GIS-based 3D landscape visualizations for improving social acceptance and public participation of wind farms

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Abstract. Wind energy is one of the most important source of renewable energy characterized by a significant growth in the last decades and giving a more and more relevant contribution to the energy supply. One of the main disadvantages of a faster integration of wind energy into the energy mix is related to the visual impact of wind turbines on the landscape. In addition, the siting of such infrastructures has the potential to threaten a community's well-being if new projects are perceived being unfair. The public perception of the impact of wind turbines on the landscape is also crucial for their acceptance. The implementation of wind energy projects is hampered often because of a lack of planning or communication tools enabling a more transparent and efficient interaction between all stakeholders involved in the projects (i.e. developers, local communities and administrations, NGOs, etc.). Concerning the visual assessment of wind farms, a critical gap lies in effective visualization tools to improve the public perception of alternative wind turbines layouts. In this paper, we describe the advantages of an interactive GIS-based 3D visualization approach integrated in a decision-support web platform with augmented reality functionalities to support wind energy planners in order to enhance the social acceptance of new wind energy projects.

Keywords: public participation, augmented reality, 3D interactive visualization, GIS.

1. Introduction

Wind energy has been a source of debates and arguments in the last decades due to general accepted willingness of renewable energy sources to reduce the CO2 emissions. On the other hand, one of the main concerns about the siting of new wind farms is the visual impact on the surroundings and their noise and impact on birds and wildlife [1]. The acronym NIMBY ('Not-In-My-Back-Yard') describes resistance to siting specific projects close to one's area of residence while exhibiting acceptance of similar projects elsewhere [2]. The local participation with respect to the installation of wind turbines has been investigated in the last decades [3, 4] showing that the acceptance is influenced by the perception of the landscape and the value given to the aesthetic impact on the environment. Previous studies showed the importance of the visual impact in different countries such as Sweden [5], Netherlands [6] and USA [7]. In addition, according to previous work, the social acceptance is a key aspect for a successful market development [8, 9] and stakeholders admit the lack of useful instruments to support social acceptance [10, 11]. The importance of involving local communities when planning wind energy projects has been investigated in many regions of the world such as Australia [12], France and Germany [13].

Overall, factors such as quality of communication, public participation in the planning process are demonstrated to play a critical role in the acceptance of new wind projects by local communities [14, 15]. This issue has been addressed in last decades in order to support planners and investors in increasing the social acceptance of wind projects and thus to reduce the construction time and investment risk.

With the technology progress, IT solutions and processes were developed aimed at supporting planners and decision makers in the planning process of wind energy projects. Typical approaches of superimposition of images from given points of view have been adopted for years [16] to show the visual impact from different distance for offshore wind turbines and onshore wind projects [17] showing limitations due to the lack of visualization from different perspectives. The more realistic the image or the visualization, the higher is the achieved credibility [18]. In addition, previous work demonstrated that the interactivity of the 3D visualization of wind farms in landscape is a benefit for users [19, 20]. Visualization software program pushed by computer games gave a significant contribution for the interactive visualization enabling for real-time navigation through virtual environment [21].

Approaches using Geographic Information Systems (GIS) have been developed to enhance the public participation and acceptance of wind energy projects [22, 23] for visualization [24] and integrating also the acoustic 3D simulation [25]. The technological advances in digital landscape visualization techniques allow using digital 3D visualizations for landscape design, planning and management [26].

In this paper, we describe the advantages of a 3D dynamical and interactive visualization platform with augmented reality functionalities to support wind energy planners to enhance the social acceptance of new energy projects. The developed process consists of a combination of GIS processes aimed at identifying the regions suitable for wind energy projects whose outcome is then used in the 3D visualization for augmented reality. The advantage of the proposed generalized method is the ability of combining the planning phase with the 3D interactive visualization into a unique tool enabling users to have an intuitive and real-time understanding of possible scenarios of new wind farms immersed in a virtual landscape. The additional benefit consists of the flexibility of tool in being adapted for public participation and thus giving investors and administrations a tool for a better communication with local communities. The tool can be also applied for planning for example transmission lines which are infrastructures necessary both for wind farm construction and the enhancement of the existing power grid.

2. Materials and Methods

2.1. Dataset

The data required for a 3D visualization and augmented reality consist of the geospatial data of the landscape (i.e. topography, satellite images) beside a 3D object library. The higher the resolution the better the landscape is represented. The objects in the landscape are added in the exact location and with their corresponding characteristics (e.g. the type and the height of trees). LiDAR data can be also integrated and used to better describe the objects in the landscape.

2.2. Method

The layout of wind turbines is optimized in order to maximize the economic profit using different IT solutions based on CFD but neglecting the analysis of their visual impact. Often visual assessments are carried out by superimposing wind turbines on fixed images taken from few viewpoints limiting thus a full perspective of the whole landscape. The developed platform uses, first, GIS data and geoprocessing (Figure 1) to identify suitable locations of wind turbines far from natural and anthropological constraints. The suitable regions are identified by excluding areas not suitable for installing wind turbines (see Figure 2) and using a multi-criteria decision analysis (MCDA)[27] which classifies areas using a matrix of weights corresponding to the land suitability as done in previous work [28, 29] and applying buffer distances [30]. These weights are set by planners based on their experience and by experts' opinions.

Then, each suitable land is discretized in cells of arbitrary spatial resolution corresponding to potential suitable wind turbines locations (Figure 3).

The obtained suitable regions are integrated into a 3D visualization (web)-platform that allows to place 3D wind turbines models in the allowed areas. Each cell contains information and data of the wind resource and the corresponding geographic position. Additional information, such as the visibility of the wind turbines from selected landmarks of the landscape, can be also estimated using a GIS-based process.

In Switzerland, when planning large infrastructures, such as wind farms or transmission lines, the visual impact plays a critical role since the landscape is considered as part of the well-fare and a quantitative assessment of the visual impact from given observers gives planners a useful information about the potential locations where issues can raise.

As investigated in previous studies [31], for instance, the visual impact of such massive infrastructures can be quantified as function of the distance from the buildings in the landscape within a certain radius from the wind farm area. In Figure 4 the estimate of the spatial distribution of the visibility is shown: with this approach the area around each cell is divided into multiple concentric rings and to each of them a weight is assigned depending on the distance from the center of each cell.

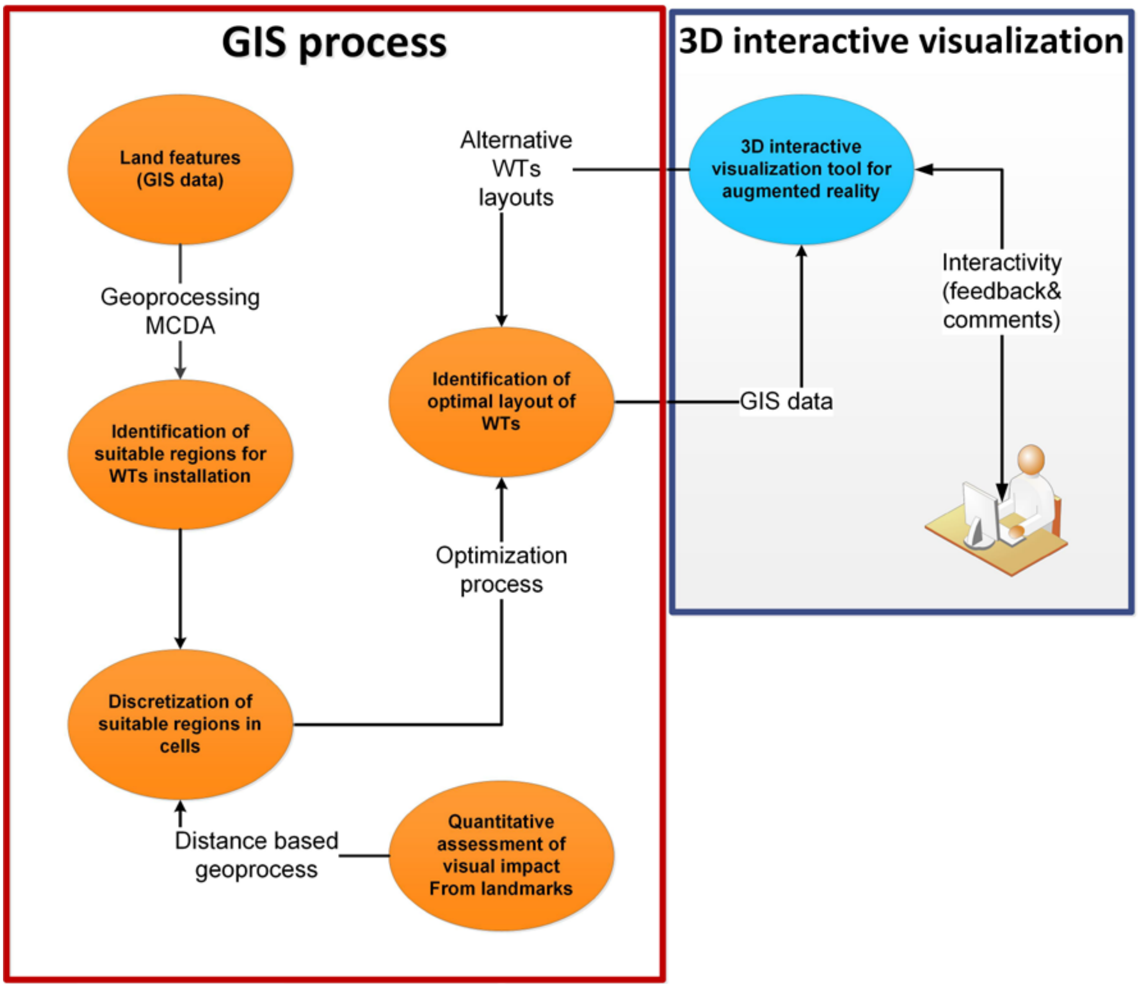

Figure 1: geoprocessing of the developed platform for an augmented 3D interactive visualization of wind turbines

The width of the histograms corresponds to the width of the rings and is determined by discretizing the function expressed in the Figure 4 (right). The weight of a circular ring equals the mean value of the impact between the inner and the outer radius and is calculated with the relation in Figure 5 (right). The difference between the inner and the outer radii increases with the distance whilst the corresponding weight decreases. The weight of each ring is roughly 0.85 smaller than the weight of the previous ring. This map can be generated for any region and any type of wind turbine and to assign a value of visual impact to each cell (Figure 5). Once the information and the data are collected, the layout of wind turbines is identified in the space, the 3D visualization can be created (Figure 6). A user can navigate through a given project using customized functions in order to get an augmented and more realistic perception of the impact of wind turbines on the landscape (Figure 7). The user can both simulate a walk at the ground level and fly over the project region to gain a personal perspective. This allows having a realistic subjective impression of the impact of wind turbines from arbitrary locations or landmarks in the landscape. In countries such as Switzerland, the environment and the landscape are highly considered as element of the welfare therefore such massive infrastructures are seen as an issue for the beauty of valleys and mountains.

Overall, the values of the landscape threatened by massive infrastructures such as wind turbines are one of the typical reasons raising local protests and opposition in many other regions worldwide, not only in Switzerland. This reasonable concern of local population stems from both a lack of knowledge of wind turbines technology and the lack of efficient form of communication and visualization allowing one to get a visual interactive experience of how a project will look like. Aware of this issue, the platform is designed in order to assess the visual impact from different points such as trails in the mountains, ridges or any other given location and can be applied to any region worldwide.

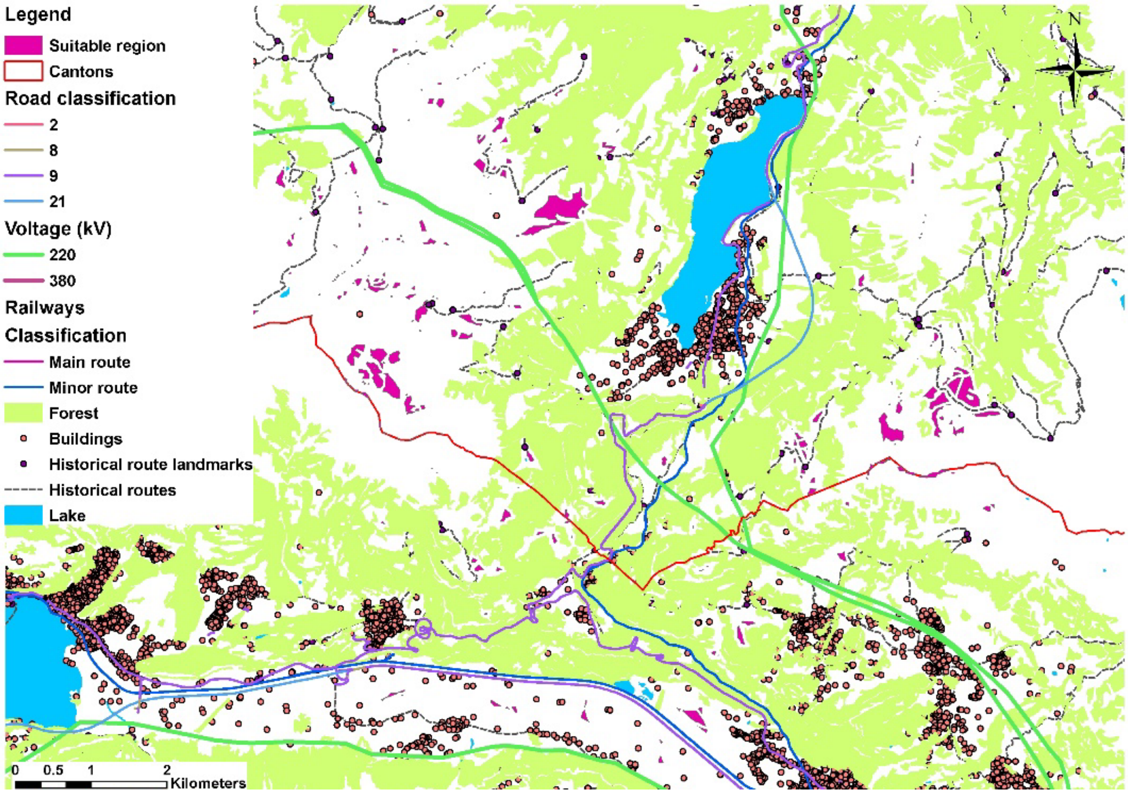

Figure 2: identification of suitable areas far from constraints

Since multiple locations are suitable for wind turbines, the interactivity feature of the platform allows modifying the positions of wind turbines within the allowed areas identified with cells. This enables identifying different scenarios both in terms of number of wind turbines and layout in order to assess the different visual impacts. At the same time, the tool performs the estimate of the long-term electricity generation and thus comparing different scenarios.

The advantage of the developed platform is its flexibility of being adapted for public communication in a form of a web-platform where stakeholders can be exchange feedback and comments about a given wind farm project. The driving concept for the development of this platform is the need of giving a more realistic and intuitive experience of a future project. The superimposition of fixed images from few viewpoints is a great limitation when showing new wind farm projects since it does not show their impact from different perspectives.

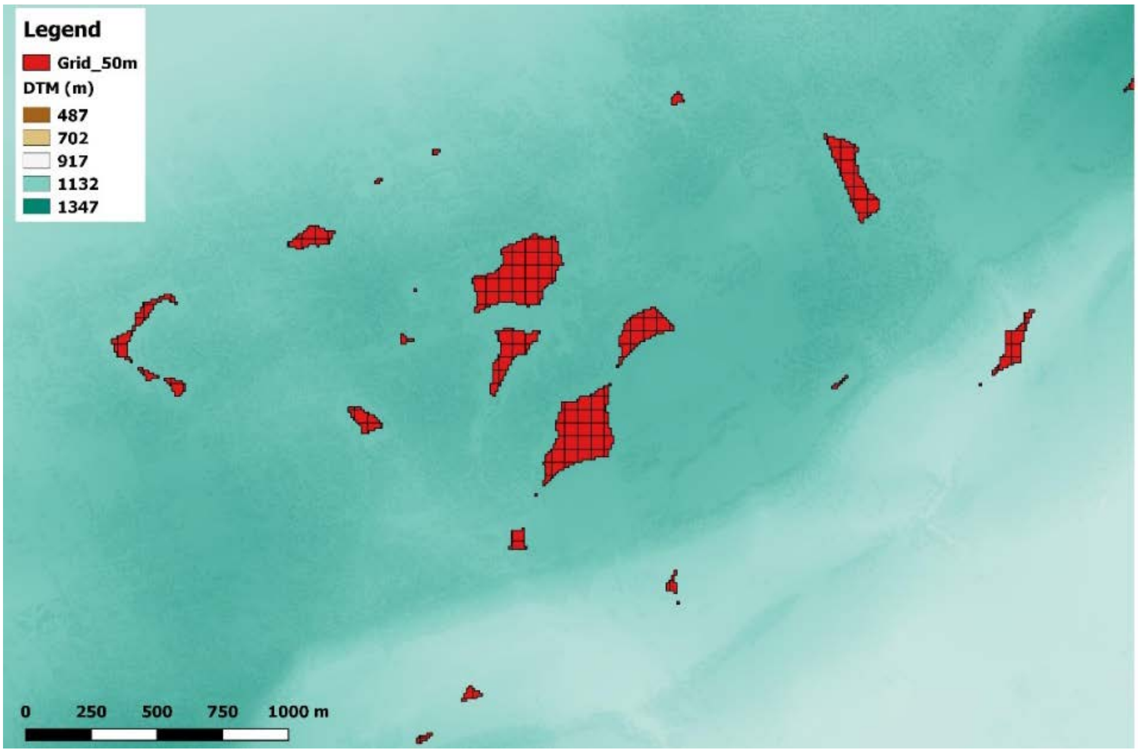

Figure 3: discretization of suitable region in cells of 50m resolution.

Since the local population is familiar with their landscape and has a high consideration of the landscape and natural values as part of their welfare, they look at the wind turbines as a thread for their wellbeing. Any sort of environment and landscape can be reproduced with high resolution and fidelity (Figure 6).

Additional features of the 3D visualization are the shadowing and flickering of the tower and the blades of wind turbines depending on the position of the sun and the simulation of the different weather conditions. The flexibility of the 3D interactive platform allows integrating functionalities useful for wind farm planners in order to obtain and quick overview and visualization of a wind farm layout. The platform is useful to enhance the communication with the local population and to identify critical aspect of a wind farm layout (e.g. wind turbines position not accepted by the population).

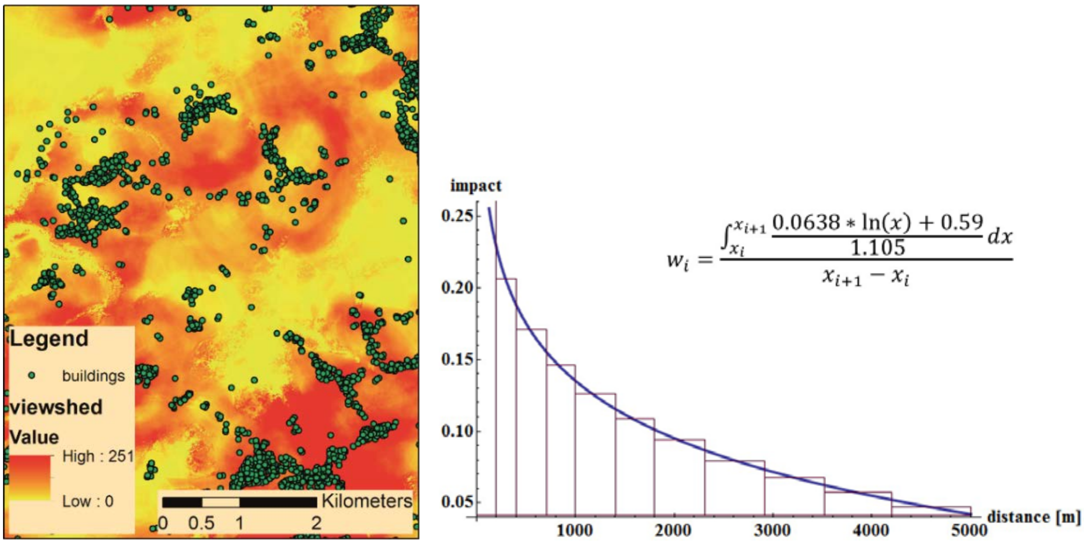

Figure 4: (left) spatial distribution of the visibility of transmission line towers from the buildings, (right) approach used to estimate the visibility depending on the distance.

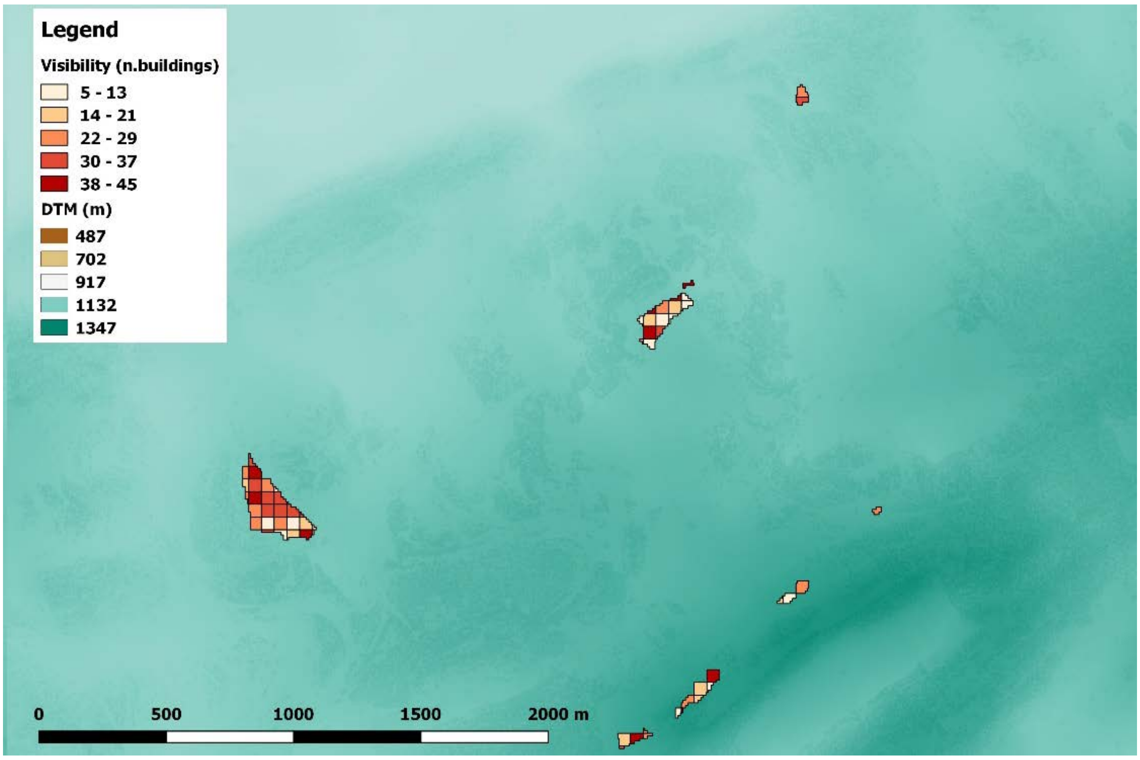

Figure 5: distribution of the number of visible buildings from each potential cell suitable for wind turbines.

Figure 6: Realistic and GIS-based 3D landscape visualization of wind turbines from pedestrian view.

Previous work demonstrated how a 3D dynamic visualization can support users in better understanding the impact of wind turbines on the landscape (Manyoky et al. 2015). The platform can be also used as a useful tool for public participation by integrating and exchanging comments and feedback between all stakeholders involved in the projects. Suitable locations for wind turbines can be graded depending on the individual perspective and finally ranked based on their suitability.

Figure 7: Assessment of a wind farm layout on site by augmented reality

3. Results and Discussions

The social acceptance of wind energy projects can be improved by using 3D interactive visualization platform which allows a user to navigate through a more realistic representation of the landscape. The 3D platform realistically reproduces 3-dimensional objects of the environment using GIS data and high-resolution satellite images and 3D objetcs. It helps users to experience the visual impact of wind energy projects from different viewpoints and to have a better understanding and perspective of the impact of wind farm projects on the landscape. The developed platform can be applied to any region and for any wind farm size, layout and wind turbine model overcoming the limitations of fixed images usually used to reproduce the visual impact from a limited number of viewpoints. The flexibility of the platform allows integrating also additional tasks to support planners during the planning phase of wind farms, in particular:

- the identification of the optimal layout of wind turbines in suitable regions for wind farms,
- a preliminary quantitative assessment of the visual impact of wind turbines from landmarks or buildings in the surroundings
- the assessments of visual impact of other elements of wind energy projects such as transmission line interconnection
- the creation of platform for enhancing the public participation and interaction between all stakeholders of the project and the local communities

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