TOWER BLOCKS IN DIFFERENT CONFIGURATIONS

- ASPECTS OF DAYLIGHT AND VIEW

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Summary

The groupings of buildings can be made in different regular geometric patterns or in more irregular arrangements. In the PLEA-study "Urban Form, Density and Solar Potential" Cheng et al. (2006) tested some alternatives with uniform/random heights and patterns. The research team concluded with pointing out the advantages of randomly positioned buildings compared to repetitive patterns with respect to daylight access and solar potential. In our opinion the conclusions about random layouts should be interpreted in terms of specific variations. This suggests that there may be strategies for patterns and heights - not simply random arrangements - which this new study clearly confirms. Although the authors of the 2006 study underlined the need for further studies, as far as we know, no research of building groupings has been done.

In this research a series of geometrical patterns of tower blocks was developed to examine daylight conditions. Some are already used in practice while others seemed to be very promising. The choice of evaluation criteria was based on the discourse in the scientific community on daylighting and on practical experience in urban planning. The view was also included as in the new EU standard. The study is carried out for an assumed FAR (Floor Area Ratio) of 1,12 with buildings of seven floors. Advanced computer based daylighting simulations and calculations of view parameters have been done for seven different designs of building groupings of equal density.

All seven groupings have good daylight conditions with Vertical Sky Components over 40%. The six alternatives to the quadratic reference model have higher sunlight radiation on façades, especially on lower floors, due to their less perpendicular orientation to the surrounding blocks. The same alternatives have sightlines up to 3-7 times longer than in the reference model. These advantages depend on the oblique, triangular and scattered configurations as well as the different shapes of the ground floor area.

The quadratic group is the most common pattern for tower blocks. Unfortunately it also has the worst possibilities for view with a perpendicular view of 30 meters compared to 50,7 to 93,3 meters for the alternatives. Local conditions as well as technical requirements must – as always – influence layouts. However, the six alternatives can still produce tangible consequences thanks to considerations of daylight and view.

Keywords: Daylight, Views, Urban Morphology, Tower Blocks.

1. Introduction

Urban geometry can be created in many different ways. Mark DeKay worked on the evaluation of different forms of a city quarter to find out which has the greatest potential for daylight autonomy by asking: '' What would the form of the city be like if we were to take seriously the provision of daylight to all buildings?''(2010). He developed different geometries of quarters and verified daylight availability. Following this, Peter Andreas Sattrup and Jakob Strømann-Andersen made energy simulations to calculate the total energy consumption and the daylight autonomy for six different building patterns (2013). Simulations examined how density ratio in urban blocks affects solar gains and daylight autonomy. Of all studied patterns the results were best for free standing tower blocks.

A previous study by Vicky Cheng et al. (2006) focused on differences between uniform groups of tower blocks (equal height and repetitive parallel patterns) and groups with variations in height and position. The research team pointed out the advantages of randomly positioned buildings of different height compared to uniform groups with respect to solar potential, but concluded there was a need for further research. The present study goes deeper into this topic and broadens the investigation to include views.

This paper presents a study of seven different groups of tower blocks which evaluates the solar radiation on façades and plots, the daylighting accessibility (vertical and standard sky factors) and the potential views. In this paper only a part of the study is presented, i.e. alternatives where all blocks are of equal height. The evaluations have been done with computer simulations. We will continue the tower block research and also comment on the present study in detail, especially with respect to strategies and "random" solutions. This ongoing project will also include other settlement configurations e.g. perimeter blocks.

The basic geometries in the modelled alternatives are simplifications of common modern examples together with some new patterns. The patterns of similar buildings in existing urban settlements are usually grouped in one of two typical patterns, parallel, P or oblique, FO, see figure 2. Even in smaller groups such as 4-5 buildings along a street the same strategies are common. Regarding the interior and the exterior qualities for daylight and view based on practical observations this study confirms that the oblique pattern is the best. A third type**,** an irregular grouping, is used mainly in some low density developments in order to adapt to the terrain.

The oblique positions can be fully rotated 45º, Full Oblique, from the parallel as well as to other angles as in the illustration below with half that rotation, SO. In a current report focusing on urban structures and energy, that pattern is also mentioned by Philipp Rode, et al (2014). Here we classify the pattern as Semi Oblique. It is sometimes used on a small scale.

Figure 1

A Typical Tower Block (©2017, hitta.se)

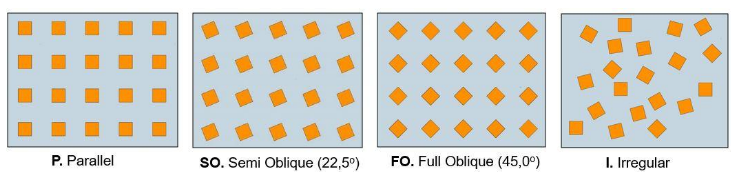


Figure 2 Four groupings of tower blocks.

We regard six important parameters in the urban morphology of tower blocks. This ongoing study deals with all of them;

1. Block heights.
2. The shape of a single block, especially the plan form of the built ground area – the urban foot print, and the proportion between the height and the foot print dimensions.
3. Orientation of the single block in different compass directions. In Trio, alternative 4 in section 2 below**,** every building in each group is orientated in a different direction.
4. The shape of the area for the whole group.
5. The patterns of the groups of the blocks.
6. Orientation of the groups of blocks in different compass directions.

2 The Alternatives

The developed alternatives represent both existing settlements and new proposals (4, 5, 6 and 7 are developed within this project). It is possible to mirror alternatives 2 and 5 to improve their adaptation to local conditions. The alternatives have been developed in Sketch Up-drawing, see figure 3. The intentions for each of the seven alternatives are stated below.

The blocks in the three "*pattern*" alternatives have variations according to the following:

1. QUADRATIC blocks are grouped in a quadratic pattern. This simple and very typical alternative is used as a reference.
2. SEMI-OBLIQUE the Quadratic alternative with every block obliquely positioned - rotated $22,5^0$.
3. FULL-OBLIQUE the Quadratic alternative with every block obliquely positioned - rotated $45,0^0$.

Both groups in the two *"courtyard"* alternatives are orientated around a courtyard:

4. TRIO blocks of three are grouped in a triangular pattern.
5. OBLIQUE-FOUR blocks of four are grouped in an "oblique pattern". This alternative is similar to TRIO but the buildings are orientated according to a rectangular grid, so it is easier to adapt them to a quadratic street grid.

The tower blocks in the two alternatives with different *"ground forms"* are arranged to develop better light and sight conditions than in the usual rectilinear layout:

6. HEXAGON hexagon-shaped blocks in a pattern of hexagonal plots. It is important that the blocks are rotated clockwise $30,0^0$ in order to improve the sight and the light perpendicular to the windows.
7. DECAHEDRON polygon-shaped blocks (ten façades) in a pattern of rectangular plots. All façades are orientated in order to improve the sightlines and the light perpendicular to the windows.

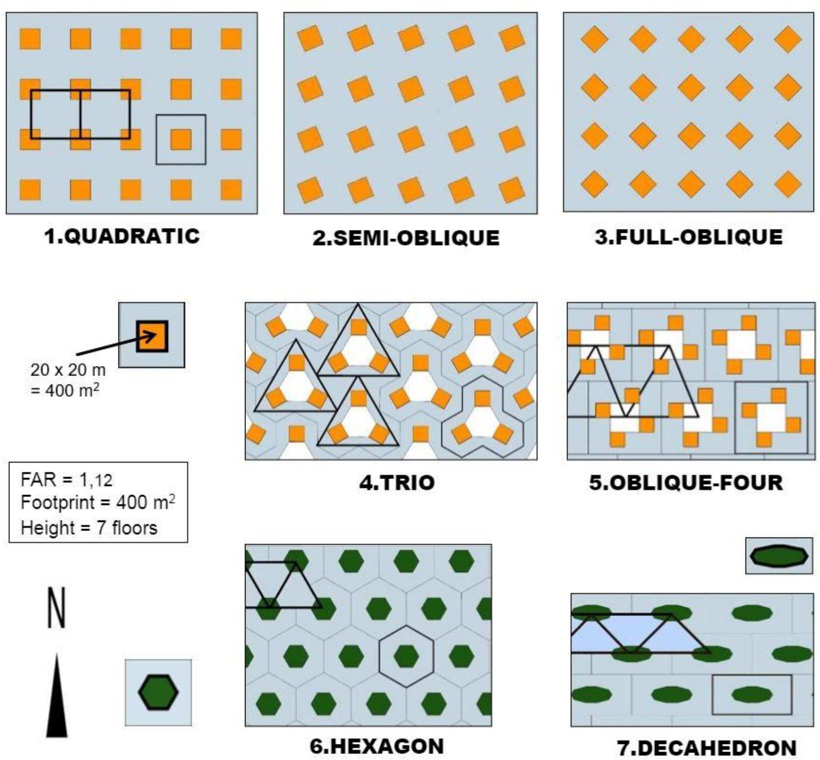


Figure 3 The seven alternatives for groups of tower blocks.

Modern tower blocks are often 20 meters wide with four apartments (one in each corner) which are wider than previous blocks of around 18 meters. This is because of new building regulations for disabled people and economic considerations. The following dimensions have been used in all alternatives (except the footprints in the alternative 6 and 7):

w = width = 20 m
$\mathbf{A_{fl}}$ **=** floor area = w x w = 400 m^2
$\mathbf{A_{bg}}$ **=** building area (built area on the ground, foot print) = w x w = 400 m^2
n = number of floors = 7
$\mathbf{h_{fl}}$ = 3 m (height of each floor)
H = 21 m (total height)
$\mathbf{A_{pl}}$ **=** plot area **=** 50x50m = 2 500 m^2
FAR = floor area ratio = total floor area/plot area =
n x $\mathbf{A_{fl}}$/$\mathbf{A_{pl}}$ = 7 x 400/2500 = 1,12
FAR = *FSR (floor space ratio)*, *FSI* (*floor space index)*, *site ratio and plot ratio.*

Even groups of taller buildings (skyscrapers) and smaller ones (villas) demonstrate the same relative advantages for patterns with the same grouping and the same foot print. However, in this study, it was important to investigate the specific conditions for each group of tower blocks.

3 The Daylight in the Urban Areas

The daylight conditions in the seven alternatives, see figure 4, have been simulated in three ways:

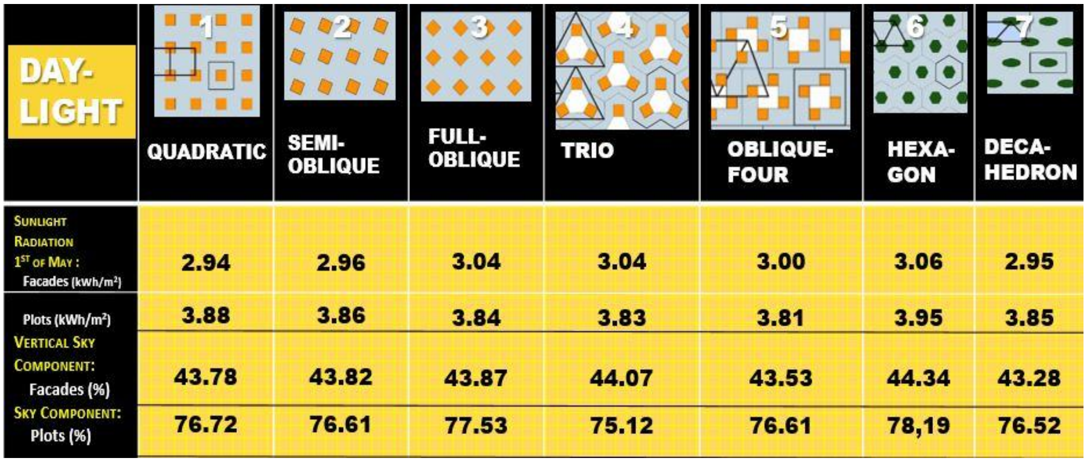
- Sunlight radiation on façades and on plots, average value, during the 1st of May from sunrise to sunset (kWh/m^2)**.**
- Vertical Sky Component on the façades (VSC), average of all façades; 50% is the maximum value.
- Sky Component on the plot area (SC), average across the plot; 100% is the maximum value including visual access to the whole hemisphere.

All the simulations have been done 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. Climate data for Stockholm was used. 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. All simulations have been executed by Postdoctoral Fellow Shabnam Arbab at the NTNU, Trondheim, Norway.

All seven alternatives have good daylight accessibility, e.g. the average VSC, Vertical Sky Components, is over 40% (27% is recognized as good enough and 50% is the maximum). The average SC, Sky Components**,** on plots is also high, see figure 4. HEXAGON has highest values both on façades (VSC) and on the plot (SC).

All the six alternatives to the QUADRATIC have slightly greater sunlight radiation on the façades due to the less perpendicular positions of the surrounding blocks. Regarding sunlight radiation on the plot areas, only HEXAGON has a higher value compared to the QUADRATIC**.** It is different to optimize for the buildings compared to optimizing for the plot. The exception, HEXAGON, has more daylight and an even better view depending on its form and a small rotation of the building (30,0^0) from the original position on the plot.

The differences between average solar radiations on façades in the alternatives are not strong as very high values of top and middle floors dominate calculations of average values. However, deeper consideration of the details of the simulation results confirms that solar radiation on façades at the level of 1st floor (worst places on façades) on all alternatives is significantly higher than in QUADRATIC.



DAY-LIGHT	1 QUADRATIC	2 SEMI-OBLIQUE	3 FULL-OBLIQUE	4 TRIO	5 OBLIQUE-FOUR	6 HEXA-GON	7 DECA-HEDRON
SUNLIGHT RADIATION 1ST OF MAY: Facades (kWh/m²)	2.94	2.96	3.04	3.04	3.00	3.06	2.95
Plots (kWh/m²)	3.88	3.86	3.84	3.83	3.81	3.95	3.85
VERTICAL SKY COMPONENT: Facades (%)	43.78	43.82	43.87	44.07	43.53	44.34	43.28
SKY COMPONENT: Plots (%)	76.72	76.61	77.53	75.12	76.61	78,19	76.52

Figure 4 Daylight conditions in the alternatives.

4 The Views in the Urban Areas

People's views in urban settlements consist of their visual experience of the outdoor environment. Qualitative details of the views of beautiful streets with well-designed outdoor furniture and decorative façades are important to that perception. The aspects of people's experiences in views from windows are many**;** see Matusiak & Klöckner (2015).

However, the crucial aspects to consider in the early stages of urban planning are the geometrical structures which limit both quantitative and qualitative opportunities of the fields of vision. Here we only consider simplified building alternatives.

Wide angle views of long distances give better opportunities for attractive views than short and narrow views even in detailed urban design. Large open spaces and strategically positioned openings between buildings are examples of how settlements can create such views. The measurements for the views described below, 1-4, are part of the criteria for the comparison of alternatives.

The views are multifaceted and include important aspects such as privacy and safety. It is also important to remember that there is a correlation between the assessment of daylight and the view quality as well as indoor privacy. The presence of people in the views is also appreciated in most cases even if exceptions exist such as noisy outdoor events.

Aesthetic values depend greatly on individual preferences which differ from person to person. However, general aspects of the aesthetics are important in urban design and are correlated with complexity, maintenance, age, composition of the view, etc. In a current EU-standard the diverse aspects of views are described as follows:

"View windows provide contact with the surrounding, information about orientation, weather changes and time over the day. A composition of a view, which includes layers of sky, city or landscape, and ground, could counteract fatiguing monotony and contribute to relief from the feeling of being closed in. All occupants should have the opportunity for the refreshment and relaxation afforded by a change of scene and focus. A natural view is preferred over a view towards man-made environment and a wide and distant view is appreciated more than a narrow and near view. A diverse and dynamic view is more interesting than a monotonous view. View to the nature may have positive influence on people's sense of wellbeing, on job satisfaction, and recovery of surgical patients." see CEN/TC, Annex C, (2018).

The view described as the length of the sightline in different directions is of primary interest. Some settlements have good possibilities for views and some do not despite the same density measured as floor area ratio. This is of importance especially in the planning of high density settlements.

4.1 Geometry Impact the Privacy

Increasing urbanization including the replacement of low buildings with taller ones and infill with new buildings leads not only to darker indoor and outdoor environments. Privacy will also be reduced.

A good view consists of many attractive elements. In contrast to the visual connection between the parents and their children, the sight of a stranger often reduces privacy. However, privacy is difficult to achieve in dense urban settlements and requires intelligent geometry such as zigzag façades, star block houses and chamfered. The six alternative groupings of tower blocks give more privacy than the QUADRATIC group depending on longer sightlines and less central views to the surrounding tower blocks in the alternatives.

4.2 Two Different Views from the Windows

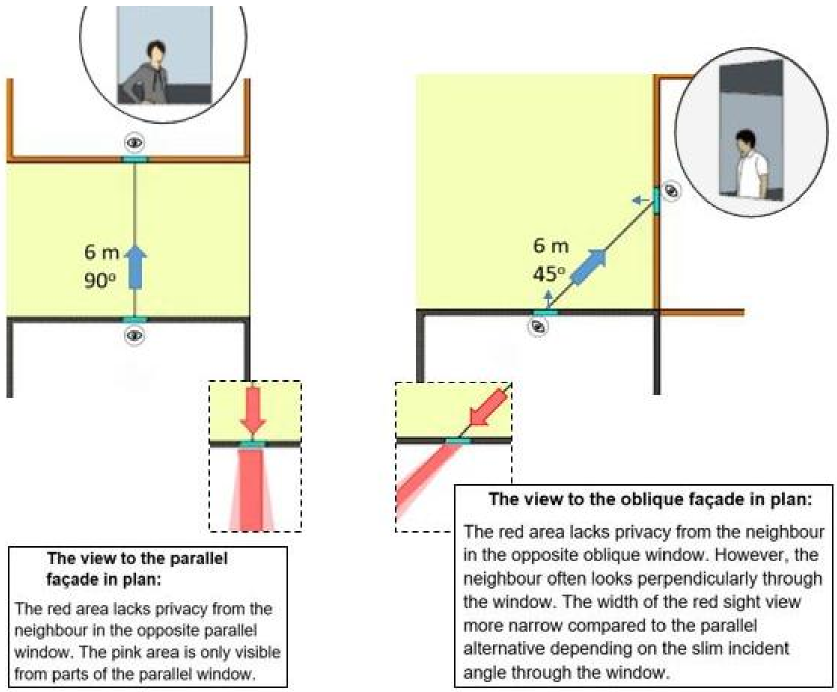


Figure 5 The view to a parallel and an oblique façade.

4.3 Obstructions in Views from the Windows

With the assumed measures of the window in the simulations it is possible to see 138º using different viewing positions. On both sides along the façade, up to 21º, there are absolute obstructions.

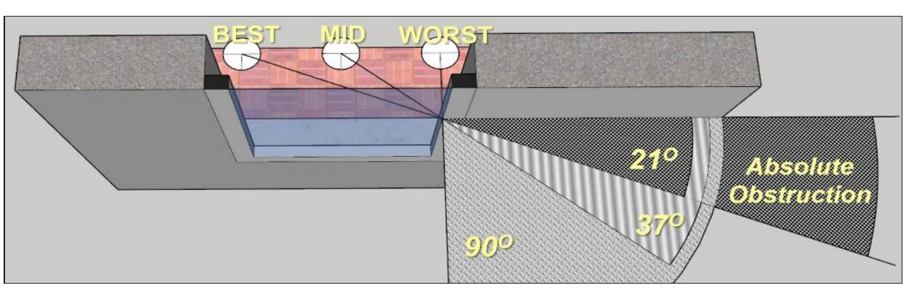


Figure 6 Three different viewing positions have different possibilities for width of view.

4.4 Viewing Conditions for the Alternatives

The following four ways describe the views in urban alternatives. All views are from one window in the building (calculated as an average of different positions along the façade):

1. $\mathbf{D}_{\mathbf{average\text{-}138}}$ Average distance to the surrounding buildings within 138° excluding 42° of the 180° of the sight which are obstructed by the frame of the window, see figure 6.

   $\mathbf{D}_{\mathbf{average\text{-}54}}$ Average distance to the surrounding buildings within 54° (m) – angle width for a central field view, (from CEN/TC 169).

2. $\mathbf{D}_{\mathbf{perpendicular}}$ Perpendicular distance to a building (m) - measured along the perpendicular sight line to the window. Broad views out consist of that sightline.

3. $\mathbf{D}_{\mathbf{max}}$ Maximal distance to a building within 138° (m). A long maximal distance is good for the view and for daylight distribution.

   C,centrality Centrality angle for the maximal distance (°). The best is the perpendicular view from the window, 90° and worst is 21° which is the lower limit depending of the obstructing beam of the window.

4. $\mathbf{D}_{\mathbf{min}}$ Minimal distance to a building within 138° (m). For good privacy the distance should be further than 20 meters according to practical guidelines.

   P,periphery The peripheral angle is the deviation in the minimal distance from the perpendicular normal (°). Oblique distances with very peripheral angles preserve privacy better and are limited to 69° depending on the obstructing frame of the window.

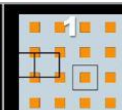
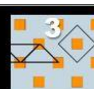
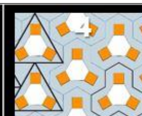
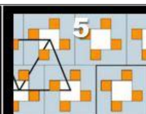
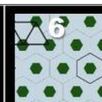
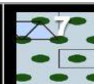
VIEW Distances: (m)	 QUADRATIC	 SEMI-OBLIQUE	 FULL-OBLIQUE	 TRIO	 OBLIQUE-FOUR	 HEXA-GON	 DECA-HEDRON
$D_{average}$ 138°	78,5	103,9	80,4	80,3	95,0	91,2	-
54°	75,7	88,5	87,6	96,8	90,2	119,7	-
$D_{perpendicular}$	30,0	90,8	50,7	73,0	90,0	71,5	93,3
D_{max}	166,3	299,6	192,8	172,6	610,7	228,0	274,2
C, *Centrality 21-90° =Perpend-icularity*	*51,5°*	*27,9°*	*54,4°*	*72,0°*	*33,7°*	*68,0°*	*83,2°*
D_{min}	30,0	27,7	29,6	32,5	22,6	32,4	27,5
P, *Periphery 0-69° =Obliqueness*	*0°*	*19,2°*	*58,8°*	*45,9°*	*26,6°*	*39,5°*	*11,5°*

Figure 7 View values in the alternatives.

The views are calculated and analysed for the QUADRATIC group and the six alternatives, see figure 7. Summing up the view analysis:

- In alternative groups of tower blocks, the sightlines can be up to 3-7 times longer than the QUADRATIC and the interior privacy can be improved and secured.
- The QUADRATIC group has the worst possibilities for views with a perpendicular view of only 30 meters compared to distances 50,7 to 93,3 meters for the alternatives.
- In all the distance parameters the results point in the same way except for some minimum distances which are up to 7,4 meters lower than the quadratic value, 30 meters. Those exceptions consist of more peripheral sightlines than the perpendicular view for the QUADRATIC so the difference in perception of privacy is not so big.

- The maximal distances are longer in all the alternatives to the QUADRATIC group - up to 610,7 meters compared to 166,3 meters.
- Each alternative has its own specific profile of view conditions. Depending on those differences in the alternatives, local needs and local conditions can often be satisfied.
- The secret to the advantages of the alternative groups is the different geometries of the oblique and triangular groups as well as the different configuration of the ground area of the blocks.

5 Conclusions

All seven models have good daylight conditions with average Vertical Sky Components on façades well above 40%. The average Sky Components on plots are also high in all alternatives, over 75%. HEXAGON scores highest values, both on façades and on the plot. The alternatives to the QUADRATIC have higher sunlight radiation, which is the result of less perpendicular positions of the surrounding blocks in the alternatives. This is especially significant at first floor level. The alternatives to the QUADRATIC group of tower blocks have up to 3-7 times longer sightlines. The special geometries give advantages to the alternative oblique, triangular and scattered groups as well as the different shapes of the ground area of the blocks.

The QUADRATIC group is the most used pattern for tower blocks in town planning. Unfortunately it also has the worst possibilities for offering views with a perpendicular view of 30 meters compared to distances 50,7 to 93,3 meters for the other alternatives. Local conditions as well as technical requirements must – as always – influence layouts. However, the alternative tower blocks can still produce tangible consequences thanks to considerations of daylight and view. After some practical applications we will know better how big these impacts can be.

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