The Towers' Conundrum: a Visual Impact Analysis

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Towers on Nun'Alvares Avenue overlook Antarctica
-**News Article Title**

Abstract

For the last of a trio of assignments exploring ArcGIS Pro Tools, I performed a visual impact analysis of a trio of towers planned in the city Porto.

I began by calculating the Lines of Sight from the towers to several viewpoints spread throughout the region using a 50cm Digital Surface Model. Afterwards, I performed a View-Shed Analysis using the same Model. Finally, I combined the Digital Surface Model with a Digital Terrain Model and focused on parks and beaches as my metric to assess wether or not the towers' height was indeed problematic.

The results suggest the visual impact of the towers is no reason for concern, as less than half of the leisure areas of the region are in the line of sight of at least one of the towers.

Keywords: ArcGIS Pro, Visual Impact, Line of Sight

1 Introduction

The Nun'Alvares Avenue in the city of Porto was first proposed more than a hundred years ago, back in 1916 (1). However, it was a victim of systematic delays and political changes, and never saw the light of day.

In 2023, the idea was revived once more (1), to much public acclaim, but the enthusiasm of the local population would start withering pretty fast with the announcement of several polemic details of the new project.

One of the many concerns of the locals was the planned construction of three 100m towers right at the start of the avenue (2). The City Hall later "clarified" that the towers' heights would be 78m, 83m and 86m (3), but, with the smallest tower being 13m ($\approx$ 25%) taller than any other building in a 2km radius, the protests didn't seize.

After being asked to use ArcGIS Pro to analyse the visual impact of a new high rise construction at a place of my choosing, I decided this was my chance to settle this discussion once and for all: are the towers really a visual stain in the landscape of the city?

2 The Digital Model

My initial instinct was to download a Digital Terrain Model (DTM) of Porto and the surrounding areas, but I was having a hard time conceptualizing how I would assess the visual impact of the towers with a DTM. Then, it occurred to me that my analysis could only be truthful if I used a Digital Surface Model (DSM), with buildings and bridges.

Determined to get it, I contacted DGT, "Direção Geral do Território" (the portuguese General Directorate for Territory), and they pointed me to the online database where I successfully obtained a 50cm DSM of the country!

3 Lines of Sight

My first approach to the problem was calculating the line of sight from each of the towers to different viewpoints, which I selected among some famous landmarks of the region, as specified on Table 1 on the following page.

Then, I ran the "Linear Line of Sight" Tool, using the viewpoints as the Observers, the towers as the Targets and a clipped version of the DSM as the "Input Elevation

Number	Name	Terrain Elevation	Structure Height
1	Felgueiras Lighthouse	4m	12m
2	Serra do Pilar Viewpoint	80m	0m
3	Arrábida Bridge	0m	70m
4	Crystal Palace Gardens' Dome	75m	35m
5	Time Out Market Panoramic Tower	57m	25m
6	Tower of the Marquis Church	145m	50m
7	Matosinhos Beach	2m	0m
8	LIPOR Hill	152m	0m

Table 1: List of viewpoints, with the respective height and surrounding terrain elevation.

Layer". After running into some problems when trying to consider the observer's height as 1,5m, I decided to settle for 1m (a small child's height), while the towers' height was assumed to be a round 80m (since I dind't know which tower was supposed to be each height).

The result, as seen on Figure 1, was that all three towers were visible from 6 out of the 8 spots I chose.

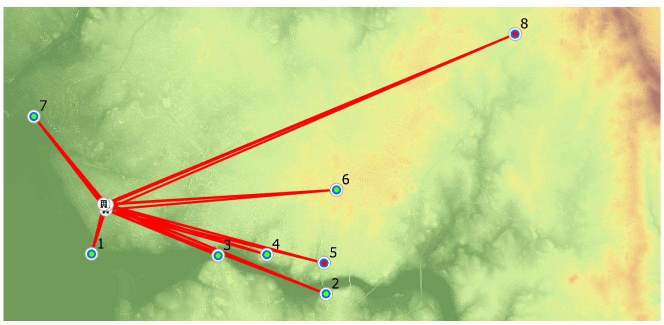


Figure 1: Representation of the 8 viewpoints and the 3 towers, on top of the clipped DSM, which is the most green for the lowest elevation. The Lines of Sight appear overwhelmingly red due to the high number of obstacles in such a fine resolution, but they are not completely red, as shown in Figure 6 on page 6, in the appendix

With the exception of the beach, one could argue I only picked structures with tall vantage points, and they would be right, but these are also the places where people will be actively appreciating the view, which means it's where the towers might feel the most intrusive. The two outliers were the LIPOR Hill, which is much further away than the rest and not tall enough to compensate for it; and the Time Out Market Panoramic Tower, which sits on a depression and really makes one question the "panoramic" aspect of it all.

In the beginning, I also planned to place an observer in the Santa Justa Mountain, clearly seen on the top right side of Figure 1, but I didn't for two reasons:

- it's pretty clear for anyone familiar with the region that the towers would be visible from there, considering the entire shoreline is visible.
- in order to be consistent with the following step, I would have to calculate an even larger view-shed raster layer, which would be extremely time-consuming.

4 Naive View-Shed Analysis

The next step was calculating the view-shed, which might also be an interesting way to evaluate the visual impact of a structure.

For my first try, I decided to calculate a view-shed of a region encompassing all 8 viewpoints. I used the "Geodesic Viewshed" Tool with the clipped DSM as the "Input Raster", used the towers as the "Input point observer feature" and chose an "Observer Offset" of 80m. The result, seen in Figure 2, was not exactly to my liking, since it mostly consists of house roofs, tree canopies, the occasional bird and the ocean. This is, of course, because I forgot to specify a "Surface Offset", which means that, for most areas, this view-shed is actually assessing whether the towers are visible from the floor.

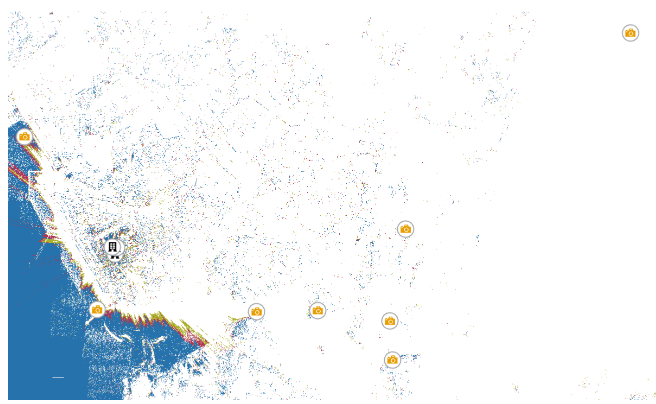


Figure 2: Representation of the 8 viewpoints (the yellow camera icons) and the 3 towers, on top of the resulting view-shed. White represents areas where no tower is visible, gold where 1 tower is visible, red where 2 are visible, and blue where all 3 can be seen.

To obtain a more realistic result, I repeated the process with a "Surface Offset" of 1m (the aforementioned height of a small child). The previous venture did teach me something, though: no tower was visible from anywhere in the vicinity of the LIPOR Hill (even from the top of trees), which means that a 1m increase of the "Surface Offset" would not change the outcome. Thus, I reduced my extent, hoping to shorten the computing time from the previous 6 hours. I (narrowly) succeeded, with the second view-shed finishing in 5 hours, instead.

Still, when looking at the complete result, it is quite hard to spot the differences, so I decided to focus my analysis on the regions surrounding each viewpoint. I also decided to calculate a hill-shade layer to help the visualization.

To avoid extending this report unnecessarily, I've decided to explain in detail only the results of the Arrábida Bridge, as seen on Figure 3. Nonetheless, I've included screenshots of the other viewpoints on Figure 7 on page 7, on the appendix.

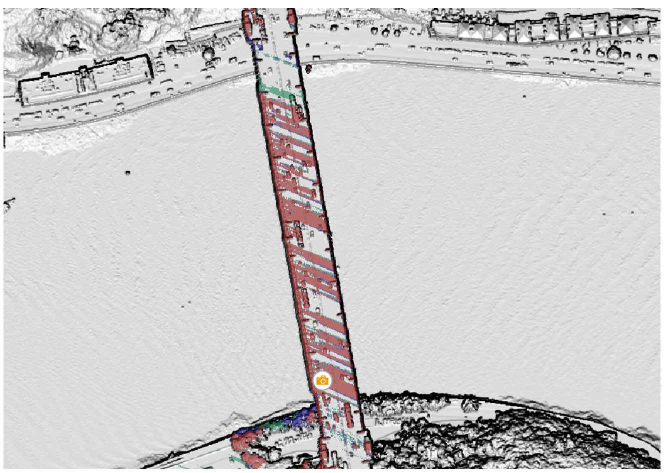


Figure 3: Arrábida Bridge over the Douro River and its valley. The viewpoint is placed at the south end of the bridge. White/grey represents areas where no tower is visible, green where 1 tower is visible, blue where 2 are visible, and red where all 3 can be seen.

The example of the Arrábida Bridge showcases everything that is right and wrong with the current approach. As expected, the entire north bank of the river is grey, since the three towers are located behind the valley hill. At the same time, most of the bridge is colored red, since it's much higher than the water surface and has an unobstructed view for most of its length. The intermittent grey bands on the bridge are mostly caused by obstacles such as lamp posts and vehicles, which are high enough to block the view of a 1m-tall child for the entire width of the bridge. Some problematic red areas (which are misleading, since no one will be sightseeing from there) include the tree canopies of the south bank of the river to the west of the bridge, two small birds flying at an altitude of 200m by the north end of the bridge, and the roof of every car crossing the bridge. On the other hand, some grey areas are also problematic, namely the entire bottom right corner of the picture: all those trees (which are situated at much higher elevation than the small red ones on the left) should be marked red as well, since the bridge has a big arch that renders it virtually transparent. Unfortunately, the program interprets the bridge as a solid object that blocks everything to the east.

To fix this, I would need a 3D model of the region, which not only would be more complicated to retrieve, but also would make the computations even more time-consuming.

5 Serious View-Shed Analysis

After all these qualitative experiments, it was time to create a serious rule-based metric to answer my conundrum, but how?

The Portuguese Census has population statistics by neighborhood, so I could easily calculate how many people and families live in areas where the towers are visible, but that didn't seem right, for three main reasons:

- first, the buildings would be considered to be in the line of sight of the towers if the roof was high enough, but most people don't visit the roof of their buildings or live close to it.
- with a few exceptions that we all remember, people spend most of the time outside of their houses; and, in a city, like Porto, most of the people on the streets don't even live close by, so the "affected" resident population is not the best metric.
- finally, being in the line of sight of the towers a few hundred meters away is not the same as being capable of seeing them from a distance of 10km

The solution became clear: I had to evaluate how visible the three towers are from areas where people actually spend their leisure time, namely public parks and beaches. And I had to limit my extent, so I settled for a maximum distance of 5km, after which the angular size of the towers is less than 1°. For my threshold, I decided to pick 50%; if at least half the total park area in the surrounding 5km was in the line of sight of at least one of the towers, I would consider them visually problematic.

The view-shed analysis of the previous section made something abundantly clear: my DSM had too many obstacles to perform a serious visual impact analysis, from trees, to cars and even birds. On the other hand, I couldn't simply use the DTM of the region, because the surrounding buildings have to be taken into account when evaluating the fitness of the three towers in the local landscape. To fix this issue, I decided to take the best of both worlds; I downloaded a shapefile of all the public parks and beaches from OpenStreetMaps, I got a 50cm-DTM of the country from the DGT database, and used the "Raster Calculator" Tool to create a new special raster which was a copy of the DSM with the exception of the areas inside the parks and beaches, which used the DTM values instead!

For some reasons beyond my understanding, the process with the new raster was much slower, but I managed to get it done in 6 hours by using a different computer.

Once again, the resulting raster isn't very visually informative, as seen in Figure 4, but the math behind it is: out of the 29,2km^2 of parks (and beaches), only 11,4km^2, i.e. less than 40%, is in the line of sight of at least one of the towers. Even if the focus was only on the parks at a maximum distance of 1,5km (when the angular size of the towers is 3°), only 40% of the area is covered.

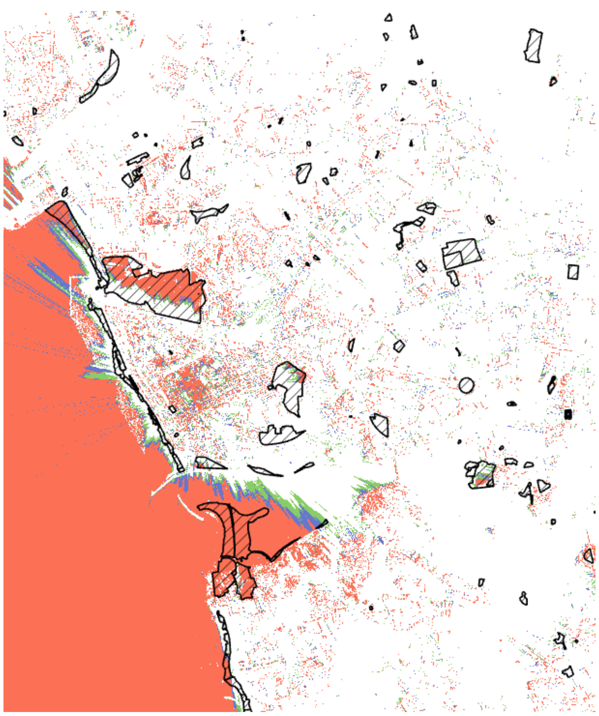
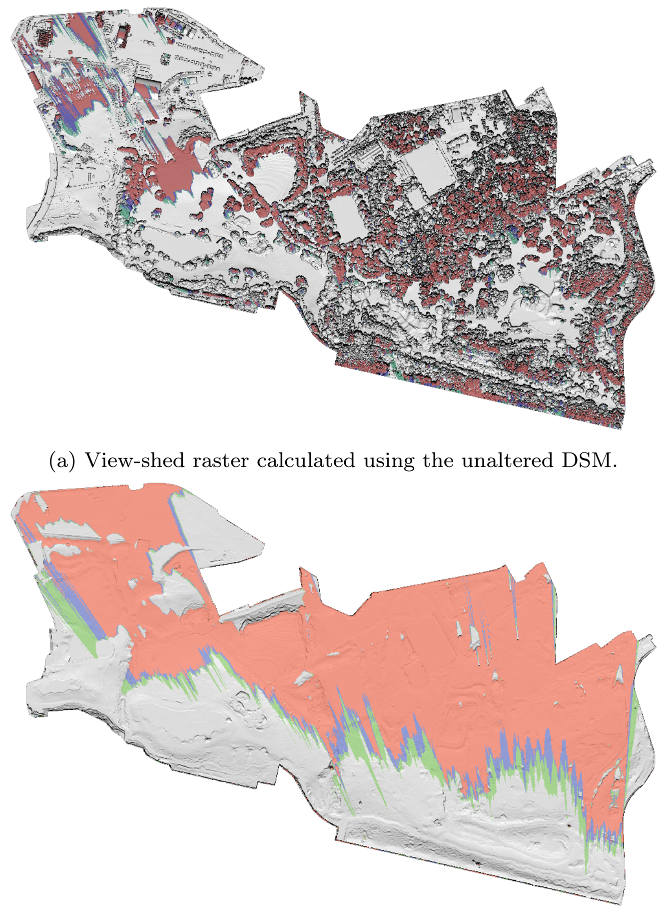


Figure 4: Representation of the parks and beaches on top of the resulting view-shed. White represents areas where no tower is visible, green where 1 tower is visible, blue where 2 are visible, and red where all 3 can be seen.

It thus seems that the towers are not problematic after all, but it is still hard to ignore the elephant in the room: the Porto City Park, the largest park in the city, seen with a large portion of its area included in the line of sight of the towers on Figure 4.

Figure 5 shows it in detail before (Figure 5a) and after (Figure 5b) creating the combined special Model. On Figure 5b, one can see that 60% of the park's area is in the line of sight of the towers, which, considering the importance of the park, is not something that can be thrown aside, even if it is agreed that the towers are not overall problematic.



(a) View-shed raster calculated using the unaltered DSM.

(b) View-shed raster calculated using the special Model.

Figure 5: View-shed rasters of the Porto City Park on top of the respective hillshade layers. White/grey represents areas where no tower is visible, green where 1 tower is visible, blue where 2 are visible, and red where all 3 can be seen.

The answer, however, lies with Figure 5a. Its percentage of red areas is not representative of reality, because, on the one hand, trees are not solid cylinders with a base diameter the size of their canopy, and, on the other hand, tree canopies are usually inaccessible and thus irrelevant if they are in the line of sight of the buildings. However, when we compare it to Figure 5b, we notice that the areas in the line of sight of the buildings are the areas with the most trees, which means that (yes, the three towers will most likely be visible from those football fields, but otherwise) the most affected parts are protected by the trees in the park!

References

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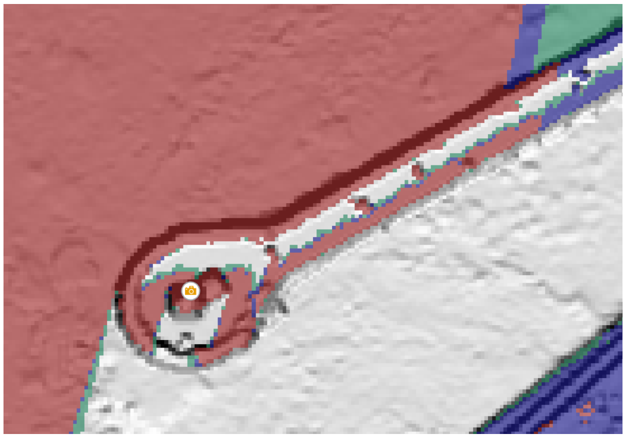
[2] Lusa, “Loteamento da avenida nun’ álvares no porto possibilita torres até 25 andares,” Jul 2025. [Online]. Available: https://www.publico.pt/2025/07/10/local/noticia/loteamento-avenida-nun-alvares-porto-possibilita-torres-ate-25-andares-2139759

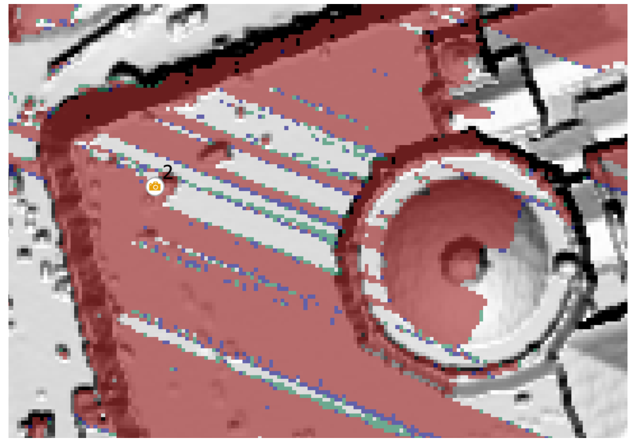
[3] 2025. [Online]. Available: https://www.cm-porto.pt/destaque/declaracao-sobre-a-uopg1-nunalvares

6 Appendix

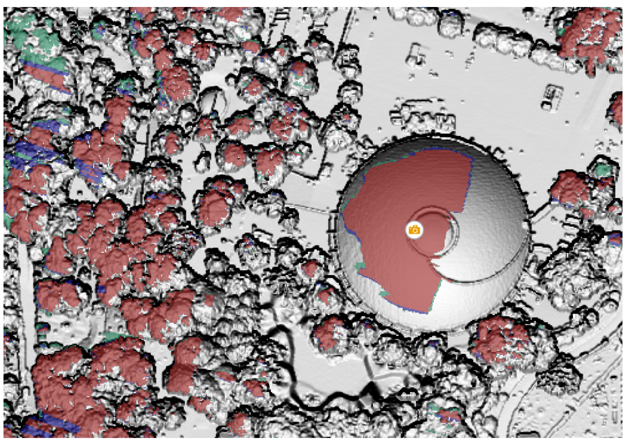
Figure 6: Detail of Lines of Sight from the Serra do Pilar Viewpoint, where green represents the visible areas from the viewpoint, while red represents the hidden ones.



(a) The Felgueiras Lighthouse and the breakwater connecting it to the coast. The viewpoint sits on top of the lighthouse.



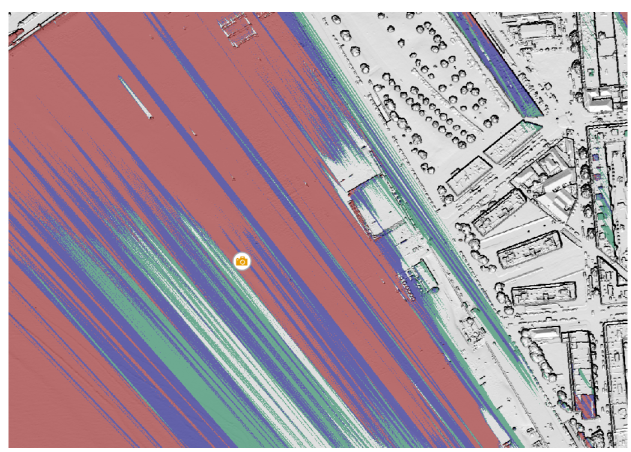
(b) Serra do Pilar and its old Monastery. The viewpoint sits at the square in front of the monastery, often used as viewpoint by sightseers.



(c) The Crystal Palace Gardens and the dome of the Rosa Mota Pavillion. The viewpoint sits on top of the dome.

(d) São Bento Train Station, where the Time Out Market is located, with its hexagonal-shaped panoramic tower on its side. The viewpoint sits on top of the tower.

(e) The Marquis Church with its two towers. The viewpoint sits on top of the tallest tower, which visitors can climb.



(f) Matosinhos Beach and enighbouring coastal areas. The viewpoint sits on the beach.

Figure 7: Viewpoints (the yellow camera icons) and surrounding areas. White/grey represents areas where no tower is visible, green where 1 tower is visible, blue where 2 are visible, and red where all 3 can be seen.