PRO 204 – Modeling Prototyping

APPEARANCE PROTOTYPES

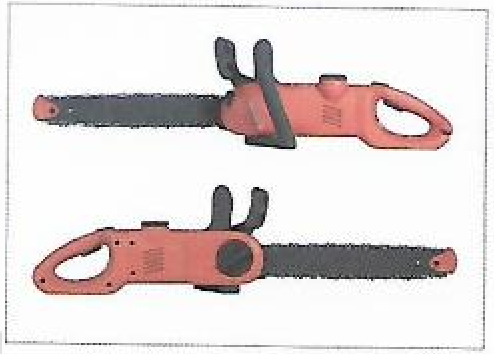
Appearance Prototypes

After idea exploration and testing with end users, the design of a product will progress toward a higher level of detail and refinement. High-fidelity looks-like prototypes are used to communicate the final appearance of the product. These final appearance models also have several prototyping uses, such as presentations to clients for sign-off before final tooling investment is made. They can also be displayed at trade shows, or used for professional product photography to announce a new product release.

This type of prototype is very much about visual refinement. Not only should the form and edges be precise and include exact edge radii, but manufacturing details such as parting lines and paint finishes should also be accurate down to the actual surface texture of the parts. Graphics will be applied to add final realism as well as to confirm placement. This level of detail can be created in computer renderings, but there is an aspect of reality that can only be appreciated through holding and turning something physical in one's hands for closer examination.

The level of skill and amount of time involved in making such models is very high. In professional practice they are almost exclusively built from 3D CAD files, either with high-resolution 3D rapid prototyping equipment or by Computer Numerical Control (CNC) machining of the parts. These processes are described in detail in Chapter 8: Tools (pages 65–78). CNC machining parts in high-density polyurethane foam has often been the preferred approach to making appearance models. This gives a high-resolution surface finish that requires very little finishing beyond painting. Increasingly, parts made by rapid prototyping are exhibiting the same surface quality and are used interchangeably.

The student project at top left demonstrates how an appearance prototype was used to communicate both the form and innovative features for a new electric chainsaw. The idea was to simplify regular electric chainsaw maintenance. The appearance prototype does not work, but it clearly communicates how this design simplifies chain lubrication and replacement. The oversized oil refill cap and chain release are both designed to release without tools, which is quite obvious by looking at the prominent visual cues in these interface areas.



This student-built appearance prototype clearly communicates the design details and innovative tool-less maintenance features.

Physical Context of Use

Physical prototypes have the benefit of being able to be studied in their real physical context of use. Teams at Motorola Consumer Experience Design Group and Insight Product Development collaborated with the US National Football League (NFL) to redesign the NFL coaches' headsets. The final design included three different configurations that were prototyped as high-fidelity appearance models. The appearance models were instrumental in making sure that the Motorola brand was clearly visible on national television. This included the use of actual broadcast video to examine different logo options in snow and autumn outdoor lighting situations.

Insight Product Development created appearance prototypes to communicate the final design intent of the redesigned Motorola NFL headsets and to make sure the Motorola brand would be visible on national television.

Guidelines for Building Prototypes for Communication:

- Who is the audience? Where will they see the prototype and when?
- What is being communicated? Will the prototype be on display or will it be used for a demonstration purpose?
- Is it something that should be done in-house or should it be sent to a professional modelmaker?
- Think about communicating corporate identity, colour options, textures and other details.
- A full-scale appearance model is an opportunity to examine the product in its intended environment of use.

Design Verification

Many aspects of a product have to be tested and optimized prior to mass production. Digital CAD simulation has become an essential part of the process to verify overlapping issues with regard to appearance, manufacturing and performance. Some common simulation features include assembly part interference checking to ensure that parts fit together properly, and photorealistic rendering to verify that the product will look as intended. More advanced tools include Finite Element Analysis to check for stresses, strains and deflection during static loading or drop testing. CAD models can in turn be output to 3D printed models (see rapid prototyping in Chapter 8). These can be fitted with working breadboards and other working components to create fully functional prototypes as shown in Chapter 3.

Verification Aspects	Physical Prototypes	Digital Simulation
Aesthetics and branding	Appearance model	CAD rendering
Task mapping	Working prototype	3D animation
Manufacturing fit	3D printed parts	Part interference checking
Mechanisms	3D printed parts	Kinematic analysis
Strength	Machined components	Finite element analysis
Heat dissipation	Working prototype in lab	Heat transfer analysis

The table above shows how digital and physical prototyping complement each other. There are distinct advantages to both. Virtual simulation can happen very quickly and is useful to study the effects of loading and other functional parameters.

At the same time it is impossible to verify ergonomic issues such as comfort without real physical prototypes. In the NFL coaches headset redesign (page 24), it was necessary to verify the comfort and wearability of each one of the three distinct and different headsets through physical prototypes that could be worn and tested.

Technical Performance Testing

Technical components such as motors, fans and batteries are sourced from specialized manufacturers. Although technical specifications are provided by the manufacturers, it is common to verify these components in a lab environment as

This test set-up was built by FilterStream to test the suction of its hand-held vacuums. The amount of suction inside the box is measured while the vacuum is running to verify performance.

This test set-up was built by Mixer Design Group to simulate and test the effect of a dog biting a pet toy. The metal rods and clamping pressure mimic the dog's mouth.

part of the engineering process. The testing may include a benchmark of competitors' components to compare performance and cost. This type of prototyping often requires the construction of test jigs and fixtures, which depending on the test and situation may require professional engineering involvement. The testing apparatus in this case is made to obtain repeatable and measurable quantitative data.

The comfort of each of the redesigned Motorola headsets for the NFL was verified through prototyping.

Safety Standards Testing

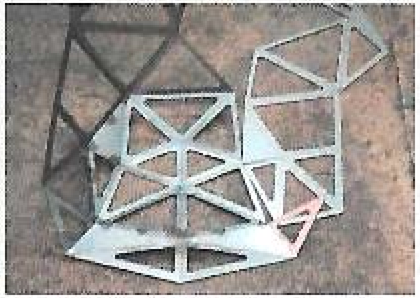
Product safety standards involve physical testing in a controlled laboratory environment. These standards are designed to protect consumers and are produced by organizations that specialize in assessing product risks and dangers. Standards organizations and independent testing labs will perform these tests for companies, to act as third-party validation. The tests simulate possible dangers, including impact, electrocution, strangulation or whatever hazards have been identified for the product category. The testing is done in highly controlled environments to ensure safety for the technicians and to have accurate results. Bicycle helmets, for example, are tested by dropping them on to anvils from a certain height in a drop tower. This simulates a person falling off a bike travelling a certain speed and hitting various objects.

Prototyping in Different Disciplines

In closing it should be noted that product designers have to work with professionals from other disciplines where the term prototype could be used to describe many things that are not three-dimensional. Software designers use the term prototype in the context of code. Electronics engineers speak about prototyping printed circuit boards. Similarly, when an interaction designer speaks about a paper prototype, it is in reference to mocking-up screen interfaces for computers. When they speak about a wireframe they are referring to the layout of a website, whereas in product design this refers to lines in space that define the edges of a physical product in a CAD model. It is worthwhile becoming more aware of these semantic differences since product design has become inherently interdisciplinary.

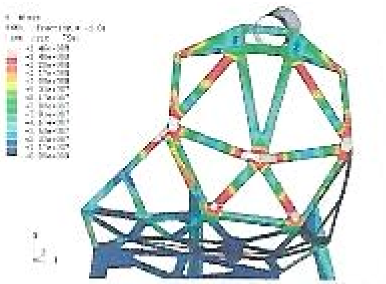
From Start to Finish: Comprehensive Case Studies

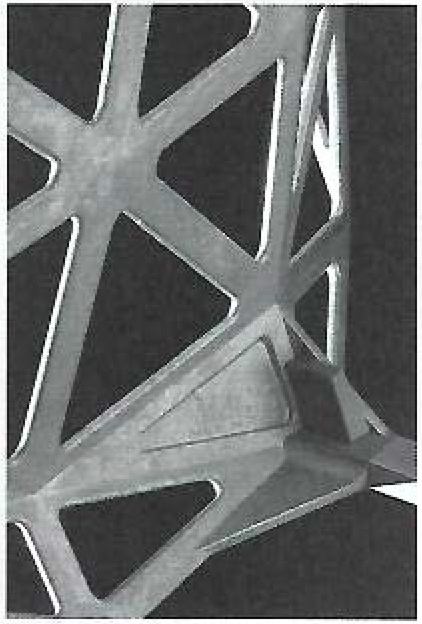
The use of prototypes will now be shown in the context of a few complete professional real-world design projects. As can be seen, the exact nature of the process will vary from organization to organization, as well as with the scope of the project. Student projects may last a few days or a whole year. In industry, projects could last for several years and be part of an ongoing product-development process.



The first explorations in creating Chair_ONE were in metal wire, but the final shape started to appear only when the work moved to paper.

A computer-constructed cardboard pattern (top) was followed by a laser cut metal prototype (above).





The work of Munich-based Konstantin Grcic Industrial Design (KGID) spans a range of products, from furniture to kitchenware. Konstantin Grcic's chair designs have received particular acclaim, including Chair_ONE for Magis, and Myto, a cantilevered plastic chair created in collaboration with BASF and the furniture manufacturer Plank.

In exploring design solutions, Grcic's process moves back and forth between drawing, computer and quick prototypes. There is a playfulness and curiosity in the early prototypes that is focused yet experimental. Grcic gives many reasons when asked about the importance of making prototypes. For one, he has observed that when someone is building something physical, other people tend to gather around and give creative input more readily than when someone is working on the computer. Quick explorative prototypes can be examined, destroyed and then reconstructed quickly. This is a form of iteration that necessitates that neither the prototype nor the design be seen as 'too precious' early on. Instead the focus is on learning, keeping the prototypes at what he terms 'an appropriate level'. He employs all kinds of materials and approaches in building his prototypes, depending on what is being tested.

In the development of the award-winning Chair_ONE for the company Magis, the challenge was to design a chair entirely out of aluminium as one die-cast part. The initial explorations started with bent wire in order to create the semblance of an all-metal chair. It was only when he started experimenting with cardboard that the true shape of the chair started taking form.

'Chair_ONE is constructed just like a football: a number of flat planes assembled at angles to each other, creating the three-dimensional form.' (Böhm 2005) This allowed the design to be created as simple planes on the computer that could be printed out and used as templates for cardboard prototypes. Once proportions had been explored, the same templates could be used to laser-cut metal for a presentation model to Magis. The final design still needed to be translated into a die-cast aluminium part. The final design was done in 3D CAD, which also allowed Finite Element Analysis tools to be used for design verification prior to creating the die-cast tooling.

The Myto cantilevered plastic chair was created to demonstrate the structural possibilities of a plastic material made by BASF called Ultradur® thermoplastic polyester. A cantilevered plastic chair presents a problem for ordinary plastic materials, as they would tend to bend or crack over time. Glass-reinforced Ultradur®, on the other hand, offered the required structural possibilities. The chair needed to be attractive and strong, yet springy, since that is a fundamental enjoyment of sitting in a cantilevered chair.

An early prototype for the Myto chair made from cardboard and perforated sheet metal was used to explore the overall form factor and design strategy. This model was reverse-engineered into CAD using measurements.

A solid Styrofoam model (shown in white) was used to verify the shape of the seating surface.

A final prototype of the Myto chair was made using the laser-sintering process. This prototype receives some final tweaks before the production tooling is made.

The first prototypes were made out of cardboard and perforated sheet metal. These explored the construction strategy of creating one solid form that was separated into a thick frame-bearing section with a thinner perforated seating surface. Extra strength could be added to the frame-bearing portion if necessary, making the design strategy more flexible. This model was then reverse-engineered by physical measurement back into the computer.

A solid Styrofoam prototype with a supporting core was useful in verifying the seat shape and ergonomic comfort. The seat surface was covered with tape to explore and communicate different perforation patterns.

Achieving a balance between functional comfort and strength required further prototyping and verification. The 3D CAD model was used both to run FEA simulation and to output a full-scale 3D rapid prototype. This laser-sintered prototype did not have the strength of the final Ultradur® but allowed the designers to understand the chair's behaviour and make some final tweaks to the design. The final production chair could be further tweaked by changing the material composition, which in fact was minimal given the extensive verification that preceded it.

Case Study

ECOtality Blink Range of Electric Vehicle Chargers

The ECOtality line of Blink electric vehicle chargers includes a wall-mounted residential charger (left), a pedestal commercial charger (top) and a commercial DC fast-charging station (above). Each of the three different types of use had to be considered in its own context.

This case study showcases the work of Frog Design of San Francisco working in partnership with ECOtality, a company specializing in clean electric transport technologies, to develop its range of three different 'Blink' charging stations for electric vehicles. It not only illustrates the importance of real physical prototyping throughout the design process, but also shows how the prototyping needs and methods may vary based on the intended environment and specific issues for each product. According to design director Howard Nuk at Frog, 'Physical experimentation (in-studio and on location) was the only way to both challenge and prove our theories. For each of the three chargers, we created a series of models to test specific usability, structural and aesthetic hypotheses.' The context of each product is different, even though the products are all chargers.

The first of the three chargers was a wall-mounted unit designed for private garages or carports. Secondly, a pedestal-mounted charger was designed for multiple installations across carparks. Lastly, a larger commercial unit, designed to fit between two parking spaces in a petrol station environment or in front of a superstore, was developed for fast-charging a vehicle in about 20 minutes.

All these environments had to be studied and understood in detail, requiring extensive exploration and investigation using models.

For the wall-mounted residential unit, a full-scale foamboard mock-up was created in the studio. This was instrumental in gaining two insights that would influence the product's configuration in this environment. The first observation was that garage spaces are tight and consequently the charger's profile had to be kept as close as possible to the wall. The second was that constraining the cable wrap to the charger housing (like almost every wall-mounted charger to date) had a series of functional limitations. The cable wrap was instead made into a separate entity, allowing the customer to mount it closer to the electric vehicle charging port while keeping the charger housing and touch screen at a more comfortable eye level. Simple low-fidelity models of the charger were used to act out scenarios and to confirm the proper design configuration.

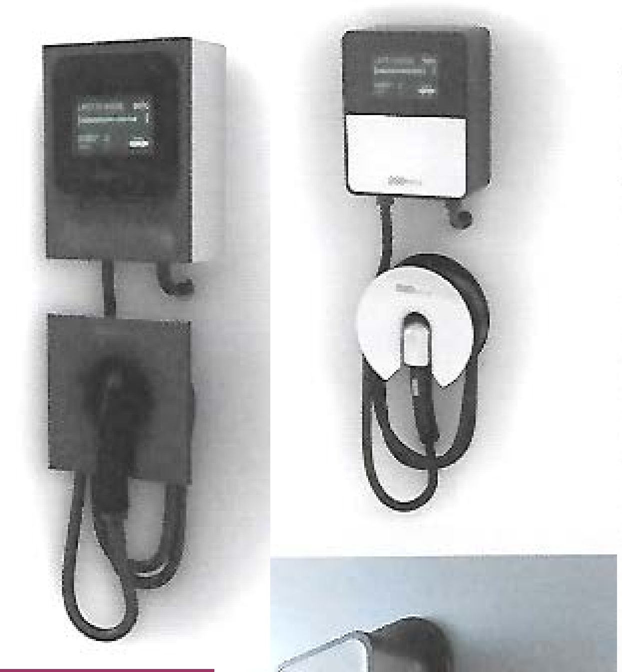
Electric vehicle chargers operate with thick copper wire. This raised many questions about functionality. Would users find the cable heavy? How far can a cable be conveniently pulled? What would happen when the temperature fell below freezing and the copper hardened?

To address such questions, the team froze cabling to understand bend radii and manoeuvrability, mocked-up parking/charging situations of all kinds and even devised weighted pulley systems to test cable weight management.

For the pedestal-mounted unit, it was critical to understand how the design would be suitable to the many different types of environment around shopfronts and carparks. Taking photographs and creating layouts of various real-life configurations allowed the team to examine the flexibility of installation.

Simple scale models examined different means by which to alleviate some of the fast-charger cable weight from the user's hands. Simple models help people visualize ideas and aid discussion among team members.

Low-fidelity full-scale prototypes were useful for user testing and showed that the residential cable wrap should be kept very close to the wall and separate from the charger housing.

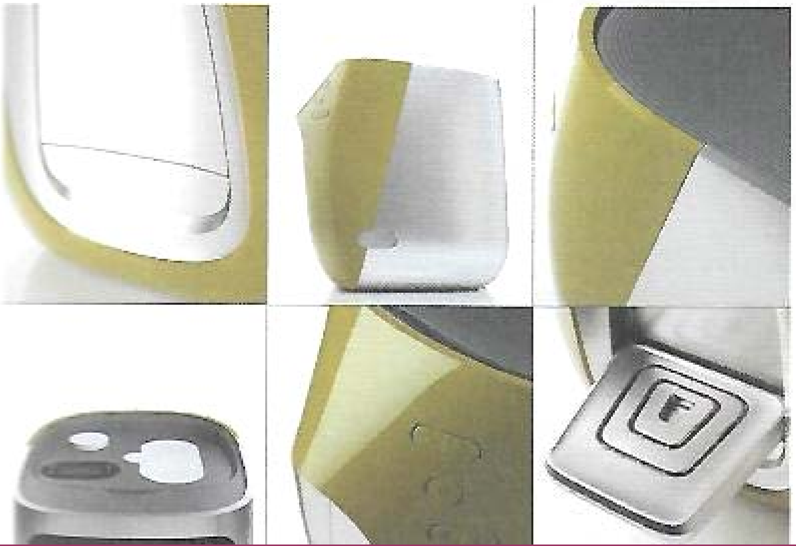


For the fast charger, the primary issue was the size and weight of the charging cable. In order to achieve the 20-minute charge, the cables needed to be almost twice the weight of the other charger units. Different solutions were brainstormed and visualized as small-scale models. These were useful for discussion and enabled the team to discount complex and unworkable ideas from the start. Instead, they chose a simpler strategy that suspended the cables from a high point, thereby reducing the resultant lifting force.

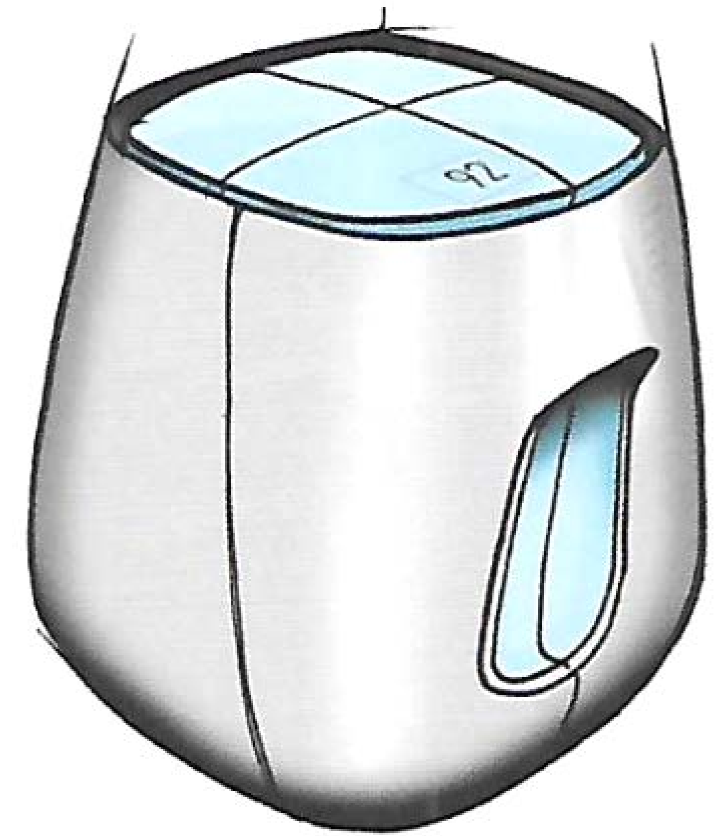
As the design of all three configurations progressed, high-fidelity appearance models were produced to complement 3D CAD virtual models. These physical models were used for final assessment of aesthetics (including colour, material, finish and proportion), as well as for media purposes via photos, videos and live conferences and exhibitions.

In order to evaluate the design in its proper physical context, models could not be judged in the studio alone. Howard Nuk points out that the 'product's proportions can often be misjudged due to artificial lighting, confined spaces and ceilings. Taking our DC fast-charger model to the intended install location to be judged among other devices like gas pumps and water/air pumps, and the infinite ceiling of the sky, gave the designers (and clients) a true understanding of the product's impression.'

3D CAD allowed designers to create numerous detailed design iterations. Computer renderings were complemented with real physical prototypes made in high-density modelling board (page 122) that could be evaluated in their intended environment.



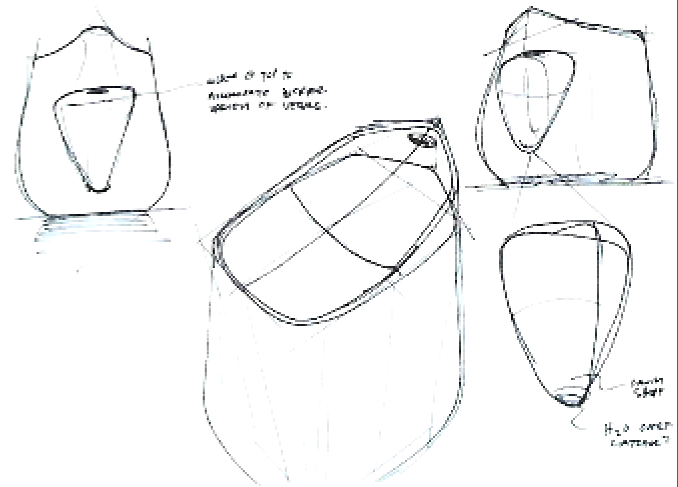
NewDeal designers collaborated to fill an entire wall with different ideas for the product. At this stage anything goes and forms the basis for exploration.



The Tana Water Bar is a water appliance that sits on a worktop, connected to the water main, and both filters and chills or heats drinking water. The form, designed by NewDeal Design of San Francisco as the silhouette of a vase, was meant to evoke in an understated way a natural form of a water vessel.

During the initial part of the project NewDeal designers researched the issues that were important for the design of the product. This established certain requirements, such as where it would be used, by whom (target audience), price point and other important marketing and performance objectives.

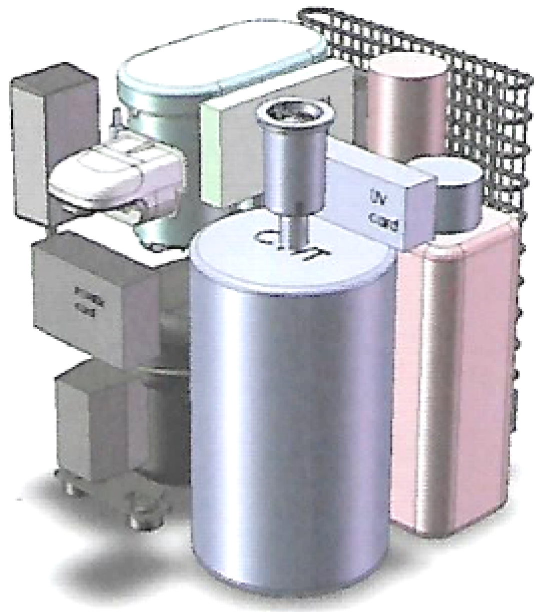
An approved brief and understanding of the product's intended use formed the basis for ideation. The designers covered the walls with sketches, both in order to communicate their ideas and to help identify issues for further design development.



The initial ideas were reviewed and then refined into successively more focused concepts.

After reviewing the initial sketch and model explorations with the client, the design team received enough feedback and direction to start the next step of the process. The objective of this step would be to define one design direction, so as to start focusing toward a solution. The aim was to develop a very precise and plausible design, including all technical constraints and inputs.

This required a more precise drawing approach and a layout of the internal components in 3D CAD so that



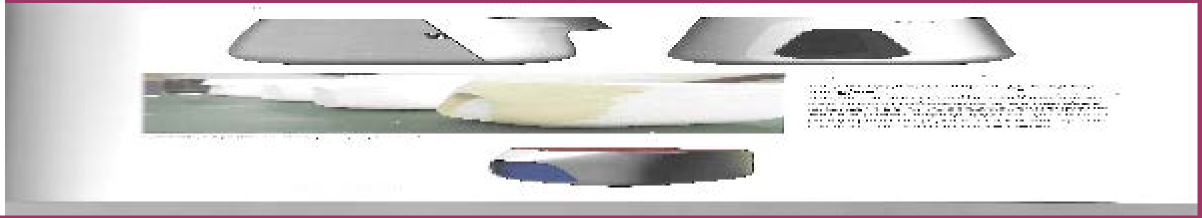
The inner workings were first modelled in 3D CAD to give a realistic size and overall form factor, which the designers could then draw around.

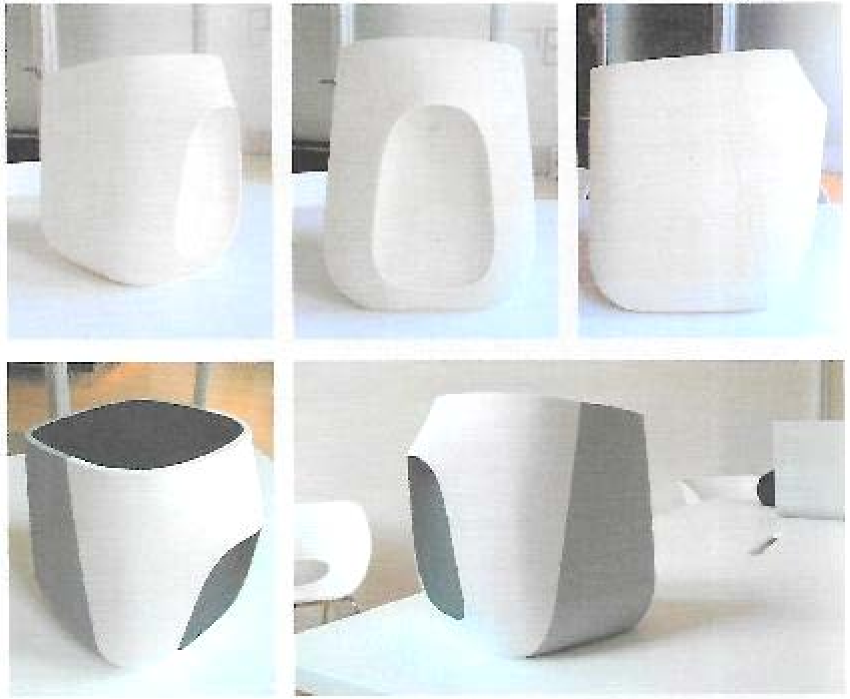
Explorative handmade models in polystyrene foam allowed the designers to explore the form in more detail.

Two-dimensional elevations gave an idea of what the product would look like.

the overall form could be developed on top of the internal configuration in full scale.

Elevation views gave a good idea of the visual and sculptural design intent, and were complemented with physical low-fidelity prototypes in polystyrene foam based on these two-dimensional layouts. The 3D polystyrene models gave a much clearer idea of the overall proportions and what the water-dispensing area should look like at the front. The models were thus used to explore the form in more detail.





The first set of appearance models focused on the overall form factor and proportions. They were accurately machined on a CNC to be suitable for presentation to a wider audience.

Final high-fidelity appearance prototypes took the design to the next level, examining every aspect of the product's detailing. The design went through two final iterations of refinement and physical prototyping to communicate and verify design details.

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