The interdependence between architectural form and light in the urban environment, based on a case study of Dragør, a sea port in Denmark

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“Man is an image of the Sun”
- Hermetic writings\(^1\)

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This dissertation is 18861 words.

In accordance with Regulation 8 of the General Regulations for the M.Phil. degree (one-year course), I declare that this thesis is not substantially the same as any that I have submitted for a degree or diploma or other qualification at any other University.

I further state that no part of my dissertation/thesis has already been or is being concurrently submitted for any such degree, diploma or other qualification.

I further declare that this thesis is substantially my own work. Where reference is made to the works of others, the extent to which that work has been used is indicated and duly acknowledged in the text and bibliography.
Introduction

This dissertation intends to examine the relationship between architectural form and natural light in the urban environment. The ways in which building design can improve the level of natural lighting in the urban environment will be explored using the Danish fishing city of Dragør Old City (located a few kilometres south of Copenhagen) as a case study. To try and determine the form of design which allows for the most efficient provision of natural light, both daylight conditions and sunlight will be investigated.

Fig. 1 Dragør, Von Ostensgade, a street, partly overcast sky (source: author)

Nothing is more important to Earth’s survival than the sun. Life could not exist without it. With no heat or light, all vegetation would die. In the form of direct sunlight or diffused daylight, the sun is a fundamental aspect of human life, responsible for regulating the body’s natural cycles. The importance of its affects on both the body and the psyche has been the subject of much research.

As we spend more and more time indoors, it is crucial for our health and well-being to have buildings designed to provide adequate levels of natural lighting. The light is the connection between the internal and external environments. As half of the world’s population live, work and socialise in urban areas, the way urban tissue is design is as important as the architectural envelopes themselves.
In its capacity as a space where people spend their free time and interact with others, as well as providing security and an aesthetic experience, the quality of the urban environment directly influences human well-being. Both the diversity of urban structure and its aesthetic value impact the quality of civic life. The quantity and quality of natural light are important components of these principles of diversity and aesthetics. As Marietta S. Millet states in her book, *Light Revealing Architecture*: “Light is an indelible part of our experience of life”\(^2\) and we depend upon it in more ways than we are often are aware, both psychologically and physiologically.

![Fig. 2 Dynamics of Light, changing shadow patterns in Dragør (source: author)](image)

Daylight is a dynamic phenomenon, therefore “the relationship to natural rhythms of the surroundings requires a dynamic design response, specific to time and space. Designers must learn to approach the design process with this dynamic in mind and understand that the building will be visually and functionally different according to day and season”.\(^3\) The same can be said of the urban environment, in that the provision of interesting, diversified space is just as important as the buildings themselves. The principle of providing natural light must be incorporated into the design process as a whole, implicit in every design decision. It is not

\(^3\) The Sun’s Rhythm as Generator of Form, AIA Journal/ September 1979, pp. 66-67
something that can be considered as an afterthought, implemented only in the final stages of design.

Because of its relative scarcity, the need for natural light is often more appreciated in the northern rather than lower latitudes. Consciousness and consideration of this issue is also generally much higher in countries where a scarcity of daylight and sunlight exists, and the importance of exposure to the sun and having apartments which maximise the provision of natural light is better understood.

This dissertation will attempt to develop design methods which more efficiently utilise daylight in the urban context, with a view to assisting the work of architects and urban planners. Studies will concentrate on the incorporation of realistic prediction methods based on design investigation, qualitative and quantitative research, and physical and computerised measurements of existing conditions. An attempt will be made to give numerical significance to the subject of Northern European climatic conditions, with a particular focus on Denmark.

This dissertation consists of an introduction and four chapters. The first chapter defines the elements of the urban environment from the natural light perspective and discusses the importance of its role in the fabric of urban living. Existing recommendations and guidelines are also discussed. Chapter two introduces Dragør Old City; both its history and the history of its urban architectural forms, presently characterised by typically long houses. Climatic conditions specific to the area will also be discussed. Chapter three presents the results of investigation into the issue of architectural design, while chapter four presents the conclusions drawn and details the implications of the study as a whole on architectural and urban design. Chapter four would include conclusions.
Chapter 1

Why Dragør Old City is an interesting example. The definition of the elements of urban environment from the natural light point of view. The importance of light in the urban fabric and its aesthetic significance. Existing recommendations and guidelines for daylight on an urban scale.

1.1 Why Dragør?

Visiting Dragør Old City over the years has been a great inspiration. This homogenous, though completely non-uniform, town has provided an impetus to many thoughts relating to the quality of modern urban development. The manifold forms and individual character of its buildings make it an ideal benchmark for comparison with more modern environments, allowing the effects of the Industrial Revolution’s creation of mass production and consumption of a wide range of products to be more closely observed. Just as these products tended to lack an expression of beauty in their production, so did the cities constructed during this time lack personality, failing to relate to human values and psychological needs.

Fig. 1 Dragør, Strandstræde – a lane, with overcast sky (source: author)
As the ‘right to light’ is protected in England and Wales under common law, adverse possession and the Prescription Act (1832), it seems natural to assume that such laws would exist in Denmark, considering the similarities in weather conditions, with the frequent dominance of overcast skies. Though similar provisions were not found in Danish law, historical studies of urban architectural form show that, traditionally, construction in Denmark has been heavily influenced by local climatic conditions, and has guaranteed a necessary level of light in buildings.

In the book *Long dwellings. About long houses, elongated houses, houses on the rows, row houses* by Jørn Ørum-Nielsen (original title *Længeboligen. Om langhuse, længehuse, huse på række og rækkehuse*—author’s translation), one can read about building forms traditional in Northern Europe since the Iron Age. This period introduced the popularity of elongated north-south oriented houses that were able to provide a necessary amount of light and heat while also protecting their dwellers from the prevailing north-western winds. Quoted by Paul Oliver in the *Encyclopaedia of Vernacular Architecture of the World*, the author underlines the importance of settlements such as Dragør Old City, describing it as follows:

“*In a residential environment of extremely high density, each family home is ensured its full share of light and fresh air and a sunlit garden space corresponding to the size of the house,...the resulting urban environment is characterised by richness of structure and intermediate spaces, and by a great variety of architectural expression in the individual houses. This combination of urban regulation with individual freedom has in recent years been inspirational in the revival of low-rise, high-density residential planning in Denmark.*”

Dragør’s unique structures and architectural forms add a significant amount of knowledge to the subject of this study. Taking the importance of natural light a step further, detailed investigation of the Dragør Old City structure can be seen as important in leading towards the discovery of new knowledge relevant for future work in the area of architectural design. The study of historical examples can often provide new perspectives on contemporary design and lead to necessary improvements. The development of vernacular buildings and cities over time display improvements and changes that have been gradually introduced. Thus, in relation to the importance of climate-sensitive design, history can provide some valuable lessons.

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1.2 Elements of urban environment and their importance

The style of architecture in Dragør Old City differs somewhat from other Danish cities. The majority of Danish housing is designed according to traditions established in the Middle Ages, or even earlier, resulting in the predominance of narrow, elongated houses with steep pitched roofs. In this context, Dragør’s urban structure is atypical of most of the country’s settlements. Traces of the medieval street plan still exist in Dragør, with a north-south way close to the harbour and an east-west walking street opening the way to Copenhagen. Although the layout of the buildings remains faithful to 17th century city planning ideals introduced by King Christian IV, it does not precisely follow the planning of other settlements created during this period, such as Nyboder in Copenhagen, Kristianstad, Kristiania (present Oslo) and others (Fig. 3). The influence of individual builders and owners is particularly apparent in the final stages of construction. Though no two buildings are the same, neither are they completely different. These individual stylistic touches ensure that, while general elements and details can be discerned in the design of Dragør Old City, no two streets are exactly the same.
If a proper attempt to characterise Dragør Old City’s urban structure is to be made, the most important elements should be classified. According to Ralph L. Knowles, three levels of city planning control should be defined: order, structure and system. These provide a “framework for community development requiring different levels of control related to potential diversity”.

Such a discussion must necessarily involve the importance of the relationship between existing urban architecture and natural light as a factor in the creation of urban space and the ways in which people inhabit this space. “Spaces encourage people to relate to each other in consistent, predictable ways”. For example, the narrow streets and low levels of light in Barcelona’s Old Town do not encourage the diversity of activity that a large, open sunny square would. During the course of the day, the colours and patterns of light shift, providing such spaces with different qualities suitable for a range of varying activities. The character of these spaces is thus developed, and “beyond providing physical frames for human activities, also interprets to human beings their place in nature and society”.

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“Places sculpt both individual behaviour and interpersonal behaviour”. Elements of urban structure can suggest domination or equality, isolation or intimacy, relaxation or tension, cooperative or solitary work, social roles, and all sorts of things that happen between people. The size and character of civic buildings give us ideas about our place in society and the nature of that society. The size and character of private houses tell us who we are, who we should be, and how much noise we can make. These social, cultural and personal differences may end up 'encoded' into the built environment too, with natural light being an important factor.

The importance of these more interpersonal elements on urban design strategy and their possible relationship with natural light will be covered in Chapter 3.

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Fig.4 Dragør, an aerial photo (source: Abrahamsen)

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1.3 The role and need of sun in northern countries

Our climate has a bigger influence on our physical and psychological health than we are aware of. Although the sun plays such an important role in our health and well-being, most people are not exposed to enough sunlight on a daily basis. Bright light is used to alleviate symptoms associated with seasonal affective disorder (winter depression), jet lag, shift work fatigue, seasonal change and insomnia. As these are all common occurrences in northern latitudes, more action should be taken towards providing the best possible conditions for their city residents. A way of achieving this is through improving the environment in which people live; in this case the urban environment.

Natural light is essential for the health of the mind, body and spirit. The human body was designed to operate under natural light. In physiological terms, sunlight aids metabolism and nutrient absorption, and enables the body to maintain proper hormone levels for maximum well-being. If exposed to a sufficient amount of sunlight, a person can ‘feel better’- more comfortable. Regular exposure to sunlight also ensures the systematic operation of circadian rhythms, which improves the quality of sleep, reducing the occurrence of the Seasonal Affective Disorder (SAD).

This chapter has so far outlined the reasons why the subject of this research is so important. Urban architectural forms have a direct impact on all areas of daily life. Both physically and psychologically, human existence depends on daylight. This research will now try to continue to improve the understanding of how light impacts the human environment and physiology.
1.4 The existing environmental recommendations and guidance

Before looking at the specific example, in this case Dragør Old City, a short review of existing recommendations and guidelines would be beneficial. The template for sustainable urban housing, formulated by Koen Steemers and adapted by Edwards and Hyett\(^9\), includes the following suggestions that can be applied to building design:

- plan depth limited to 10-12 m
- solar orientation between SE-SW
- avoid obstruction angle above 30º
- theoretical density of 200 dwellings per hectare
- three or four storey buildings preferable
- every % point increase in obstruction over 30% results in the same % point increase in energy use

“A balance is needed between defensible space and sustainability, producing streets that are neither alienating nor energy-efficient. Beyond 80 dwellings per hectare, overshadowing makes it difficult to take advantage of passive solar gain, though use of the suburban examples with density as low as 20 dwellings per hectare can cause problems of land shortage as well as difficulties with supply possibilities. Here lies another dilemma for sustainable housing: the creation of communities entails shared values, shared space and physical enclosure, whereas the physics of solar gain leads to long anti-social spaces, parallel buildings and private gardens (to protect solar aperture)”\(^{10}\)

"adequate light for the ordinary notions of mankind"\(^{11}\)

A search for other recommendations leads to the concept of the ‘rights to light’, which are not a legally binding set of regulations directed at planners and architects, but rather guidelines used to assess the impact a development will have, based on their own planning polices. The ‘right to light’ is a civil matter between property owners, and does not fall under the jurisdiction of official planning laws. The ‘right to light’ is protected in England and Wales under common law, adverse possession and by the Prescription Act (1832). Unlike the right to freedom from smell and noise, a right to light has to be acquired before it can be enforced. “Natural light is a commodity that can be bought, sold or even transferred between parties. Rights can be registered, granted by deed or simply acquired by having a minimum of 20

\(^{10}\) Edwards, B., Hyett, P.; 2002, p.101
\(^{11}\) Prescription Act of 1832
years enjoyment of light through a window or opening. Once a window has received over 20 years of unobstructed daylight, it automatically earns itself a ‘right to light’. Such rights are, for land registration purposes, overriding interests. They are valid whether or not they are registered on the title deed to the property which claims the right.”

There is no general right to daylight (or to a view) within English law; only rights acquired over time.

The most common reference used by planning authorities in Britain is *A Guide to Good Practice (BR209) Site Layout Planning for Daylight and Sunlight*, which gives advice on how to plan the layout of a site in order to achieve optimum levels of sunlight and daylight within buildings and adjacent open spaces, such as gardens. It includes methods for the calculation of sunlight or daylight levels at 4 different latitudes within the UK and for different times of the year. An additional section discusses the subject of site layout and design for obtaining maximum solar energy.

In general, a building will retain the potential for good diffuse daylighting, provided its planning adheres to the following:

(a) there is no obstruction on all its main faces, measured in vertical section perpendicular to the main face, from a point 2 m above ground level, sub-tends an angle of more than 25° to the horizon; (see Fig. 5 below) or

(b) if (a) is not satisfied, then all points on the main face on a line 2 m above ground level are within 4 m (measured sideways) of a point which has as vertical sky component of 27 % or more.

(c)

![Fig. 5 The 25° reference limit, above which a test for rights to light must be made (source: Littlefair)](image)

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12 http://www.planning-applications.co.uk/righttolight.htm
13 Littlefair, P.J. Site layout planning for daylight and sunlight: guide to good practice, (BR209), 1995
Another point suggested by BR209 introduces criteria for existing buildings. The windows of a dwelling’s living room and conservatory should face within 90° of due south. Overshadowing can be prevented by placing solar-collecting glazing within 30° of due south.

In addition, the new development must not reduce the amount of hours of direct sunlight received by more than 20%. It is also recommended that “a development site next to a proposed new building will retain the potential for good diffuse daylighting provided on each common boundary:

(a) no new building, measured in vertical section perpendicular to the boundary, from point 2 m above ground level, subtends an angle of more than 43° to the horizontal; (see Fig. 6) or

(b) if (a) is not satisfied, then all points 2 m above the boundary line within 4 m (measured along boundary) of a point which has a vertical sky component, looking towards the new building, of 17% or more.

Fig. 6 The 43° boundary criterion (source: Littlefair)

Looking at other sources, in his book Solar Energy and Housing Design, Simmos Yannas suggests separation distance between buildings (see Fig. 7 below). According to Yannas, therefore, an adequate separation between buildings depends on latitude, but should be as low as possible. 13.5° and 16.5° values would require 29 m and 24 m.14

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14 Yannas, S, Solar Energy and Housing Design Vols 1&2, Architectural Assoc 1994
The situation in Denmark is similar. Buildings are constructed in accordance with Dansk Byggelov (Danish Building Standards), but the question of daylight access is not covered by general laws. Provision for natural light is generally the result of adherence to traditional building practices, in which the benefits of solar exposure have become a part of the mindset.
1.5 Recommendations for daylight in residential buildings

A measure for assessing the adequacy of skylight during the early stages in design is the average daylight factor. This is the mean daylight factor in a room over the horizontal working plane. A formula for the average daylight factor can be used and calculations based on the interior and exterior daylight levels performed.

\[ DF = \frac{I_{in} \times 100}{I_{out}} \]

Plotting the daylight factor along a cross-section or with isolux contour on a plane (such as a typical workplane height of 0.8m metres above floor level) will then describe daylight penetration. The display of the daylight factor (DF) contours provides a clear interpretation of daylight penetration in the monitored room. Recommended daylight factors for dwellings are shown below:

**Average daylight factors to give daylit appearance**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Minimum average daylight factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mainly daylit</td>
<td>5%</td>
</tr>
<tr>
<td>With supplementary electric lighting</td>
<td>2%</td>
</tr>
</tbody>
</table>

**Average daylight factors in dwellings**

<table>
<thead>
<tr>
<th>Type of room</th>
<th>Minimum average daylight factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen</td>
<td>2%</td>
</tr>
<tr>
<td>Living room</td>
<td>1.5%</td>
</tr>
<tr>
<td>Bedroom</td>
<td>1%</td>
</tr>
</tbody>
</table>

*Even if a daylit appearance is not required

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15 Bell, J., Burt, W., Design buildings for daylight, CIBSE, 1995, p31
16 Bell, J., Burt, W., p31
1.6 Sunshine availability - climatic specifics of the area

Denmark is situated in the zone between three European bio-geographical provinces (the Boreal, the Atlantic and the Continental provinces) and its vegetation consists of a mixture of that common throughout these provinces. The climatic factors are rather variable. Generally, the western parts of the country have an Atlantic climate while the climate in the eastern parts is Continental. However, as Denmark is an archipelago, conditions are somewhat modified. The yearly precipitation is over 900 mm in some parts of Jutland and below 500 mm over The Great Belt between Jutland and Saeland. The rain is more or less evenly distributed through the year, but as the evaporation is less in the cool months of October to March, winter is the most humid time of the year.

The temperature is naturally highest (over 8.5 degrees C) in the southern parts of the country and lowest (below 7.5 degrees C) in the northern parts of Jutland. July is the warmest month, with a mean temperature of over 17.5 degrees C in the southeast and just below 16 degrees C in the northwest of Jutland. January is the coldest period in Denmark, but the mean temperature of 0 degrees C is more evenly distributed throughout the country because of the warming effect from the surrounding sea.

Fig. 8 Map of Denmark (source: multimap)
The duration of sunshine in Denmark varies from place to place. Generally, the highest yearly totals occur in the northern part of Jutland, the Kattegat regions and Bornholm. The lowest values are found in central Jutland. The reasons for the high values have something to do with the fact that island stations in Denmark, affected by the sea, receive more sunshine than inland stations. The area in Denmark that received the most sunshine during the period 1961-90 was the island station of Christiansø, in Østersøen, while the inland station of Askov, in central Jutland, received the lowest levels during the same period. Christiansø receives an average of 378 hours more sunshine each year than Askov. During the summertime the inland station is more affected by thermal activity, resulting in the formation of more clouds than over the island station. In springtime, on the other hand, the weather is unstable on the islands because of the relatively cold sea water.

<table>
<thead>
<tr>
<th>Station</th>
<th>Jan</th>
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Fig. 9 Sunshine hours, for Denmark and Copenhagen marked (source: DMI)17

The relatively high amounts of sunshine in the northern part of Jutland could also be explained by the sheltering effect of the Norwegian mountains, in cases where the weather comes from a north-westerly direction. The Table of Hours of Bright Sunshine, calculated by the Danish Meteorological Institute and displayed on the previous page, shows the total

17 DMI, Denmark Meteorological Institute
yearly sunshine hours for Copenhagen as 1753, placing it amongst the most overcast cities in Europe.

To further this discussion, it is important to get a clear picture of Dragør’s climate. Data collected for Copenhagen was used for this purpose, as the meteorological observatory at the Kastrup Airport is located only two kilometres away from Dragør, closer than to Copenhagen itself. The values of cloud coverage also need to be examined in order to better understand the climatic conditions of the area. According to the graph below (developed in the Ecotect weather analysis program) completely clear skies are a rarity in the area, though it must be stipulated that this a somewhat simplified diagram which does not take in to account all related factors. It can, however, be concluded that cloud coverage in Dragør lies at relatively equal levels and varies between 20-60%, with 100% coverage in winter months.

Fig. 10 Clouds coverage, a weekly summary for Copenhagen (source: Ecotect- author)

The characteristics of the Danish sky highlight the importance of daylight-sensitive design for the region, in both architectural and urban terms. Such knowledge of the existing conditions should therefore be incorporated into the first stages of the design process. A more detailed description of the characteristics of sky conditions and light levels, and their influence on the character of Dragør Old City, will be undertaken in chapter 3.
Chapter 2
Dragør city: its history and the history of its urban and architectural forms.
Present characteristics.

2.1 Dragør Old City - the Sea Captains’ Village - history

Dragør Old City, a seaport on the eastern coast of Denmark, was used as a background for this study. Dragør city is known for its beautiful yellow houses, narrow streets and cosy atmosphere. It consists of the old city, the harbour area and surrounding villas.

According to Danmarks Statistik, StatBank Denmark, the population of the municipality is 13 076, and 11 075 in the city (data for 1 January 2004). Since the opening of the Øresund Bridge in 2000, some of the city’s previous character has been lost. Today, there are only a few fishermen in Dragør, and 75 % of the village’s citizens earn their income outside the municipality. However, the village has maintained its position as an attractive, well-functioning and friendly oasis on the outskirts of Copenhagen.

Fig. 1 Map of Denmark in European context (source: Atlas of Europe)
Dragør Old City is one of the municipality’s preservation areas. Unlike most of the villages in the capital area, its original building style has been maintained, as well as its exposure to the open landscape. The island’s flat landscape provides no shelter from the prevailing westerly winds so characteristic of Denmark. The weather simply changes according to the direction of the wind. Furthermore, it is generally more often windy than calm in Denmark. At all events, the wind is a key factor of daily life. A detailed description of the Danish climate is provided towards the end of this chapter.
Like most of the larger Danish cities, Dragør was founded during the Middle Ages. It was an important trading centre between the 13th and 15th century, with its location at the Drogden, a fairway between islands Amager and Saltholm. In 1342 the settlement received handle privileges from King Valdemar Atterdag. It belonged to the so-called Skånemarked, Northern Europe’s largest market at that time, along with other fishing, settlements, such as Sanör and Falsterbo (present Sweden). Every year, from July 25 to October 9, between 10 000 and 20 000 people were hired. Unfortunately, there are few remaining archaeological materials from this period which enable analysis of the city structure or building traditions, mainly because the king only allowed market activities for a short time.

This situation did not stimulate permanent settlement. It wasn’t until 1422, when permission was granted by the crown to keep market booths open throughout winter, that the formation of a permanent city became a genuine possibility. Much of the information significant to this period has been supplied by the ‘Stakhaven’ excavations. However, this site is located at a distance away from the main city, and therefore can not be relied upon to reflect accurate archaeological traces of cultural change. Traces of the Middle-Aged city can only be discerned in a few streets, in parts of the quay line, and in the fork-shaped form created around the Strandhotelet (Strand Hotel) by the Kongevejen and the Toldergade. Another factor preventing an accurate mapping of the city’s Medieval history is fire. The city was burned to the ground in 1536, as a result of a civil war known as Grevens Fejde (The Count’s Feud)\(^\text{18}\).

In comparing Dragør’s structure with that of other Danish harbours from the same period, mention of the stretched shape along the coast line should be made. Though traditionally streets were constructed along the harbour line, no such street exists along Dragør’s harbour. The reason for this may relate to changes in city planning implemented after the Middle Ages, in which a more uniform north-south and east-west street pattern was introduced.

The street plan pictured below is a reflection of the 16th century planning changes introduced by King Christina IV, and is typical of Copenhagen and other Danish cities developed during the period. These plans were intended to produce the ideal city, and were used in the construction of new city areas such as Nyboder in Copenhagen, Kristianstad and Kristiania (present Oslo). The regularity of street planning, as illustrated in Fig.4 and Fig. 5, is somewhat broken, with displaced street courses and spread street development. In this way, Dragør does not conform to the chessboard planning of other cities.

\(^{18}\) Grevens Fejde, The Count's Feud, civil war in Denmark, 1534-36
Fig. 4 Plan of Nyboder, Copenhagen (source: http://home6.inet.tele.dk/flemclar/nyboder.html )

Fig. 5 Nyboder, Copenhagen (source: http://home6.inet.tele.dk/flemclar/nyboder.html )
Most of the picturesque yellow houses in Dragør Old City were built between the end of the late 1700s and 1850. Twenty-five per cent of the houses are preserved, covered by a local preservation plan which ensures the village will keep its special character. The old village consists of a network of east-west streets, and north-south alleys with open squares. Many of the houses have their own fascinating history, which unfortunately cannot be covered in this dissertation due to considerations of length.

Fig.6 Map with age of the houses in Dragør (source: E. Fisher)
**Historical overview over amount of citizens in Dragør**

**The Middle Ages, Skånemarkedet**
1250 – internationally recognised as an important market place for the Hanseatic merchants

20,000 attending the market

1333 - Dragør mentioned for the first time as a city

1430 – First official permanent buildings

**King’s fisherman harbour**
1520 - the arrival of the Dutch farmers

40,000 attending the market

1536 - burned down in Grevens Fejde (The Count's Feud), civil war in Denmark,

1534-36  

150-200 inhabitants  

20 houses

**Skipper time**
The village develops into a prosperous shipping town whose male population provides for their families as seamen or skippers plying the oceans, and by piloting ships through the narrow fairway in Drogden.

1700 - quick development  

900 inhabitants  

200 houses

1748 - second biggest harbour  

1250  

293 houses

1801-1813 depression  

1700  

350 > 280 houses

1877 - third biggest harbour  

1864  

300 houses

1900 - the end of the Skipper Time  

1850  

360 houses

2004  

1107  

375 houses

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Fig. 7 Historical overview of citizen numbers in Dragør\(^{19}\) (source: E. Fisher)

\(^{19}\) E. Fisher, 1949, pp 50, 51
Fig. 8, 9 and 10 Historical maps of Dragør (from years 1400, 1746, 1803, source: E. Fisher)

Fig. 11 Historical map of Dragør 1948 (source: E. Fisher)
2.2 The urban and architectural forms

“In the Old city of Dragør the city planning and houses are in such a state of oneness, that a single house’s plan and form must follow the main planning idea. The result is a town that, though logical and balanced in its building plan, seldom expresses harmony.”

As previously mentioned, Dragør’s present urban structure was developed at the beginning of the 18th century, though it does not follow the principles applied to other cities developed during the same period. It is an exception to the general rule that cities be developed according to street plans inherited from previous periods—a practice resulting from the conservatism inherent in Danish land registering principles. These radical changes in the network of streets are often explained by the changes in the country’s national and legislative laws between the 14th and 18th centuries.

The 18th century street plan, as seen on most maps of Dragør, consists principally of east-west bound streets crossed by north-south bound lanes; a pattern which still exists today, with the exception Kongevejen (Kings Street), and another street called Strandgade that connects the eastern and western boundaries of the city. The result of Dragør’s unique planning framework is an urban environment characterised by a richness of structure and intermediate spaces. A “very important feature of Dragør’s town plan are the many ‘squares’ and square-like features that break street patterns. It is moreover characteristic for the unmonumental attitude, and the expression ‘market-place’ is never used, even if the square has this character. An essential element of the city’s preservation involves taking a position on the future look of the square, taking in to consideration the distinctive architectural surroundings and vegetation. As a result of traffic policies, most of the markets have changed from being traffic areas into recreational pedestrian fields.”

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20 Ørum-Nielsen, J., Kængeboligen, Kunstakademiets Forlag, Arkitektskolen og Arkitektens Forlag, 1988, p.98
21 Abrahamsen, P., Historiske Huse i Dragør, Nationalmuseests ”afd., p.102
2.2.1 Orientation

Sometimes one can find differences, namely in the way that the west-end of a building turns slightly to the north, and the east side to the south, though seldom will one observe a west-north-west or an east-south-east orientation. Only a few houses lie in a north-south axis. One explanation for this change in direction is that the warmest time of the day falls one or two hours after two o’clock, when the sun is situated slightly west of the south. Another explanation could be the mostly north-western wind direction in this area, which could have influenced the decision to orient a house with its gable up against the wind, and in this way ensure the roof surface has less chance of being ripped up by strong winds from this direction. Regardless of the explanation, most houses are oriented in an east-west direction (See maps on page 33).

Fig. 12 Houses orientation in the Viking times (source: J. Ørum-Nielsen)
2.2.2 Built form

Alongside the east-west bound streets, houses are oriented towards the sun, lengthways, in an east-west direction, in accordance with Danish custom. Houses appear to be built together lengthways, in a principal known from the Middle Ages as “boder” (booths). The same patterns were followed by builders in later epochs.

Dragør’s city plan can be described as follows: the distance between streets is two to four site widths, creating so called ‘karré’, which in its urban meaning can be translated as ‘a block’. On the south street border, houses are built according to the Danish tradition, with gardens placed behind them or with the yard areas placed in the front. Just after them, a new house wing follows, with its garden just behind. This is the pattern used all the way along, until it reaches the next street. Depending on the distance between streets, this repetitive system forms an asymmetric street picture as the ‘karré’ length varies (Fig. 13 and 14). To the north, almost every site has a fence border, while in the south, house façade plays the same role.

Fig 13 and 14  Plans of two Karré types, with entrance from the street or from the lane. Principle also shows the depth to length relation of the city structure. (source: J. Ørum-Nielsen)
Another principle used in Dragør concerns entrance direction to the houses, and is dependent on the width of the ‘karré’. In order to enter a house, a passage from the yard or a direct connection to the street is required. If the ‘karré’ is the depth of two sites, it contains only two houses in length, and entrance can be made via the north-south lanes. ‘Karré’ that is longer than two sites (houses) can be no deeper than two houses, as it would then create problems of entry. This principle, however, is not consistently followed, and sometimes very narrow mews between buildings acts as an entrance to the house or its garden. As stated by Abrahamsen: “This planning principle offers maximum utilisation of the city space, south-oriented rooms and sunny leisure areas.”

The issue of depth will be investigated further in chapter 3, where light levels provided by this form of structure will also be examined.

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Fig. 15 Typical South view of the street (source: author)

Fig. 16 Typical view of the North side of the street (source: author)

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22 Abrahamsen, P., Historiske Huse i Dragør. Nationalmuseests ”afd., p.106
2.2.3 Longhouses - historical perspective

Longhouses were first constructed during the Bronze Age. During the Iron Age, they became the typical form of housing structure in Danish towns, as well as in single settlements. The Northern European tendency to orient houses in an east-west direction dominated, initially at the Jutland then later across the whole of Denmark.

As can be observed in the drawings below, houses are between 6-8 metres in width, while length is predominately determined by the urban structure. A typical example of Dragør’s housing can be found at Bjergeslav Street, which connects dwellings number 5, 7, 9 and 11. (see: Fig. 17)

Fig. 17 Traditional elongated Danish houses, plans and façade (source: J. Ørum-Nielsen)
Fig. 18 Traditional elongated Danish houses, plans from Iron Age until present
(source: J. Ørum-Nielsen)
2.2.4 Two stories city houses

Another type of house represented in Dragør Old City is erected in two full storeys and called “Patricierhuse” (Patrician house), or “Skipperhuse” (Skipper house). These houses were erected during a period of prosperity towards the end of the 18th century. The name Johan Hendrich Jørgensen Blichmann is connected with many of them, as he was active in Dragør during this period as the first building master. Many of his drawings are preserved in the City Museum, though it is difficult to connect them to the existing buildings purely through comparison because many of them are either unfinished projects or were altered significantly during construction. The Skipper houses in Dragør are unlike those in other cities, and differ from the local traditional building style. Yet they are characterised by the same simplicity inherent in the town’s other houses. There are still 10 of them left, mostly situated on the western or eastern borders of the city, and are mostly oriented in an east-west direction.

Fig. 19 Skipper house - two storey houses of Dragør (source: author)
2.2.5 Traditional space division inside the houses

“Stuerne” - Rooms
Most of the houses in Dragør contain an ante-room, situated in the middle of the building and surrounded by other rooms and chambers. Even though the rooms on both sides of the ante-room are very often of the same size, one senses a difference between living room and lounge. In some cases, the expression ‘big-room’ is used to describe a room of similar size. Setting them apart from other east Danish elongated houses, rooms in Dragør houses are square in shape. This, along with the often one-sided lighting, gives a specific character to the rooms. Though the houses are of small width, approximately 8-11 alen\textsuperscript{23}, this does not mean they are underlit. They are, in fact, often well-lit, particularly when oriented towards the south of the street, or when rooms have windows to both facades.

“Salen” – big room
The space under the roof is often adapted to become the gable rooms. If it is of significant size, it is often called ‘salen’. The ‘salen’ is normally equipped with permanent alcoves, and in most cases contains a room equally as presentable as the ground floor living rooms.

“Kamrene” – chambers
Houses in Dragør are divided by a space which separates the living rooms from each other. These are the darkest spaces in the house. They are normally no bigger than 1 “fag” in width (1.88 m); a size which restricts furniture possibilities. At the same time, their depth is three times their width, and in most examples are only lit from the short side of the building. The gable room therefore offers the opportunity of utilising the chamber window, often making it the most attractive space in the house, from where one can see people passing on the street.

Fig. 20 Room division in traditional Dragør house (source: author)

\textsuperscript{23} alen = approximately two feet (24.72 ins.)
2.2.6 House plan

As a consequence of Dragør’s varied city planning, two types of house layout have developed. They are both very narrow long-houses, with depths not exceeding 10 metres, though mostly varying between 7 and 8 metres; with cross-placed kitchen/entry area with the possibility of entrance from the south or north. Houses are divided through the middle, splitting the building into two parts, left and right from the entrance. Depending on the characteristics of the ‘karré’ the house belongs to, it may have windows which open on to the south and north, or only the south when a neighbouring house’s garden is situated just behind it (see Fig. 21 below). This creates different interiors from the accessibility of the natural light point of view.

A detailed description of the housing layout can be found in chapter 2.2.3, which discusses the traditional division of space within houses.

Fig. 21 Plans of typical Dragør houses according to their relation to the street or to the neighbour. (Source: J. Ørum-Nielsen) The row to the left shows layouts where back walls (mostly northern) have no windows, while the right ones have windows facing both the garden and onto the street.
2.2.7 Courtyards and Board fence

On the northern sides of each building and in between houses, board fences divide the space and provide protection from people passing by. Every house has a little courtyard or a simple place in front of it. One differentiates between a ‘yard’ and a ‘little yard’, separated by a fence. Small sheds and ‘locums’ are placed in the ‘little yard’, whilst the ‘yard’ is used for different type of outside work; a kind of outside workspace.

Fig. 22 Gable elevation to the lane, space between houses protected from the street by wooden fence (Source: J. Ørum-Nielsen)
2.2.8 Traffic

A final element characterising the urban qualities of Dragør Old City is its status of “fodgængereby” (city of pedestrians). On a signboard near the city's entrance is written: “Walking area. Driving only allowed to and from houses, and for the delivery of goods. Parking prohibited”. Whether necessary because of confined space, or to control traffic or protect pedestrians, traffic restrictions influence everyday behaviour. More will be said on this subject in relation to the citizen questionnaire discussed near the end of chapter 3.

Fig. 23 A street sign telling that only traffic is only allowed for residents and shopping quests, bicycles allowed all the time (source: author)
Chapter 3

Investigations and their results would be discussed in this Chapter.

Fig 1. Aerial view of Dragør Old City (source: J. Ørum-Nielsen)

3.1 Geometrical studies of urban fabric

To gain a better understanding of Dragør Old City’s urban structure, some geometrical investigations were undertaken. All illustrations are based on the maps taken from Abrahamsen, P. book Historical Houses of Dragør, “Historiske Huse i Dragør” where they were used as a background. Maps such as the one below allow a more precise uncovering of street patterns and their orientations. Elements of the urban fabric, such as streets and lanes, and squares and square-like features (‘pockets’) can be observed. Primary streets going from west to east, and lanes cutting the city’s north-south axis form an almost perpendicular intersection. However, one can not talk of the typical gridiron form introduced in cities developed during the same period in Denmark and other European countries. “Use of the
gridiron, history’s oldest known urban form regulator, conforms to the ideals of aesthetic uniformity, even if the resulting townscape all too frequently reveals this to be mere monotony”. The situation in Dragør is definitely the opposite. It consists of broken and differentiated street patterns of different form and width, displaced streets courses and a spread street development. Dragør therefore appears freer than the chessboard planning typical of other cities.

![Fig. 2 Street patterns in Dragør (source: author)](image)

The way in which streets and lanes connect borders of the city can be seen in Fig. 3. Streets do not appear as dividing elements, apart from the broadest of them, Kongevejen (King Way), in the northern part of the city, and Strandgade further South, which connect both edges from the western border to the harbour. The rest of the streets are simply used as entrance ways to the houses in the central parts of the city.

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Thinner lines of lanes appear as secondary street types; this can be verified by investigation of the width of all streets shown in Fig. 4. The following types were characterised: Black lines—streets over 10 metres, mostly on the outside of the city border; Green—streets between 7-9.3 m; Blue—‘town squares’; Yellow—lanes narrower than 5 m; and Red—mews under 2 m.
P. Abrahamsen, in his publication *Historical Houses of Dragør* (Danish title “Historiske Huse i Dragør”) states: “A very important feature of Dragør’s town plan are the many ‘squares’ and square-like features that break street patterns. It is moreover characteristic of the unmonumental attitude, and the expression ‘market-place’ is never used, even if the square has this character. An essential element of the city’s preservation involves taking a position on the future look of the square, taking in to consideration the distinctive architectural surroundings and vegetation. As a result of traffic policies, most of the markets have changed from being traffic areas into recreational pedestrian fields.”

In this study, a new term has been assigned to describe what Abrahamsen calls a ‘square-like feature’. ‘Pocket’, in this author’s opinion, is able to characterise those forms visible on the plan of Dragør. They occur mostly in the middle of the city, where building density is most pronounced. Varied in forms and shape, ‘pockets’ have similar purposes as squares in other cities, though their character is much more private and can be classified as a semi-private urban form. Natural light qualities relating to this urban form will be investigated later in this chapter.

Fig. 5 ‘Pockets’ - a newly introduced urban form (source: author)

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25 Abrahamsen, P., Historiske Huse i Dragør, Nationalmuseests ”afd., p.102
3.1.2 Form and void

The area (Fig. 6) marked with a red rectangle (between Strandgade in the North, and Von Ostensgade in the South, with Bjergerlav in the middle; north-south alleys Slippen, Trein Jylmands Gade, Hollandsfed, and mews Vægterstræde, Kampensgade, Deventergade and Smedegangen on the eastern side with views to the sea) was designated as the section of town to be investigated. The city’s repetitive structure allowed one to concentrate on this section of the town as a representation of the urban fabric of Dragør Old City. The size of the chosen area is approximately 85 m x 270 m and includes all the urban elements typical of Dragør, such as streets, lanes and ‘pockets’, as well as the two typical types of buildings.

Fig. 6 Plan of Dragør highlighting section used for a part of the primary investigations (source: author)

The diagrams below show the space division in the section of the city chosen for detailed investigation. Firstly, streets and residential areas, including gardens, were separated (Fig. 7), though in order to observe factual division between form and void, gardens and yards were added to the space created by streets. The conclusion made from the measurements is that the distance between houses lies between 5.7-7.1 metres and 21 metres. Measurements performed
in AutoCAD show the numerical relationship between form (9690 m²) and void (for a section area of 22950 m²). It was concluded that form represents 42% of the whole section, with a 1:1.3 ratio to void.

Fig. 7 Space division between streets (black), gardens (grey) and houses (source: author)

Fig. 8 Space division between form (red) and void (black) (source: author)

Fig. 9 Space division between form and void, the negative (source: author)
3.1.3 Compass orientation

Most of the houses are north-south oriented, though some of them stray from this description by between 5 and 12.5 degrees to the south-east. West-east oriented houses are noticeable in the western areas, on the borderline of the Old City, along with a few other examples, such as the two-storey dens built in the east and the enclosure of the only preserved farmyard. Some of them vary from the compass by between 7.8º and 11.3º to the south-west (see Fig. 10 below). The best orientation, calculated for Dragør’s climate (see Fig. 10, page 48) by the Ecotect weather simulation program, recommends an orientation of 162.5º SE. A comparison with geometrical analysis performed on the map of the city shows a very small deviation from the recommendation, an orientation mainly between 167.5º and 175º SE. It never reaches the worst possibility shown in Ecotect, of 130º SE.

Fig. 10 Orientations of buildings (source: author)
Obvious orientation change in the middle of the diagram (the area marked with a red line) possibly suggests that a new comparison should be done to determine the existence of a relationship between a building’s age and its orientation. A study of old maps of Dragør (see Figs 8, 9, 10 & 11 on page 33) and the map showing the age of houses (see Fig. 6, page 31), as well as an examination of the orientation on the diagram above, did not uncover a direct relationship. Most of the houses in Dragør Old City stem from the period between 1750 and 1811, and follow a street pattern that already existed on the map from 1746; which most likely follows a layout dating back to 1400 (Fig. 8, page 33).

Fig. 11 Recommended orientation (source: Ecotect, author)

The comparison of the length of south to west façades, while cognisant of the fact that houses are mostly oriented in these two directions and that the fronts of the houses face them, can inform us of the proportions between these two. Numerical studies were performed, as they were in chapter 3.1.2 on Form and Void, in the section covering the city plan (Fig. 14 and 15 page 53).

The ratio of façade length to the section area was calculated as 1:1.4 for south facades and 1:2.4 for west.

Because not all west-facing facades have windows (very often they are just gable facades with single small windows), the importance of their relationship with daylight can not be overestimated.
Fig. 12 and 13
Diagrams of the south (left hand side) and west (right hand side) facades, showing their length on the city plan (source: author)

Fig. 14 Section of the city map showing south façades, ratio of façade to area is 1:1.4 (source: author)

Fig. 15 Section of the city showing west façades, ratio of façade to area is 1:2.4 (source: author)
3.2 Density

Urban density is one of the elements that should be considered if trying to achieve an environmentally responsible urban structure. Utilisation of the daylight access to the houses and gardens, as well as public spaces, could potentially improve the quality of life in cities through the application of the principles of ecological sustainability into planning.

In his book, *Design With Nature*, Ian McHarg talks about a “pathological togetherness” where, as “density increases, so do social pressures, which manifest themselves in stress disease …”\(^{26}\) He says the evolutionary reason for this pathological behaviour is that “stress inhibits population growth”. It is nature's way of fighting increased density. McHarg appears to disagree with Jacobs,\(^ {27} \) and concludes that of all the urban stress factors, “the single obvious one is not poverty, but density …”\(^ {28} \)

The *Rough Guide to Sustainability*, by Brain Edwards and Paul Hyett, recommends a theoretical density of 200 dwellings per hectare for urban housing, with three or four storey buildings preferable. As they state: “urban structure of this density consumes less than a third of the fossil fuel energy that suburban housing constructed at 20 units per hectare consumes”,\(^ {29} \) though they later admit that beyond 80 dwellings per hectare, overshadowing makes it difficult to take advantage of passive solar gain. But they do not mention other aspects of density, such as access to the daylight and its importance for humans, that should be considered as elements of environmental design.

Population density can be used as a measurement of any tangible item. However, it is most frequently applied to living organisms. Population density is usually expressed in terms of items or organisms per unit area. For human beings, population density is the number of persons per unit of area (which may include or exclude inland water), though it may also be expressed in relation to habitable, inhabited, productive (or potentially productive) or cultivated area. It is frequently measured in persons per square mile or persons per square kilometre or hectare.

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\(^{28}\) Ian L. McHarg, *Design with nature*; p. 45

Planners should probably reconsider dictating unrealistic and artificially high density targets. A more rational approach is to let cities design and build neighbourhoods at densities that the residents actually want to live in, as can be learned from this case study of Dragør Old City. A compact urban growth form that optimises both the land use settlement pattern and infrastructure delivery costs can still be created. As the market demand changes over time with population demographics, so too should the density be adjusted according to those changes.

Before looking at the specific density in Dragør, a brief look at the density of different European countries could be useful.

<table>
<thead>
<tr>
<th>Country</th>
<th>Density per sq. Km:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monaco</td>
<td>16329</td>
</tr>
<tr>
<td>Netherlands</td>
<td>477</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>246</td>
</tr>
<tr>
<td>Switzerland</td>
<td>176</td>
</tr>
<tr>
<td><strong>Denmark</strong></td>
<td><strong>125</strong></td>
</tr>
<tr>
<td>Austria</td>
<td>97</td>
</tr>
<tr>
<td>Irland</td>
<td>56</td>
</tr>
<tr>
<td>United States</td>
<td>31</td>
</tr>
<tr>
<td>Sweden</td>
<td>20</td>
</tr>
<tr>
<td>Iceland</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Fig. 16 Density of chosen countries in Europe, density calculation is based on total area, including inland water; source: http://en.wikipedia.org)

Housing density in Denmark can be classed as middle-scale. Dragør Old City covers an area of 270 m x 380 m - 102600 m2 = 10 ha. It is inhabited by 1103 dwellers, in 375 houses: approximately 400 dwellings. Using this data, one can conclude that density in the area is equal to 40 dwellings per hectare. Though this is much lower than that recommended in the *Rough Guide to Sustainability*, it should be considered much more preferable from a natural lighting and solar exposure point of view. It is also double the typical suburban density of 20 units per hectare. Person per square metre density in Dragør Old City is 93, much lower than the Danish average of 125 (see Fig. 16), but quite high considering the city consists mainly of single storey housing.
The relationship between density and natural light levels will be discussed in the following chapters. Factors influencing the quality of life in Dragør Old City will also be described, based on data gathered from interviews conducted with the city’s citizens. A common response from interviewees related to the importance of behaving appropriately while at home. The close proximity to neighbours encourages residents to often shut their windows to avoid private discussions being made public. When entertaining, residents are also mindful of keeping noise levels down, so as not to disturb others. In response to a question concerning the level of housing density and how it influences their daily life, some respondents expressed frustration at being part of such a close-knit community. One respondent was actually selling her house for that very reason, as well as concerns about the distance from her place of work, and family and friends in Copenhagen. One interviewee was in the process of looking for employment, and therefore didn’t plan on staying in Dragør much longer. Quite opposite sentiments were expressed by those who had lived in the city for 15 years or more. They were more appreciative of the lifestyle, pointing out such benefits as safety, neighbourly cooperation and help, and an overall contentment with their place of residence.
3.3 Studies of architectural elements

The types of houses in Dragør Old City have already been described in chapter 2. Two main types were mentioned: an elongated, pitched-roof one storey house and a two-storey, so-called “Skipperhus” (Skipper house). As already described in previous chapters, Dragør’s architectural forms are dominated by narrow plan buildings with a width seldom extending above 10 m. Most of them are between 6–8 m in depth and oriented in a south-north direction, with the longest façades facing south. Buildings are also quite low, with façade height seldom higher then 3 m when measured from the street level. The height inside most of the houses is between 2.25 and 2.5 metres. As a result, windows are only elevated between 1–1.5 metres above the street level; though sometimes higher for gable windows or windows in smaller rooms situated on the west or east façade. The situation is not that different with Skipper houses (two-storey houses). First-storey windows start at the same level of between 1–1.2 metres above the street, with a similar layout on the second-storey.

A quick evaluation of window size in different houses was performed, and, as expected, very few duplications were found. As all the building details were decided on by particular builders or building masters, no standards were applied. Listing a few examples will make clear how much they vary. Measurements relate to two framed windows, and show single frame size: (19” x 34”), (18” x 42”), (17.5” x 44”), (17” x 46.5”), (17” x 46”), (17” x 42”), (17” x 37”), (16.5” x 42”), (16.5” x 41”), (16” x 39”), (14.5” x 44”), (16” x 41”), (16” x 40”), (16”x37”), (16” x 36”), (15” x 38”), (15” x 38.5”).

Fig. 18 Typical Danebrog windows (source: author)

Abrahamsen, P., Historiske huse i Dragør, København : Nationalmuseet, 1979, pp. 45-120
Similarly significant variations were found between other facades. Also, different types of windows, in all possible shapes, are used to form the typical Danish model, called the Danebrog window, whose divisions are approximate to those on the Danish national flag (see Fig. 18). It should be mentioned, however, that in general these windows are much smaller than the modern standard. A typical modern Danebrog window can be used as an example: its size varies from between 80-120 cm in width and 130-189 cm in height.

Fig. 19 Other typical window shape (source: author)
3.3.1 Characteristics of materials (external surfaces)

The type of materials allowed to be used in the construction of buildings and streets is restricted by law—all public spaces must be covered with such materials as paving-stones, granite tiles and ‘bordursten’—granite, sandstone or basalt. Houses are brick, half-timber or timber constructions, above the foundations, with pitched roofs covered with straw, tile or boards and slabs. Almost all houses are plastered and, in accordance with tradition, painted yellow. Houses painted white or light grey are much less frequent. The Dragør Historical Museum contains information about the origin of Dragør’s yellow houses, which were introduced by building master J.H. Blichman (1739-1825) about 200 years ago.

Optical properties of the materials used in Dragør Old City will be investigated in this chapter to specify their role and influence on the levels of natural lighting both inside buildings and outside. The figure below shows the main components of a skylight used to influence the level of natural light inside a house. After direct light (sky light, not sunlight) reflected light makes the most significant contribution to indoor natural light levels. As external reflected light is the element most relevant to this study, it will be used as a reference in the discussion of the optical properties of the materials used in external construction.

Fig. 20 The main components of the skylight (source: Bell, J. and Burt, W.)

The amount of light reflected depends on the reflectance of the surfaces (Appendix 1, calculations of reflectance). Detailed investigation of the luminance qualities of materials was undertaken during my visits to Dragør. The results of this investigation were subsequently
used to perform the reflectance calculations shown below alongside photographic registration of the most commonly used colours.

The hemispherical-hemispherical reflectance ($\rho_{hh}$) of materials was calculated according to the following equation:

$$\rho_1 = \rho_{\text{white}} \times \frac{L_{\text{surface}}}{L_{\text{white}}}$$

$$\rho_2 = \rho_{\text{grey}} \times \frac{L_{\text{surface}}}{L_{\text{grey}}}$$

$$\rho = \frac{\rho_1 + \rho_2}{2}$$

The following figures were used in calculations: grey card reflectance for grey –18%, for white – 90 % and for black – 3%.

Fig. 21 Fogdens Square (yellow plaster) material reflectance 50.2% (source: author)

Fig. 22 Fogdens Square 2 (yellow plaster) material reflectance 52.5% (source: author)
Fig. 23 Fogdens Square 10 (white house – white plaster) material reflectance 79.5% (source: author)

Fig. 24 Fogdens Square 3 (yellow plaster) material reflectance 45.5% (source: author)

Fig. 25 Fogdens Square 4 (rough surface- of yellow plaster) material reflectance 50% (source: author)
The results of the calculations of the reflectance properties of surfaces in Dragør show the amounts of light they reflect. This fact is of obvious importance in discussions on sky component’s complexity.

Reflectance values of the plaster used in the city vary between 45.5 % and 52.5 %. Plaster at the Fogdens Square 10 ‘white house’ has a reflectance value of 79.5%. Porosity of the plaster at the Fogdens Square 4 does not vary much, and the value of its reflective property is 50%.

The only material with very low reflective qualities is the paint used on the city’s woodwork—it's reflectance value is 7%. When compared with reflectance values of interior materials, one can conclude that the relatively bright colours used on facades more than likely has an influence on the city’s light levels.
Together with light, the colour of the walls of the building on the opposite side of the street is also reflected in to the room. The bright yellow of the neighbouring house is reflected on the interior walls, in a similar way as that shown in the photo of Gonville & Caius College (Cambridge) below, where the grass has been reflected on to the walls of the inside of the building, colouring them with a green hue.

Fig. 28 Grass from the outside reflected inside the building, Gonville & Caius College, Cambridge (source: author)

Further questions relating to the choice of colour of Dragør’s facades are if and how it influences the people living there. It is a known fact that in fashion, advertising and presentations, colour is one of the most effective tools. Psychologists have suggested that colour impression can account for 60% of the acceptance or rejection of a product or service.

In the book *Colours*, by Rem Koolhaas, Oma, Norman Foster and Alessandro Mendini, the authors present a total of 90 colours accompanied by comments on their background, significance and applications. Their study of the colours in each of their offices displays a comprehensive and consistent presentation of the varying approaches to colour. The examples used of colours in practice include load-bearing structures, facades, interior designs, furnishing, and the entire spectrum of product design.
The influence of colour on mood and feeling has been the subject of psychological study, though the precise nature of this influence is still not well understood. Research on the psychological aspects of colour is difficult for the simple reason that human emotions are not very stable, and the psychic make-up of human beings varies from person to person. Nevertheless, there seem to be a number of general and universal reactions to colour, common to most people. In terms of fundamental psychology, Freudians relate hues back to bodily function—blood, faeces, and so on; while Jungians tend toward a more liberal interpretation of hues, believing the individual's response to colour too complex to allow a simple (sexual, for example) mode of interpretation.

Evan Thompson, in his publication *Colour Vision: A Study in Cognitive Science and the Philosophy of Perception* 31 continues to debate the ontological status of colour, most introductory psychology textbooks today begin with a remark to the effect that colour is a psychological phenomenon, an entirely subjective experience” 32.

The question of whether the colour of Dragør Old City influences the emotional life of residents would be an interesting one to investigate, but it is an issue separate from the topic of this study. One conclusion, however, can be made from on-site observations: the colour most commonly used is a bright yellow with a high chromaticity level and a very pure hue value. There is no white, black or grey present in a colour that has high chroma. These colours appear very vivid and intense.

A colour without hue is achromatic or monochromatic and will appear grey. For most colours, as the brightness increases, the chroma of each increases as well. Could the use of colours with high chroma levels be more suitable for climates such as Denmark’s where the sky is predominantly grey? For the time being, this question will have to remain unanswered.

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31 In philosophy, ontology is the most fundamental branch of metaphysics. It is the study of being or existence, as well as the basic categories thereof. It has strong implications for the conceptions of reality. (http://en.wikipedia.org/wiki)
3.3.2 Glazing ratio of facades

The glazing ratio in buildings, defined as the area of glazing divided by the area of exposed exterior wall, can be a major determinant of solar gain and interior light levels. As detailed in the LT-Method\textsuperscript{33} manual, a low glazing ratio will limit natural light levels. The role openings play in the energy balance of the whole building naturally depends on the glazing ratio of the facades, the ratio between glazed surfaces and the building volume. In the case of existing buildings, the orientation and level of solar access provided by the facades is already known. What can be learnt from the buildings of Dragør is the relationship between the different elements that influence light qualities and the environment that has influenced them. The glazing ratio of the facades can generally be considered as constant, since it is seldom required to be changed.

![Glazing ratio diagram](http://www.esru.strath.ac.uk)

Fig. 29 Glazing ratio (source: http://www.esru.strath.ac.uk)

From the calculations (Appendix 2) based on the investigation of 15 houses in Dragør, it was established that the glazing ratio varies between 6\% and 20\% for southern facades, and between 6.5\% and 18\% for northern facades. Almost all of the houses are oriented south-north, though one can conclude that the glazing ratio more often relates to the direction the windows face, rather than the orientation of the house. In Von Ostensgade 13, for example, the glazing ratio of the northern facade is much higher than for the southern, being 18\% and

6% respectively. In this case, the northern façade faces the street, while the southern façade faces a private garden. A similar situation was observed at Von Ostensgade 10, where the glazing ratio for the northern façade is 13.5%, and 6% for the southern. A similar relationship exists at Strandgade 12 and Strandgade 3; the northern façade facing Badstuevælen, a city square, in the former case, while facing a street in the latter (see Fig. 30).

Of course, it is difficult to say if these were conscious decisions made by the builders. In any case, all of the buildings more or less face an open or wide space—in the form of wide street, a city square or a big garden. The least distance to another structure is 8.5 m; the greatest being from those facades facing an open area of the city square. This could be considered an efficient layout, in terms of receiving light from an unobstructed sky, even when overcast.

![Fig. 30 Houses with high glazing ratio on northern facades (source: author)](image)

The average glazing factor for northern facades is 12%, while for southern facades only 10%. The highest glazing ratio, 21%, was calculated for western façades at the Von Ostensgade 2/Vestgrønningen 28. This building is oriented west-east and will be investigated further in the chapter devoted to the issue of daylight.


3.4 Natural Light

Previous chapters have looked at aspects of the urban and architectural form from an historical and organisational point of view. In this section the relationship between those perspectives and quantity and quality of light will be discussed, based on the results of an analysis of on-site measurements.

Daylight is defined as the combination of sunlight and skylight. On a clear summer day, outside light levels can be as high as 100,000–120,000 lux on a horizontal surface, whilst on a dark overcast winter day this might fall to around 4,000-5,000 lux (depending on the latitude of the location). Water also has an influence on light levels, which is particularly noticeable in small countries surrounded by the sea, such as Denmark, where even during overcast conditions light levels can reach 10,000, and even up to 20,000 lux. Daylight refers to the level of diffused natural light coming from the surrounding sky dome or reflected off adjacent surfaces. Sunlight, on the other hand, refers to direct sunshine and is very much brighter than ambient daylight.

The sun’s position in the sky varies markedly throughout the day and, when viewed from any particular point, is often obscured by clouds, trees or other buildings. It also experiences significant changes in intensity at different times of the year. Thus it does not make a very reliable source from which to light the inside of a building. Direct sunlight is rarely included in architectural daylighting calculations, but in this case it would be useful to calculate overshadowing and solar exposure of buildings to uncover the relationship between sun movement and availability of solar energy, in the context of Dragør Old City. Daylight is obviously a very effective source of light, even on the darkest, most overcast day. Daylight levels can also be quite variable and depend on the amount or type of cloud in the sky and the time of day.

Firstly in this chapter, aspects relating to the presence of sunlight will be examined. Daylight and the qualities typical of the worst possible conditions, characteristic of this region, will then be considered. The question of how environmental conditions change at each stage of the spectrum of light will lead the investigations.
3.4.1. Sunlight

This chapter will concentrate on the relationship between urban architectural elements and solar exposure. Using Ecotect, a building design & environmental analysis program, and FormZ 3D program, solar exposure of facades and urban spaces will be analysed.

Fig. 30 A bench placed on the western façade - under the evening sun (source: author).

Solar exposure is an important aspect of building design and urban design in general. Looking at the relationship between the entire urban fabric and single buildings, one can predict the possibility of excessive solar exposure - a main cause of thermal discomfort in buildings even in relatively cold climates. It is also one of the most effective sources of natural energy for passively influencing a building's environmental performance. Studies of sunlight patterns were performed in Ecotect and FormZ by modelling a section of the town to discover the spectrum of its solar exposure.
Before analysing solar exposure, Danish sunlight conditions will be briefly explained. In Dragør Old City, at a latitude of 55°36′ N, the sun's path is 270 degrees wide at the summer solstice, with a maximum solar altitude of 58 degrees. At the winter solstice, the sun's path is 90 degrees wide, with a maximum solar altitude of 11 degrees. This results in a high summer sun and a very low winter sun, creating long shadows. This is the opposite to, for example, southern Greece—at a latitude of 36°N, the sun's path is 240 degrees wide at the summer solstice, with a maximum solar altitude of 77 degrees. At the winter solstice, the sun's path is 120 degrees wide, with a maximum solar altitude of 30 degrees.

![Fig. 31 Sun path for Copenhagen (source: Ecotect)](image)

Fig. 31 identifies the different levels of solar exposure across Dragør Old City. Darker areas represent the best lit urban spaces—often private gardens and yards (C), and in the case of (A) and (D), urban squares. Area (B), and the façades in general along Street – Strandgade receive the highest levels of exposure. The width of this street varies between 7.1 m and 8.5 m; if garden and yard width are included, the distance between buildings stretches to between 10 m and 17 m. Rectangular or square-shaped urban pockets of between 20 and 40 metres are obvious cases. Area (C) is as an exception as it consists of a large garden space atypical of the urban geometry.
Fig. 32 Solar exposure in the cityscape on 21 March; darker grey areas marked with A, B, C, D show spaces with the highest levels of exposure—numbers relate to most overshadowed spaces (source: author)

The illustrations below (Fig. 33, 34) show solar exposure levels on the buildings in one of the most dense areas of the city. In this section the ratio of building to garden is 1:1. Solar exposure levels were recorded on 21 March, and results display sites with shadow patterns. Regions marked with red arrows show the highest exposed parts of gardens and buildings. Another observation is that, in almost all cases, the roofs of buildings in Dragør Old City have the highest possible level of solar exposure. Therefore, the best lit spaces will tend to be the attics, which in most cases are used as the main living space.

Fig. 33 Shadow Patterns in the section of the city where density is highest, 21 March (source: author)
The investigation of another section of the city, an area between von Ostensgade and Bjergerslav (shown on the illustration above), shows the important role building displacement in relation to the street level has in determining the level of solar exposure. Thanks to this urban intervention, houses that would otherwise have had to depend on sunrays reaching façades in short periods from the south, are able to light rooms in the evening. Displacement ratio can be formulated as 1/2:1/2, where 1 responds to the building’s width (see Fig.35).
The geometry of the most characteristic spaces will be looked at over the following pages. It is already known that the distance between buildings plays an important role in determining the level of solar exposure received by the city’s façades, but in the case of Dragør Old City the relationship with roof angles should also be considered. The two most typical relationships will be examined: the first is a 7-metre-wide street with adjacent houses; the second where this distance extends to 9 m. The importance of other urban forms, such as pockets and squares, in relation to natural lighting conditions and their influence on the levels of light in buildings has already been covered in the discussions on the city’s solar exposure. Also, features such as very narrow mews of up to 2 m width will be shown, as they are a regular occurrence towards the edges of the city, but are more of a negative influence on natural light levels. They are often connected to private gardens and yards, and their primary importance lies in determining the real distance between buildings. They are also situated in a way that provides a path just behind the northern wall of the previous building and, even if bordered with fences, do not have any influence on the solar exposure of the northern building.

Fig. 36 Geometrical relationship between buildings alongside a 7 m street in relation to sun angles (58º for summer and 11º for winter) (source: author)

The first geometrical relationship that will be described is that in which the distance between two houses in Dragør Old City equals 7 metres, with a 45º solar angle of the obstructive building. In this case solar exposure of the house behind would be 23º (Fig.36) at the height of 1 metre (typical height of windows in Dragør). Another important relationship which should be looked at is the repetitive value ratio between the height of the roof and the body of the building itself. As one can see from the figure above, this ratio is 1: 1 1/5. The yellow triangle represents sun angles characteristic of the area; being 11º in winter and 58º in
summer, as previously mentioned. From these relationships, it can be concluded that only during the winter months would the sun altitude would be so low as to be blocked by the neighbouring building in the south.

Another condition is sun availability at the attic space of the one-storey building. Here the obstruction angle is only 12°, which means that even in winter months it is possible for sun rays to reach the window surface.

Fig. 37 Geometrical relationship between a building’s first storey, along a 7m wide street, and another building (source: author).

Fig. 38 Geometrical relationship between buildings along a 9 m wide street (source: author).

For a distance of 9 m between buildings, an angle of 19° is required to reach house windows on the ground floor (Fig. 38), with the same geometrical relations as in the previous cases - 45° roof and building to roof height ratio.
The final situation to be discussed is the one shown in Fig. 39, which occurs in narrow mews with a width of up to 2 m. Seldom do houses’ light levels depend on windows situated towards the mews—as can be seen from the very small amount of sun light that would strike facades placed in this position. In those cases, the houses depend on light entering from the east or west.

Fig. 39 Geometrical relationship between building with 2m mews and another building
(source: author)

The distance between houses determines the significance of daylight levels able to penetrate the interior and the gardens placed in front of them. The main living spaces situated in the south provide a well-lit living and leisure space.

The ratio of the building height to street width (see Fig. 41 and 42) indicates the density of the settlement. A ratio of up to 1 can be considered, in this case, as medium density, while density of 3 or more as high density. From the calculations performed, it can also be concluded that most of the urban spaces, such as ‘pockets’ and the semi-private spaces described as voids (most of the space in Dragør Old City), are of medium-density. It must be pointed out, however, that calculations only took in to account the full height of houses, and not just the space beneath roof angles.
Table 1, Building high to Street Width ratio

<table>
<thead>
<tr>
<th>Type of the street</th>
<th>height/width</th>
<th>ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streets 7-9.3 m</td>
<td>6*/7</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>6*/8</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>6*/9.3</td>
<td>0.64</td>
</tr>
<tr>
<td>*Roof angle not included</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lanes &lt;5m</td>
<td>6/5</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>6/4</td>
<td>1.50</td>
</tr>
<tr>
<td>Mews &lt; 2 m</td>
<td>6/2</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>6/1.8</td>
<td>3.33</td>
</tr>
</tbody>
</table>

Fig. 40 Investigation of sections of the city—building height to street width ratio (source: author)

Table 2, Building high to Urban Space ratio

<table>
<thead>
<tr>
<th>Type of the space</th>
<th>height/width</th>
<th>ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside area, at the edge of the Old City 10&gt; m</td>
<td>6/10</td>
<td>&gt;0.6</td>
</tr>
<tr>
<td>Outside area, at the edge of the Old City 10&gt; m for two storeys houses</td>
<td>7.5/10</td>
<td>&gt;0.75</td>
</tr>
<tr>
<td>Pockets 10-20 m</td>
<td>6/10-6/20</td>
<td>0.6 - 0.3</td>
</tr>
<tr>
<td>Void between houses 6-20m</td>
<td>6/6 - 6/20</td>
<td>1.00 – 0.30</td>
</tr>
</tbody>
</table>

Fig. 41 Investigation of sections of the city—height to depth ratio of the urban space (source: author)
3.4.2 Overshadowing

The effect of adjacent buildings obstructing the sky should be minimised to prevent overshadowing and to provide conditions for the best possible daylighting. This can be achieved by ensuring a minimum separation of buildings along a north-south axis. This subject has, in part, already been discussed in previous chapters, as one can not separate issues of sun availability and overshadowing.

Obstructions to the east and west will shade the low angle sun, causing a useful reduction in cooling load, and possibly removing the need for shading altogether—but it will also obstruct daylight. Obstructions to the south offer less benefit; for unless the obstruction is very high, it will not shade the high-angled summer sun, and will still reduce daylight. Obstructions to the north carry no benefit, only the disadvantage of obstructing daylight.

Figure 42 shows spaces with different overshadowing levels. The less overshadowed areas are 1 and 2, which relate to density levels of up to 1. The area marked as 4 belongs to the category of medium overshadowing, while 3 and 5 show the most dense parts of the city, where overshadowing is almost constant, except during periods when the sun reaches those houses from the east and west.

Fig. 42 Overshadowing of the section of the city on 21 March (source: author)
In the Ecotect simulation program, the southern facades of the buildings were investigated with respect to the overshadowing patterns during the whole year (Fig. 43). A few general tendencies can be outlined: of the 10 houses investigated, almost all reach an overshadowing level of 100% during December and January. This level can fall to around 26-30% during the spring and autumn months, and reach up to just below 60% during the same period. During the summer months, it varies between 50-60%. These values relate to house facades, with walls reaching up to 3 metres above the street level.

Fig. 43 Overshadowing percentage on the southern façades during the year (source: author)
3.4.3 Daylight

The quantity of daylight in an interior is specified by the Daylight Factor (DF), which, in some cases, can be effected by the change of light levels in differing conditions. The ratio of illuminance at a point inside to the illuminance on an unobstructed horizontal plane outside, under a specified distribution of sky luminance, was calculated. The DF was used to establish whether a room has a predominantly daylit appearance or not. All measurements were taken at 80 cm above the floor level and were performed under overcast sky conditions. Unfortunately, there were only two days with weather conditions suitable to undertake these investigations during my visit to Dragør. Therefore, data was only collected for a few houses, which may not be the most accurate representations of the city’s urban structure.

Fig. 44 Section of the city where illuminance levels were measured. (source: author)

The houses investigated are situated in the corner between Von Ostensgade, Vestgrønningen and Bjergerlav in the central-western part of the city—typically elongated houses oriented south-north and border houses with west-east facing windows. In an attempt to establish a picture of the light levels in the streets, illuminance level measurements were taken according to the blue lines on the figure above. Streets connecting the western and eastern edges of the city Strandgade and Von Ostensgade were looked at.
House no.1

The first house investigated was at the Vestgrønningen 22 on the western edge of the city. This is the final building in a row, so there are no neighbouring buildings in this direction. The north windows face a narrow (2.8 m) stretch of Bjergersjøv Street; while the eastern part of the house ends with a close gable façade, and a small garden in the south creates an open space which provides light to the rooms from the south-east corner. In this, as in other buildings, the living-room area was examined, resulting in the recommendation of an average DF of 1.5% for this room type. The illustrations below (Fig. 46 and 47) show that the DF falls to 0.7%, and even to 0.45%, close to the dividing wall. The small room depth and additional window facing north, as well as the high levels of light in the window area, would seem to make it a well-lit room but, according to the owner, it is the first of the evening in which artificial light is used. Another point should be made, namely concerning interior planning. Tasks which require higher levels of light, such as reading, are undertaken in the best lit places e.g. reading area is situated close to the entrance (red cross) where DF is calculated at 8.3%.

Fig. 45 Vestgrønningen 22 (source: author)

Fig. 46 Dayligh factor, Vestgrønningen 22 (source: author)
House no.2

The second house where measurements were taken is a neighbouring house—very narrow and with a small garden on the street side in the west and an even smaller one behind the building in the east. To the south, a one-storey building obstructs southern sun light, though the sheds in the east are the same height as the fences. Windows are situated in two directions: west and east, and the building’s depth is no more than 5 m. The DF amounts shown in Fig. 48 show that light levels are adequate for the room’s purposes. The only place where the owner uses artificial light, even during the day, is marked with a dark cross and relates to the kitchen area.
House no. 3
The third house investigated is located at the Von Ostensgade 2 (fig. 50 and 51), again on the edge of the city, and with windows facing east and west. The DF in the whole space can be described as sufficient for the purposes of the living room.
Only light levels in the living-room on the south side of the building were measured. In the 3 m wide and 12 m long living-room, the DF for a cross-section varies between 7.9%, close to the window, and 0.6%. Similar to the previous examples, placement of furniture relates to the best possible light conditions; therefore light levels on the table standing in the middle of so narrow a room are efficient for its purposes, even though slightly under 1%.
House no. 5

The last building where illumination was measured was at the Von Ostensgade 6st\textsuperscript{34}. The light qualities recorded here were similar to those in the other houses, being quite high close to the windows—8.5% in the south and 5.9% in the north. In the middle of the elongated room, the DF falls to 0.4%; but just like in the earlier cases, the owners take advantage of the best light conditions in the area close to the windows, and situate their sofa table on the one side of the room (south) and dining table closer to the northern windows.

\textsuperscript{34} st., for stue - in Denmark description of the flat at the ground floor (source: author)
An attempt was made to define daylight levels in the urban space, and to this end, the DF for vertical surfaces of the streets was calculated. From the diagram (Fig. 57) showing the average DF on the vertical surfaces of walls and fences, one can discern a relationship between urban form and light levels. One aspect not considered before, though made apparent from the results of the measurements and calculations, is that building details such as overhanging pitched roofs that protect walls from the rain also cover a part of the light that would otherwise reach the windows. The differences in light levels measured under an overcast sky were influenced by this, and the DF values are shown in Fig. 57. Another significant conclusion for urban design can be made from noting the DF in the mews (Fig. 57, right-hand corner). It falls to between 22-23%, compared with an average of 37% in the part of the street with a width of approximately 7 m.

Fig. 56 Differentiation in lighting on facades caused by presents of the pitched roofs (source: author)

Fig. 57 DF on the vertical surfaces of Von Ostensgade and Smedegangen (source author)
3.4.4 Sky Factor and Vertical Sky Component

The Sky Factor is the ratio of the amount of light received directly from a sky of uniform luminance compared to the total amount of light available on a horizontal plane at that same point. Calculations performed in Ecotect gave the following results: for southern facades the average Sky Factor is 40.9%, for northern facades 40.2% and for western, 40.02%.

Fig. 58 Stereographic diagram for southern façade in house no.10 (Ecotect calculated a Sky factor of 34.1% and a VSC of 30.9%. One can also see the shapes of surrounding houses that obstruct sun and view. (source: Ecotect, author)

More important to this investigation is the question of the Vertical Sky Component (VSC), which is a measure of the level of skylight on a vertical plane (it is the Sky Factor on a Vertical Plane). It is most commonly applied to the incidence of light at the centre of a window and in this sense is a measure of the potential for good daylighting levels. The VSC is the ratio of the skylight at a point on the horizontal plane to the unobstructed skylight available at that same point. For a uniform sky, the maximum value is 50% (since the point is on a vertical plane, clearly only half the hemisphere can contribute). For a CIE sky, the maximum value is 39.6%. Facades shown in figures 60, 61, 62 were investigated, but general conclusions can be made from the results of a few typical examples.

For the southern façade of house no.2, where the distance to the neighbour in the south, on the other side of the street, is 10 m, the VSC is 36.4% under an overcast sky. For house no.10
(Fig. 60, page 89) where neighbouring houses are situated closer (5 m to the east, 10 m to the south and 7 m to the west), the VSC is 30.9%. In dense areas, such as behind house no. 26 and no. 27, it is 31.8% and 33% respectively. In the latter two cases, the distance to the closest buildings is no greater than 6 m. To determine the best possible conditions, one should look at a house with an open space in front of it and with no obstructions on either side; house no. 12 is such an example, with a VSC of 37.7%. An even higher value is observed for house no. 1, with the distance to the first obstruction being 17 m. The VSC for this house is 37.9%. The average VSC for southern facades in Dragør Old City is 35.4%, for northern %, for eastern % and for western 34.3%. From the calculation can be concluded that VSC for different directions is quite similar, what shows similarities in space division for the chosen examples. Though it should be underlined that in cases of west and east facades, many of gable to gable situations were not taken to the account, as very seldom they have any function as daylight features see e.g. Fig. 62.

Fig. 59 Calculation of the Vertical Sky Component (source: Waterslade Ltd, http://www.waterslade.com)
Fig. 60 South facades for which calculation were performed (source: author)

Fig. 61 North facades for which calculation were performed (source: author)

Fig. 62 West facades for which calculation were performed (source: author)
3.5 How do people react to their environment?

Interviewing Dragør’s citizens was one of the research methods used in this project. A copy of the questionnaire is included in the appendix, as well as the copies of the performed interviews. Some of the interviewees completed the form themselves; others preferred to answer my questions, in which case I completed the form for them. Because the interviews were conducted in Danish, some of the questionnaires are filled out in Danish and some of them in English. The choice of language was left to the interviewee, with some being better able to communicate their thoughts when using their native tongue. Most interviews were conducted in residents’ houses; others on the streets where residents could be found during the weekend lunch hours.

Unfortunately, only 15 interviews were conducted during my visit to Dragør Old City on the 26th and 27th of June. The reason for this is the difficulty I had in finding local residents. As it was a weekend during a holiday period, many citizens had gone on their summer holiday or to their summer houses. Others were away for the weekend or had gone to meet with family and friends.

Even so, the information I was able to gather was very useful, and helpful in further colouring the picture of the city I have been trying to create.

Conclusions based on the interviews conducted:

Firstly, I must point out that what surprised me most during the conversations with my interviewees was their consciousness of the light qualities of their houses and of the city. In other circumstances, people have often been surprised by my field of research. For almost all of the citizens of Dragør, however, the subject of light inside and outside buildings seemed very natural and did not demand any explanation on my behalf. In a few houses I was even shown a book by Poul Abrahamsen, Historiske huse i Dragør (Historical Houses of Dragør), that was published in 1979 by the National Museum in Copenhagen.

In general it could be said that most of the interviewees were very satisfied with their life in Dragør, and have a very positive relationship with their city. Everyone praised the city’s security and safety which, according to them, was a result of the layout of the city, the closeness between buildings and the strong sense of community. Even those not completely
satisfied in other areas agreed with this. To the question: how would you describe Dragør community? all responses were ‘very good’. At this point I should stress that I mean the actual homogeneity of the citizens living in Dragør Old City. In general they belong to the middle or higher class of the social hierarchy; they may have a good job somewhere outside the city or are on a pension that maintains their quality of life. Almost all belong to the same ethnic and national group, and many of them have lived in the city for ten years or more, others for generations.

Light in houses:
Elongated houses with windows to the north and south have very good light conditions because of the number of windows and the width of the house. In the houses visited, most kitchens were placed on the north side, but windows and reflected light from the southern facades of their neighbours or street-facing walls supplied interiors with a sufficient amount of light.

Ninety percent of interviewees mentioned the living room as the place where they spend most of their time, independent of the time of day and tasks they are performing. Here it must be pointed out that all living rooms, as already described in chapter 2, are evenly situated on the south side of the house or in narrow buildings crossing the whole building from north to south or west to east. Also, furniture is placed close to one side, with often the coffee table on one and the dining table on the other—a traditional Danish interior design layout. In almost every house an armchair was situated close to the one of the windows, which suggests it was used as a place for reading, with daylight as the source of light. Writing tables were often placed close to the south window, which a few interviewees mentioned was the best lit spot in the house for this purpose, e.g. a house at Vestgrønningen 22. Only in a few cases was artificial light used during the day to increase light levels. In most cases kitchens were pointed out as the worse lit space, where artificial lighting was used to increase the level of light. Again, in all cases the layout of the houses was similar, with the kitchen on the northern side of the building and windows overlooking the street or garden.

An interesting issue that was raised with interviewees was the use of curtains. Thin curtains are not traditionally used in Denmark (only rarely, and mostly by the older generation), though none of the houses visited had any form of curtains at all. Curtains are mostly used for aesthetic character, and are never drawn. Only one home owner confessed to using louvers, though only in the evening and because her window faced a bus stop on the street. Generally, interviewees were not bothered by passers-by, tourists or neighbours looking inside.
In one case, the longer distance between house and street was considered a positive factor. The owner was glad to have garden space between her windows and the street, which prevented people from looking directly inside. She also had curtains, but they were used only as a decorative element. It should be pointed out here, however, that this particular house was up for sale. The owner had lived there for three and a half years without having any involvement in the community. As that person stated, the close proximity to neighbours and the fact that she did not have friends or family living in the area, motivated her to move. Other reasons were not mentioned.

Light in streets, gardens and inbetween spaces:
Owing to Denmark’s climatic conditions, outside spaces are very much appreciated—as can be concluded from the interviews. In those houses where the gardens are big enough to be used as an outside space, all residents declare using it whenever possible, independent of the time of year. The areas are mostly used for socialising and gardening, as well as for housework. Almost every garden has a table where one can socialise with family or friends. As gardens are relatively small, every square metre is used very consciously.

It has already been mentioned how important sense of community is for Dragør Old City citizens. Street areas are often used for meetings, markets and other social activities. Bigger parties are often organised in the ‘pocket’ areas when the garden or yard in front of the house is too small for the expected number of guests. Many interviewees also mentioned the importance of the street space, used by their children when they were young as a playground area. To conclude, one can say that the streets and other urban spaces, because of the scarcity of private gardens and yards, play an important part in the life of the community.
Conclusion

The implication of this work for architectural and urban design, as well as case findings, will be discussed in this chapter. By analysing the form and structure of the cityscape and the architectural forms of Dragør Old City, some relationships based on existing material and others uncovered by the author have been found. Possibly all of them can enrich the subject with a deeper insight, if not add any completely new knowledge to it.

The relationship between urban structure, architectural form, and daylight conditions and qualities were the subjects given scope by this thesis. Dragør as a vernacular example was investigated with the hope of finding new relationships and dependencies that could be applied to modern low-rise developments, with stress being placed on issues relating to natural light levels.

Analysis of Dragør’s urban planning uncovered basic patterns. What was particularly interesting, and is something discernible in all quality compositions, is that the city consists of variations and improvisations around one main subject: the division of space between houses and outside areas. Two types of city blocks were separated according to the literature on the subject: elongated north-south blocks with entrances from lanes where the relationship between building and space was like an A: B: A: B: A: B or 1:1:1:1:1, etc. formation; and blocks of elongated houses with entrances from the streets where the relationship to each other was like a C: A: B: A: B: C formation, or in numerical values C: 1: 1: 1: 1: C (street: house: space: house: space: street).

Another urban form that significantly influences the city’s natural lighting characteristics, besides traditional squares, are the square-like shapes that have here been termed ‘pockets’. In the general system of south–north lanes crossed by west-east streets in the most dense areas, small square-like forms appear. They allow the dense urban fabric to breath and are very often used as semi-public spaces, with benches where citizens can meet. The equal division of space and void in the city can be also seen through the VSC values that, in the case of differently oriented façades, are quite similar. Another observed feature was the displacement of buildings in some areas in relation to both the street and each other. This intervention creates a possibility for higher levels of light being received from the west or east, where necessary.

The town appears to have been designed with building exposure to both sun and daylight taken in to consideration, with allowances having been made for conditions of direct sunlight,
as well as the sky light received in the worse case scenario of an overcast sky. Houses investigated in chapter 3, where Daylight Factors were established for living-rooms, almost always reached the recommended values. It should be pointed out, however, that human adaptation to the existing conditions and traditional behaviour, not to mention the lack of curtains and the internal arrangement of furniture, also play an also important role. The best lit places inside the buildings are always chosen for optimum use. Dining or coffee tables are placed such a position that, for most of the day, even with an overcast sky, artificial light is unnecessary.

Architectural elements such as windows were discussed and the glazing ratio was established for several buildings. From this, one can conclude that in houses with small southern windows, light levels are often supported by bigger windows facing the north. One element that couldn’t be investigated, because of its late discovery, was the influence of pitched roofs on daylight levels and sun-ray protection—something that could be compared with the sun protection features on more modern buildings. This could be an interesting subject for further studies. Another subject which did not receive much attention in this paper was the importance of chroma in the cityscape, and its effects from both a psychological and physical point of view.

This dissertation tried to show the importance of both architectural elements and the urban fabric in questions of daylighting, with examples taken from the Dragør Old City. An awareness of detail and differentiation in the urban design would be classed as the most important point of this paper. The balance between structure, system and improvisation should be taken into consideration in future projects and integrated into contemporary proposals; not only to create spaces with a better quality of natural light, but so they might also be better appreciated by residents.
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Appendix 1

Reflectance of surfaces, examples

1. Fogdens plads  photo 96-97

White
$\rho_1 = 90 \times (889/1560) = 51$

Grey
$\rho_2 = 18 \times (889/320) = 50$

$\rho = (\rho_1 + \rho_2) / 2 = 50.2\%$

2. Fogdens plads  2

White
$\rho_1 = 90 \times (812/1340) = 54$

Grey
$\rho_2 = 18 \times (812/285) = 51$

$\rho = (\rho_1 + \rho_2) / 2 = 52.5\%$

3. Fogdens plads  3

White
$\rho_1 = 90 \times (800/1500) = 48\%$

Grey
$\rho_2 = 18 \times (800/335) = 43\%$

$\rho = (\rho_1 + \rho_2) / 2 = 45.5\%$

4. Fogdens plads 4 (rough surface)

White
$\rho_1 = 90 \times (1853/2400) = 69\%$

Grey
$\rho_2 = 18 \times (1853/1075) = 31\%$

$\rho = (\rho_1 + \rho_2) / 2 = 50\%$
Appendix 2

Glazing ratio of facades, examples

Strandgade 3

north 6 x (17” x 49”) (0.43 x 1.246)

one window area 0.535 m2 x 2 x 6 = 6.42m2
façade 14 x 2.5 m = 35 m2

glazing 18%

South 3 x (17” x 46.5”) (0.43 x 1.181)

One window area 0.507m2 x 2 x 3 = 3.042 m2
Façade 14 x 2.5 = 35 m2

Glazing 9%

Strandgade 5

north 5 x (16.5” x 37”) (0.419 x 0.939)

one window area 0.39m2 x 2 x 5 = 3.9 m2
façade 14 x 2.5 = 35 m2

Glazing 11%

West gable 2 double framed

One window area 0.39m2 x 2 x 2= 1.56 m2
Façade 10 x 2.5 =25 m2

1 x (19”x33”) (0.482 x 0.838) x2

0.40m2 x2 x 2 = 1.6 m2

Glazing 3.16 m2 of 25m2 = 12.6%

Strandgade 7

North 3 x (19” x 33”) (0.48 x 0.83) x 2

One window area 0.80m2 x 3 =2.4m2
Façade 9 x 2.5 =22.5 m2

Glazing 10.6%

Strandgade 10

North 3 x (16” x 40”) (0.40x1.01) x2

One window area 0.808 m2 x 3 =2.424 m2
Facade 10 x 2.5 m =25 m2

Glazing 9.6%

Strandgade 12

South 4x (16.5” x 41”) (0.41 x 1.04) x 2

One window area 0.85 m2 x 4 =3.4 m2
Façade 11 x 2.5 = 27.5m2

Glazing 12.3%

Von Ostensgade 2/ Vestgrønningen 28

West facade 4 x (17” x 42”) (0.43 x 1.06) x 2

One window area 0.9 m2 x 4 = 3.6 m2
Façade 7.1 x 2.5 =17.75m2

Glazing 21%
Von Ostensgade 7
North 2 x (18.5” x 43.5”) (0.47 x 1.10) x 2
One window area 1.03 m² x 2 2.06 m²
Façade 7.1 x 2.5 =17.75 m²
Glazing 11.6%

South 2 x (17” x 42”) (0.43 x 1.06) x 2
One window area 0.9 m² x 2 1.8 m²
Façade 7.1 x 2.5 =17.75 m²
Glazing 10%

Von Ostensgade 13
South 2 x (18” x 42”) (0.46 x 1.07)x2 0.98 m²
Window area 0.98 x 2= 1.96 m²
Façade 12.8 x 2.5 =32 m²
Glazing 6%

North 6 x (18” x 42”) (0.46 x 1.07)x2 0.98 m²
Window area 0.98 x 6= 5.9 m²
Façade 12.8 x 2.5 =32 m²
Glazing 18%

Von Ostensgade 26
South 2 x (17.5” x 44”) (0.44x 1.11)x2 0.98
Window area 1.96 m²
Façade 6.4 x 2.5 =16 m²
Glazing 12.25%

North 2 x (16” x 44”) (0.40 x 1.11) x2 =0.89
Window area 1.78 m²
Façade 6.4 x 2.5 =16 m²
Glazing 11%
Appendix 3
Appendix 4

Questionnaire

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June/July 2004

Questionnaire for the project: “The interdependence between architectural form and light in urban environment, based on case study of Dragør, a sea port in Denmark”

House in the context of the neighbourhood

Age  Gender: male (  ) female (  )

Profession:
Active (  ) retired (  ) studying (  )

Address

The type of house two (  ) one storey (  )
Bought (  ) rented (  )

How many persons live in the house?
1 (  ) 2 (  ) 3 (  ) 4 (  ) more (  )

Since when do you live in the house?

Year

If you should buy a house again would it be in Dragør?
Yes (  ), No (  ) Why?

House

1. House usage patterns: at what time of the day, week you are in your house mostly?
During the day: Morning (  ) afternoon (  ) evening (  ) night (  )
During the week (  ) In weekends (  )

2. Which rooms are used during the day for:
Reading  Socialising  Watching TV
Working (on a computer/laptop)

3. Where would you go in your house to get good light?
In the Morning  at Noon  In the Evening

4. Do you use artificial light when you e.g. read during the day and why?
Yes (  ) No (  ) Why?

5. Do you use artificial light in your kitchen during the day hours?
Yes (  ) No (  ) Why?

6. Do you use curtains in your windows during the day?
Yes (  ) No (  ) What type
Explain purpose
Garden
1. Where in your garden do you spend most of the time? (point out on the plan)

2. How do you mostly use the garden?
   Gardening     Socialising     DIY

3. When do you use the garden?
   Just in summer ( ), summer/spring ( ), summer/spring/autumn ( ), whole year ( )

Street/community
1. Do your children play at the streets?
   Yes ( ), No ( )

2. Do you meet your neighbours in the streets, squares to talk?
   Yes ( ), No ( )

3. Are the squares used for special occasions?
   Public meetings ( ), markets ( ), other ( ) what?

4. Is sense of community important for you?
   Yes ( ), No ( )

5. How would you describe Dragør community?
   Bad ( ), normal ( ), very good ( )

6. Is it possible to have privacy and belong to the community in Dragør?

7. Do you travel outside Dragør for recreational pursuits
   never 1 ( ), 2 ( ), 3 ( ), 4 ( ), frequently (5)

8. If so is it elsewhere in Denmark or abroad?

9. Do you have any formal responsibilities in the community (e.g. societies, local council etc?)
   Yes ( ), No ( ), what type?

   Personal interview ( ) or filled in interview ( )