Experiences from Universeum Science Centre in Sweden: Focus on delivery – a weak link between the project and the building in use

Paula Femenías[1]
[1] Department of Architecture, Chalmers University of Technology, Göteborg, Sweden

ABSTRACT: This paper presents a case study evaluation of the architecturally awarded Universeum National Science Centre (aquariums, rainforest, hands-on exhibitions), in Göteborg, Sweden. The Universeum was built as a teaching example combining architectural values and sustainable building. After 5 years in use, this complex building provides valuable practical experiences of natural ventilation systems, systems for recirculation of water and nutrition (a urine-separating toilet system), active solar energy, and a wooden structure, etc. Experiences from Universeum contribute to the creation of specific guidelines for this kind of buildings but also general guidelines for implementation of sustainable building. The Universeum project has had initial operational problems that can be explained by the complex design and the use of innovative technology, as well as high time pressure etc., but they are also due to communication problems between the design team and the users. Delivery has been a weak link between design and construction phases, and the building in use. Despite the uniqueness of the project, preliminary findings indicate that the project has been valuable for the development of sustainable building, both regarding knowledge build-up among involved actors and for the development of technological solutions.

Keywords: sustainable building, demonstration project, knowledge transfer, feed-back, evaluation, delivery phase, user phase, teaching examples

1. INTRODUCTION

This study is inscribed in the field of research and theoretical framework concerning contemporary building practices to conform to the necessary development towards more sustainable building. Sustainable building is understood from a multidimensional perspective which involves the need to integrate social, institutional and economical changes to environmental protection.

The development of building practices is dependent on a combination of theoretical advancement and practical experiences. The effectiveness of this development process is hindered by the lack of systemized feed-back and knowledge build up in practice, and a communication gap between research and practice [1]. For example, in Sweden, the adoption of successful demonstration projects of energy efficient buildings is lagging behind and theoretical knowledge is not spread and used [2].

The learning and innovation processes in the building sector are complex to understand [see further 3]. Many specific characteristics of the sector (project-based organisations, a fragmented building process, unique products, cyclic demand, the bidding system etc.) do not support long-term learning processes [4].

In order to overcome the actual loss of important experience from building projects with a pronounced ambition to support more sustainable building practices, there is a need to support the gathering, evaluation and dissemination of such experiences, both specific and generally applicably. This ought to be one important task in architectural research.

2. THE UNIVERSEUM CASE

Universeum is a rather unique institution in Sweden combining a science centre with large aquariums, a Swedish landscape and a rain forest. The project has many facets: pedagogical, environmental, economical, political etc. It has the long-term pedagogical aim to awaken the interest among youth and especially girls towards science, technology, environmental issues and higher education. At the same time the activities has a strict business plan and little governmental support. Universeum is also an important tourist attraction in Göteborg and situated in a strategically important area. The project has been financed by local industry, research foundations, the local Universities and the region authority.

2.1 An example of sustainable building

Since the early phases, the project has had strong environmental profile and the ambition to contribute to the development of sustainable building. The project received a special support from the government for additional costs for implementing a environmentally adjusted and sustainable design. In order to carry through the environmental ambitions a reference group with experts from Chalmers University of Technology and Göteborg University was formed. They supported the design and consultant team and are still active as advisor for the continued activities.

The co-ordinator of this team helped the project team to write an environmental programme. In later phases of the project an environmental consultant was engaged for the choice of materials.

2.2 The architectural design

The architectural concept is the winning entry of an invited international architectural competition chosen by a unanimous jury for its architectural qualities and potential for environmental adjustment. The architect is one of the most reputed in Sweden.

The building consists of a collage of parts with different expressions: The 'wooden barn' containing the science centre part with it's expressive sawtooth roof prepared for solar-cells, the triangular glassed rain forest between the 'wooden barn' and the 'stone coffin' which in turn contains the aquariums cut into the cliff using the blasted stone as façade material in stone 'gabions', leading over to the 'Swedish landscape' under a transparent roof of plastic (Fig. 1).

Figure 1. Universeum, the entrance and the water mirror of locally treated storm water.

3. AIM AND APPROACH

The aim for this paper is to gather and communicate experiences from Universeum in use and to make a first evaluation of the investments in the environmental profile of the project. This includes the ambitions for Universeum which goes beyond the objective of reducing the environmental impact and aims at reaching long-term objectives for sustainable development dependent on institutional and social changes of the individual and collective perception and actions. On an overall perspective, the research aims to contribute to the development of theory about learning processes in the building sector regarding sustainable building.

Based on the objectives for the Universeum project itself, and the research aim to spread experiences from use, four main questions for the evaluation have been formulated:

- Which valuable experiences of environmental solutions used at Universeum can be shared?
- Has Universeum had an impact as a demonstration example of sustainable building?
- In what way has the project contributed to the general development and knowledge build-up in the field of sustainable building?
- Has the 'pedagogical' integration of the building been successful in terms of stimulating knowledge about environmental issues and sustainable development?

Apart from the environmental adjustments, the evaluation includes the general functionality of Universeum. Due to limitations of the study as well as the complexity of the building (difficulties in finding reference values), no complete environmental impact assessment has been made.

Findings presented in this paper address mainly professionals in the building sector but also researchers and decision-makers on all levels.

4. DESIGNING THE EVALUATION

The study has been designed as a case study evaluation. Case study methodology is by Yin [5] defined as ability to integrate or 'triangulate' information from multiple sources of evidence in order to construct conclusions. The method implies a richness of data as it is intended to examine a phenomenon in its real-life context. The process of generating and generalizing results depends on the development, testing, and replication of theoretical propositions.

In line with the case study methodology this study includes varied empirical material: observations (guided by the personnel), interviews, reports and documents, archival files, measurements, and the artefact (photos and drawings). An important documentation is the evaluation of the design process made by Wallin [6]. A short external follow-up was presented in 2004 [7]. In addition, articles in major Swedish news papers and trade press have been included. These articles provide an external view and show the discursive influence of Universeum as an example of sustainable building. The study does not include the visitors view other than revealed through the interviews or the articles. The environmental data used for the evaluation is limited to measurements made by the technical staff at Universeum.

4.1. The interviews

So far, 18 semi-structured qualitative interviews have been carried out with key actors that were involved in the design and building process, and with the management team and the technical staff at Universeum. The plans are to include the results from a questionnaire carried out by the management among the whole staff. The coding of the interviews

has been supported by HyperRESEARCH software tool for qualitative data analysis.

4.2 The media study

Three databases with articles from major Swedish news papers and trade press were searched for articles about 'Universeum'. The search resulted in a corpus of 815 articles and short notices. The total corpus was analysed regarding subject and tone (negative, positive or neutral) in order to get an overall idea of the view held by the press. A core corpus of 17 descriptive articles in which the building and the environmental profile was discussed was further analysed.

4.3 Designing an evaluation matrix

In order to structure the analysis an evaluation matrix was designed (Table 1). The matrix is inspired by contemporary attempts to evaluate design (see for example [8]) and environmental quality and is adapted to match the evaluation questions (section 2). A search among possible assessment tools for application in this study showed that there is lack of 'integrated' assessment tools that take into account all dimensions of sustainable development: environmental, social, and economical (which are left out in this study) issues. Earlier research has stressed the importance of linking the product to the process, to include tangible and non-tangible factors, when evaluating and understanding the outcome of building projects [1].

Table 1: The evaluation matrix

Function	Adequacy of space	storage, circulation
	Layout	Relationship between spaces
	Working environment	Physical and social aspects
	Accessibility	
	Cleaning	
	Indoor quality	Light, air, noise, temp.
Environmental performance	Energy	Low and effective energy use
		Renewable energy resources
		'Natural' ventilation
	Water and sewage	Recirculating water system
		Urine separating toilet system
		Local waste water treatment
	Building material	Renewable materials
		Reused and recycled materials
		Demountable construction
		Material efficient solutions
		Sustainable construction
		Chemicals
	Land use (not included so far)	Protect/develop nature/biotopes
		Relation building/nature
Impact	Architectural quality	Awards, users satisfaction
	Tangible values	Example of sustainable design
	R&D	Contribution to development
	Urban & social integration	

5. THE GENERAL FUNCTION

Universeum has been running for nearly five years. In average 500.000 people visit Universeum annually. Universeum is among the 60 - 70 most popular tourist attractions in Sweden. The project is expensive and the economy has been strained since the start with several cut downs among the staff. The business is still so far dependent on sponsoring from private enterprises.

Universeum has had initial problems due to complex innovative technical solutions and difficult activities, i.e. aquariums and the rainforest with waterfalls (section 6). The project also lacked earlier experiences to refer to. Still the technical staff find that the establishment works surprisingly well. Still, the rainforest has been growing slower than expected due to miscalculations in the dimension of the artificial lightning.

5.1 The image conveyed by the media

Of the total 815 articles and short notices, 442 gives a positive tone (P), 310 are neutral (Ne) and 63 gives a negative (N) view of Universeum (Table 2). The majority of articles were short notices with information about exhibitions etc. and with a neutral character. Negative articles mainly discussed the strained economy, lack of accessibility and parking problems. No negative articles were found in the trade press that mainly focus on selling the project and the building without any analysis. The un-reflected building information given by Swedish trade press was has been confirmed by an earlier study [9]. No articles presented practical experiences from the Universeum building in use. The media study presents Universeum as an institution that provides information about natural phenomenon and gives expert support to the public in contemporary urgent environmental matters (climate, bird flue etc.) through for example open seminaries.

Table 2: Results form the media study

Subject	**Mass media**			**Trade press**			**TOT**
	P	N	Ne	P	N	Ne	
Arch.	63	6	13	12		1	***95***
Urban	7	11	28			3	***49***
Nature	77	4	11				***92***
Expert	47	0	14				***61***
Pedagogy	90	4	6				***100***
SD	19	0	2				***21***
Tourism	86	2	37				***125***
Economy	5	20	9				***34***
Business	3	0	9				***12***
Function	1	8	2				***11***
Other	32	8	175				***215***
SubTOT	**430**	**63**	**306**	**12**		**4**	
TOT			**799**			**16**	***815***

5.2 Function of design and accessibility

All respondents in the interviews reveal a large satisfaction with the building in general. A few respondents point out the lack of integration between the different parts of the exhibition and the lack of space for groups to discuss in the exhibitions parts. The staff complain about a lack of space in general for the functionality, and lack of storage space, office space and meeting rooms. Some respondents say that some parts are difficult to access for cleaning. Eight articles in the news papers reveal dissatisfaction among visitors and official

organisations for the disabled, as not all parts of the exhibitions are accessible for wheelchairs.

5.3 The working environment and indoor environment

The staff show a dissatisfaction concerning the working environment regarding: hard floors, high levels of noise, difficulties in adjusting the temperature. The open landscape office is not appreciated among the staff. The chief of personnel expresses the common view as follows (interview, 2005-12-05):

> Most of the staff like their work place. /…/ You are happy when you arrive but you loose that joy during the day. People get irritated of each other as we disturb one another.

6. THE ENVIRONMENTAL PERFORMANCE

The initial environmental objectives for the building were based on a few basic principles: resource efficiency, a closed 'eco-cycle' perspective and a pre-cautionary principle perspective to avoid risk with hazardous solutions and emissions.

6.1 Low and efficient energy use for heating/cooling

Early calculations indicated that the actual energy needed for heating would be very low, referring to passive solar contribution and heat energy from visitors and technical equipment. What would be needed for running the activities was electricity that could be provided by solar cells (see below). This presumption did however disregard the large quantities of energy needed for the pumping systems.

The need for cooling in summer, mainly for the aquariums triggered the idea of an innovative system with heat-pumps providing both heat and cooling (running the system backwards) and the underlying rock for storage of heat/cooling. Additional heating needed in (mainly for the rainforest) is bought from the city heating system.

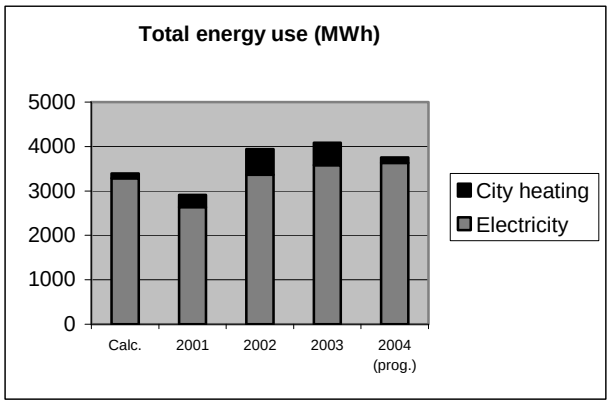

Figure 2: Total energy use: electricity and city heating, calculated compared to measured values 2001 – 2003, values for 2004 are prognosis only.

The system has had initial running problems and a higher level (4-5 times higher) of bought city heating than expected (Fig. 2). It is still not clear if this is due to a conceptual problem or a steering problem. The study indicates that the initial running phase lacks of knowledge transfer from the consultants to the technical staff. There was no organised handing over of the heating system. The technical staff says that they lacks of knowledge about the system was designed. After a longer period of testing and trimming the dedicated staff has arrived at a lower need for bought heating that approaches the calculated objectives. Interviews with the consultant engineers reveal a fear that the system is actually not run as designed. The technical staff has partly documented how they resolved the problems which can be very useful in the future. An additional study would be necessary to study what went wrong and to give feed-back to the engineers.

6.2 Renewable energy resources – solar energy

The initial objective was that all energy should be collected and transformed on the spot (see 6.1). This lead to the investment in solar energy both for electricity production and for warm water production. The spectacular sawtooth roof over the exhibition halls was designed for 1200 m^2 solar cells (PV) but this was too expensive to realise at the time for construction. Actually there is 100 m^2 solar cells and 18 m^2 solar collectors for warm water. The co-ordinator for the environmental advisory group and author of the environmental programme still finds the objective for using solar energy defensible and he thinks that Universeum should try to find sponsors for achieving more solar cells. However, the engineering consultant involved in the design, as well as the technical staff does not find that the small contribution form the solar cells make further investments interesting. The technical staffs find the solar collectors for warm water more interesting and would invest further in that technology. Without any detailed measurements the technical staffs evaluate that the solar collectors contribute with 20% to the warm water production in the summer season.

6.3 The natural ventilation

The building includes two large natural ventilation systems. Mechanical ventilation is provided in closed spaces and in the office part. This was part of the 'ecological' vision of the building held strongly by the architect. The objective was criticised by several of the interviewed consultants and advisors as more symbolic than effective. The system actually works rather satisfying depending on the outdoor temperature. During warm and humid days the effectiveness of the system is hindered. A sprinkler system on the southern façade (behind an opaque screen) is intended to cool down the in-air a few degrees in hot weather. The system has been used the last two years since it needs further developments (water is running down on café guests below). The natural ventilation system has not been technically evaluated. The architect continues to develop he potentials of this technique in non-residential buildings if the design is suitable.

6.4 Water saving - The re-circulating water system

Water from the aquariums is re-circulated and cleaned (without chemicals) in the building. The aim was to be 100% self-supporting of water. The water that evaporates should be compensated by water from the exterior pond that collects and cleans storm water from the roof. This does not work as the pond is leaking (the reason is still not found). Today about 3% of the water in the aquariums is changed on an annual basis which according to the responsible manager for the aquatic systems is very impressing for other aquariums. The system is one of the largest re-circulating systems in the world (according to staff). The system saves not only fresh water and transports (for example London aquarium has several truck loads of water delivered every week), but also space as Universeum does not need storage for incoming water. The system has been studied in a few master-projects at the University.

6.5 The urine separation and local waste water treatment

Universeum has a urine separating toilet system with the advantage to separate the useful urine from the rest. The system relieves pressure on the municipal waste water treatment, saves transport and energy, and reduces nitrification. The decision to include all toilets is part of the pedagogical ambition to teach the public about environmental solutions. The system works well but has had problem with smell and cleaning. Instructions for use of the toilets are indicted by a notice. A small part of the waste water is treated locally in a pedagogical station in the rain forest. The nutrition is used for breeding alga and fish. The rest of the urine should be collected and used by local farmers as fertilizer. This end-of the line process is actually having problems due to small volumes (to be interesting for farmers) and storage problems. A research project is connected to Universeum with the intention to crystallize urine for enhanced storage and handling.

Those who initiated the idea of the urine separating toilets remain convinced that it was the best idea to make all toilets of this kind. Some of the staff and the new director think that it was an expensive investment and should have been kept to a small number of demonstrational toilets. The inventor and seller of the system if disappointed that the system is receiving less attention and seldom included in new projects. Universeum has not resulted in either development or further spread of this technique.

6.6 Building materials

The material choices have been made regarding the environmental image of the project and to reduce environmental impact as far as possible. The project includes large volumes of wood and gluelam, a renewable resource designed for future dismanteling. A long discussion was held during the process about the sawtooth roof designed in gluelam by the architect. The wooden roof was far more expensive than a steel construction but was eventually found important for the image, the architectural quality and was found to give less environmental impact also in the long-term (an LCA was performed). The project leader is still not convinced this is a durable solution though due to need for maintenance.

Furthermore, reinforcement steel is partly recycled as is the totality of aluminium used for window frames. Part of the blasted rock from the site is used in stone gabions on the façade.

Environmental consideration is taken into account for maintenance and new additions.

7. THE IMPACT

The project has received a lot of attention in the media and several architectural awards for the use of wood, the interior design etc. When the project was just opened it received a national award by the public for the best Swedish building in the category modern building. The media study confirms the positive view among the public and many professionals about the architectural design. The project has been lively discussed in media regarding the location and the problematic traffic solution in connection to the active area where it is situated.

All respondents express a very positive attitude towards the building, the architectural design and the environmental profile despite some dissatisfaction mentioned earlier (see section 5.3).

7.1 The importance for R&D in sustainable building

Some parts of the project maybe have larger values as symbols than the optimal solution for reduced environmental impact (the stone gabions, the local waste water treatment, the solar cells). The choice of natural ventilation points at solution focused choice rather than a demand-driven. All respondents that had been involved in the design and planning process says that the project has been important for their personal learning process even if many says that they would make things differently today (see section 10). Regarding the development of general knowledge the project still suffers from lack of experiences that has been evaluated and spread.

The project is set forward as a good example regarding the use of gluelam by the Swedish gluelam wood industry. It still has to be analysed if the project has important for the development of the special heat/cooling system. The re-circulating system for the aquariums is an adoption of an innovative system that has to be further analysed.

7.2 The teaching example

The media study indicates that the building itself so far has had relatively small influence on the debate about sustainable building. Media focus on other aspects of the project. A few architectural critics set forward the building as a good example of sustainable building through a successful combination of modern architecture and environmental adjustment without regards of environmental impact. As in the following citation [10]:

For Wingård, the building's ecology is an integral part of the design. /…/ Wingårdh's makes plain that the values of modernity and ecology need not be in conflict.

The lack of influence as a teaching example is probably a resulting from the fact that the Universeum organisation has so far not used the potential the building itself has as a teaching example (see also 7.3). For the un-initiated visitor, the environmental profile, apart from the urine-separating toilets, remain invisible. The visitors are completely dazzled by the aquariums and rainforest that have been set in focus for the Universeum business. The initial idea to have monitors to expose solar energy, hidden on the roof, contribution, and how much energy that was actually stored in the ground etc. has so far not been realised. Universeum and the architect organize study tours on demand, mainly for professionals, where the environmental aspects are pointed out. Respondents among the designers and the staff find it a pity that the building is not integrated more in the expositions and this should be an utterly important task for the future. The fact that the project has not been evaluated also contributes to the reduced influence as a teaching example.

Regarding the influence on the staff and the management, all respondents say that they have learnt a lot from the building, about building management, the heating system, and environmental issues. The new director of Universeum who entered the project as late as last year says (Interview, 2006-01-12):

> It was an early example that worked with resource efficiency during the user phase. They have thought about resource efficiency. It gives a certain impact. It is important that the building is energy efficient and environmentally adjusted. When I started here I did not understand that. I am much more impressed today than I was one year ago. It is very important it is the very essence of the project.

10. TENTATIVE CONCLUSIONS

The study gives a multifaceted view of Universeum. It is a largely appreciated building. The building has some functional problems but the design is adequate for the function in general and robust that can handle additions and changes from use. The largest problems as revealed by interviews with staffs concern the working environment. The organisation has due to initial running problems (costly) not prioritised these problems even if immediate dangers have been corrected and re-building of the entrance areas has been done. Not counting the energy needed to the pump systems etc., the building is energy efficient and definitely more energy and resource-efficient than a building without the high ambitions set up for Universeum.

The main running problem concerns the heating/cooling system which should be regarded as rather innovative. The client had overseen the importance of having a receiving partner for the system. The study indicates that it is still not clear if the initial problems are due to a fault in design or in how the system is actually used. On the whole the project seems to have been a trial-and-error process as there was little experience to rely on, both regarding the special activities and at the time less knowledge was available on environmental building and technologies.

The study indicates that the project has been important for the development of sustainable building in Sweden, mainly concerning the internal knowledge build-up among the involved actors. However, due to lacking systematic evaluations and feed-back the knowledge processes are limited. The project also lacks of a receiver of the accumulated experiences as the owner is a one-of developer. The building provide possibilities for future evaluations regarding also material choices (the maintenance and durability of the wood construction, the demountable construction etc.).

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