Urban Design Alternatives in the Compact City

A Focus on Daylight and View

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Abstract: The compact city is one of the visions for future sustainable cities. The densification of cities often decreases the good daylight distribution and blocks long sightlines. The dark urban spaces with reduced privacy occur especially in the dense central urban districts. Urban design strategies can improve the access to daylight and sightlines. Urban blocks with such strategies can vary in size and proportions. This paper explores urban design alternatives to conventional perimeter blocks and analyses geometric options such as chamfered corners, strategic varied building heights and different positioned openings in a broken perimeter block. As proposed in the new European standard (CEN, 2019), the following three parameters are included in calculations: solar radiation, daylight level on facades and view out. Computer-based daylighting simulations and calculations of view parameters are performed for different designs of the perimeter blocks with equal density. This study confirms that geometrical changes can improve the conditions for views and daylight in the perimeter blocks. The advantages in the tested urban design alternatives are considerable compared to the perimeter block of the standard type. All the alternatives have already been used in practice, but the discovered advantages motivate to more frequent use and hopefully inspire even to new solutions.

1. Introduction

The continuing urbanization in the world leads to expanding cities regarding area as well as the density of the buildings. The compact city has for a long time been in the debate as an idea of a city with many square meters of building per square meters ground area. The argument for the compact city is not only economic. It has ecological advantages with short distances and an intense land use. But, without any special considerations in the urban design the ongoing densification will lead to darker urban spaces. This actual research looks for solutions in the urban design which hamper or at least, moderate the bad consequences for daylight and views in the dense city.

In an earlier study presented at the SASBE conference in December last year, different configurations of tower blocks were analyzed (Sundborg *et al.*, 2018). All the proposed alternatives to the conventional quadratic and parallel plot configurations showed higher solar radiations and longer sightlines. The configurations were evaluated for tower blocks all in seven floors but can be applied for small villas as well as high skyscrapers.

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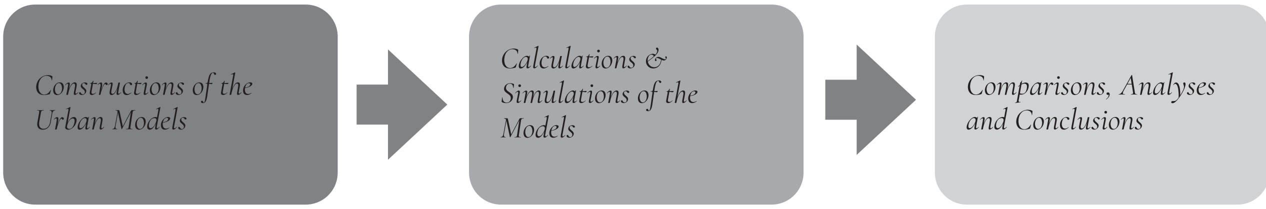


Figure 1. *The three main steps in the research.*

A different type of settlement is a district consisting of perimeter blocks, which has a long tradition within the urban history. The type has survived through the modernist era with its tower blocks and slab houses. The concept of the perimeter block is simple and economical but those who argue for daylight and views are often skeptical. This research has been motivated by the question if a strict conventional perimeter block can be developed in ways resulting with improved daylight and views.

2. Limitations

In the development of urban blocks in the compact city many aspects must be considered. This study is limited by usage of daylight and view metrics for different configurations of perimeter blocks. Both aspects are connected to the way we experience and perceive the urban space. A "high density" city type which feels open and light has economic advantages which we save for further studies.

3. Open versus closed

The calculated metrics are strongly related to openness versus enclosure in different settlements. Before modernism with its open spaces for daylight, the design principle was the opposite – the end of the streets always has buildings. However, an enclosure has difficulties in the compact city depending of its higher buildings and smaller open spaces which makes other design strategies interesting.

The alternative with the perimeter block with openings in the corners to the inner courtyard gives a reduction of the feeling of enclosure. With fences and a gate to the courtyard it is possible to give safety and preserve part of the enclosure and at the same time have more daylight and longer views. However, the only option to combine the daylight distribution, views and a reduction of noise is screens with glass or transparent plastic.

4. Methodology

Every step in the daylight simulation, including the preparation of alternative digital models of the different settlements, has been made with certain assumptions and with the help of relevant programs. The three main steps in the research were: Constructions of the Urban Models, Calculations and Simulations of the Models and Comparisons, Analyses and Conclusions. Similar scientific methodology can be used in practical town planning preferably with objectives adapted to specific urban design relevant for the actual project. Needless to say, for effective work some phases need to be automatized as e.g. calculations of the total building areas. Anyhow, the presented alternatives are probably more interesting for practitioners than the used methodology.

5. The Constructions of the Urban Models

The perimeter blocks are usually rectangular and follow the street pattern. The buildings are often of similar height within each block. Geometric options such as chamfered corners, varied building heights and differently positioned openings in a broken perimeter block may favour the views and the daylight. Some common and interesting alternatives to the conventional perimeter blocks are studied. Varied building heights within the block are also analyzed in this paper. Following sustainable design recommendation, see general guidelines as https://greenpassivesolar.com, the blocks are oriented east-west. The size of the blocks is 100 meter in east-west direction and 60 meter in north-south direction except for the alternative 10 which is quadratic, 77.5 x 77.5 meters, with the density equal with all other alternatives.

The quality of daylight and view in the studied alternatives are measured in ten models with the same density Floor Area Ratio (FAR). The density is here defined as FAR, Floor Area Ratio = total floor area/plot area. A constant value of 1.33 has been chosen where the entire plot has been enclosed by 10 meters of street, which means a total area of 80 x 120 meters (1.33 corresponds to 2.13 counted on only the built plot of 60 x 100 meters). A Floor Area Ratio (FAR) of 1.33 is a relative low value for central districts but high in a suburban context. All alternatives have been developed in Sketch Up-drawings, see figure 2.

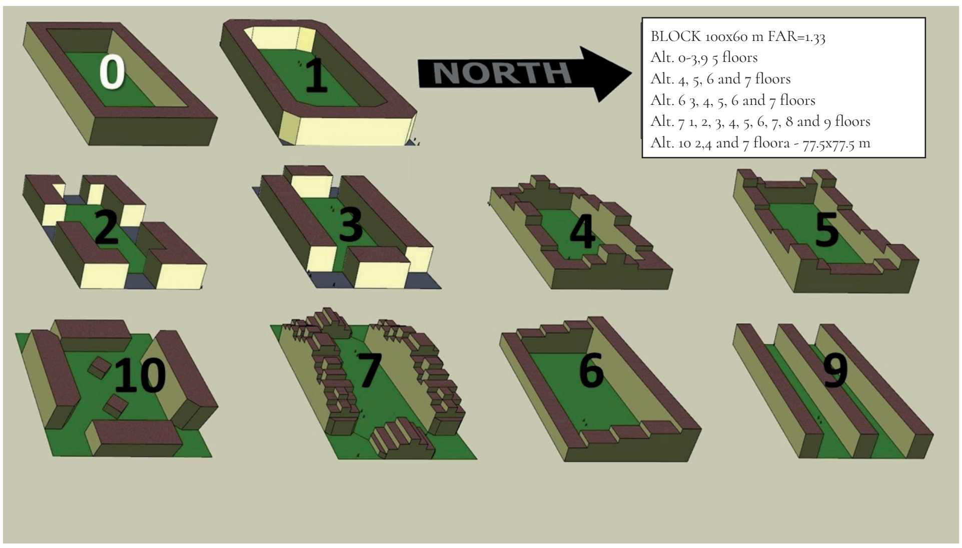


Figure 2. *The ten different alternative of perimeter block.*

6. Urban density

The urban density can be measured in many ways including number of people or building areas. In town planning the exploitations usually are described in FAR = floor area ratio = total floor area/plot area. The same division are also entitled FSI (*floor space index),* FSR (floor space ratio), site ratio and plot ratio. For the technical planning and the projects economy the FAR values are central. However, a good description of the density requires more specifications. One interesting extension of the density measurements has its origin at Delft University of Technology, the planning tool Spacemate (Berghauser Pont and Haupt, 2005). Berghauser Pont and Haupt developed a Spacemate diagram adding GSI, Ground Space Index (amount of built ground in an area), OSR, Open Space Ratio (dividing the total amount of commonly-owned open space on the residential parcel proposed for development by the total area of the entire parcel proposed for development) and L, Layer (average number of floors). That three parameters are all important for the description of the settlement's density. The land use can be totally different comparing two areas with the same FSI = FAR depending of the difference in footprints from the buildings which gives relevance for GSI, OSR and L. In a later paper the use of the axial map developed in space syntax, is proposed to measure distance ((Berghauser Pont and Marcus, 2014). The axial map is a geometric representation of urban space based on graph theory, constructed from the point of view of a human being. The researchers argue for the measure of accessible density and interpret it even as a measure of perceived density.

In the Spacemate diagram below the perimeter blocks in this study are highlighted with a P and our earlier study about tower blocks (Sundborg et al, 2018) with a T. A fictitious and extreme example is Burj Khalifa positioned lonely in a desert land reaching the same FSI as the perimeter blocks. The example, marked with a B, is of course not economic but the vertical sky components and the length of the sightlines will be great. The big differences in the ten alternatives (see figure 2) despite the same position in the diagram indicates a need of even more parameters.

We regard the approach of perceived density as important. The accessibility affects humane behaviour and the urban environment. In this paper we want to extend the interest of human perception to the visual experiences of views and of daylight. The used parameters are average distance to obstructing facades, perpendicular distance to obstructing facades, vertical sky component and solar radiation.

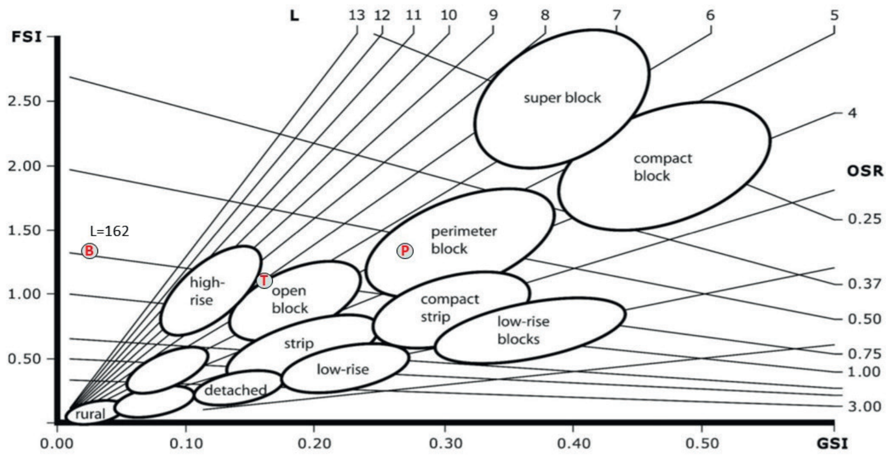


Figure 3. *Typological clusters of urban fabrics in the Spacemate diagram (from Berghauser Pont and Haupt, 2007).*

7. The Daylight Simulations

The methodology of the daylight simulations is based on the scientific discourse in the field of daylighting with origin from an early European collaboration (Baker *et al.*, 2013) and recently formulated in the EU standard (CEN, 2019). Each alternative of settlement has been analyzed in a cluster of 3 x 3 blocks, all the same type. The daylight conditions in the ten alternatives are described in the following way:

– Sunlight radiation on façades and on plots, average values, during the 1st of May from sunrise to sunset (kWh/m2).
– Sunlight radiation on the first floor of all facades, average values.
– Vertical Sky Component on the first floor of all façades (VSC), average values. 50% is the maximum value.
– Sky Component on the plot area (SC), average across the plot; 100% is the maximum value including visual access to the whole hemisphere.

The facades on the upper floors have good distribution of sunlight in all alternatives. The challenge is to create good daylight even for the worst cases, which are the first floors. Therefore, we have separate calculations for the first floors regarding both radiations and vertical sky component.

All the simulations are performed with DIVA for Rhino, a well-recognized tool for climate based and static daylighting calculations. The DIVA (Design, Iterate, Validate and Adapt). A plug-in for Rhinoceros software, enables effective calculations of daylight metrics, e.g. daylight factor, using the Radiance/Daysim engine. The climate data for Stockholm was used as well as its geographical location. By keeping the reflection factor of the block surfaces and the ground close to zero (0.01%) the daylight factor script in DIVA was used to calculate SC and VSC.

The generated data is for the facades except for the ground values. Solar radiation on facades and daylight level on facades are values in our studies to describe the conditions at the windows. We assumed that the windows are evenly distributed along the facades. This assumption is common in general studies as ours because no special details or local conditions are known.

8. Analyses of the daylight results

The conventional perimeter block, alternative 0, has been compared with nine alternatives which most of them are developments of the original structure except for the alternative nine.

8.1. *Parallel Slab Houses (alt 9)*

Alternative 9 consists of long slab houses designed in the modernist's way. The expected advantages compared with the conventional perimeter blocks didn't show up. The only value which is better than in alternative 0 is the radiation at the first floor, see table 1. Actually, all configurations of tower blocks investigated in an earlier study (Sundborg et al, 2018) have much better daylight values than the slab houses and even better than improved perimeter blocks.

8.2. *Chamfered corners of the buildings (alt 1)*

The first alternative to the conventional perimeter blocks has eight chamfered corners of the building, four against the streets and four against the courtyard. The expected advantages for the facades with the bevels along the streets and in the courtyard were present in the simulations. The ground values in the courtyard are almost the same in both alternatives. It is clever to let the inner corner of the courtyard to be chamfered for the best daylight distribution along the inner diagonal. The optimization means 45° against the streets and into the courtyard angles of 28° and 62° adapted to the actual rectangular inside.

8.3. *Openings in a broken perimeter block (alt 2 and 3)*

Openings in the perimeter blocks create new possibilities for daylight distribution. Therefore, four opening alternatives with different configurations have been developed. To preserve the stipulated exploitation of FAR=1.33 the loss of building area in the openings are compensated by an addition of the depth of the buildings from nine to thirteen meters.

Comparing alternative 2 with 3 the conclusion is; if it is the daylight indoors together with the conditions along the facades which really matters, the first choice is openings in the corners. If there are some conditions in the central part of the courtyard which are important, then the best choice is openings in the middle of the block. Looking to the courtyard the alternative 0 is better than number 3. When the openings are positioned in the corners of a broken perimeter block the studied parameters are good along the facades and indoors, but is it possible to improve the results even more? Below are some tests of improvement.

8.4. *Open corners of a broken perimeter block (alt 3, 7 and 10)*

Comparing the alternative 7 with the two other alternatives with openings in the corners of the plot alternative 7 with variated heights in steps has the best values regarding the critical first floors. The total radiation summarized on all floors is also high. The differences are even bigger comparing the alternative 7 with alternative 0.

8.5. *Openings adapted to the openings in the surrounding blocks (alt 10)*

The alternative 10 was created with openings in the block adapted to the openings in the surrounding blocks and even in the two diagonal directions to continue the low angled daylight distribution from plot to plot. The choice of the quadratic shape was made of geometrical reasons to create diagonal angles which are practical for the layout of the block. But the quadratic shape of the plot reduces the radiation and the access to the sky because a rectangular shape in east-west direction is more energy efficient thanks to the geometry of the sun path.

8.6. *Variated heights along the perimeter block (alt. 4, 5, 6 and 7)*

The perimeter block 0 has the height of five floors. The alternative 4, 5, 6 and 7 has all variated heights in different ways. Alternative 4 has lower heights in the corners which are the darkest part of the courtyard. Alternative 5 has the opposite performance. As expected alternative 4 has higher VSC than 5 but the difference is small. The advantages for number 5 are bigger regarding the courtyard probably mostly depending on that the shadows from the upper floors don't

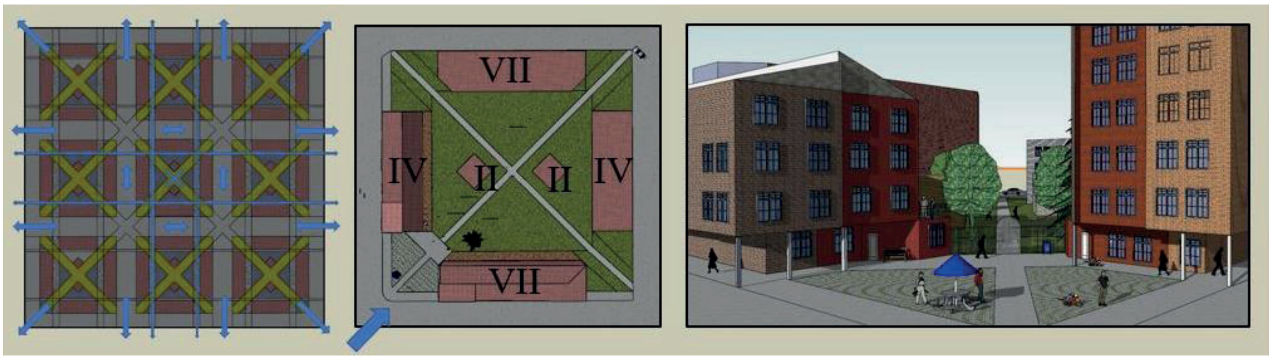


Figure 4. *The arrows illustrate "light paths" of low angled daylight in alternative 10. Each block is synchronised to the surrounding blocks.*

affect the other windows as much as in alternative 4. Comparing with alternative 0 the values for the courtyard are better in 5 and worse in 4. Why the radiation at the first floor is the best in alternative 0 still needs an answer.

A perimeter block which has heights that are stepped down against the south is the next alternative, No. 6. The results are not impressing with low values along the facades but the radiation at the courtyard is the highest of all ten simulations. The question is if there exist strategies based on variation which are very good. Our last test is the alternative 7 with openings in the corners of the plot with variated heights in steps – a mixed solution which turned out good (the number eight is saved for further design studies). Limiting the weighting to the three values along the facades alternative 7 is better than all other variations of heights and also the best of all alternatives in the study. Alternative 7 has good values even for the courtyard.

8.7. *Preference on the courtyard (alt. 2, 5 and 6)*

With focus only on the courtyard alternatives 2, 5 and 6 are the best but only alternative 2 has good facade values.

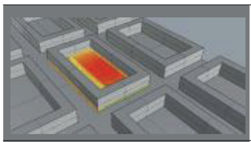
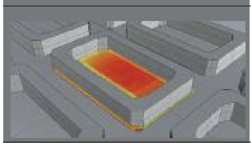
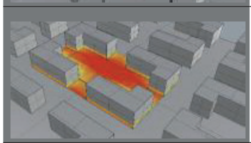
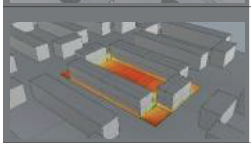
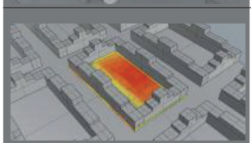
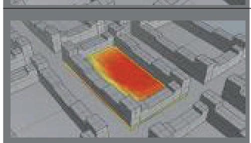
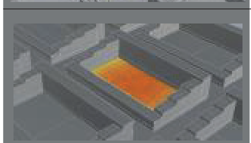
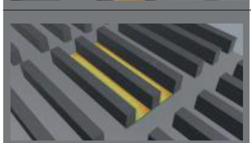
9. The View Calculations

The views in the six settlements of different urban blocks have been compared. That means that the distances of the horizontal sightlines from each window were calculated regarding the obstructing surrounding buildings using the Grasshopper software. All distances are in meters. Two types of distances have been calculated for each window:

1. Average distance to obstructing facades.
2. Perpendicular distance to obstructing facades.

Then the averages from all windows for the whole block have been processed for both values. All distances to the obstructing facades in the surrounding buildings are measured within a 138-degree cone except for the perpendicular distances. The cone represents the average visibility from a window considering the reduction caused by the obstructions in the window frame. In an earlier study about Tower Blocks we estimated that angle (Sundborg *et al.*, 2018).

Table 1. *Results of the Daylight Simulations.*

Alternative	Bold=best Italic=2nd	Radiation, first floor (kWh/m2)	Radiation, façade (kWh/m2)	Radiation, courtyard (kWh/m2)	VSC, first floor (%)	SC, courtyard (%)
	**Alt 0**	2.41	2.72	3.42	34.40	70.91
	**Alt 1**	2.47	2.77	3.41	35.28	69.98
	**Alt 2**	2.45	2.75	3.65	35.28	73.17
	**Alt 3**	2.47	2.78	3.07	35.35	65.73
	**Alt 4**	2.32	2.73	3.32	33.85	69.54
	**Alt 5**	2.33	2.72	3.55	33.70	72.39
	**Alt 6**	2.15	2.68	3.97	34.19	71.25
	**Alt 7**	2.53	2.77	3.4	37.41	70.23
	**Alt 9**	2.49	2.69	2.28	31.93	57.47
	**Alt 10**	2.28	2.76	3.34	34.67	68.84

Limitations and assumptions for the calculations of the alternatives (see figure 2) are:

- For the first four block alternatives, alternative 0-3, all facades have been analyzed in 2D regarding maximum free view, minimal free view, perpendicular view and average free view (m) for one floor (all five floors have the same conditions).
- For alternative 4 and 5, all facades have been analyzed in 2D regarding maximum free view, minimal free view, perpendicular view and average free view (m) for all seven floors.
- For alternative 9, all facades have been analyzed in 2D regarding maximum free view, minimal free view, perpendicular view and average free view (m) on a type plane.
- For alternative 6 and 10, all facades have been analyzed in 2D regarding maximum free view, minimal free view, perpendicular view and average free view (m) for all seven floors.
- For alternative 7, all facades have been analyzed in 2D regarding maximum free view, minimal free view, perpendicular view and average free view (m) for all nine floors.
- Each block structure has been analyzed in a cluster of 25 x 25 blocks where the center block refers to the block on which the measurements were made.
- Each quarter's façade has been served with measuring points at ~ 2 meters intervals and all facades have been analyzed.
- Each measuring point has 416 (1080 for 360 degrees) range measurements in the 138-degree cone.
- All analysis of the view has taken place in 2D along the horizontal plane. Max length for free view is set to 1000 m.
- Full length subtracting 20 cm on each side of the façade has been analyzed, so as not to create measurement points directly adjacent to the building's corners.

10. Analyses of the view results

The conventional perimeter block, alternative 0, has been compared with nine alternatives which most of them are developments of the original structure except for the alternative nine.

10.1. *Parallel Slab Houses (alt 9)*

The modernist configurations with parallel slab houses have a reputation to give much space. However, the expected advantages for the view comparing to the closed perimeter block (0) wasn't there. Only in one way the slab houses were better, sight lines along the long facades. The short perpendicular distances between the parallel facades explain the bad results. The average distance is only 18.18 meter compared to **35.67 meter for the perimeter block.** Configurations of tower blocks have much better view values – up to 87.5 meter (calculated as equal FAR-values) than the slab houses and even better than improved perimeter blocks. The tower blocks were investigated in an earlier study (Sundborg et al, 2018).

10.2. *Chamfered corners of the buildings (alt 1)*

Comparing the conventional perimeter block (0) with a block with chamfered corners the latter have the expected advantages for the daylight as well as for the views. The chamfers increase the average length of the sightlines with long perpendicular diagonals.

10.3. *Openings in a broken perimeter block (alt 2 and 3)*

Openings in the perimeter blocks create better possibilities for the daylight as well as for the views. Comparing alternative 2 with 3 the conclusion is that the views from the windows are longer with openings in the corners. Looking to the perpendicular views alternative 0 is better than alternative 3 depending of alternative 3's parallel shaped openings.

10.4. *Open corners of a broken perimeter block (alt 3, 7 and 10)*

Comparing the alternative 7 with the two other alternatives with openings in the corners of the plot alternative 7 with variated heights in steps has the best views. The differences are even bigger comparing the alternative 7 with alternative 0.

10.5. *Openings adapted to the openings in the surrounding blocks (alt 10)*

The alternative 10 was created with openings in the block, adapted to the other openings in the surrounding blocks. The expected positive results are not reached except for the long average obstruction distance 64.90 meter.

10.6. *Variated heights along the perimeter block (alt 4, 5, 6 and 7)*

The perimeter block 0 has the height of five floors. The alternative 4, 5, 6 and 7 has all variated heights in different ways. Alternative 4 has lower heights in the corners which are the darkest part of the courtyard. Alternative 5 has the opposite performance. The differences in views between the alternatives are relatively small except alternative 7 with the average obstruction distance 79.68 meter and alternative 6 with the average perpendicular distance 45.63 meter. Both values are the highest of all ten alternatives.

Table 2. *Results of the View Calculations of distances of the sightlines (Bold=best, Italic=2nd).*

Model	138° width obstruction distance, average (m)	Perpendicular obstruction distance, average (m)
Alt. 0	37.08	35.67
Alt. 1	39.26	37.23
Alt. 2	42.54	26.78
Alt. 3	44.10	36.47
Alt. 4	56.35	39.61
Alt. 5	55.73	35.41
Alt. 6	55.70	45.63
Alt. 7	79.68	37.51
Alt. 9	31.81	18.18
Alt. 10	64.90	36.26

The lengths of the sightlines in general are good in the alternatives. The steps in the EU standard, the chapter for view recommendations (CEN, 2019) are:

EU standard: 6 m ≤ Minimum < 20 m ≤ Medium < 50 m ≤ High

11. Implementation

Looking to earlier experiences of changes in urban planning as the periods of art noveau and modernism they were supported by oral as well as written texts. The argument was not scientific but often based on specific facts and ideas. There are also potentials to improve urban design by urban morphological knowledge (Marshall & Çalişkan, 2011, p. 381). Within the field of daylight in town planning it is a similar situation which means that there are difficulties to implement new routines and to build urban blocks in new ways. The greater the benefits, the easier it is to overcome such obstacles.

An interesting proposal to a method to design perimeter blocks based on daylight and energy criteria is a study from Korea (Kim, 2016). They stipulate at least two hours of continuous access to daylight on the winter solstice as a main principle, something that cannot be simply applied to our study (Stockholm, Sweden) because of climatic differences. An important experience from our own simulations is that the results are sensitive to the choice of criteria.

A variation of the typology of the urban blocks in the city gives character and identity. It permits adaptation to the local conditions and the actual needs and desires. Some of the alternatives are especially successful regarding the parameters in the study. However, it is not possible to point out one best solution for implementation. The practical impact of the research can be to build houses on the basis of the results and even with local modifications. Hopefully new solutions will be developed through inspiration from the research.

12. Conclusion

The alternative configurations of the perimeter blocks have special relevance in the compact city which normally has higher FAR-values than 1.33 used in this study. The ultimate value of the findings in this research is if they can contribute to better town planning. Expected advantages were confirmed but even some unexpected results occurred as for example the low values for the parallel slab houses. A few of the results of the geometrical changes are difficult to fully understand and needs further studies. If it is the view from the windows and the daylight indoors together with the conditions along the facades which really matters, the first choice is therefore openings in the corners as in alternative 7. If there are some conditions in the central part of the courtyard which are important, then the better choice is openings in the middle of the block as in alternative 2. A simple modification of the perimeter block to a block with eight chamfered corners gives also good impact.

13. Acknowledgments

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