# Underground lines that bypass monuments

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This is an image of underground lines that bypass monuments. Credit: Ortega et al. /UV

A team of mathematicians from the Engineering and Architecture Schools of the University of Seville has created a method to design underground lines whereby a city's historical buildings are unaffected. The results of the study, which has just been published in the *Journal of the Operational Research Society*, offer possible solutions for the future underground line 2 in Seville.

"The methodology applied seeks to minimise the length of underground lines -with the subsequent economic saving- and to maximise their distance from historic buildings to avoid their being damaged", Francisco A. Ortega, co-author of the study and professor at the Higher Technical School of Architecture of the University of Seville, explains to SINC.

The study, published in the *Journal of the Operational Research Society*, uses "Voronoi diagrams", a mathematical tool that divides a plane into polygons created around points (72 historic buildings, in this case), in such a way that their perimeters are equidistant from neighbouring points. These geometric constructions are used, for example, to establish mobile telephone networks in an area.

The researchers have created an algorithm that finds the shortest routes between two nodes of the Voronoi diagram, ensuring a safe distance from monuments. Polygon edges are also rounded to make the route smoother.

The study specifically applies to the construction of line 2 of the Seville underground, which over the next few years will link the city's Palacio de Congresos (Conference Centre) with Santa Justa railway station, the historic centre and the district of Triana.

Ortega asserts that "There have been doubts as to the viability of this work regarding the safety of nearby buildings due to previous experiences, such as the fact that the construction of the first underground line in Seville in the seventies was suspended out of fear that the cathedral might be affected, or more recently in the district of Carmel, Barcelona, where the structure of certain buildings was damaged as a result of the works carried out to extend the underground".

The researcher explains that the new method provides "genuine, feasible and efficient solutions" for line 2, and leaves an average safety radius of 80 metres around the historic buildings. The work offers various non-disruptive alternatives for the construction of this underground line in Seville.

Ortega emphasises that the methodology follows "multi-criteria optimisation" in the design of underground networks, but does recognise

that when it comes to the final decision-making process there will also be other factors to consider (the speed at which work is carried out, the order in which lines will open, integration with other transport systems, such as trams) and various agents (local governments, autonomous regions, transport operators etc.) will be involved.

Source: FECYT - Spanish Foundation for Science and Technology