03: Digital design and construction of organic form

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Digital design and the construction of organic form may seem, prima facie, totally disconnected, but in fact they are deeply connected in the sense that these new forms are, in the end, layered and complex. Things are not segmented off each other, but meld and morph into each other forming complex differentiated arrangements, seamlessly and transitionally. These organic forms are profoundly related to new sets of communication patterns in both workplaces and public spaces.

Today's talk will concentrate on making and realising these forms – modelling the geometry in the computer and translating these into some kind of manufacturing process. We are trying to do this in a context where this kind of research and experimentation is not taking place in dedicated institutions. We face the fact that in the architecture discipline there are no dedicated research institutions. On the one hand graduate schools have taken up the burden and are using masters degree students (bringing with it the problems of changing tenure) to conduct research, in an attempt to establish research agendas. On the other hand we are picking up that void and acting as substitute research institutions; as avant-garde studios. With such a random sample of commissions and competitions it is difficult to construct a research agenda. Zaha-Hadid has been doing this for 25 years - I joined 17 years ago - and nowadays we are going mainstream. The central building of the BMW plant in Leipzig has been a fulfilment on many levels for us and is doing active work.

Today I am showing a very narrow slice of work which is more experimental and innovative on this manufacturing and geometry level. I will show the stages we go through to get from abstract installations and exhibition designs right through to public buildings. There are a number of techniques which evolve through these stages, adding up the complex requirements. Illustration 1 shows the very early vision of Zaha-Hadid, just before I came to the office. You can see the desire for sinuous curvilinear, connective and layered forms which were further dreamed up in competition entries in the mid-Nineties.

Illustration 1: sketch showing the early vision of the Zaha Hadid office

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Ice storm, Museum of Applied Arts, Vienna
In 2000 we constructed an environment called *Ice Storm* at the Museum of Applied Arts in Vienna shown in illustration 2.

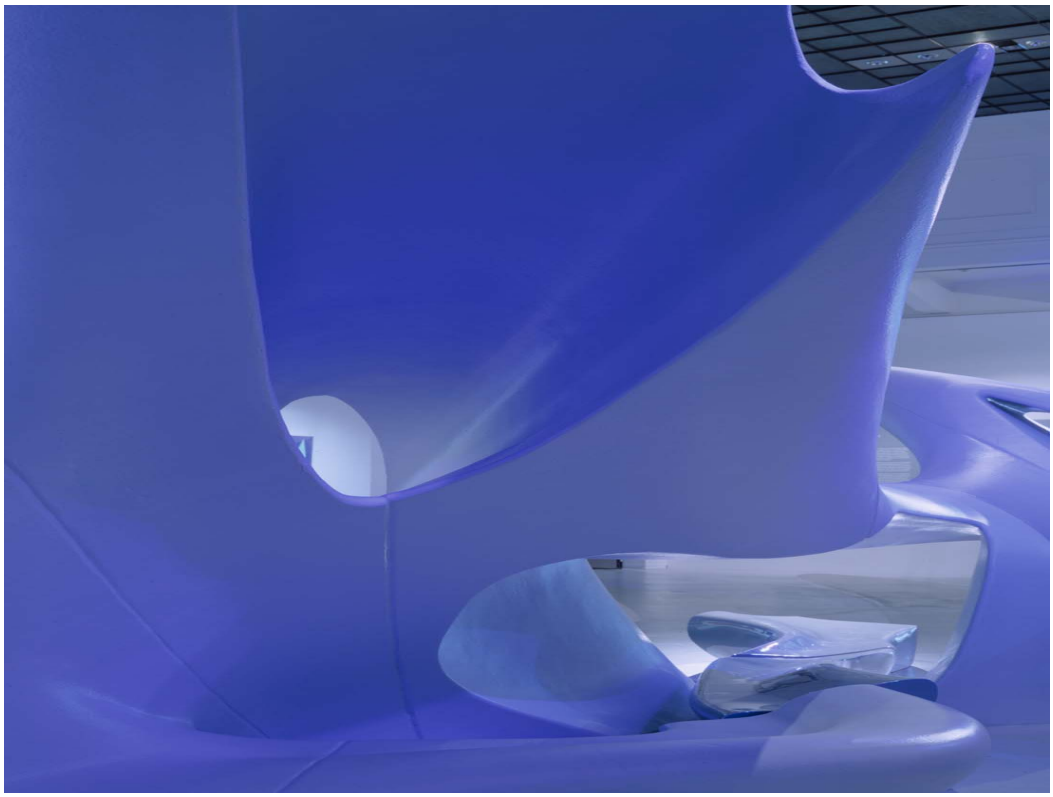


Illustration 2: 'Ice storm' at the Museum of Applied Arts, Vienna

This exhibition picked up a series of furnishings based on land formation analogies and we also worked on organic form and living systems analogies in a number of teaching contexts. This was all based on the new tools where you can sample sections and loft between them, creating continuously seamless surfaces.

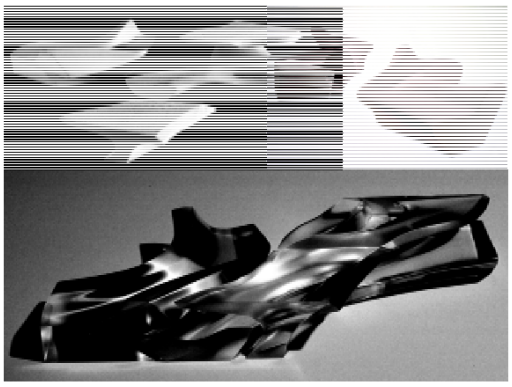


Illustration 3: interlocking furniture

Illustration 3 shows the idea of interlocking elements suddenly starting to subvert typologies. Here we have a bench, a table and a sofa, but the sofa is two-faced and things lock into each other and disappear and reconfigure. These elements have been launched as products in very simple ways of translation, where the simple lofting geometry has been dissected and CNC [Computer Numerical Control]-cut sheets are

glued together in a kind of cinematic section, literally translated in a handicraft fashion by Zawaya and Moroni in Milan.

We took these different furnishings and created a seamless environment where these elements were connected with an overall encompassing environment, all of them morphing into each other and into the continuously differentiated lounging landscape. They were the kind of spaces we could imagine for the next generation of Bureau Landschaft. Of course, here there is a lot of random form which occasionally articulates itself as recognisable elements of a sofa, chair, bench et cetera, and then gives an aspect of things to be discovered, so you explore and appropriate it in further ways. It is something we discussed extensively and relates back to management where not everything can be prescribed and there can be playfulness and a margin of randomisation, even in these highly efficient systems.

Latent Utopias

There is another exhibition, *Latent Utopias* shown in illustration 4 which was also incorporated here. This was an attempt to roll out an apartment with the different components – the bed area, study area, kitchen area – into a continuously folded strip rather than having segmented rooms with discrete objects. The idea here is also that you decode a little bit of the prescribed and highly coded use patterns which attach to us, and you build up these kinds of landscapes and certain products fall out of this. They are directly milled from the files. These are polystyrene milled and then polyurethane sprayed over to become relatively rigid, but this is still just a temporary exhibition environment.

Illustration 4: Latent Utopias

The Deutsche Guggenheim, Berlin

For the next step, we used the same Austrian manufacturer with a big milling machine, and found a technique of polyurethane coating and created a simple geometry. Illustration 5 shows a series of ellipses carving out a space in the Deutsche Guggenheim in Berlin, celebrating 20 years of the Deutsche Guggenheim collection. The exhibition is about curators but also about a series of clusters of paintings from the collection being arranged in a way which we wanted to be articulated, yet seamless, with lots of views in between. We came up with this idea of creating space segments which follow into each other and also allow the exterior surface to be utilised. It is all about framing views and creating these spaces, but for us it is also just a vehicle, another manifesto project where we want to bring these forms somewhere into the domain where they can be appreciated, where they do some work, but where they ultimately remain as manifesto structures which are not necessarily for individual use. Therefore the art becomes the kind of domain where research and experimentation,

perhaps more than systematic research, can take place. These are again large milled polystyrene blocks which are segmented off and placed and glued together creating these intricacies of layered and porous space.

Illustration 5: Deutsche Guggenheim in Berlin

The Aqua Table

Illustration 6 is the aqua table which is again an intersecting, self-dissecting surface. Instead of making moulds to create this product, the form is directly milled and coated with fibreglass, so in theory every piece you mill could be different, there is no necessity for repetition; it is a small series and it is a very light, 4.6 metre dinner-table; two people just can pick it up and it is quite sturdy and elegant.

Illustration 6: the aqua table

Beijing showroom

In Beijing we had permission to show a future home vision for an exhibition scenario, so it is a showroom with a particular function as opposed to being an apartment (illustration 7). This concept of a single surface with its crevices and folds, suggests certain styles of occupation and zones within a continuum. It was executed in a very primitive fashion but we provided all the profiles. They were then printed out, drawn by hand on plywood, cut out and then a chicken wire plastering job was done. It has too many irregularities and it looks a bit cave-like; I think the precision of execution is a part which we find lacking here, but the overall sense of a continuous, seamless environment is given. This also gives the idea of working with light and with surface differentiation, but always on a continuous geometry as experimented with here.

Illustration 7: future-home showroom in Beijing

Hotel Puerto America, Madrid

We moved on and we got a commission to do one floor in the Hotel Puerto America in Madrid and we continued this idea of a single surface that we used in the Beijing showroom. Our vision was a hotel room made out of a single surface which moulded in all the facilities – the beds, the tables, the side tables, the bathroom, and all the moving components are constructed in this way. Illustration 8 again shows the way the light works on the surfaces; there are crevices and linear elements, the seams of the elements. They were created by starting with sections, then lofting the sections, but then going back and gaining more control by creating a network of splines in two directions with a series of control points to make sure that the surfaces have a degree of precision - everything feeds into each other tangentially. We looked a lot at car design, especially the recent generation of cars - the complexity of convex to concave and going away from these primary geometries of older industrial products – cylinders and circle segments et cetera.

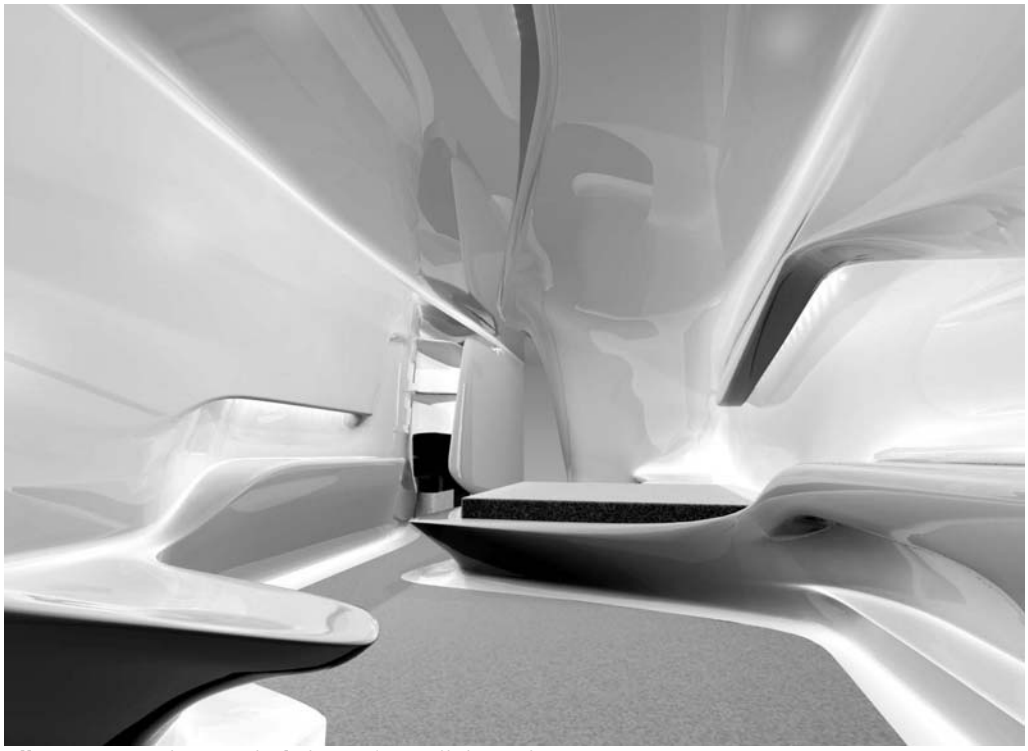


Illustration 8: showing the light working off the surfaces

We then render that out and we can produce computer-centred models; illustration 9 shows a 1:50 model of the room. It shows the two parts, the two rooms symmetrically mirrored, the corridor part, and you can see the bathroom component notched in. That is the first step, so the files are ready, that is already a demonstration

Illustration 9: model of room interior, Hotel Puerta America, Madrid

that the files are in shape.

Illustration 10 shows that this is all thermo-formed Corian – one mobile component, the cupboard, the bed, the TV, the lighting with a series of details – the crevices lighting over the bed. It is sometimes quite interesting, the non-corners are very comforting and it works very well, I spent the night there and it is beautiful. There are some strange effects; sometimes a non-corner becomes disorienting, particularly in the bathroom - you lose the depth of the space and the extent of the space. Overall it works very well and the non-corners are very soothing and calming.

Illustration 10: a bedroom in Hotel Puerto, America

Again, illustration 11 shows a model – it was dissected then in strips of 60 cm, decomposing into manageable components. At that stage we had found a company to do it, a German firm working with the LG Hymex version of Corian. First of all they tried segments and interpolating which did not work out so we insisted on having everything CNC milled, segment by segment. In this case it works out with forms because we have 30 rooms, so there is a lot of repetition and efficiency. They used a vacuum-forming machine so many of the parts can be done with just one milling. The 8mm Corian sheets are heated up and become leather-like, you lay them on and then you vacuum form over with latex. For the most tight and complex curves they have a kind of press – the Corian is heated up a little bit and put into a negative and positive form and squeezed. If you go into the room, every surface, every articulation feeds into each other – there is a lot of modelling work. I have to mention Thomas Fetske from the office who has been a virtuoso modeller – he really brought car design precision and elegance to the modelling.

Illustration 11: the process

There is still a lot of manual work to put these elements together, to put a substructure on et cetera. It costs 100,000 Euros to fit out each room. Illustration 12 shows putting together the bed frame, which feeds into the side table. Some furniture was done in the same fashion.

Illustration 12: putting together the bed frame

Illustration 13 shows the black version, with the bed feeding into the side table, inter-articulating with a piece of a chair. It is quite curious that the hardness and slight coolness of the surface is still very comforting; in the armchair it works very well.

Illustration 13: the black version

Innsbruck train stations

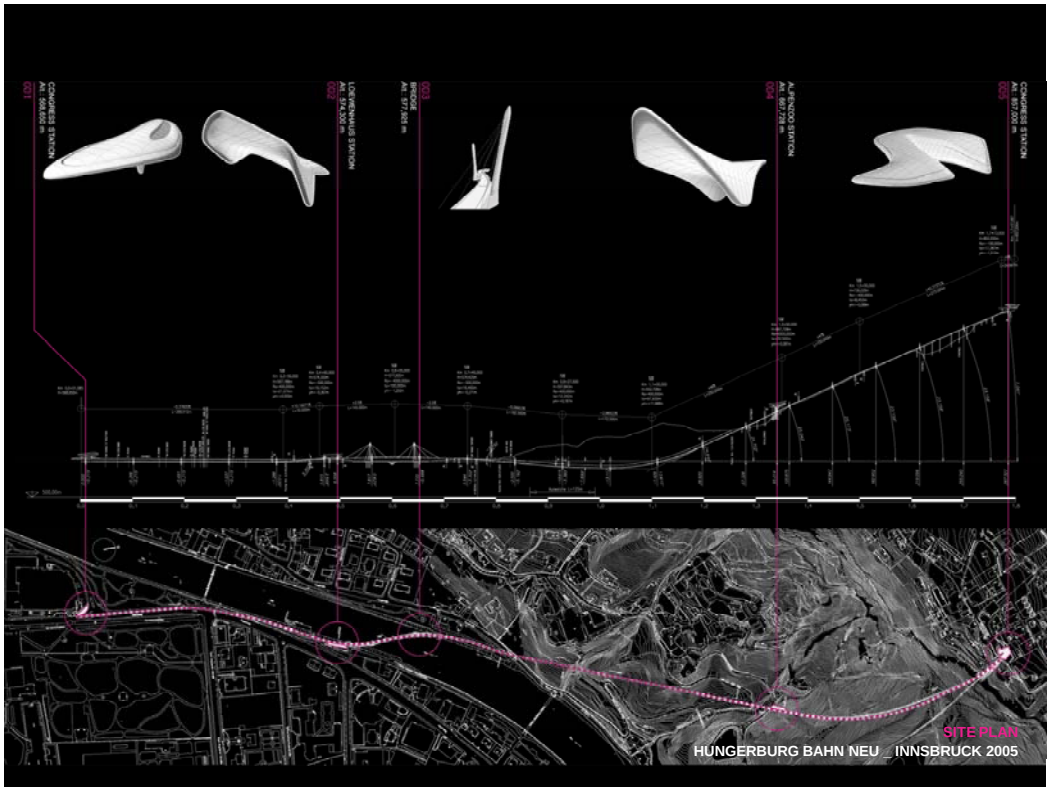


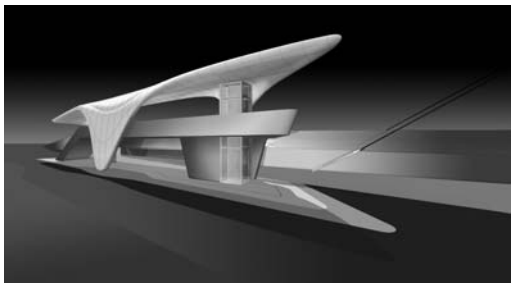
Illustration 14: plan of Nordpark railway

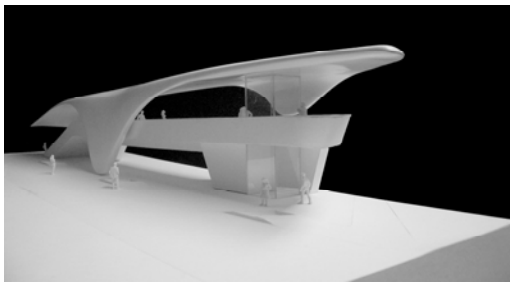
We were asked to design a series of train stations in Innsbruck for their new funicular Nordpark Railway which starts underground in the city, crosses the river and then rises up the mountain (shown in illustrations 14 and 15). We had a series of different conditions to face, but we wanted to create a family. There is this notion of a genotype and quite different phenotypes generating out of this a kind of parametric

model of the shell. The under-shell is concrete. There is one kind of covering for an underground station, the second one is before the train goes across the river; a raised structure. We designed the bridge as well and then there is one on a steep slope and we finally arrive at the plateau level.

Illustration 15: the stations

There are a lot of parameters and factors, which takes the modelling a long time. After this modelling we then created a physical model as one way of testing the files, we have done a 1:20 milled shell for all of them. Illustration 16 shows different views of the visualisation and model of the second station. There is detail in this, in this case a soft, flat gutter – it is just one of the problems we have been struggling with and facing up to. This is the way it sits – by this time the train has come out and has raised itself up a level before it goes over the bridge. This is again the computer-milled shell model, with different views to test the bridge which we are doing as well.





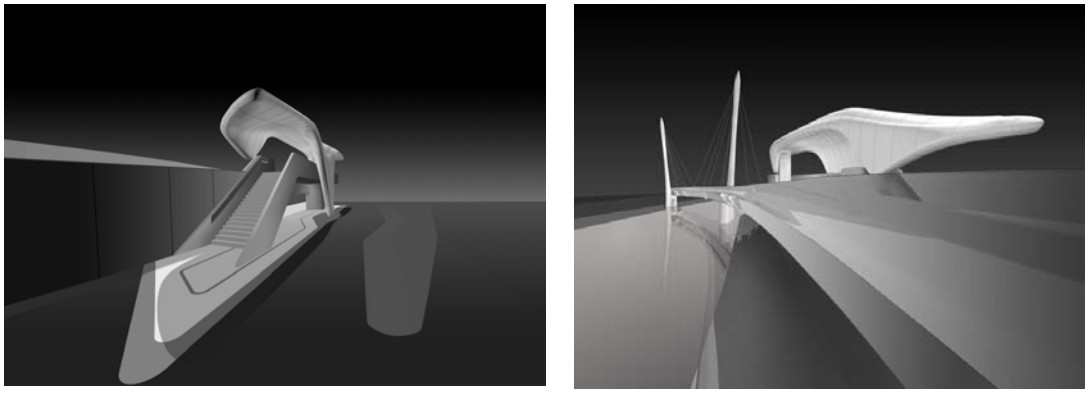


Illustration 16: models of Loewenhau station

The next one up the hill (illustration 17), on the slope, is a similar one but it is more symmetrical with two flaps coming down the side. A lot of remodelling was necessary, but again with these tools it is relatively easy – you can scale up and then stretch without losing the kind of detailed articulations you have achieved on the different edges, corners and folds et cetera.

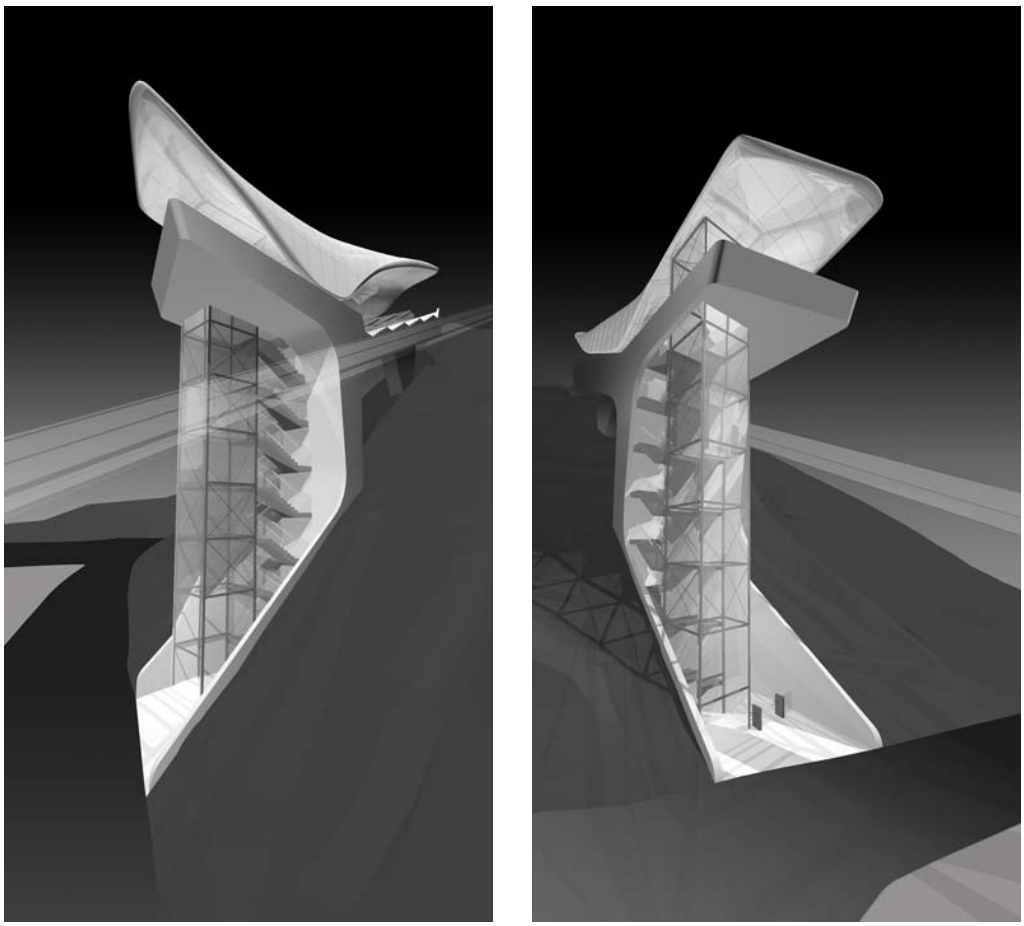


Illustration 17: Alpenzoo station

In the last station (illustrations 18 & 19) which rests on the plateau, the train comes in and spills out the passengers on the other side then it turns itself around. Each one talks about the peculiar situation and the adaptive system – one principle is modulated and picks up the different forms. It shows the power of this new language of architecture, this new paradigm of architecture, this sense of a system which has its

own coherency and logic but provides huge capacity for adaptation to different conditions.

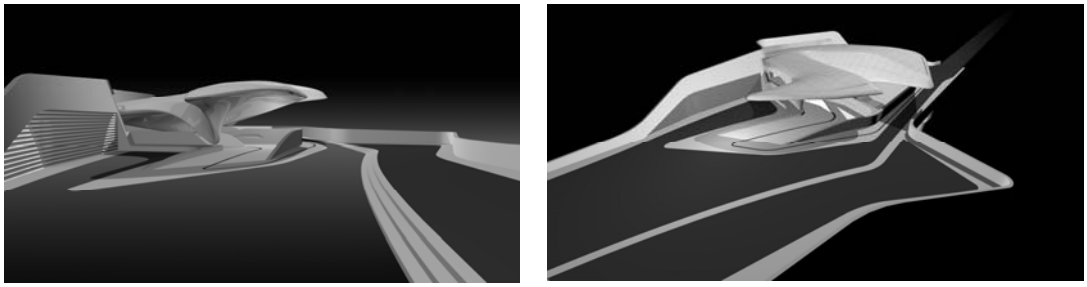


Illustration 18: Visualisations of Hungerburg Station

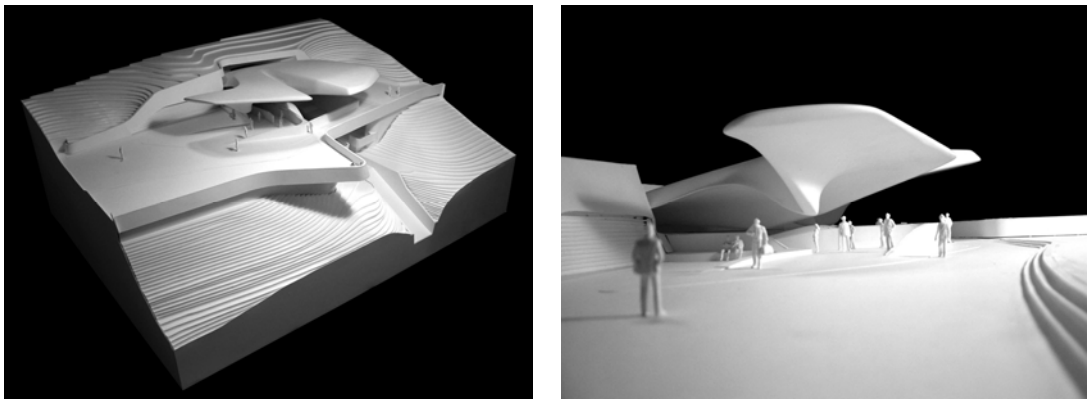


Illustration 19: Model of Hungerburg Station - different views

With the manufacturing, a lot relies on finding partners and looking out in the field to see who is doing structures with these techniques because we are talking about large buildings which have wind forces and durability questions. The interiors were comparatively simple and we could almost do them with our own resources. It has been quite interesting seeing different domains such as boat manufacturing, student housing pods and a large roof structure for the Yitzhak Rabin Centre. We visited these places and discussed the way they have worked with composite structures – it is very similar to the process of milling - doing the mould first in this case and laying out a kind of plastic foil and laying in the sandwich, the polyurethane with the fibreglass mats laid on so that these become the ribs (illustration 20). Then we have the second layer and then embedding perhaps some steel piece because with a lightweight structure there is the question of anchoring them – a painful realisation in some of our large cantilever installations that we did in different places - that points of grabbing are the snapping points.

Illustration 20: sandwich lay-up

We then combined it, moving from steel to fibreglass fins, embedding and distributing that into the lightweight structure. It is then wrapped in plastic to suck the resin into it through a vacuum fashion. We did not use this particular technique purely for money issues, it is still new and relatively expensive but you could glue these panels together and create rigidity and anchor points. It is very convincing and innovative and you have the full insulation capacity in the panel as well as the rain-shielding, the form and structural stability.

For financial reasons we are now executing the project in this fashion. This will be a series of CNC-cut steel blades which are welded together. One option was to then mill segments and embed them in non-structurally and then add fibreglass over. The latest version though is milling each segment in a lightweight, porous concrete, to then mould glass. Curiously, it became the cheapest solution – we had to go for the cheapest solution here and it is almost the most durable, which convinced the Parliament of Innsbruck to use 6mm glass with a back laminate.

We developed the forms further and decided on the glass which has certain constraints, curiously, with respect to the kind of curves it should take, and so there was a remodelling required on the nuances of the shapes. There was a lot to study about the way these should be dissected and both the upper and lower surfaces will be moulded separately. We have the steel structure, and illustration 21 shows the first sample of the corner in this laminated glass which is quite beautiful - you can have any colour and a metallic texturing underneath on the back side of the glass.

Illustration 21: laminated glass

Po library

The last project I want to show is maybe the most ambitious. It is a medium-sized public building, the library in Po shown in illustration 22 which was won as a competition. The peculiar form does make sense functionally - it is two library

segments - human sciences and natural sciences. This kind of bow-tie figure and the two packages are the reading rooms.

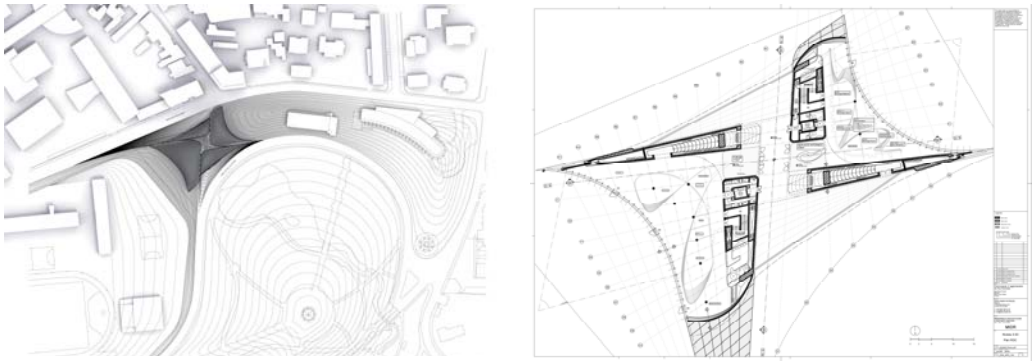


Illustration 22: Po library location and plan

The whole thing lifts up so it is sectionally bow-tied so that you are able to move through underneath. We are looking at technology transfer from racing boat construction with carbon fibre shells. The ambition is to have the whole roof span done without any steel, just these carbon fibre shells. As illustration 22 shows, there is a path into the park underneath the building. The whole under-part is done in insitu concrete, so we are looking at techniques we employed elsewhere. There will also be milled formwork et cetera. We see here the different levels and then we pick up the shell segments which will just be launched onto this concrete structure.

The modelling was done by ex-Design Research Lab students - Marc Fornes and Ivan Hoohan from the office. There is a repetition and there is a symmetry exploited where this segment is rotated over. We have to create moulds and so if we can reuse a mould it cuts down heavily on the cost. The form originally had embedded symmetry so we exploited that, but one segment is rotated over into the other segment and then we add additional pieces to regain the degree of asymmetry which we wanted because of the site location and adaptation concept.

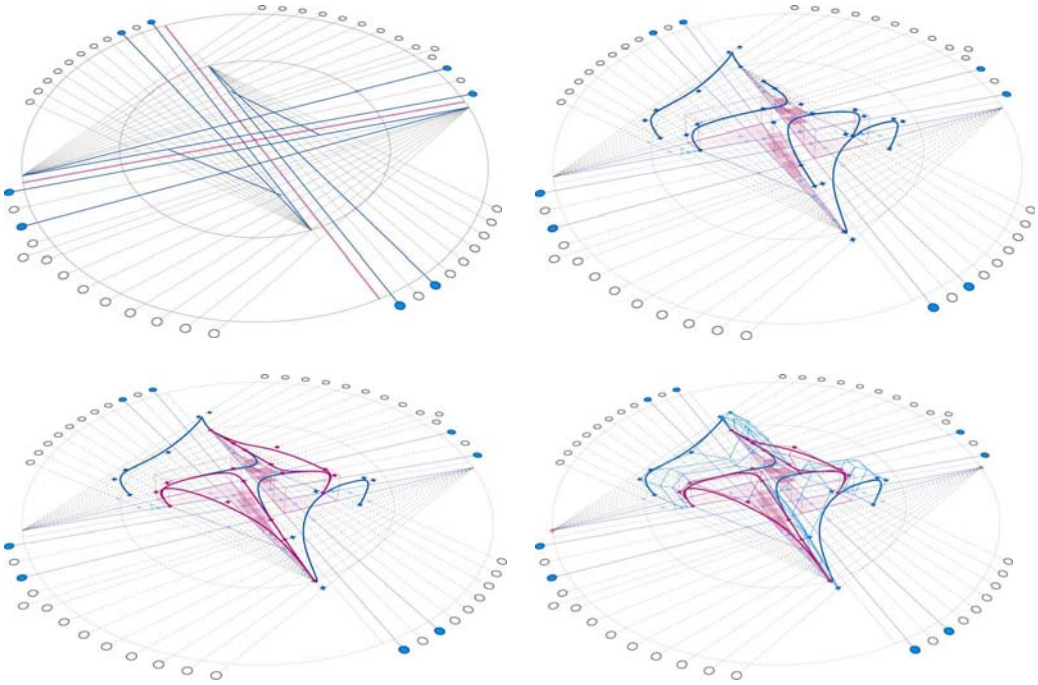


Illustration 23: The Geometry

The geometry was built-up using rhino moulding shown in illustration 23. Originally the first sketches were done quickly, with a series of seductions and lofting, but later on there was an attempt to reconstruct it with the minimum amount of splines – in this case four in one direction, each of them with the minimum amount of control points, and then to have a spline network in the other directions, also four, so we have a total of eight and then we have the four final splines in one direction. In the second direction a series of interim networks was created where all the control points actually lie on a grid below and we are getting interim splines. Now there is a possibility to go back and calibrate the form very carefully, because there has been a lot of discussion about the curvature required for shell action, spanning in both directions but also the aesthetic requirements of not wanting to look like an inflatable and having a degree of edginess also for the spaces inside. There is some negotiating going on there. The surface segments again rely on this kind of computer model of the substructure, the different components and the concrete work analysed carefully in terms of its flat surfaces, single curved surfaces and double curved surfaces – we rely on CNC milling for the formwork.

Illustration 24 shows the final computer model and again a computer-centric model and a model using carbon fibres for the mould. Again the substructure below will be done in concrete with an embedded steel girder on each side of the large span for the reading rooms. Here we have a series of images exploiting that and, again, the translation from digital to physical should be as seamless as possible.

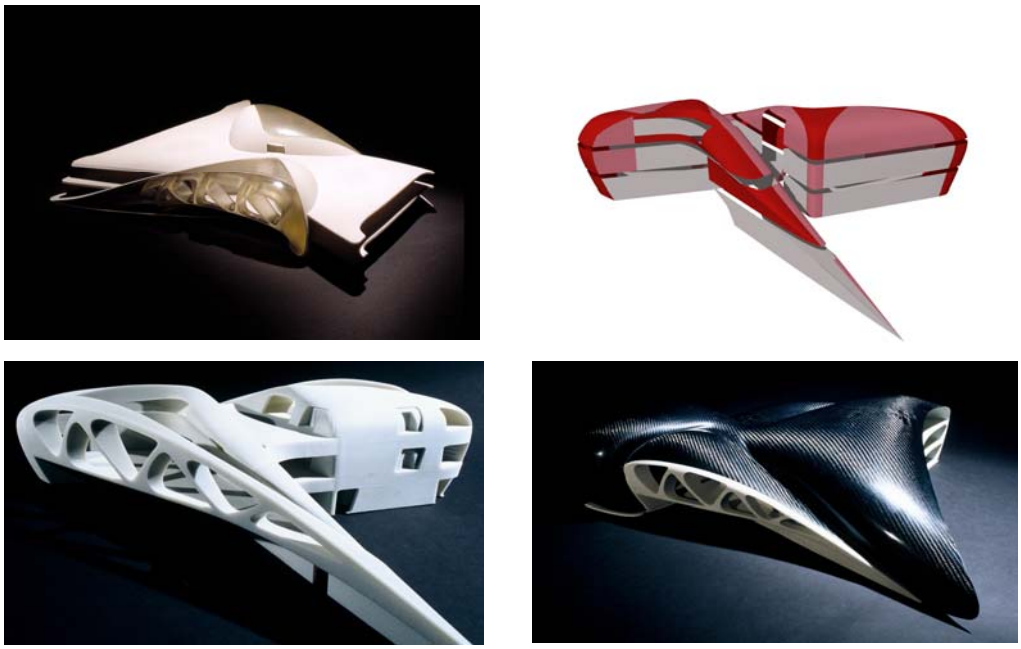


Illustration 24: models