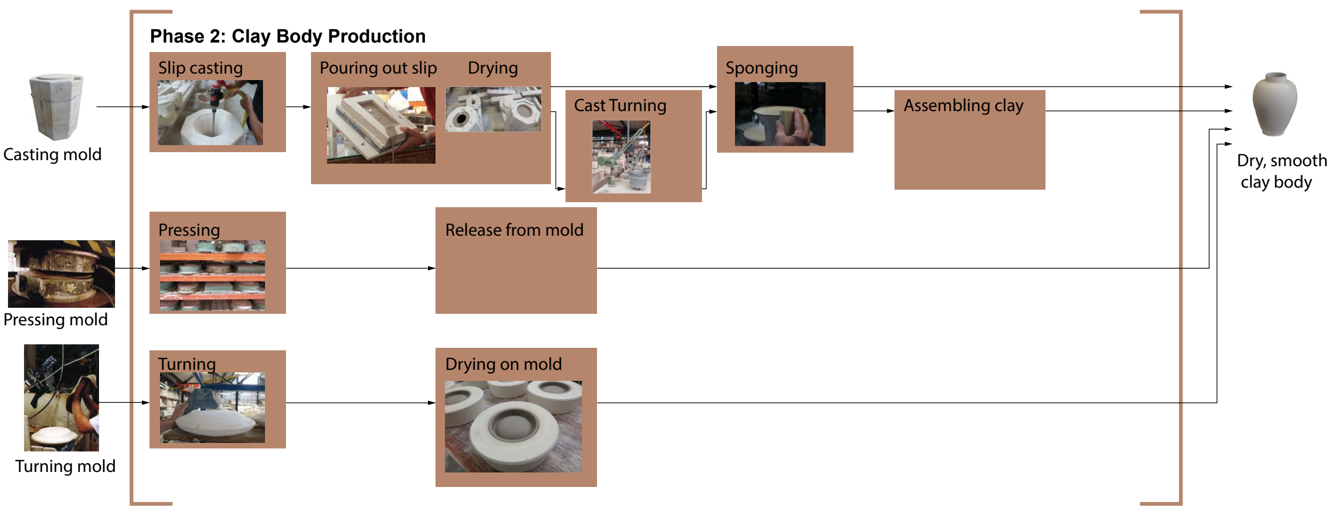
18. *Casing with mold-parts and encapsuled model; freshly poured plaster; resulting mold part*

Process	Mold life	Geometry	Example
Pressing 	1000-3000	Flat; ∅ < 40cm	
Turning 	80-120	Circular symmetric Relief possible	
Casting 	60-100	Freeform	

19. *Main production processes, mold lifespans and geometries*

Stage 2: Ceramic production

This section focusses mainly on slip casting, as it is the most interesting production type for this project. It allows for the highest complexity in shape, requires most craftsmanship and is applied for smaller production numbers than pressing or jollying, which makes it a richer source regarding personalization, flexibility in innovation and knowledge translation.



20. Overview Clay Body production steps

Material Behaviour

Something most employees mention is that the material behaves in unexpected ways. The clay, plaster, engobe and glazes are produced with a variety of raw earth materials, making them less predictable and stable than, metals or plastics. This has two implications:

1. The behaviour of all materials needs to be constantly checked, as slight deviations in batches can have a major impact on the final product.

2. The material properties change with the seasons. In summer casting times are longer; 'old plaster' absorbs differently, and glazing needs to be applied in different amounts.

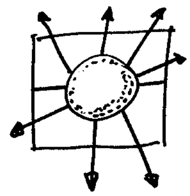
Years of experience are required to recognize these variations and to manipulate the material to deliver consistent quality.

Plaster

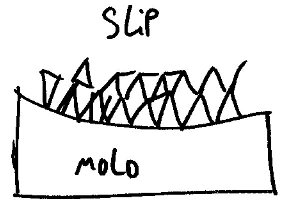
The most commonly used mold material is plaster, due to its low price and the ease with which it can be sculpted. Plaster absorbs the water from the slip, and the better the porous channels are modelled into the shape, the more homogeneous the clay structure becomes. Plaster molds are discarded when they are clogged with the slip's minerals, or when the split lines and edges are so worn away that sponging becomes tedious.

Clay

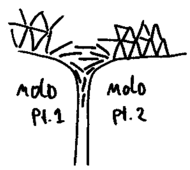
The geometry, strength and surface quality of the final ceramic are determined by the clay. The clay body grows as the mold absorbs water from the slip, and in a desirable scenario the water is absorbed in such a way that the clay-plates can build up a strong crystal-structure (fig. 18). If there are split lines, grease on the inside of the mold or if the plaster is petrified the clay plates will lie flat (fig. 19). This is undesirable, as this results in dents in the object when fired. This crucial clay plate structure is one of the reasons why pressing, slip casting or even 3D-printing clay (fig. 20) all have different oven treatments and internal strengths.



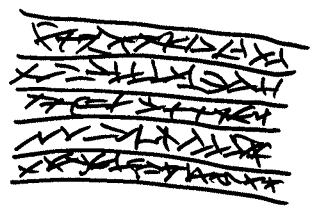
21. Liquid is transported outwards.



Clay-plate structure



22. Clay-plate structure transition at mold part split surface



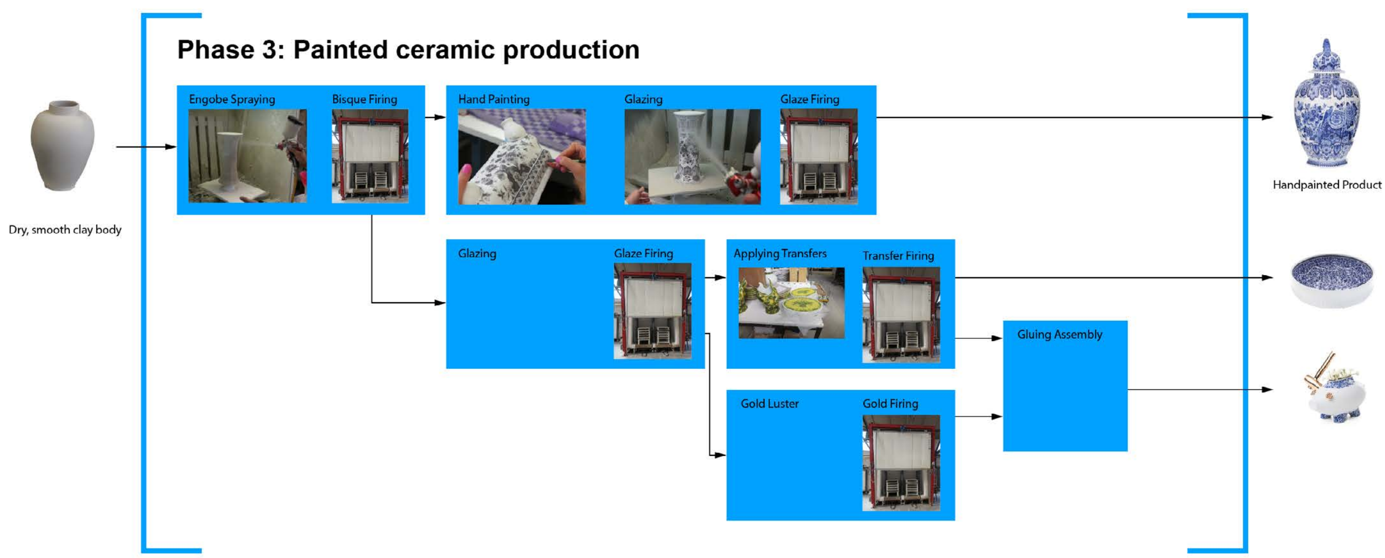
23. 3D-printed layers, with separated clay-plate structures cannot be fired as high as slip cast ceramics

	Plaster	**Slip**
Material (microproperties)	Absorption; porosity	Clay plate structure
Quality	Minimize gaps & imperfections	Sponging (always)
Physical constraints	Weight; maneuverability	Fragility; self-supportiveness
		

24. Table displaying the main characteristics of the 2 most important materials: slip and plaster

Stage 3: Decoration of the shape

The decoration may seem independent of the 3D-shape, but the importance of this step should not be overlooked. Hand-painting, transfers and the application of gold luster require different geometries, and hand-painting is a USP with significant historical weight for Royal Delft. The overview below displays the global routes of different products:



25. *Overview of decoration trajectories*

Transfers reduce costs because time spent painting is saved, but it needs to be fired 3 times instead of 2, which makes it not always a viable alternative. There are many more constraints and insights like this, summarized in the following lists:

Gold luster

- Requires an extra firing
- Difficult to fire perfectly
- To avoid risk, gold luster parts and hand painted parts are not applied to the same ceramic body, but assembled after firing.

26. *Gold luster on a separate clay body*

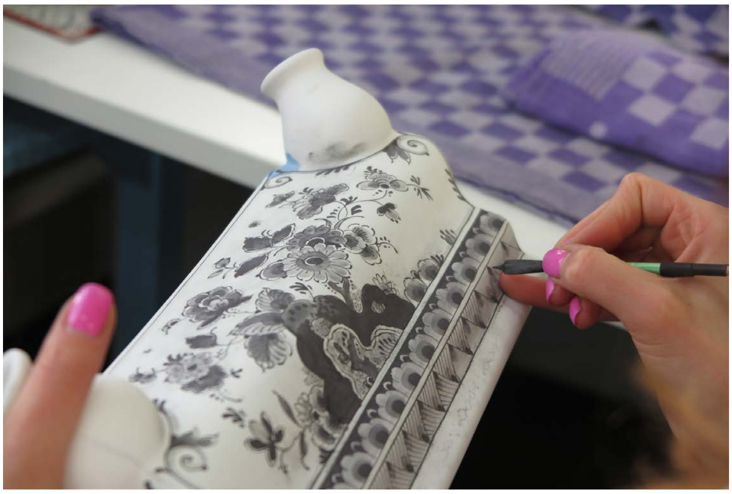
Transfers

- Requires an extra firing
- Applied to smooth and reachable surfaces
- Sometimes split up in parts

27. *Fully and partially applied transfers*

Hand painted objects

- Most traditional and chique
- Most expensive technique



28. *A hand-painted surface is preferably smooth.*

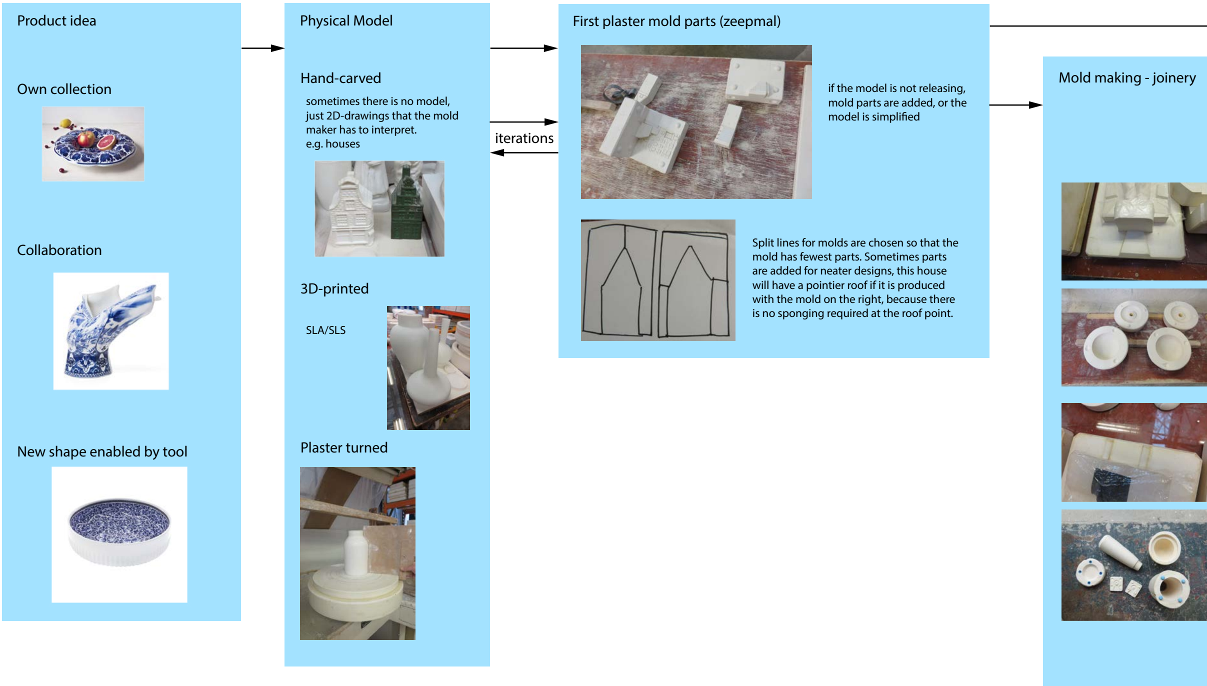
2.2 Mold Production for Slip Casting

A quality mold is crucial when slip casting ceramics. The mold not only dictates the shape, but also the amount of sponging work, the necessity for garnishing and the surface finish of the paint. This section highlights the main decisions and dilemma's within the mold making process.

Common shapes

The mold maker's life is relatively easy when making a 1-, 2- or 3-part mold. For these shapes a complete casting mold can be produced within a day, in a straightforward manner.

30. *A 1-part mold product is 'self-releasing', e.g. this dog bowl.*



29. *Design decisions in different steps of the mold making process.*

32. *Tiles are cast in this 2-part mold*

One sidenote to the ‘common shapes’ is that size does matter too. Some products are made in big and small versions, and, while geometrically identical, they have different mold structures. This is usually due to the weight of large mold pieces, they are sometimes split up in more bits as they are too difficult to lift carefully off the fragile clay body.

31. *A mirror symmetric product and its 3-part mold*

33. *Vase and one of its mold parts. While a vertically oriented 2-part mold would have required less sponging, the shape is still cut op horizontally, to reduce risk of breaking the clay body.*

All split surfaces have subtle, asymmetrical joints, in order to always line up the mold halves in the same way. This prevents breaking, and improves geometry precision.

Dovetail joints are used for parts of molds and mother molds that need to stay in place when casting. They are tapered upwards for easy fitting and removing.

Rotational joints are quickest to make. They allow for some play. Most suited for small and simple molds, big molds with many pieces have difficulty aligning these joints.

Sliding joints enable movement along 1 linear axis. This allows the plaster to expand slightly in one direction. Suited for 3-part molds, that require some play.

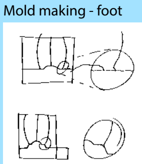
Some mold makers, not at Royal Delft, use little plastic inserts/plugs instead of drilling keys. This is quicker, but due to the expansion of the plaster they never fully align. The fixed closure makes it difficult to feel if the product is leather-hard, which means that sometimes products are torn apart when removing the mold.

Mold making - brim

Some objects require a “Giethuis”, because they have an uneven brim, like the Moooi vase.

Some objects require an “opkomer”, because the slip shrinks during settling, and more slips needs to be added automatically.

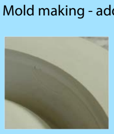
Mold making - foot



The product is often placed on a tiny pedestal, to create a mold split line on the bottom of the foot, and not on the sides. This mold takes more steps to produce, but it reduces sponging time, and increases neat surface quality.

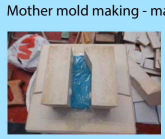
Some ceramists prefer making multiple simpler molds, and do less cycles with one mold, so that these wear-flaws are less visible.

Mold making - add-ons related



Positions for ears, spouts, or cut-outs are marked in the casting mold, to leave the tiniest trace in the clay.

Mother mold making - materials



For high-relief objects, such as facades, silicone is used for the mother-mold. The plaster casting molds expands slightly, when drying, and would break itself if the mother mold were too rigid.

Alternatively a very strong insert is used as is the case with the farmers head. Also, this insert enables for some play in the cast plaster, again to ensure that the plaster mold does not decapitate itself when expanding.

Mother mold making - casting related

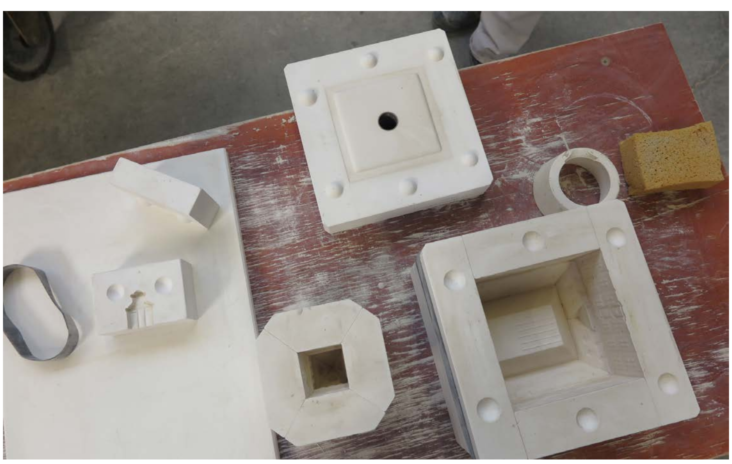
Closed objects, such as the farmer (not vases), need a casting channel in their mold. Here, this is realised with a PVC pipe that is part of the mother-mold. This part becomes the “Giethuis”.

Casting mold

Complex shapes

When shapes become more elaborate, the amount of things to take into consideration increases rapidly. There are different ways to get to Rome: the same shape can be produced with different molds. A mold maker can choose between making a complex multi-part casting mold, and making simple molds for parts of the object that are then garnished together. As image 32 shows it is not always clear when looking at the final product how the shape was built-up.

34. Similar looking features with different production methods: this shape has 3 cast sprouts, and 2 garnished sprouts.



35. Complex shapes with many mold parts, produced iteratively: Delft City Hall is produced by garnishing 3 clay bodies, made with 12 mold parts.

Custom shapes

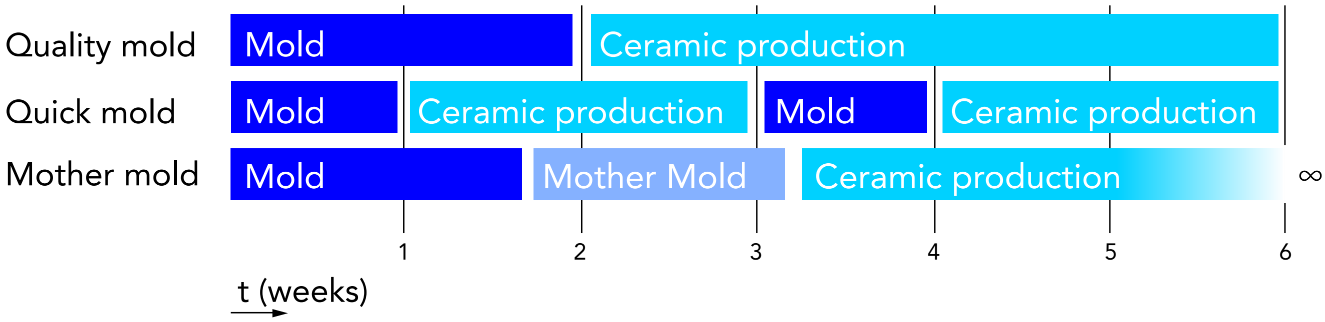
Most 3D custom work, as described earlier, consists of shapes that are rather complex, so they require the physically iterative trajectory mentioned above. If the ceramic is produced in collaboration with an external artist this adds the difficulty that changing the shape and mold design cannot be fully done internally, without consulting the designer. This dialogue is necessary to achieve a mutually pleasant project, but naturally lengthens the development process.

Another complicating factor occurred quite recently, namely that the initial model is often not made by Royal Delft's mold maker but 3D-printed in resin externally. Back in the day the mold maker could modify a model by hand when, but if 3D printed models need to be adapted to suit the mold making process it is easier to reprint them than to saw them apart or plaster some parts. This creates a second production dialogue with an external party, lengthening the development process.

36. The model for the Johan Cruijff ArenA required several iterations

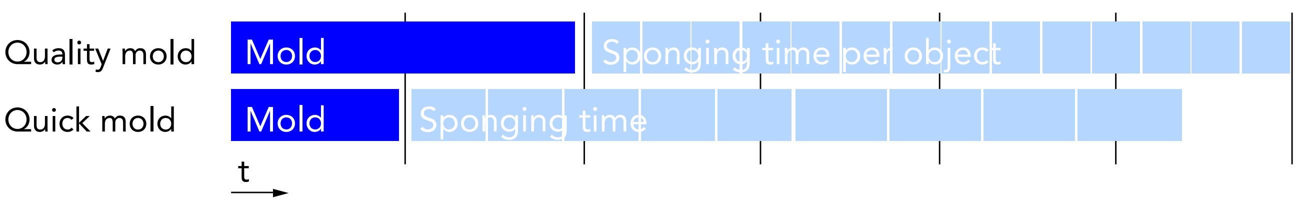
Design Dilemma's

As mentioned before, choices in mold making influence the further production sequence. One of these choices is that between a relatively neat mold that lasts more cycles but takes more time and skill to produce, or a mold with a lesser construction that is quicker to reproduce (see diagram 33). A third approach may be to produce a mother mold, which takes most time in the beginning, but enables the longest and most seamless production continuation.



37. Molds and mother molds: production investment v.s. life-cycle

No clay body is perfect, but some are more perfect than others. When the product is cast as a whole, with very thin split lines it requires no time to garnish parts together, and fewer time sponging. How this second dilemma is tackled also differs per factory and mold maker.



38. Surface quality vs sponging time.

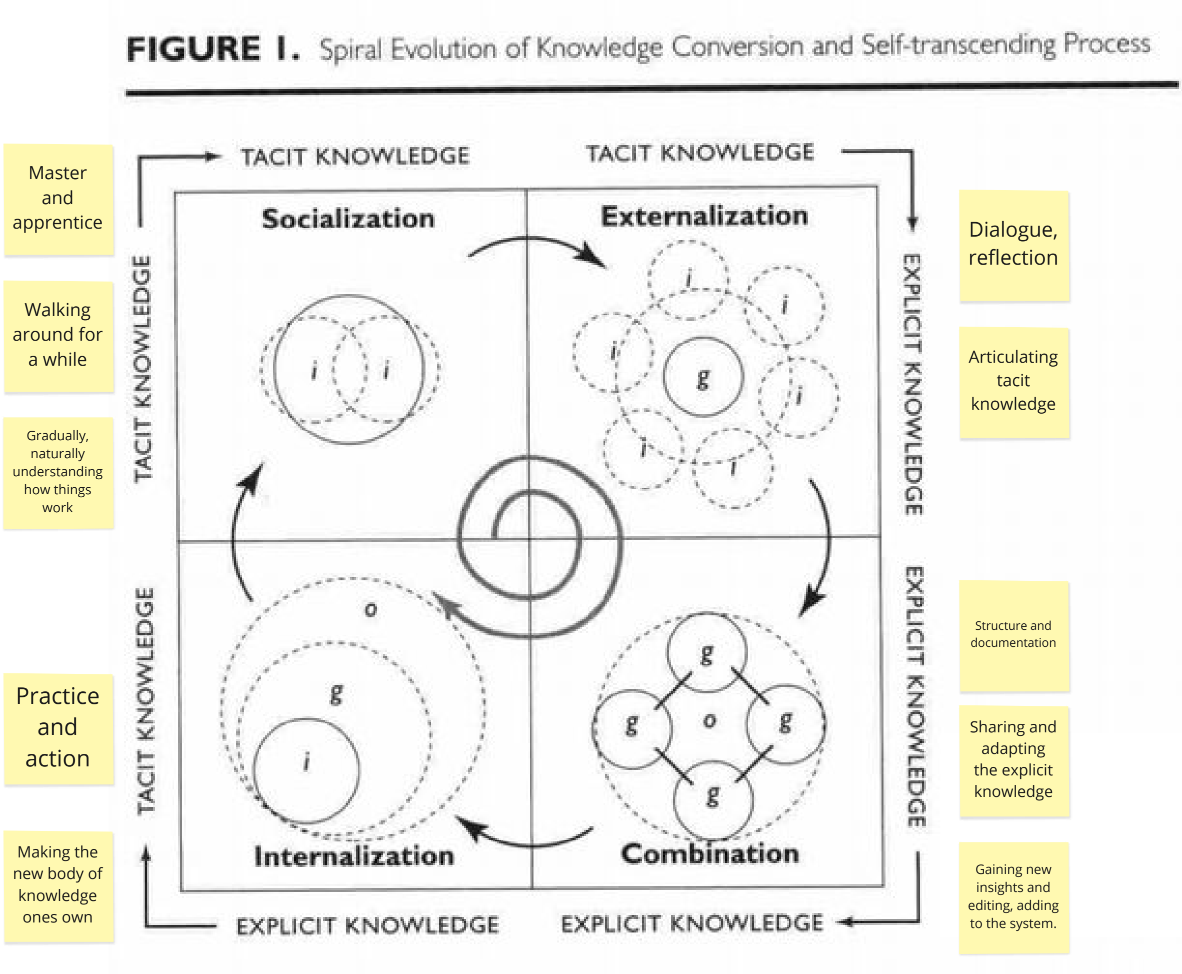
39. A3D printed mother mold produces a rougher shape (middle), but successful sponging is possible (right)

2.3 Knowledge Management

Currently the production is heavily dependent on a handful of experts that will retire in the next decade. The question is how to keep the knowledge of different aspects of the production process alive, and how to keep the different departments within Royal Delft communicating about the production well.

Theoretical Background

Nonaka's SECI model of knowledge presents a mental model to help understand how organisations can create new knowledge and maintain it, or loose internal knowledge if certain activities are neglected (spiralling up versus down) (Nonaka & Toyama, 2003). Simplified the positive preservation of knowledge can be described in the following 4 steps:



40. *SECI model of knowledge transferral (Nonaka, & Toyama, 2003) Post-its by the author.*

1. Socialization
An individual enters a company, and through dialogue, demonstration and experience they slowly get an understanding of the internal structure and production.

2. Externalization
Periodically employees get together and discuss their work and their experience of it. This step makes sure that people remain on the same page, and that communication or understanding problems are resolved.

3. Combination
Ideally, these gatherings produce documented, feasible, actionable results, such as an information management system where relevant production knowledge can be found, or plans to change the current flow of affairs to improve the work.

4. Internalization
This explicit knowledge over time becomes internal to those who practice it often; new approaches become common.

This model was helpful in understanding Royal Delft, it is well applicable to this company that produces physical objects and innovates constantly. Their production line is clearly visible but requires vast amounts of tacit knowledge, that occasionally needs to be shared and developed.

Tacit knowledge transferral

As mentioned earlier and described by several employees: all materials are alive, and changing. This means that experience is required to identify and adjust for example deviations in moisture levels of clay, or temperature flow in the oven. This also holds for the mold making process, if the plaster is old, or if the model is made of a new 3D-printed material that is very lightweight or absorb a lot of 'soap', the mold maker knows how to tweak the process with different ratios, longer or shorter mixing or settling times and lumps of clay to make it work. This knowledge is very tacit and hands-on; reading a manual about these things without ever having done them is not very informative. Royal Delft currently employs one mold maker, who will retire in 2022. It is likely that some of the mold making knowledge will be lost, and together with that the capacity to make new shapes. Recently a feeling of urgency to manage knowledge in a more external way arose.

Luckily Royal Delft offered a current intern a contract as a mold maker starting this September. With the master-apprentice approach from Nonaka's framework the knowledge is kept internal to the company, but it is obvious that all responsibility is shifted from one person to the next. This strategy may not be eternally sustainable.

Externalizing process changes

Over time material deviations arise, but also changes in the production process, for example when trying out new paint mixtures, or when combining digital transfers with food-safe glazes. Not all changes are visible to the eye (everything is a shade of beige: clay, plaster, engobe, glaze) and not all changes are brought to everyone's attention. Information about new designs, new glazes, strange clay-behaviour or slightly modified oven-cycles is transferred mostly verbally from the mold maker, to the design department, to the laboratory, to the painting department. In some situations this leads to unnecessary production flaws. If tiles can be pressed, cast and imported it is important to keep those separate - especially if they require different paint, oven cycles and glazes...

3. Analysis - External

The aim of this chapter is to present an inventory of the solution space. This entails an overview of traditional and novel ceramic production techniques, and an exploration of different approaches and examples of advanced manufacturing.

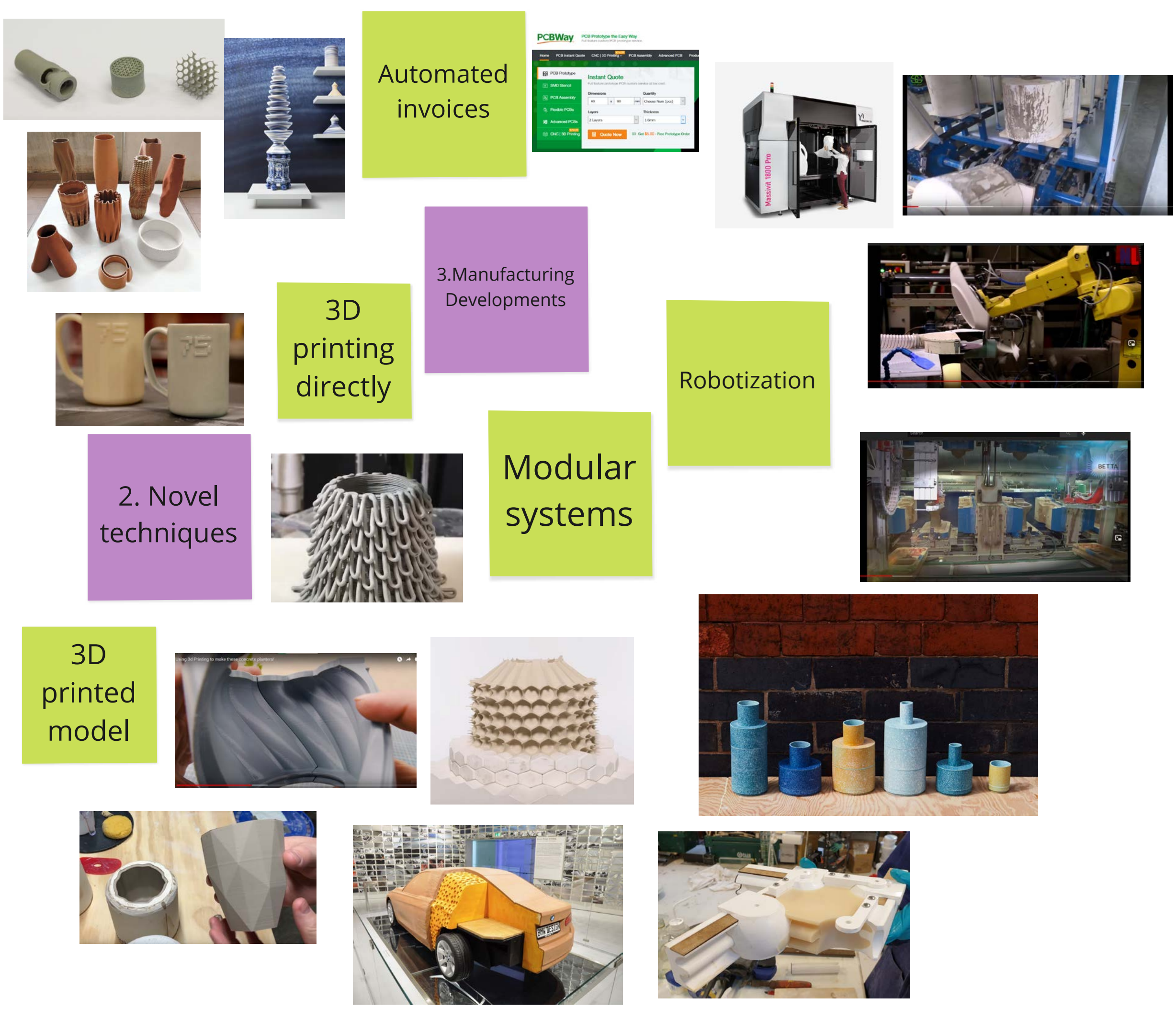
3.1 Trends and Developments

Numerous examples of ceramic products and production methods were and clustered visually, to get a grip on the broader context. This section presents these contextual elements on the levels of meaning, contemporary techniques and industry developments.

While the full Miro-boards can be found online (see Appendix A), these pages show a few examples and the main clusters for all three levels, a blend meant to inspire.

Some trends displayed below are well-known for the past few years now, for example the rise of the maker movement that finds a growing number of applications for 3D printers, amongst which ceramics, and the ongoing robotization and automation in factories. Another familiar trend is a side-effect of the pandemic: many people have started crafting and tinkering at home, and the amount of makers that share their work digitally has exploded.

It is to be seen what changes will be most relevant to Royal Delft in the future, this overview displays that the ceramic world is developing in a myriad of ways.



3.2 Advanced Manufacturing

To sketch out trajectories towards the future approach we need to understand in what ways innovation can be helpful for the specific client. This section elaborates on some definitions and frameworks, indicating areas with opportunities.

The 'smart' revolution

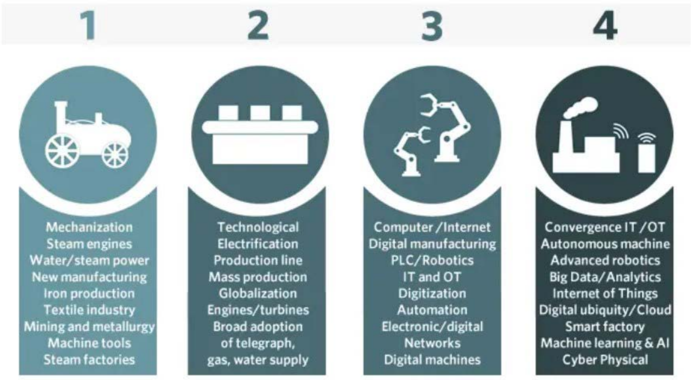
The mayor technological development we find ourselves in is often labelled the 4th Industrial Revolution. The digital age (3.0) has announced itself and extended into our lives during the past 30 years, and now the 'Smart age' is on its way. Some of the trends mentioned earlier are artefacts belonging to industry 3.0, such as robotics, automation and digital fabrication (I-Scoop, 2021). It may seem a bit much to enforce 'smart' solutions onto a 350 year old company, but there are some elements to industry 4.0 that also make sense for Royal Delft:

3.0 - Digital Revolution

- Digital Fabrication
- Automated invoices
- Robotization

4.0 - Smart Revolution

- Smart factory
- Data analysis of sales
- Digital twins (product information management)
- Automating custom orders



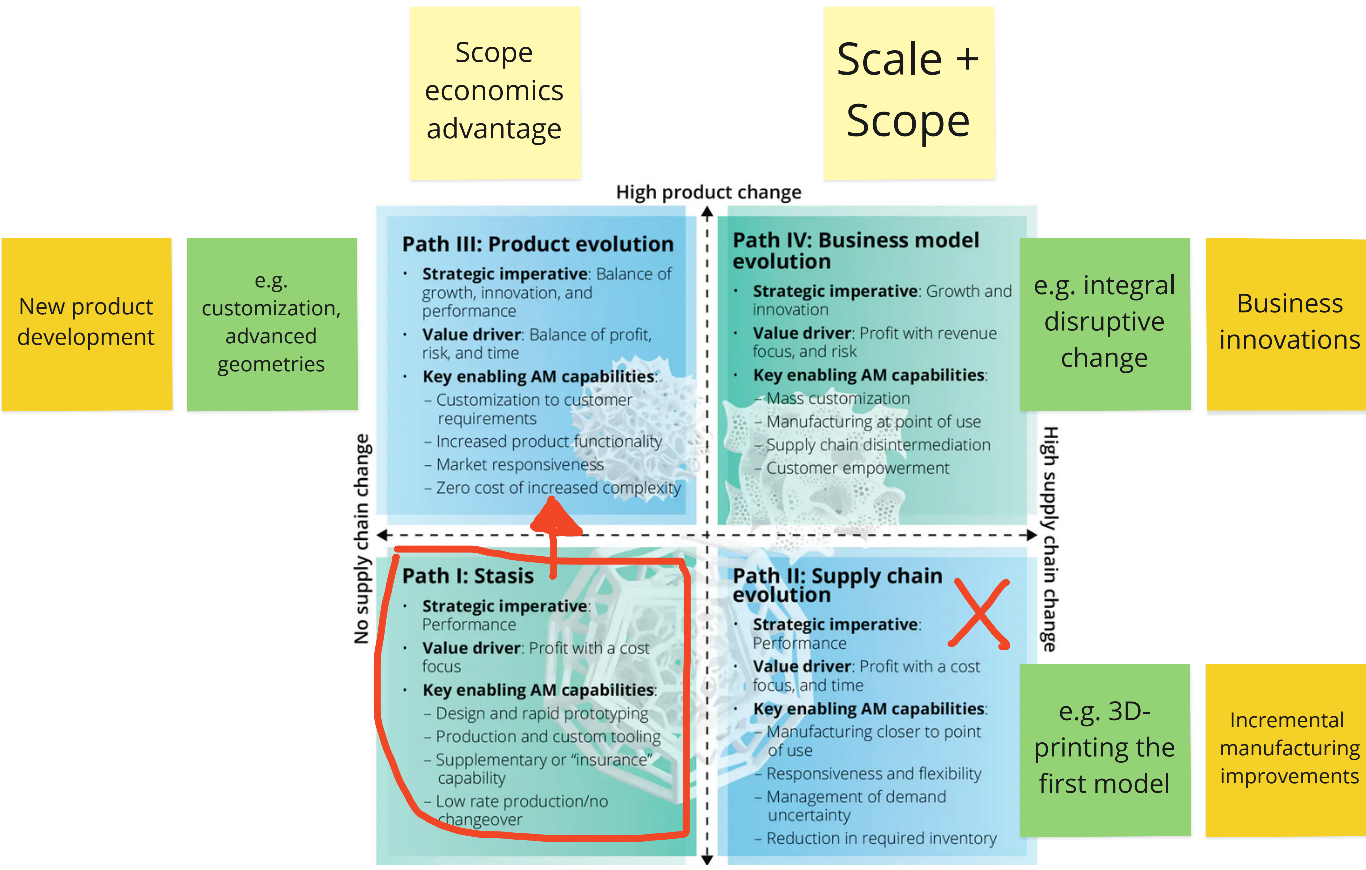
41. *Main characteristics of the 4 industrial revolutions. (I-Scoop, 2021)*

Another key benefit of smart industry is that knowledge is generally better maintained and preserved. If there is an existing platform with different production trajectories that are intertwined digitally this is easier to develop and iterate on in future approaches, than digging up tacit knowledge from individual experts all the time when trying something new.

Digital Fabrication

Additive manufacturing is one of the most common and promising modern fabrication techniques, which means that it is also relevant for the ceramic industry. The framework by Deloitte (fig. 37) displays the different impacts additive manufacturing can have on a business (Tilton, Dobner, and Holdowsky, 2017)

Currently RD is exploring the use of 3D-printed models. This enables shapes closer to the computer models, without interpretation of the mold maker, and enables complex shapes to be produced quickly. It is in Path I, not at a stage yet where their products or supply chain is radically changed.

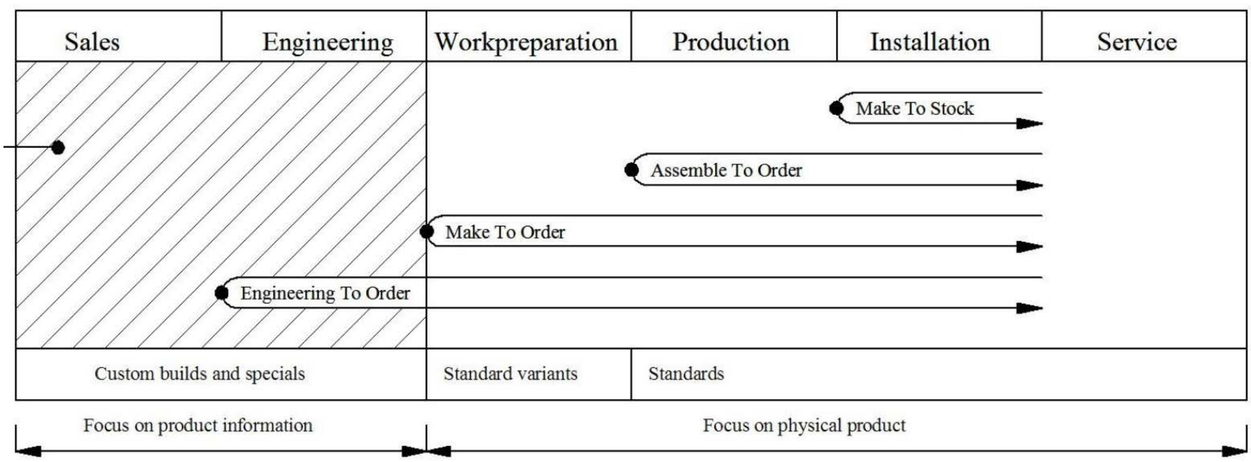


42. Envisioned direction for Royal Delft. Source: Deloitte

To update only the supply chain would not be a strategic direction fitting the company. Royal Delft's value does not solely lie in the end-product independent of the production, it is exactly the heritage and the production method that provide their competitive advantage. Discarding the ancient factory while continuing to make traditional-looking products would be a step towards copy-cat factories, not an advantage. A better aim would be to move into the product evolution direction (path III). This direction can maintain the heritage while also displaying innovativeness, opening doors to previously non-viable products, such as higher degrees of customization, and affordable one-offs.

Customization

A positive effect of both industry 4.0 and additive manufacturing mentioned above is quick customization. Customization or personalization in itself is not a new thing, it can mean different things and exist in different degrees. Naturally, the more detailed the shape is, the earlier in the production process Royal Delft needs information from the customer, shifting the so-called push/pull-point backwards. The diagram below (Verbunt, 2018) displays this push/pull-point for different levels of configuration, which helps businesses find their company setup to minimize effort and maximize the fit to the consumers desires.



43. Schematic overview of shifting push/pull-point dependent on the level of personalization

Within engineering to order (ETO) Verbunt distinguishes 3 levels of customization, which can be mapped to different ceramic products (fig. 44, next page). Combined with the previous pages we could say that one of the big promises of smart manufacturing is to shift the push/pull-point radically backwards to provide a custom treatment, without going through all labour-intensive production steps cognitively as is now the case.

Note that a TTO ashtray already feels closer to a company because of the specific visual style than the textual information in a CTO ashtray. Currently it is way more work for a mold maker to recreate a logo than to carve out a text. If this logo-production is digitized and automatized the benefit mentioned above is achieved.

1. Make to Stock [MTS]	Finished, non negotiable product	
2. Assemble to Order [ATO]	Parts assembled after invoice into a pre-defined configuration	
3. Make to Order [MTO]	Semi-finished products that are further completed after order	
4. Engineering to Order [ETO]		
4.1 Configure to Order [CTO]	Specific order built up from known elements; e.g. Type-case namesign	
4.2 Taylor to Order [TTO]	Adaptations to standard modules based on customer wishes; e.g. Logo or font integration	
4.3 Develop to Order [DTO]	Development from scratch; Unique shapes	

44. Degrees of customization and corresponding product examples.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Analysis Summary

Ch. 1

Royal Delft is a 370 year old historical production company with a solid and significant heritage. Their factory produces both traditional and modern ceramics, while it is also a major attraction for global tourists, resulting in 140.000 visitors per year. Their business model consists of the combined revenue from the tickets and ceramic sales to the visitors of the shop, which leads to the fact that 65% of all revenue is generated in Delft, on site. During the past decade a serious and successful effort has been made to re-brand Royal Delft from an old-fashioned, outdated company to a traditional, skilled institute with a strong heritage and modern collection. This effort entails collaborations with contemporary designers and artists, but also innovative approaches to production, for example the use of digital, customized transfers and robotic painting.

Ch. 2

This is interesting, because ceramic production is in 2021 still one of the most traditional and craftsmen-dependent industries. Causes for this are the material behaviour of clay, plaster, glaze and paint, but also the fact that, while shapes may seem similar, they are never produced in the same way. A factor currently overlooked in production is therefore to maintain in-house knowledge about a variety of processes. As most current experts will retire between 2-15 years and there lies no real plan yet for continuing the craft this can bring problems in production. The question is how to prevent the practical knowledge loss in order to maintain productivity and avoid a quality decrease.

Ch. 3

This ties in to external opportunities from the industry to modernize the current production methods and explore ways of knowledge transferral. Innovation of the production line can be done in various ways that have their own aims and benefits, for instance robotization for quicker production of larger numbers, or additive manufacturing for quicker customization. A direction should be taken that fits the Royal Delft universe, while opening up for novel, innovative trajectories.

Part II: Synthesis

Where part I was a breakdown of the company, the technology, and the ever-evolving context, this part distils the most fundamental problems from that breakdown and transforms it into a design direction. It consists of the following chapters:

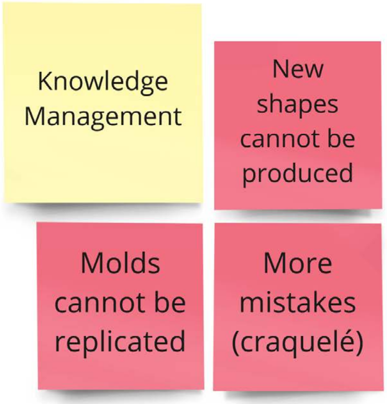
4. Problem Statement

The company was looked at through different lenses, among which those of knowledge management, brand identity and SWOT. Combined with interviews with employees (from the departments 'production', 'retail', and 'development') four themes arose that present a different perspective on the problem space, namely: knowledge & craftsmanship, ergonomics, competitive production and new product development.

Knowledge Management

1. Craftsmen dependence
As mentioned above, some steps of the production process rely heavily on the tacit knowledge of craftsmen with decades of experience. As several of them will retire in the next five years with no clear replacement this may provide a threat for the technical knowledge in the company.

2. Taylor-made
Defining a universal mold making approach is difficult. Every product needs a tailor-made treatment, dependent on its geometry, features, rotation symmetries, weight, size and application. This makes the mold making process inherently expertise-dependent.



Physical Limitations

Undesirable workarounds required (lighter models)

Limits shapes and sizes

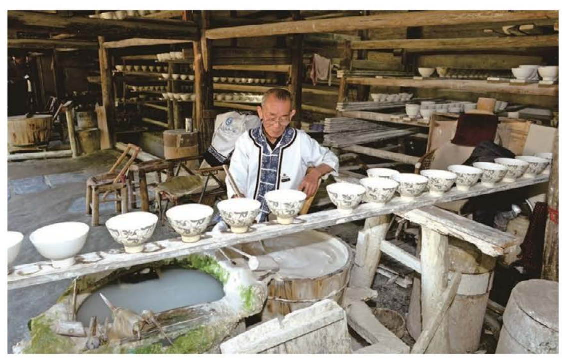
Ergonomics

3. Production limitations
In most workspaces ergonomics is important for health and productivity, but in a physical workshop ergonomics can impact the product quality. Due to the weight of plaster, most ceramic factories do not meet legal requirements (ARBO) for lifting. This problem can be avoided by only producing small objects, or using light-weight models, but that comes with other obvious disadvantages. Solutions could be robots, lifting systems or modular, manoeuvrable mold parts.

Competitive Production

4. Stigma's
Delftware is, especially for the Dutch audience, surrounded by various stigma's, whether it be old-fashioned, touristy, over-used or too expensive. To survive another 350 years it is wise to develop in both an artistic and technical manner, which has changed and saved the company several times in the past.

5. Global competition
Royal Delft must compete globally with other ceramic producers, which is difficult considering European wages. In order to do so successfully they should emphasize and exploit their specific skills, namely a high product quality, a traditional hand painted method, a personal, sometimes even taylormade approach and a certain exclusivity or uniqueness.



Competitive Production

Some processes can't be sped up

European work-hours are expensive

Undesirable: museum only / outsourcing abroad

New Product Development

6. Development time
It takes a significant amount of time to develop a producible model and present it to a client. This is due to the physical mold making, the drying of the plaster, and the physicality of the iteration-process. Occasionally new collaborations don't make it to production because of this time.

7. Development costs
The cost-prize of developing a shape and corresponding mold is another barrier for potential collaborations. Already hand-painted ceramics are costly because of the production process and location; reducing the development cost may attract more projects.

Different Problems

From these four problem sections the first two, 'knowledge management' and 'ergonomics', cover problems with the current production situation that can and should be addressed directly. The current lack of documentation, reliance on tacit knowledge, unhealthy working conditions and regulations that are not always met are issues that can be tackled relatively straightforwardly.

The other two sections, 'competitive production' and 'new product development' refer to possible issues in the future, such as a declining brand image and missing out on orders due to changing global competition.

Problems of these kinds are more long-term and uncertain, and it is less easy to quickly point out the cause of an issue than is the case for current production problems. Problems of this 'future-category' do not require solutions that take away the root of the cause, but feasible proposals for new directions with a solid vision.

Ideally all of these different problem types are addressed by the proposed solution. The most logical order of addressing the problem types is to first design and implement Royal Delft's new production method, and when doing so take knowledge management and ergonomics into account.

5. Design Drivers

The problems give input to formulate on an abstract level what the design proposal should solve. These design drivers are split up in production, business and user. Later in the project, after a concept is selected, these drivers are used as list of requirements and wishes

5.1 Design dilemma's

Some mold making dilemma's were listed explicitly before, while other considerations are present but not apparent. This section recaps main dilemma's concerning production, branding, and user satisfaction.

Mold & Mother Molds: Investment Risks

Some shapes are internal and will be produced more often, which means that investing in a mother mold is advised. Some external shapes, however, are produced year after year, yet the uncertainty remains if this shape will be produced in the future, making mother mold production a riskier investment.

Quick & Good Molds

Producing a better mold requires less sponging time, but more time making a mold. For a one-off product this is probably a waste of time, but where lies the break-even point for each shape?

Personalization: Paint or Pay

Customwork is currently either relatively cheap when it concerns hand-painted products, or very expensive when a 3D shape has to be developed from nothing. As there is no middle ground in price some consumers needs cannot be answered.

Heritage and Innovation

Royal Delft prides its history as the only 16th century delftware manufacturer still producing in Delft, but does not want to convey the message that they are living in the past. This makes it more difficult for them to go all the way in modern developments than ceramic producers like Tichelaar or the EKWC.

Delft Blue Stigma

Especially among the Dutch, delftware is frowned upon, because it is misused on a million occasions and everyone's grandparents own it. This image may be good for tourist-shops and Schiphol, but it is not beneficial to companies that make high-end, luxury ceramics. Simultaneously Royal Delft is dependent on their heritage for their existence, a balance needs to be found between an own quality distinct from the superficial junk-stores, and being recognisable as delftware.

5.1 Technology Drivers

1. The design enables complexity easier
...because the current effort in production development is what makes custom products so expensive

2. The design reduces development time
...because that's what makes people occasionally cancel their order

3. The mold system is promising to translate to other product categories
...because an innovated production approach is integral and not limited to one niche product

4. Producing the mold requires as few tacit knowledge as possible...
... because the dependence on a craftsman is what makes the supply chain fragile and labour intensive

5. The production approach stimulates RD to externalise (and document) the production steps...
...because the current lack of documentation of production specific knowledge occasionally leads to untraceable mistakes

6. Ideally the entire process is launched internally to Royal Delft (no continuous costs of ordering half-fabricates elsewhere)
...because this would benefit the reduction of costs and time

7. Ideally the design should improve the ergonomic situation of the mold maker
...because this would improve well-being and make the production of larger and complex shapes possible, instead of limited

5.2 Business & Brand Drivers

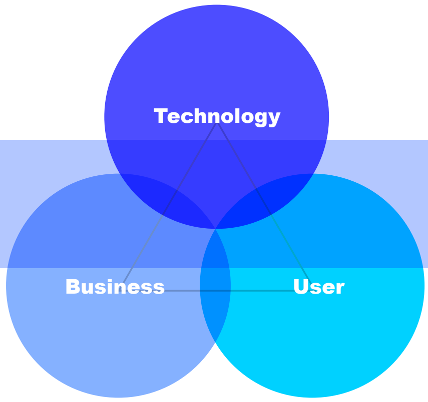
8. The design should fit the heritage and stature of Royal Delft
...because innovation is desired when implemented tastefully, science fiction should be avoided

9. The design should be compatible with the current setup
... because too radical assembly-line changes will be difficult to implement, and also disturb the production heritage that makes the brand identity

10. The design should demonstrate innovation and quality
... because Royal Delft wants to prove that they are more than something of the past

11. The design should have a viable cost build-up
... because Royal Delft is not a showcaser of possibilities, but an operating business

12. The design opens up a new market of consumers
... because one of the big promises of industry 4.0 is to enable configuration at a lower cost, this expands the group of people interested.



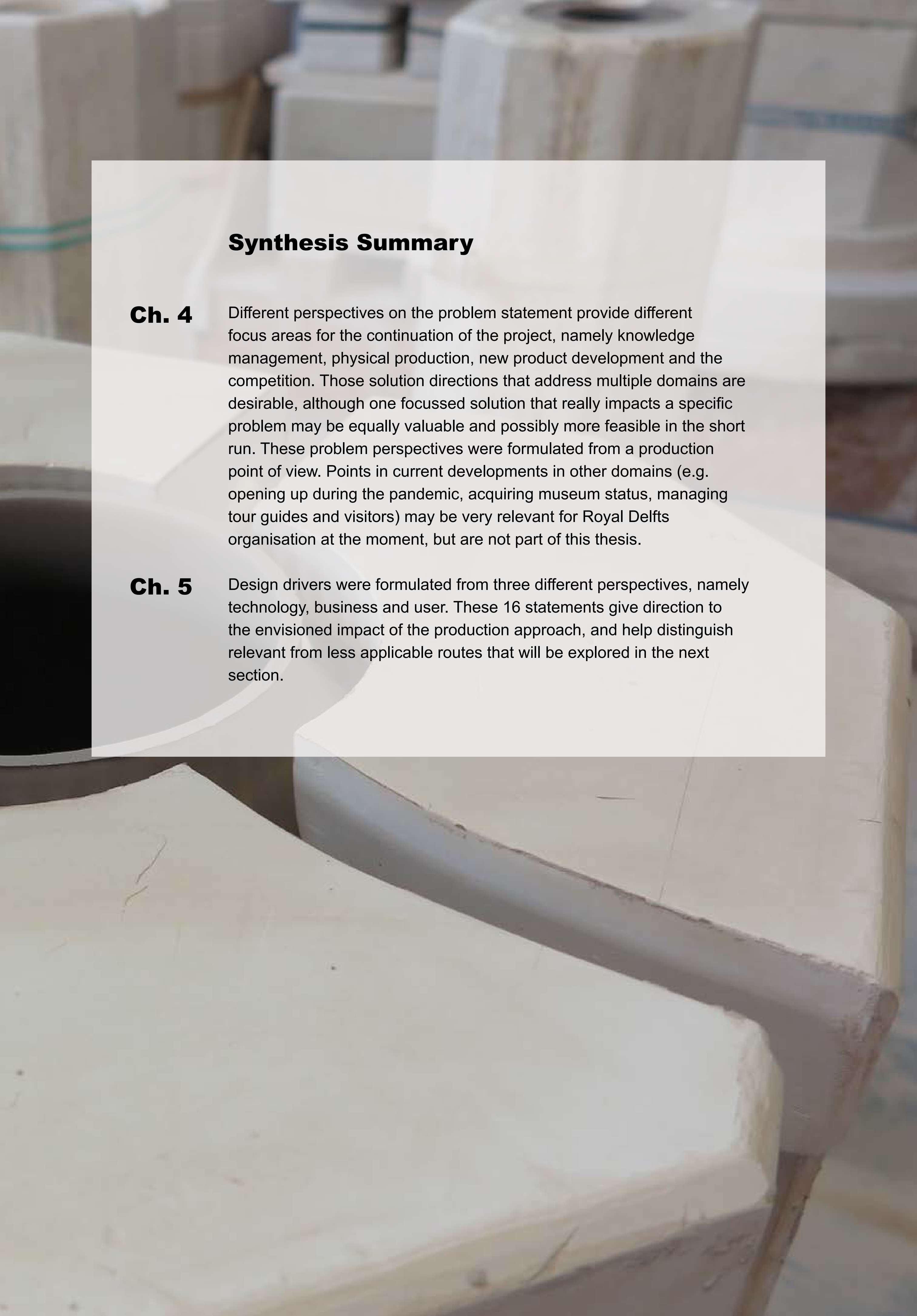
5.3 User Drivers

13. The design should be evaluated as innovative yet fitting by users
... in order to demonstrate innovation and quality while staying true to heritage

14. The design should make it accessible (laagdrempelig) to order a custom part
... because currently the website demands an e-mail to sales to get a quote

15. Design should be appealing to a wide range of customers
... because a choice between a more traditional aesthetic and a modern one will increase the chance of the concept landing successfully

16. The design should be shippable within 2 weeks
... in order to include the vast amounts of customers that are in the Netherlands only briefly



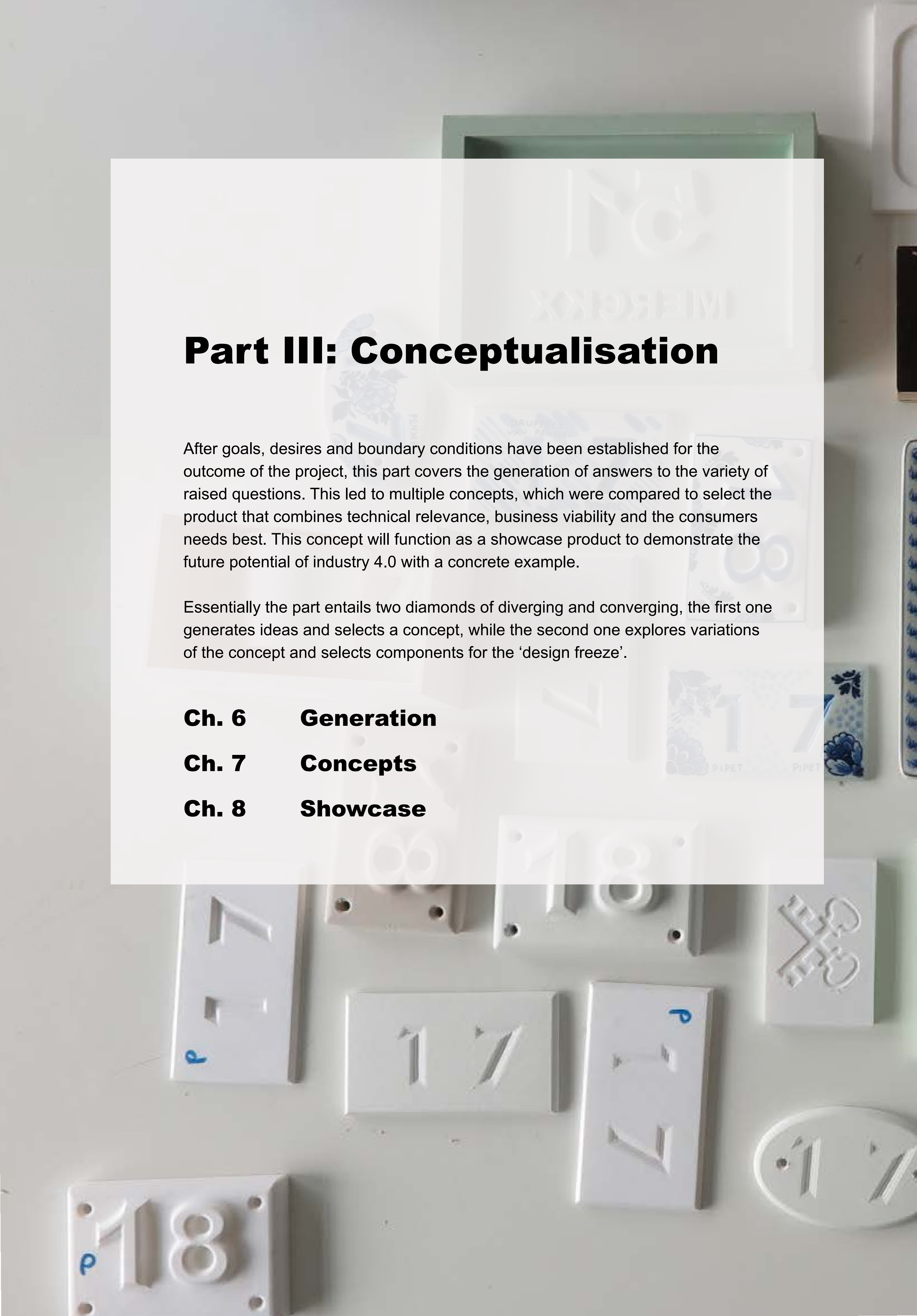
Synthesis Summary

Ch. 4

Different perspectives on the problem statement provide different focus areas for the continuation of the project, namely knowledge management, physical production, new product development and the competition. Those solution directions that address multiple domains are desirable, although one focussed solution that really impacts a specific problem may be equally valuable and possibly more feasible in the short run. These problem perspectives were formulated from a production point of view. Points in current developments in other domains (e.g. opening up during the pandemic, acquiring museum status, managing tour guides and visitors) may be very relevant for Royal Delfts organisation at the moment, but are not part of this thesis.

Ch. 5

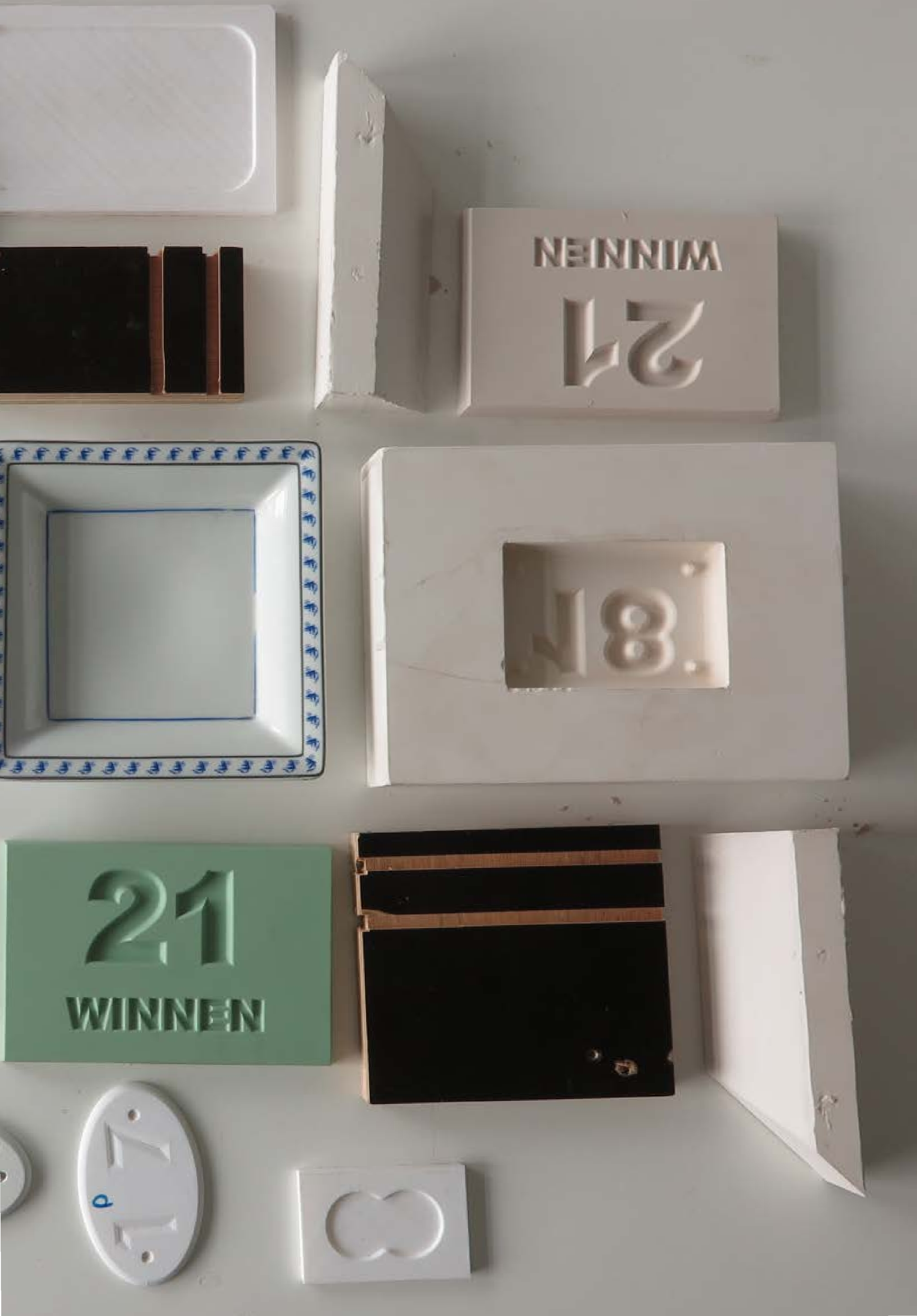
Design drivers were formulated from three different perspectives, namely technology, business and user. These 16 statements give direction to the envisioned impact of the production approach, and help distinguish relevant from less applicable routes that will be explored in the next section.



Part III: Conceptualisation

After goals, desires and boundary conditions have been established for the outcome of the project, this part covers the generation of answers to the variety of raised questions. This led to multiple concepts, which were compared to select the product that combines technical relevance, business viability and the consumers needs best. This concept will function as a showcase product to demonstrate the future potential of industry 4.0 with a concrete example.

Essentially the part entails two diamonds of diverging and converging, the first one generates ideas and selects a concept, while the second one explores variations of the concept and selects components for the ‘design freeze’.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6. Generation

Various ideation techniques were combined to generate ideas, such as brainwriting, generative prototyping and brainstorming with peers. This chapter presents some of these activities, while a full documentation can be found online in Miro.

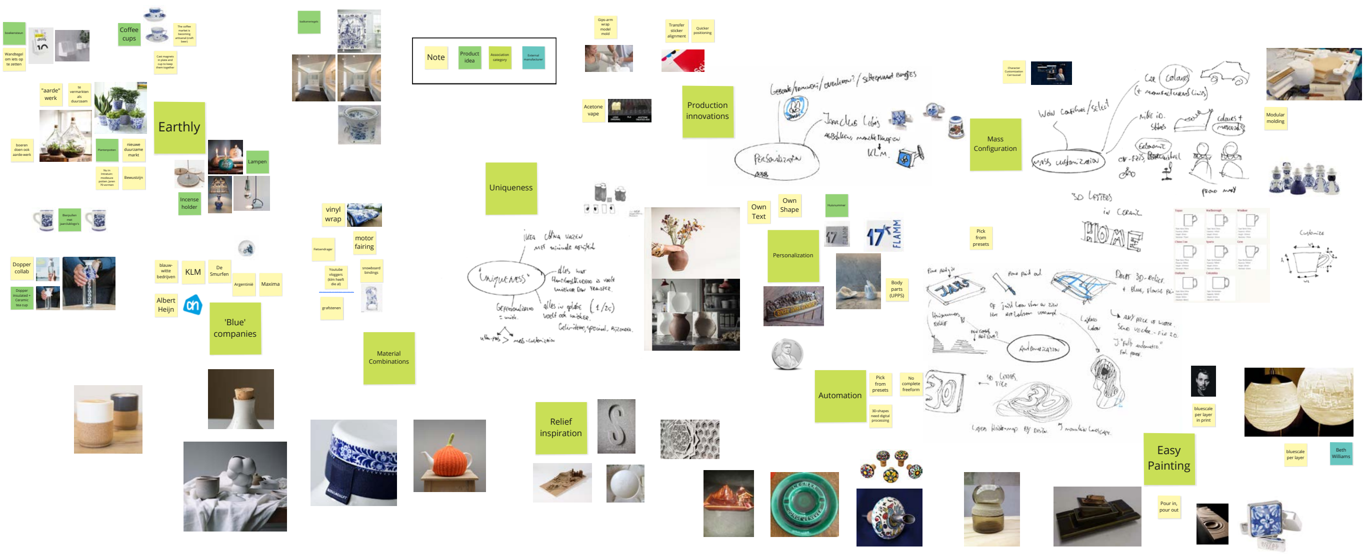
6.1 Ideation topics

The first activity is to visualize all previous associations, questions and concerns and to sketch and describe all first responses.

Brainwriting

The first method used was brainwriting: emptying all vague thoughts and ideas so far on paper, and associating freely on different questions concerning, production, personalisation, industry 4.0 and Royal Delft. The overview below gives an impression of the result. Questions were used such as:

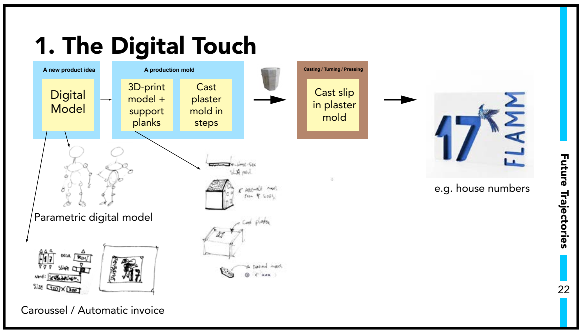
- What are the benefits of Industry 4.0?
- How to automate painting?
- How to personalize something?
- How to subtract material?
- How to mass customize on different scales?
- What companies are 'blue'?
- How to smoothen a surface?
- What are the production limitations of Royal Delft?

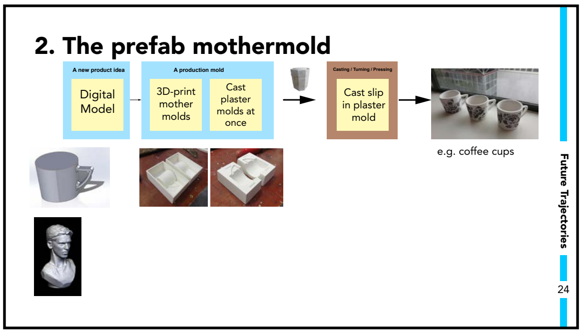


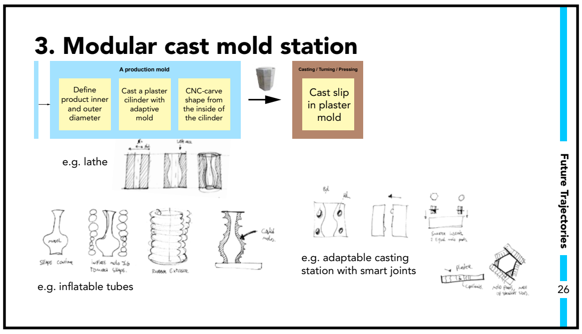
Process Morphology

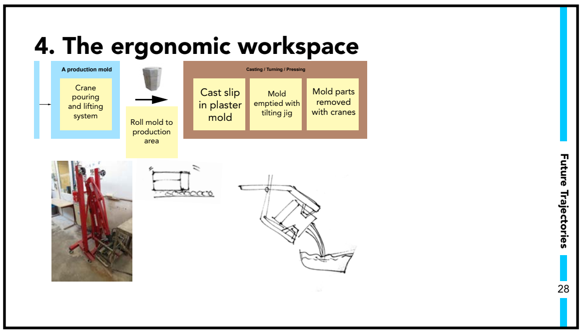
Another source for ideation was the production process. For each step, from mold making to creating the vase directly (see post-its), alternative tools and materials were associated on, creating a map of techniques that can be combined in different ways to produce a clay shape. This resulted in 4 main production approaches, displayed to the right.

Digital models | Different mother mold production | Different casting mold production | Different mold material | Different vase production | Different vase material









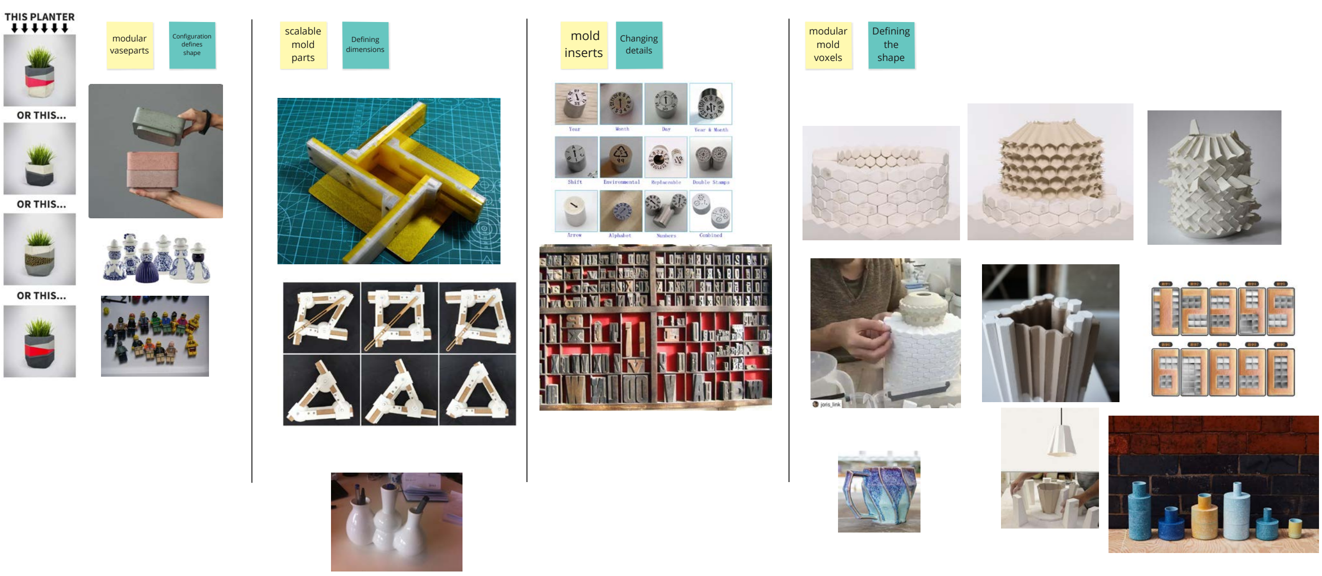
Creative Session

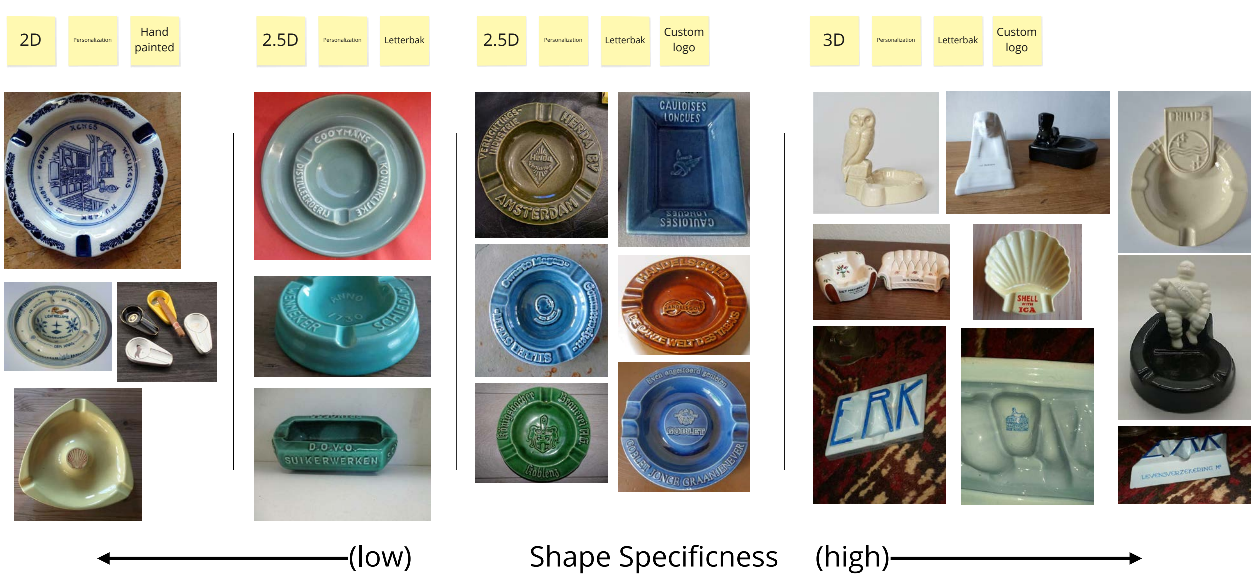
After these individual activities the brainstorming was strengthened by inviting 4 fellow TU Delft students to a do a collaborative session, making sure that no ideas were overlooked.

Degrees of Modularity

A final source for inspiration was an inventory of different modularity scales and types in existing ceramic products. This ties back to the degrees of customization as presented in the analysis.

The two diagrams below show how customization can be achieved in various ways: for instance by combining individual ceramics, casting in voxels, textual personalization and stepless scaling.



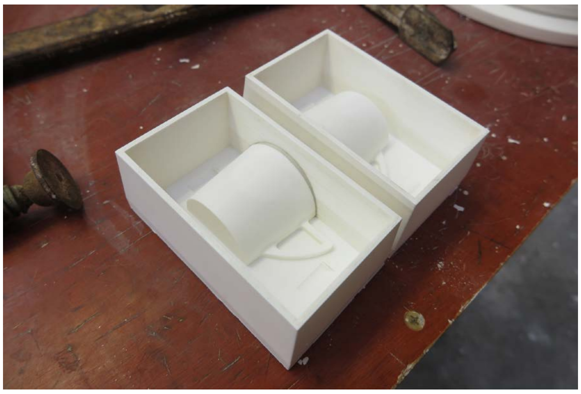


6.2 Explorative prototyping

Throughout the project, continuous small experiments were done to get more detailed information on all sorts of sub-aspects of the ceramic production process. Initially the aim was to get familiar with the material, while later on tests became more specifically oriented towards surface quality, paint effects and digital manufacturing techniques.

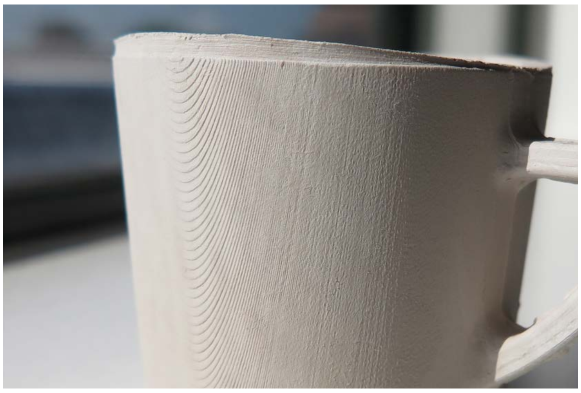
FDM-printed PLA mother mold for espresso cup

While the mold construction had some obvious flaws, the clay body turned out relatively well for an untreated PLA-mold. The biggest caveat was the relief of the print-lines, which was clearly visible after painting. However, sponging the cup heavily before painting could help reduce this effect significantly. Alternatively, parts with thick print-lines can remain unpainted, or the visible paint effect can be used for decorative purposes, demonstrating the production method.



45. PLA mother mold with printed keys

47. Relief is not covered by engobe-layer, still visible on biscuit



46. Clay body with visible print lines

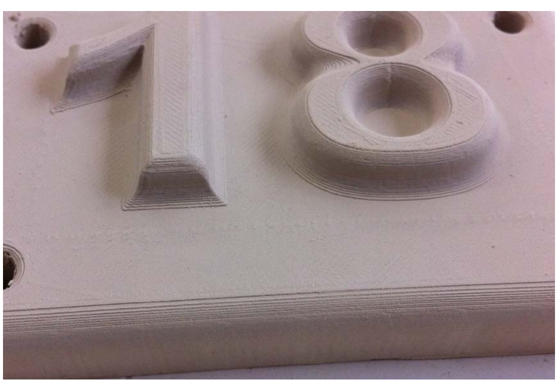
48. Relief is translated into the paint

FDM-printed PLA model for numberplates, + paint tests

Several PLA-plaques were printed to test clay release of different staircase-reliefs (next page), and also to test the paintability of the shapes. One painter remarked that the rounded 18 was difficult to paint neatly, as the entire protuding shape was filleted.

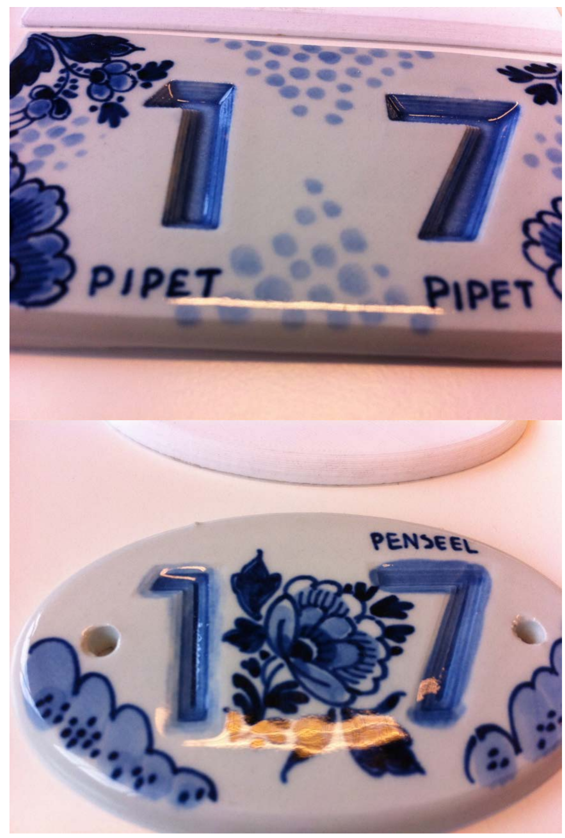
Furthermore, a difference in letter quality can be seen from these No. 17s. The three objects have a different slope within the negative letters, but the applied techniques also show a distinct effect. The specific settings for future reliefs have to be explored further, for now pipetting seems most promising to fill out sharply defined cavities for the moment.

49. *Mold chipping on edge and print relief*



50. *Rough print relief visible in clay*

51. *Close up of paint: difficult to draw a straight contour on a protruding, filleted body*



52. *'staircase'-slopes, 2 angles and 2 decoration techniques*

SLA-printed resin nameplates

As expected, and as Royal Delft occasionally does, SLA prints delivered a way smoother surface than FDM prints. Dependent on the level of surface quality, and the desired visibility of layers, one of the two can be advised for different applications.

Obumodulan model and mold

CNC-milling proved very well feasible to create a straight model with extremely smooth surface quality, which was transferred to the mold and to the clay body. The use of a 2mm round milling head gave the advantage of having a uniform fillet, aiding the clay-release. A small wooden pedestal helped resolve a sticking problem due to the straight release angle as a result from clamping. It should be noted that, however smooth and convenient, these models are rather expensive, and so is obtaining the tooling.

53. Obumodulan 750 g/L nameplate-model

54. Plaster casting mold

56. Plaster negative from SLA print

Unfortunately, pressing clay into a negative mold was unsuccessful. Regular pressing molds are made with WB30, which is slightly porous and absorbing. When blowing air through the entire mold the clay releases instantly. This mold material, however, absorbs absolutely nothing, resulting in a clay body that dries very slowly while sticking to the mold, shrinking itself to pieces.

55. Obumodulan pressing mold with cracked clay body

7. Concepts

These generative sessions and hands-on test insights contributed to a continuously growing list of ideas, of which the 13 most developed were compared using the PMI-method (plus, minus, interesting). This comparison showed that 4 ideas had a significantly high amount of positive and interesting aspects.

7.1 Four Concepts

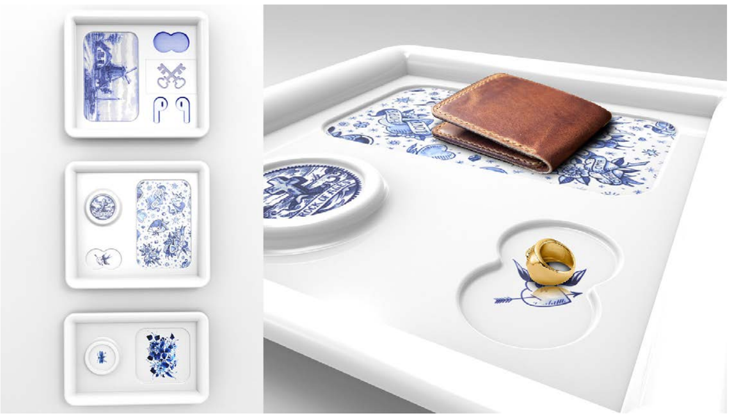
This section presents the four most promising ideas, developed into concepts, including renders and visualisations. These visuals were used in the user survey mentioned in the next section.

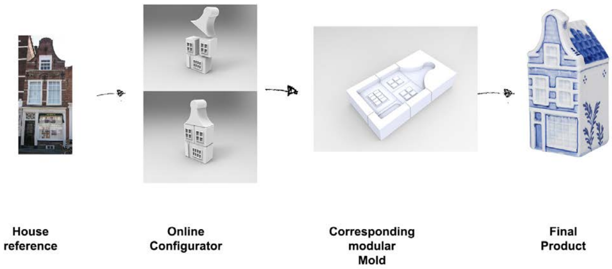
1. Relief Mug

Adding a customizable insert to a default shape enables for 2.5D customization in a way that is least invasive to the current production line. Individuals or companies can upload .stl logo’s (with certain constraints) that are translated to a 3D insert into an existing mold. Dependent on the batch-size these products will be slip-casted (small batch) or jollied.

2. Personalized Tray

A 2.5D product could be a 'vide-poche' configurator, where users can combine elements and decorations to personalize a tray for their belongings to their everyday needs. This mass configuration can be more taylor-made by integrating custom 3D-printed inserts into the modular system.





3. Miniature House

As houses are always in great demand, this concept is an opportunity to quickly increase the target market for custom products. There are plenty of producers of generic Delft Blue houses, however the concept of owning your own house is appealing on a different level.

4. Name and Numberplate

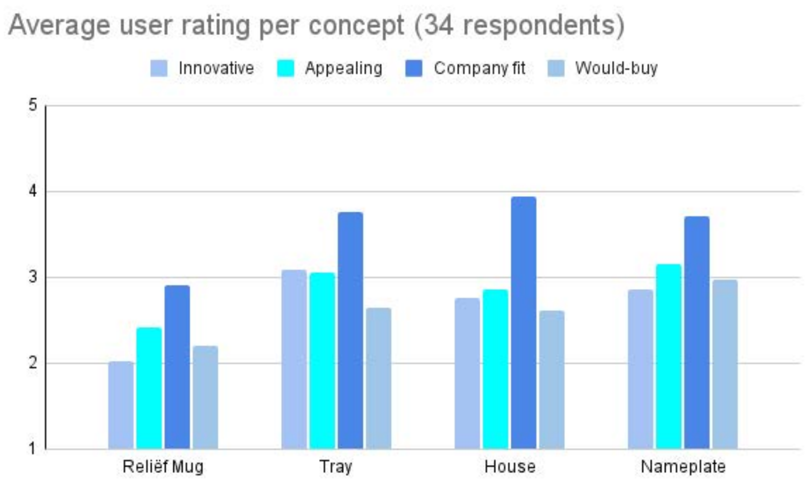
Plates combining housenumbers with family names are always personal. This could be an interesting application to apply 3D printing in as they are also easy to produce in terms of shape, with a 1-part mold. Furthermore it is an example of a product that is produced once each, which would lead to an enormous price when considering that the sale of one object would normally have to cover all production costs.

7.2 Concept Comparison

Based on technical relevance, user appreciation and business feasibility a weighted choice was made between the individual concepts.

User - Survey

The graph below (fig. 57) lists the survey results for the 4 themes, based on 34 respondents. It is clear that the reliëf mug is appreciated least by the crowd, while the other 3 concepts are considered a good company fit. The personalized tray and a nameplate with housenumber score quite similar, while the tray is deemed slightly more innovative and the nameplate slightly more worth buying.



57. Survey results for appreciation per concept

People were also asked if they had a favourite concept, out of 22 respondents who answered this question the tray, house and nameplate scored equally with 7 votes each, while the mug received only 1.

At the end of the survey participants were asked if they had any additional questions or suggestions, this page lists the most interesting remarks per concept.

1. Relief Mug
- no comments -

2. Tray
"Functional and fits every home"
"Personal and useful for everyday yet important possessions"

3. House
"An excellent gift"
"Most personal and unique"

4. Nameplate
"Bring building ceramics back to the Dutch streets"
"Good for Royal Delft exposure"

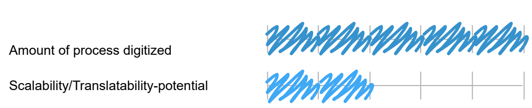
Technology - Innovation

1. Relief Mug
This concept includes customization in the most subtle way, by inserting a small part into an existing casting mold. As most aspects of the process (e.g. mold making, jollying) have to be executed the traditional way this concept scores low on digitization. However, if an insert can be realised for slip casting this minor change is implementable in several products.

2. Personalized Tray
The personalized tray enables the user to configure their own product based on some pre-made mold parts. While the online request can be digitized, assembling the mold is still done manually. Both the degree of digitization and personalization could be enhanced by enabling a name to be produced in reliëf. This concept is scalable to other relative flat products, especially the combination of modular elements and printed inserts yields many possibilities.

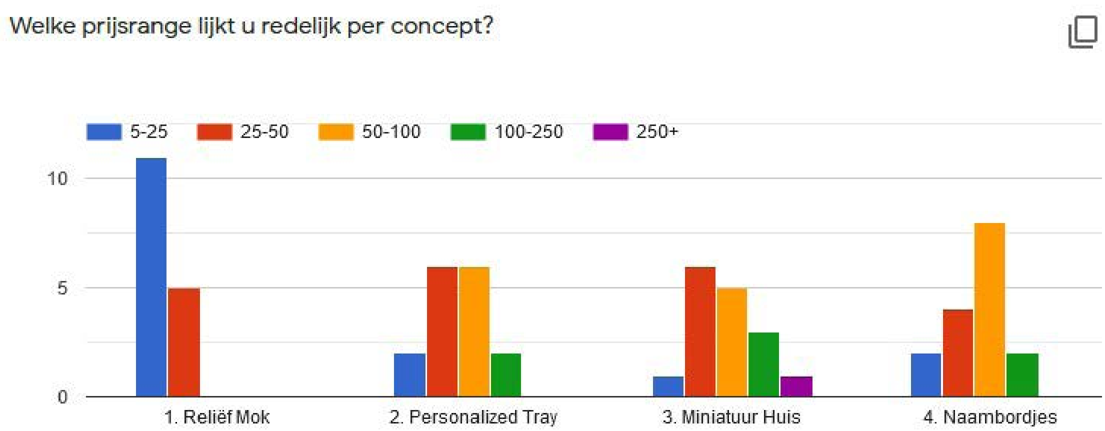
3. Miniature House
The biggest advantage of a modular casting mold for houses is that it will not require the most costly parts of the process: the making of the model, the making of the casting mold and iterating on this process by the mold maker. Therefore this concept demonstrates mainly a production-gain for one existing product category, but knowledge of modular 3D molds is translatable to other products.

4. Name and Numberplate
This concept is produced with a 2.5D 1-part casting mold. Therefore the process can be digitized from invoice, to model production, to casting mold production. The scalability is limited to products with a 1-part casting mold (e.g. dog bowls, mugs), although one could imagine this technique capable of making keys and joints, therefore 2- or 3-part molds.



Business - Price estimate

A survey was sent out to estimate the public opinion on the four concepts, which will be elaborated on in the chapter “User”. 16 respondents gave an indication for the price-range they would be willing to pay per product (fig. 58). For each concept we can evaluate if this range matches the estimated retail price, based on the production costs (fig 59).



58. Price-range respondents mentioned to be willing to pay, per product

This very rough outline shows a few things, namely that it will be almost impossible to produce a mug in Delft, and that the amount of expensive labour (mold making and painting) for all other three concepts should also be within reasonable limits. This means that the Numberplate scores best from a competitive production point of view, as its 1-part, robotically produced mold requires no labour.

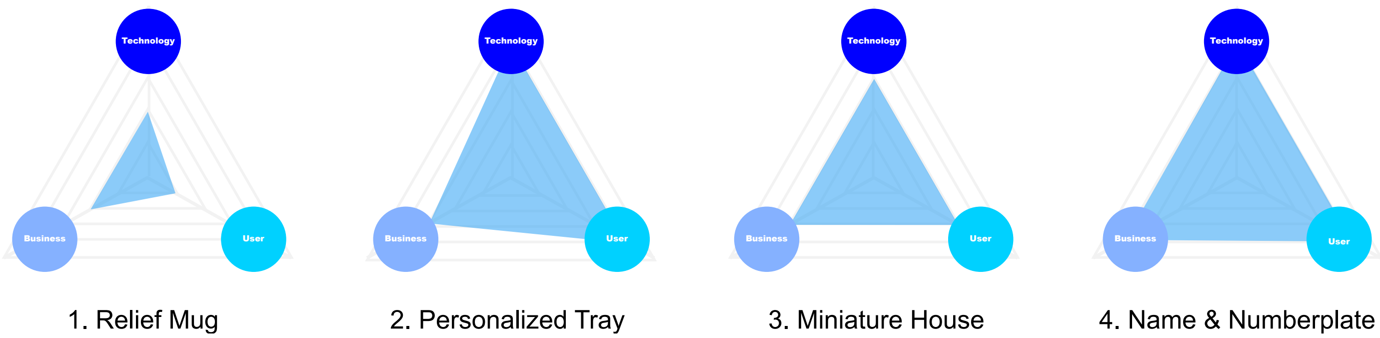
Investment costs for novel equipment or costs for externally produced positive models are not calculated yet, which will be covered in chapter 11.2 regarding the cost build up.

	Production Cost	Trade Price	Sales Price
Relief Mug	6-12	<-	25-50
Personalized Tray	6-40	<-	25-150
Miniature House	6-60	<-	25-250
Name and Numberplate	6-40	<-	25-150

59. Conversion estimation between sales price and production costs

Conclusion & Choice

Plotting the concept scores for all three categories on a 1-5 scale yields the following result:



60. Overview of the scores of four concepts

The personalized tray and housenameplates scored comparatively well on these three categories. A concept choice was made by also considering the more detailed Design Drivers from chapter 6.

The nameplates are easiest to automate fully because they can be made with a 1-part mold. This gives it a strong business case, as it requires no mold-making labour nor skill except for neatly pouring 1 can of plaster. This concept, however, bypassing some production problems by limiting production to 1-part molds. The tray has a wider variety of embodiment applications, such as modular molds, keys and digitally produced inserts. When these items are addressed and solved the gained insights from producing the tray-concept will have higher translatability, and therefore provide more potential to Royal Delft for future iterations. Therefore the personalised tray was selected to develop further; while time may be limited this concept is the most meaningful response to the initial assignment.

61. Concept impression

8. Showcase

After having chosen the personalized tray, the concept can be developed further towards shape specifics and production requirements. This chapter displays the design on a conceptual level, highlights the main design decisions and transforms the concept into a design freeze of the embodiment. This showcase product functions as a defined reference for later implementation steps regarding production, costs and user interaction.

8.1 Concept features

The tray can be personalized on different levels. Some users will be satisfied by configuring existing elements and going for a classic clean look. Others may want to add initials, a name or even a personal symbol or logo, enabled by integrating digital manufacturing in the process. The option to choose from a variety of decors, traditional and modern, makes the product versatile and personal.

8.2 Design decisions

To develop the concept into a production-ready design, a wide variety of decisions needs to be made, relating to dimensions, production techniques, customization and decoration.

Desirability: Royal Delft and User

The aim is to make a product that is both easy to produce by Royal Delft, and personal and meaningful to the user. How to evoke a feeling like 'your own house in Delft blue' without requiring the production complexity of current bespoke orders? These two stakeholders have different desires and expectations:

Royal Delft

Limited number of production complexity
Priced significantly below custom shapes
Production method is translatable

User

Freedom of choice
Comprehensible number of options
Feeling of quality, heritage, handwork

For each of these statements different design features can be emphasized, although they are not mutually exclusive. Not every benefit or effect can be predicted either, often products are brought to market that are used in different ways or appreciated for other reasons than the designers expected.

Through interviewing more potential users, or simply by implementing the technology when serving actual customers it is possible to perform some pilots, and get a better feeling of what the market wants to create a more desirable product. On the other hand we can expect that internal technological development will make the entire process more cost-efficient and also bring up new application ideas.

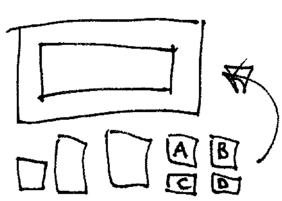
Feasibility:
Mold modularity degree

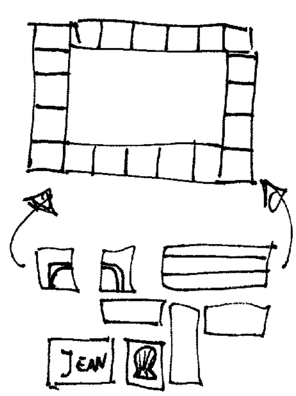
One can envision different degrees of modularity for different application purposes (see diagram in ch. 7.1).

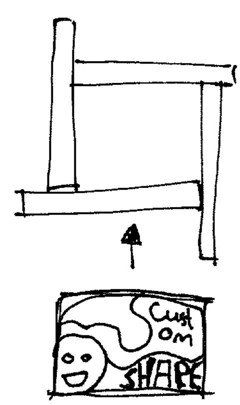
Superficially, it may seem that 'the more freedom the better', and it is true that one of the aims of the project is to develop diverse innovations to increase future impact. It should be noted, however, that freedom also puts more responsibility and strain on the user, and requires more advanced technology, both of which may be unnecessarily complicating the goal.

In the diagram below 3 initial ideas for mold designs are displayed, showing their respective pro's and con's in terms of freedom, knowledge translatability and decoration options. In the next phase these systems will be tested, starting with no. 1.

	1. Fixed Tray sizes	2. Lego casing	3. Stepless scaling
+	Least assembly work Clearly communicable Preserve shape-language	Enables longer named inserts Knowledge is more translatable to other shapes	Unlimited possibilities Custom sizes for personal niches (closets, tables, bathrooms etc) Knowledge is translatable
-	Limited dimensions	More complex mold with limited advantage	Difficult to scale transfers or plan out paint designs.







Viability:
Internal/external production costs

Currently some models are 3D printed and post-treated externally. These models can cost several hundreds of euros, and need to be shipped, making them expensive and time-consuming (which is precisely what this innovation proposal aims to avoid). These models are therefore more suitable for art-pieces in series than for individual, custom trays.

This implies that, when selecting an manufacturing principle to creating the custom inserts, it is advised to pick an option that can be implemented in-house, to reduce production costs and production time. This means that the focus shifts towards desktop additive manufacturing devices (3D-printers) as they are significantly cheaper to acquire and require a low level of skill to operate.

The suitable type of printer depends on the desired material quality (relief/staircase/demonstrate technology = FDM; smooth/hide technology = SLA) and object size (tabletop printers for inserts v.s. Massivit-size printers for everything from now on). From prototyping it became clear that FDM is sufficiently detailed for most reliefs, including cursive initials, and is therefore recommended. Minor disadvantages of FDM are that it takes more care in preparing the 3D model (draft angle, curvature), and the clay body requires more sponging.

If machined parts are required for setting up the modular system these are initial costs that are made only once: it is not mandatory that all elements of the production line are made in-house, only the custom parts.

62. Unsponged clay body based on an FDM PLA-print

63. Plaster mold part based on an SLA-print

64. Sponged clay body based on an FMD-print

8.3 Design Freeze

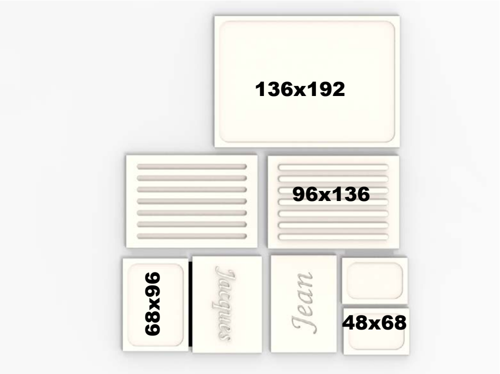
After having compared all the pro's and con's from the dilemma's sketched above, a first product version can be defined to be developed further. The sections below describe this product on the level of the physical object, on the level of the user impression and on the level of Royal Delft's workflow. This design freeze functions as a zero-series for prototyping, cost-analysis and user perception validation.

Physicalities

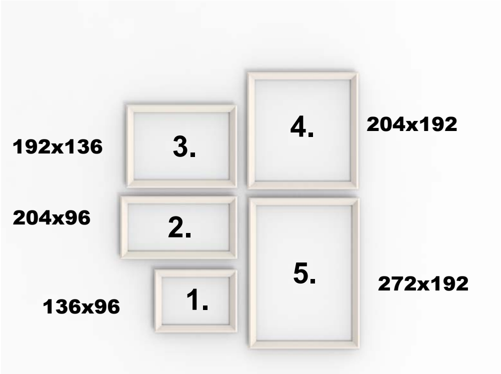
By testing various pocketable objects and maintaining the 1:√2 ratio, 4 module sizes were found (fig 67), so that jewellery, keys, card-holders and phones all have a fitting module.

To have a variety in trays from phone-size to A4-size without increasing the complexity too much 5 overall sizes were established (fig68).

66. Example products and module fit

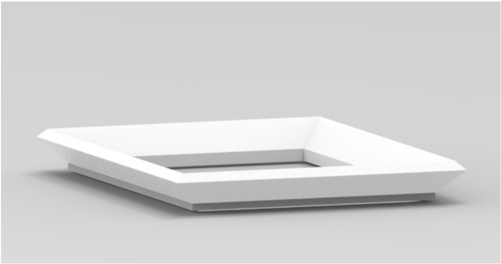


67. Example products and module fit



68. Example products and module fit

As the emphasis of the product is in this stage on the inserts, a geometric, neutral brim is chosen without curvature(fig. 58). A rim-decoration is common in current Royal Delft plates, and can visually help to tie the individual modules together. Therefore it remains optional but not mandatory to add it to the design.



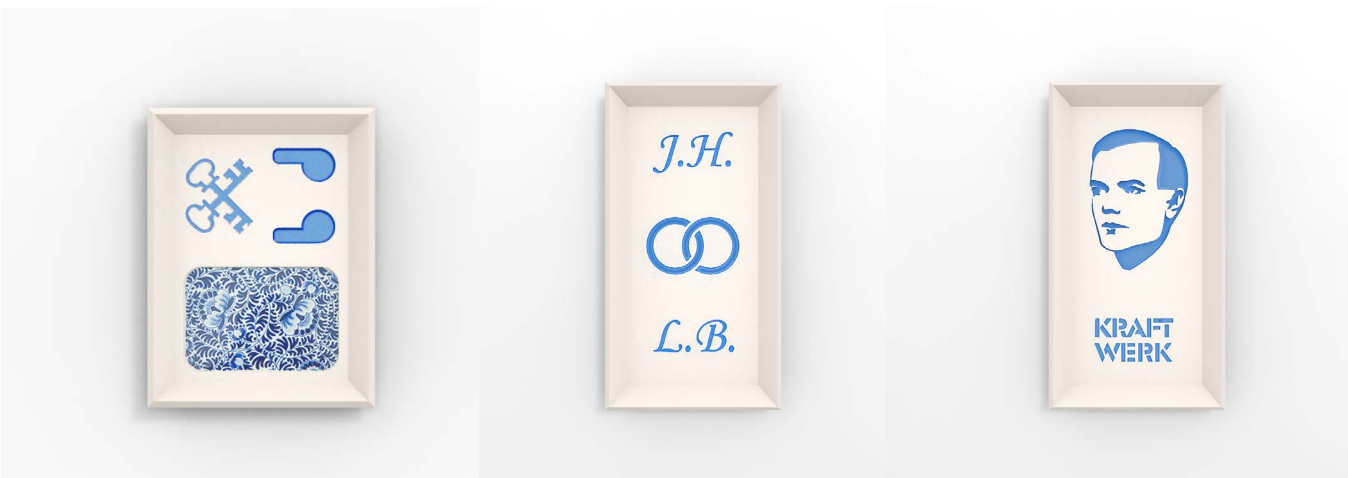
65. Minimal brim design

Degrees of Freedom

In effect there will be three niveaus of personalization possible, namely (fig. 59):

> 1. *Configuration,*
> 2. *Configuration + text,*
> 3. *Custom graphics*

Strictly speaking initials are also a 'configuration' of letters, but this category is mentioned here separately because it requires a different invoice route than both configuration and custom vectors, which is covered in the next section.



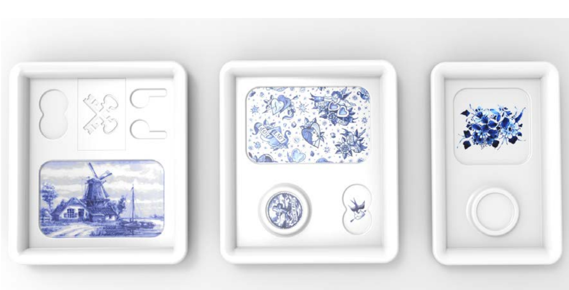
69. Trays with 3 levels of customization: configuration only (left), personal text (middle) and vector-graphics (right)

Decoration

For the configured trays different transfers can be designed in bulk, and applied to the patches dependent on the desire of each client (fig. 65). This is the cheapest and quickest way of decorating.

Initials and shapes with fine details (e.g keys, earpods, rings) are preferably painted, as stickering thin letters is difficult, while they are quickly painted and therefore relatively cheap (2 minutes per 3x2cm letter).These items then are best hand-painted and offered in one tint (fully blue) to reduce complexity.

For custom invoices of vector graphics (e.g. silhouettes, logo's) it is not possible to make a transfer (unless it is digital). As this invoice already requires interaction with customer services, it is best to decide there if the relief be painted monochrome, or with a decoration, the latter being more costly of course.



70. Flat modules are most suitable for transfers


PENSEEL
DRUPPELS VAN PENSEEL
17
PENSEEL
PIPET
PIPET

Conceptualisation Summary

Ch. 6

In the second diverging phase various ideas were developed as a response to the problem statement. This was done by brainwriting, rapid prototyping, an analysis of ceramic modularity degrees and different degrees of customization. Iterating on the outcomes and adding to an ever increasing miro-board helped produce a range of idea directions and example products.

Ch. 7

A plus/minus/interesting evaluation of all ideas showed four ideas that were most promising, which were developed into concepts. These concepts were evaluated on feasibility, viability and desirability, the three main topics from the design drivers. This was done by estimating technological relevance and potential, making a preliminary cost-estimate based on potential buyers and performing a user survey.

Ch. 8

The concept that performed best on these domains was a tray for personal belongings that can be configured, decorated, and customized to ones own taste. This concept combines a technical challenge, a promising cost-buildup and a pleasing aesthetic, and is therefore most suited to develop further.

Part IV: “Realisation”

After the product is defined on a conceptual level it is time to move further and deliver a proof of concept and proposal for implementation. This section demonstrates iterative developments of the modular mold embodiment, a user perspective on configuring and ordering the product, and a cost analysis with recommendations for Royal Delft to create a viable production line. Finally the future potential of the new approach is sketched out, hinting at possible shapes the method can be translated to. It consists of the following chapters:

9. Embodiment

The embodiment should be such that it supports all design features and production features as described in the program of requirements in the best way possible. Its main purpose is to be able to produce configured clay bodies that occasionally have customized inserts. Therefore the design is a modular system of plaster blocks that can be assembled in numerous ways, while new blocks with custom reliefs can be easily added with the help of 3D prints.

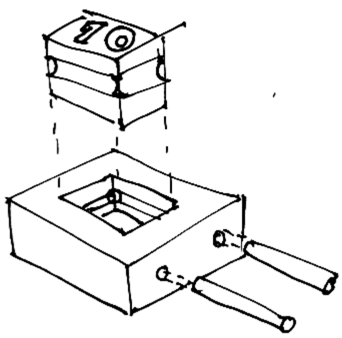
9.1 Mold designs

Decisions guiding the ideation of the mold and production of the prototype were based on the requirements and influenced by my knowledge of material behaviour, and the materials accessible to me.

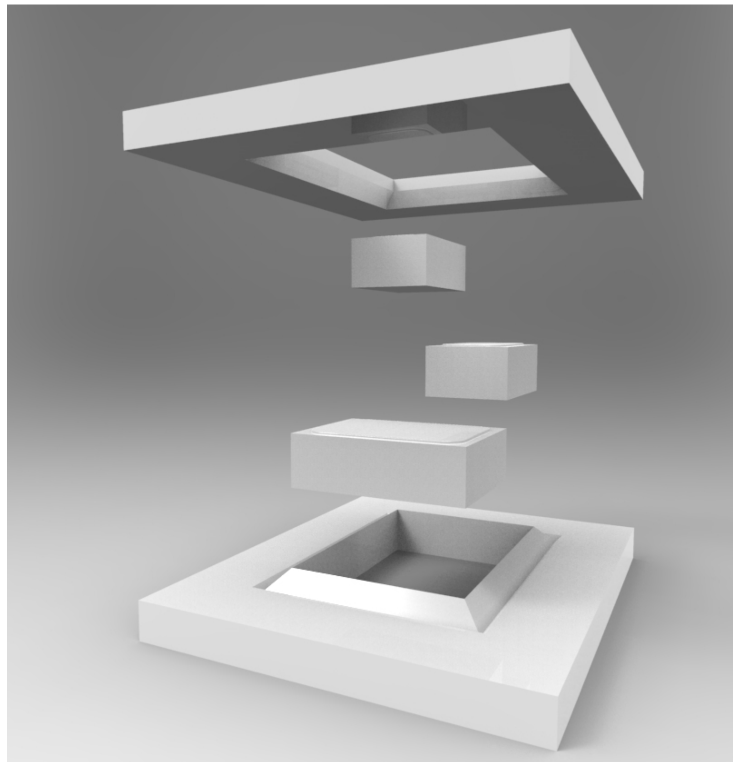
Mold design V1.1

The first mold idea is based on the original mold for casting plates (fig. 71), with a simple cut-out in the bottom part (fig.72). This design adds the least complexity to an existing mold, but has some limitations. The inserts are cast blocks of plaster, and it is difficult to cast them at a certain height. This makes alignment with the bottom ring difficult (although it can be done with pieces of paper) which is why wooden keys were added to align the surface of the inserts with the tray brim (fig 73).

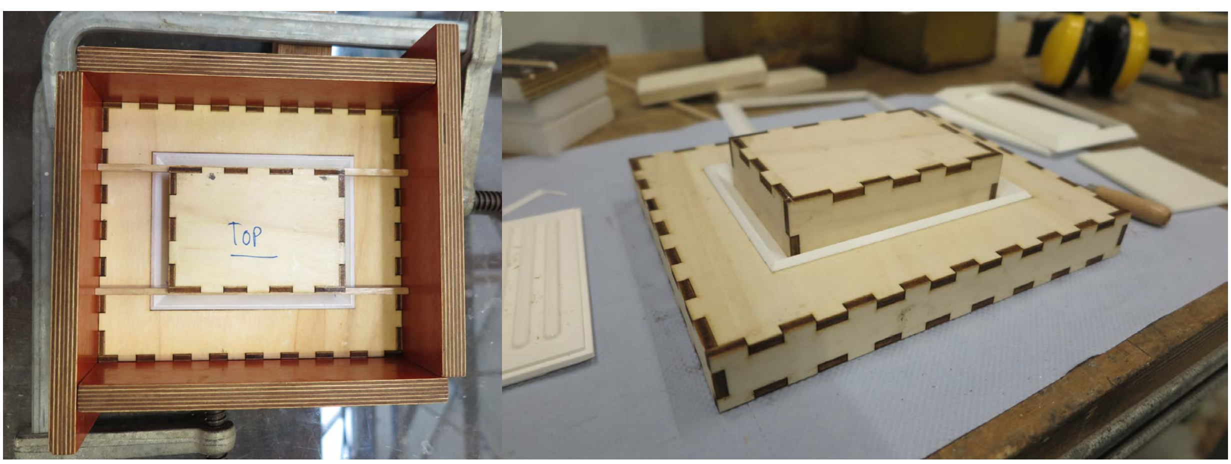
71. Bottom (left) and top (right) mold part of a large plate



73. *Sketch of first key design.*



72. *Exploded view mold configuration (bottom mold part, inserts and top ring)*

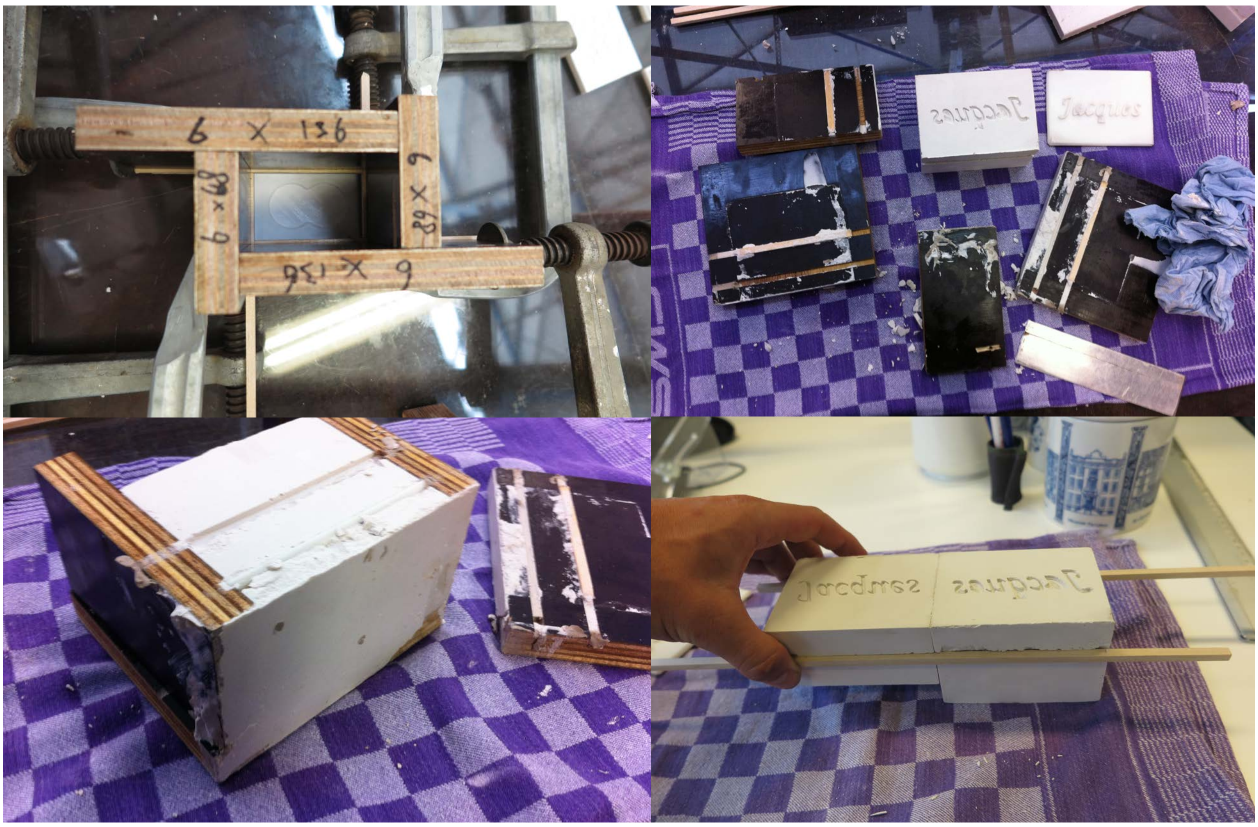


74. *lasercut box-casing with exchangeable PLA-insert for different rim designs.*

The idea that wooden sticks would be releasable from cast plaster proved too optimistic, which led to the keys being completely stuck and a broken plaster mold.

75. *Wood encapsulated in plaster, upon attempting to release the wood the brim naturally broke*

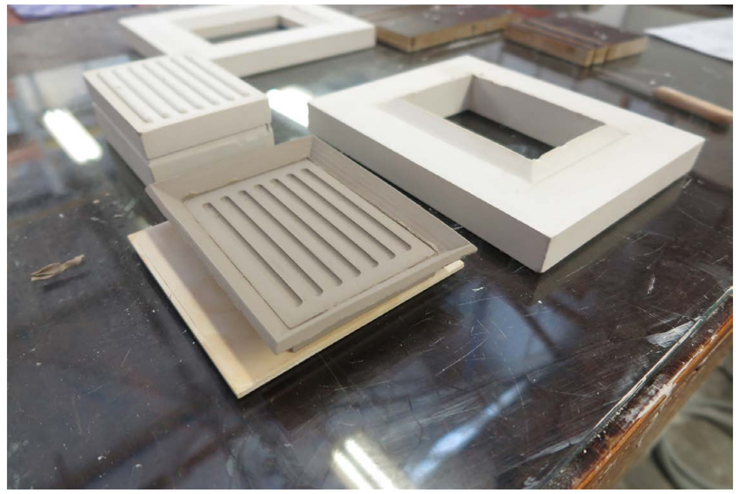
The inserts, on the other hand, could be cast successfully and fairly straight with a 'windmill'-like boxing design constructed from milled multiplex (fig. 76). To create plaster cubes continuously with a higher precision some adaptations to the casing are desirable, but this setup seems to work sufficiently precise for the prototype.



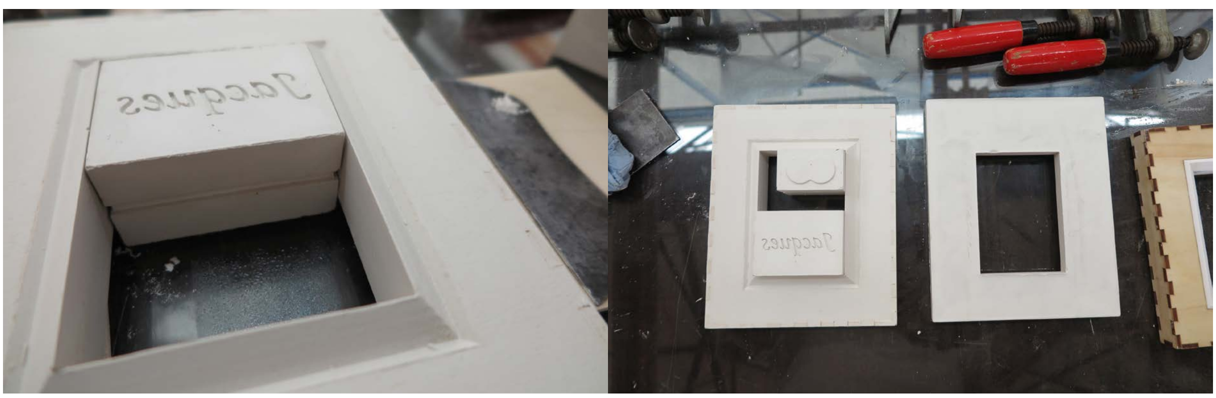
76. *Clockwise: PLA-print with windmill casing; casing parts, SLA-insert and plaster cast; envisioned joint system with wooden sticks; plaster block release from casing.*

Mold design V1.2

A casting of the ring without the keys proved to work quite well, making it possible to cast the first clay tray (fig. 77). However, the modular inserts had to be positioned parallel to the brim using pieces of paper, and it was impossible to get multiple inserts into the brim because of the tolerances in the plaster (fig. 78). This version is not a serious proposal for a mold design system, but a brief test if the envisioned clay body shape has any chance of success, which seemed to be the case.



77. First successfully cast tray with one module

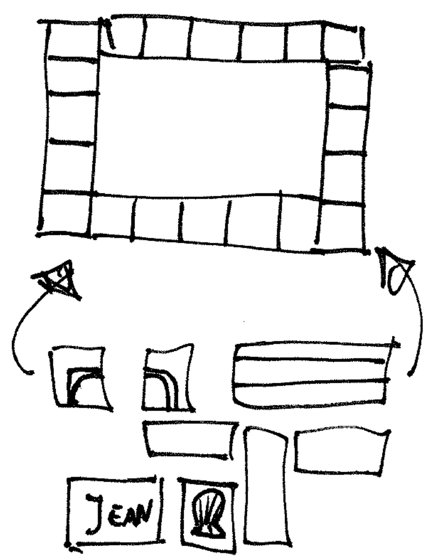


78. Ring-shaped mold design without wooden keys - poorly constructed yet effective

Mold design V2.0

The stuck keys problem remained, and sparked the first real iteration in mold design by splitting up the bottom ring in multiple parts. Increasing the number of plaster mold parts traditionally has some obvious downsides, namely:

- Cumulative tolerances
- More mold production work (cutting keys, setting up casings)
- More edges where chipping occurs

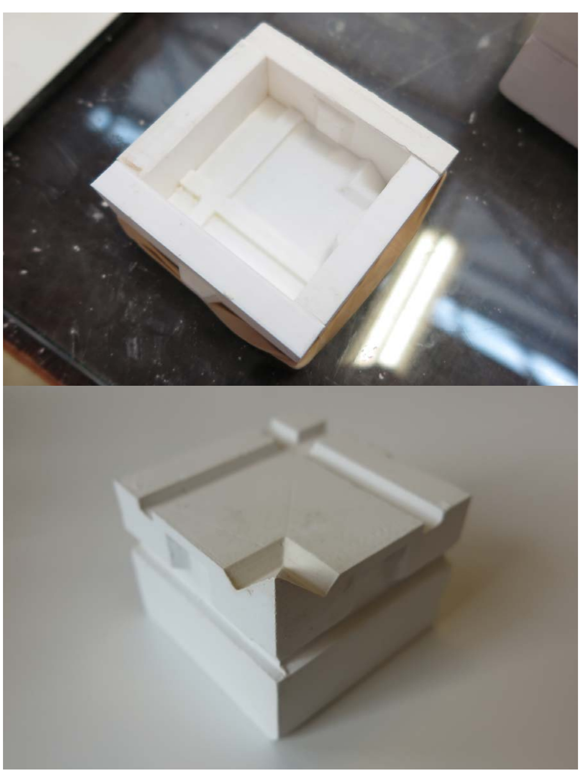


79. Modular sidewall design

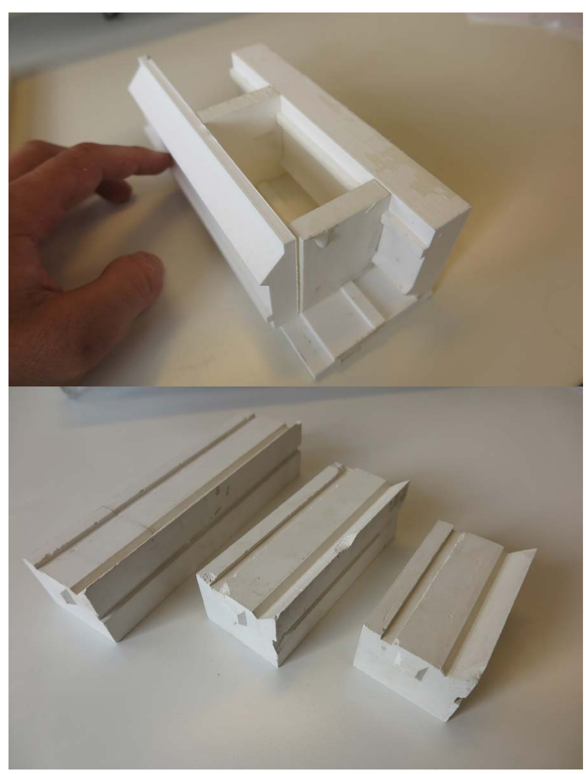
On the other hand there are sufficient benefits that make this design an interesting option, namely:

- Reduced complexity with 2 mold parts: corners and sides
- Sides can be stretched steplessly if desired
- No long stretches of plaster that expand and break the model when casting the mold

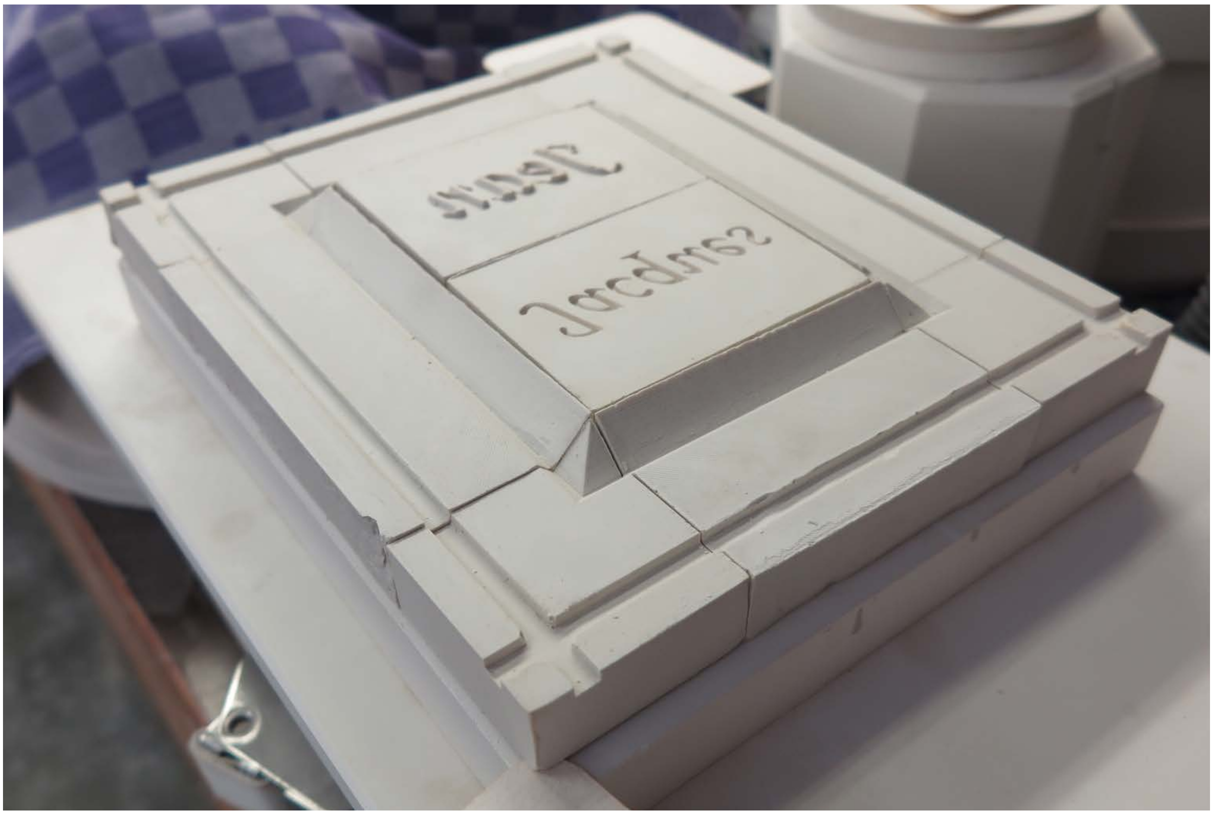
A casing for a cornerpiece and a scalable sidewall were modelled and 3D-printed in PLA, and plaster was cast to create the mold parts for the brim of the design (figs. 80 & 81). These casing parts are advised to be milled later to reduce distortion and gaps (preferably from aluminium) especially if one specific brim-design is used often. PLA is sufficiently precise for this prototype, and a bonus is that the pieces snap into each other due to the flexing of the plastic. As a result of the relief in the untreated prints, and the slight deviation in size for the plaster inserts the mold parts do not match up everywhere neatly (fig. 82). This is reflected in the clay body: as wet slip creeps in between the gaps this creates torn split lines. Some of these are fixable with sponging, but a tighter mold fit would be a more sustainable fix if many trays are to be produced.



80. *Corner mold piece and its PLA casing*

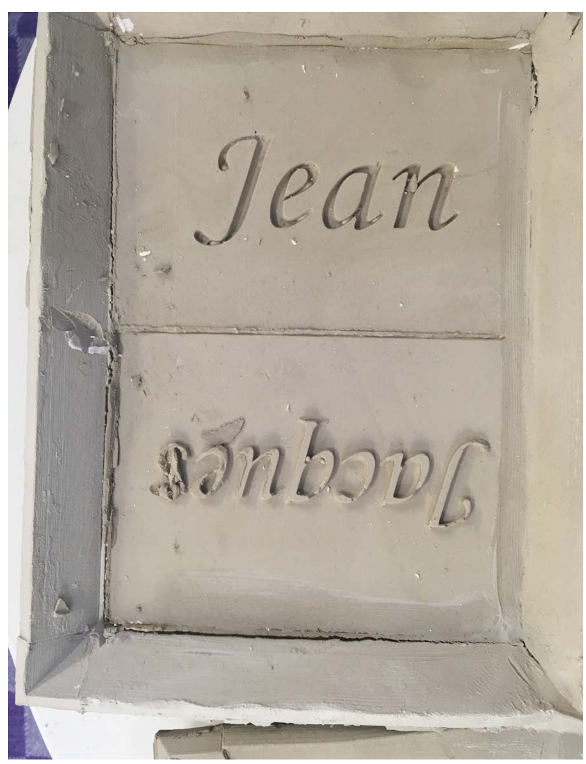


81. *Scalable side mold pieces and their PLA casing*



82. Visible gaps between mold edges and inserts

83. Mold part gaps



84. Corresponding clay body with rough edges

9.2 Post Processing

The success of the mold is defined by the outcome of the final product. Steps after slip casting, such as letting the clay body dry, sponging edges, decorating the shape and firing all need to be performed well to get a good final result. At the time of writing the biscuit is being fired, which means that most steps can be described in this section, except for glazing and firing.

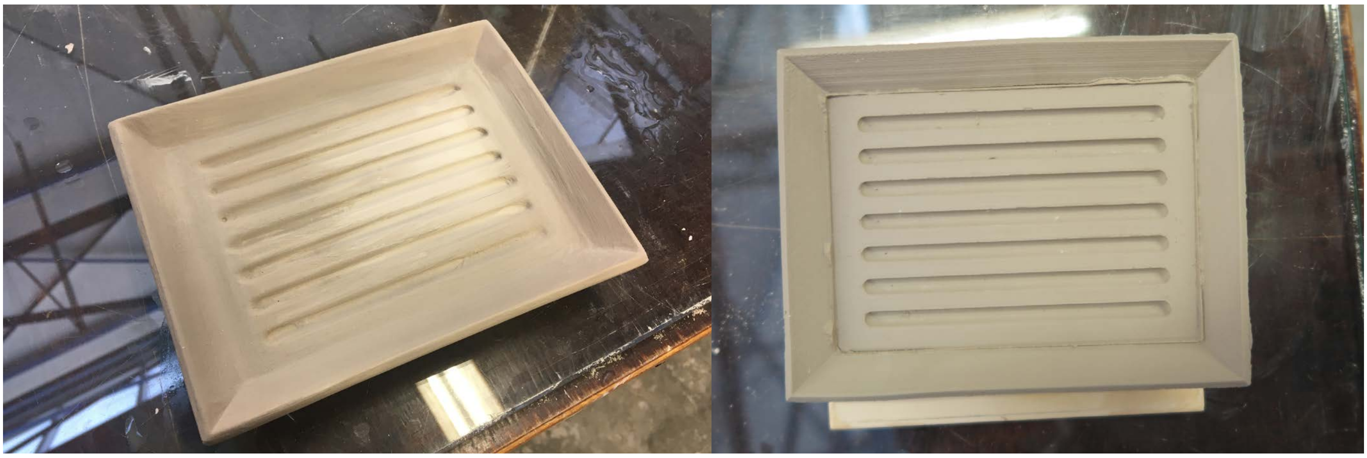
Clay Body release

Because of the interlinked modules, it was less straightforward how to release the clay body from the mold than with a traditional, two-part plate mold (fig. 85). The modules are held together with a strap, but flipping the entire assembly is undesirable because of the fragility of the leather-hard clay shape. Possibly creating a less geometric shape and smoother mold parts (no print-lines) already helps release the clay body, but iterating on the release sequence is advised.

85. Clay body release: how to proceed?

Sponging

First attempts at sponging the clay bodies show that it is fairly quick to get rid of the biggest split lines, although some details (straight edges) are quickly lost when sponged excessively.



86. Tray before and after sponging

Decoration

As described before, the option between handpainted and transfered decorations is dependent on the specific geometry; transfers are suitable for flat surfaces while some reliefs can only be handpainted such as serif text. A third suggestion for decoration was proposed and explored, namely pipetting paint into the relief cavities to get a mono-coloured blue effect without painting effort (figs. 87, 88 & 89).

While this report is written the biscuit had just been fired but not yet painted and glazed. Internally Royal Delft is unsure if this approach can still be described as 'hand-painted', possibly the visual effect is sufficiently aesthetic, yet handpainting the reliefs may be more desirable due to the stronger association with craftsmanship.

87. Wet clay body vis-a-vis the envisioned paint effect

88. Pipetting into differently shaped cavities

89. Sharp paint effects in reliefs, possible up to very dark level of blue

10. User Journey

Next to the physical build-up of the product it is also important that customers are capable of configuring and ordering a tray in a straightforward manner. Both digital and physical touchpoints are envisioned, and a digital mock-up for the online interface was tested with users.

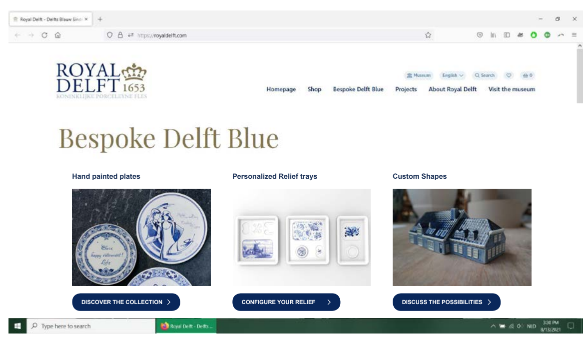
10.1 Touchpoints

As is the case for most Royal Delft products: the possibility to order online is desirable and should be thought out. A physical setup in the Delft showroom can add value in demonstrating the technology and convincing the user to buy the concept.

Digital: website

Due to cost restrictions each tray cannot be treated as a bespoke custom shape, so a digital interface where users can configure the tray and directly send an invoice is required.

As invoices for a custom hand-painted text are already automated on the current website this approach is familiar to both Royal Delft and the loyal customer, although technical implementation requires a significantly bigger amount of programming than a text-box.



90. *Landing page for bespoke orders*

91. *Delft Blue by me, image retrieved from hoogendiep.nl*

Physical: shop

Additionally a device in the shop or factory can be considered, comparable to the machine that used to produce the Delft Blue By me plates with digital transfers of selfies. When users can play around with physical mold parts lying around this may lower the threshold to configure their own product, and engage them in the production technology. The advantage of such a physical setup, whether it be a device or just a setup, is therefore not only to attract attention for this new production line, but it also helps to demonstrate the innovative production method and its potential.

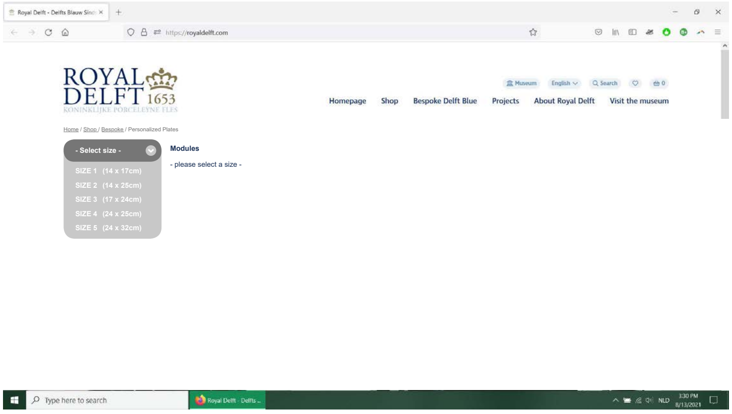
10.2 Interface testing

A mock-up of the interface was build, and four participants were given two tasks:

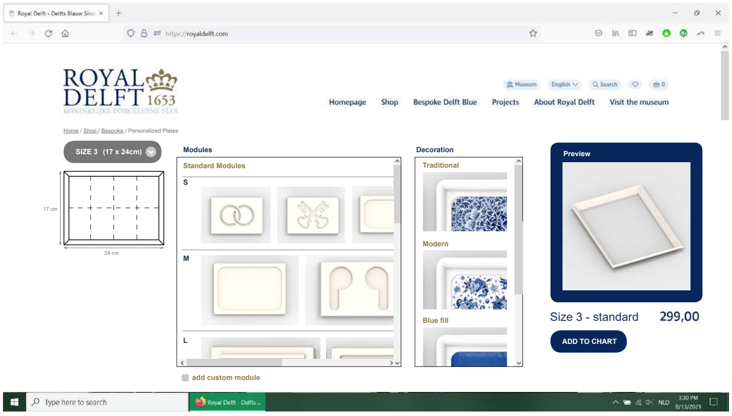
- Configure a size 3 tray with sunglasses with a modern design and blue stripes
- Configure a size 2 tray with wedding rings and 4 initials

As the mock-up was a slidedeck, the outcome of clicking was naturally the result of the task. Most respondents remarked some buggy-ness of the prototype, while none of them realized they were clicking through images; the mock-up proved sufficiently effective.

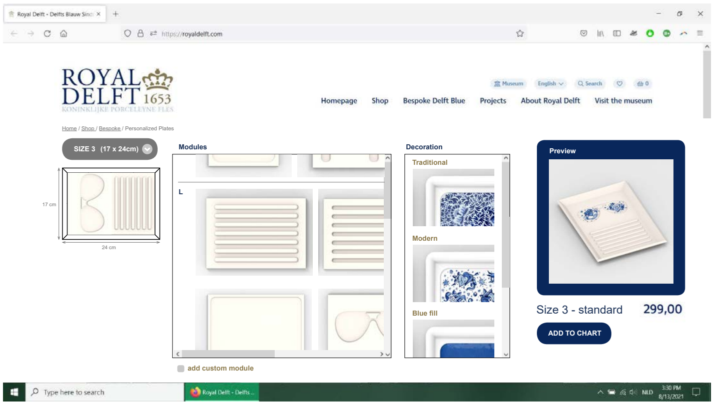
The participants went through several steps in the process (fig. 92-94), such as selecting a size, click-and-dragging elements and adding decorations. The next task featured adding a custom module and typing in initials (fig 95), which is where it became clear that the prototype was limited.



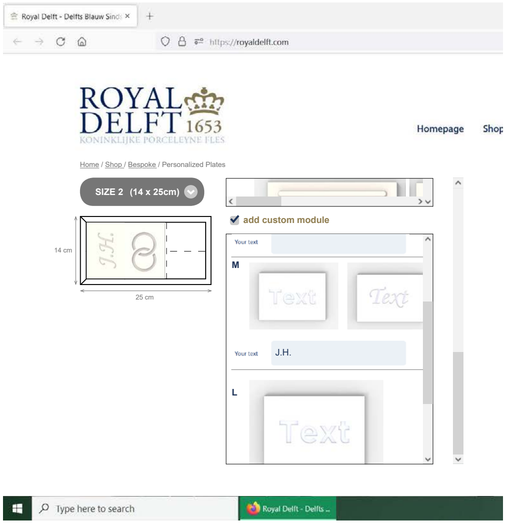
92. Step 1: choose tray size



93. Step 2: choose modules



94. Step 3: add decorations



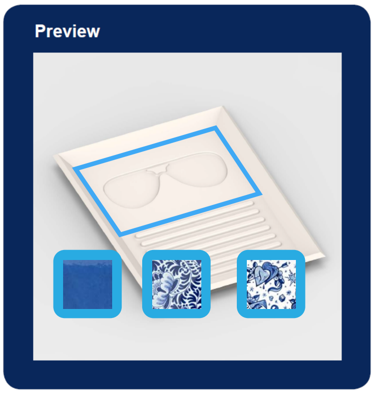
95. Adding a custom module and text

10.3 Recommendations

A few suggestions for improvements were proposed by either the participants or the researcher.

Selecting Decorations

In general people found the relief parts relatively straightforward to configure, but the individual decorations were not always too clear. Also, the double quadrants with sliding bars top/bottom and left/right were filling up most of the screen without showing many elements. To simplify the selection of decorations a second page could be added after the entire physical shape is assembled, or alternatively, some sort of pop-up display for each individual module to select one out of three decoration types (fig 96). Many online configurators for all sorts of products can be used for further inspiration, and also to reach web developers that can build such an interface.



96. Concept for pop-up colour choices

ROYAL DELFT 1653
KONINKLIJKE PORCELEYNE FLES

Your order

Thank you for placing your order!

Our design department will evaluate your request and inform you about the production time and costs within 48 hours.

At this moment no further action from your side is required. You will receive an e-mail in 2 days with the production details and payment link.

Kind regards,

Royal Delft

97. Thank-you message

Communication

Something two participants appreciated was the order confirmation at the end of configuring a tray with initials. Initially this screen was added to distinguish between a configured plate that could be ordered right away, and a personalized plate that needs some processing time by the invoice department to check producibility. The participant remarked that an order confirmation with the proposed two day delay, may, even though unnecessary for configured objects, feel like a person internally is actively taking care of your order - a tailormade, personal approach.

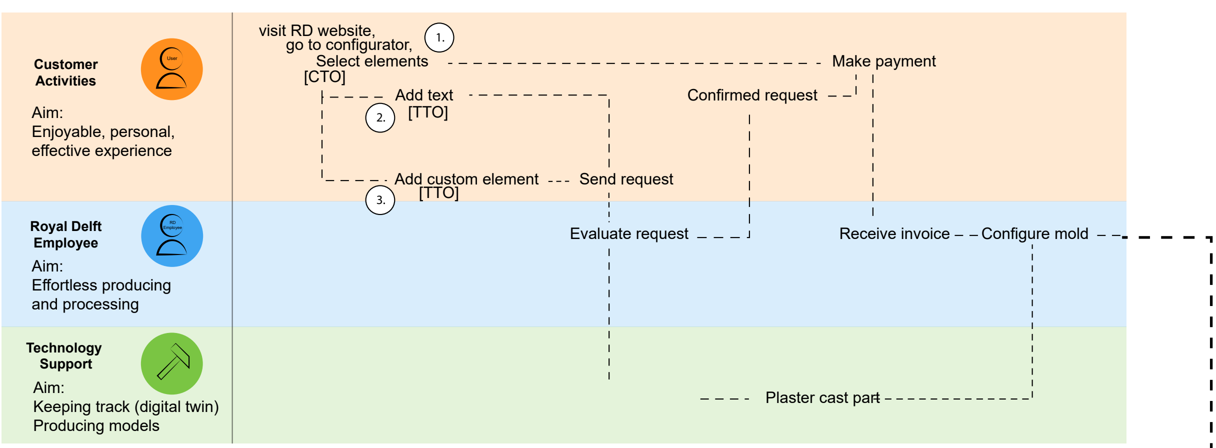
A final suggestion to add to the clarity of the interface could be to produce an instruction video to show how the configurator works. This is not the pinnacle of good web-design, but (home-made) instruction videos for everything become more and more common.

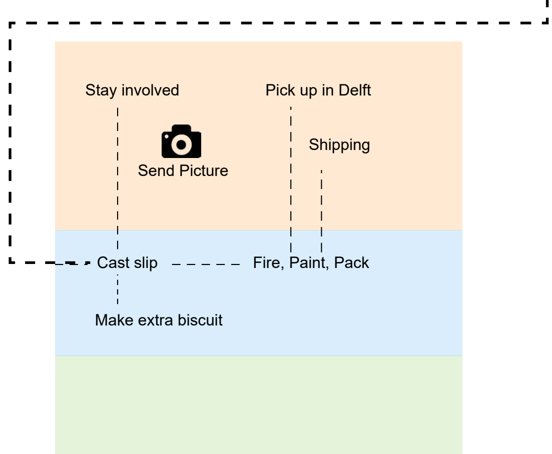
11. Implementation

While a proof of concept for the mold making was delivered, and a first design for the user interaction is validated it is not yet clear what Royal Delft should do in order to actually start up the production of the tray. This chapter presents the envisioned workflow when receiving an invoice, and a cost calculation is done to highlight the critical areas in production in terms of setting up a viable business case.

11.1 Workflow

This chapter sketches the journey of a customer when ordering a tray, and the corresponding actions to be taken by Royal Delft to produce the product and stay in contact with the consumer.





For this route it is assumed that the customer has successfully ordered a tray online. As mentioned in the design freeze, three degrees of personalization can be distinguished, which have different invoice routes. Configured trays can be paid and ordered directly, while trays with initials or custom contours need to be checked for producibility before the invoice can be confirmed.

In order to keep customers engaged in the production process a picture of the clay body can be sent after one week.

11.2 Cost Analysis

A quantitative analysis of the production costs for different variations of the tray was performed. This calculation will present estimations for production prices, to validate if the product can be made within the earlier defined range. Another aim of this activity is to indicate what factors influence the production price most, and how they contribute to the overall concept.

In order to get to these insights 3 sets of products were compared side by side, for each case highlighting the effect of handpainted vs transferred, relief vs flat trays, and handpainted, vs digital transfers. Painters were asked to estimate the minutes required for these specific examples, material prices and factory minutes are known. The full calculations can be found in appendix B.

Investment costs were also part of this calculation, so that costs per product could be calculated for different series sizes. Small series sizes should not be taken too literally, however, because it is not realistic to buy expensive equipment and use it less than 10 times: in these cases the work is usually outsourced.

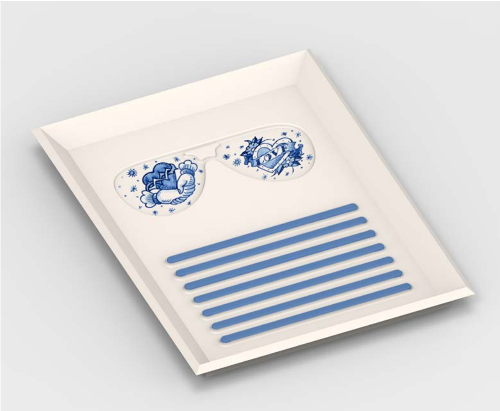
Scenario 1a Config Handpaint		
Configured plate (glasses+stripes)		
Handpainted		
Material weight		
Material costs	0.70 €	Material costs
Production time		
Production costs	99.60 €	Process costs
	100.30 €	Product total
Investments (materials, objects)		
Investment costs	458.98 €	Investment material costs
Investment time costs	1,920.00 €	Investment process costs
	2,378.98 €	Investment total
Scenario 1b Config Transfer		
Configured plate (glasses+stripes)		
Transfer		
Material weight		
Material costs	1.82 €	Material costs
Production time		
Production costs	65.60 €	Process costs
	67.42 €	Product total
Investments		
Investment costs	1,658.98 €	Investment material costs
Investment time costs	1,920.00 €	Investment process costs
	3,578.98 €	Investment total

98. Snippet of cost build-up calculations

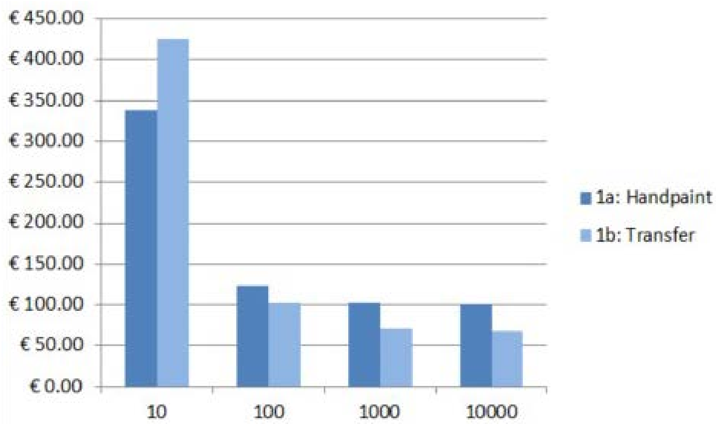
Comparison 1: Handpainted VS Transfered

The example product for the first comparison is a tray of 192x136mm with sunglasses and relief stripes (fig. 99). A first obvious result from the comparison is that the material costs are negligible compared to the costs of the process, which is the same for hand-painted products and transfers (fig. 98). Producing the product without any decoration would cost €66,30, excluding all investment costs. This price is comparable to some of the larger, difficult to cast plates: relatively high for biscuit, but understandable because of the configuration work.

When decoration costs, investment costs for the 3D-printer, and work hours for casting all modular mold parts are added this price goes up. Most investments are equal for both products, but for transfers 4 transfer screens need to be bought externally before production. The graph below (fig. 100) compares the production costs for the two products, showing the high investment costs for transfers clearly at a series size of 10, but the price benefit for series above 100 is obvious.



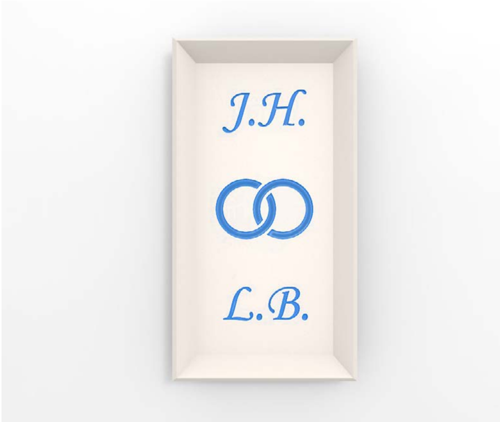
99. *Example product for comparison 1*



100. Cost per product for different series sizes (horizontal axes)

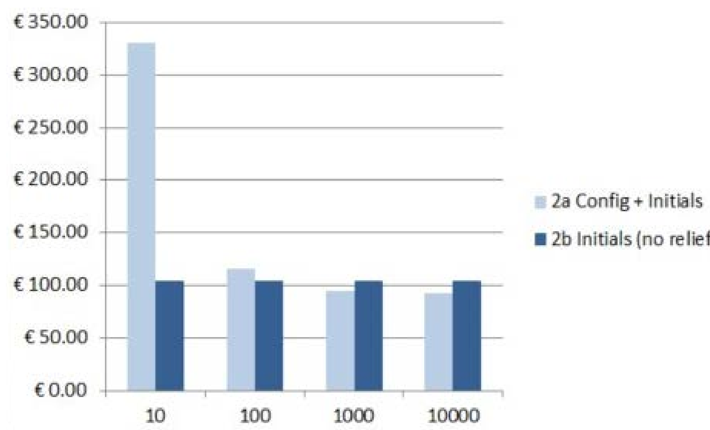
Comparison 2: Relief VS Paint

For products with initials in relief one can wonder if the 3D-effect is worth paying extra for when Royal Delft produces many products with hand-painted letters. In this analysis a tray with 4 initials and two wedding rings in relief (fig. 101) was compared to its imaginary flat counterpart. This latter product can be handpainted on existing biscuit, and requires no investment costs whatsoever. The question is how expensive it is to add relief, and if that price difference is worth the effect.



101. Example product for comparison 2

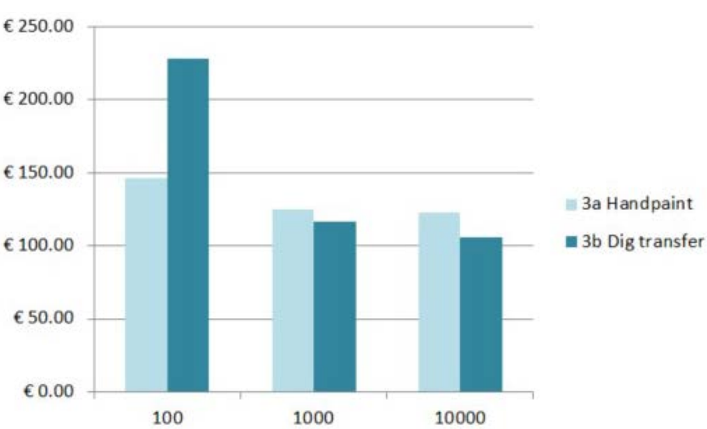
The calculations show that for less than 10 pieces the price difference is ludicrous, but after 100 units are sold it stabilizes(fig. 102). In the end the relief is a bit cheaper than handpainting on flat biscuit, because it takes less time to colour in a few items than to align the text first in charcoal and then paint it.



102. Cost per product for different series sizes (horizontal axes)

Comparison 3: Handpainted VS Digital Transfers

A third comparison was made between handpainted reliefs and digital transfers, using a new example product (fig. 103). As digital transfers enable design to be used once without the investment costs of a screen-print installation, Royal Delft is strongly considering to buy a digital transfer-machine. Its investment costs are high: €10.000, but its applications are numerous. Once over 1000 products (trays or others) are sold its investment will pay itself back.



104. Cost per product for different series sizes (horizontal axes)

103. A possible custom relief invoice

Investment Advice

Considering the stats above the conclusion seems to be that handpainting is cheapest for series size below 100, and after that transfers or digital transfers win terrain with each sale. As it is expected that this number is exceeded (for such a variety of possible clay shapes) investing in transfers is advised. Also, current transfers can be re-used if they fit the module format well enough, for example individual Schiffmacher or Wunderkammer decorations (fig 105).

As for the rest of the cost analysis the investment costs seem to be relatively litte. An FDM-printer, for example a Prusa, is cheap (€750), and once mold casings are milled from modeling foam instead of 3D-printed it is expected that

Based on the costs of 3D-printers, milling and milling materials, and based on my own experience with preparing the models for the casings I expect the investment costs to be between 2000-3000 euros (printer + obumodulan + milling costs), and the work of setting up the 3D-models, ordering the milled parts and preparing the casings to be 2-4 work weeks.

With the expected translatability to different shapes this is a relatively minor investment, although it should be noted that for each shape added to the collection (for instance a round plate with relief modules) a new plaster casting casing needs to be developed. This will be elaborated further on in the next chapter on translatability.

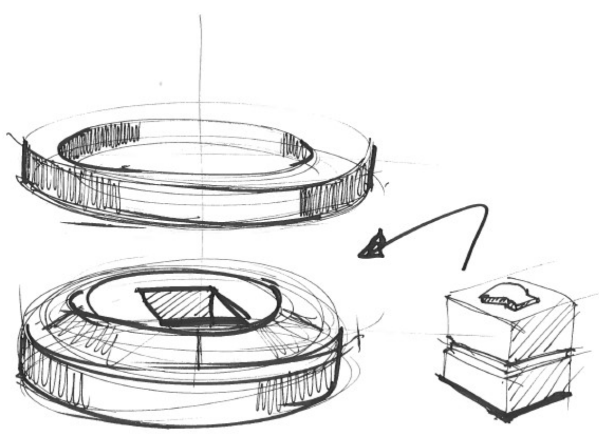
105. Stand-alone transfer applicable to multiple products

12. Future Prospects

While the initial aim was to develop a new mold making approach, the past chapters have been mainly concerning implementation of the showcase product: the tray. A proof of concept for a mold system was prototyped for this specific product, but the question remains how this production approach is valuable for future endeavours. This chapter sketches some possible variations on the new mold making approach to explore the translatability potential for future projects.

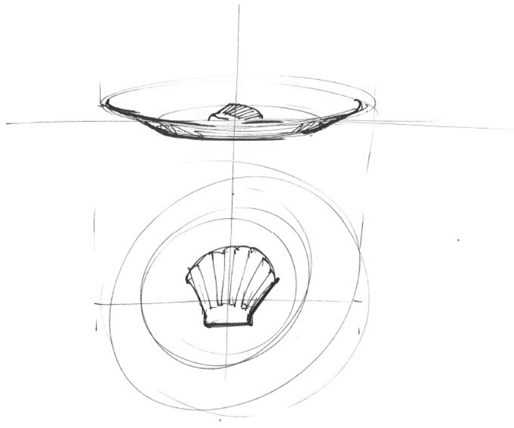
Stage 1: All Flat Shapes

A first step is to create a few basic plate shapes that can be customized with inserts. A square tray, a few round plates and an applique with a curvy edge will be a good start. Having modular molds ready for these applications makes it more appealing for clients to order a special object which has a 2D paint decoration, and as an added bonus a relief detail. Many delftware manufacturers make 2D-decorations (ranging from pretty to rather tasteless), but adding the relief could be a unique touch by royal Delft. The plate below for example can easily be enriched with a relief globe or mushroom-robot (fig. 108).



106. Mold ideation with insert

108. A modern, elaborate painting design for a company

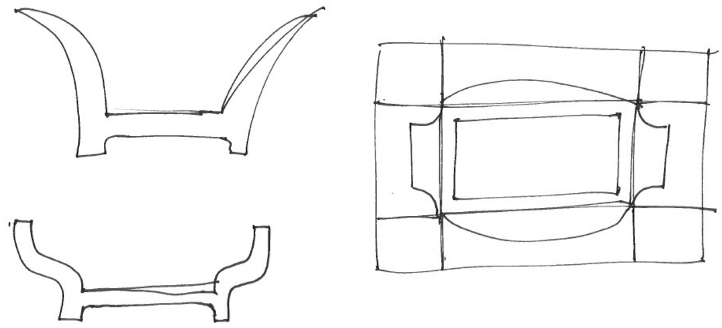


107. Side and top view of Shell-plate

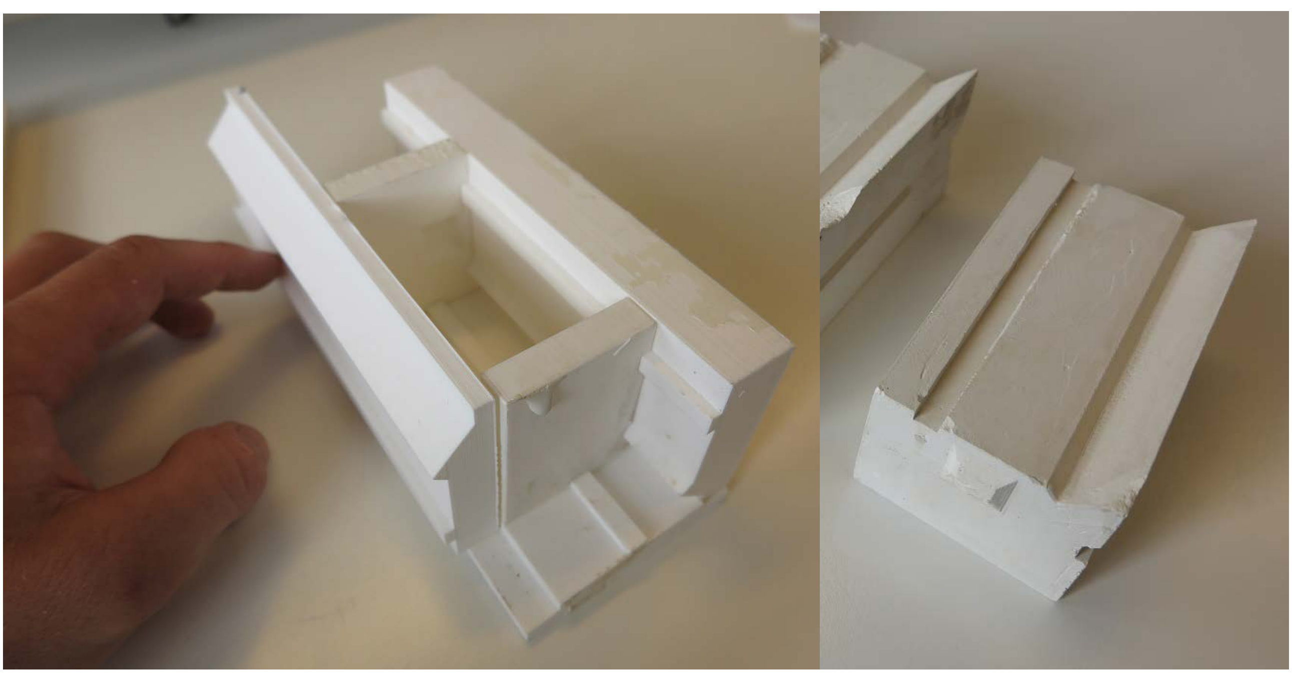
Stage 2: Contours

Also part of stage 1 could be to add freedom in brims. As the edge parts of the mold are modular these can be easily replaced to change the contour of the cross-section of the tray, or to change the overall shape (fig. 109).

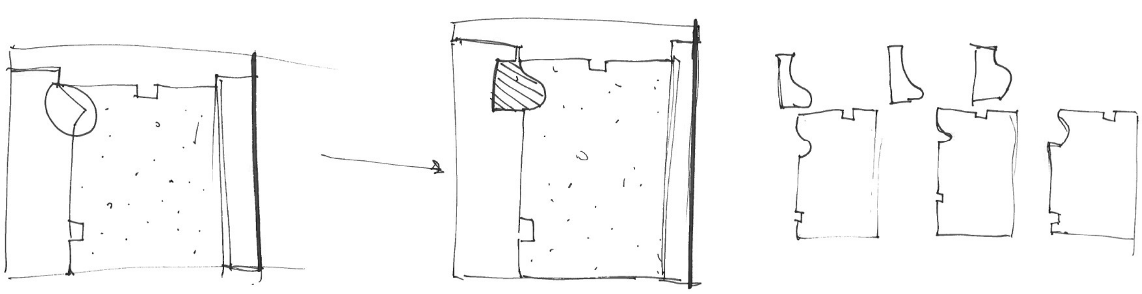
As only the edge part of the plaster casting is reflected in the clay body (fig. 110), much of the modular casting casing can be kept, where changing a small insert can directly change the contour (fig. 111).



109. Cross-section (left) and top view (right)



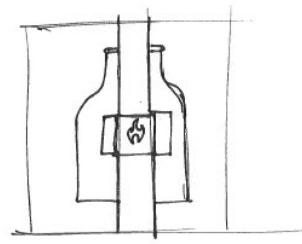
110. PLA casing (left) and plaster cast (right)

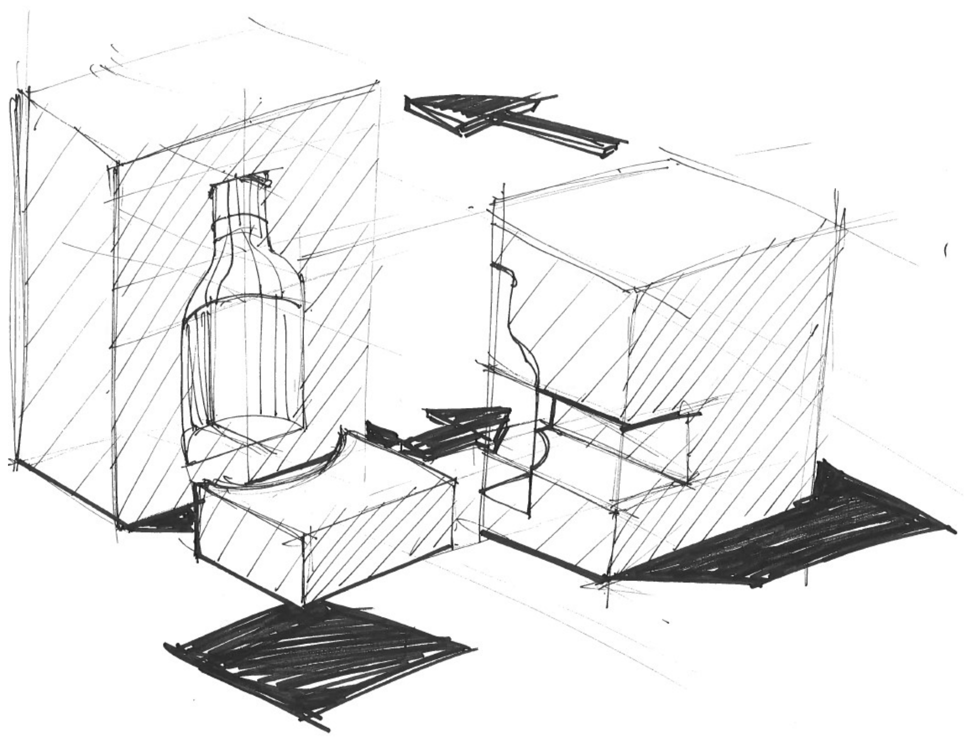


111. Effective contour (left, circled), can be replaced with an insert (hatched) and a 3D-printed side plate (right)

Stage 3: Inserts in vases

Then, once this modular system has become common practice, it can be easily integrated into existing molds, to enhance more geometries with a personalized insert (fig. 112). Such designs have already been produced for Kubo and Skully (figs. 113 & 114), and can now be offered for smaller series sizes and lower prices.





112. Impression of mold assembly

113. Kubo greenhouse

114. Skully Bottle

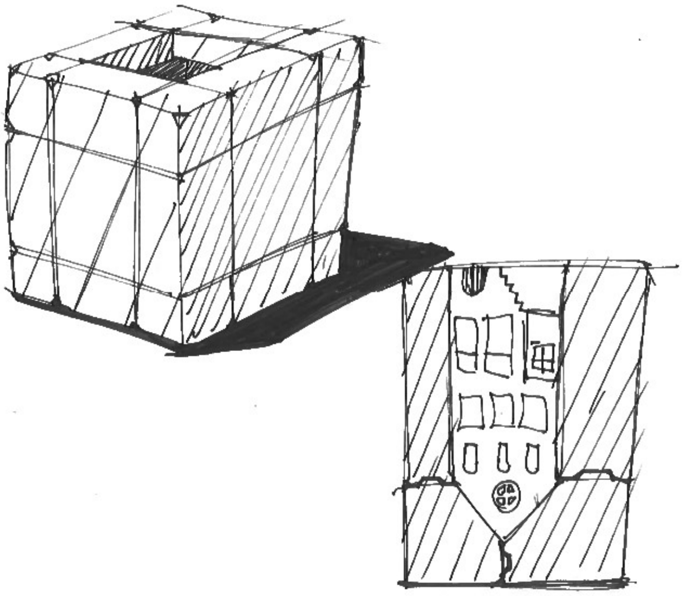
Stage 4: 2D grid to 3D

Once the production system is properly integrated throughout the entire organisation one can start thinking about fully modular production molds. For simple shapes this is less of an issue, as is demonstrated by some ceramists already (figs. 115 & 116). Creating a Lego-like casting mold however still remains a big step. This can only take place once issues with tolerances between mold parts, structural integrity of the entire assembled mold and emptying slip from these assembled shapes is thoroughly integrated.

The translatability potential of 3D printed mother mold parts in which plaster casting molds can be directly poured is high. In the future houses can possibly made just off a few photos from the outside (fig. 117), provided that the digitization step and the 3D computermodel are sufficiently advanced by then to seemlessly switch from pictures to printed mothermold parts.

115. Modular lampshade mold. Image: Philip Cuttance

116. Vases from modular molds. Image Dezeen



117. Impression of mold assembly

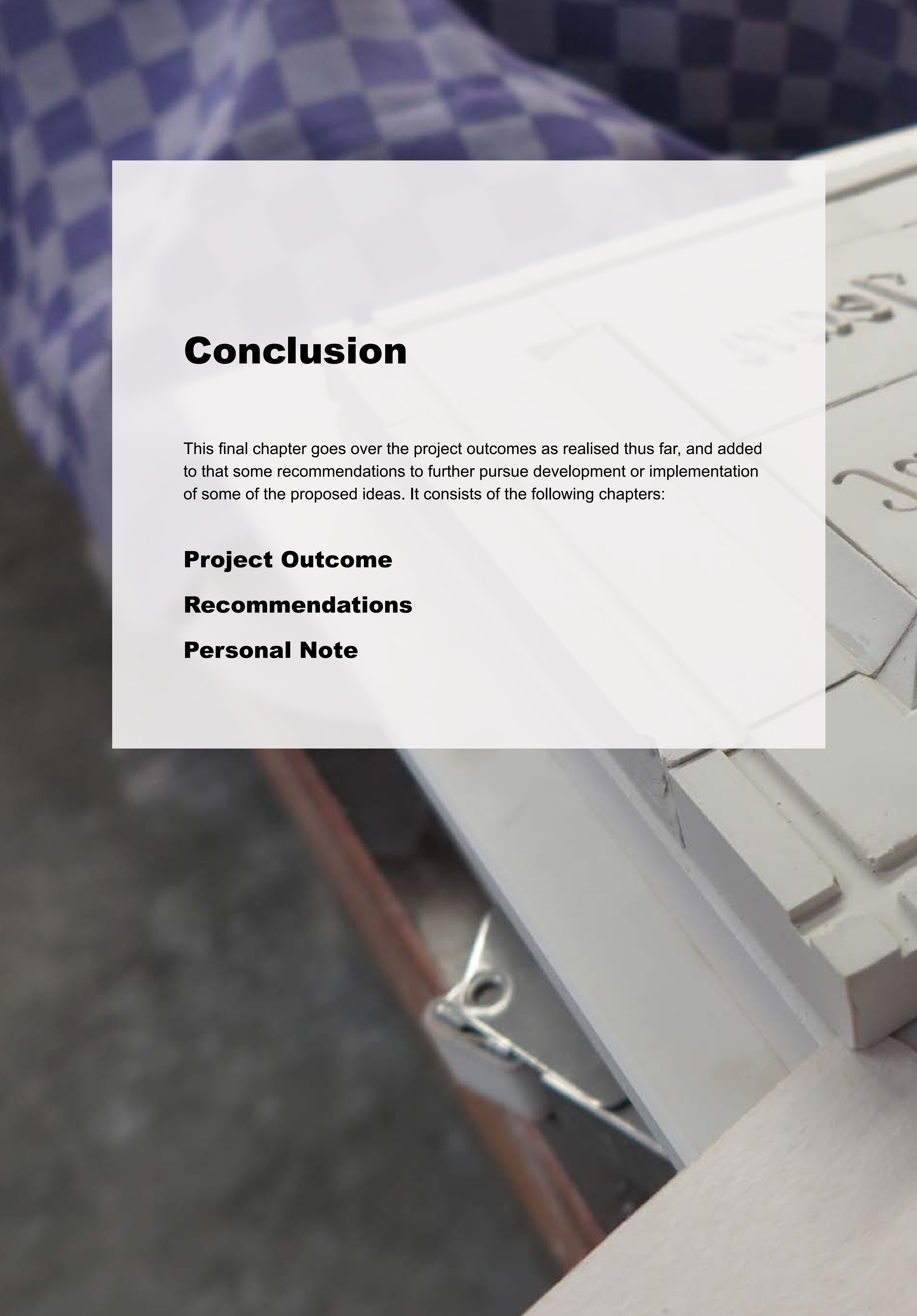
Realisation Summary

Ch. 9 The original starting point of the project was the mold system. This system was developed from a concept product to a functioning embodiment, with several iterations. Not all combinations of materials and joint systems were equally succesful, but some clay bodies were produced with sufficient potential for further production.

Ch. 10 The user end of the story was visualised digitally and tested with four participants. The interface presented is a first design proposal that will require iterations based on programming possibilities and effectiveness of the website.

Ch. 11 From the cost build-up it became clear that transfers are an interesting price-option from series sizes above 100, which is not a surprise. What is interesting, however, is that the relief trays in terms of production do not exceed common hand-painted custom objects, making it a desirable feature added for a negligible price. The painters may even be aided through the relief, fastening the process. Also, the future will demonstrate the full potential of an in-house digital transfer machine.

Ch. 12 Ultimately some more future prospecting was performed, sketching freely the categories of products that can step-wise be enriched with the modular molding system.



Conclusion

This final chapter goes over the project outcomes as realised thus far, and added to that some recommendations to further pursue development or implementation of some of the proposed ideas. It consists of the following chapters:

Project Outcome

Recommendations

Personal Note

Conclusion

Project Outcome

Result

This graduation report presented a proposal for a new mold making approach for Royal Delft. The traditional production trajectory starts with a positive model and pouring plaster mold parts onto it one by one, producing a negative casting mold for one shape. This new proposal takes the plaster mold parts as a starting point, combining them into a modular system that can be modified continuously in order to produce many variations of a shape without starting from scratch for every new shape. The benefit of this approach is that shapes such as plates, vases and boxes can be quickly tailored to individual customers, changing elements, adding personal texts and creating custom vector reliefs.

Demonstration

The application of the method was communicated through a showcase product, namely a tray for personalized belongings. By choosing this approach the project became a combination of production design and product design, as it was required to demonstrate that the production proposal is actually applicable to concrete products Royal Delft could produce.

Validation

This demand put more emphasis on the product, as it had to be convincing in terms of producibility with the new mold system, desirability for future Royal Delft consumers and viability regarding the business model behind the product. These three aspects were developed further, with the following results.

A mold system was created to produce trays with inserts successfully. Currently the prototype is limited to two sizes of trays and a handful of inserts, where most modules had a successful clay body release. This was not the case for the entire shape; when the design is made less geometric and the edges smoother the odds of producing a non-torn clay body increase rapidly, which is an easy step in further testing the concept.

A digital user interface to configure and order a tray online was prototyped ant tested for clarity and ease of understanding with four participants. Most participants experienced the tasks as clear and found the interface convincing. However, as the actual envisioned interface is rather programming-heavy to produce it is difficult to estimate if users will be equally successful in ordering a tray as they think they are now. The physical equivalent proposed where visitors to the shop can interact with plaster mold pieces to configure their tray and get to know the technology behind it has not yet been tested.

The business case was validated through comparing several scenarios, thus highlighting the impact of certain production decisions on the price. It was found that transfers, as is generally the case, can save a significant amount of production costs if the series sizes are big enough. It was also noted that the relief is a relatively affordable feature that can even help guide the painting process, and is therefore potential to be implemented in various products.

Recommendations for further development

Product Design

It was briefly mentioned earlier, but the current geometric shape and rough surface quality of the mold parts complicate successful clay body release significantly. These features are merely there as a side-effect of the rapid prototyping process and can be easily improved. The painting effects will be tested further in the following week, and shall be presented during the final presentation. This will give a concrete sample to reflect on when considering the effect of painting versus pipetting.

Mold Design

Directions for reducing the amount of gaps can be inspired by traditional mold making techniques: using less mold parts and pouring plaster directly onto other mold parts, ensuring a perfect fit. These directions were not pursued further in this thesis.

Possibly it does not work for bigger trays at the moment. Difficulties could arise in the structural stiffness if there is too much overhang for the leather-hard clay body to remain intact. Alternatively, adding up tolerances from multiple modules may bring problems with assembling the mold (for reference, in theory the biggest size could be filled with 16 modules of 48x68). This could mean that the design of the bottom of the tray needs to be improved.

Business

Although the production cost build-up seems promising it is difficult to estimate now how successful the first clay bodies will be in practice. If the amount of effort by the design department or mold maker is significantly higher than established now, due to re-prints or extensive digital touch-up, this can completely upset the viability of the product. It is therefore advised to start with internally defined modules and initials, as those shapes are known to be producible. Once the complexity of this step has been mastered by the company expansion towards custom vectors can be tried, investing in seamless 3D-modelling software algorithms is highly advised to reduce labour and increase the chance of success.

Another business-related discussion point is whether the project can it be understood as a stand-alone money-making product, or should its value also be understood in terms of developing the modular platform, or in terms of improving the image of Royal Delft? Potentially it is a good showcase in the museum, or elsewhere, like the tile-painting robot. For an organization as diversely active as Royal Delft it is not always clear beforehand where the added value of a development will lie in the future, which is why it remains something to reflect on.

Knowledge Management

While not being an explicit topic after the analysis phase there is some things to say about knowledge management. The mold maker gets an apprentice, but reliance on tacit knowledge remains an issue as most other professions (firing, glazing, sponging) consist of 1-2 employees that are 50 or above. Future knowledge loss and miscommunication can possibly be reduced, mainly by focussing on the Externalization and Combination segments, as the current inaccessibility to information leads to errors. Some suggestions:

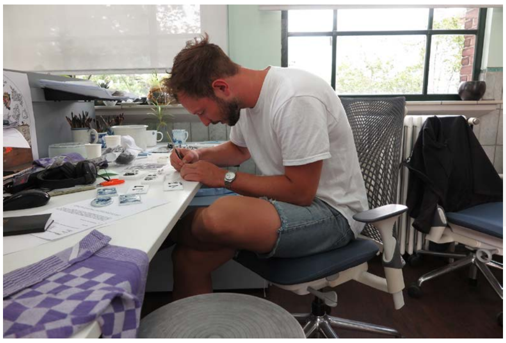
1. A unique identifier per object with a digital twin can help keep track of every step of the process, but attaching some sort of identifier can be a challenge. A stricter physical separation of workstations may aid in keeping similar-looking things apart.

2. Gathering and saving data during each step of the process may help, but it should be avoided that employees spend more time putting numbers in spreadsheets than producing ceramics.

3. “Better communication” sounds good, but what does it mean in practice? More recurring meetings; printed information sheets with new production trajectories; tablets with Trello-boards that can be accessed?

In any case the awareness within the company that some processes could use more knowledge management (in various ways) has increased over the past months. I am curious and excited to see how the mold making and production processes will develop over the next years.

Personal Note



In this final section I want to express my appreciation and enjoyment throughout the project. For me the setting, especially considering the second year of the pandemic, was close to perfect, and during this time in life that is tough for most of my peers I was very lucky to be able to work in an office, on an interesting project, surrounded by skilled and kind people.

While some of my fellow students were allowed to be on the third floor of the faculty one day a week to prepare their slides for their monthly digital interaction with a client in another country, I was being sent away by the security guard for days in a row while I was producing some more plaster mold parts before dinner, smiling.

When discussing graduation with others the topic of Delft Blue was met with sympathy, but often also with scepticism, disinterestedness or laughter. I occasionally wondered myself why I would rather spend time creating more plates that no-one I know really needs or can afford. Why was I not working on a topic more urgent and fashionable at our faculty right now: developing a new online collaboration tool, a co-creation canvas for different stakeholders in municipalities, a medical innovation or a smart wearable combining IoT with AI?

On the other hand, everyone seemed slightly jealous that they were not working on tangible luxury products and real production processes. A part of me also believes or hopes that overconsumption and climate change will backfire at our growth-based system and change the economy towards one more focused on meaning-giving products that we remain connected with and want to repair.

From this perspective the traditional factory is not outdated and slow but an institute ready for the future: a production space where history and skill create meaningful jobs, and personal interactions with visitors. We may currently not be in need of more delftware, but we are definitely not in need of more throw-away ceramics that are flooding the thrift-shops. For all these reasons I am still very happy to have chosen this project.

My only wish is that the end was less rushed, I feel satisfied with the amount of work produced, but my conclusions could have been sharper with a week of reflection between this version of the report and an updated one. The upside is that I managed to graduate in 20 weeks exactly, and I stuck to that deadline, despite the tendency to always want to do more, a characteristic of most designers. I am also very aware of the fact that I chose to produce the entire clay shape, although this was strictly speaking not completely necessary to deliver a proof of concept. I am happy I did it anyway, not because now I can take home so many beautiful Delft Blue objects (they are fairly broken), but by going through the entire cycle of mold making, casting, sponging, painting and firing twice I learned more about the difficulties of ceramic production than I would have, had I stopped at the mold.

I want to thank the three of you, Joffrey, Joris and Sander for giving me the freedom to experiment and to play, but also questioning my actions when the surplus of enthusiastic activity lacked structure.

Appendices


BLAAUW
EPEQUIP
ORDER NR : 54190360
ROYAL
DELFT
1653
FRAGILE
USE NO HOOKS
P.O.E
C/T NO :78 OF 168
BREEKBAAR
SERVIES.NL

Appendix A - References

Articles

Nonaka, I., Toyama, R. (2003). *The knowledge-creating theory revisited: knowledge creation as a synthesizing process.*

I-Scoop, (2021). *Industry 4.0 and the fourth industrial revolution explained*. Retrieved from https://www.i-scoop.eu/industry-4-0/

Tilton, B., Dobner, E., and Holdowsky, J. (2017, Nov 9). *3D opportunity for standards.* Retreived from https://www2.deloitte.com/us/en/insights/focus/3d-opportunity/additive-manufacturing-standards-for-3d-printed-products.html

Verbunt, B. (2018, Oct 19). *De weg naar Smart Customization*. Retrieved from https://www.linkedin.com/pulse/de-weg-naar-smart-customization-bas-verbunt/?originalSubdomain=nl

Books

Van Boeijen, A.G.C., Daalhuizen, J.J., Zijlstra, J.J.M. and van der Schoor, R.S.A. (eds.) (2013). *Delft Design Guide*. Amsterdam: BIS Publishers.

Thompson, R. (2007) *Manufacturing Processes for Design Professionals.* London: Thames & Hudson.

(Van Erkel, 2013)
Van Erkel, J. (2013). *De Koninklijke Porceleyne Fles*. Amersfoort: Bekking & Blitz Uitgevers B.V.

Online

www.royaldelft.com

https://miro.com/app/board/o9J_lK4amoI=/
e-mail the author for the password @ y.heesakkers@gmail.com

Human Beings

Edo Anceaux, Jenneke van der Ende, Huib van der Ende, Peter van den Ham, Bob van Schie, Frank Verhoeven, Joffrey Walonker

Appendix B - Cost Calculation

Plaster	0.321	€/kg		
Slip	0.7	€/kg		
PLA	19.5	€/kg	@	123inkt.nl
Resin	200	€/kg	@	TU Delft
Time (factory)	2	€/minute		
Time (painting)	1	€/minute		
Time (office)	1	€/minute		
Firing	200	€/oven		

Overview of material costs and production costs

Transfereren							
Transfer extern (4 kleuren blauw)	opstartkosten	1200	€				
	100 vellen (60x40cm)	12.5	€/vel		0.005	€/cm^2	
	500 vellen (60x40cm)	5	€/vel		0.002	€/cm^2	
transfer digitaal	1 vel (40x30)	15	€/vel		0.0125	€/cm^2	
transfer digitaal intern (toekomst)	1 vel (40x30)	7.5	€/vel		0.00625	€/cm^2	
Schilderen		cm^2		min			
Initiaal deboss 3x2cm	3x2cm	6		2	min	0.33333	€/cm^2
Schiffmacher decoratie (met ponsief)	5x5cm	25		10	min	0.4	€/cm^2
Rand peterselie	70cmx2cm	140		30	min	0.21429	€/cm^2
Kraftwerk gezicht 1 laag	10x14cm	140		20	min	0.14286	€/cm^2
Portret gezicht 2 laags	10x14cm	140		25	min	0.17857	€/cm^2
strepen lang 7 stuks	11x7	77		14	min	0.18182	€/cm^2

Overview of decoration costs (transfers + handpainted)

	Stage	1. Pre-production			

Scenario 1a Config Handpaint

Configured plate (glasses+stripes)		Printing all inserts	Printing all casting casings	-	-
Handpainted					
Material weight		-	-		
Material costs		-	-		
Production time		-	-		
Production costs		-	-		
	buy printer				
Investments (materials, objects)	1	1	2		
Investment costs	400	19.5	39		
Investment time costs		480	480		

Scenario 1b Config Transfer

Configured plate (glasses+stripes)		Printing all inserts	Printing all casting casings	-	-
Transfer					
Material weight		-	-		
Material costs		-	-		
Production time		-	-		
Production costs		-	-		
	buy printer				
Investments		1	2		
Investment costs	400	19.5	39		
Investment time costs		480	480		

Scenario 2a Config + Initials

Configured plate (initials)		Printing all inserts	Printing all casting casings	Model initials insert	Print initials insert
Handpainted (hard to transfer)					
Material weight		-	-	-	0.02
Material costs		-	-	-	4
Production time		-	-	5	-
Production costs		-	-	10	-
	buy printer				
Investments		1	2		
Investment costs	400	19.5	39		
Investment time costs		480	480		

Scenario 2b Initials (flat)

Configured plate (initials - non relief)		Printing all inserts	Printing all casting casings	Model initials insert	Print initials insert
Handpainted					
Material weight		-	-	-	0.02
Material costs		-	-	-	4
Production time		-	-	5	-
Production costs		-	-	10	-
Investments					
Investment costs					
Investment time costs					

Scenario 3a Config Custom Handpaint

Configured plate with custom insert		Printing all inserts	Printing all casting casings	Model custom insert	Print initials insert
Handpainted					
Material weight				-	0.05
Material costs				-	0.975
Production time				20	5
Production costs				20	5
Investments	FDM-printer	1	2		
Investment costs	400	19.5	39		
Investment time costs		480	480		

Scenario 3b Config Custom Transfer

Configured plate with custom insert		Printing all inserts	Printing all casting casings	Model custom insert	Print initials insert
Digital Transfer (if possible)					
Material weight				-	0.05
Material costs				-	0.975
Production time				20	5
Production costs				20	5
Investments	FDM-printer	1	2		
Investment costs	400	19.5	39		
Investment time costs		480	480		

		2. Clay Body Production				3. Bisque Firing	
Casting all mold modules	Casting all mold sides	Assembling Mold	Slip Casting	Sponging	Engobing	Loading Oven	Firing
-	-	-	1	-	0	-	-
-	-	-	0.7	-	0	-	-
-	-	5	10	7	2.4	1	-
-	-	10	20	14	4.8	2	5
1	0.5						
0.321	0.1605						
480	480						

Casting all mold modules	Casting all mold sides	Assembling Mold	Slip Casting	Sponging	Engobing	Loading Oven	Firing
1	0.5	-	1	-	0	-	-
0.321	0.1605	-	0.7	-	0	-	-
-	-	5	10	7	2.4	1	-
-	-	0	20	14	4.8	2	5
1	0.5						
0.321	0.1605						
480	480						

Casting all mold modules	Casting all mold sides	Assembling Mold	Slip Casting	Sponging	Engobing	Loading Oven	Firing
-	-	-	1	-	0	-	-
-	-	-	0.7	-	0	-	-
-	-	5	10	7	2.4	1	-
-	-	10	20	14	4.8	2	5
1	0.5						
0.321	0.1605						
480	480						

Casting all mold modules	Casting all mold sides	Assembling Mold	Slip Casting	Sponging	Engobing	Loading Oven	Firing
-	-	-	1	-	0	-	-
-	-	-	0.7	-	0	-	-
-	-	5	10	7	2.4	1	-
-	-	10	20	14	4.8	2	5

Casting mold modules	Casting mold sides	Assembling Mold	Slip Casting	Sponging	Engobing	Loading Oven	Firing
0.1	0.5	-	1	-	0	-	-
0.0321	0.1605	-	0.7	-	0	-	-
		5	10	7	2.4	1	-
		10	20	14	4.8	2	5
1	0.5						
0.321	0.1605						
480	480						

Casting all mold modules	Casting all mold sides	Assembling Mold	Slip Casting	Sponging	Engobing	Loading Oven	Firing
0.1	0.5	-	1	-	0	-	-
0.0321	0.1605	-	0.7	-	0	-	-
		5	10	7	2.4	1	-
		10	20	14	4.8	2	5
1	0.5						
0.321	0.1605						
480	480						

4. Decoration		5. Glaze firing		Total Costs	
Painting	Glazing	Firing			
-	0	-			
-	0	-		0.70 €	Material costs
34	2.4	-			
34	4.8	5		99.60 €	Process costs
				100.30 €	Product total
				458.98 €	Investment material costs
				1,920.00 €	Investment process costs
				2,378.98 €	Investment total
-	Glazing	Firing	Transfering + firing		
-	0	-	127		
-	0	-	0.635	1.82 €	Material costs
-	2.4	-	10		
-	4.8	5	10	65.60 €	Process costs
				67.42 €	Product total
			1200	1,658.98 €	Investment material costs
				1,920.00 €	Investment process costs
				3,578.98 €	Investment total

Painting	Glazing	Firing			
-	0	-			
-	0	-		4.70 €	Material costs
12	2.4	-			
12	4.8	5		87.60 €	Process costs
				92.30 €	
				458.98 €	Investment material costs
				1,920.00 €	Investment process costs
				2,378.98 €	Investment total
Painting	Glazing	Firing			
-	0	-			
-	0	-		4.70 €	Material costs
24	2.4	-			
24	4.8	5		99.60 €	Process costs
				104.30 €	
				0.00 €	Investment material costs
				0.00 €	Investment process costs
				0.00 €	Investment total

Painting	Glazing	Firing			
-	0	-			
-	0	-		1.87 €	Material costs
30	2.4	-			
30	4.8	5		120.60 €	Process costs
				122.47 €	
				458.98 €	Investment material costs
				1,920.00 €	Investment process costs
				2,378.98 €	Investment total
-	Glazing	Firing	Transfering + firing		
-	0	-	140		
-	0	-	1.75	3.62 €	Material costs
-	2.4	-	10		
-	4.8	5	10	100.60 €	Process costs
				104.22 €	
			10000	10,458.98 €	Investment material costs
				1,920.00 €	Investment process costs
				12,378.98 €	Investment total

TU Delft

DESIGN FOR our future

Appendix C - Project Brief

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT
Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Heesakkers 4916
initials: J.F. given name: Yannic
student number: 4354273
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):
IDE master(s): ★ IPD ◯ Dfl ◯ SPD
2nd non-IDE master: -
individual programme: - - (give date of approval)
honours programme: ◯ Honours Programme Master
specialisation / annotation: ◯ Medisign
◯ Tech. in Sustainable Design
◯ Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: A.L.M. Minnoye (Sander) dept. / section: SDE / Mechatronics
** mentor: J.J.F. van Dam (Joris) dept. / section: SDE / Tech Support
2nd mentor: Joffrey Walonker
organisation: Royal Delft Group
city: Delft country: The Netherlands

comments (optional): The expertise and experience of chair and mentor are complimentary. Where Sander is knowledgeable in production processes, embodiment and agile manufacturing, Joris' expertise is digital manufacturing, robotics & industry 4.0

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair A.L.M. Minnoye (Sander) date 30 - 03 - 2021 signature

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: 30 EC

Of which, taking the conditional requirements into account, can be part of the exam programme 30 EC

List of electives obtained before the third semester without approval of the BoE

★ YES all 1st year master courses passed

NO missing 1st year master courses are:

name J. J. de Bruin date 14 - 04 - 2021 signature J. J. de Bruin, SPA Digitally signed by J. J. de Bruin, SPA Date: 2021.04.14 09:09:16 +02'00'

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: ★ APPROVED NOT APPROVED

Procedure: ★ APPROVED NOT APPROVED

- advice: add pottery at the end of the title

comments

name Monique von Morgen date 28 - 04 - 2021 signature

Future-proofing the mold-making process for Royal Delft

project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 22 - 03 - 2020

15 - 08 - 2021 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

Royal Delft (dutch: De Porceleyne Fles) is the last manufacturer of delftware to still produce this day. Delft blue is a well-known, traditional luxury product, that has been around since 1650, although the number of factories and the production volume has declined significantly over the last century. The question rises how Delft blue in general and Royal Delft in particular can innovate their activities to position itself in the future, both in terms of technical production as brand identity. Currently some examples of this innovation taking place are collaborations with artists for 3D-designs and paintings, the production of custom ordered ceramic work, as well as the exploration of advanced manufacturing solutions for painting decorations.

As some aspects of the production process build on techniques that are several centuries old, there are certainly opportunities to enhance the current factory with tools and methods belonging to industry 4.0. For this specific project the mold making process is analysed and improved. Traditionally this process is both labour and knowledge intensive, as the design of a high-quality mold is currently done by a craftsman with decades of experience. This expert decides on the number of mold parts, the build-up and assembly of the mold, the necessity for a base-mold (moedermal), and also on slight design changes that are necessary to enable release of the poured ceramic from the plaster mold.

Advanced manufacturing techniques, such as 3D-printing, CNC-milling, 3D-scanning and parametric modelling are slowly entering the ceramic industry, for instance by 3D-printing the initial model, as opposed to using traditional production techniques. This graduation project aims to analyse the current mold making process, identify opportunities to use industry 4.0 technology and implement these opportunities to validate and improve their impact.

space available for images / figures on next page

introduction (continued): space for images

image / figure 1: Molds and half-fabricates at Royal Delft (image courtesy of Royal Delft)

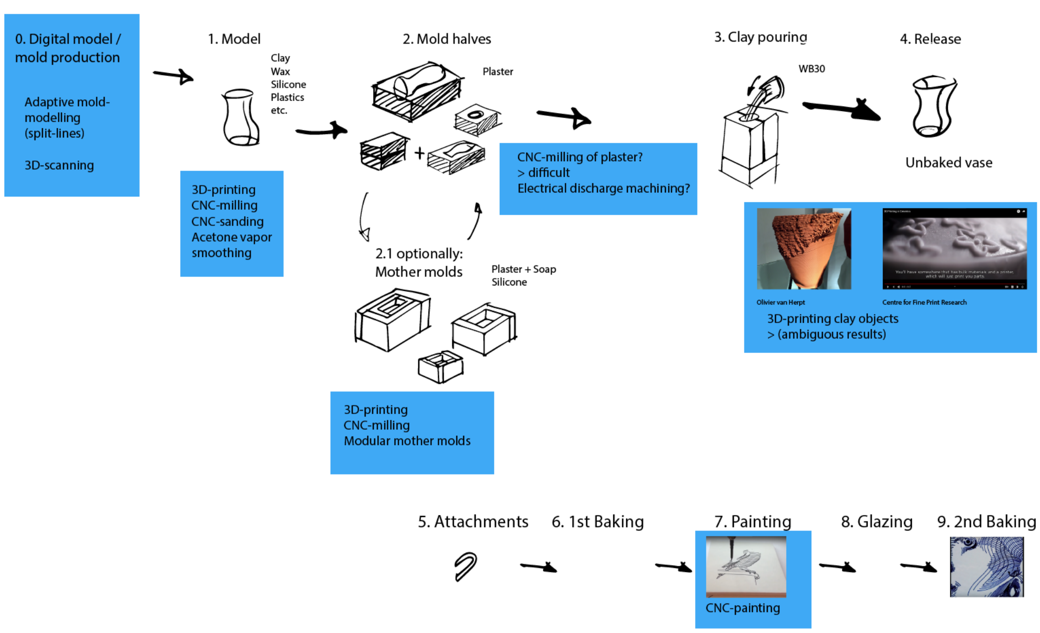


image / figure 2: Opportunities (blue highlighted) in different aspects of the mold-making process

Initials & Name J.F. Heesakkers 4916 Student number 4354273

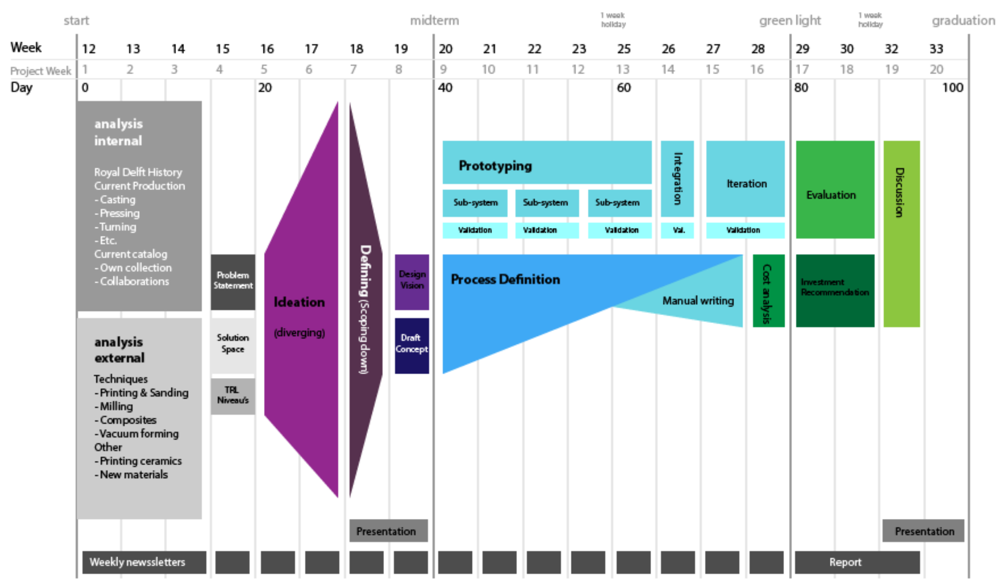
Title of Project Future-proofing the mold-making process for Royal Delft

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 22 - 3 - 2020

15 - 8 - 2021 end date



Initials & Name J.F. Heesakkers 4916 Student number 4354273

Title of Project Future-proofing the mold-making process for Royal Delft

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

Currently Royal Delft produces ceramic products with pressing molds (e.g. plates), turning molds (e.g. bowls) and casting molds (e.g. vases). This project focusses on the casting molds, as this production method allows for the biggest variety of shapes, and combines complex, large shapes with fine details so typical of ceramic designs. However, compared to the other mold-types, casting molds require the most effort in creation, and as they have a rather short lifespan (60-90 cycles) molds need to be reproduced often.

The mold making process entails several complex steps, namely making the initial designed shape suitable to be casted succesfully, the design and production of a functioning casting mold, and the design and production of mother molds with which new casting molds can be created. These actions rely heavily on the knowledge and skill of one craftsman, which means that the process is dependent on expertise that is slowly disappearing.

In order to preserve the capacity to produce competitively in the future it is advised to digitalize some parts of the moldmakers knowledge, and shape it into a novel production approach that is up to date with modern standards, and in line with developments of work in the future. In doing so Royal Delft can continue to produce new designs and modern, novel shapes, while also enabling collaboration with external artists and designers.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

This project will research the opportunities for digital production in the mold making process and design a new production approach for a category of Royal Delft products, adding to the existing product catalogue and production methods.

The first part of the process consist of an internal analysis into the production processes and working methods of Royal Delft, and external research into companies and developments related to digital production (3D-printing, CNC-milling, CNC sanding), mold systems and processes, and material properties (surface quality, water absorbtion). In this step, products and production-steps are categorized and opportunities are evaluated to determine which steps of the process can be modernized yielding most impact.

These directions will be explored, adapted and validated through iterative prototypes. This will lead to a proof of concept of the suggested method, demonstrating that some category of Royal Delft products can succesfully be produced by this novel production approach. This toolbox for digital fabrication features new production methods, which may bring new design features in terms of joinery, modularity and product shape.

Deliverables
- An analysis report on the current mold making process, also indicating opportunities.
- An 'instruction manual' or overview of the newly proposed approach, indicating how the digital toolbox can be applied.
- Physical prototypes demonstrating the technical feasibility of the most critical/novel steps of the proposed method.

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

Personal development / Competences
1. A first personal reason for Royal Delft is related to the material: delftware. Ceramics are underrepresented in our education programme, which focuses primarily on plastics, metals, and occasionally wood, while everyone is familiar with and appreciates well-made tableware, sanitary products and constructive elements (glazed bricks, rooftiles). This project gives me the opportunity to get more familiar with this omnipresent, classical material and its production process.

2. A second reason for defining this specific project is that it combines a classical material with its production techniques and new developments in advanced manufacturing in a meaningful way. When applied with care, I think there is the opportunity for digital manufacturing techniques to prove themselves necessary to keep a craft alive, that they are more than a hype, that they increase freedom and producibility, without giving in to quality. I want to learn more about this range of developments named 'Advanced manufacturing' or 'Industry 4.0', especially applying parts of them in a real production line.

3. As graduation is the lengthiest and most individual project of my studies so far, I am the main party responsible for working effectively and planning properly. This is something I want to work on, in order to make decisions about directions and useful activities in time instead of too late.

My ambitions, briefly summarized:
- Learning about ceramic production
- Getting better acquainted with novel production techniques, and attempting to implement them
- Delivering a proof of concept of a mechanism/technical (sub)function
- Experiencing how it is to work closely with/for a production company
- Learning how to select the right design tools for a technical innovation project

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

2021
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DIMENSIONS:
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The End

Future proofing the

mold making process

for Royal Delft ceramics

J.F. Heesakkers, 2021