Rural Connections

New Architecture for Farming and Consumer Experience

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Theme: **Urban Farming**

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Synopsis

This report is the result of the first half of the long master thesis project: "*Rural Connections, New Architecture for Farming and Consumer Experience*". The report presents the theoretical framework created for the design proposal for an urban cattle farm.

The objective of the theoretical investigations is the developed parameters and knowledge that can aid a design process that focus on using the concept of urban farming to develop the modern dairy farm.

A connection between rural and urban was earlier an important aspect for the cities in order to produce a sufficient amount of food, but as industrialisation happened, the food disappeared from the cityscape and into the refrigerators.

The investigations made in this report seeks to explore the challenges faced for the modern farming facilities when moving to urban areas. Especially the perception that modern farming lack considerations for the environment and animal welfare needs to be addressed in order to re-establish a connection between the consumer production.

Motivation

As a conclusion of my studies in architecture I have got the privilege of doing a 2 semester long master thesis. I hereby got an opportunity to work intensively with a topic I feel inspired by, and to develop my architectural skills and the specialisation I want to bring with me after graduation.
As main theme for the long master thesis, 7 fellow students and I got the opportunity to investigate new potentials in the concept of Urban Farming, and how it can be integrated into architectural design. In my case this resulted in a project dealing with the challenges of getting fresh and locally produced food integrated into the constantly growing cities.

Born into a family of cattle farmers and with a childhood spend on the family farm, this topic also inspires me on a personal level and allows me to combine my personal background with my professional future.

Growing up on a farm, the freshly produced milk and meat was a natural everyday thing, and it was not until I moved away from my childhood home that I realized the privilege I earlier had taken for granted. When realizing the qualities of fresh food I felt the urge of trying to develop a project working with re-establishing the connection previously existing between cities and the food production in the rural areas. With my childhood in mind, the choice of working with an urban cattle farm was natural, and the knowledge, feelings, and inspirations acquired after years of working in the stables after school, I get to utilize in this project.

As a part of my studies in architecture, a tectonic and structural approach to architecture has at all times inspired me. When looking at modern agricultural buildings, they only consist of the essential elements in order to keep buildings costs as low as possible, a series of steel frames covered with a light steel roof.
Working with structural architecture, the challenge of developing the traditional modern agricultural buildings into buildings with a heightened quality without compromising the animal welfare and interior environment was a very inspiring assignment.

The first part of this long master thesis intended to investigate the challenges and potentials of working with an urban cattle farm, and aimed to generate a strategy and parameters for the design phase that is the second part of the thesis.

Enjoy.

Acknowledgement

Throughout this project I have had the pleasure of being inspired and enlightened by several people, making it possible for me to both develop this master thesis, and at the same time develop my architectural skills.

A year go, Anna Marie Fisker invited me into a selected group of students to create a series of project with the theme of urban farming, which has been the base of this project. The belief of Anna Marie that I would be able to create a long master thesis project, inspired me to take the challenge that I today proudly can present the result of.

The Urban Farming group, with whom I have been developing the projects, has at all times during the thesis been good sparring partners in order to create the best possible outcome of the process. Especially Elias, Mads and Kasper with whom I have been sharing group room with for the last 10 months have on daily basis influenced the outcome of this project.

During the thesis, external partners Anne-Vibeke Skovmark , land surveyor at Aalborg Municipality, and Kræn Ole Birkkjær, architect at Knowledge Centre for Agriculture, have been kind enough to spare time to discuss the framework of my project in both relation to municipal considerations and working with the cattle as an unconventional user group.

Not least I would like to thank my supervisors professor Claus Bonderup and professor Poul Henning Kirkegaard for their commitment in guiding me through the development of the project.

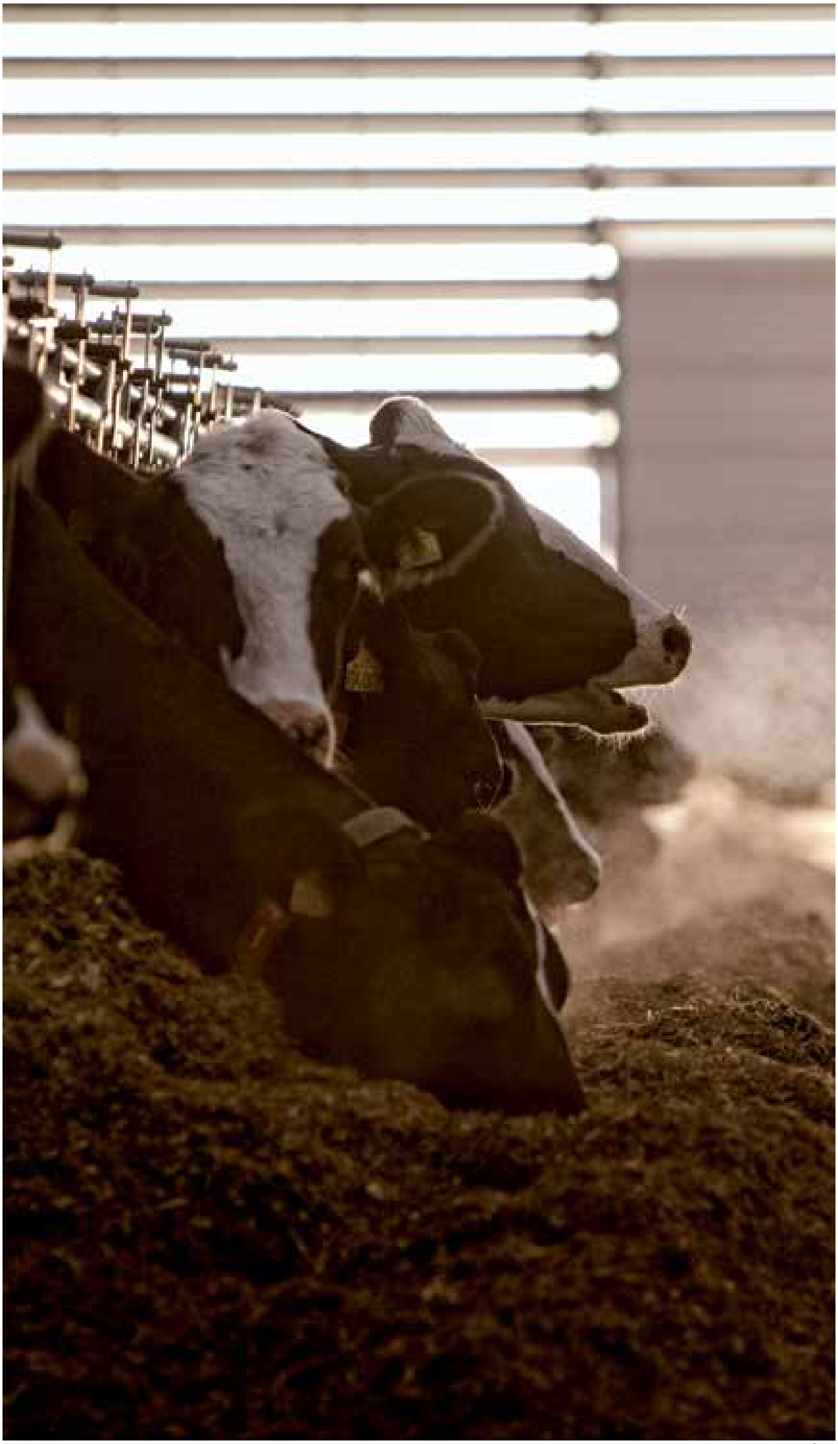

Fig. 1. Cattle at Vejlskovgård

Introduction

"A recent report by Defra reckoned that British food transport accounted for 30 billion vehicle kilometers in 2002 - 10 times further than a decade earlier and the equivalent of circumnavigating the globe 750.000 times" [Steel 2008:64].
The statement by Carolyn Steel describes a challenge for the growing cities, a challenge that has resulted in food with a lowered quality and freshness. This is a result of the food industry moving further away from the cities in order to constantly answer to the strict legislations, growing demands from consumers, and industrial production striving to make the growing productions more efficient in order to create a bigger profit.

This is a challenge that needs to be addressed in the future city development plan as an integrated part of the cities. But how will this affect the cities, and how can architecture aid the creation of a connection to the production of food?

In Denmark the first villages was based on new knowledge obtained about agriculture and farming, which led to people being able to get food without having to move around as hunters. This relation and connection to food was also a leading driver in the first modern cities, which allowed other occupations to evolve because of the food being sold on the weekly markets. At this time food was a natural part of the cityscape, but due to risk of infection caused by the animals, and the modern technologies that allowed freezing and storage, the food moved from the cities and into industrialised productions hidden from the consumers.

The concept of Urban Farming is potentially an answer to the challenge of bringing the food back to the cities, and generate knowledge and awareness of how our food are being produced today.

As a part of Aalborg Municipalities *Vision 2025*, they describe a future possibility of having industrialised livestock farms placed in new industrial areas of the city. This idea is described as a way to optimise mainly the transportation need by utilising the big cities connection to the national infrastructural system.
Urban Farming, and especially urban livestock farming, will raise questions of the perception by the consumers living in the city, whom for several years have been debating the lack of consideration for the environment and animal welfare practised in the modern industrialised farms.

This perception need to be challenged in order to create a better image for modern farming, and to re-establish a connection to rural areas and food productions.

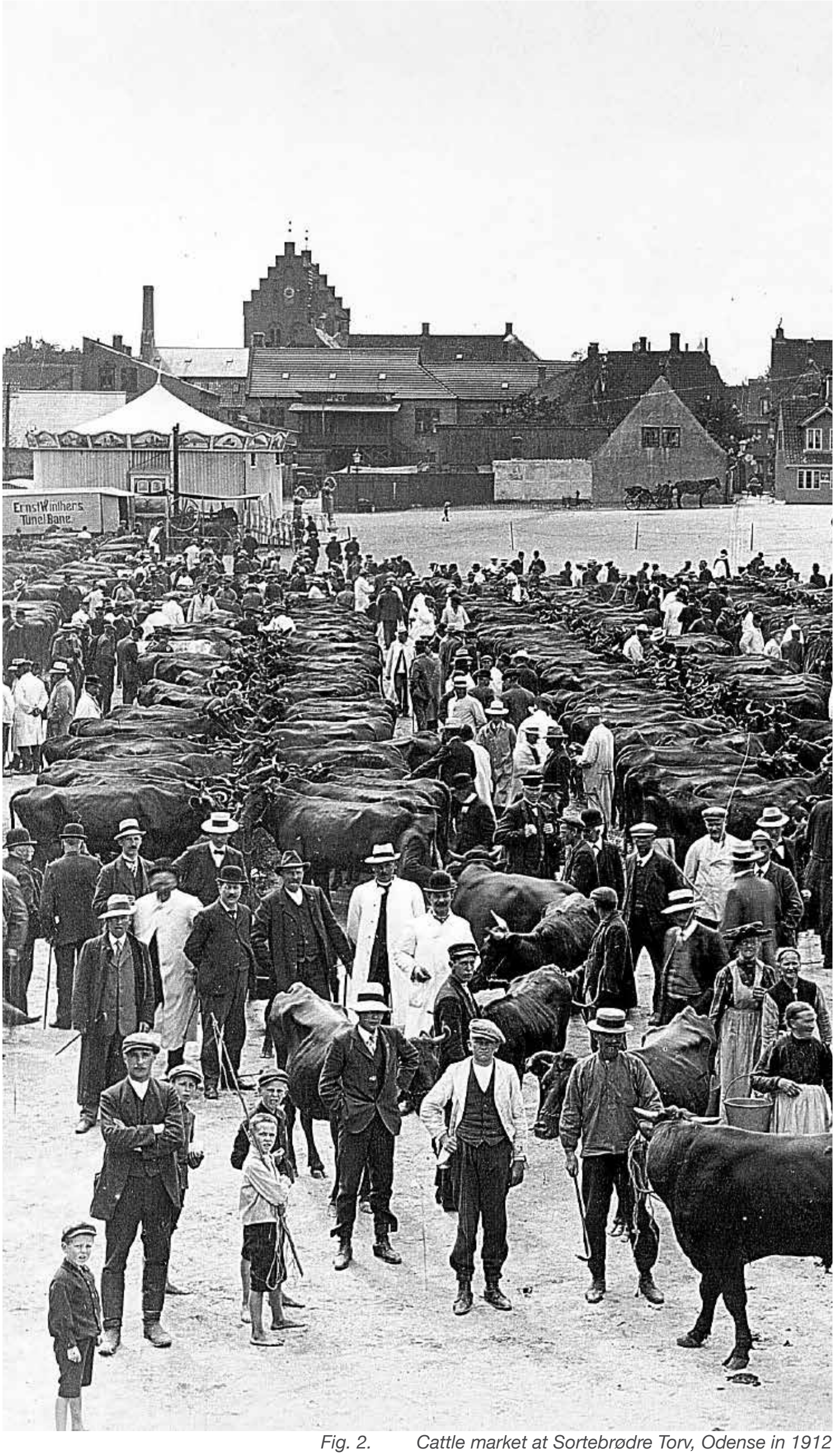

Fig. 2. Cattle market at Sortebrødre Torv, Odense in 1912

Objective and delimitation

In the introduction it is stated that "*The concept of Urban Farming is potentially an answer to the challenge of bringing the food back to the cities, and to generate knowledge and awareness of how our food today are being produced*."

This idea together with my personal background leads to a master thesis project that seeks to include the concept of urban farming with the traditional industrial cattle farms. The joining of these two concepts however requires understanding of how they have developed through history in order to understand how to create a closer connection between production and consumer. This is stated in the problem:

How can the concept of urban farming develop the industrial dairy farm into a platform of knowledge and experience, without compromising the modern production methods and complicating the daily routines of the farmer?

The subject described in the motivation will end in a concrete design proposal that with the aid of architecture solves the problem of re-establishing a closer connection between the production and consumer, with the theoretical framework established in the first part of the project.

In the project a problematic aspect arises, due to the current legislation regarding the environmental approvals required for agricultural buildings today. The legislation is made for the purpose of keeping down the disturbances caused by sound and smell that is a natural part of a dairy farm.

The project will because of the objective of creating a cattle farm placed in an urban area not follow all the demands needed to get an environmental approval, but will instead focus on creating a good internal environment for both cattle and farmer.

Fig. 3. Wheatfield - A Confrontation by Agnes Denes

Urban Agricultural Challenges

Urban Farming can be the solution to the rising challenge of getting fresh food into the constantly growing cities, where especially the utilisation of leftover spaces like facades, rooftops, and vacant lots in the city can be utilised for urban food production. The concept of Urban Farming however needs to be further developed into more efficient productions, and integrated into the overall city scheme to provide an actual contribution to the food consumption.
Urban Farming often revolves around production of vegetables and fruit, but investigations of the ideas, posed by Aalborg municipality, of creating new industrial areas in the city for industrialised livestock farms, will generate new possibilities of locally produced food. Urban livestock farms will however face distinct challenges with the critical perceptions existing by the urban inhabitants and with that the consumers.
In the following section, these challenges and potentials faced by an urban livestock farm will be investigated in order to obtain parameters that can influence solutions for a future closer connection between farmer and consumer.

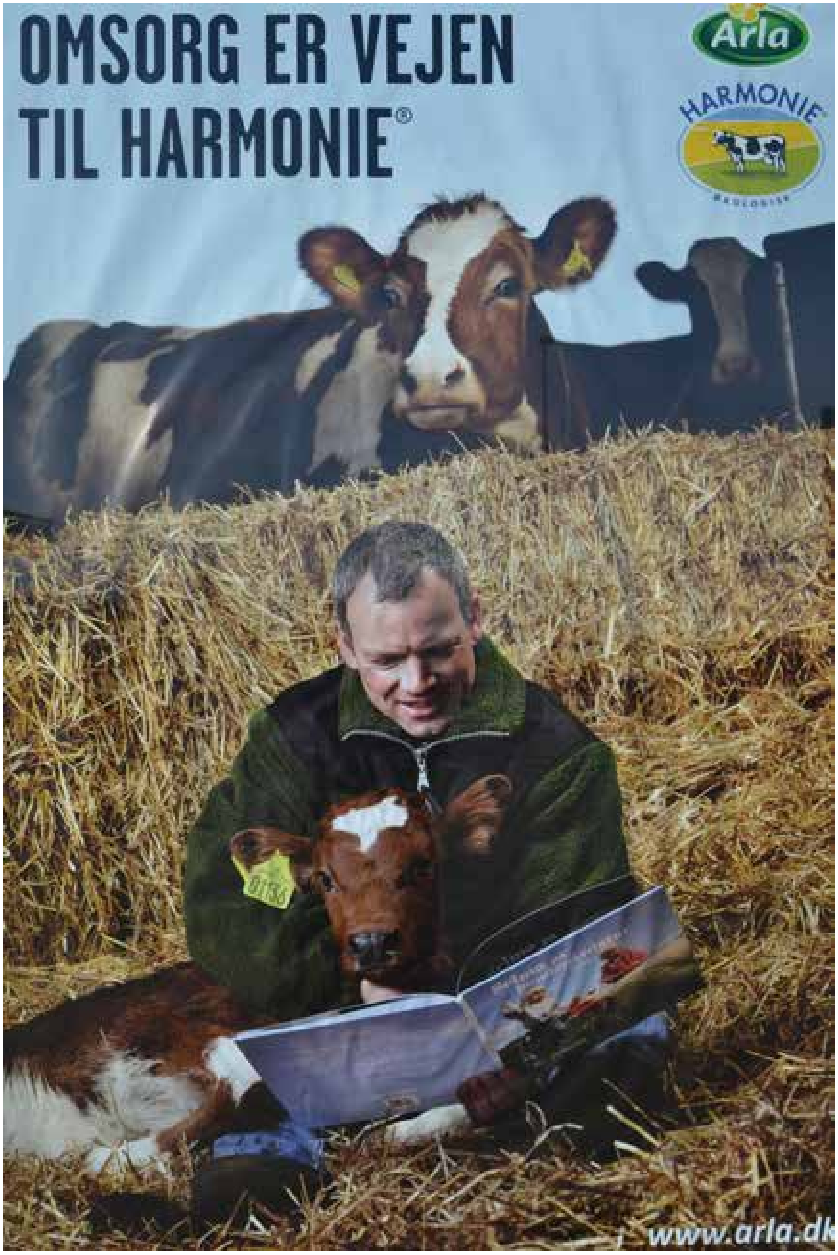

Fig. 4. Arla Harmonie campaign from 2010

Introduction

Food has ever since the first farmers started utilising the nature and domesticating cattle played an essential part in the development of the modern society, and the food and animals was until the 20th century still a part of the cityscape during the weekly markets. Because of the risk of infections spreading in the city, the animals disappeared from the city, and modern farming today are still moving even further away from the consumer, leaving the previous close connection to the city broken. As a result of this, consumers lack knowledge about how food is being produced and processed, and furthermore commercials tend to focus on associations between farm products and the romantic idea of the small family owned production. Both result in the consumers getting a distorted image of modern farming [Rentz-Petersen 2010].

With a growing interest on how we treat our nature and animal amongst the consumer, a conviction that industrial farms lack consideration for the environment and animal welfare is the result when seeing the actual modern production that looks nothing like the romantic commercials.

New campaigns by *Landbrug & Fødevare* are trying to address the problem through commercials with the slogan "*The future is not as bleak as it has been*". These are trying to create a new and better image for the farms by showing actual modern productions, and aim to give a better understanding of the challenges and potentials faced. This campaign should help farms out of the current target of critique and into a new future [Thalbitzer 2011].

Integrating Urban Farming concepts into the city development plans may be a way to address the challenges caused by both the consumers and farmers. The close integration between the production and consumption may generate more knowledge, and help restoring a more positive image of farming.

An urban livestock farm is however a further development of the concept of Urban Farming that not only face discussions of how to grow crop, but also a question of animal welfare that will be challenged when moving to an urban area. To address these challenges and potentials faced by an urban livestock farm, it is important to examine the history and the original connection to get a better understanding of what influence this previously had on society, and how this connection with the aid of Urban Farming can restore food and production of food as a part of the cityscape.

Society Based on Agriculture

Carolyn Steel [2008:7] states that *"without farmers and farming, cities would not exist"*, and in the concept of the Garden City created by Ebenezer Howard [1985:24] he states, *"…the combination of town and country is not only healthful, but economic"*, meaning that besides that fact that we have the possibility of having greener cities where fresh food is produced in the city, we can also save a lot of money and lower the CO_2 emission when not having to transport the food from produc-

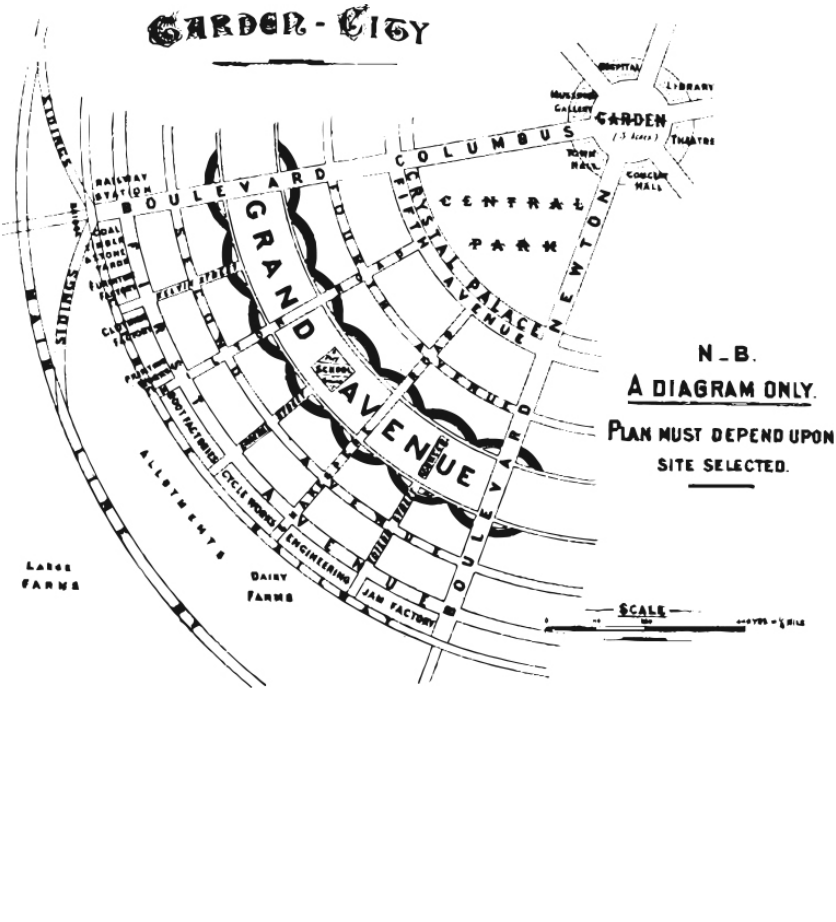

Fig. 5. Segment of the plan for Garden City

tion, to processing, to the store, and then to the table.
Howard describes the concept of the Garden City as a city with an area of 1000 acres, in the centre of a 6000 acres big area that should house approximately 30.000 inhabitants. The possibly circular city is facing a central park, which is surrounded by an arcade that allows the park to be an all year central green space in the city. All houses in the city each face the avenues that circulate around the central park and all the way to the city border where, an important aspect of the Garden City, the farm areas meets the city.
Because of this close connection, every farmer would have a market close to the production, and with that a secured economy and buyers for the produced food. At the same time, one of the main aspects of making these cities economical possible was that the food was produced right outside the city, resulting in low transport expenses, and because of that, cheaper food for the inhabitants of the city, which at the same time has a significantly positive effect on the freshness of food [Howard 1985].

But in reality *"we have never been more cut off from farms and farming…"* [Steel 2008:5] and *"by the time that it reaches us, our food has often travelled thousands of miles through airports and docksides, warehouses and factory kitchens, and been touched by dozens of unseen hands. Yet most of us live in ignorance of the effort it takes to feed us"* [Steel 2008:6].
This has however not always been the situation. The first known villages in Denmark from around 3000 B.C. was small gatherings of longhouses, that was placed in a bigger fenced area surrounded by crops. These small societies based on farming emerged after a realisation that hunting and fishing, which was the main way of getting food, was not sufficient or sustainable. Because of this the Danish people sought the knowledge about farming that already was already spreading through the southern parts of Europe [Bjørn 1988 (I)]. After the knowledge was obtained, space for the new fields for crops and animals was created by the farmers that tore and burnt down forest, leaving open fields ready for being cultivated [Brogaard et al. 1980].
Each of the longhouses from this era only housed a couple of cattle or pigs, but joined together in villages gave the possibility of housing approximately 70 animals and cultivate bigger areas of crops for both the animals and people of the village [Bjørn 1988 (I)].
In the first villages, the farming methods were inefficient, but during the Middle Age the farmers started developing new tools and methods in order to produce bigger amounts of food. The more efficient production led to farm societies having surplus production, which led to the opening of the first boroughs from where the crops, milk and meat could be traded. Most farmers were at this point renting the land used for farming from either the crown or the church, and because of this they needed to pay rent. This was, at the time before the introduction of a monetary system, done with a part of the surplus production, which was also being sold at the markets held in the boroughs.
Because of the markets, where fresh food was sold once or twice per week, modern society, with a more diverse choice of specialised occu-

pation apart from those in food production, arose. The markets were not only a way to get food into the city, but also a way in which the farmers could buy more processed goods needed in the daily work. The markets played because of that an important part in the development of both farming and city [Bjørn 1988 (I)].
At this time the food brought into the city was still shaping the city itself and affecting the way people lived. *"Roads were full of carts and wagons carrying vegetables and grain, rivers and docksides were packed with cargo ships and fishing boats, street and back yards were full of cows, pigs and chickens. Living in such a city, there could be no doubt as to where your food came from: it was all around you, snorting and steaming and getting in the way."* [Steel 2008:6]
In Denmark cattle trading was one of the dominating elements in the boroughs. In the centre of Aalborg, *Kvægtorvet*, which for over 100 years was the largest cattle markets in the Northern Europe, was open for auction and trades until 1997. The closing of this big market came as reaction to the first outbreak of mad cow disease in England in 1996, and with that a growing awareness of the possible risk of the dangerous diseases spreading from cattle to humans. But already during the 1970's trading levels fell because of centralised efficient abattoirs and the growing opportunity of transporting refrigerated meat into the city [Lyngby Poulsen 2012].

"…in an ideal world, one would not salt food or blast it with gas simply in order to preserve it. One would harvest or butcher it, cook it as necessary and put it in one's mouth - which, give or take a custom or two, is how rural communities have eaten for centuries" [Steel 2008:63]. The possibility of taking the locally produced food directly to the table, without the need of preservation, would result in *fresher* products, and with that higher food quality and healthier products. At the same time the production cost could be lowered significantly by removal of profit for middlemen and transportation cost from the final price.

Perception of Nature Change Consumer Experience
Carolyn Steel [2008:4-5] states that *"we have never spend less on food than we do now: food shopping accounted for just 10 per cent of our income in 2007, down from 23 per cent in 1980. Eighty per cent of our groceries are bought in supermarkets, and when we shop for food our choices are overwhelmingly influenced by cost, well ahead of taste, quality or healthiness."*
This is a result of a time period were the urban inhabitants lack information about freshness of food and the quality this brings along. If the farms had a more transparent approach to production and welcomed visitors in, a more precise image of the industrialised productions could be presented and more knowledge obtained. Åbent *Landbrug* is a yearly event that invites people into farms around Denmark to show the production methods and aims to generate knowledge about the farm and products made here. In 2013 more than 65.000 people visited the farms [Åbent Landbrug October 2013], this shows that there is an actu-

al interest for the modern food productions in Denmark, but this interest needs to be transformed into a bigger awareness of what we eat and how it is produced.
There are however still places to go for an experience when buying food, not as a necessity but merely as a luxury. *Torvehallerne* in Copenhagen is a food market that opened in 2011 and contains over 60 different stalls selling quality food and goods. The market is however often being criticised for the high prices and the fact that most stalls are only branches of already existing luxury shop, instead local farmers getting the possibility of selling their surplus production. This is resulting in food still being bought in the supermarkets instead of exploiting the possibility of supplying the city with fresh locally produced quality food.
The lack of food experience can be traced back to the industrialisation where it started disappearing from the streets, changing into a more industrialised supply to keep up with the growing demand.
As a part of this industrialisation in Europe, philosophers started describing the nature as mechanical [Dallmayr 2011]. René Descartes describes in his meditations that the body of a human and an animal is like a watch, but instead of being build by a watchmaker of cogwheels and weights, the body is created by god, build of bones and muscles. Humans however still have the ability to feel emotions and have a common sense. Basic abilities animals lack [Descartes 2002]. This mechanical view played a part in the start of industrialisation that from 1700 spread through Europe, and slowly changed the cities and how we lived in them. For rural inhabitants and farmers, this mechanical view only differed slightly from the utilitarian perception of nature that has existed from the time of the first farmers. They perceive the nature that can be useful in a production, as the beautiful nature. This perception however requires knowledge about fauna and flora in order to value the utilised nature [Schjerup Hansen 1989].
As a reaction to the industrialisation and urbanisation happening, a more romantic perception of nature emerged. Idealists led way, in romantic literature, to a union of spirit and nature, which led to a new romantic perception of nature [Dallmayr 2011]. Novalis considers in his writings nature to be independent and self-modifying, and cannot be seen as static but as a progression towards morality [Novalis 1997]. This perception led urban inhabitants to start seeking the nature being lost during the urbanisation, resulting in wealthy citizens buying big estates in rural areas to use as summer residences from where the untouched nature could be enjoyed as recreational areas [Schjerup Hansen 1989].
A functionalistic perception of nature developed from the romantic perception, but a division between work and pleasure was created and with that production and recreation. Even though gardens and gardening was seen as work, green areas in the city became essential, but merely as a view [Schjerup Hansen 1989].
Whilst the romantic perception was based on feelings and being in close connection to the nature, the functionalistic perception of nature describes a more distant relation to nature, and a relation based on the

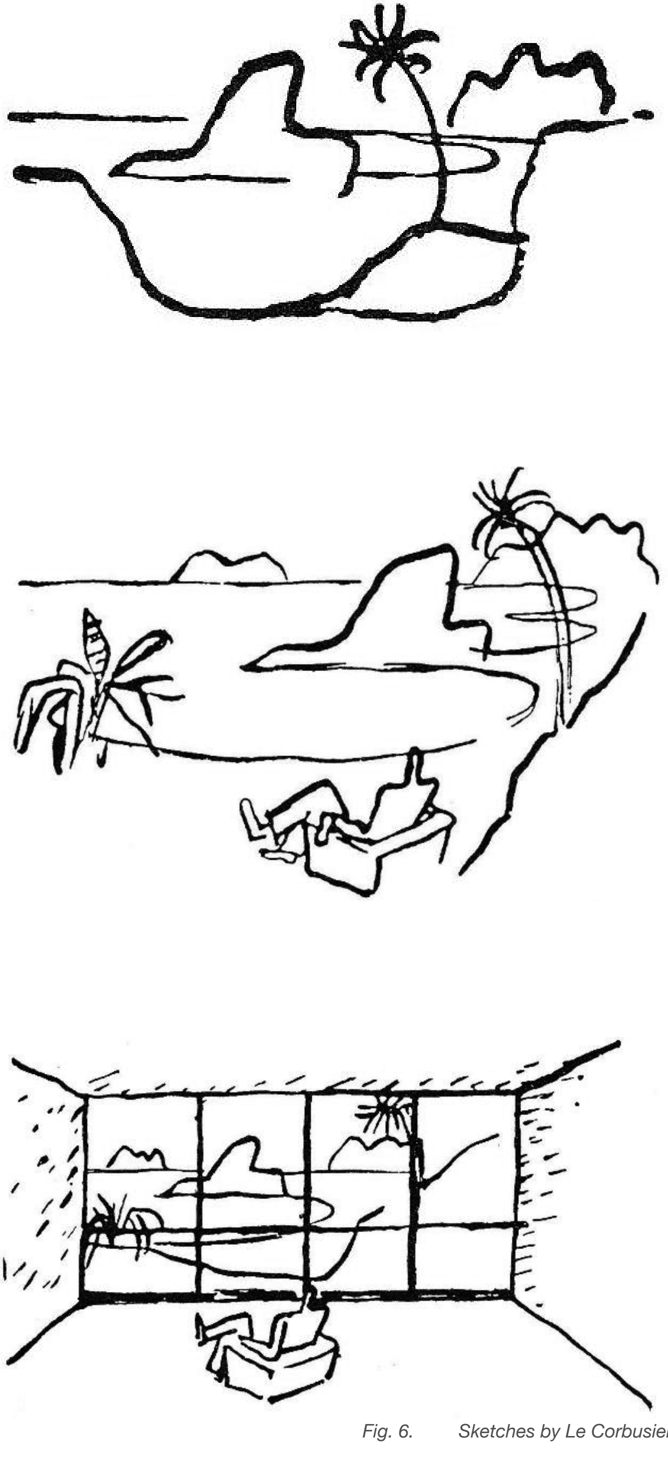

Fig. 6. Sketches by Le Corbusier

possibility of viewing the wild and untouched, without having to put an effort into it.
"Nature – it is the view over a landscape, compelling horizons, mounds, mountains, streams, rivers and the ocean", was the way Le Corbusier described nature, as something you merely view and not stay in [Le Corbusier 1945:40]. This perception had a big impact on how the big industrial cities were being planned. Green areas, parks, and gardens were introduced in the cityscape as essential part of gaining better health and recreation for the inhabitants [Schjerup Hansen 1989]. *"The pact with nature has been sealed! By means available to town planning it is possible to enter nature into the lease"* [Le Corbusier 1945:40].

Together with a new and growing understanding of the ecosystem and how humans and nature are connected, an organic perception of nature arose as correspond to the earlier utilisation of the nature. Where the functionalistic perception saw a distance between nature and humans, people now started arguing that whatever we as humans do affect the ecosystem, and with that the nature [Schjerup Hansen 1989].
With this new perception of the nature, more focus has again been drawn to farming and food production, which is often resulting in critique about lack of consideration for the environment and the nature. This is however happening after several years of segregation and therefore the consumer has very little knowledge of how the food going into the cities is actually produced. The current critique of the modern food production however still has a big impact on how we produce food because the urban inhabitants, being the consumers, pay for the products. Therefore, the consumers' experience of how food is being produced and processed is a big part of the debate about legislations for farms. Consumers' experience may however often be misguided, which for example can be seen in the results from a questionnaire, which showed that many consumers believe that organic eggs are brown. This is paradoxical since the poultry laying brown eggs also have a higher tendency of feather picking and cannibalism, which is a large problem in poultry farms [Alrøe et al. 2001].
The debate between consumer and farmer could potentially lead to an increase in the quality of the final products, but for it to matter a closer relation between the two needs to be established in order to create a *knowledge*-based debate.

Urban Agriculture

The concept of Urban Farming has the potentials of developing into a concept of integrating the production of food into the cityscape so that food in the future could be produced locally and close to the consumer. Moving the production closer to the consumer would result in a *fresher* product that need a minimum of preservation, no storing, and limited transportation are needed. This way we could exploit the potentials of letting the future cities evolve around the food productions in the same way the boroughs evolved and developed around the food.
Integrating food productions into the city will not only affect the health-

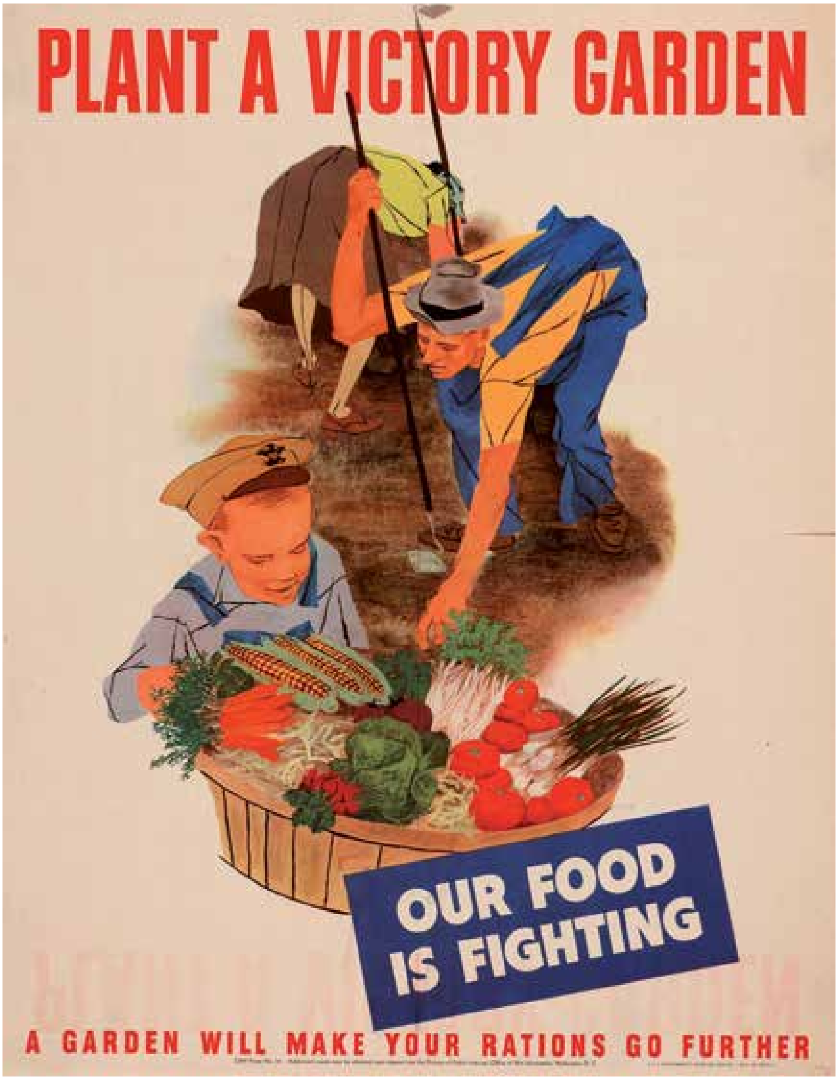

Fig. 7. Poster for Victory Gardens

iness of the urban inhabitants due to fresher food, but will also affect the urban inhabitants stance through the *knowledge* obtained by being surrounded of food and the production of it.
Urban Farming can traditionally be seen as *"… agriculture that happens to fall within or at the edge of a metropolitan area, perhaps adding its relationship to urban populations"* [Smit et al. 2001:1], and a production method that seeks to be space efficient by making use of vertical as well as horizontal spaces in the city, and using natural resources with consideration to the environment. There are a lot of different ways to integrate the production of food into the city, but 5 have proven particular effective as methods of farming in urban areas:
"Aquaculture - water crops produced in artificial water bodies, some under roofs;
Zero-grazing - production of livestock (poultry, rabbits, pigs, etc.) in cages and enclosed structures;
Plastic tunnels - production under plastic roofs that protect from weather and insects;
Hydroponics - production without soil; and
Drip irrigation - systems that use much less water per unit of production than trenches or overhead sprinklers" [Smit et al. 2001:13].
These systems are all ways to grow crops or produce livestock in cities. They are all in some way used today but often in small-scaled production, like tomatoes grown on the roof of a bicycle shed, and is therefore not a significant contributor to the overall food consumption [Løvenbalk Hansen 2013].
To utilise the systems in the best way, it is not only important to focus on producing more but also which kind of product that can be better suited for production in urban then rural environments. Products like mushroom that requires delicate handling and are highly perishable has a greater potential to grow in a Danish city than for example oranges that both need a more sunny climate and are easier transported because of the sturdy natural skin [Smit et al. 2001]. Having the food being produced visible for the consumer in the cityscape with the aid of Urban Farming, consumers would automatically generate knowledge about which products that are in season at specific times, and experience how to produce food and what it requires.
The experience of producing your own food in urban areas has gotten more attention lately, which can be seen in the rising number of food and greenery projects and communities in the bigger cities. In Copenhagen alone there are more than 40 different on-going projects that teach and let people be involved in producing their own food [Vores Omstilling October 2013].

The phenomenon Urban Farming is not a new thing, but instead an old concept that has been revived as a backlash to the negative attitude to rural farming and the methods being used. The concept of *Urban Farming* however started as a reaction to the food insecurity that existed in the low-income areas of the industrialised cities [Smit et al. 2001], and since that, "… *urban agriculture has played some role in ensuring a food supply for urban residents*" [Smit et al. 2001:5 in

Fig. 8. Birdview of Pig City

chapter 2].
Production in the big cities has always been a natural thing, but the first big boost to the amount of farming happening in the cities was seen during World War I. Municipalities urged with the concept of Victory Gardens production of home grown food to make a contribution to the food consumption. Furthermore, bigger corporations and companies followed with the goal of creating greener and self-sustaining cities in a period where product from outside the city could not be counted on [Smit et al. 2001]. A few of the Victory Gardens still exist today and function as community gardens.
In the big boroughs in Europe relics can be seen from where the big markets was happening, and it is clear how the city got shaped because of these [Steel 2008]. Before the modern infrastructural system was developed, food like milk and meat had to be produced and processed in the urban areas in connection with the big boroughs, to avoid food going bad before reaching the consumer [Steel 2008]. All animals therefore had to be transported alive into the city because of the lack of possibilities to keep meat fresh during transportation. Cattle, that where one of the biggest commodities, could by it self walk into the city. This however resulted in weight loss during the trips and therefore they had to be fed up in the adjoining cowsheds [Bjørn 1988]. In the late eighteenth-century, urban cattle farms in the central part of London housed approximately 8.500 cows to produce milk, which at this time already was recognized for its natural qualities [Steel 2008].

Modern Livestock farming

As a part of Aalborg municipalities *Vision 2025*, new industrialised zero-grazing livestock farms are proposed re-integrated into the city as a way to minimise the transportation costs. The urban livestock farms are commonly referring to pig or poultry farms because of the possibility of having an enclosed building without the need of grazing areas. Several projects have already been exploring the potential of new architecture for livestock farming to integrate the production into urban areas.
The project *Pig City,* which was developed for the competition *Fremtidens Landbrugsbyggeri,* explored the possibility of not only combining urban and rural functions, but also how to combine livestock, vegetable, and energy production in one facility that could be placed in urban areas. The proposal was based on an idea to utilise the energy produced by the pig: to use manure as fertilisation for the vegetables and in a biogas system. This would result in one production with 3 outputs, which could be integrated into, and supply a city.
Even though milk has been an important source of nutrition since the eighteenth century, dairy farms have not yet been tried implemented into the industrialised cities. Especially the legislations created after the outbreak of mad cow disease and the danger of infections spreading have made it almost impossible. Today milk is still an important part of our nutrition, and the general dietary guidelines say that a person in the age range between 4 and 75 should consume 500 grams of milk or other dairy products per day [Meyer et al. 2010], which for the inhabitants of

Aalborg is a total of approximately 53.500 kg of milk or dairy products each day [Aalborg Kommune 2013 2]. Integrating a cattle farm into an urban area could ensure the accessibility of fresh dairy products for the inhabitants without the need of transporting the milk hundreds of kilometres before reaching the stores.
Zero-grazing urban cattle farms will however face a distinct challenge in order to meet the current legislation for organic farming, which is a major topic in the discussion of modern cattle farming. In the organic farms in Denmark, cattle should be grazing outside for 150 days in the summer months per year on 0,5 ha per animal. This conflicts with the urban farming concept of being space efficient.
The legislation today may however be mainly controlled by the perception of the consumers of what good animal welfare is, even though this often does not correspond to what scientist argue [Alrøe et al. 2001]. Placing cattle farms in a closer connection to the urban areas and consumers will create more knowledge about the production, and instead of discussions about organic farming consumers could focus on the welfare of each individual animal.
Animal welfare should be one of the main aspects in modern cattle farming. However, there is still no clear definition of what good animal welfare is, but suggestions could be that *"the animals should feel well"*, *"the animal should function well"*, and *"the animal should lead a natural life"* [Alrøe et al. 2001:284].
That the animal should feel and function well is something most people can relate to, but the living of a natural life is one of the main parameters that differs between conventional and organic farming. The organic principles will argue that field grazing is part of the natural life and innate nature of the cattle. However, it can be questioned if the innate nature of cattle still to graze in the fields, since the modern cattle through evolution and breeding has adapted into the life in the stables.
In new non-organic farms, systems and solutions are being made to try to achieve a more natural behaviour and higher welfare for the cattle. *Landbrugets Forskningscenter* is making several experiments in Denmark trying to create better environments for the cattle inside the farms, both regarding health, welfare, and behaviour [LandTV 2013]. The test farms are making experiments with new deep litter areas to obtain more natural behaviour, new flooring types to ensure healthier legs, and new ventilation system to lower to emission of gasses; all challenges faced by the modern farms.

The environment in which the cattle are stalled has changed drastically since the domestication of the first cattle. When looking at the traditional longhouses from the Iron Age, the importance of the animals is clear, since they were living under the same roof as the people. The placement of the cattle was mainly practically because it was important to keep an eye on them, but it also served the side function of helping with the interior temperature of the longhouse [Bjørn 1988 (I): 275].
From the 17th century the farm buildings started changing drastically, and the 4-winged farm, which still can be found around Denmark, gave the opportunity of having the animals more separated from the living

areas. These buildings also had a lot of barn space for corn and fodder for the animals. During the 19th century the living area started moving away from the production buildings, which left more space for the growing farm buildings during the industrialisation. It also became normal to move the living areas even further away from the farm building, and with that leaving even more space to expand [Brogaard et al. 1980]. In the old farm buildings, the interior climate was often of a very low standard, and with the big productions, problems with humidity arose, which ended up in a rule saying rather low temperatures than high humidity [Bjørn 1988 (IV)].
This resulted in demands of bigger and more open buildings in order to create a better airflow. These new modern hall structures created new possibilities of replacing the traditional system where each cattle was stabled in a fixed position without the possibility of moving around. Instead new loose housing systems were created, that allowed the cattle to move freely around in either a deep litter system or with individual stalls. These new systems also included sections for milking, rest, fodder, gathering and exercise [Bjørn 1988 (IV)]. The new stable system was an improvement in order to secure healthier cattle and the efficiency of the farmer due to the fact that the cattle could walk to the milking section instead of the farmer moving around.
The small productions that earlier was normal has today been replaced with fewer big and efficient industrial productions that seek to optimise every process to create the highest possible revenue. In 2006 the farms in Denmark has an average of 95 cattle, in 2012 that number rose to 127, and it is expected to continue rising [Danmarks Statestik November 2013]. These big productions have started to place new buildings away from the existing building and the farmhouse, which is resulting in 60 million m2 leftover farm buildings all over Denmark [Rasmussen 2006]. These new buildings lie like big industrial structures in the open landscape with a big difference in scale to the context surrounding it. This is in contrast to the traditional manors where a close relation to the nature was created by building more into it [Rentz-Petersen 2010].

In 2007 Realdania held an architectural competition to explore the future agricultural buildings. One of the winners, Vejlskovgaard, is a conventional modern cattle farm where both changes to the functionality and aesthetics are big parts of the final result.
Even though the final result of the competition is build in a way that resembles the current building tradition, several small improvements are done to achieve the best possible interior environment for the cattle. The farm are because of the facade solutions and functional solutions both filled with natural light and fresh air, which has proved to have a positive effect on the amount of milk, with an increase in the production by 10% [Realdania 2012].
As a part of the stable, consumers are invited in to the farm to buy freshly produced milk, and with that are getting to see a modern cattle farm. This is done with a system that treats and refines the milk, that normally would be done in a dairy but with aid of this system, the fresh milk can be sold directly to the consumers.

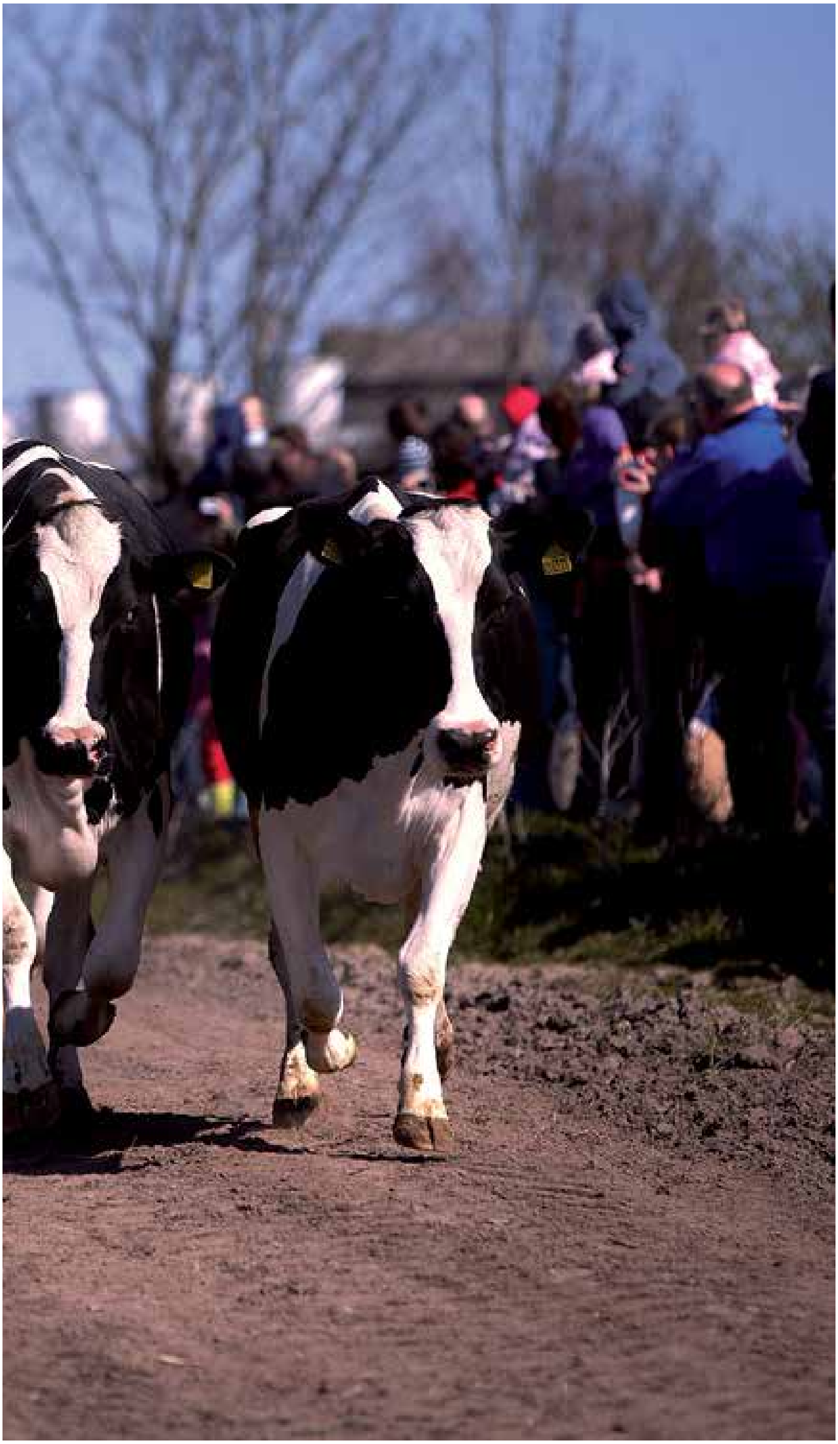

Fig. 9. Visiting people watching the cattle on ecoday

Placing a cattle farm in the city will create the possibility of integrating a similar system that can create a direct connection to the consumers, and let them buy milk fresh from the farm. This connection would also let the urban inhabitant have a first hand experience of the livestock and production of food, which would create more knowledge and understanding of the quality in the freshly produced food.

Conclusion

"One of the reasons it can be hard to appreciate the effort it takes to feed a modern city is the sheer invisibility of the process" [Steel 2008:67]. This problem can with the development of the urban farming concepts be addressed by re-establishing the connection between producer and consumer that have been lost during the industrialisation.
An urban cattle farm can be an aspect to further develop in the future city development plans, but the issues discussed in the above sections has to be addressed if the productions are to have a successful connection to the city. Aalborg Municipality defined the potential of urban livestock farms as a mean to optimise the transport needed in food productions [Aalborg Kommune 2013], but urban cattle farms can prove to be more than that.

For it to be integrated, three main parameters need to be included in a design in order to address the challenges faced and described in the sections above.

Transparency
The urban placement of a cattle farm will not necessarily result in more awareness of the food being produced. If the cattle and food production should be an actual part of the cityscape the production need to be transparent to the surroundings, both functionally and aesthetically.

Experience
In order to further develop the connection to the city from the point of being visible in the cityscape, the consumers need to get a better understanding and obtain knowledge about the production, which can only be done by experiencing it.

Direct connection
Producing food locally has limited potential if the food still needs to be transported elsewhere for processing before ending up in a store. Creating an urban cattle farm therefore need to serve the inhabitants of the city directly to ensure a fresh product, which at the same time will have a low production cost due to the limited transportation need.

Successfully joining the three parameters will create the possibility of adding a closer connection between the producer and consumer, which can lead to a mutual understand of the requirements and challenges from both sides of the final product.

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Fig. 10. *Building the structure at Vejlskovgård*

Optimising Agricultural Architecture

Today the agricultural buildings are often built with economy, rather than architectural quality, as the main parameter. This leads to the building of big industrial halls only consisting of a series of steel frames covered with a roof to shelter from the climate.
The buildings, which are created with no ornamentation or superfluous elements, has a close resemblance to the tectonic architecture defined in the Vitruvian triangle by firmitas, utilitas and venustas; structure, function and aesthetics.
Working with these tectonic parameters in an architectural process may often be ineffective with analogue tools. Instead potentials of analysing the parameters, that can be given a numerical value, with the use of computational tools, is investigated in order to create a digital tectonic design process, and a final design based on performance criteria.

Fig. 11. The primitive hut

Introduction

The agricultural buildings that we know today is a result of a standardisation process that has led to the cheapest possible square meter prize, but still meeting the demands for air change, light, and space for the animals.

These big buildings only consist of the absolute necessary, and most of the time no consideration is being made for detailing, quality of materials, or other aesthetic qualities. The basic elements can however be compared to the primitive hut described in Marc-Antoine Laugiers *An essay on architecture*, that for many is an essential part of the definition of tectonic architecture. Agricultural architecture however needs to be discussed in a broader tectonic understanding in order to define how to develop it into architectural quality.

Aspects of the tectonic and agricultural architecture can be evaluated with a numerical value, such as light intake and structural system, which can be included in a computational design process. This will create a performance aided design process where every parameter can be used to facilitate the conceptual development of an architectural scheme.

This method needs to be tested in order to evaluate it as a driver in a conceptual architectural process.

Agricultural Tectonics

New modern agricultural buildings focus on having the lowest possible square meter price in order to balance the very slim economical frame. This leads to a functionalistic plan distribution to create efficient interior spaces and good interior environment for the cattle. *"The plan proceeds from within to without; the exterior is the result of an interior. The elements of architecture are light and shade, walls and space"* [Le Corbusier 1986:177].

The evolution of the agricultural buildings can be compared to the making of human houses following basic instinct, described by Marc-Antoine Laugier in *An essay on architecture*. To need for protection from the sun leads to seeking the shade created by the trees, the rain leads to hiding in caves, and the need for clean and fresh air leads to the building of the primitive hut. This is containing only the basic elements in architecture; the column, the entablature, and the pediment. *"If each of these three parts are found placed in the situation and with the form which is necessary for it, there will be nothing to add; for the work is perfectly done"* [Laugier 1755:13].

These basic architectural elements combined with legislation about basic airflow create the image of the modern agricultural building, which typically is a building created by only the most necessary structural elements and a roof to provide sheltering from the climate. In that sense the farm buildings known today can be compared with what Laugier described; *"… there will be nothing to add"* [Laugier 1755:13].

Agricultural buildings today is however more an engineering task than architectural visions. When trying to obtain the lowest possible price per square meter, mathematical calculations and table values design the

Fig. 12. Therme Vals by Peter Zumthor

final building. *"Our engineers produce architecture, for they employ a mathematical calculation which derives from natural law, and their works give us the feeling of harmony"* [Le Corbusier 1986:15]. Even though Le Corbusier describes the use of mathematical calculations as a way to create harmony, the modern agricultural buildings lack the quality and detailing that can change the buildings from being merely steel frames covered by a roof, to actual tectonic buildings with architectural quality.
The calculation based architecture ensure that the buildings do not fall when being exposed to the natural laws, but when only calculating and not detailing, the building itself fails as architecture. *"The art of detailing is really the joining of materials, elements, components, and building parts in a functional and aesthetic manner"* [Frascari 1984:2]. The agricultural buildings, which are defined by the tight economy, are based on and created by standard elements in order to keep building expenses to the minimum. *"Standards are a matter of logic, analysis and minute study: they are based on a problem which has been well stated"* [Le Corbusier 1986:131]. But in order to use the standard elements in the art of detailing and obtain architectural quality, *"we must aim at the fixing of standards in order to face the problem of perfection"* [Le Corbusier 1986:131].
Architectural quality is to Peter Zumthor *"… when a building manages to move me"* [Zumthor 2006:11], which is done by the atmosphere created by the architecture through emotions.
One of the elements Zumthor describes as a means of creating atmosphere is *"the light on things"* [Zumthor 2006:57]. Using daylight to create light and shadow can give an almost spiritual quality to a room, but is also a way to shape, and as Le Corbusier describes it as *"architecture is the masterly, correct and magnificent play of masses brought together in light"* [Le Corbusier 1986:29].
The light has a big impact on how we perceive things, and when having trouble seeing them we demand more light, even though the quality of light is more important than the amount [Rasmussen 1989].
Good atmosphere for cattle may differ from what is wanted by humans, because cattle demands very little contrast in the light in order to function naturally. Studies have shown, that while humans are good at adapting their eyes to light levels, and therefore have the ability to enjoy contrasts in light, cattle do not have that skills and therefore requires a more even light level, both during the whole stable area, but also a constant light level in several hours during the day.

Taking a tectonic approach to the designing of new agricultural architecture requires an understanding and ability to combine the elements of functional efficiency derived from the plan, architectural quality in the work with atmosphere and detailing of elements, and structural stability. Or as Vitruvius describes it; a combination of structure *(Firmitas)*, functionality *(Utilitas)*, and aesthetics *(Venustas)*.
This approach will help ensuring not only a heightened quality of the buildings, but also a better environment for the cattle living in the new buildings, and when analysing buildings in relation to the tectonic understand, *functionality*, *structure,* and *aesthetics* will be the main parameters.

Fig. 13. Vejlskovgård - exterior

Fig. 14. Vejlskovgård - connection to interior

Vejlskovgård

2012 by LUMO Arkitekter

Vejlskovgård is one of the winning projects in the competition *Fremtidens Landbrugsbyggeri* (Future Agriculture Construction), held in 2007 by Realdania. The project is a modern farm designed to accommodate 600 cattle and is built on greenfield land, away from the existing farm buildings.

Functionality
The new building was made with maximum attention to the animal welfare and the health of the animals, which resulted in a rational and efficient plan solution and an environment with a lot of fresh air and light. The centre of the cross-shaped plan works as distribution area and from here the farmer has maximum view to entire production and the different functions in the farm. From here the building spreads into the 4 wings, where the two longest contain the stall and milking facilities, which with a flexible layout, allows the cattle to move freely around.
In the two smaller wings the farmer has most of his daily routine. These contain office, milk processing, fodder barn and fodder preparation areas. The administration and milk handling facilities are placed in an inserted box in the open space, in order to create a cleaner and more quite area. In this box guests are invited in, as freshly produced milk are being sold from here. The roof of the box also works as viewpoint for guest to see the production without actually going into it.

Structure
In the modern farms the structural system is a significant element in the space due to the very open buildings, and Vejlskovgård is no exception. The series of steel frames with a span of 36 meters creates an open space without the need of support to interrupt the view around the building. The standardised steel frames are combined with more complex elements like the garrets to distort this traditional modular building system.
In the original design proposal, a canvas membrane roof was proposed; this would have resulted in a lighter roof that would have given the possibility of having a smaller cross section of the steel frame. This could have given a more elegant structure.

Aesthetics
Being a project built on greenfield land, the placement of the mass has been done in relation with the context. In order to blend into the nature and the natural contours the building is placed in a small valley, which results in not being able to see the building before actually arriving.
The close connection to the nature is also present from inside the building, where the open facades invites nature inside and create views to the nature, spaces filled with light, and fresh air, which is ideal environment for the cattle.
The big garrets, that all the way around the building helps letting even more light in and help achieving a high air change rate, breaks down the big volume and create an expression that joins both vertical and horizontal elements in the mass. They are created with a small differentiation between them, resulting in a distortion of the otherwise subsequently building system.

Fig. 15. Gut Garkau - cowshed exterior

Fig. 16. Gut Garkau - cowshed exterior

Gut Garkau

1922-1926 by Hugo Häring

Gut Garkau, that by many is called Hugo Härings masterpiece, lies just north of Lübeck and was working as a cowshed until the early 1960s. The projects was created for a progressive farmer who was striving to utilise the latest techniques, and therefore hired Häring with a very strict functional programme that needed to be solved [Blundell Jones 1999].

Functionality
The project created by Hugo Häring is more than just a cowshed. It is consisting of four main buildings, the cowshed, the calf-house, the barn, and the farmhouse. The main production buildings are placed together, surrounding a farmyard from where distribution to the different functions happen. The general layout can be compared with the more traditional 4-winged farm, but in this case being split up.
The pear-shaped layout of the cowshed was created because Hugo Häring saw this shape as the must suitable way of arranging 42 cows which allows easy access to the feeding floor, view to the individual animals because of the curve, and space between animals to minimise the infection caused by inhalation of contaminated air [Blundell Jones 1999]. Like other older cattle farms, the cows are tied in one place, making it easier for the farmer to milk and feed but may not give the possibility of natural behaviour for the cows.
On the second floor of the cowshed, a hayloft is placed in order to easily get hay for bedding and fodder to the cattle.

Structure
Because of the need to get as much light and fresh air into the cowshed as possible, Häring created horizontal windows all the way around the exterior wall, and because of this the exterior walls could not be load bearing. The columns follow the pear-shaped layout of the stalls and define the outline of the feeding floor.
In the barn a more complex structural system is created in order to avoid columns in the middle of the high room. The span is achieved with the use of only short interlocking timber lamellas, which with the aid of the gothic-like arch section of the roof create a spacious area for storage of fodder and tools.

Aesthetics
Härings work with detailing the whole scheme has resulted in coherence from detail to the overall expression. Even though the different buildings are placed with space between and in different shapes, there is a clear coherence between the buildings as a joined scheme, but also with the nature surrounding them, with the use and detailing of the exterior cladding.
The natural bricks and the untreated timber help the buildings fade into the nature even though it is not trying to hide away with the aid of topology.
The joints between the brick and vertical timber cladding on the facade of the cowshed elegantly divides the hayloft placed on top of the cowshed with the rest of the building, and thereby breaking up the otherwise massive volume. Also on the barn the detailed use of material can be seen on the curved brick wall, where each brick gets rotated vertically to create the fairly small radius curved shape.

Fig. 17. Cow Shed - exterior

Fig. 18. Cow Shed - interior

Cow Shed

2005 by Localarchiteture

Build in the surroundings of the Swiss nature; Localarchitecture created a cowshed that focus on natural materials, authenticity, quality, and respect for the nature.

Functionality
The cowshed is a free-stall barn for 30 cows, with a hayloft placed on the mezzanine level, which works as extension to an already existing farm building.
With the strict legislation for organic productions, a key aspect in this new design was to fit the standards of an organic farm without going over budget. This is achieved with natural ventilation system in the stable created by the open facades that allow airflow through the building leaving fresh air for the cattle. Furthermore, in order to meet the strict budget, local timber was used for the framing to keep transportation costs to a minimum.

Structure
The structural system is consisting of a series of timber frames placed like contour lines through the building mass. With the aid of the simple structural system, a dynamic roof shape is made that resembles the natural curvature surrounding the farm.
In the two longitudinal facades, the frames are the main element, creating an elegant facade that is open to the surroundings and creates visual connection to the nature.

Aesthetics
Whilst the structure creates the expression of the two longitudinal facades, the end facades is closed off with a timber cladding that, because of the monolithic shape, look more as a solid block of wood carved with openings to get inside. Entering the mass, the timber material surrounds you and creates a warm interior space that, with the aid of the open facades, is filled with light and air.
All the detailing is done with the precision and quality known in Swiss architecture and only leaves visible joints on every second beam. This adds to the overall expression of the building feeling like one massive timber block.

Digital Tectonics

When working with a holistic design approach based on the values deducted from the tectonic architecture, a challenge is faced trying to balance the possible complex hierarchies between parameters.
Trying to balance the parameters in a traditionally analogue design process requires either a well-developed understanding of basic principles of structure, light, acoustics, and other technical elements, or a constant demand to test and calculate the designs. Both these methods can slow a design process and can result in the need of testing several concepts before detailing a project.
Taking this technical approach to architecture can lead to a process that sequentially develop form, structure and material, instead of the formal concept firstly being developed by an architect and subsequently integrated with material and structural analysis. Creating technical relationships in the development of architecture is a way to logically develop parts of the whole.
A necessity in the development of digital tectonics is the creation of a part-to-whole relationship between technical and architectural objectives where a combination of mathematical and geometrical logics could aid the development of each element in the architecture [Oxman et al. 2010].
The architectural engineering creates new collaboration models between architect and engineer and results in processes where structural patterns, configurations or any other structural order can be explored in an architectural process. This results in the technical parameters being applied to the conceptual design and developed sequentially and making sure that the structure, energy calculations, acoustical qualities, etc. is not add-ons but as a part of a logical developed performance based design.
Structuring a process of exploring configurations in relation to engineering and architectural objectives, can be done with digital models and scripting as a media to handle the complex calculations and models, that in an analogue design approach would prove a challenge to work with.
"Scripting programs are the design media of structuring. In digital tectonics, scripting is used to produce geometric representations within the topology of the pattern or structure. Digital crafting is the ability to produce code that operates on the basis of such tectonic design models" [Oxman et al. 2010:20].

Parametric tools like *Grasshopper,* a visual scripting plugin for *Rhinoceros,* in combination with software like finite element methods solvers can create digital environments and parametric models that can be used as part of a concept development [Grasshopper]. Scripting combined with analysis software can create the possibility of sequentially solve simulations with the development of a formal expression. For instance can a grid-shell roof be investigated in relation to solar radiation on each face for photovoltaic panels and at the same time making sure of the smallest possible deflection of the structure.

In projects like the Astana National Library by BIG, the skin of the building is a result of a complex relation between form, structure, and light developed around the architectural concept of a Möbius Strip.

Looking at agricultural buildings like the *Vejlskovgaard* by *LUMO arkitekter*, it can be seen that the overall shape of the building is changed from the merely serial placement of steel frames into a more complex shape that take the light and air exchange in the stable into account. The complex relation in agricultural architecture between structure, light, air exchange, and space demands that all are objectives needed solved in order to sufficiently create an interior space that meets the requirements. These objectives can just like shading devices in the Astana National Library be part of a parametric process to combine the engineering and architectural objectives.

This complex relation between parameters can be developed into a process of optimising in relation to one of more objectives. In architecture the process of optimisation may not be the most favoured way of developing a design, because it removes some of the decision-making away from the architect and to algorithms. Structuring the architectural design in a parametric system may however give the possibility of adding boundary conditions that will ensure that the exploration of a design is only done within the framework of the architectural concept being developed before trying to optimise shape or technical problems.

Multi-Objective Optimisation

In a digital process with the use of measurable numerical values, optimisation processes can be used to achieve the best possible solution to problems with one objective. This would create the possibility of solving challenges like obtaining the best possible light levels in a room, smallest amount of deflection, or other numerical challenges. The purpose of finding an extreme solution, either maximum or minimum value, to a problem is coursed by the need of designing the best possible interior space, best structural principle, minimum fabrication cost or others. In basic math, differential calculations can be used to find extreme solutions to functions, but for more complex problems algorithms are used to search the decision space for the best possible solutions.

When an optimization problem involves more than one objective function, the task of finding one or more optimum solutions is known as multi-objective optimization [Deb 2009:1], and most problems in the real trying to search and optimise problems will naturally involve several objectives.

When in a single-objective optimisation process, there can be found one optimal solution, in a multi-objective optimisation problem, an extreme value cannot be found without compromising other objectives.

To explain the method, the problem of buying a car can be used as example to show how solutions compromise the objectives. Cars can be bought in several prices ranging from around 70.000 kr. to 1.000.000 kr. and if seeing the two extremes as solutions in a single-objective optimisation problem, we would only drive the cheapest model. This decision is however not a single-objective solution because of the fact that the cheaper car most likely is less comfortable than the more expensive model. With that realisation, we now have to compromise either money or comfort in order to buy the optimal car. Several solutions between the two extremes are also available, but every solution comes with a compromise in one or both objectives [Deb 2009].

The set of trade-off solution can be divided into dominated and non-dominated solutions. The set of dominated solution is a list of trade-off solutions that by one or more of the other solution is less optimised in all the objectives. The non-dominated set of solutions is however the once where none of the other solutions is more optimised in any of the objectives. The set of non-dominated solutions create the pareto front on where all the feasible trade-off solutions are placed.

"Now comes the big question. With all of these trade-off solutions in mind, can one say which solution is the best with respect to both objectives? The irony is that none of these trade-off solutions is the best with respect to both objectives" [Deb 2009:4].

When knowing the possible solutions of trade-offs between cost and comfort available on the market, then comes the question of which car to buy? The answer to that involves several considerations that are higher-level and non-technical, qualitative and based on experience. This could be consideration of number of passengers, fuel consumption and in which conditions the car is often driven.

The higher-level information can be included into the process two ways, which will result in two different methods of solving a multi-objective optimisation problem.
The typical multi-objective optimisation process solves the functions and results in multiple non-dominated trade-off solutions that all reaches the requirement, but without one optimal solution. The higher-level information will then help define the best solution to the problem from the list of possible solutions.
Methods to translate complex multi-objective optimisation problems into a process resulting in one optimal solution can be done by adding a weight vector to the objectives resulting in a scale between them. This can only be done with knowledge of the possible trade-off solutions, and requires therefore more analysis of the problem trying to be solved. Doing this will result in one result relative to the weight between the objectives put up before the optimisation, and changing the weight vector will also result in change of the optimal solution. This method can also be called a *"preference-based multi objective optimisation"* [Deb 2009: 6], even though the actual problem is transformed into a single-objective optimisation problem.

Preference-based and Trade-off Problem Solutions

To illustrate the difference between the two methods, a problem of solving the cross-section and length of a simple cantilevered beam, in relation to the weight and deflection, can be used as an example. Constraints for the length (200 mm – 1200 mm) and the cross-section (10 mm – 50 mm), with the only demand being that the deflection of the beam cannot be bigger than 5 mm. As a load on the simple beam is chosen a point load at the tip of the beam on 1 kN. This problem can be described like the following:

Minimize $f_1(x)$	Deflection
Minimize $f_2(x)$	Weight
Subject to	$f_1(x) \leq \delta_{max}$
	$200 \text{ mm} \leq l \leq 1200 \text{ mm}$
	$10 \text{ mm} \leq d \leq 50 \text{ mm}$

$\delta_{max} = 5$ mm
P = 1 kN

Solving this problem with the two different methods described above can result in two different results: a set of non-dominated trade-off solutions or one optimal solution.
Solving a simple deflection function and calculating weight can be done with formulas, but in order to work with a parametric design with a bigger complexity, the plugin Grasshopper for Rhinoceros is chosen as base for the calculations, the FEM plugin Karamba is chosen to solve the structural calculations, whilst Octopus and Galapagos handles the optimisation algorithms.
In Fig. 20 the pareto front based on the non-dominated trade-off solutions can be seen. These solutions all meet the requirements and have no other trade-off solution that is better in both objectives. Therefore

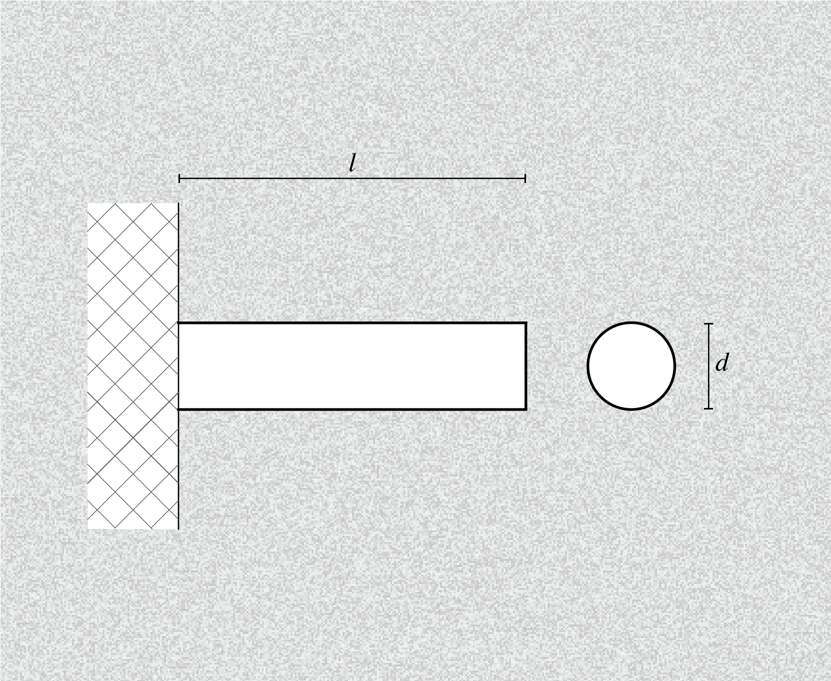

Fig. 19. Cantilevered Beam

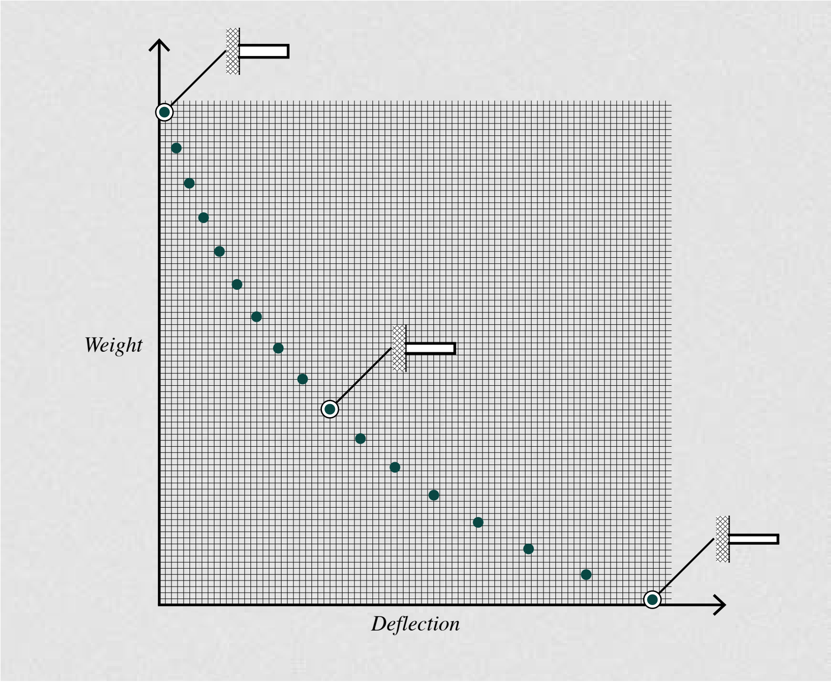

Fig. 20. Pareto front of trade-off solutions

there can now be chosen the best beam design with the help of higher-level information that in this case can be design choice, transportation costs, productions cost, importance of the two objectives, or other. When solving the problem with the higher-level information already being implemented in the algorithm, the objectives needs to be weighted in relation to each other. Different solutions will occur when changing the weight-vector, but the final result will in this method be less based on personal preferences because the algorithm finds one optimal solution instead of a set of trade-off solutions. Doing this will with the aid of different weight-vectors result in single-objective solutions that all in a true multi-objective problem would be possible trade-off solutions.

Using the method of multi-objective optimisation in an architectural conceptual phase can aid the design in several different processes. The method can, as soon as the basic ideas for the design is created, aid in selecting which direction to push the design in order to achieve the best possible technical solutions in the constant change of the design. It can however also aid in the final changes of the design where a few parameters can be changed in order to significantly improve technical or other numerical objectives. In the following section multi-objective optimisation is tested in an architectural design phase to create the best possible shape of a roof in order to optimise light, deflection and acoustics.

Fig. 21. Utzon Center

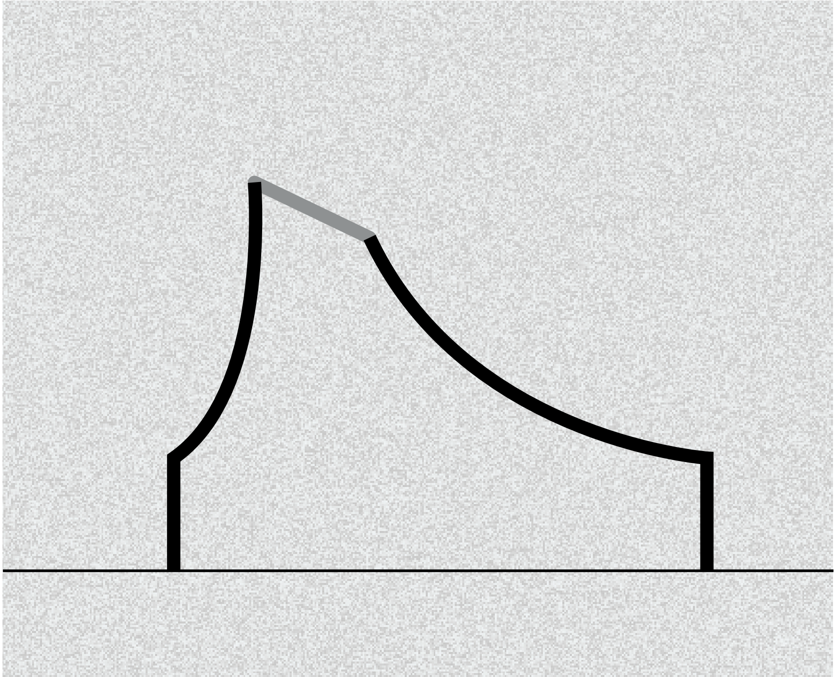

Fig. 22. Profile of Utzon Center roof

Multi-Objective Optimisation in Architectural Concept Development

The Utzon Center on the harbour front in Aalborg was the last project by the Danish architect Jørn Utzon and was opened in 2008. The design of the Utzon Center has a clear reference to ship design, that was great influence to Jørn Utzon growing up, and the big roof structures is placed like big sails along the fjord.

The architectural concept developed by Jørn Utzon is chosen to work as case study for the testing of the multi-objective optimisation method in the development of an architecture project. The auditorium creates with its convex roof shape the idea that it was done with a focus on having the best possible acoustic environment and best distribution of light in the room.

A parametric model of the auditorium and roof is created, and boundary conditions have been created in order to get as close to the actual architectural concept before trying to optimise the shape in relation to acoustic, structure, and light without compromising the main design concept.

In the parametric version of the auditorium, the room is simplified in order to ensure faster calculation time. Therefore the model is an extruded version of the profile curve (Fig. 22) that defines the shape of the roof. Windows in the base of the auditorium is removed in order to ensure that the window in top of the profile curve has the biggest possible effect on the interior space.

A successful auditorium has demands of both light level (both high general level, and distribution in the room), acoustics, and like everything else structure. Therefore a system is created to test for all these parameters where light is calculated in DIVA for Grasshopper, acoustics are calculated with Sabines Formula and raytracing, and structure is calculated in Karamba. Optimisation is for single-objectives done in Galapagos, and Octopus is used for multi-objective.

Parameters that in the calculation can be changed, and the limits are:

Height North	4000 – 12000 mm
Height South	“Height North” + -1000 – 1000 mm
Top Width	100 – 4000 mm
Top Offset	0 – 10000 mm
Amplitude North	
Amplitude South	

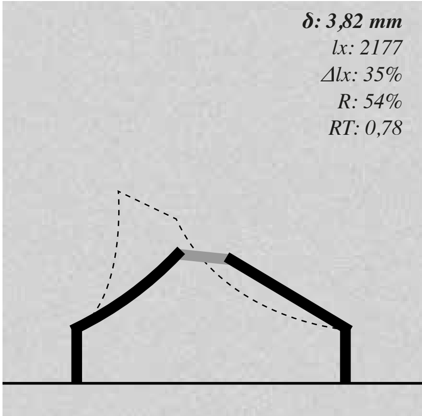

Fig. 23. Optimal: Deflection

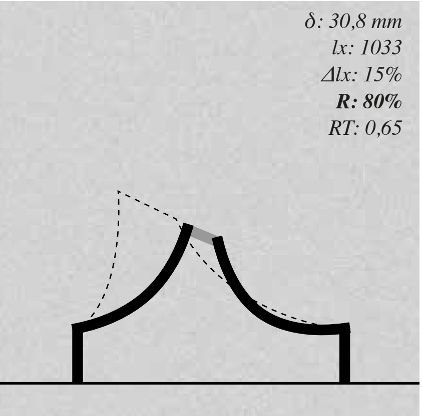

Fig. 24. Optimal: Acoustics

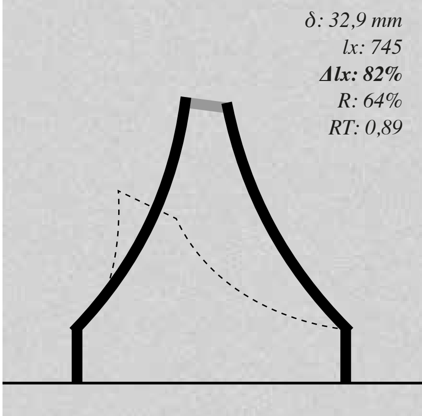

Fig. 25. Optimal: Distributed light

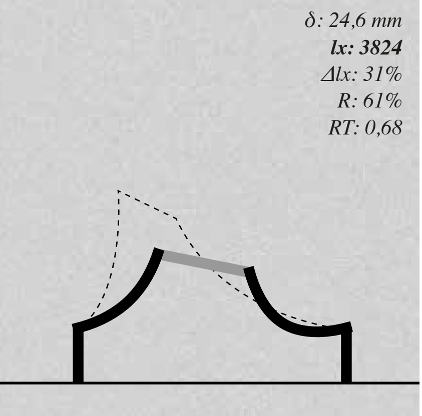

Fig. 26. Optimal: Avarage light

Single-objective Solutions

As a point of departure, the profile is tried optimised as a single-objective problem in order to understand how the different objective are trying to effect the overall shape, before starting complex multi-objective calculations.

The objectives all the solutions are tested for are

δ	Deflection	Minimise
lx	Light level	Maximise
Δ lx	Lowest compared to highest lux	Maximise
R	Sound rays hitting audience plane	Maximise
RT	Reverberation time	Maximise

Each optimisation is done with no constraints other than finding the optimal solution, resulting in big compromises in the other objectives. This can especially be seen when trying to obtain the best distributed light level (Fig. 25), which is done mainly by moving the light intake as high as possible.

Comparing the results with the architectural concept will reveal solutions that has non or very little resemblance with the dynamic sail-like profile, and instead result in more static solution that clearly has a good impact on each different objective. These results also show the importance of understanding and clarifying the parameters and objectives used in the optimisation problems; the output will never be better than the inputs.

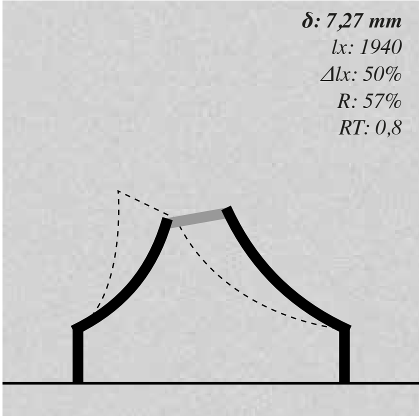

Fig. 27. Optimal: Deflection

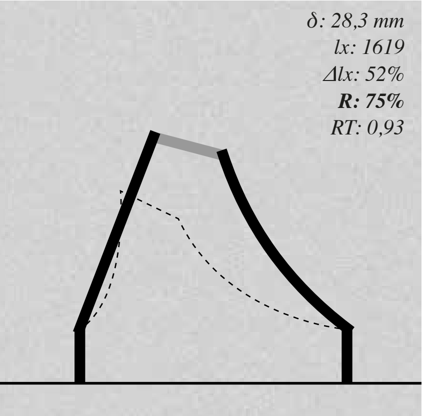

Fig. 29. Optimal: Acoustics

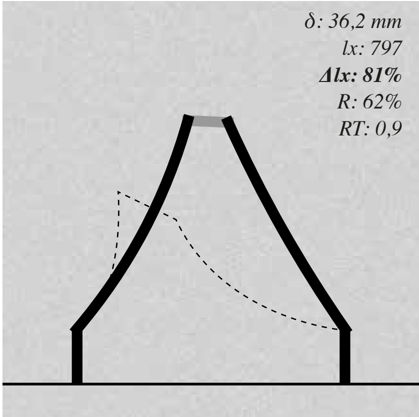

Fig. 28. Optimal: Distributed light

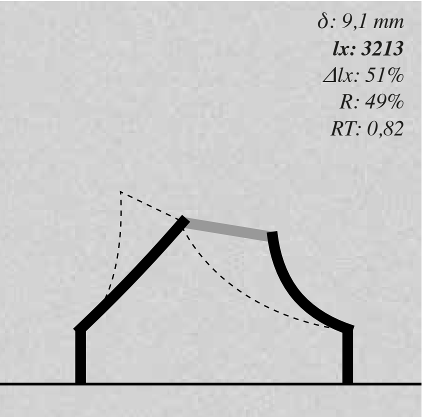

Fig. 30. Optimal: Avarage DF

Preference-based optimisation

Adding simple constraints to the optimisation problems, each objective are starting to reduce the compromise being made in each of the other objectives, but still with only one goal.
The constraints could be used to create a preference based optimisation, if knowing and understanding all the objectives and the levels required, but in this case it is only being done to ensure that some base requirements are being met, like the general lux level not being under 500, while still having a good distribution of the light.

The base constraints used here is:

Deflection	l/400
Light level	500 lux
Distributed light	50%
Rays in area	50%
Reverberation	0,7

Compared to the earlier optimised profile shapes, the constraints are resulting in the profiles being less extreme, in order to create a trade-off solution that meet all the criteria.

Creating a correct preference based optimisation can be done in a simple way by paring the objectives together with a weight vector. This will result in a common fitness index for each solution that will be compared.
On the following pages preference based trade-off solutions are tested by changing the weight vector, resulting in solutions placed on a pareto front that all meet the constraints set up in the previous tests. The light level itself will not be tried optimised because it is expected that the constraint of minimum 500 lux is sufficient for the room. Therefore, it is not attempted to make this level greater instead the distribution of light is used to get the best overall lighting level in the room.
For all the following results based on a weight vector, the weights are described in the figure text.

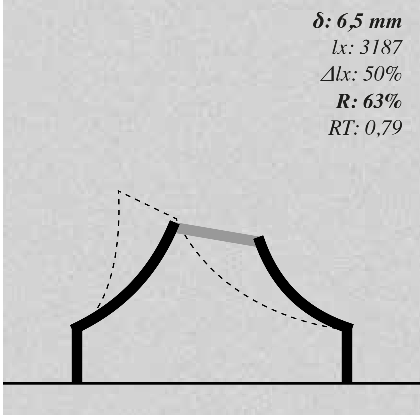

Fig. 31. δ: 9 - R: 1

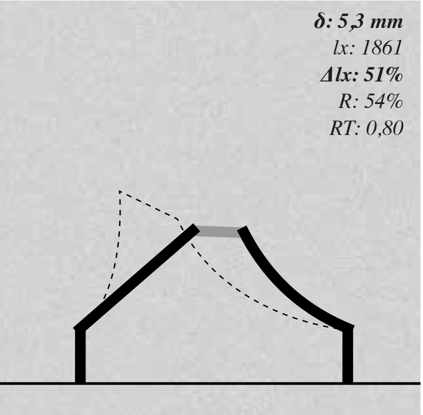

Fig. 33. δ: 9 - Δlx: 1

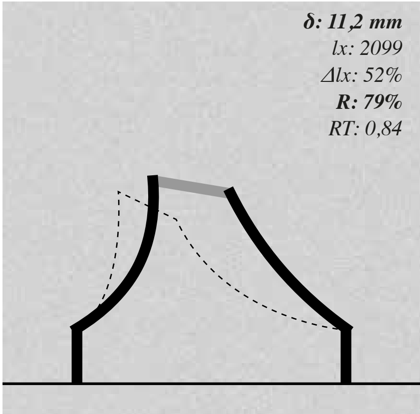

Fig. 32. δ: 5 - R: 5

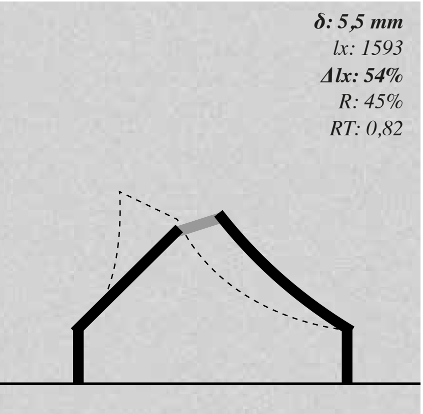

Fig. 34. δ: 5 - Δlx: 5

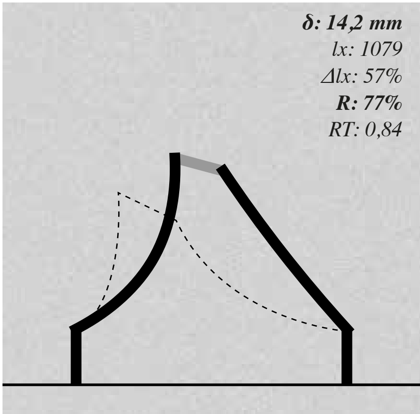

Fig. 35. δ: 1 - R: 9

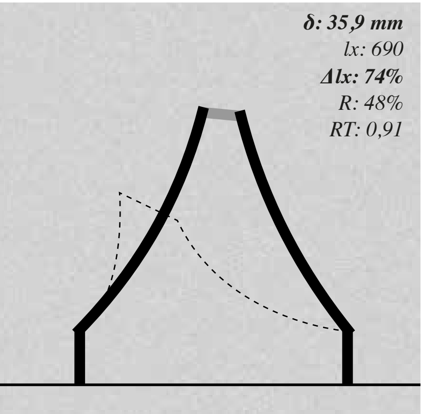

Fig. 36. δ: 1 - Δlx: 9

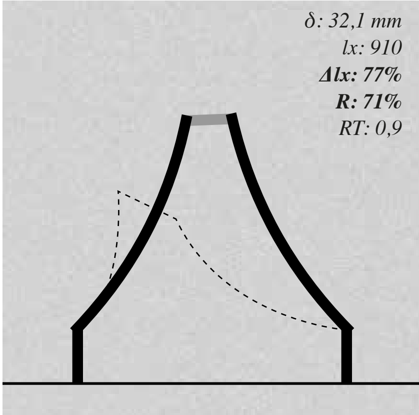

Fig. 37. Δlx*: 9* - R*: 1*

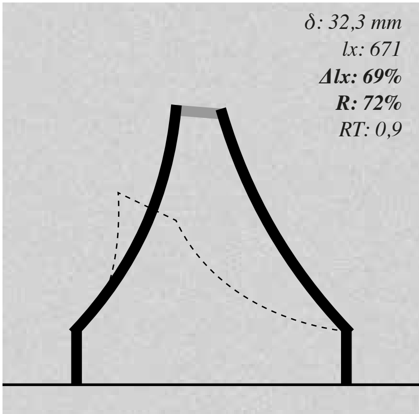

Fig. 38. Δlx*: 5* - R*: 5*

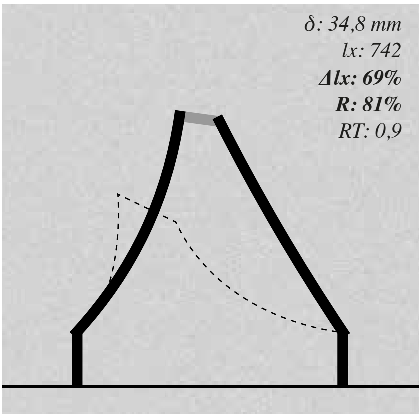

Fig. 39. Δlx*: 1* - R*: 9*

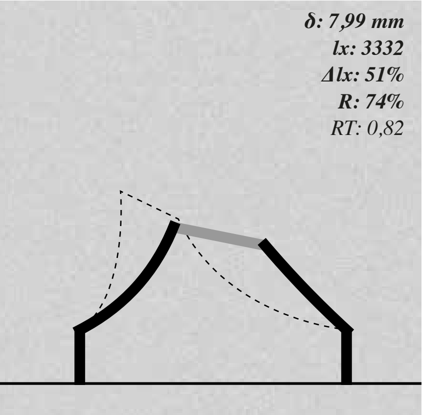

Fig. 40. lx*: 5* - Δlx*: 5*
R*: 5* - δ*: 5*

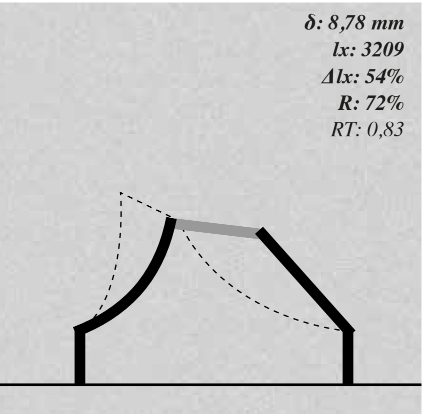

Fig. 41. lx*: 2* - Δlx*: 5*
R*: 8* - δ*: 8*

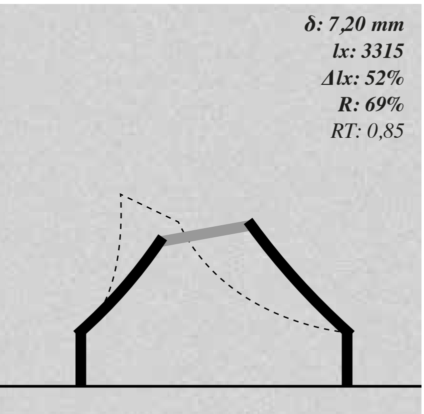

Fig. 42. lx*: 8* - Δlx*: 5*
R*: 8* - δ*: 2*

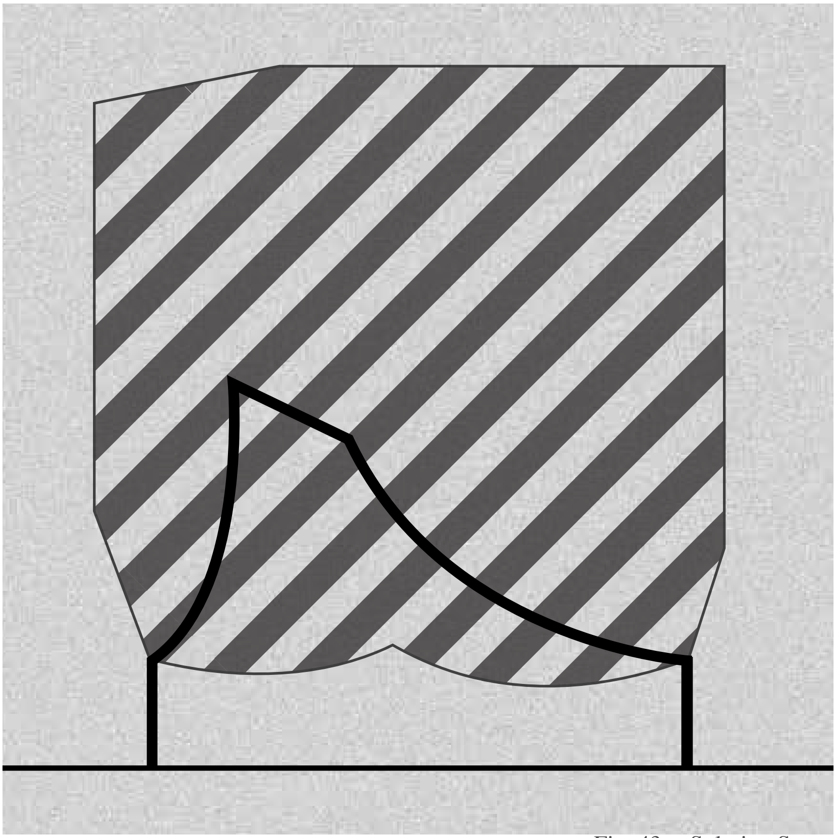

Fig. 43. Solution Space

Optimised Trade-off Solutions

The preference based trade-off solutions show a big variety in the optimal shape in relation to the different weight vectors, and some differs a lot from the initial architectural concept wanted to optimise through the process of multi-objective optimisation, even though all solutions are generated with the following constraints:

Minimise	$f(x1)=\delta$
Maximise	$f(x2)=lx$
Maximise	$f(x3)=\Delta lx$
Maximise	$f(x4)=R$
Maximise	$f(x5)=RT$
Subject to	$\delta \leq l/400$
	$lx \geq 500$
	$\Delta lx \geq 50\%$
	$R \geq 60\%$
	$RT \geq 0,5$
	Architectural Concept

Looking at the illustrated solution space based on the possible parameters show that to get closer to the wanted expression of the shape, the allowed extremes of the parameters need to be decreased. This will allow smaller changes to the shape, but will aid in the optimisation of the exact shape instead of optimising any shape to the constraints set up. Decreasing the extreme parameters will result in trade-off solution closer to the initial concept.

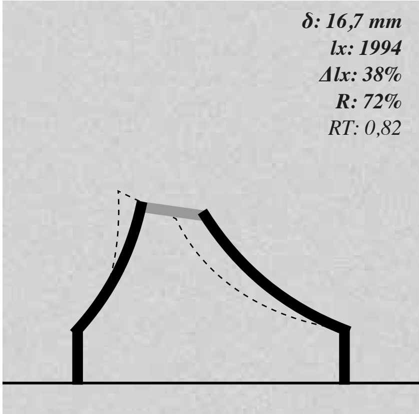

Fig. 44. lx*: 5* - Δlx*: 5*
R*: 5* - δ*: 5*

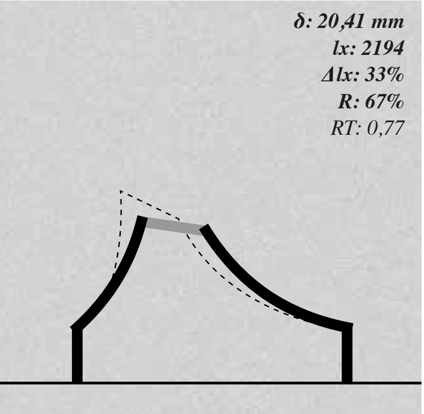

Fig. 47. Non-dominated solution

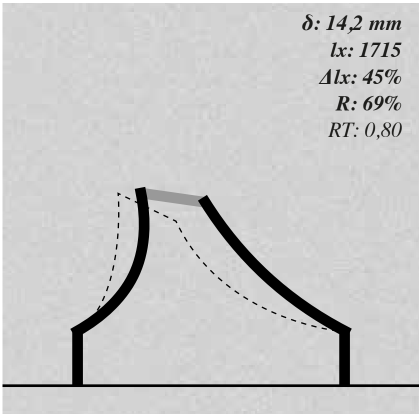

Fig. 45. lx*: 2* - Δlx*: 5*
R*: 8* - δ*: 8*

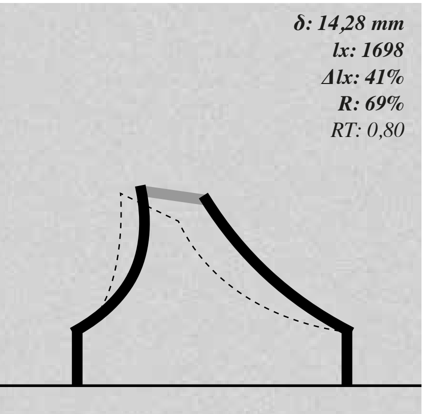

Fig. 48. Non-dominated solution

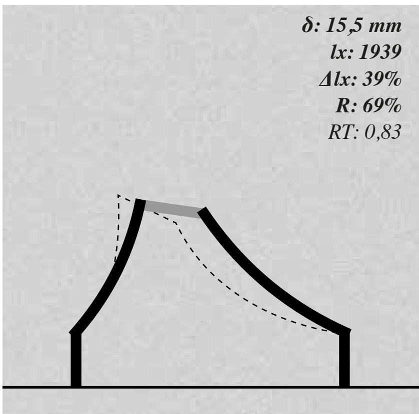

Fig. 46. lx*: 8* - Δlx*: 8*
R*: 5* - δ*: 2*

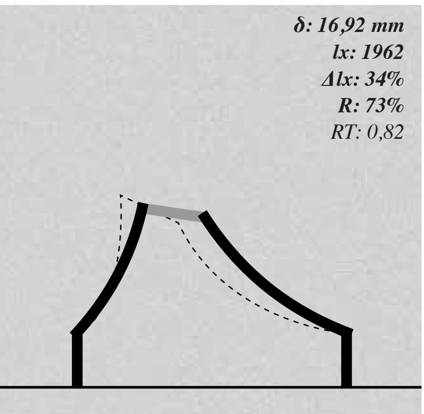

Fig. 49. Non-dominated solution

Optimised trade-off solution based on architectural concept

With the decreased solution space, the trade-off solutions now has closer resemblance to the initial shape wanted to optimise, and can therefore be seen as an optimisation of the shape rather than with a big solution space that arguably could be seen as a form-finding rather than a optimisation process.

The optimal solution can now be found and chosen with the aid of either a weight vector or the pareto front, but which ever way chosen as selection method will result in non-dominated solution and therefore an optimal solution.

When decreasing the solution space, the realisation of the though constraints created was made. Therefore the constraint of the distributed lux level was decreased, making the final problem the following:

Minimise	$f(x1)=\delta$
Maximise	$f(x2)=lx$
Maximise	$f(x3)=\Delta lx$
Maximise	$f(x4)=R$
Maximise	$f(x5)=RT$
Subject to	$\delta \leq l/400$
	$lx \geq 500$
	$\Delta lx \geq 50\%$
	$R \geq 60\%$
	$RT \geq 0,5$
	Architectural Concept

As architectural designer the considerations of which model to chose for finding the optimal solution has to be made. The complex multi-objective optimisation resulting in several non-dominated solutions were a decision afterwards has to be made may often be the best choice when complex problems needs solving because of the difficulty knowing what effect changing the weight vector will have. This way is however also the most demanding in relation to technical understanding, and can be time consuming when applied in a design process.

Conclusion

The tectonic approach in the agricultural architecture is a topic that may not be discussed often due to the lack of interest in aesthetics compared to the demand of building as cheep as possible. However, with the structure being the main element of the building, an optimisation process that can facilitate in the design of a structural system meeting the strict demands in relation to light level and airflow in the building. This complex problem is today commonly solved with completely open facades, high buildings to ensure thermal buoyancy and cheep mass-produced steel frames.

Structure as form driver

Letting the structural system be a main decider in the expression will create a method of refining the traditional method of building agricultural buildings, where the demands for the interior climate can be met whilst working with an overall expression. This requires a rethinking and re-evaluation of the standard elements used in agricultural buildings in order to create not only the cheapest possible solution but also buildings offering spatial qualities for both farmer and animal and buildings while not working against our nature but getting embedded into the surroundings.

The investigations made and method developed with the multi-objective optimisation has a big potential in a design process, but especially the calculations of light has proven to be imprecise. Because of this, making small changes to a design based on the exact light level may prove not to be as efficient as having a basic constraint for the light, and not trying the optimise the exact light level. However, when doing this, the method can prove very efficient in a design process, ensuring a intelligent solution that considers the technical challenges.

"…we must aim at the fixing of standards in order to face the problem of perfection" [Le Corbusier 1986:131].

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Interim Conclusion

On a basis of the introduction, it is stated that the project seeks to investigate the potentials of moving industrialised food production into urban areas in order to create a closer connection between production and consumer, and how this can be achieved with the thoughts and ideas behind urban farming, which in this project will be further transformed into a concept of an urban cattle farm.

Urban Farming creating architectural scheme

With the goal of creating a first hand experience, investigation of the concept of urban farming in relation to dairy farms resulted in parameters that in a design process will be able to affect the architectural concept in a way that will ensure that the small scale thoughts of urban farming can be developed into architectural ideas. *Transparency*, *experience*, and a *direct connection* will in the future design process work as evaluators when developing an overall architectural scheme, where all 3 parameters needs to be addressed in order successfully design an urban dairy farm.

Optimisation developed architectural design

With the overall scheme being developed with the ideas of urban farming, the architectural design will be created with the aid of the optimisation methods developed in the investigation of roof shape of the Utzon Center. By introducing the digital tools after the overall scheme is created, a constant awareness of the relation between structure, light level, airflow and overall shape will aid the creation of an intelligent design reached with an integrated design process.

The two levels of design parameters will together create the overall design tool, that with the basis of site investigations creates an integrated design method that will result in the creation of new architecture for farming and consumer experience.

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