MANAGING THE CONSTRUCTION OF THE MUSEO GUGGENHEIM BILBAO (B)

THE REVISED COST ESTIMATE

On January 17, 1993, IDOM presented an initial cost estimate for the construction of the new Guggenheim Museum in Bilbao, Spain. After the client, Consorcio Museo Guggenheim (CMG), requested a lower budget, a team representing the Design Architect, Frank O. Gehry and Associates (FOG/A), and the Executive Architect, IDOM, struggled to meet the client’s goal. Establishing a viable budget quickly was essential, since a press conference and reception had been scheduled to allow FOG/A to present the budget and schematic design of the project to the public in Bilbao a week later.

The team working on the revisions consisted of FOG/A project principal Randy Jefferson, IDOM project director José María Asumendi, IDOM project manager Luis Rodríguez Llopis and CMG’s Juan Ignacio Vidarte. Further description of the design from FOG/A helped the team review the initial cost estimate point by point. After several days of negotiation, all parties agreed to the following:

- The building footprint would be reduced by 20%
- Certain materials might be changed to lower the cost, if necessary
- The price of the building’s primary finish materials, stone and steel, should be renegotiated
- An additional 333 million Pesetas (approximately US $3 million) would be allocated for Furniture and Equipment costs
- The cost of permits would be waived by the City of Bilbao
- The cost of training museum personnel would be excluded from the estimate

These decisions lowered the cost estimate to 14,028 M Pesetas \(^{(1)}\) ($127.5 million USD).
IDOM’s Responsibilities

On January 30, 1993, CMG approved this Target Cost. The project was on its way and IDOM had clear objectives and deliverables established by the client, CMG. These included:

1. The Executive Architect (IDOM) shall be responsible for meeting the specified Target Cost, with a financial penalty if it is exceeded.
2. The Museum shall open to the public before the end of 1997.
3. The Museum shall be completed using the highest quality construction standards.
4. The Executive Architect shall maximize the use of local employees and materials for construction.
5. The Executive Architect shall facilitate the Design Architect's creativity.

At the time, the Target Cost was approved, certain cultural and political groups in Bilbao regarded the museum project with a high degree of skepticism. Furthermore, the Basque government elections of Fall 1994 were on the horizon. The project’s directors wanted to ensure that the Museum construction was well under way before the elections to prevent the Museum from being used as an election issue, and to ensure its completion.

The project was still in the schematic design phase. Only 30 drawings had been completed to describe the gargantuan project. IDOM estimated that more than 1,000 detail drawings were necessary to reliably bid a project of such complexity. Using a traditional design, bid, build, delivery method with discrete, sequential phases, development alone would have taken two years. Under such a schedule, construction could not have begun until 1995, far later than the desired date.

Cost control was a major concern. With the estimated building cost agreed upon at 14,028M Pesetas (approximately $1.27 billion USD), careful cost monitoring was required. IDOM needed to implement an organizational system that would ensure control and coordination of construction jobs. The intricate, curvilinear shapes of Gehry’s design would also call for innovative building solutions. These factors combined to make the Bilbao Guggenheim the most complex architectural project in IDOM’s history.

Luis Rodríguez Llopis explains that possible financial penalties were the least of IDOM's concerns. “The biggest cost would not have been the fine,” he says, “but the damage to our professional reputation.”

PROJECT PLANNING

IDOM, FOG/A and CMG decided to establish a series of key procedures for:

- Overlapping design and construction phases
- Establishing a real time cost control model
- Dividing the project in construction packages or “Paquetes”
Overlapping Design and Construction

The Bilbao Guggenheim had to be completed in five years, although IDOM’s experience suggested that at least seven were needed. At the suggestion of Frank Gehry’s office to use a fast track system, IDOM’s initial rough schedule dedicated 1993 to developing the project to a point where construction could begin, 1994 to erecting the structural systems, 1995 to building the facades and 1996 to completing the interiors. To meet such aggressive deadlines, design development and construction phases had to be significantly overlapped. If the phases were not overlapped, the design would need to be far less complicated or the project schedule would need to be extended.

By taking into account this overlap, IDOM developed a schedule including a calendar of design freeze dates designated by project area. Once each area was “frozen,” design decisions could not be modified if they increased the Target Cost or timeline.

Cost Control

The Target Cost of 14,028M Pesetas included all design fees, licenses, infrastructure work and furniture. The client was committed to paying this amount, and did not feel that it was important to further reduce the budget. CMG was more interested in obtaining the best quality facility possible for the agreed-upon amount. IDOM’s task was to allow FOG/A to express a maximum of creativity while holding the budget to its target.

IDOM, in agreement with the project team, established a responsive process to equilibrate the design and budget. Every six weeks, a new, detailed cost estimate would be prepared which reflected changes in the design’s evolution. This estimate was then compared with the Target Cost. Thus, designers and managers had up-to-date information that allowed them to evaluate the consequences of design decisions and quickly propose alternatives in cases where the Target Cost might be exceeded. To ensure its accuracy, the Target Cost was recalculated in its entirety three times during the design phase.

Construction Paquetes

As a public institution, CMG had to follow certain, legislated rules. According to standard public procedures, the project had to be awarded to a single General Contractor, who would then undertake the entire project. IDOM had vast experience in large-size, complex industrial projects – many of them larger than the Museum – in which the subdivision of contracting jobs had proven an important factor in to the effective managing the project. Juan Ignacio Vidarte and Carlos Iturriaga from CMG, and José María Asumendi, César Caicoya and Luis Rodríguez from IDOM met with the Diputado de Obras Públicas (Public Commissions Deputy) and convinced him that dividing the construction between several contractors was the best way to complete the Bilbao Guggenheim on time.

Accordingly, construction jobs were divided into several areas. The criteria were to have as few as possible, to minimize the interference from one to the other as much as feasible, and to divide the job in
such a way to make sure that the construction documents for each contract were well completed to go for bidding without compromising either the design process or the construction schedule. Each area was assigned to a key professional from IDOM, who was responsible for controlling quality, cost and schedule. These Paquetes were:

1. Demolition
2. Foundations
3. Structure
4. Exteriors
5. Interiors and Installations
6. Urban Infrastructure
7. Furniture, Fixtures and Equipment

After IDOM prepared the bidding documents for each Paquete, CMG issued a request for bids to select the contractors.

**The CMG Team (Consortio Museo Guggenheim)**

The Basque Government and the Vizcaya Deputy Representatives were the institutions who provided and managed the funds to build the Museum, while the Municipality of Bilbao donated the site. Juan Ignacio Vidarte, General Manager of CMG, had every-day decision making power. The Solomon F. Guggenheim Foundation’s Thomas Krens were the consultants so the new building could serve as the Museum for the Guggenheim art. Krens immediately realized that Vidarte was the perfect candidate to serve as a bridge between the Foundation and the Basque institutions.

The CMG team was headquartered in an office across the street from the Museum’s site, where they could easily monitor the construction progress. The interiors of the 400-square meter office were designed by FOG/A. CMG’s small but energetic team included legal consultant Arantxa Odiaga, Roberto Cearsolo as financial controller, and architect Carlos Iturriaga as CMG’s design consultant. In 1996, Nerea Abasolo joined the team as Communications Director.

**The IDOM Team**

José María Asumendi, an executive with experience in complex architectural, engineering and industrial developments, led IDOM through the initial stages of the Bilbao Guggenheim project. Once the operational strategy was determined, it was time to assemble the team that would carry out the project. IDOM established a dual leadership position to oversee the team. Engineer Luis Rodríguez Llopis, Ph.D. and MBA, and well-known and respected, local architect César Caicoya were selected. Combining managerial and design skills, Rodríguez Llopis and Caicoya led a team of 150 professionals that were selected for experience and innovation. Teams were organized according to Paquete:

Engineer Amando Castroviejo was in charge of two Paquetes, Foundations and Structure. Castroviejo
Fernando Perez Fraile was responsible for the Exteriors Package. Perez Fraile says he wanted to "preserve Frank Gehry’s aesthetic approach by any means necessary."³

The Interior and Installations Package was the responsibility of Javier Aja and Javier Arostegui. Aja recalled: “80% of the construction systems and materials used in the Bilbao Guggenheim project were totally innovative in the building industry.”⁴

Architect Anton Amann was in charge of coordinating Fixtures, Furniture and Equipment (FF&E). This Package was divided into 16 areas, which ranged from lighting fixtures to computers. He also assisted César Caicoya in coordinating architectural issues. Amann remembers that "the main risk was the large number of different companies involved, with the consequent risk of budget overruns."

Another important player was José Manuel Uribarri, Jefe de Obra (Construction Manager). An engineer with over 30 years of experience, Uribarri was permanently stationed on site as the main representative of IDOM. He coordinated the contractors, subcontractors and daily visits of the professionals in charge of each construction package. As the project progressed, the time commitment of each of these professionals varied.

**Contractors and Subcontractors**

One of the objectives of the project was to complete construction using local contractors and local resources. IDOM analyzed design solutions in a local context.

Gehry’s design featured complex shapes that called for innovative construction methods. It became clear that the contractors were to play a central role in developing technical solutions that met the design challenges. A public qualification competition was created to both educate contractors about the unique challenges of the project, and to establish a ground for selecting those firms which had the required technical and economic abilities.

IDOM then asked key qualifying contractors to participate in the design development phase. This produced a close relationship between IDOM and potential contractors that was beneficial to each party. The contractors devoted time and resources to clarifying construction details before the actual bidding. Thus, they had an advantage when preparing their bid. This methodology allowed FOG/A to receive rapid feedback on the technical feasibility of the design, helped IDOM determine what contractors were best suited for the job, and allowed contractors to understand the rationale behind the design decisions.
IDOM realized that no contractor in the world had ever built a project like the Bilbao Guggenheim. Caicoya recalls:

“I was looking for contractors to whom I could talk for hours. I needed counterparts who, having met technical and fiscal qualifications, were willing to learn how to build the project rather than being rigid in adhering to their usual methodologies. During the five years of the project I had lunch every day with contractors and subcontractors, evaluating every possible construction solution.”

After a public bid process, CMG selected key contractors to assemble the building according to the Paquetes. Given the complexity and size of the project, working with several contractors rather than a single one was risky. IDOM assumed sole responsibility for construction management. The contractors selected for each Paquete were:

- Demolition: Petralanda
- Foundations: Cimentaciones Abando
- Structure: a joint venture between Ursa/Lauki/Ferrovial (UTE Guggenheim)
- Exteriors: Balzola
- Interiors and Installations: Ferrovial
- Urban Infrastructure: Ferrovial
- FF&E: Various companies, including Erco, Lledó, Poltrona Frau, Fujitsu and other manufacturers.

Following CMG guidelines, all key contractors—with the exception of some equipment manufacturers—were Spanish. In addition, most of them were based in the Basque country. Each contractor selected subcontractors as needed based on guidelines established by IDOM. A few of the subcontractors were international firms. An example of this is joint venture Umaran/Permasteelisa, Balzola’s subcontractor, which was responsible for the curtain wall and titanium cladding.

The Exteriors package was the most crucial, representing the largest single item in the budget. The awarding of this Paquete to Balzola was the conclusion of a dramatic story. The difficulty of the Exteriors Paquete lay in the execution of complex shapes in diverse materials—stone, glass and titanium. A new construction system to make these undulating forms possible was needed. Five construction companies fulfilled the participation requirements. These companies were asked to participate in the design development phase, which represented an increased degree of involvement for the contractors. In the Fall of 1994, the request for bid documents was ready and these contractors were asked to submit proposals. Only three companies did so, and all of them exceeded the budget limit.

These failed bids created a critical moment in the life of the project. By law, IDOM could not accept these over-budget bids. This jeopardized the already-tight schedule because of project time lost in the
preparation of new bids. It also called into question whether the Target Cost was accurate or had been underestimated. A decision was made to issue a new request for bids with a two-week deadline. IDOM worked with the remaining contractors to clarify the design and adjust pricing. In the second round of bidding, only two companies presented proposals, both matching the Target Cost. Finally, CMG selected Balzola.

**DESIGN DEVELOPMENT AND CONSTRUCTION**

Frank O. Gehry and Associates’ unique, scale-model based design method was new to IDOM. As Design Architect, FOG/A was responsible for all aesthetic decisions throughout the project. The first models were of cardboard and wood, and the final models of high-density plastic. In its role as Executive Architect, IDOM allocated resources in an attempt to allow the Design Architect to express maximal artistry.

FOG/A’s Project Principal for the Bilbao Guggenheim was Randy Jefferson. Vano Haritunians was the Project Manager, and became more involved as the project progressed. Jefferson was able to communicate daily with Frank Gehry, who otherwise might have been difficult to reach. Other key Guggenheim team members from the then 50-person firm were Project Designer Edwin Chan and Project Architect Doug Hanson. Several methods of communication were used in transmitting project information and design documentation, including faxes, couriers and electronic mail. Approximately 16,000 faxes regarding the project were sent over its duration. Daily, the team spent many hours on the telephone making sure all participants in the project were kept informed.

Team meetings were scheduled every six weeks to evaluate progress. These were held in Santa Monica, California in the early stages and in Bilbao after construction began. These rounds of meetings lasted one week and were rather intense, usually lasting from 9 AM to 9 PM. Participants varied based on the relevant agenda, which was prepared in advance. The Target Cost was carefully monitored at every session, and FOG/A was keenly interested in designing within the budget.

Within a few months of the start of construction, FOG/A and IDOM had developed a friendly relationship. Mutual confidence and dedication contributed to the success of the project. The 9-hour
time difference between Los Angeles and Bilbao was treated as a positive factor. In addition to a daily conference call window from 9 to 11 AM in Los Angeles (6 to 8 PM in Bilbao), electronic documentation was sent many times a day. The Bilbao Guggenheim became a project with 24-hour a day activity.

About 80% of the design documentation was produced by FOG/A. Although most of the information was generated electronically, some detail drawings were hand drawn. The official language of the project was English, currency the Peseta and the standard units for drawing documents were metric. Documentation was sent to IDOM, which then redraw, translated, and adapted the drawings to local codes and regulations while revising availability of materials to ensure the project’s continuing feasibility. This “contextualizing” sometimes necessitated design changes that were resolved as a team between FOG/A and IDOM.

The Ayuntamiento, Bilbao’s municipal authority, had to issue a permit before construction could begin. In order to approve this permit, the Ayuntamiento had to evaluate the design’s compliance with fire and other city codes, structure, and size. As the design was not completed at the time of the permit request, IDOM had to adapt existing information and prepare provisional but extensive documentation.

**Demolition and Foundations**

Construction started in October 1993 with the demolition of several industrial ruins located on the site. The Foundations Paquete was next. IDOM designed and produced foundation documents based on calculations made by consultants Skidmore, Owings & Merrill (SOM), who also served as the structural engineers. IDOM again issued bidding documents, and the Foundations Paquete was awarded to Cimentaciones Abando.

Meanwhile, FOG/A was still in the design development phase. The freeze date for all of the structural concrete documents was February 28, 1994.

![Figure 2: Guggenheim site after demolition of abandoned industrial buildings](image)

After this date, FOG/A should base the evolving designs for the museum around these early construction documents. However, these limitations were not rigid. One of the foundations that was
constructed was not used in the final building. Since design development continued beyond this early freeze date, FOG/A was able to spend more time on the design. The unused foundation portion cost only 0.5% of the total budget but extended FOG/A's design time by 6 months.

One interesting feature of the foundation design was necessitated by the proximity of the Nervión River to the museum site. Floods were a real possibility, so “water anchors” of different sizes were built to counteract buoyancy in the event of a flood. These cable anchors were created by driving piles into the bedrock, then boring out their centers. A cable was then fed through the hole and anchored into the bedrock, after which the bores were filled with concrete. As a last step, the cables were tightened from the top. By the end of October 1993, 664 concrete piles had been built in-situ 14 meters below the surface. 18,000 m$^3$ of low-permeability, reinforced concrete structural walls formed the basement and mechanical areas. As an additional precaution, all art displayed at the museum is mounted about the 500 year flood level. Foundation construction continued until April 1995, overlapping almost entirely with the concrete and structural jobs.

Once again, the overlapping of phases facilitated better design, one of the project’s primary goals. Without concurrency in the design and construction phases, work on the Foundations could not have started before June 1995. This concurrent development allowed for 20 additional months for design. However, one trade-off of this flexibility was the uncertainty of the project environment.

**Structure**

One challenge in the structural development lay in the large, discrete geometric volumes of the Museum. Frank Gehry called these “integrated forms,” and named each one. The complex polygonal building blocks were called River, Neo, T1000, Potemkin, Cobra, Fox, Flower, Tower S17, Fish, Boot and Canopy. The first problem arose early in the project while performing the intricate calculations necessitated by the design.

SOM had performed structural calculations using their proprietary AES software and forwarded the information to IDOM, who had only one week to produce bid documents. After the bid documents were released, contractors had two weeks to prepare proposals. Somewhere in this process, a coordination error caused an underestimation of the structure’s weight, resulting in a cost increase from the original
maximum estimate of 2,270M Pesetas (approximately $20.6 million USD) to 2,410M Pesetas (approximately $22 million USD). The disparity between the estimated and actual costs in this early and significant bid made the client, CMG, very uneasy.

Figures 4 and 5: Atrium with primary, three-meter structural grid; Secondary, horizontally-curved structure

Reaction was immediate. CMG met with IDOM in Bilbao, then the entire team assembled in Santa Monica to attempt to avert similar problems. The meetings were tense, but resulted in an adjusted Target Cost, some changes to certain portions of the design, and a large reduction of the estimated contingency costs. The cost control measures had proven essential to the early detection of cost discrepancies, which allowed the team to respond swiftly and keep the project on schedule and within budget.

The construction of the steel structure started in September 1994. The system comprised three layers of steel, each one serving a different function. The structure was connected using high strength bolts.

First, the primary structure was erected in modular, 3-meter square sections with a minimum of wide flange shoring. This allowed all structural members, with the exception of those in the “Boot” and “Tower S17”, to be rectilinear in section. The surface complexity of the overall forms was achieved via the secondary structures and sheathing.
Between the primary steel structure and the titanium cladding there were two additional layers of structure. The innermost layer, formed of horizontal galvanized steel tubes (60mm diameter) at three-meter vertical intervals, established the horizontal curvature of the skin. This layer was connected to the primary structure with a universal joint, which allowed fine adjustment in all directions.

The tertiary structure established the vertical curvature. To achieve this all C-shaped studs were curved in one or more directions. The C shape allowed torsion to occur (to a maximum angle of 4º), helping to maintain perpendicularity of the facing materials. Every element in the secondary and tertiary structures allowed for smooth skin curvature and thermal expansion. On-site cutting and welding was virtually eliminated.

A 2mm galvanized steel cladding was bolted to the tertiary layer. On its interior side it was covered with thermal insulation and externally with an asphalt-based Bituthene membrane. Finally the titanium tiles were bolted to the steel using L-shaped stainless steel anchors.

Figure 6: Galvanized steel cladding and Bituthene waterproofing

Figure 7: Detail of titanium sheet clamping

Structural components were bar coded and marked with notes of intersection with the adjacent layers of...
the structures. No expansion joints were necessary, the structure performed as an integrated element. When SOM started to design the structure, they found some of the “integrated forms” statically efficient, while others needed some additional reinforcement during the construction phase. Caicoya recalled “The structure was not rigid until it was completed.”

The structure performed well under vertical loading, but lateral loads like wind began to cause problems. Hybrid solutions were developed to reinforce the frame assembly during its completion. These solutions included the use of anchoring cables and cranes.

By the time construction had been underway a year, a strong sense of unity had developed between the team members at CMG, IDOM, and FOG/A. Gehry himself, a fan of unfinished buildings, made frequent site visits, and called Vidarte and the IDOM group “my Basque family.” By September 1996 the roof and sheathing systems were almost finished, while the structural works continued until November.

Materials and Exteriors

The initial specification of and final choice on all materials used at the Bilbao Guggenheim was FOG/A’s responsibility. IDOM assisted with recommendations for alternate materials when necessary.

Titanium

During the competition, the primary external cladding material specified was hand-polished stainless steel, and the first bid documents were prepared accordingly. Nevertheless, Gehry was not entirely pleased with the appearance of the material and investigated many other options including zinc and leaded copper. IDOM suggested avoiding leaded copper because of the rainy Bilbao climate might wash lead into the environment. A few days before the bidding documentation was made public, FOG/A received a titanium promotional sample from a vendor, and became interested in using it. After examining the titanium under many of the possible conditions at the site, Gehry decided that titanium was the right material. He found that stainless steel was too bright in full sun and too dull under clouds. The titanium always appeared to have a “velvety” sheen, whether in sun or shade. Gehry especially liked the titanium’s reflective properties and its dramatic ability to take on the color of the current light.
Permasteelisa tested the titanium using a full-scale mockup and an aircraft engine to create wind. The material performed very well, but it was discovered that additional clamps were necessary in high wind conditions. Ultimately, a configuration using three clamps on each side of a panel easily withstood a test of 200 kilometers per hour winds accompanied by heavy rain.

Research showed that titanium only had been used previously as a construction material for small areas of roofing in Japan. IDOM was concerned about the cost of the titanium, and included it in the bid documents as an alternative to the stainless steel. In an extremely fortunate coincidence, the world’s largest titanium manufacturer, Russia, put huge amounts of the product on the market just at this time, causing the price to drop dramatically. A week after the price dropped, all the titanium necessary for the Bilbao Guggenheim had been purchased. As could be expected of supply and demand, the price rose again directly after the material was purchased.

The raw material was chemically treated and laminated by Timet of Pittsburgh and sent in rolls to Umaran/Permasteelisa. Permasteelisa cut the titanium into panels using Computer Numerically Controlled machines (CNC), and Umaran folded their edges, packed them, and shipped them to the site.

The titanium panels arrived at the site flat, where they were bent to fit to the curved structure. Only four standard sizes were needed for 80% of the titanium-clad areas. However, the remaining 20% needed
16 different types of panels. After erecting the supporting structure, Umaran added two layers of insulation, thermal and waterproofing membranes, to the tertiary structure. Next, the titanium cladding panels were affixed to an L-shaped, stainless steel connector using steel nails welded by thermocovery. The size and weight of the panels eased their installation. The titanium, although much harder than stainless steel, is an extremely lightweight material. Each sheet was 0.38mm thick, approximately of 60x80cm in size, and light enough to be comfortably handled by a single installer.

Finally, Umaran installed the panels one at a time. Certain portions of the buildings feature concave, vertical curves which rendered them inaccessible to cranes during the installation process. Therefore, installers were taught how to climb and rappelled down the building, affixing the panels. Says Rodríguez Llopis of this process: “We found that it was easier to hire climbers and train them as crimpers than to hire crimpers and train them as climbers.”

Another result of the hand-application of the titanium sheets is the soft bends that appear on each individual panel. Gehry said he wanted something soft looking and handmade, not overtly high-tech. When the thin sheets are clamped, they bend, giving the desired effect.

**Stone**

Another key material was the stone revetment used on both interior and exterior surfaces. The specifications called for a beige limestone that could be mechanically manipulated and withstand Bilbao’s humid and rainy weather. After evaluating more than 100 samples, FOG/A suggested Caliza Santa, a stone believed to come from Italy. However, inquiries revealed that this stone was quarried in one of the most politically turbulent areas of Israel, then imported by an Italian distributor. Therefore, a continuous supply was not reliably available.

The stone finally selected came from a closed quarry. Huéscar, a quarry in southern Spain’s province of Granada, had filed for bankruptcy because of the difficulty of quarrying the extremely hard stone. The quarry was reopened for the Bilbao Guggenheim. The stone, too hard to manipulate using conventional methods, was the ideal material for the demanding needs of the museum because of its density and low porosity. Since the fame of the Bilbao Guggenheim has spread, Huéscar has remained open and thriving.
Once on the site, each stone panel was reshaped and hand-selected for its color relative to the panels surrounding it. Panels had to be applied to the structure one by one using numbered templates, but there was no support system commercially available that met the weight, size and pressure resistance needs of the museum. The wind pressure at the Bilbao Guggenheim site can reach as much as 200kg/cm². IDOM and Balzola designed, produced, tested and manufactured special clips to support the stone panels to meet these stringent requirements.

As a final precaution, each stone panel was also secured to the structure by a steel cable in the unlikely event that a panel should loosen. At the time this document was prepared, no panels had separated from the structure.

**Glass**

Another challenge faced by Balzola was the extremely complicated geometry of the glass walls.

Out of the total 2,200 glass panels, 2,000 of them were uniquely shaped, and most of the shapes were quite complex. The AutoCAD drawings of the glass panels were taken to the site, then exact measurements were made to allow for slight deviations in the actual construction. Then, CNC machines were used to cut all the glass panels.
Arrays of triangular panes created the effect of curving surfaces without the additional expense and complexity of curved glass. The glass is a special “California Glass” that does not color incoming light, but protects against ultraviolet light and radiation.

**Wood**

FOG/A originally specified the flooring for all exhibit galleries as 7x40cm maple wood panels. IDOM questioned whether this material could withstand the expected intense use, and whether the appearance would seem too fine-grained for the scale of the galleries. They suggested high density, resin-impregnated maple wood panels as an alternative. Composites Gurea, based in San Sebastian, tested the product in their laboratory, where it successfully passed a durability test and was specified in 60x240 cm panels. As was typical for the project, FOG/A needed to approve the material. Although this was their first experience with this type of material, the excellent look, feel and strength of the product resulted in its immediate approval.

![Figure 13: The Classical Gallery East with maple flooring](image)

During installation of the mechanical systems, some differences between American and European building codes became important issues. For example, Cosentini specified bronze valves for fire suppression systems, but in Spain bronze is considered too expensive for this use. FOG/A accepted IDOM’s proposal that they use stainless steel instead.

**INFORMATION TECHNOLOGY DURING THE CONSTRUCTION PHASE**

Information technology continued to be a vital component of the project during construction. In late 1998, César Caicoya said:

“One of the key factors in construction was the massive use of CAD/CAM technology, something fairly unusual in architecture. Without this technology, the Bilbao Guggenheim would still be under construction today.”

FOG/A used CATIA software by Dassault Systèmes to create a computer model the complicated geometry of the project. CATIA allows numerical control of complex shapes and definition of surfaces...
by mathematical formulae. The software, which was first developed in 1980, ran on IBM RISC System 6000 workstations. CATIA is more commonly used in mechanical engineering industries including aerospace, automotive, and shipbuilding.

FOG/A input the forms of their wood and plastic models into CATIA using 3D scanning devices that recorded points on the model into a virtual three-dimensional coordinate system. Once each of the prototypical pieces of the building was completed in CATIA, the computer model containing its face and surface geometry was sent to a machine shop where a scale model was milled out of foam by numerically controlled machinery. Next, the files were sent to IDOM on DAT tapes. The files, each typically larger than 30 megabytes, were too large to send efficiently via email using the currently available connections.

The files were the equivalent a three-dimensional sketch of the building’s skin. These computer models were used in place of the more conventional sets of two-dimensional drawings. IDOM had no previous experience using CATIA, so they collaborated with ABGAM, the CAD/CAM specialized subsidiary of GAMESA, a Spanish aerospace and industrial engineering firm. ABGAM provided 45 CATIA workstations, and IDOM, its contractors and subcontractors worked with ABGAM operators to develop sketches of structural systems and components.

Spanish fabricator URSSA, which led the joint venture in charge of the Structures Paquete, used BOCAD software to create detail member and joint designs.

The structural contractor, URSSA, used BOCAD software for the primary structural designs. BOCAD is a 3D solid modeling CAD/CAM program intended for detailing steel structures and workshop management. BOCAD, a commercial package first developed in Germany at Bochum University in 1978, interpreted data from both FOG/A’s CATIA files and SOM’s AES software, drawing the resulting structure in three dimensions. Through BOCAD, information was sent directly to CNC machines. A robot cut, folded and bolted the primary structure. URSSA pre-assembled the largest structural lattices that could be trucked and shipped them to the site.

IDOM and Umaran developed the design of the secondary structure—to support the titanium and stone cladding—using CATIA workstations and operators from ABGAM. CATIA provided mathematical data of the geometry and intersection of skin and structure. IDOM sent DAT tapes to Permasteelisa in Venice, Italy. Permasteelisa, who had purchased a copy of CATIA in 1992 while working on a previous project with FOG/A, cut the titanium into panels using data directly from the CATIA files. In Bilbao, Umaran translated CATIA information to AutoCAD software to fold the panels.
IDOM also sent CATIA files to Balzola so they could mill the limestone panels. These files were used directly to cut the stone panels using a CNC machine. A machine for milling metal had to be specially adapted to mill the stone, and this adaptation alone took a year to accomplish. The footprint of the finished machine, which was assembled at the site, was twelve square meters. The machine cut limestone 24 hours a day, 7 days a week for two years.

Many pieces of stone revetment for the tower portion of the museum featured double-curvature. For these panels, a thick block of limestone was carved away in successive passes to create the desired form.

Information technology was also used to produce drawings for architectural details and to document the building in compliance with local regulations. This documentation was produced using Microstation and AutoCAD software, and used the three-dimensional computer data as a reference.

**Coordination during the final months**

Coordination was the primary challenge in the final months of construction. The Solomon R. Guggenheim Foundation had requested that six months be allowed after the completion of the building to install the exhibitions. Based on the huge scope of the project, it became clear that this much time would not be available. Additionally, exterior and interior jobs were initially planned based on successive completion of gallery areas, with the objective of allowing the interior contractors to work protected from the outside weather. This required the Exteriors contractor to fully complete the each before the Interiors contractors could begin their work.

Coordination efforts had to be organized in several ways. First, it was necessary to convince the SRGF to allow opportunities for more phase overlapping. Construction planning was reviewed to optimize the schedules of the Exteriors and Interiors contractors. In case of delay, Balzola was expected to temporarily cover unfinished areas to shield the Interiors. Ferrovial had to begin their work under less-than-perfect conditions if the Exteriors were not completed.

CMG’s participation in these final negotiations was critical. Always ready to mediate, Juan Ignacio Vidarte’s diplomatic abilities continued to facilitate agreement as they had throughout the project. Vidarte helped clarify the various roles and responsibilities of the SRGF, FOG/A, and IDOM.
By 1996, the museum’s shell was virtually completed. The Interiors Paquete had started in August 1995. The internal shapes were as complex as those on the exterior, and were sculpted of plaster, drywall and glass. The sheet rock was specially treated to improve its resistance measurement from 30 to 3,000. In gallery spaces, it was faced with two-centimeter thick plywood to allow art to be firmly mounted. In certain areas, the drywall was only one centimeter in depth to allow it to fit the tight curves of the design, and was dampened before mounting to increase its pliability.

The amounts of materials used were astonishing: 25,221m$^2$ of titanium, 34,343m$^3$ of limestone and 6,164m$^2$ of glass had been installed. Finishing work along the perimeter of the building, including landscaping, construction of walkways, and signage began in May 1996 and lasted until November. Final detailing started in early 1997 and lasted until the completion of construction in October. In January 1997, the Solomon F. Guggenheim Foundation’s curators finally entered the new Museum.

**THE 1997 PRITZKER PRIZE**

The previous year, Rafael Moneo had been awarded the 1996 Pritzker Prize, the highest honor in architecture. The presentation had been held at the not-yet-finished Getty Center in Los Angeles, a complex designed by the 1984 Pritzker Laureate Richard Meier. Because Moneo is Spanish, the next Pritzker presentation ceremony would be hosted in Spain. The Hyatt Foundation of Chicago, sponsor of the Pritzker Prize, proposed that the 1997 award to Sverre Fehn of Norway be presented at the new Bilbao Guggenheim Museum. According to the Foundation, the location for the honor was appropriate not only as an homage to Spain, but also because the ceremony was being held in “work-in-progress” designed by a previous Pritzker Laureate. Frank Gehry had received the award in 1989.

Juan Ignacio Vidarte raised the issue of hosting the presentation ceremony at a regular progress review meeting in January 1997. He asked Luis Rodríguez Llopis if the building could be prepared to host the event by May. Since the Pritzker is the architectural equivalent of a Nobel Prize, the worldwide attention that would be drawn by the ceremony was very attractive to CMG.

IDOM carefully considered the implications bringing international celebrities into an active construction site. Air conditioning had not been installed, the roofing was incomplete, and the perimeter walls were unfinished. With the opening of the museum scheduled for October 3rd, contractors and subcontractors were already working at full capacity. Laborers were asked to work on Sundays, which caused increased tension at the site.

Accepting the invitation to host the Pritzker Prize meant carrying out a variety of previously unplanned tasks. IDOM was concerned about this deviation of priorities putting more pressure on the already stressed workers. They also worried that working 24 hours a day; 7 days a week in triple shifts could compromise construction quality. If tasks were not organized with surgical precision, the October 3rd opening date could be jeopardized. The alternate location, the Alhambra in Granada, a World Heritage Site, was available to host the event.
On the other hand, IDOM's approach to service prioritized looking after the client's interests. (Exhibit 1) Well managed, the event could become an incentive for workers to maintain an intense work pace. In either case, the moment for a decision regarding the Pritzker Prize ceremony was approaching rapidly.

Endnotes

1 The Peseta-Dollar exchange rate in 1992 was 110 Pesetas = $1.00 USD. In December 1998, the exchange rate is 150 Pesetas = $1.00 USD.
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Exhibit 1

**IDOM CORPORATE STRATEGY**

- IDOM considers that if the company is to offer a valid service, this must be customized in every case, in accordance with the characteristics and requirements of each client.
- The quality of IDOM's professional services is guaranteed by the high level of technical and professional training of its staff.
- The company's main assets are its individual members, whose professional independence ensures the objectiveness of its proposals and solutions.
- IDOM's structure and spirit is open to all the changes which are occurring in today's business environment, so that the company can respond quickly to the needs of each specific moment in time, and attempt to offer solutions which go beyond the client's own perception of the problem.
- The accumulated expertise and the research and development process itself mean that IDOM can draw on a pool of know-how, systems and working methods that make up the formal support for its services.

*Source: IDOM*