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# **EVALUATING SUSTAINABLE ARCHITECTURAL SOLUTIONS SUCH AS MULTI-ANGLED FACADES IN SPECIFIC URBAN CONTEXTS**

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## **INTRODUCTION**

The multi-angled façade system described here is part of an interdisciplinary study situated within the fields of architectural design and engineering, with a focus on studying and analysing the architectural and technical potential of different renovation strategies.

A multi-angled façade system can be used for a renovation of façades of different orientations, proposing the use of two different orientations of windows in each façade to optimize the use of solar radiation and daylight through the façades, depending on the appropriate window properties and the solar shading control system. This is achieved by designing the geometry of the façade in a close integration of architectural and engineering concerns. Two shading control systems, depending on either solar radiation intensity or operative temperature, are used in this system according to the window orientation. The specific emphasis in this study is on the renovation of the façades of buildings built between 1960 and 1980.

Aesthetically, the multi-angled façade must relate to the urban context in which it is implemented. This paper focuses on the use of multi-angled façade systems in specific urban contexts and analyses their architectural relations to surrounding buildings. The aim of the paper is to structure and qualify discussions about, and architectural evaluations of, the use of multi-angled façades in given urban contexts to further the implementation of sustainable solutions in ways that may architecturally improve the local environment. This is combined with a presentation of the sustainable potential of this façade system in a holistic perspective.

## **METHOD**

A review of the available literature has been performed to investigate the advantages and potential applications of multi-angled façade systems. A qualitative research/ phenomenological method is applied to provide deeper understanding of the implications of implementing this façade system on existing buildings, and to investigate what the impacts of this phenomenon – the renovated façade – may be in an urban context. The study also uses a simulation research method to visualise office buildings renovated with a multi-angled façade system, using the software packages AutoCad, 3D Max and Photoshop. The simulation has been performed in three specific urban contexts, all in Copenhagen: a densely developed traditional part of the city; a densely developed modern part; and a less dense area with, detached buildings.

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## THE POTENTIAL OF MULTI-ANGLED FAÇADE SYSTEMS

### The technical potential

Different scenarios were previously simulated for an office room, and the results show that there is a large potential saving in primary energy consumption when renovating with a multi-angled façade system. The difference in total primary energy consumption between renovating with an energy-efficient flat façade and a multi-angled façade varies between 4.9 and 6.5 kWh/(m<sup>2</sup>•year), depending on the orientation of the façade.<sup>1</sup>

The more the façade is oriented to the south, the greater the energy saved. A large part of the saved energy is for electrical lighting: between about 1.4 and 1.8 kWh/(m<sup>2</sup>•year) compared with renovating with an energy-efficient flat façade. This is because there is greater daylight penetration through a multi-angled façade, through the large part oriented more to the north. There is also greater energy saving for heating with a multi-angled façade system, about 1.1 to 3.1 kWh/(m<sup>2</sup>•year) compared with renovating with an energy efficient flat façade. The situation where the large part of the multi-angled façade is oriented more to the north and the small part of the multi-angled façade more to the south is preferred as it has a significant impact on primary energy consumption, which is lower by about 5.9 kWh/(m<sup>2</sup>•year) than if the large part of the multi-angled façade is more to the south and the small part of the multi-angled façade is more to the north, due to less ventilation demands.<sup>2</sup>

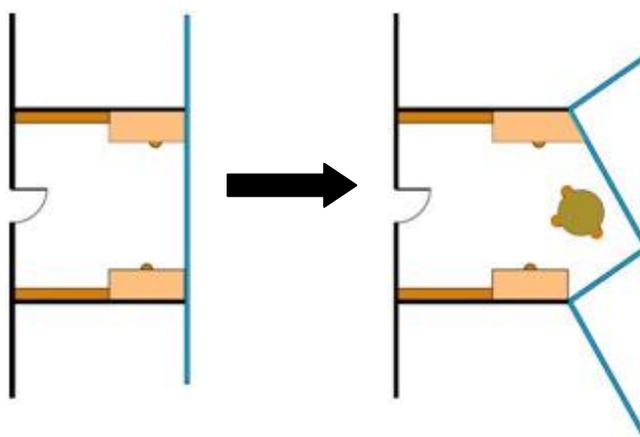


Figure 1: Renovating the flat façade of a cell-office room to a multi-angled façade

In all the scenarios, the number of overheating hours inside the office room exceeding 26<sup>0</sup>C are below 100 and the number of overheating hours exceeding 27<sup>0</sup>C are below 25 hours thus fulfilling the Danish Building Regulations. This is achieved through the correct control of the shading device, the use of a VAV ventilation system and mechanical nighttime ventilation.<sup>3</sup>

### The architectural potential

Using a multi-angled façade provides many potential architectural benefits. Functionally, the multi-angled façade increases the area of the office room and provides more space.

There are also many potential aesthetic advantages provided by multi-angled façades. For example, from inside, the multi-angled façade in general provides more daylight to the office room, which has better rendering, leading to improved optical quality and a positive impact on indoor climate. Multi-angled façades provide a better visual quality for the users inside the office room. A very big advantage may be that, while having the solar shading shut on one part of the room façade, another part of the façade may have no shading, thus continuing to provide daylight and views to the outside

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on sunny days. The multi-angled solution also provides an interesting façade with a more dynamic form from the outside. This will be focused upon in the coming sections in order to evaluate how these façades are perceived from the outside in different urban contexts.

### **THE USE OF MULTI-ANGLED FAÇADES IN GIVEN URBAN CONTEXTS: EVALUATION AND DISCUSSION**

The evaluation of multi-angled façades has been achieved in two ways: The first method was by studying real cases of buildings in Denmark through interviews with the designers. The second method was through a virtual simulation of the post-renovation façades of office buildings built between 1960 and 1980.

#### **Discussing the use of multi-angled façades in real projects in Denmark**

Evaluating and discussing the use of multi-angled façades in a sample of buildings in Denmark was achieved with the help of interviews carried out with the designers of these buildings. Two buildings were chosen as case studies, as described below.

##### ***Horten Headquarters designed by 3XN***

There was a focus, when designing the Danish Law Firm Horten's new head office, on the quality of the surrounding area. There was a canal to the north and office buildings on other sides, so the most attractive orientation was to the north. By directing the building to this orientation, it was also possible to block the sun from the south and minimise the duration for which the shading devices are shut down.<sup>3</sup> The designer tried to create a visual and optical quality for the people inside the office building and improve the indoor thermal climate.

There was a focus on the correct choice of cladding materials for the building. The designers believed that using natural stone sourced from Italy with a beige colour could create an expression of trust,<sup>5</sup> and thus succeeded in creating an expression that suits the function of the company.

An interesting characteristic of this building façade is that when viewers come from the south they will only see a stone façade, and when they approach from the north they will see only glass, while from the east and west they will see a pattern combining glass and stone.<sup>6</sup> This sudden change in the façade when moving around it gives a feeling of interest to the viewers.



Figure 2: Horten Headquarters designed by 3XN, Hellerup, Denmark  
Source: 3XN website, <http://www.3xn.com>.<sup>4</sup>

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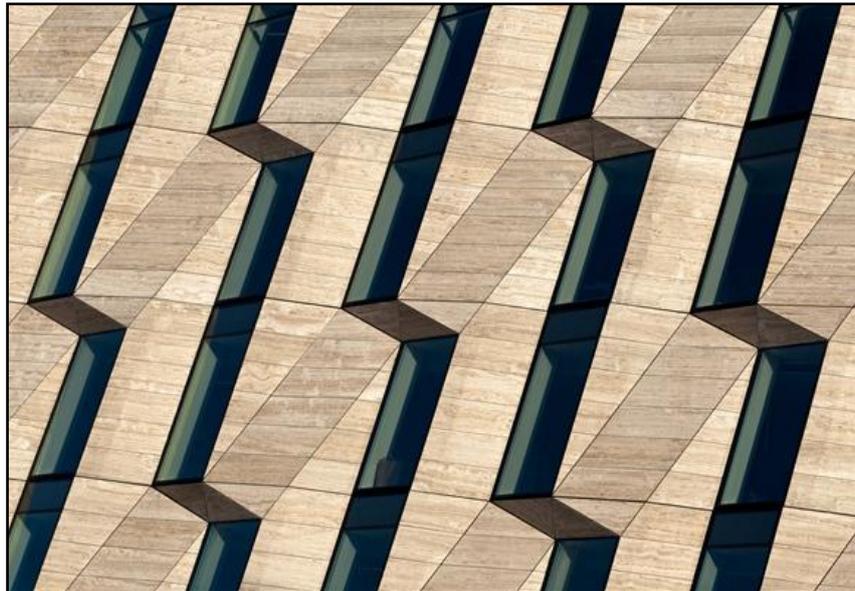


Figure 3: The interesting pattern of the façade which is based on the repetition of more than one element<sup>8</sup>

The designers tried to create a pattern based on the repetition of more than one element, thus creating a dynamic form for the façade which was mirrored in the façade on the other side of the building.<sup>7</sup> However, the designers also attempted to avoid creating an expression that might be boring if repeating one element only in a simple way.

On the other side of the canal there is a shopping centre where people can sit and enjoy the view across to the Horten office building, so the appearance of the façade is important for the street and the viewers on the other side of the canal.<sup>9</sup> This reflects the impact of the façade design on the people working or shopping in the surrounding areas.

### ***The Culture Yard designed by AART***

The vision behind the Culture Yard is to provide a setting for a vibrant cultural life and preserve the identity and historical value of its former shipyard location.<sup>10</sup> This will increase satisfaction among the local population through preserving their heritage.

In order to create a coherent expression and interlink the existing buildings, a multifaceted façade of glass, steel and sheets was developed based on triangles in different geometric expressions, where all design elements are designed individually. The transparent façade also reinforces the relation between inside and outside.<sup>11</sup> Local people or the visitors can enjoy the magnificent sea view and view of Kronborg Castle from every floor of the building.

The façade encloses the yard in a distinctive atmosphere, as the dazzling and dramatic play of lines generates a sense of spaciousness. Although the façade is made of hundreds of lines and triangles it appears as one big volume, generating a sense of place and time.<sup>12</sup>

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Figure 4: The multi-angled façade of The Culture Yard<sup>13</sup>

## Virtual simulation of the façades of office buildings built between 1960 and 1980 following their renovation

Three cases of office buildings built between 1960 and 1980 are virtually simulated to evaluate architecturally the impact of renovating them with multi-angled façades to surrounding buildings in different urban contexts. The architectural evaluation is based upon six of the main constituents of architecture: form, style, rhythm, transparency, colour and texture of both the multi-angled facade and the urban context. The configuration of the multi-angled façades of the three real cases described above, is based primarily on aesthetic considerations, while the configuration of the virtual simulated façades is based primarily on economic and environmental considerations, in particular reducing energy consumption and improving the indoor climate.

### ***An office building attached to a traditional building.***

The neighbouring building attached to the newly renovated office building has a traditional style. Concerning the form, the multi-angled facade has a more dynamic form and the proportion of the windows to the parapets of the renovated building is very different from the small window units in the traditional building. The size of the whole renovated building is much larger than the traditional building. Concerning the style, the neighbouring building has a traditional style with arched windows and with a symmetry around a central vertical axis of the front facade, while the renovated facade has a modern style and sharply angled facade units. Concerning the rhythm, the repetition of the facade units can create a kind of a rhythm, which is very different from the rigid symmetric facade and the rhythm it might express. Concerning the transparency, the new facade elements, are much more transparent than the traditional building with its large area of solid walls.

Concerning colour and texture, the traditional building has a sharp red colour which is different from the brown colour (not sharp but a little dark) of the renovated facade as in Figure 7 and also different from the light coloured facade (not sharp but light) as in Figure 8. There is no texture in the red painted wall of the traditional facade, while the cladding materials (fibre cement plates) might have a texture or a pattern on them.

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*Figure 5: Three perspectives for the attached office building to a traditional building before the virtual simulation*



*Figure 6: A perspective for the attached office building to a traditional building before the virtual simulation*



*Figure 7: A perspective for the attached office building after the virtual simulation with brown cladding material (fibre cement plates)*

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*Figure 8: A perspective for the attached office building after the virtual simulation with light colored cladding material (fibre cement plates)*

### **An office building attached to a modern building.**

The renovated office building with a multi-angled façade is attached to a building with a modern style. Concerning the form, the renovated building has a more dynamic form. There is also similarity regarding the height of the two buildings and the continuity of parallel rows (windows and parapets) between the two buildings. The proportions of the facade elements (between windows and parapets) are almost the same between the two buildings. Concerning the style, both of the two buildings have a modern style. Concerning the transparency, both buildings have a high transparency. Concerning the rhythm, it is deeper in the renovated facade while it is simpler in the neighbouring facade (only horizontal lines)

Concerning colour and texture, it is possible to create a similarity between the cladding materials of the two buildings. In the case of using different colours on both sides of the multi-angled units, the expression will be sharper and the difference will increase with the neighbouring building as shown in figure 12.



*Figure 9: Two perspectives for the attached office building to a modern building before the virtual simulation*

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*Figure 10: The attached office building to a modern building before the virtual simulation*



*Figure 11: A perspective for the attached office building after the virtual simulation. The same cladding materials are used on both sides of the multi-angle units*



*Figure 12: A perspective for the attached office building after the virtual simulation. Two different types of cladding materials are used on both sides of the multi-angle units*

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### ***An office building detached from a neighbouring building.***

The renovated office-building facade with multi-angled units is detached from the surrounding buildings. The closest buildings to the detached building front facade are across the street. Concerning the form, the front façade after the renovation has a more dynamic form compared to the building to the right. The proportions of the facade elements are different in the renovated facade compared to the buildings across the street to the left (which has also columns) and to the right (which also has separate squared windows). Concerning the style, the renovated facade has a modern style and it is different from the building to the right across the street, which presumably built in the forties or the fifties of the last century. Concerning the rhythm, there is a kind of similarity between the renovated facade and the building to the left across the street regarding the repetition of the facade elements, which gives a rhythm to the façades. Concerning the transparency, the renovated facade has more transparency compared to both buildings to the left and right across the street. Concerning colour and texture, the renovated facade has much lighter colours compared to both buildings to the left and right across the street. The texture of the fibre cement panels used in the renovation has a kind of a pattern and is different from the texture of the brick used in the building to the left across the street.

It is possible to use different cladding materials on the multi-angled units but in a careful way without disturbing the continuity between the side and the front facades (see Figure 18).



Figure 13: Two perspectives for the detached office building's front façade before the virtual simulation



Figure 14: The two side facades of the office building before the renovation, which are detached from the surrounding buildings

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Figure 15: A front perspective for the detached office building before the virtual simulation



Figure 16: A front perspective for the detached office building after the virtual simulation



Figure 17: A side perspective for the detached office building after the virtual simulation

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*Figure 18: A side perspective for the detached office building after the virtual simulation, where the multi-angled façade units have different cladding materials.*

## DISCUSSION

This paper presents an interdisciplinary study situated within the fields of architectural design and engineering focused on analysing the architectural and technical potential of multi-angled façades. From the technical side, the optical and visual potential can be considered to get important benefits from this system. These two potentials provide the possibility of more daylight in the building, and also the consideration that, while having solar shading closed on one part of the room façade, another part of the façade may have no shading, thus providing daylight and views to the outside on sunny days.

From the aesthetic side, the configuration of multi-angled units provides an interesting façade with a dynamic external form in some cases or it might give a noisy expression in some other cases. Different façade cladding concepts are possible, such as the use of contrast and harmony between the two-façade parts through appropriate selection of materials and colours.

Different parameters can affect the acceptance of the renovated building in an urban context and its relation to the surrounding buildings, like whether it is physically detached or attached, the size, form, style, rhythm, transparency, colour and texture and some other properties. When the renovated building is attached to other buildings, careful decisions need to be made regarding the chosen materials to create visual matching with surrounding buildings in the urban context. Having the renovated building attached to a traditional building might create a profound contrast between both buildings' façade designs. The renovated building might be dominating the traditional building, and the latter might have an interesting style that needs to be preserved or maybe only shown without disturbance from other different styles. In this case, the concept of using multi-angled facade might not be suitable. In the case of there being no dominance and there are similarities between the two buildings regarding the size or shape, a careful choice of cladding materials can be made to create harmony or visual matching between the two building expressions. Having the renovated building detached from the surrounding buildings gives more freedom in the design of the new façade's dimensions, colour and texture.

## CONCLUSION

The multi-angled façade has considerable technical potential, especially optical and visual, which can lead to improved indoor climate and increase the productivity of the employees. The configuration of the multi-angled façade might be interesting and dynamic, but not as creative as the configuration of the three real cases discussed in the paper. This is due to the greater focus on the technical potential,

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which affects the configuration of the façade. Having the building detached or attached to neighbouring buildings can have an influence on the freedom of the designer when choosing the cladding materials and deciding their colour, texture and other properties. The choice of cladding materials is important in order to create a kind of harmony between the renovated and the neighbouring buildings and not to be significantly different or in contrast. Having the renovated building attached to a building with a modern style helps the renovated building to be more accepted in an urban context compared to an attachment to a traditional building, which might create some problems concerning the traditional style.

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