Design of a New Toilet Cistern for the Replacement Market

ÅSA JACOBSSON

MASTER OF SCIENCE PROGRAMME
Ergonomic Design & Production Engineering
Luleå University of Technology
Department of Human Work Sciences
Division of Industrial Design
Foreword

This is the written report obtained after having done my Master Thesis at Caroma Industries Limited under the supervision of CAMR (The Centre for Advanced Manufacturing Research), UniSA (University of South Australia). This is the final project for my Master of Science degree in Industrial Design and Engineering at Luleå University of Technology.

The project involves the product development of a new plastic toilet cistern for the replacement market to be manufactured at Caromas manufacturing plant in Adelaide. The main objective of this report is to present the design of the cistern emphasizing on the styling but taken under consideration manufacturability, material properties and Caroma standard components. The report presents the whole design process: concept generation, concept selection, concept refinement and the making of a prototype of the final design.

I want to thank Caroma for the opportunity they have given me to do this project with them at their manufacturing plant in Adelaide. I especially want to thank my supervisor Jason Dorsey, the Project Development Manager and all the design engineers working at the R&D office at Caroma Norwood.
I also want to thank Bob Speedy at CAMR, UniSA, for all his help finding this project, giving me the possibility to get this experience. A special thanks to Sandy Walker at the Industrial Design department at UniSA.
I want to thank Åsa Wikberg, my tutor in Sweden for very useful inputs during the whole project.

Adelaide, Australia 2006-02-17

Åsa Jacobsson
Abstract

This thesis was performed at Caroma Industries Limited, Adelaide, Australia. Caroma is the leading manufacturers of toilets and bathroom accessories in Australia. One of their most popular products is the plastic toilet cistern, a cheaper alternative to the vitreous china cistern. Caromas plastic cisterns are very common in Australian homes and public bathrooms. All of their plastic cisterns are manufactured at Caromas manufacturing plant in Norwood, Adelaide, where they also produce other plastic components such as valves and toilet seats.

The main aim of this thesis is to present the product development and design of a new plastic cistern intended for the replacement market. The new cistern shall be big enough to cover the footprint of plastic cisterns out on the market, Caromas own brands and other producers. Caroma has got more than ten different models of plastic cisterns and they all got different footprints (the footprint is the wall area that the cistern covers). Some of the models are up to 30 years old and need to be replaced because of malfunction but also because of their old-fashioned styling. The old models are often very big and have got a big footprint. If a cistern has to be replaced the new cistern shall cover the footprint so that no marks, left by the old cistern, are visible on the wall and no further renovation is necessary. In order to optimize the required footprint, plastic cisterns were measured and charted.

This project will be emphasizing on the styling of a new cistern and its design. The cistern will consist of a tank, a lid, a connection plate and dual flush button setup.

The product development started with brainstorming and an ITK, Identity Tool Kit. The ITK was used to get a general idea about what style was wanted. Three concepts were generated and presented to the marketing division in Sydney. A concept was chosen by using systematic concept selection and after feedback from marketing.

The result of the project is a new plastic cistern that covers the required footprint and has a style that goes well with contemporary bathroom design as well as with older. It has a slim shape and looks proportional. The cistern has also got a shelf feature that allows placing objects on top. The button setup is designed as a rocker and adds a new type of button to the Caroma product range.

The new cistern design is presented with rendered CAD pictures and a full-scale prototype. A physical model is from a marketing point of view more convincing. It gives not only a visual experience but also a tactile.

When designing the new cistern, manufacturability has been taken into consideration. Knowledge about the processes and manufacturing techniques has improved the design, utilizing the properties instead of considering them as limitations.

This project will hopefully give Caroma inspiration to start manufacturing a new plastic cistern design.
# Table of Contents

1 Introduction .................................................................................................................. 7
  1.1 Project Background ................................................................................................. 7
  1.2 Main Aim ................................................................................................................ 8
  1.3 Assumptions and Constrains ................................................................................ 8
  1.4 Product Specifications ............................................................................................ 9
    1.4.1 Geometry .......................................................................................................... 9
    1.4.2 Manufacturing .................................................................................................. 9
    1.4.3 Material ........................................................................................................... 9
    1.4.4 Toilet Seat ........................................................................................................ 9
    1.4.5 Connection Plate .............................................................................................. 9
    1.4.6 Flush Buttons ................................................................................................... 9
  1.5 Product Analysis ...................................................................................................... 10
    1.5.1 Trends ............................................................................................................. 10
    1.5.2 Usage ............................................................................................................... 10
    1.5.3 Material ........................................................................................................... 10
    1.5.4 Manufacturability ............................................................................................. 10
  2.1 Manufacturing ......................................................................................................... 12
    2.1.1 Injection moulding ............................................................................................ 12
    2.1.2 Reciprocating-Screw Injection Machine ......................................................... 13
    2.1.3 Colouring ......................................................................................................... 14
    2.1.4 Laser ................................................................................................................ 14
    2.1.5 Hot stamping .................................................................................................... 15
    2.1.6 Prototyping ....................................................................................................... 15
  2.2 Manufacturing considerations .................................................................................. 16
    2.2.1 Wall thickness ................................................................................................... 16
    2.2.2 Sink marks ........................................................................................................ 16
    2.2.3 Undercuts ......................................................................................................... 16
    2.2.4 Rounds .............................................................................................................. 16
  2.3 Material ................................................................................................................... 17
    2.3.1 Thermoplastics ................................................................................................. 17
    2.3.2 Polypropylene ................................................................................................. 17
    2.3.3 ABS (Acrylonitrile Butadiene Styrene) ........................................................... 18
  2.4 About the toilet ....................................................................................................... 19
    2.4.1 Toilet Footprint ............................................................................................... 19
    2.4.2 How a toilet works ........................................................................................... 19
    2.4.3 Inner Components .......................................................................................... 19
    2.4.4 Water Saving ................................................................................................... 22
    2.4.5 The Half Flush ................................................................................................. 22
  2.5 Design Perception .................................................................................................... 23
    2.5.1 Shapes ............................................................................................................. 23
    2.5.2 Proportions ...................................................................................................... 23
    2.5.3 Fibonacci (The Golden Number) .................................................................... 23
4.7 Inner Components ........................................................................... 54
5 Result ........................................................................................................... 55

5.1 Product Requirements ............................................................................... 55
  5.1.1 Cover the Footprint ........................................................................ 55
  5.1.2 Connection plate ........................................................................... 56
  5.1.3 Toilet Seat .................................................................................... 56
  5.1.4 Flush Buttons ............................................................................... 56
  5.1.5 Manufacturing Considerations ....................................................... 57
  5.1.6 Accommodating Inner Components .............................................. 57

5.2 Design ........................................................................................................... 58
  5.2.1 Angles and Rounds ...................................................................... 58
  5.2.2 Proportions .................................................................................. 59
  5.2.3 Shapes ........................................................................................ 59
  5.2.4 Intended shelf ............................................................................. 59

5.3 Final Design ................................................................................................. 60
  5.3.1 Uniform ....................................................................................... 60
  5.3.2 The Prototype .............................................................................. 61

6 Discussion ....................................................................................................... 64
  6.1 Information Gathering ......................................................................... 64
  6.2 Concept Generation ............................................................................ 64
  6.3 Concept Selection ............................................................................... 64
  6.4 Design .................................................................................................... 65
  6.5 Manufacturing .................................................................................... 65
  6.6 Continuation ....................................................................................... 65

References .......................................................................................................... 66

Appendix 1  Design Brief
Appendix 2  Reciprocating Injection Moulding
Appendix 3  Product Data, Polypropylene
Appendix 4  Plastic Cisterns
Appendix 5  Connection Plates
Appendix 6  Criteria
Appendix 7  Concept Scoring
1 Introduction

1.1 Project Background
This project was performed at Caroma, Adelaide, Australia. The project is part of the MSc programme in Industrial Engineering, Ergonomic Design and Production at Luleå University of Technology. Caroma is an Australian company that develops and produces a variety of bathroom supplies for the Australian and Asian market. At their manufacturing plant in Norwood, Caroma produces plastic toilet cisterns. Caroma has got several models of plastic toilet cisterns in production and some of them out “in the field” are not longer in production. The company now wants to develop a new cistern that can replace some of the old models. The new cistern should be placed on the same place on the wall as the old cistern, covering the old cisterns footprint. If the old footprint is covered there will be little or no redecoration required. Caroma wants to add a new plastic cistern to their product range that is intended for the replacement market. There have been done attempts from other manufacturers creating a similar product but the required footprint has not been totally covered. Some of Caromas present cisterns have been in production for over 30 years and they have got an old-fashioned styling. Therefore the new cistern shall have a styling that goes well with contemporary bathroom interiors.

Reasons why a cistern may be replaced is because of malfunction or because the user consider the cistern to be old-fashioned. A user can also chose to replace an old cistern to reduce water consumption. Old models often have one big flush volume. The new cistern will have two flush volumes, allowing the user to chose between whole and half flush, using less water.

![Figure 1.1 Marks on the wall after an old cistern](image-url)
1.2 Main Aim
The main aim for this project has been to design a cistern that covers the required footprint of all the old plastic cisterns on the market, made by Caroma or other producers. The intention with the project is to develop a replacement product that will cover the footprint so that no further redecoration is necessary.
Figure 1.1 shows marks on the wall left from a previous cistern. A smaller cistern has been placed on top of an old cisterns footprint but the coverage is not complete. Since the new cistern does not cover the previous cisterns footprint, an ugly mark is left on the wall. The main aim of this project is to avoid this scenario.

The cistern is designed to cover the required footprint and to incorporate Caroma standard components. The design is also done considering manufacturability and material properties. The cistern is designed to have an appealing appearance and be easy to integrate in an existing bathroom interior. The project includes the design of a connection plate that will be included in a kit that accompanies every purchase of a new cistern.

The design approach of the project is to communicate simplicity and freshness. The product is a hygiene product that requires clean surfaces. The design of the cistern should highlight its main task, to clean the toilet pan.

The final result of the project is a physical full-scale model. The model is made in the rapid prototype machine and placed on a pan and presented to Caromas marketing division in Sydney. Rendered CAD pictures of the model are done in Alias. Caromas aim is to use the new cistern design in a new product release.

1.3 Assumptions and Constrains
The project has been ongoing for 20 weeks at the Caroma manufacturing plant in Norwood, Adelaide at their Research and Development office. A time-line has been used during the project to give structure and guidelines, see appendix 1. Requirements for the project have been the manufacturing material (polypropylene) and the manufacturing process (injection moulding). To cover the footprint, has been the most important constrain since the main aim of the project has been to have it covered.

The new cistern will have the geometry to accommodate Caroma standard components but the project does not include the internal functions of the flushing mechanism. The cistern should be able to be placed on different levels on the wall, depending on where the previous cistern was placed, on high, mid, low or ultra-low level. For the ultra-low level the cistern will be attached to the toilet pan with a connection plate. Consideration will not be taken to the water volume or to the cisterns attachment to the wall.

There were no constrains given for the visual design of the cistern, Caroma wanted a fresh look, something new, not seen before in their product range.
1.4 Product Specifications
Since the new cistern is going to be a replacement product it has got to fulfil a lot of requirements. The design of the new cistern will be regulated by various measurements and requirement from the company.

1.4.1 Geometry
The design must be made considering the required footprint and standard components. The footprint will be decided by measuring all previous plastic cistern models. The new cistern has got to have the width to accommodate inner components, Caromas standard inlet and outlet valve (the Hi-Flow valve). The cistern will also accommodate a float and a float-arm that regulates the water level in the water container.

1.4.2 Manufacturing
The cistern will be designed for injection moulding. Injection moulding restricts the design and a lot of factors have got to be taken under consideration. There are other manufacturing techniques available at the manufacturing plant such as laser inscription and hot stamping for buttons and logotypes. Parts can also be produced by other manufacturers and assembled at Caromas manufacturing plant.

1.4.3 Material
The material that will be used for the new cistern is polypropylene. Polypropylene is very well suited for injection moulding and it has got good properties for this application. Chrome paltered details will be made out of ABS plastic, since it is harder and more brittle then polypropylene.

1.4.4 Toilet Seat
Together with every purchase of a new cistern a kit will be delivered. The kit consists of a toilet seat and a connection plate. The toilet seat is a Caroma standard toilet seat, called Low-line seat. It is made out of polypropylene and manufactured at Caroma Norwood in polypropylene.

1.4.5 Connection Plate
A connection plate for ultra-low wall placement will accompany the cistern. Ultra-low placement means that the cistern is placed close to the pan and the connection plate makes the toilet look like one integrated product. The connection plate shall preferably be made in a style that matches the cistern and goes well with the toilet seat. This project will include the design of a new connection plate for this application.

1.4.6 Flush Buttons
The new cistern will have a dual-flush function. This is standard for all of Caromas newly produced toilet cisterns.
1.5 Product Analysis

1.5.1 Trends
The trend in toilets and bathroom interior tend to be minimalistic and the toilet is often hidden in the wall. Bathrooms are often furnished and decorated with objects and materials that are easy to clean. The trend in cistern design has been to make it as small as possible, maybe because the water consumption has been reduced and the water volume has been decreased. Later years bathroom design has become more important, the bathroom interior makes part of the whole home interior. Often the toilet is given a bigger shape and has become part of the interior, almost as a piece of furniture with integrity, a product to show off. Companies like Alessi, Laufen and Duravit (with designs made by Philip Starck) have lately increased the size of the toilet. See figure 3.1.

1.5.2 Usage
The main usage of the toilet cistern is to clean the pan by flushing a certain amount of water down the pan pushing the waste down the drain. The cistern is also used as an accidental shelf where users put rolls of toilet paper and other hygiene products, see figure 1.2.

![Figure 1.2 Cisterns in use](image)

1.5.3 Material
In Australia toilet cisterns are often produced in plastic. The plastic cistern is not a high-end product. It can be considered to be a cheaper alternative to the vitreous china cistern. The plastic is often white and glossy to imitate the properties of porcelain.

1.5.4 Manufacturability
Cisterns from other cheaper producers are often produced in China, were production cost is lower. Caroma has had the policy “Australian Made” and have been proud to offer Australian products. But times are changing, competition and low prices may force Caroma to move their production over seas, to China or other Asian countries. Caroma is only using injection moulding for their plastic cisterns but there are alternative production techniques used for other products that may be used for this application.
1.6 The Company – Caroma

The project with the new cistern was done at Caromas manufacturing plant in Norwood, Adelaide, South Australia. Caroma is Australia’s leading company when it comes to bathroom supplies. Caroma is part of a group called GWC International Limited. The company was founded in 1941 by a man called Charles Rothauser. Today they have over 2000 employees.

Caroma were the inventors of the full and half flush mechanism in 1980. They designed a cistern with two buttons and flush volumes (11 and 5.5 litres). They are constantly developing new product solutions to reduce water consumption. Water consumption is a very important issue in Australia, since Australia is a very dry continent, water restrictions make part of every day life.

Caroma is famous when it comes to plastic moulding and toilet cistern. Caroma has got the most advanced plastic moulding plant in Adelaide and they are famous for their advanced manufacturing techniques. The production is to a great extend automatic and the cells are mainly operated by robots and they run partly automatically. The usage of plastic cisterns is very extended in Australia and Asia. The plastic cistern is a cheaper alternative to the vitreous china cistern (that is more common in Europe) and can be purchased at a lower price.

Caromas management and marketing division are placed in Sydney as well as the Industrial design division. Just until recently there was an industrial designer at Caroma, Adelaide, responsible for the design of all the plastic designs. But now all the designs are made in Sydney and the design and production engineers make design refinements in Adelaide to make the products ready for production.

Caroma has not introduced a new plastic cistern in five years and some of their present cisterns have been in production for over 30 years. The future of the company is not certain and a lot of changes are being made. Some of their bathroom accessories are produced in China and a part of their production may move there because of lower production costs.

Figure 1.3 The Caroma logotype
2 Theory
In this chapter the theory relevant for the product development of the new cistern can be found.

2.1 Manufacturing
The main manufacturing technique used to produce the new cistern will be injection moulding. There are a lot of things to consider being able to design a producible and durable that is cost effective product. The project also involves other manufacturing techniques such as colouring and hot stamping. (1,2,3).

2.1.1 Injection moulding
Injection moulding is one of the prime processes for producing plastic articles. It is a fast process and it is used to produce large numbers of identical plastic items. It is a process that is capable of producing moulded parts of relatively complex configuration with good dimensional accuracy. Injection moulding is the process of forcing melted plastic, powdered or granular, into a mould cavity. Once the plastic has cooled, the part can be ejected. The products manufactured can be everything from high precision engineering components to disposable consumer goods. Injection moulding can keep high production rates and tolerance. There are low labour costs and there is a small need to finish parts after moulding. The equipment is expensive but many parts can be made out of one machine. When designing a part for production in an injection moulding process consideration must be made for the manufacturability, such as undercuts and sink marks. Injection moulding was invented in 1872 and 32% of all plastics are injection moulded. The plastic is fed from a hopper to a heated chamber where it is heated and melted. The plastic is then injected into a cool metal mold by a screw. Pressure is held on the molten plastic material until the mass has hardened enough for removal from the mould. The pressure of injection is high, up to one thousand atmospheres. An injection mould is usually made in two halves or sections and held together in the closed position by the molding press, see figure 2.1. The mould is generally made out of steel and is provided with channels for cooling, heating and venting. To achieve a good finish and perfect surface on the moulded plastic parts the mould is provided with hard chromium plating.

![Figure 2.1 The pictures show both halves of a plastic cistern mould](image-url)
There are four basic types of injection moulding machines: Conventional injection moulding machine, piston-type preplastifying machine, screw-type preplastifying machine and Reciprocating-Screw Injection machine. The type of injection moulding machines used at Caroma are called Reciprocating-Screw Injection machine.

2.1.2 Reciprocating-Screw Injection Machine

In this type of injection moulding machine the plastic is moved forward by the rotation of a screw. The screw is situated in a heated barrel that is placed horizontally on the machine. As the material passes through the barrel it is heated and changes condition from its granular condition to the plastic molten state. The heat delivered to the plastic is caused both by the friction and the conduction between the screw and the walls of the barrel. When the material is injected to the mould the screw moves forward to displace the material in the barrel. The screw performs as a ram as well as a screw. This method of injection moulding plasticizes heat-sensitive material efficiently. It blends the colors rapidly, due to the mixing action of the screw. The material heat can be kept low and the overall cycle time can be short. The time for the actual injection of the material is very short in comparison to the time it takes for the material to cool down before it can be removed from the mould, see figure 2.2. Every cycle takes less than one minute.

There are six major steps in the injection moulding process:
1. **Clamping**
   The clamping unit is what holds the mould under pressure during the injection and cooling. It holds the two halves of the injection mould together.
2. **Injection**
   During the injection phase, plastic material, often in form of pellets is feed into the cylinder where they are melted. The screw mixes the pellets and forces them to the end of the cylinder. The molten plastic is inserted into the mould through a sprue and the screw controls the pressure and the speed.
3. **Dwelling**
   The dwelling phase consists of a pause in the injection process. The molten plastic has been injected into the mould and the pressure is applied to make sure all of the mould cavities are filled.
4. **Cooling**
   The plastic is allowed to cool to its solid form within the mould.
5. **Mould opening**
   The clamping unit is opened, which separates the two halves of the mould.
6. **Ejection**
   An ejection rod and plate ejects the finished piece from the mould.

For detailed graphic description of the procedure, see appendix 2.
2.1.3 Colouring

It is possible to colour plastic parts. In this case the whole cistern or small parts like buttons. To colour the whole cistern, coloured pellets called “master batch”, are added to natural polypropylene. These are mixed in the moulding machine and an even colour can be achieved. The cisterns are often coloured in white or ivory. Caroma does mould cisterns in more extreme colours like blue and red. Those cisterns are only produced if ordered and are often delivered overseas.

To give a button or another specific parts a metallic look the plastic is chromed. It is not possible to get a perfect finish when chroming polypropylene so ABS is used that has got other properties. Another company makes this process and the parts return to Caroma for further work and assembly. It is also possible to get different finish on the chromed parts to simulate different materials. It is possible to make it matt or glossy. It is for example possible to imitate brushed aluminium.

All the chrome platering is done in another factory, the parts then return to Caroma for further assembly.

Real metal could also be used for the buttons, in aluminium or stainless steel. There are materials that are highly suitable for this kind of application, but then the parts have to be bought in and it gets more expensive.

2.1.4 Laser

Plastic parts can be engraved with laser to get logotypes, signs or characters written on them. This can be made in Caromas factory in Norwood and can be done on both polypropylene and ABS plastic, see figure 2.3.
2.1.5 Hot stamping
To engrave logotypes or characters the plastic can be hot stamped. Colour can be added to get a permanent and resistant imprint. In the process the decorative coating is transferred to the part from a foil by heat and pressure, see figure 2.4. The foil is pressed against the plastic surface by means of a heated die. Selected areas of the foil are transferred to the plastic surface.

![Figure 2.3 Laser engraved buttons](image1)
![Figure 2.4 Hot stamping machine](image2)

2.1.6 Prototyping
To get a good idea about a new product design a prototype can be made. A prototype is an original, full-scale and usually functioning model of a new product. A full-scale model makes it possible to touch and study the design from all angles. It makes it easier to comprehend then a rendered picture.
The prototype machine at Caroma, Dimension Rapid Prototyping (RP) is linked to the software Catia. 3D files are either created in Catia or imported as IGES files. The files are then sent to the prototype machine for the build. The RP machine builds 3D models from the bottom up, one layer at a time with ABS plastic. The plastic is fed into an extrusion head, heated to a semi-liquid state and deposited in layers. The RP machine fills up with support material where the model needs support. This material is very brittle and removed after completion of the model. (12)
2.2 Manufacturing considerations
There are issues to consider when designing a plastic moulded product. The plastic moulding technique can restrict options for a design but also offer and open up for possibilities. (1)

2.2.1 Wall thickness
It is desirable to have a uniform wall thickness. If the wall is not uniform sink marks or distortion can occur. Minimum and maximum wall thickness for Polypropylene is 0.025 and 0.300 inches. Most common is to have the wall thickness 3mm. This wall thickness will provide a good rigidity and short cycle time. For ABS it is 0.030 and 0.125 inches. A thick wall means long cycle times and less productivity. The thicker the wall is, the longer the part will have to stay in the mould to cure and cool properly.

2.2.2 Sink marks
A sink mark is a depression on a surface of a moulded part caused by internal shrinkage. A sink mark can appear on an uneven surface where the material thickness varies. If placing a rib inside a part for increased stability, a sink mark can be visible on the visual surface because of material shrinkage. This can be avoided by placing ribs not behind a flat surface but where the part has got a dividing line or a radius.

2.2.3 Undercuts
When using injection moulding it is important to avoid undercuts. The part has to have at least right angles in the “out falling” direction for the jig to leave hold of the part. An undercut is a projection on a moulded part that makes ejection from a simple two-part mould impossible. The mould then has to be designed in a different way with moving parts that makes it possible to mould the designed part. Split moulds can be designed for parts with undercuts, but these moulds are more expensive. These more complex moulds work in several steps. Undercuts should be avoided whenever possible, as they increase mould cost, part prices and lengthen moulding cycles. If the design includes raised lettering or design, these should be located on a surface perpendicular to the mould opening to avoid undercuts.

2.2.4 Rounds
To get rounds on a corner that will be in the edge to where the part is ejected from the tool, a dividing line will show. The tool cannot allow a round in the negative direction. The rounds become undercuts and impossible to produce. Therefore many plastic parts have got sharp edges. If it is preferred to have a round, a small dividing line cannot be avoided. The line will not be very obvious but it can collect dirt.
2.3 Material
There are materials that are highly recommended for the production of plastic cisterns. Mainly they use polypropylene, but also ABS plastic for parts that will be coloured. (1,4)

2.3.1 Thermoplastics
Thermoplastics are heat-sensitive materials, which are solid at room temperature. Upon heating the thermoplastics begins to soften and eventually reaches a melting point and becomes liquid. Allowing the thermoplastics to cool below the melting point causes resolidification. The fact that thermoplastics melts is the basis for their processing into finished parts. Thermoplastics may be processed by any method that causes softening or melting of the material. Examples of fabrication techniques are: injection moulding, extrusion, rotation casting and blow moulding. Thermoplastics can also be processed and cut in the solid state. Common thermoplastics are: polyethylene, polystyrene, polyvinyl chloride (PVC), nylon, ABS and polypropylene.

2.3.2 Polypropylene
The material that will be used for the cistern is the thermoplastic material polypropylene. It is a material that is commonly used when moulding plastic parts. Caroma uses polypropylene for all their plastic cisterns. It is stored in silos on the plant and is automatically fed into injection moulding machines. Polypropylene has got good corrosion and chemical resistance as well as low water absorption. This makes it an ideal material for the toilet cistern, which is continually exposed to water and subjected to chemical cleaners and disinfectants. Polypropylene has also got good fatigue resistance, good elastic recovery and excellent surface finish. The material allows production of articles and texture surfaces with either a matt or glossy appearance. Components like very small instrument parts up to large items such as chairs and toilet seats can be made in polypropylene see figure 2.5.
Polypropylene is a crystalline thermoplastic material that has one of the lowest densities of all plastics. It is translucent and has a milk-white natural color. The material has excellent colourability and can be pigmented to an unlimited array of colors. The excellent physical and electrical insulating properties of polypropylene are due to its crystalline structure. It is immune to stress cracking. Its main disadvantage is low-temperature brittleness and this can be overcome by adding synthetic elastomers. It can be modified to obtain improved properties by adding fillers such as asbestos or glass fibers. Polypropylene is easy to fabricate and can be processed by injection molding, extrusion and blow molding. The material can be decorated with methods such as: spray painting, paint-wipe, hot stamping and vacuum metalizing etc.

Polypropylene shows phenomenon like cold flow, creep and after shrinkage. The shrinkage is normally 1.5-2.0% but can range 1.0-2.5%. Shrinkage can cause sink marks and uneven surfaces. Sink marks may appear if the material is thicker on the opposite side of a rib or an extrusion. Reducing or increasing the wall thickness or the radius, often makes it possible to avoid these phenomenon’s. Sink marks can be camouflaged by the design. To reduce cost, attention should be given to the weight (wall thickness) of the component.
When designing products to be produced in polypropylene it is important to consider the following: Thickness of material, rounds, planar surfaces, sink marks and flow lines.

Polypropylene can be reused, the sprues, that appear in the moulding process can be can be melted again and used in another mould. (1) The polypropylene is injected to a jig in liquid form at a temperature of 180°C, although depending on moulding conditions and material thickness.

<table>
<thead>
<tr>
<th>Softening point</th>
<th>150 Celsius degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Density</td>
<td>1200 kg/m³</td>
</tr>
<tr>
<td>Material Cost</td>
<td>1.60 ASD/kg</td>
</tr>
</tbody>
</table>

(2)

For specific product data see appendix 3.

2.3.3 ABS (Acrylonitrile Butadiene Styrene)

For details like chromed buttons ABS is used instead of polypropylene. It is easier to paint and gives the piece a nice finish. But it is a bit more brittle. ABS plastics are thermoplastics of the styrene family. They are comprised of monomers of styrene plastic and acrylonitrile and butadiene rubbers. By varying the content of these different materials a wide range of specific materials becomes available. High gloss and unlimited colorability make ABS materials well suited in decorative applications see figure 2.6. It is well suited for chrome-plated parts and is often used for big and demanding applications like automobile grills. ABS has also got a high impact resistance and is a low-cost material.
2.4 About the toilet
There are some facts about the toilet that have to be taken under consideration when designing a new cistern. For example; how a toilet work and what it consists of. (5,6)

2.4.1 Toilet Footprint
The toilet footprint is the space that the toilet pan or/and cistern takes up on the floor and on the wall. If you choose a new toilet that has a smaller footprint then your existing cistern, you may need to paint or redo the tiling around the new toilet cistern. You’ll avoid this work if you choose a toilet that has a similar or larger footprint size than the one you are replacing.

2.4.2 How a toilet works
The toilet cistern is a water container in which water is stored. When pushing the flush button a valve is opened and allows the water to flow down the pan. The internal mechanism consists of an inlet and an outlet valve and a float-arm.
Caromas toilets are wash-down toilets, which means that water pushes down the waste and the water comes behind. The cisterns produced by Caroma are therefore placed over the pan and the water falls down into the pan, washing down the waste. In America and Europe it is common to have siphon toilets where the water comes first creating a suction that drags out the waste.

2.4.3 Inner Components
The components that will go into the cistern are the inlet and outlet valve and a float arm with a float. The inlet valve controls the water entering the cistern. A float arm and a float controls the water volume. The inlet valve can be placed on both the left and the right side of the cistern depending on the water supply and the tubes.
Caroma has got an award-winning outlet valve that allows a more efficient flush. In some cases it has reduced the usage of water from 11 litres to 3 litres for one single flush. This valve is called the “High-Flow valve” and it has got the dual flush function that is standard for all of Caromas new cisterns. The outlet valve can effectuate a flush using 6 litres for whole flush and 3 litres for half flush. The consumer can choose to use more water 9/4,5 litres and remove a component from the valve that increases the amount of water used when flushing. This can be the case if the existing pan requires a bigger amount of water to effectuate an effective flush. Some old pans require 9/4,5 litres to achieve a god flush and to remove all the waste.
The width of the outlet valve is a critical measurement that will decide the width of the cistern. There are different measurements on different valves but the thinnest one that is the one that will be chosen for the new cistern. The thickest part of the valve that will be attached to the cistern in called the bridge and has got the width of 110mm.
**Inlet valve:**
The inlet valve consists of a pipe trough where water comes through into the cistern. The inlet valve is directly connected to the plumbing and the pressure of the water pushes it into the cistern. It operates with a lever mechanism where a force is provided by a float. This force is used in a lever arrangement to force a rubber seal onto the valve. The inlet valve is controlled by a float and a float arm that when the water level reduces it opens the valve and water can flow into the cistern. In the same way the float shuts of the water flow when the water level has reached the right position. The rubber seal shuts of the water flow. Inside the inlet valve there is an overflow tube that will prevent the cistern from overflowing. If the water level rises because of a leak the water will go directly down into the pan instead of causing an over flow. See figure 2.7.

![Figure 2.7 Inlet valve components](image-url)
Outlet valve (Hi-Flow valve):
The outlet valve is the mechanism that releases the water into the pan. It is controlled by the water level. When pushing the whole-flush button, all the water in the cistern is released into the pan. When all the water is gone a rubber sealing shuts the outlet and the cistern can fill up again with the inlet valve. Because the buoyancy of the float is less than the total weight of the valve, the valve will drop when the water level reaches a certain height (almost empty). Once the cistern is emptied, the valve is held closed by the weight of water above the rubber seal. The water pushes down the sealing that will not open again before the cistern is flushed again. This valve, the Hi-Flow valve has won the Australian Design Award for its design and capacity to reduce water consumption. See figure 2.8.
2.4.4 Water Saving

Water saving has become a very important issue in Australia and people are conscious about the cost and environmental impact. 20% of the domestic water consumption is due to toilet flushing. Caroma has got a water saving policy and tries to develop products that reduce the usage of water. Their outlet valve the Hi-Flow valve, has made it possible to decrease the water flow rate by 60% and has increased the flush efficacy with over 140% compared to other producer’s outlet valves. The Australian National Water Conservation Rating and Labelling Scheme (WSAA) advice people to purchase products that protect the environment and that reduces costs for the consumer. They have a symbol that they place on products that match their requirements. Caromas outlet valve, that flushes 6/3 litres has got 3 out of 5 possible A’s, see figure 2.9. (7)

![Figure 2.9 WSAA’s product rated labels](image)

Table 2.1 These figures are based on current Australian standards for calculating averages flushing volumes per person equal to 1 full flush and 4 half flushes per day. The average Australian household is calculated based on 2.5 persons per household.

<table>
<thead>
<tr>
<th>Toilet suit</th>
<th>Annual water usage (liters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 liters single flush</td>
<td>50188</td>
</tr>
<tr>
<td>11/5.5 liters dual flush</td>
<td>30113</td>
</tr>
<tr>
<td>9/4.5 liters dual flush</td>
<td>24638</td>
</tr>
<tr>
<td>6/3 liters dual flush</td>
<td>16425</td>
</tr>
</tbody>
</table>

2.4.5 The Half Flush

Because of Australian water restrictions and the awareness of water consumption the half-flush function is standard in all toilets produced today. Caroma is a pioneer when it comes to the half-flush function and was one of the first to introduce this feature. In Caromas standard valve, (the Hi-Flow valve used in the new cistern), the half-flush function is controlled by a bucket that decides at what level the water knocks down the valve. When pushing the half-flush, hooks release the bucket that floats on the surface and pushes down the valve with its weight. Only half the water volume is released down into the pan before the sealing shuts and stops the water, see figure 2.8.

Two buttons (with different shapes or symbols) tell the user which button to push for desired flush volume. Symbols are often used to represent whole- and half-flush.
2.5 Design Perception
The perception of what is a good design or a beautiful shape is different to everybody but there are some universal rules that can be applied. (8,9)

2.5.1 Shapes
To design a product that will be pleasing to people it is important that it goes well with the surrounding. The product should follow the pattern of the rest of the room and be accurate for the material.

2.5.2 Proportions
To make an objects look smaller, not bigger, proportions can be used:
- Making components bigger than on other objects.
- Making objects slim, not thick.
- Usage of curves can make the user think that an object is smaller then it really is.

2.5.3 Fibonacci (The Golden Number)
There are mathematic numbers and relations that the eye likes better than others. Most of nature’s patterns follow the same relation. This number is generated by taking the ratio of two successive numbers in the Fibonacci series and divide each number by the previous number. The ratio settles down to a particular value, which is called the golden ratio or the golden number. The relation is approximately 0.618034. (10)

The Fibonacci numbers follow this equation:

\[ F_{n+1} = F_n + F_{n-1} \]

The first Fibonacci numbers are \( n=1,2,3,5,8,13,21,34,55, 89, 144, 233, 377, 610 \ldots \)
2.6 Usability (Semiotics Psychology)

According to Norman, Donald A in his book “The design of everyday things”, the usability of a product affects the user when interacting with a product. (11) The usability of the new plastic cistern concerns the buttons. The user shall know what to do by looking at the button, which button to push for half or whole flush. A good design exploits constraints so that the user feels as if there is only one possible thing to do.

2.6.1 Visibility

By looking at the product the user shall be able to tell the state of the device and the alternatives for action.

2.6.2 Conceptual models

Everybody makes mental models about how things work. These models are essential in helping us understand our experience, predict the outcome of our actions and handle unexpected occurrences. We base our models on whatever knowledge we have, real or imaginary. A good conceptual model provides the user with consistency in the presentation of operations and results.

2.6.3 Natural Mapping

Natural mapping is cultural or biological. It can be the universal standard that a rising number or amount represents more and a diminishing number represents less. Natural mapping can be that a control is in the shape of the intended action, as in bigger and smaller. A device is easy to use when there is visibility to the set of possible actions, where the controls exploit natural mapping.

There shall be a close, natural relationship between the control and its function. Controls should be placed where they ought to be and one function shall have one control. With a good mapping it is possible to determine the relationship between actions and results and between controls and their effects. Sometimes standard conventions are stronger then natural mapping, in shape and direction.

2.6.4 Feedback

Feedback-sending back to the user, information about what action has actually been done and what result has been accomplished. Push buttons shall be designed to give an appropriate feel-tactile feedback.
2.6.5 Constrains

There are four different classes of constrains: physical, semantic, cultural and logical. These constrains are telling us how to act when encountering a new product without having used it before. A good design shall signal the appropriate action and limit the number of alternatives.

*Physical constrains* limits the number of possible operation (what can be done). Physical constrains restrict the set of actions before anything has been made by the physical shape.

*Semantic constrains* rely upon the meaning of the situation to control the set of possible actions and rely upon our knowledge of the situation and of the world. Usage of symbols and well-known concepts.

*Cultural constrains* rely upon cultural conventions, even if they do not affect the physical or semantic operation of the device. Cultural constrains determines the location of for example buttons. Each culture has a set of allowable actions for social situations.

*Logical Constrains* rely upon the logical relation between the spatial or functional layout of components and the things that they affect or are affected by. If two indicators reflect the state of two different parts of a system, the location and operation of the indicators should have a natural relationship to the spatial of functional layout of the system.
3 Methods
The methods used for this project are presented in this chapter. The methods are used to gather information to generate concepts that will result in the final design of the new plastic cistern.

3.1 Problem Analysis
The product development of the new plastic cistern consists of a number of requirements.

3.1.1 Footprint
The main aim of the project, to design the new toilet cistern, is to cover the required footprint. The footprint includes the area behind today existing cisterns that are placed and used in homes and public bathrooms. The new cistern will be a replacement product that will be placed over the wall area where the old cistern was placed. The term “footprint” is explained in the theory chapter.

The new cistern must cover the marks left on the wall after the old cistern. The problem is to cover the footprint of all existing plastic cisterns models on the market and still keep the cistern aesthetically appealing, not looking too big.

3.1.2 Manufacturing
The cistern will be manufactured at Caromas manufacturing plant in Norwood using polypropylene and injection moulding. The manufacturing limits the possible shapes of the cistern because of undercuts, draft angles and rounds. These design considerations are described in the theory chapter.

3.2 Function Analysis
The basic function of the cistern is to flush waste in the toilet pan down the drain. The cistern has also got other functions.

3.2.1 Flush
The cistern will offer a dual flush function. The flush will be activated by a button setup that will be easy for the user to understand.

3.2.2 Cover Footprint
The cistern will cover marks on the wall caused by a previous cistern and cover its footprint.

3.2.3 Shelf
The cistern will act as an intended shelf for hygiene products. The usage of the cistern as a shelf is today accidental.
3.3 Information Gathering
To get necessary information about other brands and products on the market, benchmarking was done to establish styling directions and trends. Information about the product was gathered by interviewing the company plumber and working out in the production.

3.3.1 Benchmarking
The market of existing toilet cisterns was examined, mainly plastic cisterns but also styles of ceramic cisterns and toilets. Trends and styles could be observed. Visits were made at different showrooms and a lot of information was found on the Internet. Many bathroom and toilet producers have got their own style and design, some rather experimental and less conventional. In the showroom and on the Internet it is very notable that the convention of how a toilet should look like is changing. See figure 3.1.

![Figure 3.1 Picture of products on the market](image)

3.3.2 Toilets in Use
To get an idea about the usage and interaction between people and toilets, field studies where made visiting private and public bathrooms, see figure 3.2. Most of the toilets found had a dual-flush function, but some old models were still found with the single-flush function. The most common cistern out of Caromas range is the Uniset. Caromas plastic cisterns are the most common toilet cisterns found out in restaurants and public restrooms. The plastic cistern is a cheap and durable product, but many of them used today are old and will soon have to be replaced. Visiting different bathrooms it was very notable that people use the cistern as a shelf for toilet paper and other hygiene products.
3.3.3 Interview with the Company Plumber

The new cistern is designed for the replacement market. Therefore the person who has got most experience of cisterns in use and installation is the company plumber. Since the new cistern will be placed in an already existing bathroom and placed on an old pan, the plumber knows all about how it will be mounted and how it will fit in an existing bathroom interior. The company plumber has got 15 years of experience from service work out on the field with product from Caroma and other producers of toilets. He gave a lot of input to the project; about the most common toilet cisterns used and which ones are preferred by the customers. He had a look at the research done and made a few comments on the models examined for the required footprint. At that time I talked to the plumber the footprint included also a model called Profile from a producer called Brent. This model is shown in appendix 4. The Brent cistern was the widest one found out of all examined models. According to the plumber the Brent cistern, and cisterns as wide, are not very common. He said that he replaced maybe two of those every year. Covering the Brent footprint would make the cistern unnecessarily big just covering a very small number of cisterns. He thought that the Uniset, the Duoset and the Fowler Tasman cisterns would cover a very high percentage of the cisterns that will be replaced by the new replacement cistern. He said that the most common are the Duoset and the Uniset, both produced by Caroma.

About the connection plate he said that 50-60 % of the cisterns used have got a connection plate and that 95% of the users want cistern with a connection plate if replacing the old cistern. The footprint of the connection plate was not very important according to him. The area behind the connection plate is painted or tiled before placing the cistern. Often the connection plate is not in contact with the wall and does not leave any marks that have got to be covered up.
3.3.4 Work Experience

For two days a work experience was made out on the production floor. This experience gave a good understanding for the product and the manufacturing. Understanding for how the dice and the jigs are set up to produce and assemble a toilet cistern are essential in the development of a new plastic cistern. A good design can make the work go smoother and reduce the number of jigs and fixtures.

The production at Caroma is to a high extend automated. Robots are used to assemble the cisterns. The robots eject the cisterns from the mould, run the flush-test of the cistern and load it on to the pallet. One injection mould-cycle runs for about 1 minute. Within that time the worker has to set up of the jig and do the packing, otherwise the robot has to wait and production is inefficient and watermarks can occur on the moulded parts.

The production workers know a lot about the product and talking to them gave an understanding for obstacles in production of plastic cisterns. The production workers handled the cisterns very carefully. They observed damages in the finish, like scratches and sink marks. If flaws were found the whole cistern was rejected and recycled. A lot of attention was also paid to variations in color. Variations can occur if remains from a different colored plastic is left in the machine from a previous part being moulded. For the visual parts the color and finish is very important, whereas for inner components and not visual parts, the colour can be blotched and matt. The quality was regularly checked, three times a day, to see that all the components matched the requirements, visually and functionally.

![Figure 3.3 Plastic parts being moulded](image-url)
3.3.5 Charting Old Models

Before designing the cistern the footprint of all existing plastic cisterns were charted in a survey. The models examined were plastic cisterns found on the market, produced by Caroma but also other producers. The footprint had to be optimized to cover all of the footprints but without making the cistern unnecessarily big. See appendix 4 for the complete survey.

The survey made it easy to see which cisterns were the biggest, with the biggest footprints. Some of these were not included in the required footprint because of a low percentage of cisterns used on the market. The models that were taken under consideration were: Uniset and Duoset, both Caroma cisterns, and a cistern called Tasman from a producer called Fowler, see figure 3.4. These models were the biggest ones of the most common cisterns.

![Figure 3.4 The biggest cistern models](image)

3.3.6 Charting Connection plates

Caromas plastic cisterns can be placed on different heights on the wall. The positions are called high, mid, low and ultra low level. This project will concern cisterns placed on mid, low and ultra-low level. The ultra-low level cisterns have got a connection plate that joins the toilet cistern and the pan. The connection plate covers the pipe that runs between the cistern and the pan. All the different models of cisterns have got different connection plates with individual designs and fittings, see figure 3.5.

The new cistern alone will cover the footprint for high and mid level. But for cisterns placed in the ultra low level, different connection plates have to be taken into consideration as well as how high up on the wall the previous cistern was placed. All the connection plates were measured and charted determining the width of the new connection plate in the same way as for the footprint for the cistern, see appendix 5.

![Figure 3.5 The connection plate joins the cistern and the toilet seat](image)
3.4 Generating Footprints

To be sure that all the older cisterns footprints were covered with the new design, all the present models footprints were drawn and compared. Out of these some critical models were detected and an optimized footprint was generated for the cistern and for the connection plate.

3.4.1 Cistern Footprint

Examining all the models and determining which models that had critical measurement limited the number of models that had to be taken under consideration. Putting the measurements and shapes of the critical models on top of each other generated the footprint. By doing that it was easy to see where the models overlapped each other and where certain critical points could be detected, see figure 3.7

After having examined all the models and their measurements, critical points were observed, see table 3.1. A coordinate system was drawn to establish the measurements required for the optimized footprint.

Table 3.1 The critical points observed that will decide the minimum shape of the cistern, the required footprint.

<table>
<thead>
<tr>
<th>Model</th>
<th>Width</th>
<th>Height</th>
<th>x</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniset</td>
<td>510</td>
<td>370</td>
<td>255</td>
<td>380</td>
</tr>
<tr>
<td>Duoset (1)</td>
<td>0</td>
<td>400</td>
<td>0</td>
<td>400</td>
</tr>
<tr>
<td>Duoset (2)</td>
<td>360</td>
<td>400</td>
<td>180</td>
<td>400</td>
</tr>
<tr>
<td>Fowler Tasman (1)</td>
<td>500</td>
<td>30</td>
<td>250</td>
<td>30</td>
</tr>
<tr>
<td>Fowler Tasman (2)</td>
<td>530</td>
<td>360</td>
<td>265</td>
<td>360</td>
</tr>
</tbody>
</table>

These are the outer contours for the three critical models; Uniset, Duoset and Fowler Tasman. See figure 3.6.
Placing the models contours on top of each other, see figure 3.7, doing an outline of all the critical points generate an optimized footprint. All the critical points are covered and the main requirement for the development of the new cistern is obtained.

This is the optimized footprint that has been used when designing the new cistern that will be used as a replacement product. A bit of margin is left on the sides to make sure that marks on the wall will be totally covered. See figure 3.8.
3.4.2 Connection Plate Footprint

The footprint for the connection plate was obtained by measuring all the old models to get an optimized footprint that covers the required area. The Uniset and the Duoset cisterns are the critical ones even when it comes to the connection plate and they decided the size of the required footprint for the connection plate, see figure 3.9.

These two have got to be covered and since they have different heights the cisterns are placed on different levels on the wall. The Uniset is the lowest (50mm high) and the Duoset that has the tallest (100mm high). This result in that the footprint for the connection plate will have to cover the lower part of the Uniset cistern. The new cistern will be placed higher then where the Uniset was originally placed and this will result in marks on the wall from the cistern.

After having discussed the connection plate issue with the plumber and having examined bathrooms, it was clear that connection plate it self does not leave marks on the wall. Therefore the design of the connection plate was done considering the Uniset, the Duoset cistern and the width of the Low-Line seat with the wide hinge bracket, which is 260mm wide (the seat set for this application).

Figure 3.9 Requirements for the connection plate
3.5 Concept Generation
The concept generation is the most important part of the product development, generating and optimizing ideas to come up with a strong and durable concept. Various methods were used and combined to generate new interesting concepts.

3.5.1 SWOT Analysis
Early in the process a SWOT analysis was made. SWOT stands for Strengths, Weaknesses, Opportunities and Threats. A SWOT analysis is used to bring forward the strengths, weaknesses, opportunities and threats in an idea. The SWOT analysis makes it easier to develop the idea and to predict the problems and solve them early in the process. At the same time making the most out of the possibilities and making the idea as strong and durable as possible. The results of the SWOT analysis are shown in figure 3.10.

![Figure 3.10 Result of the SWOT Analysis](image-url)
3.5.2 ITK - Identity Tool Kit

ITK-Identity Tool Kit is a process for concept development where pictures and words create a conceptual platform from which the design work assumes. ITK is a method to capture visions and valuations. It helps setting up guidelines for what is desired in the new product early in the process. ITK is used to stimulate the communication and to clarify goals for the final product. The method is very useful when working with people from different cultures, when the language can become a barrier. Pictures visualizes an idea better then using only words to describe it.

To establish how the product is today a Stateboard was created and a to describe what is wanted in the new product a Futureboard was created.

The Stateboard describes how a product is perceived today, what emotions it communicates and an image of its general state is created out of words and pictures. The Stateboard describes how a product is experienced right now. Pictures and words are linked together to mediate a feeling and understanding of the company and its products as a whole. This was done describing plastic cisterns today, see figure 3.11.

![Figure 3.11 The Stateboard](image)

Coronas plastic toilet cisterns can be found in many private and public bathrooms. The toilet cistern is an essential that most people take for granted. Its presence is expected. The cistern is a time indicator, you can tell from its design when it was installed. It may be considered as a beautiful part of the home but often it is a remains from a past era. Today’s cisterns do not always feel to be an integrated part of the toilet pan and of the rest of the bathroom. In some cases the cistern pretends to be a part of the toilet pan but often in a non-integrated way. It has a poor fit and it becomes a mishmash of shapes and volumes. The cistern gets stained by time. Physically it gets old and dirty. Psychologically, in people’s minds it is stained and associates with negative values.
The Futureboard is the desired image with the qualities that the future product shall communicate. The Futureboard is a first visualisation of how a product will look like and how it will be perceived. I chose to use these pictures and words to communicate the feeling and the image of the new plastic cisterns, see picture 3.12.

![Figure 3.12 The Futureboard](image)

The design of the new cistern will make it evident and easy to integrate. The cistern will signal confidence and the interface will be user friendly and comprehensible. It will be applicable and cover all existing footprints and easy to fit in an existing bathroom interior. The cistern contains water that is a purifying element. The main task of the cistern is to purify and clean the toilet pan. Maniscus (water tension) is a phenomenon that appears where air and water meet. Simulating the phenomenon on the surface of the cistern will accentuating the purifying property of water and of the cistern. To make it look proportional will counteract the fact that it is bigger than all prior models.

To generate words for the Stateboard and the Futureboard sessions of Brainstorming were performed. The Brainstorming helps gathering words that are relevant for the product. The words are then collected into subgroups, reducing the words to five strong words that cover and describe the whole product image.
3.5.3 Scrapbook

To gather all the design ideas during the concept generation and to help gathering early sketches and combining different designs, a Scrapbook was used. Pictures and shapes were collected in one book, making it easy to go back and look to develop design ideas further. The inspirational pictures were gathered from magazines, photographs and showrooms. Pictures and sketches from the Scrapbook are shown in figure 3.13.

*Figure 3.13 Pictures and sketches from the Scrapbook*
3.6 Concepts
After having used different methods to get ideas for concepts to design a new plastic cistern, 3 concepts were generated. To present 3 concepts was also part of the Design Brief, for the company to choose from. These concepts are presented in this chapter.

3.6.1 Concept I - The Organic Concept

The Inspiration

![Figure 3.14 Inspiration for the Organic Concept](image)

Retro shapes from the sixties influence the design of this concept, The Organic Concept. Big rounds and distinct edges will give this very simple geometry an interesting and very clean feeling. The lid and the water container shall constitute a single shape and just be divided by a clear cut. You shall feel the presence of water and its purifying qualities. Cleaning is the cisterns main task and this shall be accentuated. The meniscus phenomenon will appear in the button setup.

![Figure 3.15 Sketches of cistern shapes](image)

At first the concept had a small lid as on conventional toilet cistern. But when having studied other proportions a bigger lid was to prefer. It makes the cistern look more proportional. The clean shape may seem too simple but in a bathroom where hygiene is important easy cleaned shapes are to prefer. Round shapes that go well with round pans and bathroom basins.
The Geometry

The geometry for the Organic Concept is very simple. It is made out of a rectangular block with big rounds added to it.

Figure 3.16 Top, side and front view of the Organic Concept

The relation between the size of the water container and the lid follows the Fibonacci numbers, even called the golden number.

The cistern has got the following dimensions:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>400</td>
</tr>
<tr>
<td>Width</td>
<td>530</td>
</tr>
<tr>
<td>Depth</td>
<td>110-120</td>
</tr>
</tbody>
</table>

Relation between water container and lid:

- Cistern: \( \frac{400}{0.618} = 247.2 \)
- Lid: \( 400 - 247.2 = 152.8 \)
The Organic Concept will integrate as a natural part of a bathroom. It will not stand out but add a fresh feeling to an existing bathroom interior. Its simple shapes will be very obvious and the new button setup will make it innovative and different to other Caroma products. Simple shapes signal quality and resistance. Instead of a lid that overlaps the water container, the lid will have an extrusion on the inside that slides into the water container leaving a clear gap between the two parts.
The Button Setup

The button setup for this concept is a toggle that is shaped as a lever. Since the cistern is wider than other cisterns and oblong, a long toggle gives the whole design balance. The oval shape goes well with the big rounds of the cistern. The toggle works as a rocker and is a new type of button for Caromas toilet cisterns.

The toggle works as a rocker, when pushing for example full flush, the other side rises. Raised symbols shaped like water drops represent the full and half flush. Here the presence of water becomes obvious and adds a fresh feeling to the concept. The surface tension (meniscus, the curved upper surface of a still liquid) will be represented as a slight convex round on the toggle. The requirement of 18mm push down distance can be reduced by an internal mechanism that increases the lever and its moment (the product of a force multiplied by its perpendicular distance from the centre point).
The representation of full and half flush on the toggle can be made as an extrusion, a raise or in writing. The full flush button will be placed to the right and the half flush button to the left. That is the convention and thought behaviour for most users, a cultural constrain. The material of the toggle is chromed plated ABS plastic. The finish is called satin chrome and will give the toggle a matt and sophisticated look. The satin chrome finish has got the advantage that greasy stains does not show as much as on a glossy chromed surface.
3.6.2 Concept 2 and 3 - The Panel Concept I and II

There are two panel concepts inspired by the same shapes. These two concepts have got similar shapes and looks, but they are so much different that they are divided into two concepts.

The Inspiration

![Figure 3.21 Inspiration for the Panel Concepts](image1)

The inspiration for these two concepts has been today’s kitchen and bathroom interiors that tend to be very minimalistic. The shape for the concepts is made to fit in an existing bathroom where the shapes often are clean and simple. The toilet cistern should not interfere too much with an existing interior since the cistern is a replacement product. The material shall feel solid and hard and not look bulky or soft. In a bathroom the hygiene is very important and therefore the toilet shall have surfaces that are easy to clean.

At first the idea was to make a very square and rectangular cistern with sharp edges and plain surfaces. But since it is difficult to produce flat surfaces when using injection moulding the concept was modified. See figure 3.22.

![Figure 3.22 Sketch](image2)

In the new version curved surfaces and bigger rounds have substituted the perpendicular angles. But the feeling of clean minimalism still remains. The concept is made in the shape of a shell or a shield. The cisterns smooth surface covers the footprint and fits the valve. The idea has been to keep it as simple as possible and to minimize the volume as much as possible in a non-obvious way. See figure 3.23.

![Figure 3.23 Sketch](image3)
Two concepts were generated both inspired by the simplicity of the material and minimalistic shapes and edges. These concepts are called Panel I and Panel II.

The Geometry - Panel I

![Figure 3.24 Top, side and front view of the Panel I Concept](image)

**Dimensions**

To give the cistern a balanced shape the relation between the size of the water container and the lid follows the golden relation or Fibonacci numbers. This will give the cistern a totally new expression in comparison to Caromas other cisterns where the lid often is much smaller than the water container.

- Cistern: $\frac{400}{0.618}=247.2$ (mm)
- Lid: $400-247.2=152.8$
The Panel I Concept has got a slim design that can fit in many existing bathroom interiors. It will be more like a divided shape than a shape with a lid. One important feature is the top surface that can be used as a shelf. When placing a roll of toilet paper or air freshener on top of the cistern the object will not be tilted or accidentally placed on the button setup. The placing of objects on the top surface is not just a possible action but also an intended action. The "accidental" shelf becomes an "intended" bathroom shelf that allows placing and encourages it. The top surface will have a small curve to it (not be completely planar) that makes it easier to produce. But the surface will still look planar. This goes for all planar surfaces, since it looks better when moulding the part.
The second Panel Concept, Panel II Concept, has got the same simple shape as the Panel I Concept but a geometry that makes it easier to produce. The concept has got the same type of curve on the front surface but the sides are perpendicular, not angled. The water container and the lid will have the same width. This shape is easier to produce and easy to get out of the mould.

The Fibonacci relation is still there but in the middle of a ribbon that runs over the whole cistern. The ribbon can be made as a separate part or as part of either the lid or the water container. The ribbon adds an interesting detail that covers the gap between the lid and the water container.

Fibonacci relation:
- Cistern: \(400 / 0.618 = 247.2\) (mm)
- Lid: \(400 - 247.2 = 152.8\)

The two parts can be divided close to the upper edge of the “ribbon”, to make the water container bigger. At the same time the perception will be that it is on the middle.
The Panel II Concept has not got a visible gap between the lid and the water container but an overlapping “ribbon”. The ribbon covers the gap between the two parts and allows the water container to be bigger keeping the same dimensions between lid and tank. The name of the model, or a logotype, can be placed on the ribbon with hot stamping or laser inscription. The ribbon will be satin chromed as the button setup and produced in ABS plastic. The ribbon could also be done in other colours to match the colour of the rest of the bathroom.
The Button Setup

The button setup for this concept has got a more rough feeling to it than the Organic Concept. More focus is put onto the material and sharp edges. Both concepts, Panel I and II, have the same button setup just with different edges.

*Figure 3.29 Inspiration for the button setup*

Inspiration was taken from brushed steel components from industrial machinery. The chrome shall have a matt finish, not shiny or glossy, see figure 3.29.

*Figure 3.30 Sketches of button setups*
Figurer 3.31 Renderings of the button setups

The buttons can be laser burnt to get a permanent and resistant inscription. A big and a small circle represent full and half flush. See figure 3.31.

3.32 Rendering of alternative button setup

An alternative concept for the button setup is to have regular push buttons that work the conventional way. Full-flush is a cylinder shaped button while the half flush is shaped as half a cylinder. In each case the whole button is a symbol and not only an inscription. See figure 3.32.
3.7 Concept Selection
A concept selection was made out of the three generated concepts, the Organic Concept and Panel I and Panel II Concept. To select a concept out of these three, in an objective and structured way, a Concept Scoring Matrix was made and the concepts where presented to the marketing division in Sydney.

3.7.1 Criteria
To make sure that the new cistern fulfils all the requirements a number of criteria were listed that had to be included in the new design. The criteria were divided into required and desired criteria. The required criteria are the ones that are included in the Design Brief and limited by manufacturing and company policy. The desired criteria are the ones that does not have to be included in the design but that increase the value of the product. The criteria are listed in different categories, see appendix 6.

3.7.2 Concept Scoring Matrix
The matrix is made out of all the desired criteria that the product preferable shall incorporate. The Concept Scoring Matrix is made in three steps. First the different criteria that are desired for the product are listed and given a grade to determine their importance. This is a model that helps choosing a concept out of several. The desired criteria are listed and evaluated in matrices. The importance of each criteria or desirable quality is ranked and a percentage shows their importance. Each concept is given grades 1-5, according to how they match each criteria.

After having done the evaluation, two of the concepts got more or less the same “score”.

It was the Organic and the Panel I Concepts. Since they are both “strong” when it comes to the “easy to integrate” and “easy to clean” criteria, they got high scores. Accentuating that these are the most desired qualities of the new cistern.

There are some of the criteria that are not included in the evaluation, such as quality and assembly time. These aspects will be taken into consideration later in the product development process. There are some of the criteria that will be changed and that may be modified but this model gives a general idea about how the concept fulfils the desired criteria that were established early on in the process.

The last concept Panel II got the lowest score because of the ribbon. The ribbon is more expensive to produce and would have to be elaborated in another production plant. It also makes the cistern less easy to clean. But depending on who sets the matrix and does the evaluation, the concepts can be ranked differently. The ribbon will increase the cost but may also increase the value of the product. An example: giving the cost a lower importance in the matrix will give the Panel II concept a higher score, see appendix 7.

After having analysed the matrix further, the Panel I Concept got the highest score and was therefore my choice of preference for the new cistern design.
3.7.3 Input from Marketing

To be sure that the new cistern will suit Caromas product range and intended users, the marketing division in Sydney were involved in the concept selection process. A presentation of each concept was sent to Sydney. Each concept was presented in detail, the inspiration behind each design and specific features. The marketing people then made comments and chose which concept to develop further.

After having done the Concept Scoring Matrix to establish which concept to go with and after having discussed the concept with marketing and product engineers at Caroma the Panel I Concept was chosen.

3.8 Prototyping

To get a good idea about how the cistern will look in real size and on an existing toilet pan a prototype was made. A prototype is a non-functional product in real size that shows the styling of a product and can be placed in an intended environment.

After having done the Computer Aided Design (CAD) model using the software Alias Studio Tools the model was exported to the programme Catia. In Catia the model was modified for prototyping and sent to a rapid prototyping machine (RP machine). The prototyping process is described in detail in the theory chapter.

![Figure 3.33 The RP machine building the prototype](image)

The model was divided into parts for the machine to be able to model it. The parts were glued together then sanded and polished. When a wanted finish was achieved the parts were spray painted, first with a “coat colour”, acrylic primer surfacer, and then with a white glossy colour to imitate the plastic material. The button setup was created in the same way. But too give the button the right satin-chromed colour a metallic spray paint was used.

The prototype was placed on an actual pan made by Caroma. Too create an authentic environment a bathroom interior was created by tiling a wall and a floor section to place the prototype on. The tile that was chosen had a dark brown colour that makes it easy to distinguish the design of the cistern, its angles and rounds. The brown colour was chosen not only for the high contrast, but also for its modern look. The name of the tile chosen was Coffee.
4 Product Requirements

The requirements for the new cistern were set by the company, in the Design Brief and by the company policy. Some requirements were also found after having done the project research. All the product requirements for the new plastic toilet cistern intended for the replacement market are presented in this chapter.

4.1 Cover the Footprint

The new cistern has got to have the dimensions that covers the required footprint generated by examining all previous plastic cisterns. A survey was done over all Caroma plastic cisterns and other producers cisterns found on the market, see appendix 4. Three models decide the size of the footprint, two of Caromas own cistern and a cistern model made by Fowler; Caroma Uniset and Duoset and Fowler Tasman. The cisterns were measured and the survey resulted in the footprint shown in figure 4.1.

![Figure 4.1 The required footprint](image)

4.2 Connection plate

A survey covering all connection plates was done, see appendix 5. Out of those a footprint was generated to decide the width and height of the connection plate for the new cistern. See figure 4.2.

![Figure 4.2 Required measurements for the connection plate](image)
4.3 Toilet Seat
The toilet seat that will be used for the new cistern is Caromas Low-line seat, which is a Caroma standard toilet seat already in production at the manufacturing plant in Adelaide. The Low-line seat is available with two different hinge brackets with different widths, 220mm and 260mm, see figure 4.4. Since the new cistern will be big and wide, the wider hinge bracket was chosen for this project to make the design look more balanced.

Figure 4.3 The seat that will accompany the new cistern, 260mm and 220mm wide

The new cistern will be delivered with a kit, see figure 4.4. The kit includes a Low-line toilet seat and the new connection plate.

Figure 4.4 The kit includes: a cistern, a toilet seat and a connection plate

4.4 Flush Buttons
All of Caromas toilet cisterns are provided with a dual-flush function. When two buttons are used, the half-flush is placed to the left and the whole-flush to the right. This has become the convention and people may go on their reflex when using these buttons (5 times a day *). It has become a “taught behaviour”. People are now costumed to this placement and may not even look at the symbols before flushing. The outlet valve used for the new cistern is operated from above to release the water. Therefore the flush buttons have to be placed on top of the cistern. Another requirement for the flush button is that the flush button has got to be pushed down 1.8 cm to get a fully efficient flush. The flush-button setup may be moulded in polypropylene or ABS plastic.

* According to a survey made by Caroma, 1 full flush and 4 half flushes.
4.5 Manufacturing
The new cistern will be produced using injection moulding at Caromas manufacturing plant in Adelaide. A new mould will be designed for the new cistern and set up in a moulding cell, operated by robots and production workers.

4.6 Material
The material used for the new cistern is polypropylene. It is a material that is highly suitable for injection moulding. It is possible to give the plastic a glossy finish depending on the quality of the mould.

The thickness of the material will be 3 mm, which will give the cistern enough stability and still keeping a low production cost, keeping the time of each moulding cycle short.

For the button setup the material can be ABS plastic to make it possible to colour the button.

4.7 Inner Components
The cistern will incorporate Caromas standard inlet and outlet valve, see figure 4.4. The width of the outlet valve is a critical measurement that will decide the width of the cistern. The valve will be mounted at 300 mm from the button of the cistern. The width of the valve at that height is 110 mm.

The valve will make the cistern flush 6 litres for whole-flush and 3 litres for half-flush. The flush volume can also be 9/4.5 litres if the user has got an old pan that requires a bigger flush volume to clean the pan efficiently.
5 Result

This is the result from the research and concept development for a new plastic cistern aimed for the replacement market projected at Caromas manufacturing plant in Norwood, Adelaide. In this chapter the results of the final solution and design is presented in CAD renderings and photos of a full-scale prototype made for demonstration purposes. After gotten feedback from the marketing division in Sydney and having done a Concept Scoring Matrix, the Panel I Concept was chosen as the design to develop further. Some adjustments and refinements were made to make the cistern ready for prototyping and possible future production.

5.1 Product Requirements

The result of the product requirements set up in the Design Brief and requirements found doing research is presented in this chapter.

5.1.1 Cover the Footprint

The new cistern is designed to cover the footprint of all of Caromas and other brands plastic cisterns already existing on the market. The new cistern has got a geometry that covers the footprint in an optimized way. The new cistern will cover marks left on the wall caused by the previous cistern. See figure 5.1

![Figure 5.1 Rendered picture, front view, covering the footprint](image)
5.1.2 Connection plate
The cistern has got a connection plate that joins the cistern and the pan. The connection plate is used if the cistern is placed on ultra-low level, mounted close to the pan. The design of the connection plate was done on the basis of a footprint generated after having measured the size of present connection plates. It makes the toilet look like one integrated piece instead of a cistern and a pan connected with a pipe. The connection plate follows the design of the cistern and has got the same curve on the front and the same radius. The new connection plate will be included in the kit that accompanies every purchase of a new cistern. The kit consists of the new cistern, the new connection plate and a Low-line toilet seat.

![Figure 5.2 Rendered pictures of the new cistern and its connection plate](image)

5.1.3 Toilet Seat
The connection plate is designed to fit perfectly onto the Low-line seat, which is going to be included in a kit together with the new cistern. The connection plate has got the same round as the seat and integrates well with the rest of the toilet.

5.1.4 Flush Buttons
The button setup for the new cistern is designed as a rocker. It is an elongated toggle with differently sized water drops used as symbols for whole- and half-flush. The whole-flush symbol is placed to the right and the half-flush symbol is placed to the left. The material for the toggle is chrome plated ABS plastic that gives it a feeling of brushed aluminium. The colour used is called satin chrome and gives the button a matt and stylish finish that does not easily get stained by fingerprints and moist. The button will appeal to users looking for a product with something in addition to a conventional cistern. The satin chrome finish will make it easy to incorporate in a modern bathroom but can also add that little extra to an older interior.
The rocker mechanism makes the button innovative and is a feature not used before in a Caroma product. There will be a lever inside the cistern that will increase the momentary force. The actual distance that the button is pushed down is smaller than the internal outcome. The button shall feel like it is corresponding to the following action, the flush. The button setup is provided with a frame that is snapped on to the cistern on the assembly line. The frame covers the edges of the hole in the cistern that is cut out to accommodate the button. The button itself is placed on the valve to enable the flush. See figure 5.3.

![Figure 5.3 Rendered pictures of the new cistern and its button setup](image)

5.1.5 Manufacturing Considerations

To be able to produce the cistern by using injection moulding some changes in the design had to be made. The lid is designed with a draft angle that does not allow the piece to be ejected from the mould. Talking to the design engineers and discussing different alternatives ended up in two different ways to come past this problem. One way is to design the lid in two parts with a snap-on-top. The other option is to make a lid with an open back and making a mould with a collapsible core that works in two steps. The second option might be the most expensive solution but with the best result.

5.1.6 Accommodating Inner Components

The Hi-Flow valve that will be used for the cistern has got the height of 300mm. The valve acts as a stiffener for the water container and helps keeping the curved front shape of the cistern, since the plastic is soft. The valve is fixed in place by strips on the inside of the container. The water container will have an extrusion that will be overlapped by the lid on which the valve is mounted. The extrusion will make the cistern stiffer and the proportions are kept, with the golden relation.
5.2 Design
The new cistern has been designed with the approach to create a toilet that does feel as a new fresh part of the bathroom. The concept is called the Panel I Concept and the aim has been to create a concept with clean edges and shapes. The design shall appeal to a wide range of people, not being to radical but at the same time adding a new dimension to Caromas range of plastic toilet cisterns. Working with simple geometries and proportions adds a new touch to a traditional product. The design is obvious and easy to integrate in an existing bathroom interior. The simple geometry and even surfaces makes it easy to clean, no unnecessary gaps or spaces allows dirt to collect.

5.2.1 Angles and Rounds
The cistern is provided with angles that give it a slim and sophisticated look. The lid and the water container consist of one single shape that is divided by a distinct line, a gap. To create a “Panel feeling” the angles are moderate but distinct and repeat themselves in the connection plate and form an integrated product. The rounds chosen for the cistern are rather small to give it a “Panel feeling” wanted from the concept generation. The same rounds and angles are used on many of the edges of both the cistern and the connection plate to create a consistent design an a feeling of uniformity. The rounds chosen for the connection plate matches the ones on the toilet seat to create an integrated look and a smooth transition between the two parts.

Figure 5.4 Rendered pictures of the cistern seen from the side
5.2.2 Proportions
The proportions used in the design of the new cistern, come from “The Golden Number” or “Fibonacci's golden relation”. This relation is obtained by giving the height of the lid and the water container the ratio 0.618034. This is used to create a new look and to make the cistern look proportional avoiding the small conventional lid seen in many other models of toilet cisterns. The new ratio between the lid and water container at first may look strange since all other cisterns have got a small lid. But taking into consideration the required size for the cistern, using a dividing line to break it off, gives it the impression of being smaller and more balanced. The dividing line also gives it a new look, asked for by the Caroma management.

5.2.3 Shapes
The cistern is slightly shaped as a shield covering the wall and giving the design an interesting shape. The cistern shall feel as a natural part of the interior and almost as a piece of furniture. The user shall feel a natural interaction and use the cistern in the interior, not only as a toilet cistern but also as an intended shelf.

5.2.4 Intended shelf
The new cistern is designed with a top part that is intended as a shelf. It is flat surface on which objects can be placed. The area on top of the cistern is big enough to accommodate rolls of toilet paper and other hygiene products without blocking the flush button.
5.3 Final Design
After the concept development work and feedback from marketing, the design of the new cistern was set to a shape not seen before in a Caroma product. The company wanted to have a different look and add something new to their range of plastic cisterns.

5.3.1 Uniform
The name of the new cistern is “Uniform”. The name refers to its main purpose to cover the footprint of all the other cisterns with one form, a uni-form. The cistern will cover all footprints with one shape. It also refers to the action of covering, the cistern will dress up the wall and cover marks from previous cisterns, as a set of clothes, a uniform. The name is also easy to associate with Caroma, since a previous model is called Uniset. It is the Uniset and the Duoset that are Caromas biggest cisterns, these are the main reason for this product development project.

The definition of the word uniform (13):

1. A distinctive set of clothes worn to identify somebody’s occupation, affiliation, or status
2. A single outfit of identifying clothes
3. A particular style or other feature that identifies somebody as a member of a certain group
Adjective
1. Always the same in quality, degree, character, or manner
2. Conforming to one standard or rule
3. Being the same as another or others
4. Unvarying in colour, texture, or design
Verb
1. To provide people or a group with uniforms
2. To make something homogeneous, unvarying, or consistent

![uniform](image)

Figure 5.6 Example, Uniform logotype

The logotype for the cistern can be applied in a number of ways to get a nice visual effect to the product. The logotype can be hot stamped into the plastic on the front of the cistern. It can also be laser marked onto the button setup. An example made for the Uniform logotype is shown above, figure 5.6.
5.3.2 The Prototype

The final design is here presented in a full-scale prototype. The prototype is made in ABS plastic and printed in a rapid prototype machine. The prototype is placed on a Caroma toilet pan and connected to the Low-line toilet seat. The connection plate, that also was prototyped for this purpose, fits perfectly to the Low-line toilet seat with the wide hinge bracket.

The wall and the floor behind the toilet were tiled for this purpose to highlight the design of the cistern, giving the background a dark colour to create a high contrast to the white plastic.

The prototype makes the design very visual and easy to comprehend for visitors and marketing.

Figure 5.7 Picture of the full-scale prototype of the Uniform cistern
The design of the flush button is made as a rocker and the material is chrome plated ABS plastic with a satin chrome finish that makes it look like brushed aluminium. The styling of the flush button gives the whole cistern a feeling of being fresh and modern and it also makes it easy to integrate in a contemporary bathroom interior.

![Figure 5.8 The flush button setup](image)

The cistern is provided with an intended shelf on which it is possible to place objects without interfering with the button setup. Objects are easily placed on top of the flat surface on top of the cistern and it will interact with the usage of the bathroom.

![Figure 5.9 Cistern used as a shelf](image)
The new toilet cistern has got a design not seen before in Caroma product. It will appeal a younger range of users as well as to older users wanting to replace their old-fashioned cisterns with big footprints.

The Uniform cistern adds a new touch to an old product. The new cistern design opens up for the replacement market. It makes it possible to replace an old cistern without redecorating the whole bathroom. The new cistern will also attract users who want something new and different to their bathroom interior. The design is kept simple and clean, it allows keeping the toilet clean since there are fewer spaces where dirt can collect.

The new cistern gives a fresh touch to an old bathroom and it adds a fresh product to Caromas range of plastic toilet cisterns.
6 Discussion

The project was done fulfilling a Design Brief that the company and I formulated together. We also set up a time-line to help me structure my work and to help the company knowing how I progressed with my work. Sometimes too much attention was put into the time-line and it almost became a goal itself keeping up with the time-line instead of maybe get a good end-result.

6.1 Information Gathering

Information has been gathered throughout the whole project. Since I had a fixed position at Caroma and worked almost as an employee at their Research and Development office, I had access to their literature, cisterns and manufacturing plant. My work experience out in the factory was very useful for my design since I could follow the production and study manufacturing processes. All the personnel was very helpful and helped me and answered all my questions.

The interview with the company plumber was also very useful. He gave a lot of interesting input to the project since he is the person with the most experience from actual replacements. He also by experience know what users want and look for when choosing a new toilet cistern.

Unlimited access to the UniSA library and a meeting with Sandy Walker, professor at the industrial design department also gave valuable input to the project.

6.2 Concept Generation

The method, Identity Tool Kit (ITK), was used to generate a visual image of what I wanted to accomplish in my project. The method was new to the company and was not what they had expected. They found it a bit indistinct and hard to understand but it helped me communicate the style I wanted to achieve, using images instead of only words. After discussions with the engineers the ITK helped creating a common platform to start from and it enriched the project.

6.3 Concept Selection

Part of the concept selection was supposed to have been made by David Humphreys, head of the marketing division in Sydney. A presentation was put together for him to look at with all the background behind each concept and solutions to sub-problems. Mr Humphreys was on vacation and could not take part of the presentation or give any feedback. Another person from marketing in Sydney was then contacted and after having seen the concepts her choice of preference was the Panel 1 Concept. Also the director at the manufacturing plant in Adelaide, Peter Dunstan, preferred this concept. So that was the concept we decided to develop further.
6.4 Design
The cistern design was very much determined by the required footprint, which resulted in a very big cistern. The volume of the cistern is bigger than the required flush-volume. This feel incorrect since the signal that the cistern gives is that it contains a lot of water.

The prototype made for demonstration purposes gave a very good idea about the cistern design. The possibility of touching it, not only watching a rendered picture made it easier to comprehend the design. A lot of time was put into making the prototype, but after having seen the result placed on a pan, it was definitely worth it.

6.5 Manufacturing
At Caroma, plastic moulding is fundamental. Using only injection moulding limits the designs and possible geometries. It would have been interesting to examine other techniques such as blow moulding and over moulding. Blow moulding could be an alternative to get geometries that cannot be achieved with injection moulding. When blow moulding no core has got to be extracted and the mould can easily be opened in several directions not limiting the geometry. Over-moulding or twin shooting is a moulding technique where different plastics are joined together. When over-moulding the tolerance is very important to avoid flash and there is an extra moment placing the part in the mould before each mould and it becomes more expensive. But the effect over-moulding can give would make the design more interesting. Co-moulding is another technique where plastics and metals are joined together. Joining polypropylene and aluminium could make a nice effect for the button setup. It could make the cistern easier to clean, eliminating edges and spaces where dirt can collect.

6.6 Continuation
The concept presented in this report is not a finished product ready for production. A lot of issues still have to be solved. The mould for the cistern might have to have a collapsible core that would make it expensive to produce. Since the cistern is a replacement product and not aims for the high-end market, manufacturing costs have to be minimized.

Caroma has not released a new plastic cistern for many years and the market is changing with new styles and trends. There is definitely a market for a new cistern replacing old malfunctioning cisterns made 30 years ago.

Conclusions made during the project have been the importance of knowledge about the material and manufacturability. These factors are essential in the design of a product, especially a plastic moulded product with many limitations. Another conclusion is that discussing the design and possible solutions with design engineers in an early stage and throughout the project eliminates the number of redesigns.
References


(2) www.what-is-injection-moulding.com.au

(3) www.design-technology.org/injectionmoulding

(4) Montell Polyolefins “Polypropylene Product Data” Catalog

(5) www.caroma.com.au

(6) www.toiletology.com

(7) https://www.wsaa.asn.au

(8) Rowland Kurt, 1964, *Pattern and Shape*, F W Cheshire Pty, Ltd, Melbourne

(9) Sowers, Robert, 1990, *Rethinking the forms of visual expression*, University of California Press, Los Angeles


(12) www.cadcamsystems.com

(13) Encarta World English Dictionary

www.reece.com.au
www.beaumont-tiles.com.au
www.technologystudent.com
www.answers.com
Caroma Plumbers Technical Manual
“Design of a new Toilet Cistern”

Project members
Åsa Jacobsson, student, Luleå University of Technology
Jason Dorsey, Project Development Manager, Caroma
Bob Speedie, University of South Australia

Caroma Industries Limited is a manufacturer of bathroom supplies. They have been developing moulded plastic products since 1941 and are considered pioneers when it comes to injection moulding. At the plant in Norwood Adelaide they produce plastic components such as toilet cisterns, lids and valves. Caroma was the first company to release the two button dual flush cistern, which made it possible to reduce the water usage by up to 67%.

The project
The project will involve the design and development of a new plastic cistern which is suitable for the replacement market. The three major requirements for the cistern:

- It must cover the ‘footprint’ of all the old plastic cisterns made by Caroma and or other manufacturers. At a rough guess there is possibly more then 10 different styles of plastic cisterns and they all have different ‘footprints’ (the ‘footprint’ is the wall-area that the cistern covers)
- It must accommodate all existing internal components that Caroma manufacture ie. Inlet and Outlet Valve
- It must be suitable for injection moulding using Polypropylene material

Majority of the old cisterns only have single flush and consume a lot of water, up to 11 litres per flush. The new cistern will be dual flush with flush volumes set to either 9/4.5 litres or 6/3 litres per flush. This enables the consumer to save water without having to replace the pan.

Another benefit to the consumer is the new cistern can be placed on the wall and because the old footprint is covered there is little or no redecoration required.

The project will be emphasizing on the styling of the new cistern. Concepts will also be made for the buttons for the dual flush in an obvious and user-friendly way. When designing the new cistern manufacturability will be taken into consideration. The product will consist of a tank, lid and dual flush button set.

For the completion of the project 3 computer generated concepts will be presented. From those 1 will be selected and an actual model will be made for demonstration purposes and possible further development.
The time frame for the project is 20 weeks commencing Monday 17th October 2005. During this time research, concept generation, selection of concept and concept refinement will be made.

- **Research**: examine old models, establish requirements and specifications, benchmarking, photographing
- **Concept generation**: brainstorming, ITK, sketching, 3D modelling (3 concepts)
- **Selection of concept**: Feedback from marketing and choosing the concept to work with (1 concept)
- **Concept refinement**: Model making (physical and virtual) and renderings

Documentation will be ongoing throughout the entire project and a written report presented on completion.

The project will follow a time-line.
1. Mould fills via gates and runners

2. Mould packing stage under pressure

3. Injection unit retracts. Screw recharges barrel with another shot of plastic. Mould coolant cools and solidifies the plastic.


5. The component drops out of mould. Sometimes this is a robotized operation.
1. GRANULATED POLYPROPYLENE
2. HOPPER
3. FORCE HALF OF MOULD
4. CAVITY HALF OF MOULD
5. MOULD CLAMPING FORCE
6. RECIPROCASTING SCREW
7. HEATERS
8. FIXED PLATEN
9. MOVABLE MOULD PLATEN
Homopolymer PM6100

Montell Australia's Polypropylene grade PM6100 is a moderate flow homopolymer with a conventional molecular weight distribution and is formulated with a general purpose additive package. PM6100 is designed for injection moulding applications. End use products typically made from PM6100 include high quality hollow containers, closures and lids.

<table>
<thead>
<tr>
<th>Physical properties</th>
<th>Test Method (b)</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melt Flow Rate (230°C, 2.16 kg)</td>
<td>ISO 1133</td>
<td>g/10 min</td>
<td>5.5</td>
</tr>
<tr>
<td>Density</td>
<td>ISO 1183</td>
<td>g/ml</td>
<td>0.905</td>
</tr>
<tr>
<td>Method D</td>
<td>ISO 868</td>
<td>Shore D</td>
<td>70</td>
</tr>
<tr>
<td>Hardness</td>
<td>after 1 second</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanical Properties</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexural Modulus</td>
<td>ISO 178</td>
<td>MPa</td>
<td>1300</td>
</tr>
<tr>
<td>2mm/min</td>
<td>ISO R527</td>
<td>MPa</td>
<td>34</td>
</tr>
<tr>
<td>Tensile Yield</td>
<td>55mm/min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notched Izod Impact Strength at 23°C</td>
<td>ISO 180/1A</td>
<td>kJ/m²</td>
<td>3.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thermal properties</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vicat Softening Point</td>
<td>ISO 306</td>
<td>°C</td>
<td>152</td>
</tr>
<tr>
<td>Method A</td>
<td>ISO 75</td>
<td>°C</td>
<td>57</td>
</tr>
<tr>
<td>Heat Distortion Temperature</td>
<td>Method A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>at 1.8 MN/m²</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a) The values quoted here are typical of the grade, however, it is important to recognise that some variation around these values is to be expected as a result of uncertainties associated with measurement of the specific property and due to the normal variations encountered during the manufacturing process.
b) Typical properties characterizing PM6100, determined from laboratory samples prepared in accordance to ISO 1673-2 moulding conditions are presented here.
Plastic Cisterns

Caroma models

**Uniset /Solitaire**
Dual/Single Flush
W: 527mm
H: 386mm
D: 159mm

**Mini Uniset**
Dual Flush
W: 390mm
H: 425mm from pan
D: 140mm

**Duoset**
Dual/Singel Flush
W: 490mm
H: 400mm
D: 150mm

**Flowline/Pedigree**
Single Flush
W: 490mm
H: 375mm
D: 190mm

**Diamond**
Single Flush
W: 502mm
H: 575mm from pan
D: 214mm
**Concorde/Verona**  
Dual/Single Flush  
W: 460mm  
H: 390mm  
D: 160mm

**Concorde Slimline**  
Dual Flush  
W: 450mm  
H: 405mm from pan  
D: 143mm

**Trident/Posh**  
Dual Flush  
W: 390mm  
H: 395mm  
D: 125mm

**Cosmo**  
Dual Flush  
W: 420mm  
H: 445mm from pan  
D: 145mm
Other Brands

Tasman

Symphony

Fowler Tasman

Brent

Unknown Brands
Connection Plates

All the connection plates used for Caroma cisterns

<table>
<thead>
<tr>
<th>Model</th>
<th>Width</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slimline</td>
<td>260</td>
<td>50</td>
</tr>
<tr>
<td>Fowler Tasman</td>
<td>220</td>
<td>65</td>
</tr>
<tr>
<td>Mini Uniset</td>
<td>290</td>
<td>50</td>
</tr>
<tr>
<td>Uniset</td>
<td>290</td>
<td>50</td>
</tr>
<tr>
<td>Duoset</td>
<td>450</td>
<td>100</td>
</tr>
<tr>
<td>Concord</td>
<td>280</td>
<td>60</td>
</tr>
<tr>
<td>Cosmo</td>
<td>260</td>
<td>50</td>
</tr>
<tr>
<td>tTident</td>
<td>260</td>
<td>50</td>
</tr>
</tbody>
</table>

Measurements for the connection plates
Criteria

R = Required
D = Desired

Geometry
Cover footprint  R
Cover high, mid, low ultra low level installation  R
18 mm push down for buttons  R
Fit the inlet/outlet valve, 120 mm  R
East to clean  D

Installation
Install onto an old pan  R
Easy to install  D
No need for redecoration  D
Connection plate for ultra low level  R

Function
Full- and half-flush  R
Place things on  D

Signals
Audio feedback when flushing  D
Easy to understand interface  D
Clear graphics  D

Style
Easy to integrate in bathroom interior  D
Look robust, not bulky  D
Express quality (Caroma)  D
Caroma logo  R

Ergonomics
Easy to understand interface  D
Tactile feedback  D

Material
Polypropylene for cistern  R
ABS for chromed parts  R
Easy to clean  D
Smooth finish  D
Resist scratches  D

Maintenance
Easy to remove lid  D
<table>
<thead>
<tr>
<th>Environment</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Recyclable</td>
<td>D</td>
</tr>
<tr>
<td>Dual flush function to reduce water consumption</td>
<td>R</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Manufacturing</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard inner components (inlet/outlet valve)</td>
<td>R</td>
</tr>
<tr>
<td>Manufactured at Caroma</td>
<td>D</td>
</tr>
<tr>
<td>High quality manufacturing</td>
<td>D</td>
</tr>
<tr>
<td>Injection moulded at Caroma</td>
<td>R</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assembling</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Short assembly time</td>
<td>D</td>
</tr>
<tr>
<td>Assembling at Caroma</td>
<td>R</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Costs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Low cost product</td>
<td>D</td>
</tr>
<tr>
<td>Standard components</td>
<td>D</td>
</tr>
<tr>
<td>Cost effective manufacturing</td>
<td>D</td>
</tr>
<tr>
<td>Criteria</td>
<td>Geo</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----</td>
</tr>
<tr>
<td>Geometry</td>
<td>1</td>
</tr>
<tr>
<td>Installation</td>
<td>1</td>
</tr>
<tr>
<td>Function</td>
<td>0</td>
</tr>
<tr>
<td>Signals</td>
<td>0</td>
</tr>
<tr>
<td>Style</td>
<td>1</td>
</tr>
<tr>
<td>Ergonomics</td>
<td>0</td>
</tr>
<tr>
<td>Material</td>
<td>1</td>
</tr>
<tr>
<td>Maintenance</td>
<td>0</td>
</tr>
<tr>
<td>Environment</td>
<td>0</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>1</td>
</tr>
<tr>
<td>Assembling</td>
<td>0</td>
</tr>
<tr>
<td>Costs</td>
<td>0</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td></td>
</tr>
</tbody>
</table>

Concept Scoring
<table>
<thead>
<tr>
<th></th>
<th>Desires</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geo</td>
<td>easy to clean</td>
<td>100</td>
</tr>
<tr>
<td>Inst</td>
<td>easy to install</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>no need for redeco</td>
<td>75</td>
</tr>
<tr>
<td>Func</td>
<td>Place things on</td>
<td>100</td>
</tr>
<tr>
<td>Sign</td>
<td>audio feedback</td>
<td></td>
</tr>
<tr>
<td></td>
<td>easy interface</td>
<td></td>
</tr>
<tr>
<td></td>
<td>clear graphics</td>
<td></td>
</tr>
<tr>
<td></td>
<td>audio feedback</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>easy interface</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>clear graphics</td>
<td>2</td>
</tr>
<tr>
<td>Sty</td>
<td>easy to integrate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>look robust</td>
<td></td>
</tr>
<tr>
<td></td>
<td>express qual.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>easy to integrate</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>look robust</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>express quality</td>
<td>0</td>
</tr>
<tr>
<td>Ergo</td>
<td>understandable. Interface</td>
<td></td>
</tr>
<tr>
<td></td>
<td>tactile feedback</td>
<td></td>
</tr>
<tr>
<td></td>
<td>understandable. Interface</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>tactile feedback</td>
<td>0</td>
</tr>
<tr>
<td>Mat</td>
<td>easy to clean</td>
<td></td>
</tr>
<tr>
<td></td>
<td>smooth finish</td>
<td></td>
</tr>
<tr>
<td></td>
<td>resist scrach</td>
<td></td>
</tr>
<tr>
<td></td>
<td>easy to clean</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>smooth finish</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>resist scratches</td>
<td>0</td>
</tr>
<tr>
<td>Main</td>
<td>easy to remove lid</td>
<td>100</td>
</tr>
<tr>
<td>Env</td>
<td>recyclable</td>
<td>100</td>
</tr>
<tr>
<td>Manu</td>
<td>man. at Caroma</td>
<td></td>
</tr>
<tr>
<td></td>
<td>high quality</td>
<td></td>
</tr>
<tr>
<td></td>
<td>man. at Caroma</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>high quality</td>
<td>2</td>
</tr>
<tr>
<td>Ass</td>
<td>short ass. time</td>
<td>100</td>
</tr>
<tr>
<td>Cost</td>
<td>low cost product</td>
<td></td>
</tr>
<tr>
<td></td>
<td>standard comp</td>
<td></td>
</tr>
<tr>
<td></td>
<td>cost eff. manu</td>
<td></td>
</tr>
<tr>
<td></td>
<td>low cost product</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>standard comp.</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>cost eff. manu</td>
<td>1</td>
</tr>
<tr>
<td>%</td>
<td>%</td>
<td>Grading</td>
</tr>
<tr>
<td>------</td>
<td>------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concept1</td>
</tr>
<tr>
<td><strong>Geometry</strong></td>
<td>13,2</td>
<td>easy to clean</td>
</tr>
<tr>
<td><strong>Installation</strong></td>
<td>13,2</td>
<td>easy to install</td>
</tr>
<tr>
<td></td>
<td></td>
<td>no redecoration</td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td>12,5</td>
<td>place things on</td>
</tr>
<tr>
<td><strong>Signals</strong></td>
<td>7,6</td>
<td>audio feedback</td>
</tr>
<tr>
<td></td>
<td></td>
<td>easy interface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>clear graphics</td>
</tr>
<tr>
<td><strong>Style</strong></td>
<td>12,5</td>
<td>easy to integrate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>look robust</td>
</tr>
<tr>
<td></td>
<td></td>
<td>express quality</td>
</tr>
<tr>
<td><strong>Ergonomics</strong></td>
<td>6,9</td>
<td>understandable. interface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tactile feedback</td>
</tr>
<tr>
<td><strong>Material</strong></td>
<td>10,4</td>
<td>easy to clean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>smooth finish</td>
</tr>
<tr>
<td></td>
<td></td>
<td>resist scratches</td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td>5,6</td>
<td>easy to remove lid</td>
</tr>
<tr>
<td><strong>Environment</strong></td>
<td>3,4</td>
<td>recyclable</td>
</tr>
<tr>
<td><strong>Manufacturing</strong></td>
<td>9</td>
<td>manu. at Caroma</td>
</tr>
<tr>
<td></td>
<td></td>
<td>high quality</td>
</tr>
<tr>
<td><strong>Assembling</strong></td>
<td>2,8</td>
<td>short ass. time</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>2,8</td>
<td>low cost product</td>
</tr>
<tr>
<td></td>
<td></td>
<td>standard comp.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cost eff. Manu</td>
</tr>
<tr>
<td>Organic</td>
<td>Panel I</td>
<td>Panel II</td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>Concept1</td>
<td>0.66</td>
<td>0.132</td>
</tr>
<tr>
<td></td>
<td>0.66</td>
<td>0.132</td>
</tr>
<tr>
<td></td>
<td>0.396</td>
<td>0.132</td>
</tr>
<tr>
<td>Concept2</td>
<td>0.495</td>
<td>0.495</td>
</tr>
<tr>
<td></td>
<td>0.495</td>
<td>0.495</td>
</tr>
<tr>
<td></td>
<td>0.495</td>
<td>0.495</td>
</tr>
<tr>
<td>Concept3</td>
<td>0.375</td>
<td>0.625</td>
</tr>
<tr>
<td></td>
<td>0.375</td>
<td>0.625</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>0.016872</td>
<td>0.016872</td>
</tr>
<tr>
<td></td>
<td>0.016872</td>
<td>0.016872</td>
</tr>
<tr>
<td></td>
<td>0.016872</td>
<td>0.016872</td>
</tr>
<tr>
<td></td>
<td>0.134976</td>
<td>0.134976</td>
</tr>
<tr>
<td></td>
<td>0.134976</td>
<td>0.134976</td>
</tr>
<tr>
<td></td>
<td>0.134976</td>
<td>0.101232</td>
</tr>
<tr>
<td></td>
<td>0.3475</td>
<td>0.278</td>
</tr>
<tr>
<td></td>
<td>0.555</td>
<td>0.041625</td>
</tr>
<tr>
<td></td>
<td>0.1665</td>
<td>0.1665</td>
</tr>
<tr>
<td></td>
<td>0.25875</td>
<td>0.25875</td>
</tr>
<tr>
<td></td>
<td>0.25875</td>
<td>0.25875</td>
</tr>
<tr>
<td></td>
<td>0.25875</td>
<td>0.25875</td>
</tr>
<tr>
<td></td>
<td>0.069</td>
<td>0.069</td>
</tr>
<tr>
<td></td>
<td>0.069</td>
<td>0.069</td>
</tr>
<tr>
<td></td>
<td>0.069</td>
<td>0.069</td>
</tr>
<tr>
<td></td>
<td>0.28912</td>
<td>0.28912</td>
</tr>
<tr>
<td></td>
<td>0.28912</td>
<td>0.231296</td>
</tr>
<tr>
<td></td>
<td>0.17316</td>
<td>0.138528</td>
</tr>
<tr>
<td></td>
<td>0.17316</td>
<td>0.138528</td>
</tr>
<tr>
<td></td>
<td>0.134976</td>
<td>0.046176</td>
</tr>
<tr>
<td></td>
<td>0.134976</td>
<td>0.046176</td>
</tr>
<tr>
<td></td>
<td>0.134976</td>
<td>0.046176</td>
</tr>
<tr>
<td></td>
<td>0.224</td>
<td>0.224</td>
</tr>
<tr>
<td></td>
<td>0.224</td>
<td>0.168</td>
</tr>
<tr>
<td></td>
<td>0.102</td>
<td>0.102</td>
</tr>
<tr>
<td></td>
<td>0.102</td>
<td>0.102</td>
</tr>
<tr>
<td></td>
<td>0.1125</td>
<td>0.1125</td>
</tr>
<tr>
<td></td>
<td>0.1125</td>
<td>0.0675</td>
</tr>
<tr>
<td></td>
<td>0.049728</td>
<td>0.037296</td>
</tr>
<tr>
<td></td>
<td>0.049728</td>
<td>0.037296</td>
</tr>
<tr>
<td></td>
<td>0.049728</td>
<td>0.037296</td>
</tr>
<tr>
<td></td>
<td>0.012432</td>
<td>0.009324</td>
</tr>
<tr>
<td></td>
<td>0.012432</td>
<td>0.012432</td>
</tr>
<tr>
<td></td>
<td>0.012432</td>
<td>0.012432</td>
</tr>
<tr>
<td></td>
<td>0.049728</td>
<td>0.037296</td>
</tr>
<tr>
<td></td>
<td>0.049728</td>
<td>0.037296</td>
</tr>
<tr>
<td></td>
<td>0.049728</td>
<td>0.037296</td>
</tr>
<tr>
<td></td>
<td>3.904918</td>
<td>4.008939</td>
</tr>
<tr>
<td></td>
<td>3.904918</td>
<td>4.008939</td>
</tr>
<tr>
<td></td>
<td>3.904918</td>
<td>4.008939</td>
</tr>
<tr>
<td></td>
<td>3.360979</td>
<td>3.360979</td>
</tr>
</tbody>
</table>