ADAPTIVE TOLDO SYSTEMS™
by Simon Schleicher

Pre-Diploma (Architecture and Urban Planning)
University of Stuttgart (2004)

SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE
IN PARTIAL FULFILLMENT FOR THE DEGREE OF

MASTER OF ARCHITECTURE AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

February 2009

© Simon Schleicher. All rights reserved.

The author grants to MIT permission to reproduce and to distribute publicly paper and electronic
copies of this document in whole or in part in any medium now known or hereafter created.
Thesis Committee

Sheila Kennedy
Professor of the Practice, Architectural Design
Thesis Supervisor

William J. Mitchell
Professor of Architecture and Media Arts and Sciences
Director of Media Lab’s Smart Cities research group
Thesis Reader

Nasser Rabbat
Aga Khan Professor of Islamic Architecture
Thesis Reader
Abstract
by Simon Schleicher
Submitted to the Department of Architecture on January 15, 2009
in partial fulfillment of the requirements for
the Degree of Master of Architecture

Thesis Supervisor: Sheila Kennedy
Title: Professor of the Practice, Architectural Design

ADAPTIVE TOLDO SYSTEMS™

This thesis investigates 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, the thesis aims at setting a framework on the basis of which to speculate its reincarnation within contemporary practice. Such framework provides the theoretical foundations and technological opportunities to reinvent the primitive Toldo as a commercial spin-off, which envisions its 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. Finally, different case studies in Cairo 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.
Acknowledgement

My sincerest gratitude to:

Sheila Kennedy for your tremendous guidance, faith in my thesis, and for reminding me of what it means to be an architect.

William Mitchell and Nasser Rabbat for your always inspiring and motivating input.

The Aga Khan Program for Islamic Architecture for supporting me with a travel grant to Cairo and thereby, for opening my eyes to a fascinating culture.

Neri Oxman for your sympathetic guidance, unending encouragement, and being this kindred spirit.

Shirley Shen for our years of close friendship and mutual support.

Steffi Hickl and Thomas Quisinsky for bridging all spatial distances with their assistance.

Steffen Reichert and Adela Kalenja for helping me out in the very last second.

Lucy Ynosencio and Andrew & Yukie Wit for making my final semester the best I've ever had.

The numerous faculty, administrators and students at MIT who have contributed in small but significant ways.

My family, whose unconditional support enabled me to go as far as I wanted, even if it was away from home.

I dedicate this thesis to the University of Stuttgart and the Massachusetts Institute of Technology, which both became my spiritual home and enriched me by their transdisciplinary culture.
## Contents

<table>
<thead>
<tr>
<th>Page</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>05</td>
<td>Abstract</td>
</tr>
<tr>
<td>06</td>
<td>Acknowledgements</td>
</tr>
<tr>
<td>08</td>
<td>Precedent Study</td>
</tr>
<tr>
<td>14</td>
<td>Toldo Economy</td>
</tr>
</tbody>
</table>
| 18   | Vision  
  Academic Initiative & Commercial Spin-off |
| 20   | Product  
  Digital Customization Tool |
| 34   | Business Model  
  Globalized Product & Local Color |
| 36   | Case Study I  
  Toldo for Pigeon Coop |
| 38   | Case Study II  
  Street Toldo for Darb al-Ahmar |
| 50   | Case Study III  
  Rooftop Toldo for the AKTC |
| 74   | Appendix  
  Informative Background Studies |
| 94   | Bibliography |
Precedent Study
Origin

Toldo is the Spanish word for awning and describes various textiles and retractable sun shades, which are spanned in between streets and courtyards. This small-scale architectural 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 and the Middle East, however, they can also be found in central America, for example in Mexico as well as in Japan and China. Most likely, their early design was influenced by the Arab and Roman tent roofs and was then further developed through manufacturing processes and kinetics, which were used in shipbuilding.

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 micro-climate 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 heavy cotton sails are designed to 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 temperatures by 30°C and the offset temperatures of the air inside and outside the Toldo by up to 10-15°C. In the winter this principle is reversed by absorbing warmth through a folded roof during the day, and preventing its escape by closing the roof at night.

Spatial performance

Besides their impressive environmental performance, Toldos are also highly valued for their 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 proportion and can easily bridge gaps or equalize differences in height. This space-enclosing and space-creating effect can be created by one Toldo or amplified by a series of Toldos to frame entire shopping streets and boulevards. This geometric flexibility on the one hand side, and its inherent expendability allows this
application to easily range from a singular architectural intervention to an 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 transfer this 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), they published many structural studies regarding various Toldo typologies and distinguished between three main categories:

The smallest categorie 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 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. One of the largest courtyard toldos was informed by the research of the IL-Institute and was built in 1987 by Frei Otto’s colleague Mahmud Bodo Rasch. This Toldo covers the courtyard of the Quba Mosque, the oldest mosque in Saudi Arabia. It consists of two awnings, each with a dimension of 15 x 35 meters. This span, however, demonstrates the upper limit of this construction type and was only possible by the use of high performing textiles and a sophisticated wind resistant cable structure.

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 sewn or tied together and have exquisite colorful geometric patterns inside. This typology is either erected in between narrow streets or is 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 in Old Cairo, 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 in Cairo – Shari Khayamiya. 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, or 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 Muhammad’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.

Conclusion
So far Toldos were largely ignored by the profession of architects and engineers. In addition, they 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 in the focus 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 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.
Courtyard Toldo of the Darb Shoughlan Community Center

Images: Simon Schlesker
Toldo Economy
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 thesis investigates the Toldo's 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. According to the author John Feeney, thousands of men were working once 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 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.

Reincarnation by expanded tool-set
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 thesis, 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 some 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.
Vision - Academic Initiative & Commercial Spin-off

This 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 trans-disciplinary dialogue could teach another approach and separate itself from traditional schools with its own unique identity of architectural education.

Part of this thesis is a hypothetical collaboration of multiple research groups and academic initiatives here 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 for 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 Institute of Lightweight Structures and Conceptual Design at the University of Stuttgart. Frei Otto’s former institute is still the leading name when it comes to analysis and construction of textile structures.
Partners:

AGA KHAN PROGRAM FOR ISLAMIC ARCHITECTURE (AKPIA)

AGA KHAN TRUST FOR CULTURE
Historic Cities Support Programme

Aga Khan Agency for Microfinance

ADAPTIVE TOLDO SYSTEMS™

English  German  Arabic  Chinese
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.
NEW **toldodesign© freeware**

“We believe that everybody has a spark of creativity in them.
That’s why we let you design your own Toldo.”

*Toldodesign©* is all you need and it’s so intuitive you start designing straight away. Shape your Toldo, see it in 3D and save it.
This online tool makes it easy and fun to design, for everyone!
To make the design process simpler, faster and give you more feedback about the performance range, we have created an intuitive patterning system. It will help you to create cool designs in no-time and leaves lots of space for exploration and experimentation.

[online design tool](#)
**Step 1: introducing the interface**
An intuitive interface enables the end-user to actively manipulate the pattern of the Toldo with all its construction elements.

**How to design with toldodesign® freeware**

**Avoid crossing rail curves**
This will result in unretractable surfaces. You will be automatically notified whenever a design is not bunchable.

**Avoid really narrow sections**
Use the random button in the editor mode to have a look through some producable designs or check our design library.

**Our final check**
Every design that is ordered will be personally checked by us. If it can’t be made you will get a voucher to order a new one.

let’s start designing ›
Step 2: defining the environmental constraints
The customer specifies the location and thereby accesses a climatic database, which defines the environmental constraints.
Step 3: setting of Toldo typology
Various frameworks can be selected and define the structural parameters, which are responsible for the design of the Toldo.
Step 4: adapting Toldo proportion
Having adjusted the Toldo’s dimensions, the surface area gives information about the possible solar energy gain.
Step 5: generating the pattern
The customer can modulate the textile geometry with high and low points and gets feedback through an animated 3d preview.
ADAPTIVE TOLDO SYSTEMS™

forming it  customizing cost/performance ratio  making it producable

design step by step

01 location / orientation
02 proportion / typology
03 pattern / layers
04 kinetic system
05 elec. application
06 fabrication pattern
07 confirm & send

pattern preview

3d preview

Step 6: uploading pattern
Once a pattern is finished, the customer uploads the design to a user-generated database and makes it available for others.
Step 7: specifying kinetic mechanism
To support the folding process, the Toldo can be driven by manual pulleys as well as by sensor activated electric motors.
Step 8: equipping the Toldo with solar cells

In this step design tool becomes the framework to drag and drop electronic applications like energy harvesting solar cells.
Step 9: turning the Toldo into a lighting device
The harvested energy can power ultra-bright LED lamps in the night and recharge their batteries fully within the course of a day.
Step 10: building up a self-sustaining electrical system

The solar cells can also provide communication hotspots by powering WLAN router for mobile phones and notebooks.
Step 11: preview of electrical applications
The online platform allows sub-contractors to advertise their by-products and show them already during the design process.

Feedback tools:
- help
- save
- reset
- gallery

Climatic performance
- Double Layer

Solar energy gain
- $Q_{\text{sun}} = 6990 \text{ [Wh/m}^2\text{d]}$
- Latitude: +30.06
- Longitude: +31.25
- Elevation: +40 m

Photovoltaic harvesting
- $Q = 498 \text{ [Wh/d]}$
- $Q = 0.036 \times 6990 \text{ Wh/m}^2\text{d} \times 0.33 \text{ m}^2 \times 6$
- Number of PV panels: 6
- May Sunlinq 12W

Electrical demand
- $Q = 390 \text{ [Wh/d]} < 498$
- Number of lamps = 20
- $Q_{\text{lamps}} = 20 \times 3 \text{W} = 60 \text{W}$
- Operating time = 6.5h
- $Q = Q_{\text{lamps}} \times \text{topeat} = 60 \text{W} \times 6.5\text{h} = 390 \text{ Wh/d}$

Cost/financing
- $1100.00$
- Ships: 6 business days
- Get it as low as $40.00 per month with a Micro-Credit.

Total:
- $Q = 498 \text{ [Wh/d]}$
- $Q = 390 \text{ [Wh/d]} < 498$
- $Q = 390 \text{ [Wh/d]} < 498$

Total:
- Number of lamps: 20
- Q = 390 [Wh/d] < 498

Lamp design preview
- TRADITIONAL

Total:
- $Q = 498 \text{ [Wh/d]}$
- $Q = 390 \text{ [Wh/d]} < 498$
- $Q = 390 \text{ [Wh/d]} < 498$

Total:
- Number of lamps: 20
- $Q = 390 \text{ [Wh/d]} < 498$
- $Q = 390 \text{ [Wh/d]} < 498$

Total:
- Number of lamps: 20
- $Q = 390 \text{ [Wh/d]} < 498$
- $Q = 390 \text{ [Wh/d]} < 498$

Total:
- Number of lamps: 20
- $Q = 390 \text{ [Wh/d]} < 498$
- $Q = 390 \text{ [Wh/d]} < 498$

Total:
- Number of lamps: 20
- $Q = 390 \text{ [Wh/d]} < 498$
- $Q = 390 \text{ [Wh/d]} < 498$

Total:
- Number of lamps: 20
- $Q = 390 \text{ [Wh/d]} < 498$
- $Q = 390 \text{ [Wh/d]} < 498$

Total:
- Number of lamps: 20
- $Q = 390 \text{ [Wh/d]} < 498$
- $Q = 390 \text{ [Wh/d]} < 498$
Step 12: generating detailed solutions
The eyelet details are custom-fit to the chosen applications and inform the fabrication document for the craftsman.
Business Model - Globalized Product & Local Color

The idea for the business model is partially inspired by the Ikea brand and their internet-marketing. 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 sub-contractors to offer their external goods and use Ikea as a framework. For long the range of these products has 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 re-adjust 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 Internet marketing, it can be ordered from everywhere, and be delivered to everyplace 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 aesthetical 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.
Confirm we successfully received your order, thank you!

We successfully received your order, thank you!
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 the scale of this potential user group is 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 of animals in this region means to protect them from direct sun and resulting 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 low and thereby is hardly in danger to overheat. In addition, the coop uses its height to exposed 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 would 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 a 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.
Pigeons:

x 500

each: $3

total: $1,500

Poults:

x 150

1/3 perish by cold in the night
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 by the expansion of their application range. Especially the new function of self-recharging street lighting could be a usable feature for main streets and market places. The example to the right 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 and would only be deactivated for three hours, in which it is necessary to retract it 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.
Street lighting for Old Cairo
The frequently used Darb Shoughlan Street in Old Cairo is the perfect beacon project to demonstrate the Toldo’s new performance range and in particularly its ability to provide self-sustaining street lighting during the night. Along the street are many workshops, retail stores and cafés, which all could profit from a climatic micro-modulation through the Toldo. Their electronic demands, for example for lighting and communication devices vary from each other and show the entire bandwidth of design possibilities. As is the rule in many Islamic cities, all shop owners and inhabitants along the street have elected a local authority as representative, who could organize the ordering process and act as the main customer for this project.
Adapting to various spatial constraints
These concept sketches show that the Toldo’s cross section and its geometric modulation could be used to address specific side constraints and create various spatial configurations.
Parametric design tool to generate Toldo cross-sections

In order to give the customers the freedom to design all possible cross-sections and thereby find the one perfect geometry fitting to their specific side constraints, an additional parametric tool was needed. In an interdisciplinary collaboration with the SMArchS student Adela Kalenja, we developed a parametric model of a Toldo section in a software called Solid Works. This digital model was not fixed in its proportions; only the relationship of its design elements to each other was defined. Thereby, the length of a line or the position of a point was still flexible and could glide along given rail curves, which were imported from the top view-patternning tool. Moreover, the user of this sectional tool can click on points and lines and drag them according to a preferred position, change the sack of multiple textile layers or vary the distances between the lamps and the Toldo.
Multiple cross-sections inform parametric surfaces and define the sack of the fabric. Six cross-sections were generated with the parametric design tool and imported into the software “rhinoceros”. A scripted command is used to moderate the sections and create multiple helper surfaces.
Helper surfaces show various spatial configurations
The color-coded helper surfaces already show the diversified spatial qualities of the Toldo. Concave and convex ceiling geometries invite for centralized and peripheral habitations and activities under the Toldo.
Projecting of all construction points
All points necessary for the construction of the Toldo, are projected on the helper surfaces and thereby constraint in their three-dimensional coordinates. Each textile layer has its own color-coding, which defines either hanging points, or low points of the textile.
Point-based design of the Toldo
This point-based design approach allows for a user-friendly degree of complexity by a manageable amount of geometrical data. In addition, it also allows for an easy exchange among multiple other design tools.
Computer-aided generation of the cutting pattern

Bringing in the computer into the next step of the design process has the advantage that sophisticated calculations like the generation of textile cutting patterns, can be automated and handle easily multiple Toldo layers.
Placing electronic devices on neuralgic spots
Various applications like lamps, could accentuate the spatial impression of the Toldo by lighting hotspots in the center or by directing the attention to a shop entrance at the Toldo’s periphery.
Surface geometry allows for further functions
Having constructed this digital model in the described way draws the attention to the Toldo’s diverse surface geometry. In a next step the rough-textured areas will also get an additional climatic function by fostering a ventilation effect.
Thermal driven micro-ventilation in between the textile layers
The already active cooling effect of the Toldo can be enhanced by allow for micro-ventilation in between multiple textile layers. The surface geometry of the Toldo can thereby form little updraft chimneys to control the airflow.
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) 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 difficulty for example is that the roof dimensions are beyond the conventional structural spans which requires new adjustments to extent these limits. Another problem is the exposed position on top of a building with no shade whatsoever. This demands for an increased climatic performance of the Toldo. This example will show that the new systematic design and fabrication tool 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.
Panoramic view over the Al-Azhar Park

Right next to the restored Ayyubid city wall and connected to the visitors’ circuit along the park, the proposed rooftop extensions of the Darb Shoughlan Community Center could offer the perfect panoramic view over the cityscape of Cairo and the newly developed park.
The binary system of the toldo already reduces the heat loads a lot. Micro-climatic effects in multilayered membranes can enhance this performance even more and can help moderating the temperature differences during the day and the night.

**Enhancing the climatic performance of the Toldo**

Just by opening and closing the Toldo during the course of a day, it can reduce the surface temperature by around 30°C and the air temperature by around 10-15°C. In order to accommodate habitation on Cairo’s rooftops, however, it is necessary support the Toldo’s climatic performance through additional cooling strategies. One of which could be a thermally driven micro-ventilation in between multiple textile layers that increases the air change rate inside the enclosed space.
**Climatic concept for a Rooftop Toldo**

The cooling effect of the Toldo is amplified by various secondary thermal effects, which allow for controlled regulation of the airflow. This climatic concept is active when the Toldo is retracted and uses the sun as its driver. The higher the temperature difference is between the inside and the outside space, the more efficient is the thermally driven micro-ventilation.

---

**Thermo-responsive spacer**
The spacer which holds both layers of the membrane is made of an air-filled spring. During the day the air expands because of the heat and thus shortens the spacer's length. As a result the layers will bring closer together and the venturi effect will increase.

**Buoyancy effect**
Conduction heat gain increases temperature of air beneath shade and buoyancy induces air movement upwards.

**Cold air “pool”**
The commonly used parapets frame a pool in which the cold air of the night-time can be stored.

**Modulated thermal mass**
The Toldo prevents the space underneath from being overheated by the sun and thus allows the climate to be regulated. The cooling effect, thereby, is achieved not only by shading but also by the thermal mass, which absorbs heat loads during daytime. In order to recharge this capacity the Toldo is open during night-time to allow radiation to the sky.

**Venturi effect**
Reduced cross-section between layers increases the pressure and thus the velocity of the air. A spoiler blade at the high point increases the underpressure and the suction of the hot air.

**Low-e coating**
Outer skin of PVC-coated fabric with a reflection of 70% lowers surface temp. 50°->30°. Low-E coated inner layer greatly reduces the internal level of infrared radiation and has a noise reduction coefficient of 70%.

**Flexible photovoltaic panels**
PV panels harvest the solar energy and power the motors of the Toldo as well as various elect. applications like LED lights.

---

The cooling effect of the Toldo is amplified by various secondary thermal effects, which allow for controlled regulation of the airflow. This climatic concept is active when the Toldo is retracted and uses the sun as its driver. The higher the temperature difference is between the inside and the outside space, the more efficient is the thermally driven micro-ventilation.
Using the design tool to generate the Toldo pattern.

The dimensions of the available rooftop require that the pattern serves two purposes. Firstly, it has to support the structure with many hanging points in the middle of the roof, where the field loads are the highest. Secondly, it has to provide many ventilation openings in the center of the space to allow for optimal ventilation effects. The customized pattern combines both requirements into one design.
Applying electronic devices to the pattern
Besides the structural benefits, the generated pattern also provides a handy solution for the placement of the demanded electronic devices. With both roof areas being transferred into seminar rooms and festival spaces, the customer asked for as many solar powered lamps as possible. (36 solar panels and 74 LED lamps each with 3 Watts)
Climatic concept is integrated into the proposed Rooftop Toldo
The presented sections of the Rooftop Toldo for the Darb Shoughlan Community Center show it in its extended condition and demonstrate that the climatic concept is universal enough to be integrated into this design proposal. The double-layered side curtains of this Toldo have a special functionality – they are not only regulating the airflow into the layers of the Toldo but can also provide windows on demand for an optimal panorama view.
**Assembly process 1 – columns**

In the first step of the assembly process for the Rooftop Toldo it is needed to attach columns to the built environment. These columns are simple but very efficient and can easily be manufactured and deployed by local craftsmen in Old Cairo.
Assembly process 2 - lightweight frame and rail cables
The erected columns are connected with a lightweight frame into which the rail cables of the Toldo can be mounted in. The frame consists of a modular system and can easily be adapted in its proportions to fit other rooftop geometries.
Assembly process 3 – flexible photovoltaic panels
The lightweight frame acts as support structure for flexible photovoltaic panels. These can be mounted or replaced easily by snap-on attachments, which also allow for belated upgrading of the Rooftop Toldo with solar panels.
Assembly process 4 – wiring of electronic devices
After the installation of the solar panels all demanded electronic devices like lamps and WLAN routers can be wired together. Even without the textiles this system is already fully functional and could provide rooftop lighting and thereby extent the usable space of the building by another story.
Structural concept
To achieve optimal structural integrity as well as highest bracing against wind suction and uplift, the Rooftop Toldo consists of two counter-curved cable grids, which are permanently linked together by gliding trolleys.
**Trolleys and lamps**
The gliding trolleys are the only rigid part of the Toldo and act as the adapter for the LED lamps. The trolleys are designed in such a way that it is easy to quickly clip the Toldo textiles onto the retractable cable grid structure.
**Inner skin**

The inner skin of the Toldo is attached to the lower cable grid. The textile cannot only be retracted horizontally like a traditional Toldo but also vertically to offer windows on demand with a panoramic view over the cityscape of Cairo.
Outer skin
The outer skin offers the same curtain-like flexibility as the inner skin and thereby makes it possible to compartmentalize the space in between the two textile layers. To control the micro-climatic ventilation effect of the Toldo it is beneficial to be able to switch this intermediate space either to the inside or the outside environment.
**Gradient facade**

The multilayered curtain façade gives the Rooftop Toldo the ability to constantly change its visual appearance and to adapt to environmental loads from all directions. The user can easily block sandy wind gusts from one side, filter unsavory glare from another, or just open the building façade to a panoramic view.
Potential of the climatic buffer zone
Further research for this project should definitely focus on the potential of the intermediate space in between the two textile layers and test out how its geometric modulation, its material choice, and its micro-perforation could possibly increase the environmental performance of this climatic buffer zone.
Assembly process 5 - highly reflective inner skin

The inner skin of the Toldo consists of exquisite textiles of high quality. Furthermore, they can be ordered with traditional geometric patterning or other decorative motives. The high reflectivity of the fabric is enhancing the illumination effect of the lamps additionally.
Assembly process 6 - weather resistant outer skin

For the outer skin of the Toldo the traditional plain grayish-white textile is used. This cotton fabric has proofed its high reliability in many textile applications in Cairo. Whereas modern textiles loose their higher performance over time, the traditional cotton provides longer-term weather resistance for a relatively low price.
Illumination in the night
With the enhanced performance range, the Toldo becomes a light source in the night and can be used to host manifold events while making an unused space available in a city of constant shortage of spatial opportunities.
Top view of the Rooftop Toldo

The 36 photovoltaic panels provide 504 Watts, which is enough to power 74 ultra-bright LED lamps.
Event space during the night
With this newly accessible space the Darb Shoughlan Community Center can easily host festivals or any other form of social gatherings. Furthermore, this space could be rented to local groups in the neighborhood and private costumers for short or long term use and thereby create an additional income for the owner of the Rooftop Toldo.
Seminar rooms and conference space during the day
With its climatic performance and additional electronic applications the Toldo can provide even during the day well-tempered seminar rooms for education purposes or fully equipped conferences spaces with an exquisite view over the Al-Azhar Park and the skyline of Cairo.
Appendix - Informative Background Studies

This thesis aims to understand the traditional Toldo design and wants to transcend it with the help of multi-disciplinary expertise and modern design tools. Therefore, it was crucial to conceptualize digital techniques, whose simulation range is based on actual physical textile studies. To get a keen sense for the behavior of fabrics and the bandwidth of their possible geometric transformations, many structural and kinetic models were built. Even though these experiments were done within the framework of a student research, they successfully bridged multiple crafts and media. In the focus was the predictability of fabrics in the folding process as well as the consciously provoked unpredictability to test their fascinating capacity for geometric self-organization. Only after introducing a kit of surface manipulators, which all acted on the fabric in different ways, was it possible to achieve comparable, multipliable, and repeatable results. This approach became the set-up to evaluate various design iterations according to their aesthetic, structural, and kinetic performance. Furthermore, this systematization clarified the needed design components and was directly transferable into the development of the digital software.
Simulating new technological opportunities to reinvent the Toldo

Even though the thesis investigates this topic with the limited means, which are accessible to students, it tries to be as interdisciplinary as possible by approaching it with a wide variety of techniques and knowledge from traditional craftsmanship.
Coding geometrical transformation of textiles

Curtain tapes, as they are commonly used for decorative draperies, demonstrate how geometric information can be scripted into smaller elements, while spreading their transformation out over a larger area. These tapes are easy to produce and manageable in their processing.
Physical studies with curtain tapes
Various physical studies with curtain tapes revealed their potential to manipulate fabrics but also showed their limits in terms of scalability and predictability of the geometric outcome.
Coding geometrical transformation into larger textile areas
This study model transfers the underlying principles of a curtain tape onto a larger area to inform its folding behavior in the bunching process. It shows that even with a regular manipulation grid the outcome of its geometric transformation can be highly unpredictable.
Set-up for controlled surface manipulation
The first physical investigations informed the set-up of various surface manipulators. The geometric impact of rail cables, trolleys and weights on the textile is repeatable, multipliable and traceable. On this basis, it is possible to map their behavior, evaluate their performance, and arrange them according to their use. As a result you can start to design patterns, which transform a textile membrane in a predictable way.
Frames for Toldo mock-ups
A series of identical frames allowed for multiple textiles and different patterns to be tested simultaneously under comparable conditions. Applying the same input for geometric transformation makes the evaluation of the results comprehensible and their differences visible.
Bunching of fabrics
Using this set-up made it easy to bunch various textiles and to start understanding their behavior. Some patterns folded the textile for example into very regular shapes; others caused perturbing interferences, which counteracted the bunching process.
Geometrical homogeneity and heterogeneity

This table is the first attempt to map the connection between two dimensional patterns and the folding behavior of their three dimensional counterparts. Further research could provide additional information to what extent a crease pattern will show either a homogeneous or a heterogeneous outcome. This would increase the predictability in the design process. As a result Toldos could have high regularity and an undisturbed appearances or be highly complex with an aesthetically appealing surface texture.
I morphological variations of patterns
(1st focus on single surface / parallel bunching)

OBSERVATIONS
Bunching: very predictable folding pattern
little geometric interference
various conditions of difference and heterogeneity possible

Shading: various gradiance possible
Ventilation: to be continued

OBSERVATIONS
Bunching: predictable folding pattern
some geometric interference
various conditions of difference and heterogeneity possible

Shading: various gradiance possible
Ventilation: to be continued

OBSERVATIONS
Bunching: highly unpredictable folding pattern
high geometric interference
various conditions of difference and heterogeneity possible

Shading: various gradiance possible
Ventilation: high potential for ventilation in between the layers

CONCLUSION
Predictability: + + +
Homogeneity: +
Heterogeneity: +
Shading range: +
Complexity: +

CONCLUSION
Predictability: + +
Homogeneity: +
Heterogeneity: + +
Shading range: ++
Complexity: + +

CONCLUSION
Predictability: +
Homogeneity: +
Heterogeneity: +++
Shading range: +++
Complexity: +++

CONCLUSION
Predictability: + + +
Homogeneity: +
Heterogeneity: +
Shading range: +++
Complexity: +

Possible geometrical transformations
regular bunching
stretched condition
irregular bunching
regular bunching
irregular bunching
regular bunching
irregular bunching
regular bunching
irregular bunching

Possible geometrical transformations
regular bunching
stretched condition
irregular bunching
regular bunching
irregular bunching
regular bunching
irregular bunching
regular bunching
irregular bunching

Possible geometrical transformations
regular bunching
stretched condition
irregular bunching
regular bunching
irregular bunching
regular bunching
irregular bunching
regular bunching
irregular bunching

Possible geometrical transformations
regular bunching
stretched condition
irregular bunching
regular bunching
irregular bunching
regular bunching
irregular bunching
regular bunching
irregular bunching

Possible geometrical transformations
regular bunching
stretched condition
irregular bunching
regular bunching
irregular bunching
regular bunching
irregular bunching
regular bunching
irregular bunching

Possible geometrical transformations
regular bunching
stretched condition
irregular bunching
regular bunching
irregular bunching
regular bunching
irregular bunching
regular bunching
irregular bunching

Environmental responsive skins
The studies on geometrical transformation of textiles and the potential of multilayered fabrics led to research on environmental responsive skins, which could become part of a PhD proposal and the next step in my study:

Today’s architectural membranes amaze with their superior strength to weight ratio, which allows for unseen implementations as lightweight building envelopes. These claddings are, however, quite often limited to monofunctional materials with constant physical behavior and defined constriction in use. Further research could argue that inevitable loads shouldn’t be seen only as perturbing interferences to a façade. Moreover, environmental changes, internal forces, and individual utilization patterns could also become potential design drivers and help to discover novel cladding concepts. They would not only redefine the appearance of our buildings but also significantly influence their ecological footprint and energy demand.

A key contribution to this research could be a systematical transformation of the textile in its material make-up into a system of distributed sensors and actuators, which monitor and respond to the surrounding environment. Exposure to the sun for example could trigger thermo-responsive fibers that can assume different shapes at different temperatures. As a result the anisotropic orientation, the stiffness, or the permeability of the membrane would change. In a larger scale this could equip a membrane or the entire Toldo with the ability of solar tracing - a necessity for applications like self-regulated shading, micro-ventilation, or energy harvesting.
The research of the Institute for Lightweight Structures has shown that it is very complex to embed high and low points into textiles, especially if they are loaded with additional weights. In order to hang lamps to the fabric it was needed to develop a system of details.
Mock-up of low point lamp
This lamp mock-up is attached to a low point in the textile and hangs on three cables for optimal stability. Two of the cables are conducting and connected to an external energy source, which is representative for the solar panel.
Reflecting the light from the textile 1
One purpose of this mock-up was to build the lamp in such a way that the inner fabric layer could reflect the lighting to provide ambient illumination for the space underneath.
Reflecting the light from the textile 2
The other purpose of this mock-up was to build the lamp in such a way that its lights is tilted slightly and thereby illuminate the space in between the inner and the outer skin for a volumetric and spatial lighting effect.
The lamp for a high point in the Toldo structures was designed based on traditional ornaments. One interesting precedent to inspire the design were the beautiful lamps of the Sultan Hassan Mosque in Cairo.
Re-designing a lamp based on traditional ornaments 2
Traditional lamps were designed to carry candle lights and are mostly made out of glass. This new lamp however is illuminated only by a very small ultra-bright LED light and can therefore have a much more filigree design. In order to do so, this lamp was completely printed in 3d.
Re-designing a lamp based on traditional ornaments 3
This concept sketch shows the lamp and its connection to a multi-layered Toldo. It is positioned in such a way that the surface geometry acts as a reflector and mirrors the light for optimal ambient illumination.
The mock-up revealed that by dimming the light, the textile reflector could also act as a display to show the projected shadow patterns of the lamp. This gives the Toldo an additional atmospheric feature and allows for the re-integration of traditional ornaments into the design.
Bibliography


