'La Ville Radieuse' by Le Corbusier once again a case study

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ABSTRACT: *La Ville Radieuse*, 'The Contemporary City for Three Million Inhabitants' proposed by Le Corbusier for central Paris is a myth in the history of contemporary town planning. The proposal, according to Le Corbusier, could increase the urban capacity and at the same time improve the urban environment and the efficiency of the city. The thoughts and design principles embedded in the proposal of *La Ville Radieuse* quickly became models for architects of the post-war period. Le Corbusier was ambitious for the proposal and he even suggested demolishing the whole part of central Paris in order to adopt it; this of course raised strong objections. Though the proposal has never been realized, it has attracted a lot of discussion. This study employs computer simulation to evaluate the daylight and solar performance of *La Ville Radieuse*; it attempts to test the propositions of Le Corbusier, with reference to daylight design and to draw conclusions about the design of high density solar cities.

Keywords: Urban Design, Daylight, Heliothermic axis

1. INTRODUCTION

The authors have previously conducted studies to investigate the diverse influences of built density on urban daylight access and solar potential, with reference to both theoretical generic built forms and existing urban blocks. The findings demonstrated the possibilities of increasing usable floor area and plot ratio without undermining the opportunities of urban daylight and solar applications. [1] [2]

This study is an investigation of urban design between the purely theoretical generic built forms and the real existing urban blocks; it focuses on the proposal of *La Ville Radieuse*, the 'City of To-morrow' proposed by Le Corbusier for central Paris in the 1920s. This proposal, though never adopted, represents a notion of a hyper-dense city which is currently a topic of debate in contemporary town planning.

Gaston Bardet, a renowned French city planner and theorist has argued in his book '*Pierre sur pierre*' that the design of *La Ville Radieuse* is, in fact, not environmentally sound, in terms of urban microclimate and human comfort. Bardet, through his drawings of shadow casting, illustrated that the design and layout of building blocks in *La Ville Radieuse* would, in fact, create lots of overshadowing zones which do not receive any sunlight for long periods in the winter time. In conjunction with wind flow and cold temperature, these overshadowing zones could bring about intolerable thermal conditions to pedestrians in winter. [3]

In response to Bardet's remark and the propositions of Le Corbusier, this study comprises daylight and solar modelling of La Ville Radieuse to address the following questions:

- Are the propositions made by Le Corbusier in the design of *La Ville Radieuse* better than a more traditional design, in terms of daylight performance?
- What are the most important characteristics or factors that influence the success or failure of *La Ville Radieuse*, with respect to daylight performance?
- What we can learn from *La Ville Radieuse* about the design of high density solar cities?

1.1 La Ville Radieuse

La Ville Radieuse, which is known as 'The Contemporary City of Three Million Inhabitants' was designed by Le Corbusier for central Paris and was first shown in November 1922 at Salon d'Automne, Paris. It was designed to accommodate as many as six times the population of central Paris at that time. According to Le Corbusier, the design of *La Ville Radieuse* represents an indisputable ideal of personal freedom. He believed that many cities in the early twentieth century were chaotic and inefficient; he therefore came up with the proposal of *La Ville Radieuse* which had the following objectives:

- Provide effective means of communications
- Provide large amount of green area
- Provide better access to the sun
- Reduce urban traffic

He eventually realized that building high is the ultimate means to fulfil these aims and at the same time, accommodate the growing urban population. Figure 1 shows a rendering of *La Ville Radieuse*.

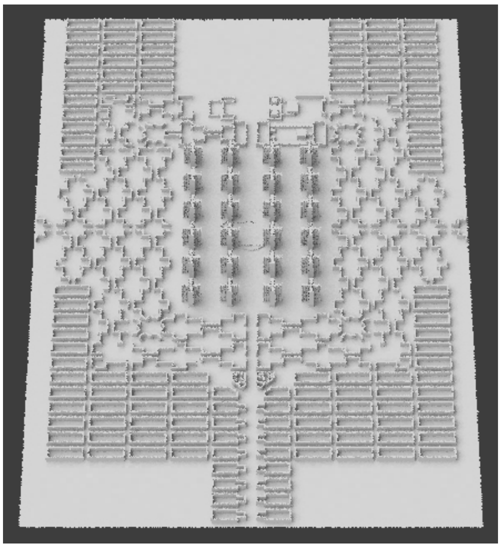

Figure 1: 3D rendering of *La Ville Radieuse.*

As can be seen from Figure 1, the layout of *La Ville Radieuse* is almost symmetrical ad the centre, which is the core of all types of public transport. The central terminus is an access point to the subway at the lower deck of the underground system and trains at the upper deck of the underground system. The ground level is open to air-buses and air-taxis.

The central part of the site is reserved for twenty-four skyscrapers, which are also the most controversial elements in the whole design. These cruciform skyscrapers are mainly for business and hotel purposes. Each skyscraper with dimensions about 190m x 190m and a height over 200m were designed to house five to eight hundred thousands people. According to Le Corbusier, this area would become the civic centre and headquarters of all the leading firms. Figure 2 shows a rendering of a skyscraper.

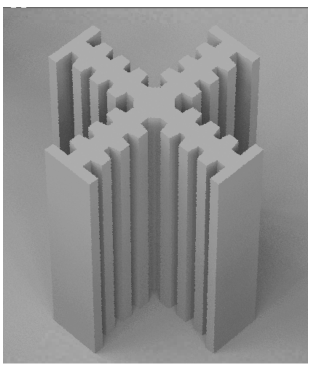

Figure 2: 3D rendering of skyscraper.

Surrounding those skyscrapers are residential districts which provide accommodation for people who work in the skyscrapers. These housing blocks were known as apartment-villas. Inside these housing blocks, each duplex apartment has its own hanging garden and according to Le Corbusier, each apartment is a house on its own.

The built-up area only accounts for 15% of the total site area of *La Ville Radieuse*, as so, the formation of concrete canyons could be avoided and inhabitants would be able to enjoy the large amount of gardens and open green spaces provided. Moreover, the apartments would have full daylight access and the urban noise problem would be reduced to the minimum.

In *La Ville Radieuse*, the business district, the residential district, the transportation core and the high street shopping area are organized in a Cartesian way where all elements as a whole function like a 'living machine'. In light of the advancement of construction technology, Le Corbusier believed that millions of residents could benefit from the advantages of this rational planning.

Although the proposal of *La Ville Radieuse* was first proposed for central Paris, Le Corbusier also proposed to adapt it to other places such as Algiers in Algeria, Barcelona in Spain, Buenos Aires in Argentina and Sao Paulo in Brazil.

Nevertheless, the lack of financial support from the business sector has left the scheme as drawings on papers and it has never been realized.

1.2 Methodology

The assessment of daylight and solar potential are purely based on computer simulation. A solar simulation tool named PPF [4] has been applied for daylight and solar radiation modelling; PPF is Radiance based modelling which uses Monte Carlo ray tracing methods to calculate solar availability. Besides PPF, digital elevation modelling (DEM), a tool for image processing of three-dimensional urban texture, has also been used to predict sky view factors at ground level. Both techniques have been previously developed and employed within the framework of the *PRECis European project: Assessing the potential for renewable energy in cities* [5] and they also have been used in various urban form studies. [6] [7] [8]

The modelling tools calculate the solar radiation and daylight intensities on building facades, roofs and ground surfaces. Based on the results, different performance indicators can be used to assess the daylight and solar potential of the proposal of *La Ville Radieuse*. Daylight viability is the major performance indicator employed in this study; it is defined as the percentage of façade area which receives, on average, 10 klux or more daylight annually. [9]

The simulation has been conducted using Paris typical annual sky condition and winter sky condition. In addition, a set of simulations has also been carried out using the typical annual sky condition in Sao Paulo. This data could provide a ground for comparison and evaluation of Le Corbusier's suggestion of adapting his design principles to different parts of the world.

As mentioned before, the plan of *La Ville Radieuse* can be divided into two major districts i.e. the business district and the residential district. The sky scrapers represent the unique built form in the business district, whilst the residential district comprises three different housing blocks. These housing blocks are named housing 'set-backs', housing 'cellular' and 'garden cities'. In the simulation, only the sky scrapers, housing 'set-backs' and housing 'cellular' were included. Figure 3 shows rendering of the two housing blocks being studied.

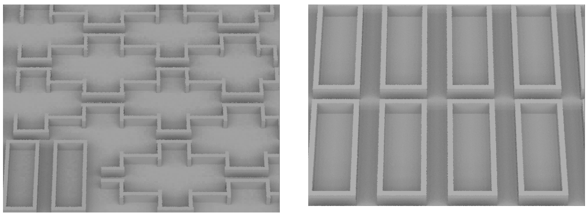

Figure 3: 3D rendering of housing blocks. (left) housing 'set-backs' and (right) housing 'cellular'.

2. RESULTS AND ANALYSIS

2.1 Density

In this study, density is described in three different ways, which are:

- Inhabitation density: ratio of number of inhabitants to site area
- Plot ratio: ratio of total floor area to site area
- Site coverage: ratio of building footprint area to site area

Figure 4 shows the three different built forms and Table 1 shows the densities of each of them.

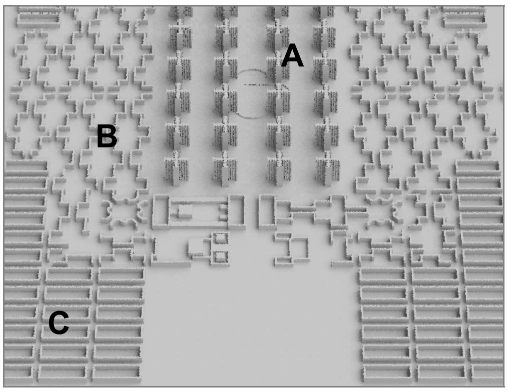

Figure 4: The three different built forms included in the study.

Table 1: Summary of cases being studied.

Density	**A Sky Scraper**	**B Housing 'Set Backs'**	**C Housing 'Cellular'**
Inhabitation	0.3 Inhab./m2	0.03 Inhab./m2	0.03 Inhab./m2
Plot Ratio	3.8	0.8	0.9
Site Coverage	6.3%	12.5%	19%

2.2 Daylight Performance of Sky Scrapers

The paper first discusses the daylight performance of the sky scrapers as they are the most controversial elements in the proposal of *La Ville Radieuse*.

Throughout the development of La Ville Radieuse, three versions of the design of the sky scrapers can be found in the literature. The most important modification among these three versions of design was the change of the façade surfaces from uniform planes to deeply serrated shapes as shown in Figure 5. According to Le Corbusier, the advantage of the serrated shape is that it forms veritable traps for light.

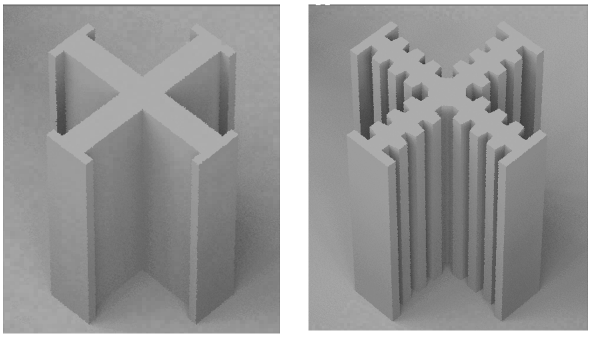

Figure 5: The 'uniform plane' and 'deeply serrated' designs of the sky scrapers.

Daylight simulation has been carried out to evaluate the performance of the original 'uniform plane' design and the modified 'serrated' design. The annual and winter daylight viability of the 'uniform plane' design are 45.9% (94820m^2 façade area) and 16.5% (34086m^2 façade area) respectively, whilst those of the 'serrated' design are 23.7% (73465m^2 façade area) and 8.5% (26348m^2 façade area). The results show a significant reduction of daylight potential with the modified 'serrated' design.

However, although the daylight viability is reduced with the 'deeply serrated' design, the veritable traps allow light come from the sides in addition to the main façade; this might result in better daylight penetration to the room and increase the light level at the inner part of the room.

Besides the modification of individual building blocks, Le Corbusier also proposed to orient the whole plan of La Ville Radieuse to the so called heliothermic axis. The heliothermic axis changes with geographic location and it is 19^o towards east for

Paris as shown in Figure 6. [10] Le Corbusier believed that to orient the whole plan to this heliothermic axis could improve the overall daylight performance.

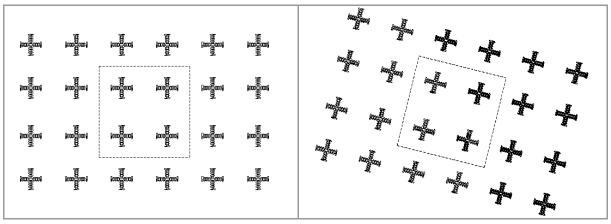

Figure 6: (left) Original orientation and (right) heliothermic axis 19^{o} towards east

The annual and winter daylight viability of the ‘serrated’ sky scrapers in the new orientation are 22% and 9.8% respectively. The results show a slight improvement in winter though; the annual daylight viability is reduced simultaneously.

Another way to evaluate the performance of the sky scraper proposal is to compare it with the urban blocks in Paris when the plan was proposed in 1920s. Two typical building blocks representing urban Paris in the early twentieth century and even nowadays have been chosen for the simulation. Figure 7 shows these two typical urban blocks.

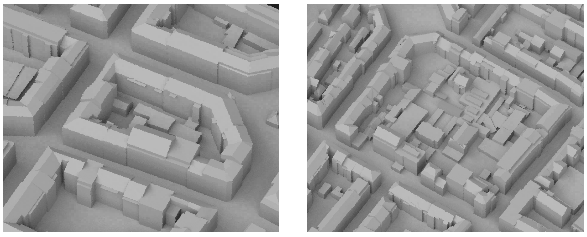

Figure 7: 3D Rendering for Paris Urban Block 1 (left) and Urban Block 2 (right).

The annual and winter daylight viability of Urban Block 1 are 34.6% and 14%, whilst those of Urban Block 2 are 48.9% and 20.3% respectively. The daylight viability of both urban blocks are significantly higher than the sky scrapers, hence the results seem to suggest that Le Corbusier’s sky scraper proposal might not be such an effective design option, in terms of daylight performance.

However, the merit of the sky scraper proposal is obviously the huge amount of usable floor area and open area it provides. The plot ratio of the sky scraper proposal is 3.8 and those of Urban Block 1 and 2 are respectively 1.5 and 2. Hence, with typical urban blocks, 2 to 2.5 times more land is needed in order to provide the same amount of usable floor area as the sky scrapers and this does not take into account the amount of open space available in the sky scraper proposal. If the open space is to be taken into account, further 1.3 to 2 times more land will be required.

2.3 Daylight performance of residential blocks

The results of the simulation of housing blocks show an interesting phenomenon. The housing ‘cellular’ performs better than the housing ‘set-backs’ annually; the daylight viability of the former is 65.7%, whilst the latter is 60.7%. Nevertheless, the situation is vice versa in winter months. The daylight viability of the housing ‘cellular’ is 14.6% in winter, which is significantly lower than the 30.5% obtained with housing ‘set-backs’.

As can be seen from the results, both housing blocks have significantly better daylight performance than the sky scrapers, this is certainly due to the very different built forms.

The annual daylight performance of these two housing blocks are a lot better than the typical Paris urban blocks as shown in Table 2. The results seem to suggest that the housing ‘set-backs’ which has a fairly good daylight performance annually and an outstanding performance in winter is a viable design option.

Though the daylight performance of the housing ‘set-backs’ is greatly appreciated, the much less usable floor area available in this layout might be a drawback. The plot ratio of the housing ‘set-backs’ is 0.7, which is much lower when comparing to the 1.5 and 2.1 plot ratios of Paris urban blocks. This means that, in order to provide the same amount of usable floor area as the Paris urban blocks, 2-3 times more land area will be needed with the housing ‘set-backs’ layout.

Table 2: Summary of results with different built forms.

Cases	**Plot Ratio**	**Site Coverage**	**Daylight Viability (Annual)**	**Daylight Viability (Winter)**
Sky Scrapers	3.8	6.3%	23.7%	8.5%
Housing ‘Set-backs’	0.7	12%	60.7%	30.5%
Housing ‘Cellular’	0.9	18%	65.7%	14.6%
La Villa Radieuse*	0.83	11.4%	53.2%	10.5%
Paris Urban Block1	1.5	28%	48.9%	20.3%
Paris Urban Block2	2.1	52%	34.6%	14%

* Overall performance including sky scrapers, housing ‘set-backs’ and housing ‘cellular’

The overall performance of *La Villa Radieuse* as seen from Table 2 does not appear to be much better than the Paris urban blocks. Although it has higher daylight viability annually, its performance in winter is worse than the Paris urban blocks. Moreover, if density is to be taken into account, the proposal of La Villa Radieuse is significantly inferior to the Paris urban blocks.

As in the case of sky scrapers, simulation of the housing ‘set-backs’ and housing ‘cellular’ have been conducted in the orientation to heliothermic axis.

Table 3 shows the results. The findings reveal an improvement in winter daylight potential and a reduction in annual daylight potential. This is parallel to the findings of the previous observation in sky scrapers.

Table 3: Summary of results with different built forms

Cases	Daylight Viability Original Orientation		Daylight Viability Heliothermic axis	
	(Annual)	(Winter)	(Annual)	(Winter)
Sky Scrapers	23.7%	8.5%	22%	9.8%
Housing 'Set-backs'	60.7%	30.5%	61.4%	30.5%
Housing 'Cellular'	65.7%	14.6%	60.9%	19.2%

Apart from the change in orientation, Le Corbusier has also reduced the building height of the two housing blocks from 50m to 30m which accounts for about 40% reduction in usable floor area. It is speculated that the intention of this modification is to improve the daylight performance of the housing blocks. The reduction in building height results in significant improvement in daylight performance. The increase in annual daylight viability for the housing 'cellular' block is about 30% and the increment in winter daylight viability ranging from 80-94% which represents a significant difference. Obviously, there is a trade-off between density and daylight performance in this case.

2.4 Comparison of Paris and Sao Paulo

The simulation of annual daylight viability for the sky scrapers, housing 'set-backs' and housing 'cellular' have been repeated with the original orientation and heliothermic axis using the sky conditions in Sao Paulo. The heliothermic axis of Sao Paulo is found to be the same as Paris i.e. 19^{o} towards the east. [11] Table 4 is a summary of the results.

Table 4: Summary of results for Paris and Sao Paulo

Cases	Daylight Viability Original Orientation		Daylight Viability Heliothermic axis	
	Paris	Sao Paulo	Paris	Sao Paulo
Sky Scrapers	23.7%	32.8%	22%	33.5%
Housing 'Set-backs'	60.7%	80.9%	61.4%	85.6%
Housing 'Cellular'	65.7%	87.5%	60.9%	87.3%

The results show significant differences between Paris and Sao Paulo and could be explained by the high solar altitude and the higher solar radiation availability in Sao Paulo. Nevertheless, one interesting finding from the results is the positive effect of heliothermic axis. In previous observations of Paris, the heliothermic axis is beneficial in winter but disadvantageous annually. Nevertheless, the results in Sao Paulo generally show positive effects of heliothermic axis on annual daylight performance. The phenomenon is worth further study and it will be discussed in detail in the next section.

2.5 Effect of the Heliothermic Axis

The Heliothermic axis represents the most desirable orientation of the buildings which accounts for solar access and the natural heating and cooling processes. It is first invented by Agustin Rey, who established the concept of heliothermic axis as the relationships between solar duration and air temperature. Le Corbusier considered it as one of the most important principles in urban design. Figure 8 is an illustration of heliothermic axis of Paris.

In order to understand more about its effect, daylight simulation of standalone surfaces facing various orientations have been conducted. Table 5 and 6 show the results.

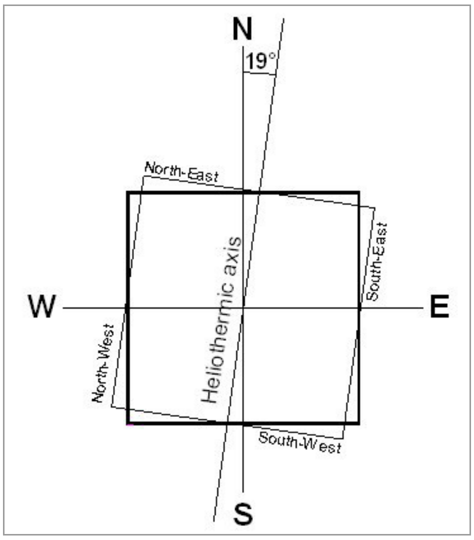

Figure 8: The Heliothermic axis of Paris

Table 5: Results of wall experiment for Paris

Surface*	Illuminance (klux) Original Orientation		Illuminance (klux) Heliothermic axis	
	Annual	Winter	Annual	Winter
N / NE	9.2	6.3	9.5	6.3
E / SE	16.7	11.0	17.7	12.3
S / SW	22.7	18.9	21.6	18.2
W / NW	14.8	10.6	13.1	9.1
∑ Sum	**63.4**	**46.8**	**61.9**	**45.9**

Table 6: Annual results of wall experiment for Sao Paulo

Surface*	Illuminance (klux) Paris		Illuminance (klux) Sao Paulo	
	0^{o}	19^{o}	0^{o}	19^{o}
N / NE	9.2	9.5	24.9	23.9
E / SE	16.7	17.7	20.0	17.9
S / SW	22.7	21.6	12.9	13.3
W / NW	14.8	13.1	21.0	21.8
∑ Sum	**63.4**	**61.9**	**78.8**	**76.9**

As can be seen from Table 5, orientation towards the heliothermic axis generally results in higher illuminance level on the N/NE and E/SE surfaces, whilst it causes reduction in illuminance level on the S/SW and W/NW surfaces. On the other hand, the results for Sao Paulo shown in Table 6 show an increment on the S/SW and W/NW surfaces and decrement on the N/NE and E/SE surfaces.

When the overall performance is to be taken into account, the effect of heliothermic axis is negative as it results in smaller total illuminance. This comparison, however, is not completely fair as the calculation of the sum assumes equal areas on all sides; the results could vary a lot if the building is not in a regular shape. Hence, the comparison suggests that built form has significant influence on the effectiveness of the heliothermic axis.

3. CONCLUSION

The findings of this study seem to suggest that *La Ville Radieuse*, the so called 'Radiant City' is not 'radiant' at all. The comparison of density and daylight potential between *La Ville Radieuse* and the old Paris urban blocks suggest that the propositions made by Le Corbusier about this ambitious urban plan may not be totally true. The proposal might be good in terms of transportation and the availability of large green and open area; however, in daylight speaking, it does not seem to perform better than the more traditional design.

The daylight performance of the sky scrapers is particularly poor. The findings appear to suggest that the sky scraper proposal is, indeed, not an effective design option for Central Paris.

On the other hand, both housing 'set-backs' and housing 'cellular' have good daylight performance though, the much less usable floor area available in these layouts could be a drawback.

The effect of the heliothermic axis is ambiguous. Although Le Corbusier considered it as one of the most important principles in urban design, its effect on daylight potential has not been justified in the study. However, the study might be a bit biased as the effect of the heliothermic axis is purely evaluated in terms of illumination; the results might be different if other factors such as solar heat gain/loss were taken into consideration.

After all, *La Ville Radieuse*, the rational and systematic urban plan designed by Le Corbusier, does not seem to be an effective design option for both density and daylight performance. On the other hand, the more random traditional pattern, which shows similar daylight potential and possibly higher density, might be a better choice.

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