



Final Report for the 2008-09 Student Travel Grant Award
Aga Khan Program for Islamic Architecture (AKPIA)

Adaptive Toldo Systems - Revitalization of an Ancient Craft

Content:

- Travelogue of the journey to Stuttgart, Germany
- Travelogue of the journey to Cairo, Egypt
- Significant effects for my MArch thesis „Adaptive Toldo Systems“
- Continuation as a PhD research focus at the University of Stuttgart

Author:

Simon Schleicher

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Rooftop Community in Cairo



Rehabilitation Plan for Old Cairo
Rehabilitation Project in Darb al-Ahmar



Adaptive Toldo Systems Revitalization of an Ancient Craft

By Simon Schleicher
Master of Architecture (MIT)

Abstract

This report for the Aga Khan Program of Islamic Architecture summarizes my research of the year 2008/09. Supported by a travel grant to Germany and Egypt as well by interviews with experts in Stuttgart and in Cairo, I'm investigating the structural, spatial, and climatic performance of the Toldo – a traditional lightweight street shading device, which is emblematic of Islamic cityscapes.

Re-examining its historical roots along with its contextual, cultural and functional traits, my research informs my MArch thesis and aims at setting a framework on the basis of which to speculate the Toldo's reincarnation within contemporary practice. Such framework provides the theoretical foundations and technological opportunities to reinvent the primitive Toldo as a commercial spin-off and as a distributed tool for rehabilitate historic cities. My project envisions the Toldo's modernization in three steps. Firstly, a digital customization tool allows for intuitive, end-user generated designs; Secondly, energy-harvesting materials and microelectronics enhance the product's application range and enrich it with a functional flexibility such that it can be used as an architectural skin beyond street level; Thirdly, an online marketing platform coordinates worldwide communication of interdisciplinary subcontractors, while integrating the product's traditional economy and craftsmanship. Furthermore, my MARCH thesis will present different case studies in Cairo that will demonstrate the widened scope of such an architectural product and prove the system's reliability, as it confronts real life demands and various propensities for investment.

Finally, this report will describe how I will continue this research with a PhD at the University of Stuttgart and as part in an interdisciplinary collaboration of three institutes from the fields of structural engineering, computational design, and biomimetics.

Background – Old Cairo

Cairo - One of the densest agglomerations in the world - suffers under its steadily increasing population density. A highly problematic consequence of this uncontrollable growth is the pressure on the city's tottering infrastructure and the deteriorating of its, partially informal, housing situation. With more than 100,000 inhabitants per square kilometer, the downtown areas of Cairo have to carry a heavy burden. The lack governmental authority, to focus on rehabilitation and historical conservation, increases this problem additionally. This example shows that one major challenge for current architects is to provide tailor-made solutions to urgent problems of our old cities. Old Cairo for instance has its very own set of socio-cultural and economic dynamics, which have to be addressed if you want to improve the living conditions of its inhabitants. The question arises how new developing projects can foster the reassess-

ment of an urban upgrading process, while staying in line with the social fabric. Only a few notable exceptions, like the rehabilitation of the Darb al-Ahmar neighborhood by the Aga Khan Trust for Culture (AKTC), demonstrate that initiatives don't have to be purely restricted on improvements of monuments, but can rather address larger urban zones. Most initiatives, however, have a centralized organization structure, which needs the "top-down" investments of solvent financiers or foundations. Therefore, this research project wants to investigate if a systematical use of ubiquitous micro-architecture, like for example traditional street shading devices, could possibly become an additional "bottom-up" rehabilitation tool, which adds value to the living conditions in historic cities. Furthermore, it is the aim to use these grassroot-products as a carrier to start a dialogue for a knowledge transfer between the western high tech science and the traditional experienced-based understanding in a culture of the Middle East.

Toldo Research in Stuttgart and Cairo

In order to learn more about micro-architecture - a scale, which is mostly neglected by architects - I traveled to Germany as well as to Egypt. In Stuttgart, I learned more about the origins of the street-shading device called Toldo. In many interviews with experts of various professions like the structural engineers and former head of the Institute of Lightweight Structures Frei Otto, I was introduced to the Toldo's impressive climatic, spatial, and structural performance as well as its various design typologies in different cultural surroundings.

An additional travel to Cairo, however, was needed to open my eyes to a more holistic view to this smart micro-architectural device and to understand how this product is actually interwoven with the city's local economy, its use culture, and its traditional craftsmanship.

Origin

Toldo is the Spanish word for awning and describes various textiles and retractable sunshades, which are spanned in between streets and courtyards. This small device can be traced back over a period of more than 2000 years and is still extensively used today. Toldos can be found in many Islamic cities around the Mediterranean Sea and are most widely used in European towns with strong Islamic roots, like Seville in Andalusia. Outside of Europe, however, they can also be found in the Middle East, central America, and in Asia. Most likely, their early design was influenced by the Arab and Roman tent and was then further developed through manufacturing processes and kinetics, which were used by shipbuilders.

Climatic performance

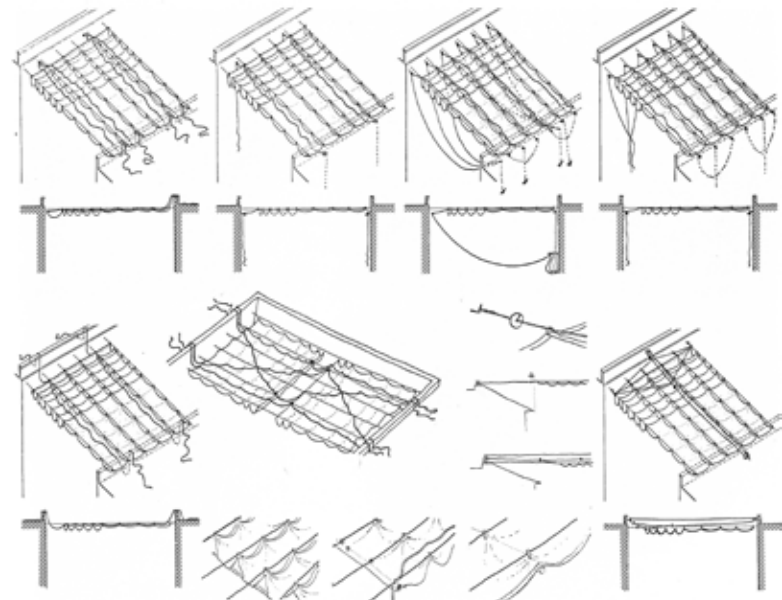
Toldos are mainly designed to protect against excessive insolation and thereby preventing the space underneath from being overheated by the sun. Most often, they are used in cityscapes to moderate the microclimate of streets, courtyards, and public spaces. Their cooling effect is based not only on shading, but also on controlling the radiation of the heat to the sky. During the course of a day the Toldo has to adapt to changing environmental loads, while always preserving a habitable space within the human comfort zones. For this reason, the Toldo's dense and



Traditional street toldo in Valencia

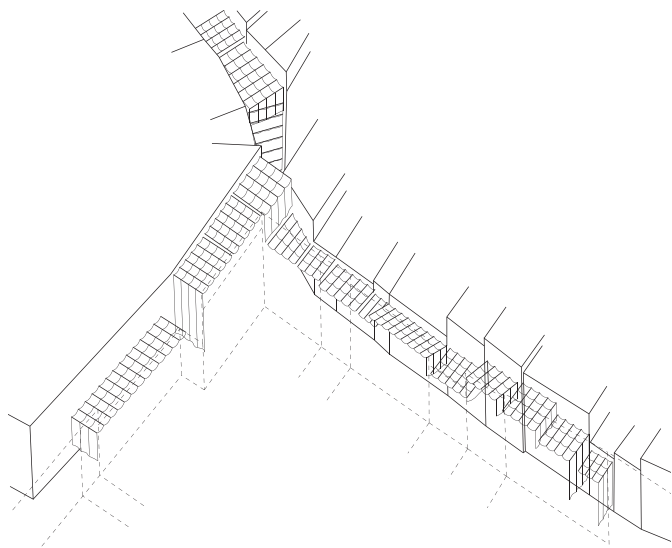


Various kinetic mechanisms for Toldos

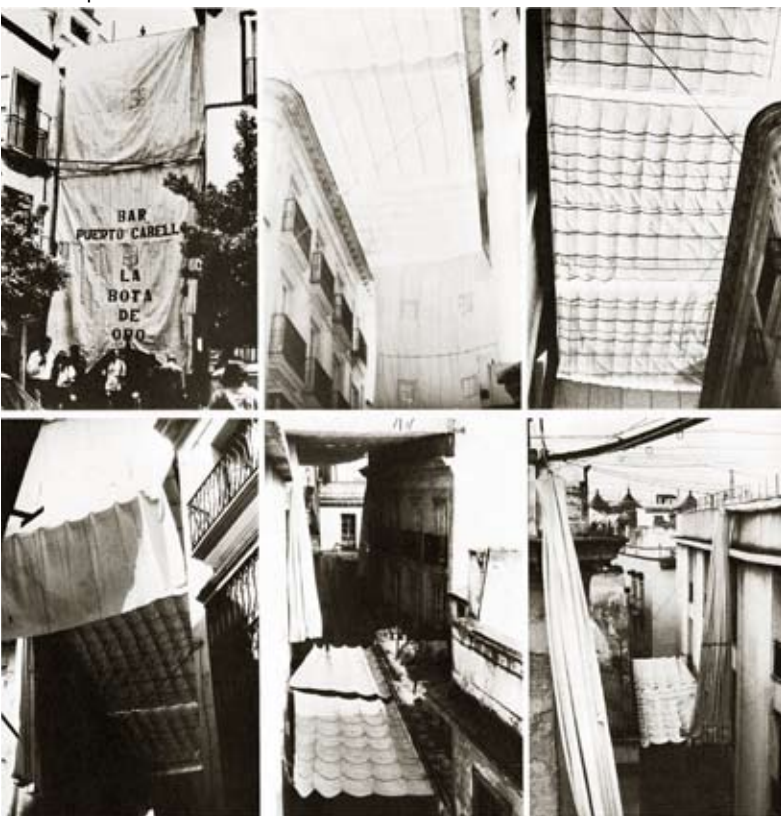




Toldo in the streets of Khan el-Khalili



Urban implementation of Toldos in the streets of Seville



heavy cotton sails allow for two conditions – an open and a closed state. In the summer, the Toldo is extended during the day and prevents the sun from hitting the thermal mass of the built architecture. As a welcome side effect it also protects against glare and airborne dust. During the night the Toldo is folded together. Thereby, the warmth stored in the thermal mass, can radiate freely to the sky. This environmental performance can reduce the measured surface temperature by 30°C and the offset temperatures of the air inside and outside the Toldo by up to 10-15°C. In the winter, absorbing warmth through a folded roof during the day, and preventing its escape by closing the roof at night reverse this principle.

Spatial performance

Besides their impressive environmental performance, Toldos have a impressive spatial quality. Apart from manifold ornamental decorations and a large number of different cutting patterns, auxiliary structures can enhance the Toldo's design language. By combining different types of canvas sails, the awning can be adapted to nearly any street typology and can easily bridge in between gaps or equalize height differences. A single Toldo or a series of Toldos can form this space-enclosing and space-creating effect and frame entire shopping streets or boulevards. Geometric flexibility on the one hand side, and its inherent expendability allows this application in addition to easily range from a singular architectural intervention to a ubiquitous urban infrastructure.

Structural performance and design typologies

Even though the use of Toldos is a very old tradition, the profession of architects and civil engineers largely ignored this architectural device. One notable exception is the research group around Frei Otto and his colleagues at the University of Stuttgart. In the 1970ties and 80ties they started to investigate the Toldo's cultural roots and its structural performance. In their research they focused particularly on the geometric transformation of the textile skin during the folding process and defined the resulting difficulties of punctual loading and suspending of textiles. Their goal was to understand more about the underlying physical principles, which are acting on retractable textile roofs, and to transfer their knowledge into the design of new structures with even wider span. In their famous publication series, called Information of the Institute of Lightweight Structures (IL-Series), they published many structural studies regarding various Toldo typologies and distinguished between three main categories: The smallest category are Toldo Sails of around 2 x 2 meters, which are most often attached to movable market stalls. They can be unfolded to protect the goods from direct sun exposure. The Classical Toldo is in the second category. It is a curtain-like awning of horizontal and sometimes vertical textile sails, which are suspended by sewn-on eyelets on parallel wires. These wires are anchored in opposing walls of house facades. This type is traditionally used as Street Toldo to cover an area of 4 x 10 meters or as Courtyard Toldo to spans up to 10 x 10 meters. The Sevillian cortège or Arabic Suradeq describes the third typology, which is a huge festival pavilion for marriages and funerals. It consists of individual grayish-white awning segments, which are tied together and have exquisite colorful geometric

patterns inside. This typology is either erected in between narrow streets or suspended from additional masts as a stand-alone tent, which cannot be drawn. The largest traditional Suradeqs have dimensions up to 10 x 25 meters.

Toldos in Cairo

Thanks to a travel grant, supported by the Aga Khan Program of Islamic Architecture, I was able to investigate the use of Toldos in the city of Cairo. Especially in the historic district of Old Cairo, Toldos and Suradeqs characterize even today the cityscape. In particular, in the area around the 10th century gate of Bab Zuwayla, the ancient craft of making Toldos and Suradeqs is still alive. Many workshops and tent lofts can be found in one of the oldest thoroughfares – Shari Khayyamiya. Khayma means “tent” in Arabic and gave the Street of Tentmakers its name. Toldos and Suradeqs are everywhere - be it as Street Toldos to cover the boulevards and cafés without which the atmosphere in the souq Khan el-Khalili wouldn't be the same, as Courtyard Toldo like in the Darb Shoughlan Community Center, or as one of the Suradeq pavilions, which seem to appear out from nowhere whenever a family gathering has to be hosted. Until quite recently, it was the custom for all the important events in a person's life to be marked by the appearance of these tents – a happy wedding feast, the arrival of a newborn child, or a funeral. When the occasion calls for it, a whole street can suddenly blossom from end to end with archways decked out in bunting, leading to a Suradeq marquee for the reception of officials and guests. The Suradeqs are especially in demand during the months of Ramadan to house groups of folkloric singers and dancers. On the Prophet Muhammed's birthday, a whole tent city rises not far from the University of al-Azhar. At dusk, religious groups from towns and villages surrounding Cairo come in procession – drums beating, hands clapping – to take possession of the tent city for a few brief hours.

Vision for Toldos in Cairo

So far the profession of architects and engineers largely ignored Toldos. Moreover, Toldos demonstrate an architectural grassroots movement, which was designed directly by the end-user, completely disregarded by any local building authority. The few exceptions in which Toldos were the topic of academic research were focused on their structural performance and their ability to cover spaces with the least amount of material. The cited examples in cities like Cairo and elsewhere, however, show that the Toldo has also a fascinating climatic, spatial, and cultural relevance, which might have the potential for far ranging improvements. Moreover, it is worthwhile to further investigate one of the Toldo's most interesting aspects, which is its inherent flexible nature of being a device in between defined architectural categories. It ranges in its performance and design manifestation from a small-scale architectural product to a ubiquitous urban infrastructure, from a protective skin to a cluster of moderated spaces for various forms of habitation, and from a mono-functional design solution to a multi-functional architectural system.

Holistic understanding of the Toldo

In order to explore the Toldo not only for its climatic, structural, and spatial performance, but to understand it more holistically, this research project investigated the Toldo's

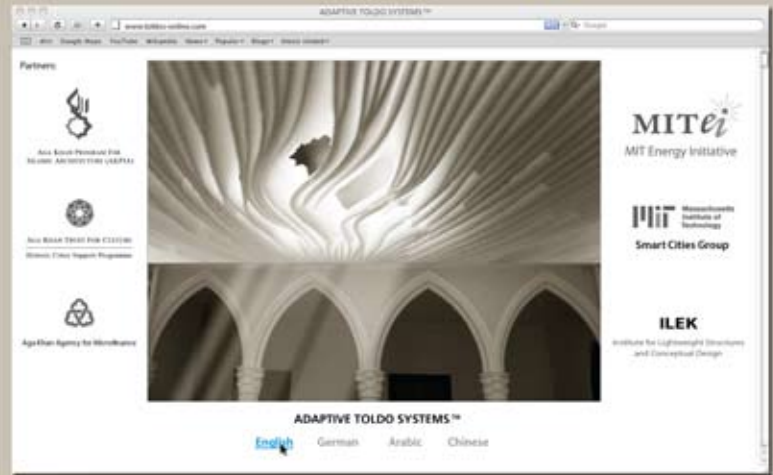


Suradeq tent in Old Cairo

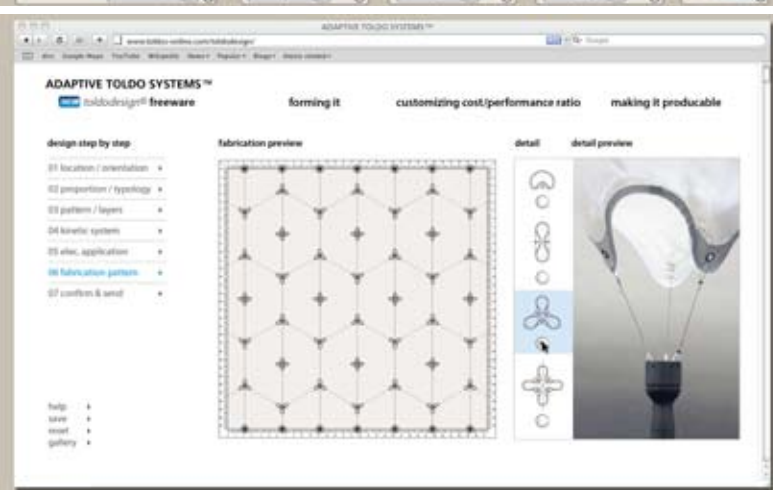
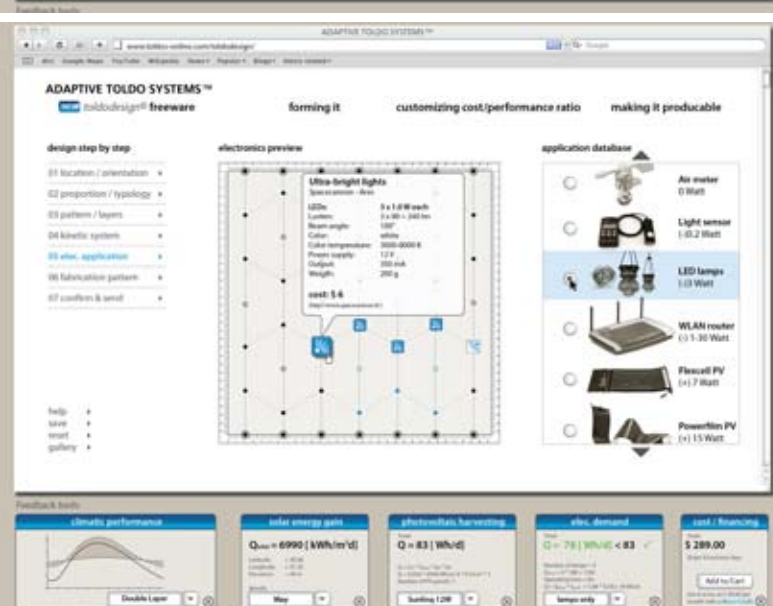
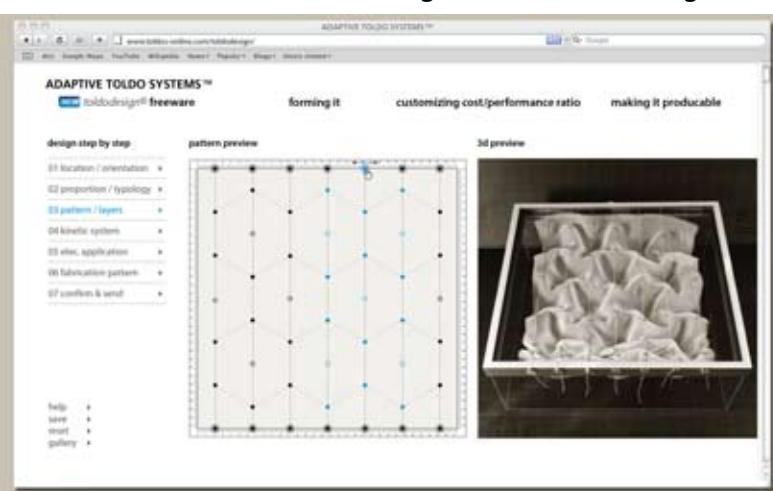


Craftsmen in the Tentmaker Street, Cairo





Intuitive online tool for end-user generated Toldo-designs



contextual and economical traits. In a city like Cairo, which suffers tremendously under its overpopulation and its lack of local authority to organize the living conditions of its inhabitants, architectural products like Toldos have an interesting standing. In this context, Toldos are not a top-down development to improve the cityscape and form a neighborhood's atmosphere; on the contrary, Toldos stand for an architectural bottom-up movement, which addresses specific demands by creating its own grassroots market, supported by an industry of expertise and craftsmanship.

A slowly dying ancient craft

Cairo is only representing one of many Islamic cities, in which this market has formed neighborhoods, completely dedicated to the fabrication of tents and Toldos for thousands of years. This market, however, is in the flux. Once, thousands of men were working in the tent lofts and surrounding workshops in Old Cairo. Local textile manufacturers made exquisite fabrics and sold them to embroiderers, who hand-stitched wonderful patterns onto them. Small tentmaker workshops have painstakingly sewn these textiles together to create Toldos and Suradeqs. Coppersmiths provided little decors, metal fittings and fixtures to assemble the tents on site. This ancient craft was passed from father to son and is now slowly dying. At the moment, there seem to be only a few hundreds craftsmen left. One reason for this development is the transformation of the cityscape, another one is the inertia of this craftsmanship, which hasn't yet found a way to compete with machine-made fabrication techniques and is not able to enthuse the younger generations any more.

Ideas for a reincarnation of the Toldo craft

To re-vitalize Toldos it is not enough to just propose appealing designs and some new applications for their use. A successful reincarnation must be based on a vision for the underlying traditional craft and speculate its reintegration to contemporary practice. This project, therefore, doesn't want to mimic or stick too strictly to the tradition, but rather wants to transcend the Toldo's craft by integrating new physical and digital tools as well as current communication forms of the economy. One important aspect thereby is to teach the young craftsmen the use of computer aided design and manufacturing techniques not by challenging them with unfamiliar tasks but to ask them to work on components, patterns, and details as they did before. On the one hand side this would make many steps in the fabrication process more efficient through automatization, on the other hand it would allow for new ways to approach familiar problems, whose complexity acted as a deterrent until now.

Resulting MArch Thesis – Adaptive Toldo Systems

My research on Toldos was integrated in my MArch thesis, called "Adaptive Toldo Systems", with which I graduated from MIT in February 2009.

Vision - Academic Initiative & Commercial Spin-off

My thesis wants to be progressive by speculating that an unusual point of departure could tremendously inform the design process. In many academic fields, for example in business schools, interdisciplinary collaborations are quite

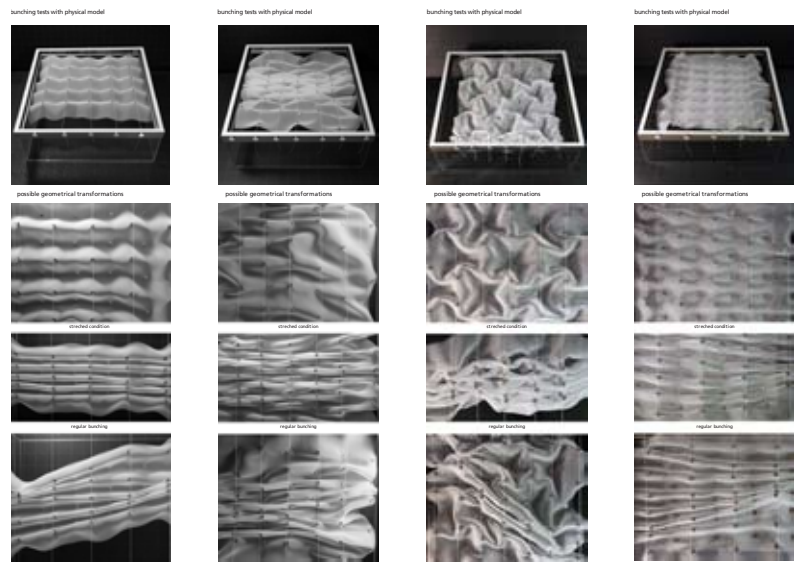
common. For them the exchange of expertise and the testing of new ideas are crucial tools to understand the economic potential of a new business concept. Under an academic umbrella they allow thereby for the emergence of possible commercial spin-offs. In architecture departments the inner-disciplinary discourse seems to be still high on the agenda. MIT, however, with its various world-class departments and long history of transdisciplinary dialogue could teach another approach and separate itself from traditional schools with its own unique identity of architectural education. Part of my thesis is a hypothetical collaboration of multiple research groups and academic initiatives at MIT. Their aim would be to understand the Toldo holistically and inform a commercial spin-off for the Toldo's reincarnation as an architectural product. Therefore, the thesis pools together four main partners to a team. The first partner is the Aga Khan Program for Islamic Architecture because of its expertise in Islamic culture and its endeavors in city rehabilitation projects. The second partner is Media Lab's Smart Cities Group for their innovative research on new technologies to enable urban energy efficiency, sustainability, and cultural creativity. The third partner in the team is MIT's Energy Initiative, which is an Institute-wide initiative designed to help transform the global energy system to meet the needs of the future and to help build a bridge to that future by improving today's energy systems. The last partner in this team is the University of Stuttgart. Especially through the heritage of Frei Otto and his former Institute of Lightweight Structures, this university is still the leading name when it comes to analysis and construction of textile structures.

Product - Digital Customization Tool

The basis for a commercial spin-off, which is informed by an academic initiative, will be a concept called Adaptive Toldo Systems. It combines the development of a digital customization tool for intuitive, end-user generated Toldo designs with an online marketing platform to coordinate the worldwide communication of interdisciplinary subcontractors, while integrating the Toldo's traditional economy and craftsmanship. This framework can attract new customers and new manufacturers. Furthermore, it can allow the Toldo to be reinvented through new materials, design, and fabrication processes.

Business Model - Globalized Product with Local Color

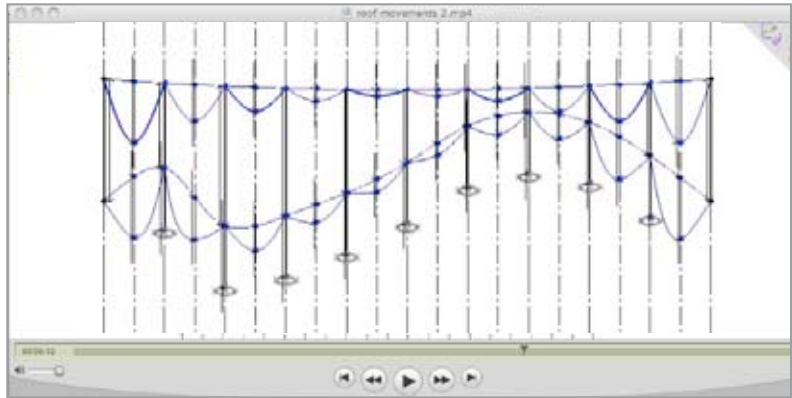
The idea for the business model is partially inspired by the Ikea brand and their online shop. They offer the same systematized product line-up worldwide to guarantee highest efficiency in their logistics. In their stores and on their website, however, they created little niches for subcontractors to offer their external goods and use Ikea as a intermediary. For long the range of these products have nothing to do with furniture any more, which was the main business of Ikea at the beginning. Everything, which supports the image of the brand and has a 'Swedish' flavor to it, is allowed. In the context of this thesis it is interesting to use this marketing strategy but to readjust its goals. The digital customization tool has proven that the design of the Toldo and its precise adaptation to customer demands can highly be systematized. This makes the Toldo to a universal product with a range of design iterations. By using online marketing, it can be ordered from everywhere, and



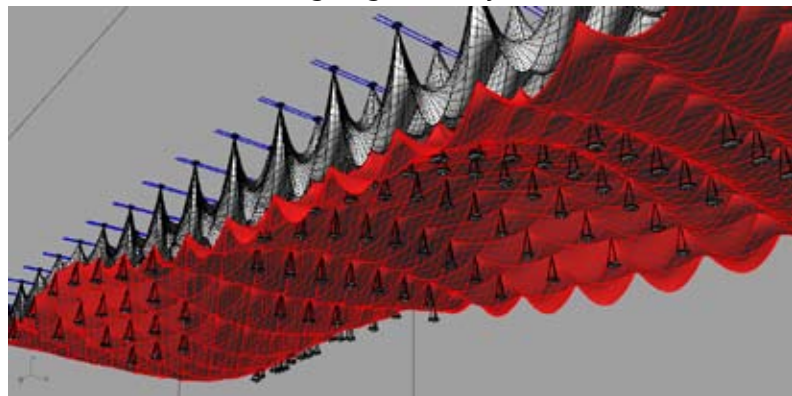
Physical textile experiments inform digital design tool



Environmental responsive textiles with performance range



Parametric tools for designing multi-layered Toldos



(a)

(b)

(c)

Toldo Set-up for Solar Powered Pigeon Coop

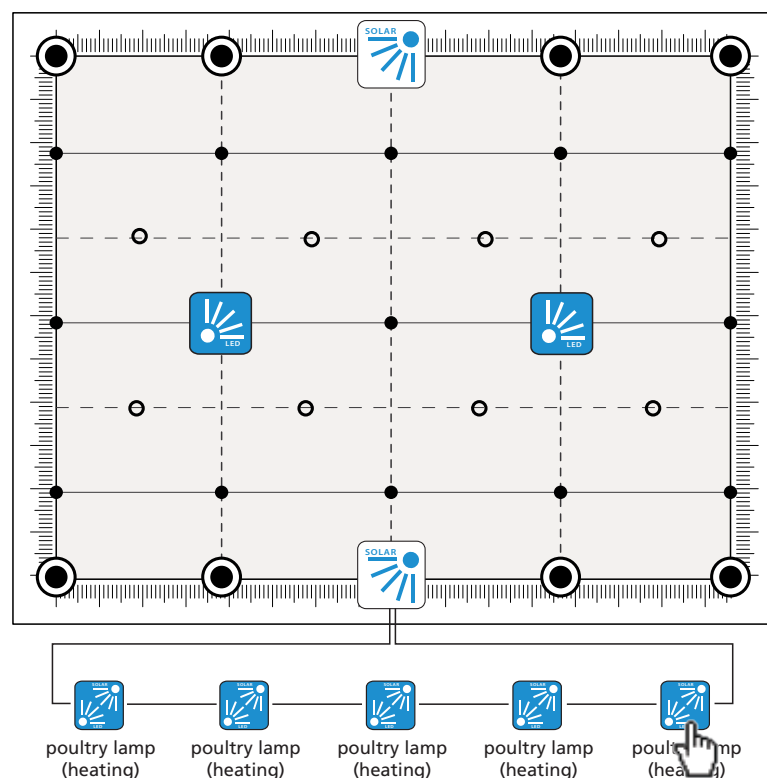
Pigeons:

x 500

each: \$ 3
total: \$ 1.500

Poults:

x 150

1/3 perish by cold
in the night

be delivered to everywhere in the world. In this process, local craftsmen like the tentmakers in Cairo would give the Toldo a specific 'local color'. Manufacturers and sub-contractors could do so from other parts in the world. This local aspect, however, doesn't have to be limited only to aesthetic features but could also include highly sophisticated parts in the manufacturing process. Contributors could specialize on complex detail solutions, electronic applications, or energy harvesting materials and promote their expertise worldwide. At the end Adaptive Toldo Systems would once more become an initiative, which coordinates the communication among multiple partners, but this time not in an academic surrounding but in the business world. In a next step the thesis tests the systems reliability by having a closer look on three exemplary case studies.

Case Study I - Toldo for a Pigeon Coop

At first glance a Toldo for a pigeon coop might seem to be a bit odd. This case study, however, arises from purely pragmatic considerations. The breeding of pigeons is very common in Cairo. There are more than thousand pigeon fanciers only in the district of Old Cairo and sometimes they have multiple coops. Not only is the scale of this potential user group interesting, but also their specific difficulties, which they have to encounter. One major problem in breeding pigeons is to deal with the extreme weather conditions. Keeping animals in this region means to protect them from direct sun and high temperatures during the day while providing warm cages in very cold nights. The design of the pigeon coop itself is already responding to these environmental constraints. Aside from hygiene reasons its aims to maximize the distance between the cages and the overheated thermal mass of the built environment. With the coop being built out of wood, its own thermal mass is relatively low and thereby hardly in danger to overheat. In addition, the coop uses its height to expose itself to cooling wind gusts. Nevertheless, the heat and the cold are still major reasons for severe declines in the pigeon stock. An upgrade with a primitive version of the Toldo could already provide environmental protection by shading and cooling effects during the day as well as solar powered heating during the night. Better climatic conditions would extent the breeding season and could reduce the death rate of poults, which are particularly affected by the cold night temperatures. The shown case study exemplifies these ideas on a representative customer, whose financial situation doesn't allow for high investments. With a total investment of 500\$, out of which 300\$ are subscribed by micro-credit loans, he could purchase a customized Toldo-kit, which includes two photovoltaic cells and five solar poultry heaters. With this set-up he would save one third of his stock, which affects around 200 pigeons, the equivalent of 650\$ per season.

Case Study II - Street Toldo for Darb al-Ahmar

The idea of mounting Street Toldos in the Darb al-Ahmar neighborhood is closely related to the traditional use of Toldos in Old Cairo. For thousands of years this architectural device can be found in this part of the city. It is very likely that their number would increase through the upgrading of the Toldo with additional functions. Especially the new applications like self-recharging street lighting could be a usable feature for main streets and market places. The

case study shows a Toldo set-up for the Darb Shoughlan Street. Its dimensions are 4x9 meters and it is equipped with 18 ultra-bright LED lamps. The six photovoltaic panels recharge the Toldo during the day and allow for an operation time of nearly 8 hours in the night. This Toldo provides illumination in the street for most of the night. It would only be deactivated for three hours, in which it is necessary to retract the Toldo and let the stored heat radiate to the sky. Besides this rather pragmatic approach, this case study also explores the aesthetic and spatial opportunities, which could emerge from the utilization of additional digital design tools.

Case Study III - Rooftop Toldo for the AKTC

The last case study wants to emphasize the new opportunities, which result from transcending the Toldo from its traditional use to new areas of implementation. In this scenario the Aga Khan Trust for Culture (AKTC) fictionally asks for a Rooftop Toldo to be assembled on top of the Darb Shoughlan Community Center. This sets new challenging problems, which can only be solved by introducing a new typology, which allows the traditional Toldo to become a Rooftop Toldo. One resulting difficulty is that the roof dimensions are beyond the conventional structural spans. This requires new adjustments to extent the Toldo's structural limits. Another problem is the exposed position on top of a building, which demands for an increased climatic performance. This example will show that the new systematic design and fabrication tools can achieve the adaptation to both obstructive constraints. If this case study meets all expectations, it could act as first of a series of beacon projects. Furthermore, it could raise once more the awareness for the use of Toldos, demonstrate an exquisite design, and make a looked-for space in the city inhabitable. All in all, this project would be a worthy kick-off for Adaptive Toldo Systems in Cairo.

Results for PhD research at the University of Stuttgart

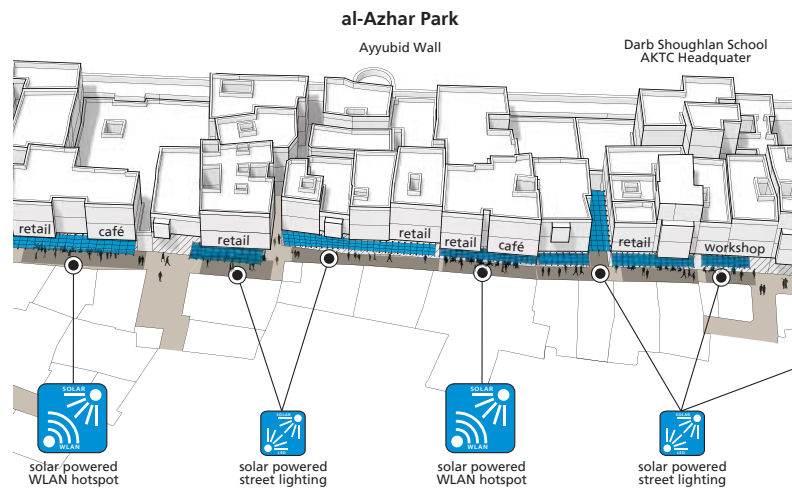
Finally, I'm very happy to announce that my Toldo research as well as my proposed vision for an academic initiative and commercial spin-off aroused great interest and will be in the focus for a PhD at the University of Stuttgart.

In an interdisciplinary collaboration of the Institute of Building Structures and Structural Design (ITKE), together with the Institute for Computational Design (ICD), and the Plant Biomechanics Group (PBG), I want to conduct further research and work towards a full-scale prototype. In my opinion, I have found the perfect advisors to further develop the concept of "Adaptive Toldo Systems" with regards of material research, structural engineering, and manufacturing techniques.

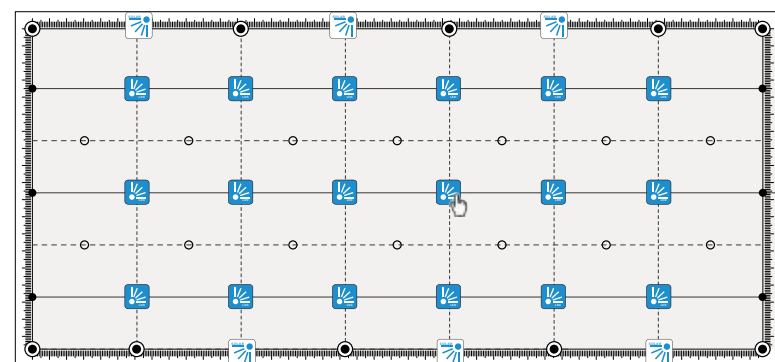
My PhD with the title "Biomimetic Foil and Membrane Structures - Design Methodologies for Adaptive Cladding Systems" aims at setting a framework for an informed design process, which promotes an approach from four different points of departure. Thereby, the dissertation combines interdisciplinary knowledge transfer, basic material research, modern computer-controlled fabrication methods, and the implementation into various use cultures. In order to provide the theoretical foundations and technological opportunities to reinvent foils and membranes as smart cladding systems the dissertation will structure its



Toldo Set-up with Solar Powered Street Lighting

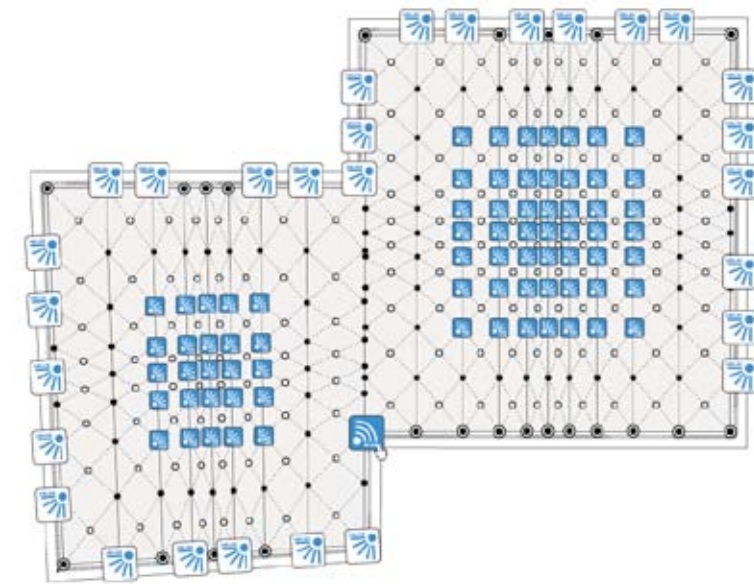


Implementation of Street Toldo in Darb al-Ahmar

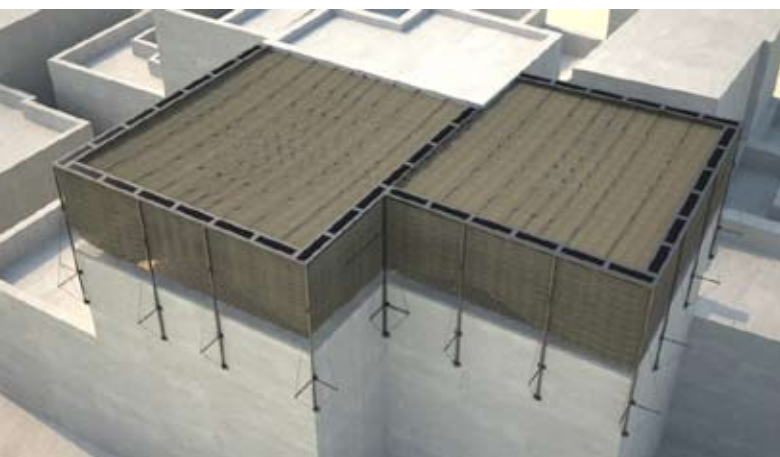
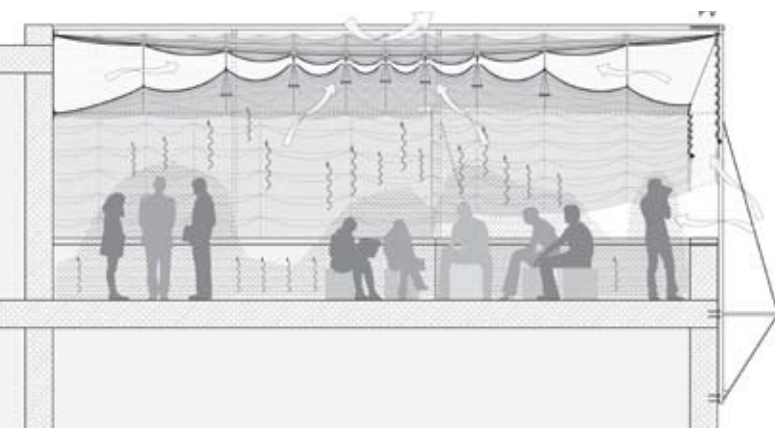




Rooftop on the Darb Shoughlan Community Center



Set-up of Photovoltaic Panels and LED Lighting



research by the following steps:

Firstly, interdisciplinary collaboration will explore inspiring biological models to systematically evaluate their ability for adaptation. In addition, it aims to analyze the observed structural and mechanical properties of natural membranes as well as to deduce and to abstract the acting physical principles. Secondly, basic material research will join this process to transfer the resulting biomimetic knowledge into the development of new adaptive textiles and fibrous composite materials. Thereby, the research will focus on non-homogenous material distribution to conceptualize a network of distributed sensors and actuators, which are embedded within the material make-up. Thirdly, the dissertation will re-examine how the simulation, prediction, and customization of material behavior and fabrication logics could inform current digital design tools. Furthermore, an informed tool-set could help to generate cladding systems, which are custom fit to a bandwidth of environmental conditions during all phases of construction, use, and deconstruction. Finally, different case studies will demonstrate the widened scope of such architectural product and prove the system's reliability, as it confronts real life demands and various propensities for investment.

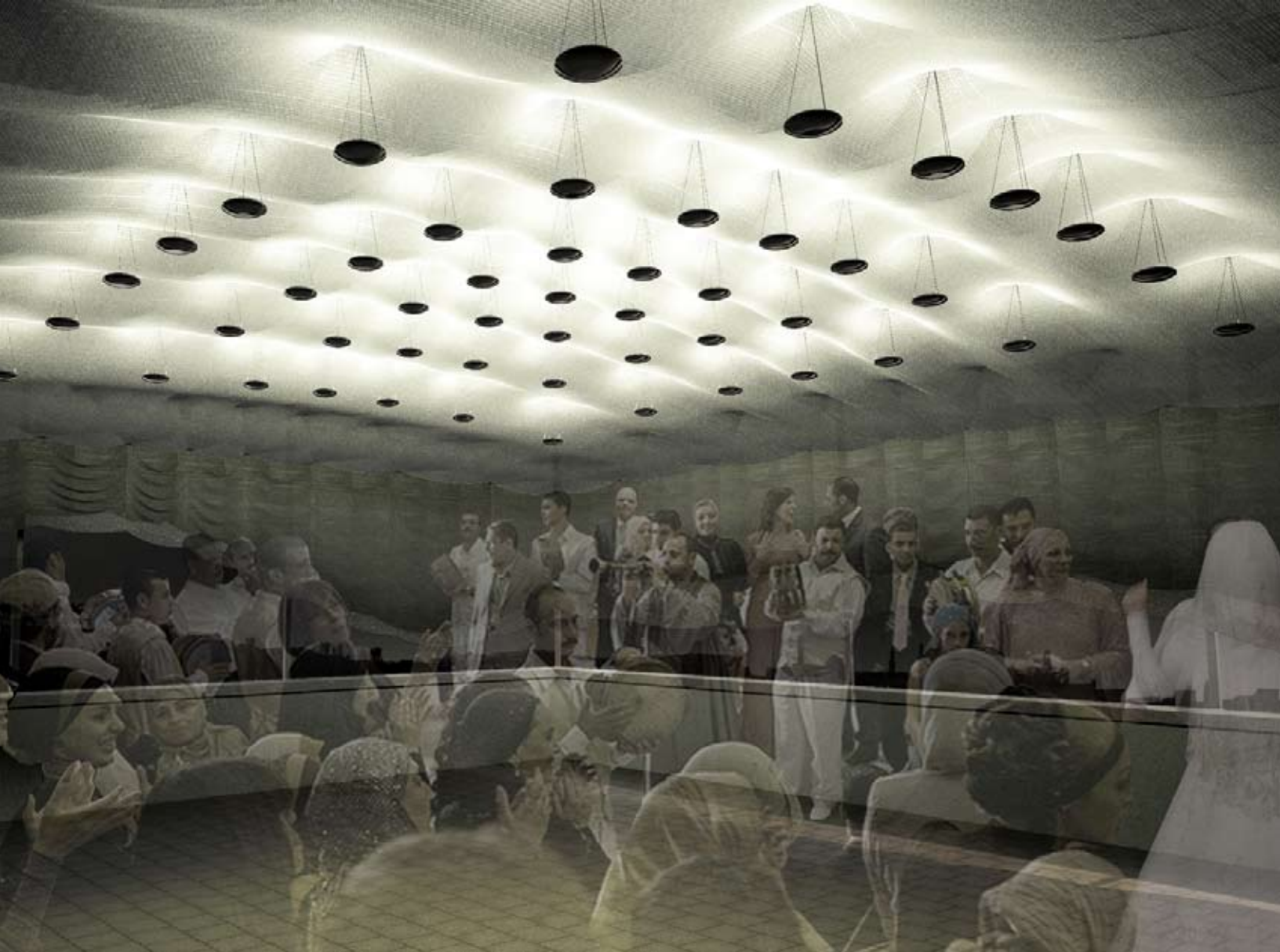
Acknowledgements

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- To my thesis readers William Mitchell and Nasser Rabbat for their always inspiring and motivating input.
- To the Aga Khan Program for Islamic Architecture for supporting me with a travel grant and thereby, for opening my eyes to a fascinating culture.
- To the many experts in Cairo and Stuttgart, who supported my project with their illuminative interviews to the topic.
- And especially to the University of Stuttgart and the Massachusetts Institute of Technology, which both became my spiritual home and enriched me by their transdisciplinary culture.

Simon Schleicher

Candidate. of Master in Architecture
Massachusetts Institute of Technology
simons@mit.edu



Rooftop Toldo becomes event space and seminar room



Contacts at the Massachusetts Institute of Technology:

Prof. Sheila Kennedy

Professor of the Practice, Architectural Design
<http://www.kvarch.net/>
Form of contact: MArch thesis committee

Prof. William J. Mitchell

Media Lab's Smart Cities Group
<http://cities.media.mit.edu/>
Form of contact: MArch thesis committee

Prof. Nasser Rabbat

Aga Khan Program for Islamic Architecture (AKPIA)
<http://web.mit.edu/akpia/www/>
Form of contact: MArch thesis committee

Cand. PhD Neri Oxman

MATERIALECOLOGY – Interdisciplinary Research Initiative
<http://www.materialecology.com/>
Form of contact: Advisor for MArch thesis

Contacts in Germany:

Prof. Jan Knippers

Institute of Building Structures and Structural Design
University of Stuttgart
<http://www.itke.uni-stuttgart.de/>
Form of contact: Dr.-Ing. thesis committee

Prof. Achim Menges

Institute for Computational Design
University of Stuttgart
<http://icd.uni-stuttgart.de/>
Form of contact: Dr.-Ing. thesis committee

Prof. Thomas Speck

Plant Biomechanics Group
Albert-Ludwigs-University of Freiburg
<http://www.botanischer-garten.uni-freiburg.de>
Form of contact: Dr.-Ing. thesis committee

Competence Network Biomimetics, Baden-Württemberg

http://www.kompetenznetz-biomimetik.de/index.php?option=com_content&task=view&id=48&Itemid=26

Proposed External Research Collaborations

Institute of Textile Technology and Process Engineering
(ITV) Denkendorf, Germany
<http://www.itv-denkendorf.de/institut/profil.htm>

em. Prof. Frei Otto

Former Institute of Lightweight Structures IL,
University of Stuttgart
Form of contact: Interview

Prof. Werner Sobek

Institute for Lightweight Structures and Conceptual Design
University of Stuttgart
<http://www.uni-stuttgart.de/ilek/>
Form of contact: Interview

Prof. Matthias Schuler

Transsolar – Climate Engineering
<http://www.transsolar.com/>
Form of contact: Interview

Contacts in Cairo, Egypt:

Kareem Ibrahim

Darb Al-Ahmar Revitalization Project
Aga Khan Cultural Services – Egypt
Web: www.akdn.org
Form of contact: Interview

Ralph Bodenstein

DAAD Lecturer for History of Islamic Architecture
Cairo University, Faculty of Archaeology
German Archaeological Institute, Cairo Dept.
Form of contact: Interview

Wolfgang Mayer

Hanns-Seidel-Foundation Cairo
Form of contact: Interview via email



Contact:

Simon Schleicher
Senefelderstr. 109
70176 Stuttgart
Germany