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APPLICATION OF VISIBILITY ANALYSIS AND VISUALISATION IN HOSPITAL WAYFINDING SIGN DESIGN

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ABSTRACT

This study aims to show the application of visibility analysis in hospital outpatient areas to improve wayfinding performance. Visibility is regarded as an essential aspect in wayfinding sign design and affected by the spatial configuration of the environment where the signs are located. The complexity of hospital environment prevents the designers to predict its visibility properties and also creates difficulties in determining the requirement for the sign system such as the location, direction, and size of signs. Based on isovist, visibility graph and visual catchment area (VCA) concept introduced from the past studies, we developed analytical and visualisation tools to aid the wayfinding design processes. The results suggest that the use of visibility analysis in wayfinding sign design can provide valuable insight into the preliminary analysis before the design process, as well as enable design optimisation in the development stages.

Keywords: Wayfinding; hospital; visibility analysis; sign design.

INTRODUCTION

Wayfinding is an important yet often overlooked aspect of hospital design. The complex nature of the hospital environment creates many wayfinding difficulties for its visitors. It is also unfamiliar to most people who do not visit the hospital regularly. The combination of the unfamiliarity and complexity of hospital buildings create wayfinding problems that need to be adequately addressed. Wayfinding problems add hidden costs to the healthcare services in hospitals (Ulrich et al., 2008). The time spent by the healthcare staffs to direct the confused visitors and the caused delay put significant impacts on the overall service efficiency. It also causes frustration to the patients and visitors (Carpman & Grant, 2016) due to disorientation. However, despite the importance of wayfinding system in healthcare facilities, it is often overlooked and underappreciated (Devlin, 2014). Wayfinding system is rarely included in the healthcare environment planning and design process.

Wayfinding system aims to enable people to navigate intuitively by providing necessary information or clues (Gibson, 2009). While signage is the most used aids in hospital wayfinding system, it is often regarded as confusing (Brown, Wright & Brown, 1997) due to its small size, inadequate colour and poor positioning. Wayfinding signs in hospitals should be designed and located appropriately in the complex hospital spatial organisations. Among the other things, visibility is the most crucial aspect that needs to be considered in a signage design (Mclaughlin, McNeil & Sebald, 2005). However, analysing the visibility in a complex environment is difficult. Many elements such as walls, column and other spatial elements can act as visual obstacles in an area. The elements prevent designers to predict the visibility properties of the space accurately. Analytical tools are thus needed to improve the wayfinding system design process in the complex healthcare facilities environments.

Visibility analysis can be conducted systematically by using computational tools (Johanes & Atmodiwirjo, 2015; McElhinney & Psarra, 2014; Turner et al., 2001). The use of visibility analytical tools can provide valuable insight for examining and optimising the visibility properties of a spatial configuration. This paper proposes the incorporation of visibility analysis in the signage system design process and its implementation in Universitas Indonesia Hospital, in particular for the wayfinding design of the lobby and outpatient areas. By incorporating the visibility analysis in wayfinding design, the decisions points as well as the signage sizes can be decided with more precision and greater assurance.

VISIBILITY ANALYSIS AND WAYFINDING SIGNS DESIGN

Visibility is the most critical aspect of the signage design. The signs should be free from any physical obstructions and must be readable in its designated condition and noticeable from specific decision points (McLaughlin et al., 2005). Montello (2014) used the notion of visual access to denote the degree of visibility of an area to be seen by people.

The higher the visibility of an area, the easier it is to be observed by people hence contributing directly to maintaining the spatial orientation. Generally, visibility of an area can be predicted by observing the shape of the area and the obstacles around it. However, the spatial configuration in the hospital environment is far from simple. Instead, it is defined by various elements that are configured in such a way to fulfil the function of the hospital. Those complex spatial arrangements prevent the assessment of visibility to be conducted intuitively, and thus the more systematic analysis is needed.

A systematic approach in analysing visibility was introduced by Benedikt (1979) by using isovist, defined as a volume of space that is visible from a particular point of view within a defined environment. This volume is analogous to the volume occupied by an optic array (Gibson, 2015) as a collection of abstract lines that are projected to the point of observation. The unoccupied volume thus denotes the areas that are not visible from the defined point. The spatial description derived from isovist has been used widely to predict the people behaviour (Wiener & Franz, 2004) and experience (Sengke & Atmodiwirjo, 2017) in a spatial setting. The geometric properties of isovist can be calculated further through some quantitative measures such as area, perimeter, occlusivity, variance, skewness and circularity (Benedikt, 1979). Isovist thereby provides both visual and quantitative method to analyse the visibility properties of an area in a defined environment.

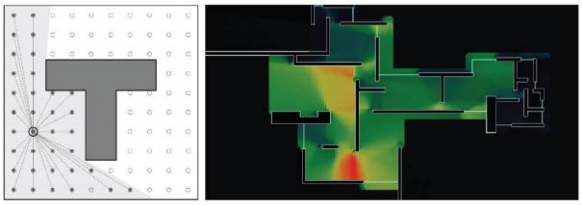

Fig. 1. Neighbouring Isovist to Construct Visibility Graph

Turner, Doxa, O'Sullivan & Penn (2001) extended the approach by systematically constructing visibility graph using a set of isovists in a grid configuration across the analysed environment. A graph is constructed by mapping the number of neighbouring isovists in the first-order connectivity that occurs within the set (McElhinney & Psarra, 2014; Turner et al., 2001). First order connectivity is defined as the direct visibility between an isovist to other isovists. The number of neighbouring isovists from a point indicates the degree of visibility of that point. The larger the number, the higher visual access of that point and *vice versa*. In contrast to single isovist that describes visibility locally, visibility graph maps the visibility degree across the defined area of space. The resulted map offers a more global and continuous visualisation as shown in Figure 1.

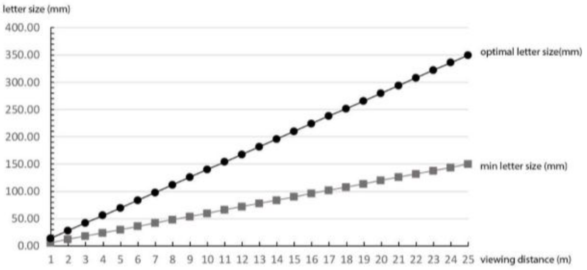

Fig. 2. Relation between Viewing Distance and Letter Size for Visual Angle Range from 0.003 to 0.007 rad (Source: author, based on Smith, 1979).

The visual appearance of signage is also crucial in ensuring its legibility. There is a certain text size required for a sign to be legible from a defined distance. The conducted field study confirms that a proper letter size to guarantee readability should range between 0.003 to 0.007 rad visual angle or visual acuity (Smith, 1979) at any viewing distance. The size of the text thus increases and decreases according to viewing distance in a linear manner (Figure 2.). Incorporating the viewing distance of the text is crucial since it affects the way the signs are located. If the placement of a sign is located too far from the designated viewing points, the required size is perhaps impractical. On the other hand, locating too many signs in the closer distance is costly and potentially confusing. The empirical evidence shows that the text size at visual acuity 0.003 rad has over 90% legibility while virtually went to 100% legibility at 0.007 rad, the mean value of the limit of legibility is measured at 0.0019 rad (Smith, 1979). However, the legibility of the text varies from one person to another thus creating text for a sign on the limit of legibility is not advisable.

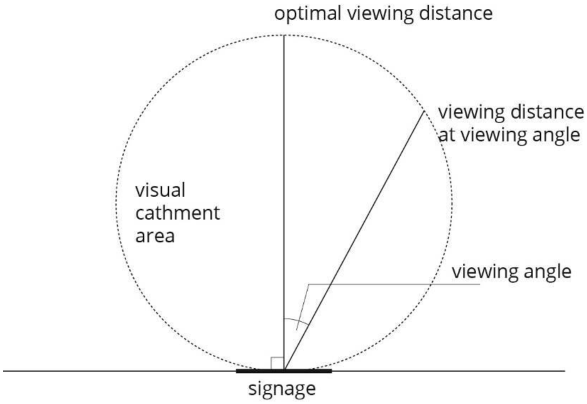

Fig. 3. Visual Catchment Area of a Sign Resemble a Circle Tangent to the Sign (Source: author, based on Xie et al., 2007).

The direction of the signage to the observer affects the optimal viewing distance to the sign. Filippidis, Galea, Gwynne & Lawrence (2006) introduced the concept of visual catchment area (VCA) of signage. VCA is defined as the area from which the observer can retrieve information from the signage. Xie et al. (2007) further constructed the enhanced theoretical model of visual catchment area (VCA) and conducted experimental trials to ensure its validity. They discovered that the optimal observation distance between the observer and a sign approximates the shape of a circle tangent to the sign (Figure 3). The diameter of the circle indicates the optimal viewing distance perpendicular to the sign. The viewing distance decreases as the viewing angle increases from the optimal viewing direction which is perpendicular to the sign. The combination of signage VCA model with isovist visualisation can be used to show the visibility coverage of a sign within defined environment directly. The effect of viewing angle to the viewing distance highlights the importance of anticipating the visitors' circulation pattern to match with the direction of the signs.

The nexus between spatial configuration, visibility and visual catchment area (VCA) of the signs provide a framework in the wayfinding design process to create better signage system that is necessary for a modern hospital. Visibility graph, together with other wayfinding preliminary analysis data, offers a general outline from which potentials signage position can be projected. On the other hand, the visualisation of the signage's VCA for each signage locations can both simulate and optimise the signage position programming by showing the signage visibility coverage within the plan. The following sections explain the integration of visibility analysis in a signage design process and its implementation to Universitas Indonesia Hospital which was in the design stage when this study was conducted.

VISIBILITY ANALYSIS AND SIGNAGE DESIGN WORKFLOW

This research uses a computational approach to analyse the spatial organisations of the lobby and outpatient area of Universitas Indonesia Hospital. A computational tool based on isovist and visibility graph in analysing the visibility properties of a spatial configuration has been developed in our previous study (Johanes & Atmodiwirjo, 2015). In the current study, the tool is extended to visualise the VCA of the signage to assist the wayfinding system optimisation. The plan is drawn using CAD drawing tool Rhinoceros 5 (2014) and systematically converted to an SVG file (Dahlström et al., 2011) by using Grasshopper (McNeel, 2010) as the input data for the tools.

Three main stages are adopted in the design process: research and analysis, strategy development, and signage programming (Gibson, 2009). Those stages are adopted in the workflow to incorporate the visibility analysis within the process: 1) preliminary and visibility graph analysis of hospital plan; 2) signage system strategy development; 3) determining the wayfinding system and signs location using VCA simulation tool. The preliminary hospital plan analysis is intended to gather all the required information to conduct the study. The information such as rooms and circulation spaces are collected to identify the general circulation system as well as the wayfinding requirements. At this stage, the groups of zones are also identified and classified. Visibility assessment is conducted using the developed tool to assist the strategy in the placement of signs. The measured visual access using visibility graph is synthesised with the preliminary spatial organisation study to determine the optimal signage strategy. The available options are then simulated in VCA visualisation to ensure the continuity of information throughout each decision points.

The scope of the study presented in this paper is limited to the directional signage system for the lobby and outpatient area on the ground floor of the hospital. This research is not focused on the visual design of the signage per se; instead, it attempts to generate the requirements and recommendations of signage system in its architectural setting based on the visibility and wayfinding analysis and visualisation.

HOSPITAL LOBBY AND OUTPATIENT AREA WAYFINDING SIGNS DESIGN

The hospital building analysed in this study consists of two adjacent blocks on the ground floor (Figure 4.). The main lobby and information station are located in an ellipse building that also becomes its main entrance. In the lobby areas, there are two elevators and an escalator that connect to the upper lobby areas. The lobby is connected to the main rectangular building through a single corridor which connects the registration and cashier desk before it is branching into two main parallel corridors. The two corridors connect the circulation area to the main outpatient destination areas such as pharmacy, laboratories and clinics, as well as stairs and elevators to the upper level. The double corridor system is simple enough to connect various areas of the outpatient areas, but its separated axis with lobby area potentially creates confusion for people who enter or exit the main building from the lobby because they are not directly visible from one point to another. The long corridor also hinders people to directly identify the areas that are located on the other end of the passage. There are also some long corridors connecting the main corridor to the smaller areas in the hospital. However, the corridor is not branched, thus decreasing the chance of people getting lost. The hospital plan indicates that wayfinding problems potentially emerge in the bottleneck between main building and lobby areas as well as the high number of destinations that are restricted by the amount of information that can be contained in a single sign.

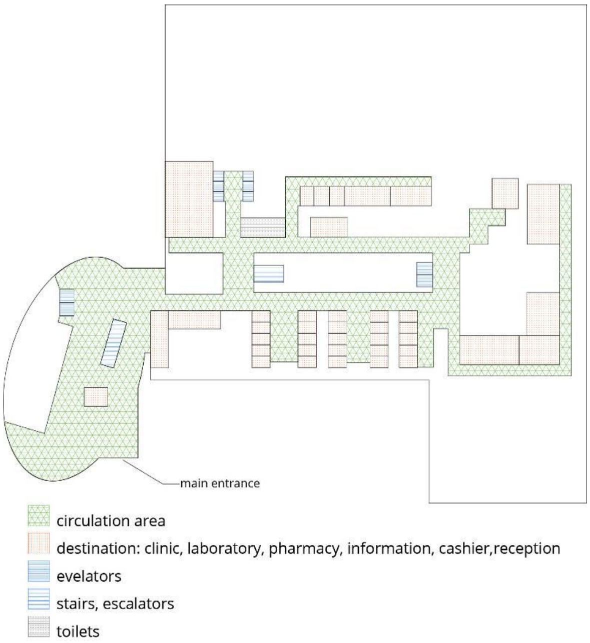

Fig. 4. Identified Spatial Organisation of Outpatient Area

Figure 5 shows the visibility graph of hospital main circulation area that is generated using the developed analytical tool. It is shown that every area has the different levels of visibility according to its spatial configuration. The darker area indicates the low level of visibility while the brighter area indicates a higher level of visibility from its surrounding. The intersection between the main corridors and hospital lobby has the highest visibility degree compared to other areas. However, isovist simulation shows that only part of that area is visible from the entrance and the main corridor. The front area of the elevator is found to have a high degree of visibility, but unfortunately, it is mostly visible only from a large area on the other side of the escalator and information station, which are not included in the main circulation. It is shown that a higher degree of visibility alone cannot be used as the determinant of signage position. It must be combined with other results of wayfinding analysis such as circulation pattern analysis and more locally isovist visualisation. Nevertheless, the visibility graph offers a quick, valuable insight into the visibility properties that can be used to avoid inefficient or redundant signs. For example, the relatively low visibility degree area in front of the elevator on the opposite end of the corridor indicates a lower necessity to locate directional signs since it is rarely visible from its neighbouring area. Instead, placing the signage along the corridor which is also visible from the elevator is perhaps more beneficial.

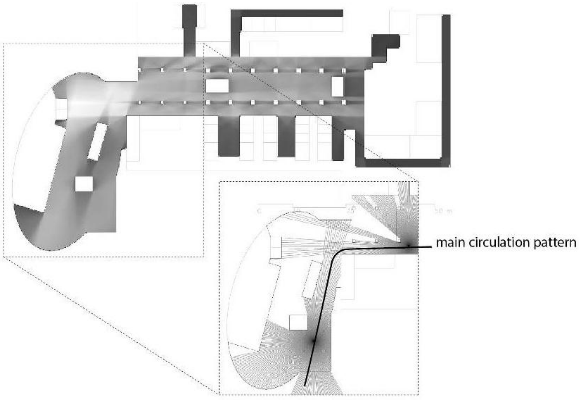

Fig. 5. Visibility Graph of Hospital Plan

Gibson (2009) listed four strategies that can be used in the wayfinding strategies that are derived from urban design: the connector model, the district model, the landmark model and the street model. The connector model highlights the main path as the connector that ties different areas together. The district model divides the areas into conceivable geographic clusters that are named and coded. The landmark model identifies the essential destinations as landmarks. The street model is analogous to the street name in the urban environment in which every corridor is named and coded accordingly. In this study, we opt to choose both the connector model and the district model as the wayfinding strategies to be used in the hospital outpatient area (Figure 6). The connector model is easily applied when there is an apparent main circulation pattern that can tie different areas together. The double corridor model connected to the lobby is considered fit with this model. The thick lines in the figure thereby show the connectors that tie different smaller areas together. However, the outpatient areas consist of many small areas, and the information of these areas can hardly be contained in a single sign. Providing too much information in one signage can hinder the wayfinding process (Enterprise IG Information Design Unit, 2005). The district model is thus applied to group similar outpatient areas such as lobby, administration, clinics and other groups of areas into clusters. The clusters are named and coded with colour to ensure easy identification. By grouping the areas into clusters, the information that needs to be contained in the bottleneck between the lobby and the main areas can be classified into a hierarchical model, avoiding the use of a long list of destination on a single sign that is potentially confusing and difficult to read.

Visibility analysis, circulation analysis and wayfinding strategies together become the frameworks for determining the signs position, orientation and size requirements (Figure 7 (a) and (b)). Calori & Vanden-Eynden (2015) suggested that the signs be perpendicular to the line of the movement and sight to enable people to see the sign without turning their head. In addition to locating the signs at the decision points, they also require additional directional signs along the long path to ensure people to head in the right direction, while the identification signs confirm their arrival. In this stage, the circulation analysis is used as the primary framework to determine the decision points, while the visibility graph provides the general visibility measurements for the decision points. The visibility information can prevent the signages to be located in inefficient areas where the visibility is low. It also enables the designers to identify the most effective locations for signage. The decision points thus are determined to have an effective position from circulation pattern and also to have enough visibility level. The efficient directional signs locations can provide less yet useful signs that reduce the construction cost and improve wayfinding performance.

The position and orientation of each sign location need to be optimised to ensure the optimum performance of signs. Viewing distances, viewing angles, physical obstacles are the factors that need to be considered at this stage (Calori & Vanden-Eynden, 2015). Visual catchment area (VCA) visualisation is used at this stage to perform such optimisation (Figure 7 (c)). The tool visualises the visual coverage of each sign according to the viewing distance, the viewing angles and the physical obstacles such as columns, walls, elevators and stairs. It is shown that the most effective visual coverage is produced when the signs are located perpendicular to the movement and pathway of the people. The less effective viewing distance at the vast viewing distance also confirms the principle in locating the signs perpendicular to the movement of the people to optimise the wayfinding performance. The visualisation also shows that every sign has multiple directions according to its location. The signs located in the intersections need to accommodate three directions, and the signs located on the long pathway only need to accommodate two directions.

The visualisation shows that the longest yet effective distance between directional signs is approximately 18 m. The red shades in the figure indicate that the VCA resulted from the signs have 18 m optimal viewing distance at its perpendicular viewing angle. For such reason, the signage number 4 in Figure 7 (b) needs to be closer to signage number 2, while also maintaining its visibility from position number 5. Some of the signs only require 12 m viewing distance, as indicated by the VCA with green shades. The signages number 3 and 4 are considered ineffective and thus should be removed from the plan. Despite the difference in viewing distance requirement, the text size for both 12 m and 18 m viewing distance can be optimised to a single value for improving fabrication efficiency and design consistency. According to the text size range in Figure 2, the range between 16 to 20 cm text height is considered optimal for both viewing distances.

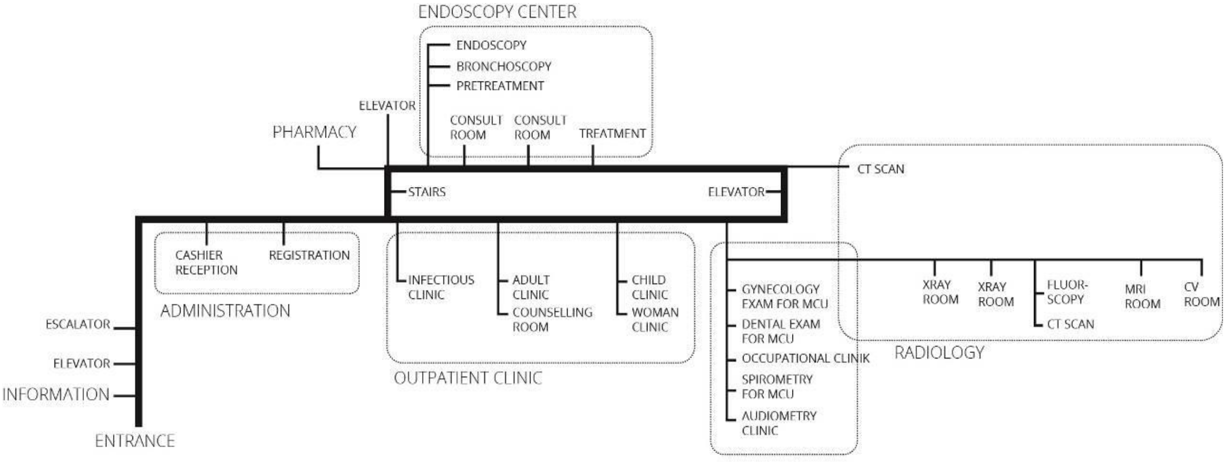

Fig. 6. Connector Model of Hospital Spatial Organization and Its Clusters

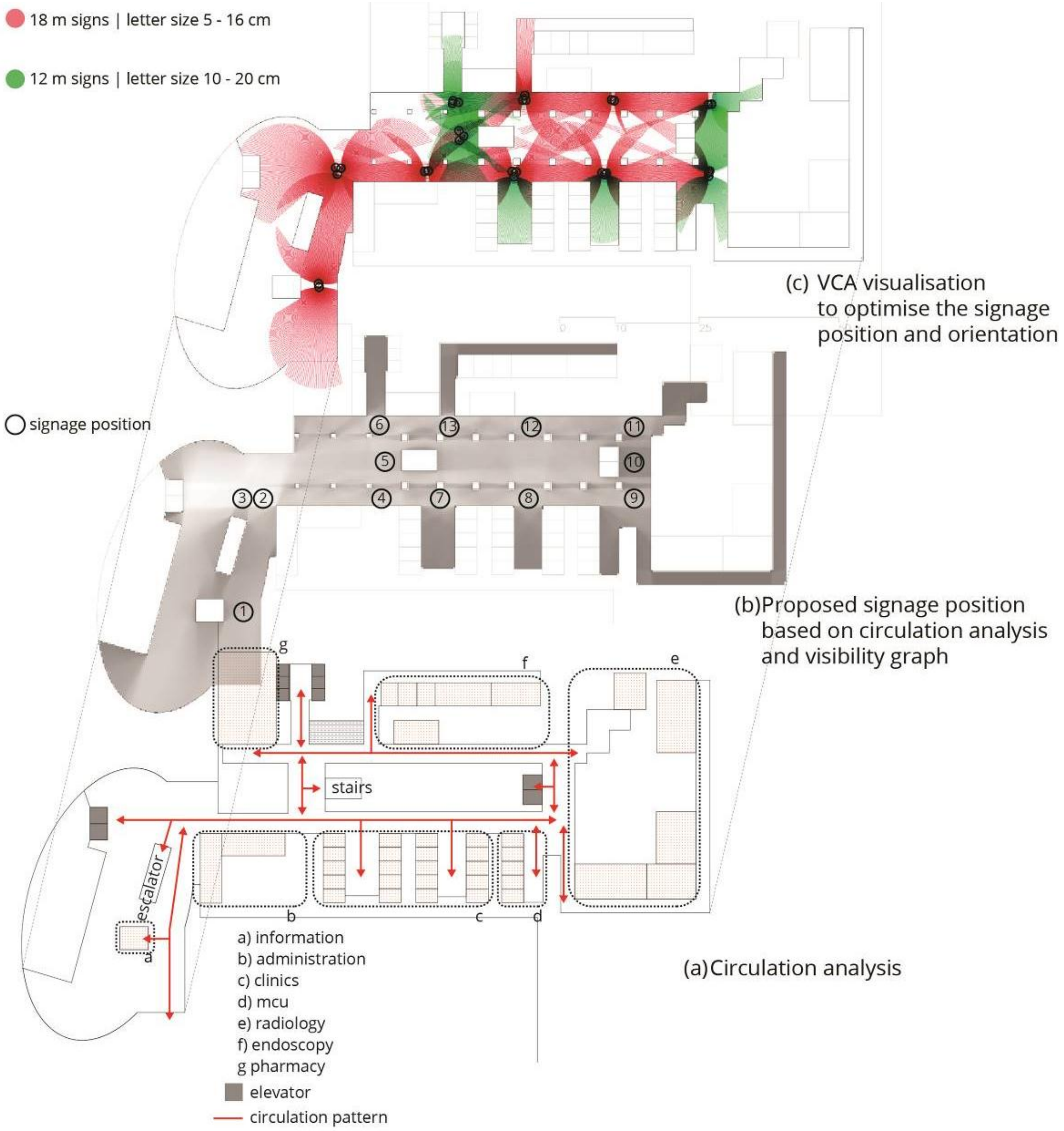

Fig. 7. Visibility Analysis of Signage Positions

CONCLUSION

This paper has illustrated the use of visibility analysis tool in the wayfinding design process in a hospital outpatient area. The tool is developed based on the idea of a visibility graph and isovist to measure the visibility degree for a complex spatial configuretion, as well as to visualise the VCA for a sign within the signage plan. The visibility analysis and visualisation are conducted in several ways. In the early phase, the visibility graph and isovist are used to analyse the visual properties of the hospital plan, combined with the circulation and spatial organisation analysis to build a framework to decide the wayfinding strategies and sign locations. Afterwards, the visualisation of VCA is used to simulate the visual coverage of each sign that is affected by the surrounding obstacles. The sign VCA simulation clearly shows the relation among viewing distance, viewing angle, sign position and sign direction to optimise the performance of the designed wayfinding system. The use of visibility analysis and visualisation thereby can improve the wayfinding design process especially in a complex environment such as hospitals.

The findings of the study indicate that the implementation of visibility analysis and visualisation tools can improve the wayfinding sign design process by giving useful insight and instrumental means to the designers. Visibility graphs and isovist can be used to gauge the visibility properties of the complex environments which can be vital in anticipating potential problems. Visual catchment area (VCA) visualisation is very helpful in simulating the visibility performance of signs during the design process. The visualisation tool offers the direct and interactive interface where the designers can simultaneously test and simulate different options quickly. The current study is limited to the visualisation and analysis in a two-dimensional floor plan which reduces some spatial information that might be critical. Further research is needed to integrate the analysis within the BIM environment where the analysis can be performed in three-dimensional space to give a more comprehensive spatial information on the visibility.

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