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Simulation For New Methodology Of Legislation On The Setback Of Residential Buildings In The Hilly Areas Of Amman (Jordan)

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ABSTRACT

The aim of this study is to create the conditions necessary to obtain the right amount of solar radiation and ventilation in the buildings located in the hilly areas of the city of Amman (sloping land). By examining these areas, we have found that the main problem is that many residents suffer from diseases, allergies or show general symptoms of discomfort due to staying in unhealthy homes, in which we have found a very high humidity level, caused by insufficient or absent ventilation and by general conditions that severely limit access to sunlight.

The methodology adopted for our study is based on several environmental simulations, using the Revit software, to obtain the best design compatible with the life of man, with his activities and with the natural environment. A first simulation applied to buildings, evaluates the shadows at different times and seasons of the year; the second simulation evaluates the correct adjustment to the distance between buildings (setback), based on their height and the slope of the ground, to obtain sufficient sunshine and ventilation and reduce the shading caused by the projection of the shadow on the adjacent buildings.The conclusion of our study consists in the proposal of a new legislation on the setback of residential buildings in the hilly areas of Amman (Jordan).

Keywords: setback, legislation, Amman, sloping land, solar radiation, ~~ventilation~~, Revit simulation.

1.0 INTRODUCTION

The land on which the city of Amman stands is characterized by hilly slopes and the most peculiar site is the hilly area of old Amman, characterized by particularly pronounced slopes (AlAzhari, W.; AlNajjar, S.; 2012).

The necessity we found observing most of the buildings in the hilly areas of Amman is the lack of evaluation - in the design phase –of the importance that the slope of the land has on the buildings; the correct approach must consider the insertion of the building in the environmental context and must simulate the movement of the sun, evaluating the shading deriving from the projection of each building on the others, and evaluating how to obtain the maximum benefit from natural lighting, considering the variations seasonal throughout the year.

Some regulations concerning the design of buildings in Amman, fix the setback of buildings at a certain distance from the property boundary, delimiting the construction lines. Setbacks are building restrictions imposed on property owners; it is also defined as the horizontal distance between the building and the boundary of the plot of land or the road line adjacent to the plot. Local government creates setbacks through building regulations, usually for public order reasons such as citizen safety, privacy, and environmental control regulations (Amman Building & Urban Planning Regulation, 2011and subsequent amendments and additions).

Despite the application of building regulations, most of the buildings in Amman present significant problems related to the control of ventilation and solar radiation, which obviously implies an analytical study of the place and the specific environmental context, considering the orientation of the buildings, the movement of the sun, the height of the buildings and - most of all - the slope of the land, aspect that is not considered in the current building regulations.

Our study of the Al Manara area, which is one of the least served neighborhoods in Amman and located on the slopes of the hills, has derived from these assessments.

We have carried out several inspections, photographed the interiors and talked with the residents, who complain of discomfort and health problems, in particular allergic disorders - even chronic - of the respiratory tract and of skin, due to the stay in unhealthy buildings, in which it is often found the presence of humidity, condensation and mold.

Human well-being in built space has too often been considered only from a physiological point of view, while the World Health Organization itself describes health as "a state of complete physical, mental and social well-being and not the mere absence of the state of illness or infirmity".

The necessity to humanize space has always been strongly felt by architects and it is assuming ever greater importance, understanding how much influence the realization of space in a broad sense has on the human being, considered in its component not only physical, but also emotional and spiritual (Dynameisreview for living organic architecture, 2016).

Most metropolitan urban landscapes, in fact, can cause inactivity, depression and the loss of the sense of community. Architects should humanize the design and focus on the construction for the benefit of the residents' health. This approach is known as salutogenesis, which means dealing with the "sources" of health.Aaron Antonovsky, coined the term "salutogenesis" by combining the Latin word salus, health, with the Greek word genesis, origin, and he focused on those qualities that make some people more resistant to cope with stress in their daily life (Architecura,2015).

The close relationship between design, space management and health is demonstrated by various studies, such as those of Prof. Alan Dilani of the International Academy for Design & Health, in which he explains how the construction of beneficial spaces for health can reduce the spread of diseases (Dilani, A.; 2012).The cause of many disorders - from flu to digestive and psychological problems - often comes from lack of exposure to natural light, a factor that many of us suffer today. The architecture must be based on continuous research of the relationships between the internal and external environment, trying not to screen the climatic conditions but to manage them at best(Dilani,A.;2017).Dilani explains how the basic function of psychosocially supportive design is to start a mental process by attracting human attention, which may reduce anxiety and promote positive psychological emotions. Health processes could be strengthened and promoted by implementing design that is salutogenic and that focuses on the factors that keep us well, rather than those that make us unwell.In the 1990s Alan Dilani suggested that Antonovsky's salutogenic principles be applied to the architectural design of healthcare facilities as a means to promote health. Although the presence of stress is not solely due to architecture, architecture and design can either intensify or mitigate the effects of stress on health. Countless studies show a relationship between the design of our built environment and health. For example, there is a direct link between access to natural light and blood pressure, between over-crowding or chronic noise and psychological stress and between healing and nature.

Richard Hobday is an internationally recognized researcher and author working in the sector of infection control, of public health and of building design. He is considered an authority in the field of heliotherapy and the complex relationships that link sunlight, vitamin D and medicine (Hobday,R., A.;1999). Hobday studied the evolution of the so-called Spanish flu pandemic, which claimed tens of millions of victims worldwide between 1918 and 1920, after the end of the First World War, comparing it with the current Coronavirus epidemic, and also considered the different systems implemented to eradicate the infection.Hobday says that during the time of the Spanish flu, doctors organized field hospitals set up inside tents. The patients were therefore in absolutely ventilated environments; in good weather, the beds were brought outside, to enjoy the sun's rays, and patients who had been placed outdoors recovered better than those treated indoors. In short, a combination of fresh air and sunlight appears to have prevented many deaths among the sick persons, as well as infections among medical staff.

Until the advent of antibiotics, in the 1950s, in America the so-called "open therapy" was often used as a cure, because it was realized that in case of respiratory tract infections (such as flu and tuberculosis) the deaths between patients were reduced from 40% to 13% if they were kept outdoors or in well-ventilated spaces.The outdoor air kills many bacteria, both at night and during the day and a similar result is also obtained in indoor environments with adequate ventilation.Today we also know that in the sun - if its light is strong enough - the vitamin D present in the skin can be synthesized. Low levels of vitamin D are linked to respiratory infections and can increase the chance of catching the flu. Additionally, sunlight affects our body's biological rhythms, which partly determine how we resist infections.

The architect Enrico Agostino Griffini, in the volume “Rational construction of the house”, underlines the importance of considering in the design of a building multiple variables, such as latitude and the diversity of climatic conditions, and proposes the simultaneous study of various correlated factors: orientation, layout of rooms, distance between buildings, height, shadow lines and irradiation (Griffini,1932).

In recent years, natural light has acquired a central role in architecture, becoming itself a material for architecture, like other materials that are used to define the envelopes of internal environments, from facades to roofs and to internal divisions. The controlled exploitation of daylight makes work and living environments dynamic over time and more stimulating, maintaining contact with the outside world, allowing you to perceive the passing of days, the changing of the seasons and the climate changes. In addition to the psychophysiological advantages, the potential of natural lighting in terms of energy-saving strategies is equally important: a conscious use of sunlight, a free resource, is at the basis of the reduction of energy consumption linked to artificial lighting and air conditioning systems for summer cooling(Lo Verso,2006).

The Middle East has huge amounts of sunlight and it makes perfect sense to use this resource effectively by incorporating it early in the design process. It is very important to understand the concept of daylight and its effective use in interior space. Daylighting is the practice of placing windows and reflective surfaces to control the admission of natural light in order to provide effective internal lighting during daylight hours, in order to maximize visual comfort and reduce energy use. It has potential to reduce the energy consumption of any building and it works with all projects such as offices, hotels, hospitals and residential communities.

The first thing to understand is the sun’s path across the horizon at any given location. A building designed with careful consideration of these elements can take advantage of natural daylighting, passive heating, photovoltaic energy generation and even natural ventilation. However, careful consideration is necessary to ensure these potential advantages don’t work against building efficiency by producing glare or overheating(Ashutosh Jha, 2016).

2.0 RESEARCH METHODOLOGY

2.1 Method of study

During the various stages of development of any project, it is essential to have tools and working methods that allow in-depth assessments in relation to solar radiation and to the sun, assessments which are undoubtedly the basis of integrated and sustainable design.About this, in addition to monitoring and managing data and information relating to the project, it will be particularly useful to be able to analyzethe effects of the sun on a building, in relation to its location and the context in which it is inserted(Samilolab.it, 2021).

Multi-day solar studies produce animations that show the movement of shadows at a project location for a specific date range at a specific time, or for a range of time.You can specify a time interval of 1 hour, 1 day, 1 week, or 1 month between the images in the animation (Autodesk, 2019).

The methodology adopted for our study is based on several environmental simulations on selected sites, using the Revit software, in order to obtain the best design compatible with the well-being of residents, with their activities and with the natural environment.

The first simulation, applied to existing buildings in Al Manara area, evaluates the shadows at different times of the day on four different days of the year; which are:

- The summer solstice (21 June);it’s the day that the Sun reaches its northernmost point (which is the highest point in the sky) throughout the year, and it gives us the maximum number of daylight hours possible in a day. The shadows are the shortest of the year.
- The winter solstice (21 December);the duration of daytime hours is minimal, while the duration of night hours is maximum. The Sun is low on the horizon and the shadows are the longest of the year. If the sun enters the building on this day, it means that it will receive good sunlight for most days of the year.
- The spring equinox (21 March) and theautumnalequinox (21 September);on the days of the equinoxes the duration of the day is the same as that of the night (12 hours each) all over the world, because the sun rays affect perpendicularly to the terrestrial axis. These are the only days when the Sun rises exactly to the East and sets exactly to the West.

The second simulation is carried outon a hypothetical site and evaluates the correct adjustment to the distance between buildings (setback), based on their height and the slope of the land, to obtainsufficient sunshine and ventilation and reduce the shading caused by the projection of the shadow on the adjacent buildings.

2.2 Area of study

The study was applied to the Al Manara area, which is one of the least served neighborhoods in the older area of Amman and located on the slopes of a hill. Two sites (A and B) of this area, with different orientation,according to the earth topography,were considered, and then a plot of landof each site was selected as case study, on which the simulations with Revit were carried out. All data were collected and compared.In these sites the building regulations establishes the following parameters:

- minimum area of plot of land: 150 m^2;
- minimum limit of the façade: 10 m;
- minimum limit of front setback: 2m;
- minimum limit of rear setback: 2 m;
- minimum limit of side setback: 1 m ;(Amman Building & Urban Planning Regulation, 2011).

Site A- Land in Al Manara area, with North-East orientation

Slope	Front setback	Rear setback	Side setback	Height
37%	2m	2m	1 m	4 levels=12 m

Site B- Land in Al Manara Area, With South-West Orientation

Slope	Front setback	Rear setback	Side setback	Height
35%	2m	2m	1m	4 levels=12 m

Table 1: summary of the characteristics of the two sites with different orientation.

(Source: the authors based on site visits and Google Earth maps).

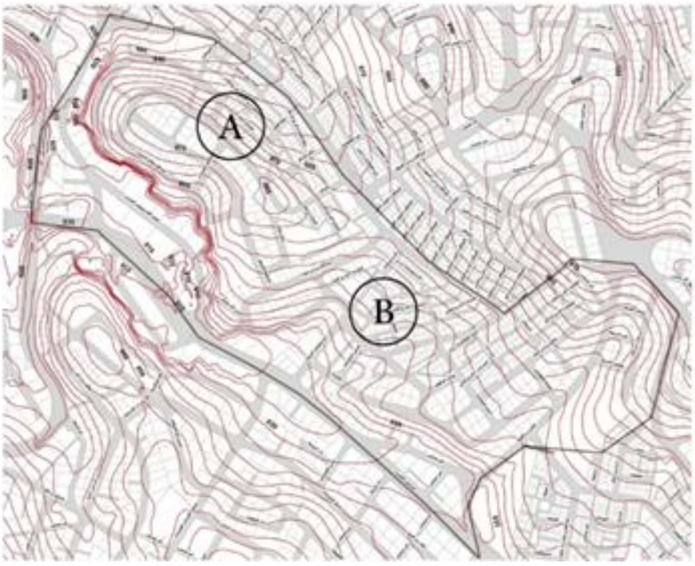


Figure 1: Identification of the two sites (A and B) with different orientation, in Al Manara area.

The land's orientation is according to the earth topography.

(Source: Greater Amman municipality, modified by the authors).


Figures 2 and 3: sun radiationin the late morning in Site A. (Source: the authors).


Figures 4 and 5: sun radiationin the late morningin Site B. (Source: the authors).

3. DISCUSSION

3.1 Environmental Simulations of the Solar Radiation in Al Manara Area

Four different days of the year were identified and simulations of solar radiation were carried out in three different hours of the day, to assess the level of comfort and inconveniencesin terms of light and heat in the different seasons of the year.

I. Figures 6 and 7 show the solar radiation and the projection of shadows at the spring equinox (21 March) in site A and in site B, as displayed in the Revit simulation results:

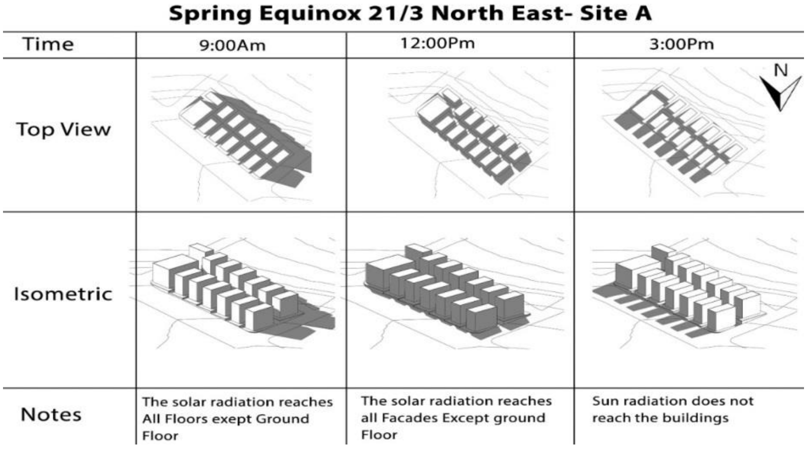


Figure 6: simulation on Site A at the spring equinox.

(Source: the authors, based on Revit program simulation).

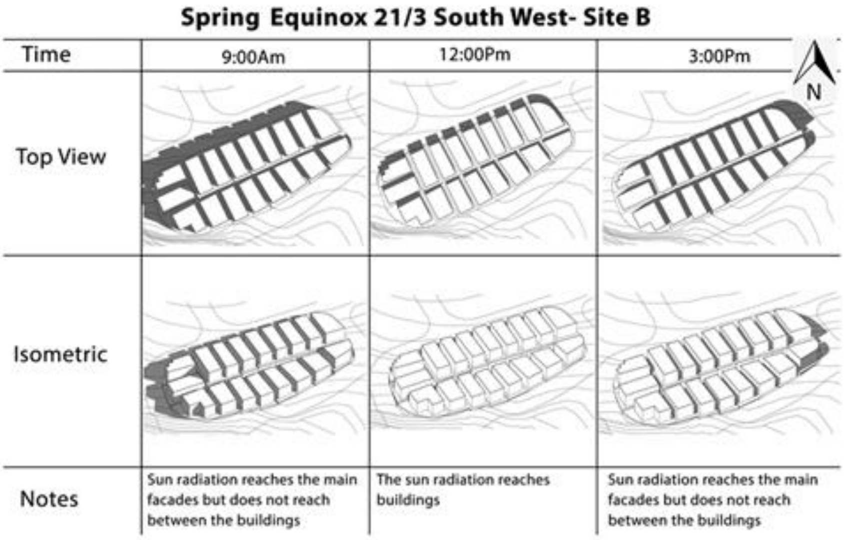


Figure 7: simulation on SiteB at the spring equinox.

(Source: the authors, based on Revit program simulation).

II. Figures 8 and 9 show the solar radiation and the projection of shadows at the summer solstice (21 June) in site A and in site B, as displayed in the Revit simulation results:

Figure 8: simulation on SiteA at the summer solstice.

(Source: the authors, based on Revit program simulation).

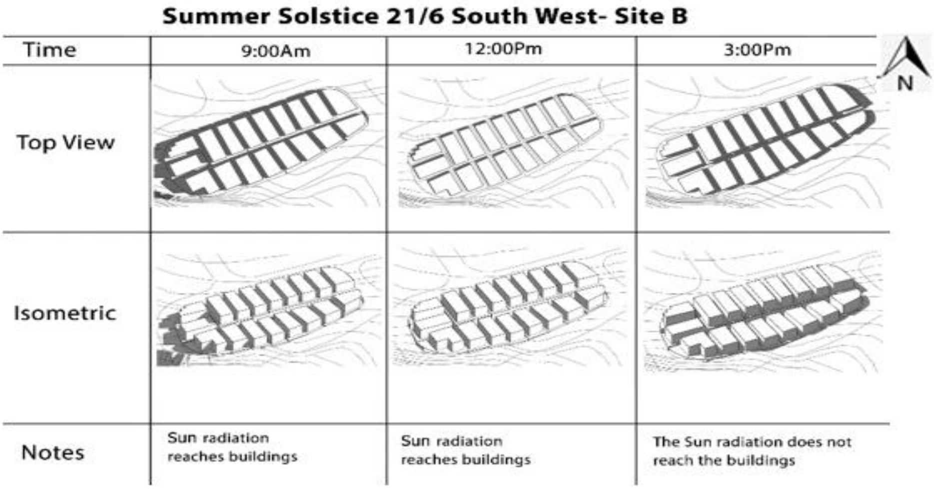


Figure 9: simulation on SiteB at the summer solstice.

(**Source:** the authors, based on Revit program simulation).

III. Figures 10 and 11 show the solar radiation and the projection of shadows at the autumnal equinox (21 September) in site A and in site B, as displayed in the Revit simulation results:

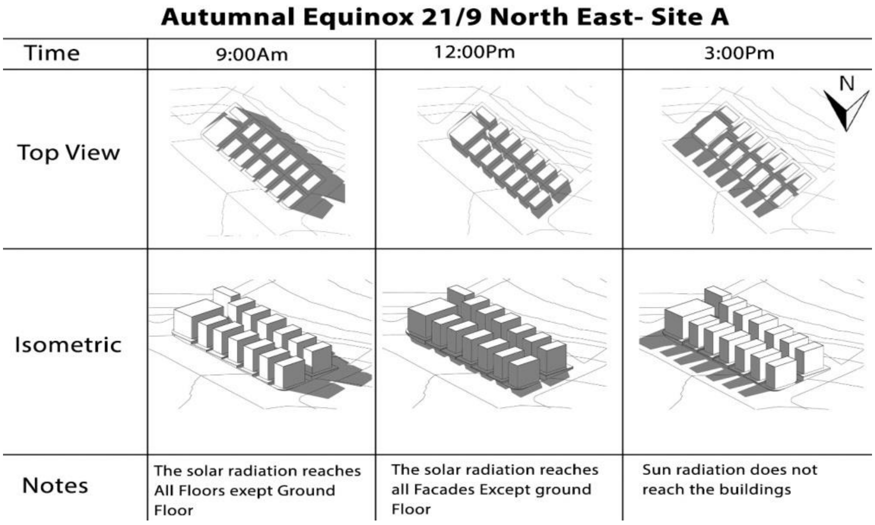


Figure 10: simulation on Site A at the autumnal equinox.

(**Source:** the authors, based on Revit program simulation).

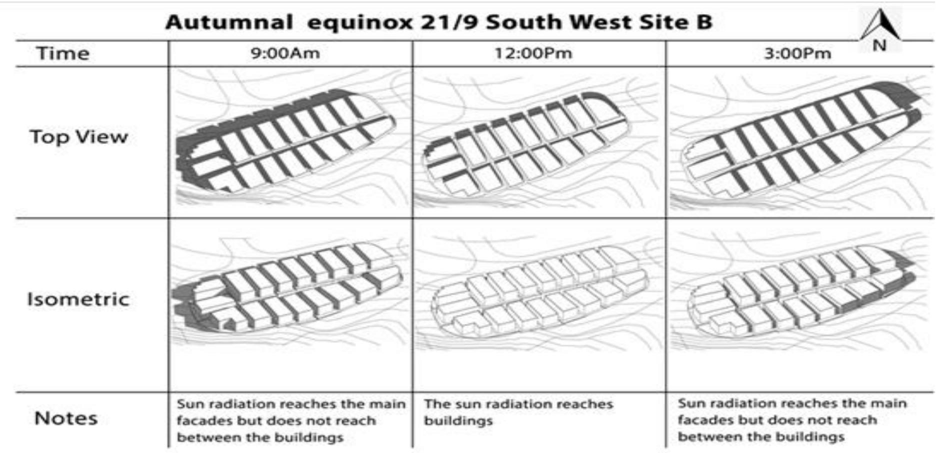


Figure 11: simulation on SiteB at the autumnal equinox.

(Source: the authors, based on Revit program simulation).

IV. Figures 12 and 13 show the solar radiation and the projection of shadows at the winter solstice (21 December) in site A and in site B, as displayed in the Revit simulation results:

Figure 12: simulation on SiteA at the winter solstice.

(Source: the authors, based on Revit program simulation).

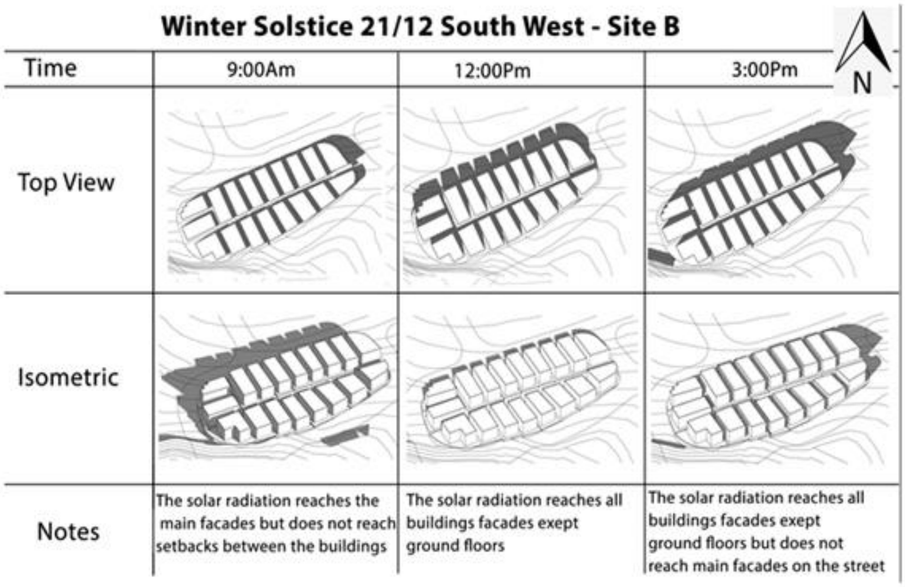


Figure 13: simulation on SiteB at the winter solstice.

(Source: the authors, based on Revit program simulation).

3.2 Conclusion of the Simulations

	North east(site A)	South west(site B)
Summer solstice (21/6)	At sunrise the sun doesn't enter the buildings, but it enters the rest of the day.	At sunset the sun doesn't enter the buildings, but it enters the rest of the day.
Spring equinox (21/3) and autumnal equinox (21/9)	The sun reaches all sides of the buildings, except the ground floors.	There are difficulties in receiving sunlight on the ground floors and between buildings.
Winter solstice (21/12)	The sun doesn't reach the buildings during the whole day.	There are difficulties in receiving sunlight on the ground floors and between buildings.

Table 2: comparison for the two sites in the different seasons.

3.3Environmental simulation carried outon a hypothetical site, considering the relationship between the slope of land and the building height and orientation.

Legislation regarding setbacks in Jordan is established without considering the building type, height/number of stories, slope gradient and direction and size of the plot.

The following charts illustrate the environmental simulation by linking the legislation with the topography of the land and the height of the buildings, in order to resolve the problems deriving from setbacks.

It is very important to consider the relation with the degree of solar radiation, orienting the buildings according to the sun and linking the coordinates of the geographical area with the Revit software, to simulate the effect of solar radiation on the specific area and to set the right minimum space between buildings; the day of winter solstice, 21 December,is the best day to apply the simulations, due to the long shadow projection on the adjacent buildings.

The simulation followed the next important points:

1. the calculations in charts below were applied according to the topography of the land with different slopes, from 0-degree slope with an increase in slope of five degrees, until reaching 40 degrees;

2. 2. the same simulation was applied to the four fundamental cardinal points, the northern, western, eastern, southern and to slopes and then the correct distances of setbacks were obtained(Charts 1,2,3,4 and Fig. 14, 15, 16 17);

3. The same simulation was applied to the intermediate cardinal pointS-E and then the correct distances of setbacks were obtained (Chart 5 and Fig. 18).

Slope	Distance
0	17
5	17
10	23
15	24
20	26
25	24
30	26
35	37
40	47

Chart 1: proposed legislation considering the relationship between the slope of the land and the **north**façade setback. (Source: the authors).

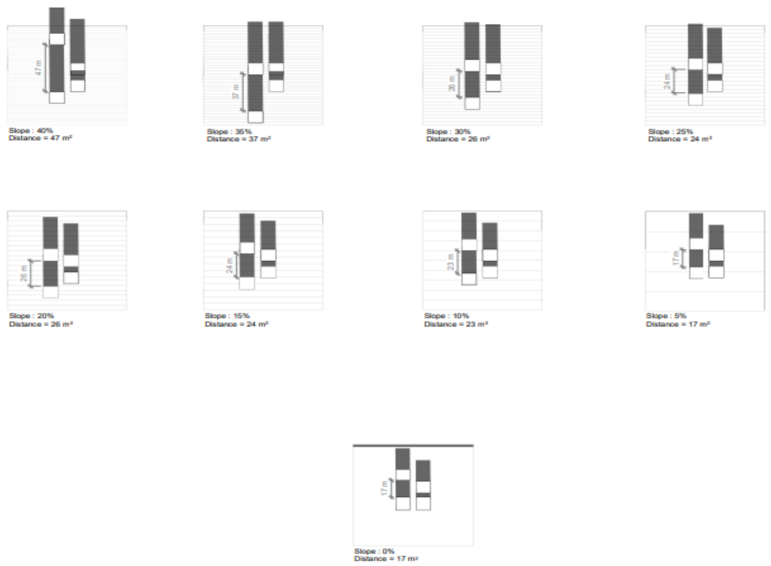
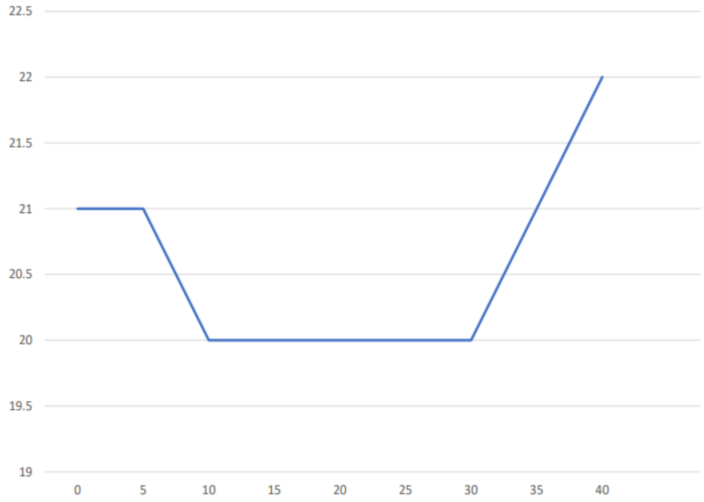


Figure 14:simulationof the correct distances of setbacks, based on Revit program. **(Source:** the authors).



Slope	Distance
0	21
5	21
10	20
15	20
20	20
25	20
30	20
35	21
40	22

Chart 2: proposed legislation considering the relationship between the slope of the land and the **west**façade setback. (Source: the authors).

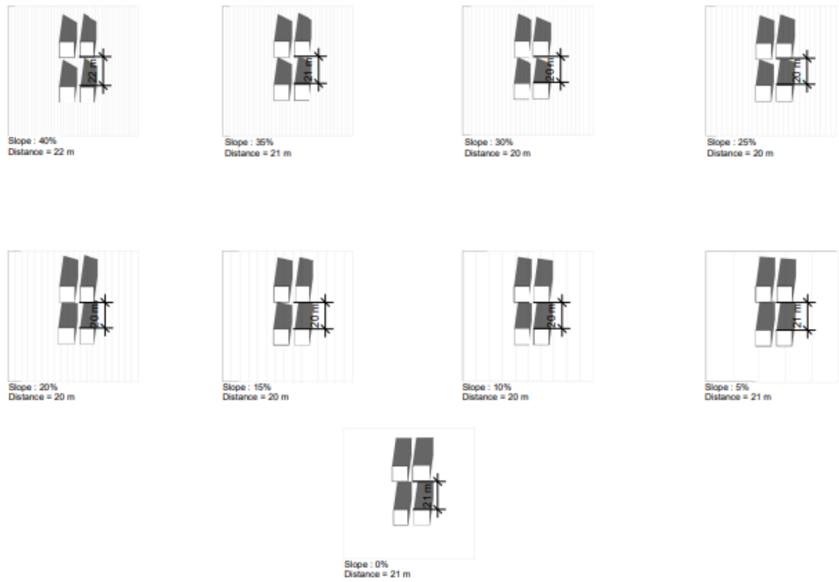
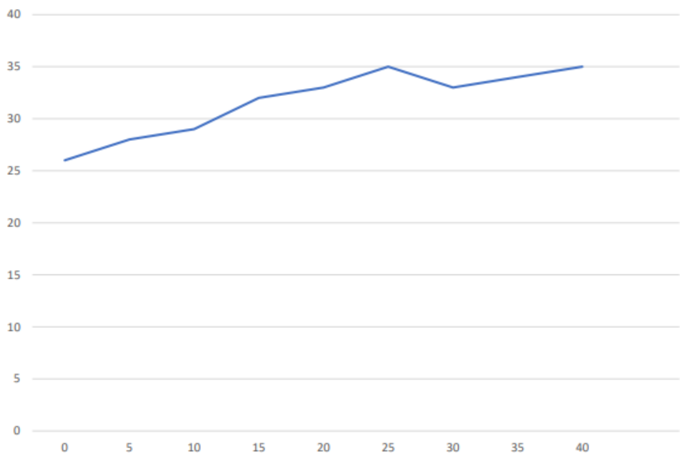


Figure 15: simulationof the correct distances of setbacks, based on Revit program. (**Source:** the authors).



Slope	Distance
0	26
5	28
10	29
15	32
20	33
25	35
30	33
35	34
40	35

Chart 3: proposed legislation considering the relationship between the slope of the land and the **east**façade setback. (Source: the authors).

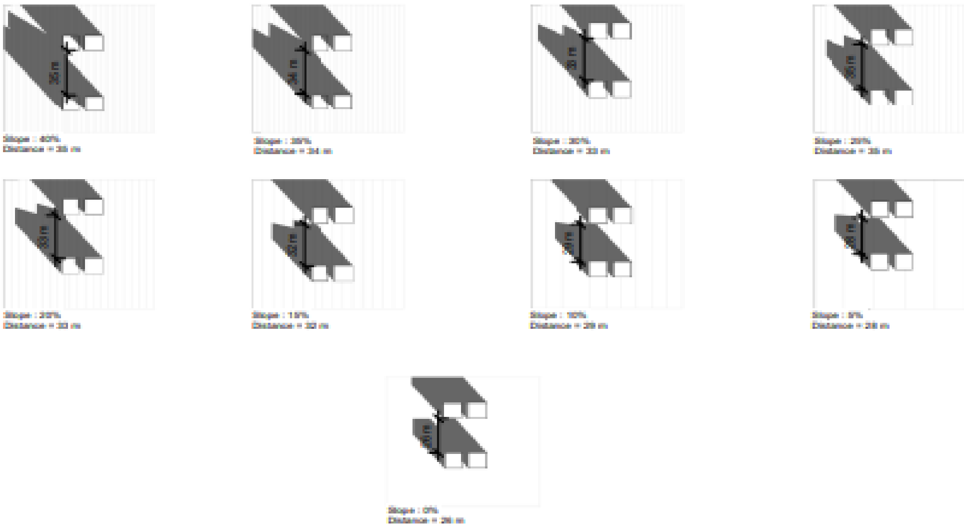
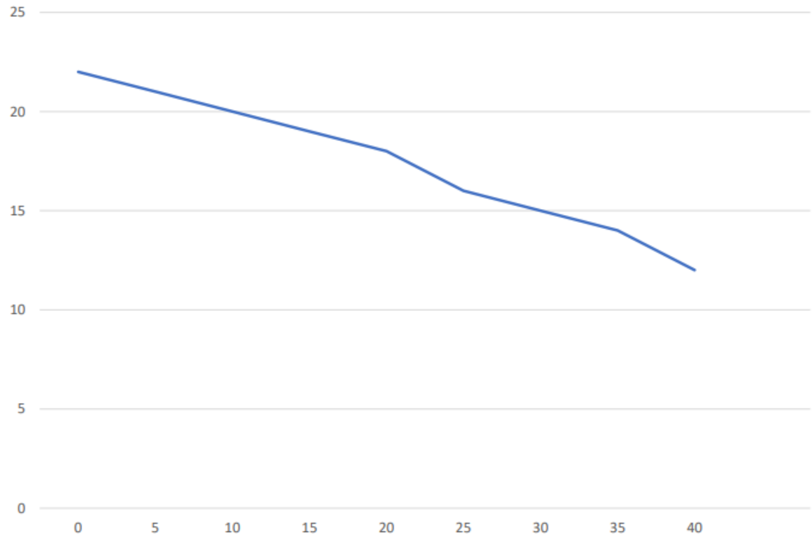


Figure 16: simulationof the correct distances of setbacks, based on Revit program.

(Source: the authors).

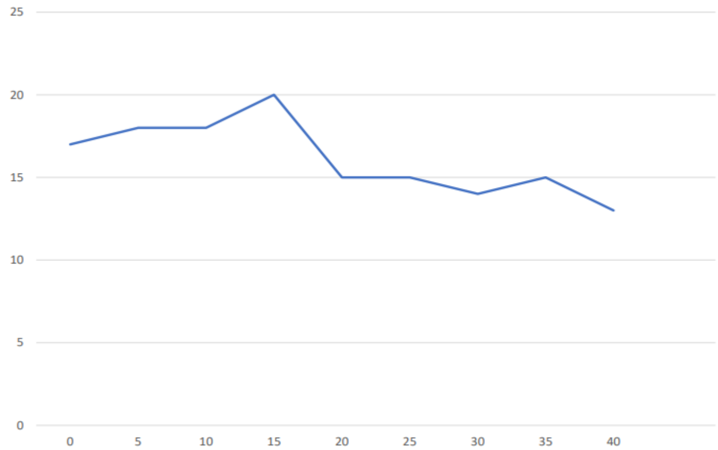


Slope	Distance
0	22
5	21
10	20
15	19
20	18
25	16
30	15
35	14
40	12

Chart 4: proposed legislation considering the relationship between the slope of the land and the **south**façade setback. (Source: the authors).

Figure 17: simulationof the correct distances of setbacks, based on Revit program.

(Source: the authors).



Slope	Distance
0	17
5	18
10	18
15	20
20	15
25	15
30	14
35	15
40	13

Chart 5: proposed legislation considering the relationship between the slope of the land and the **south-eastern**façade setback. (Source: the authors).

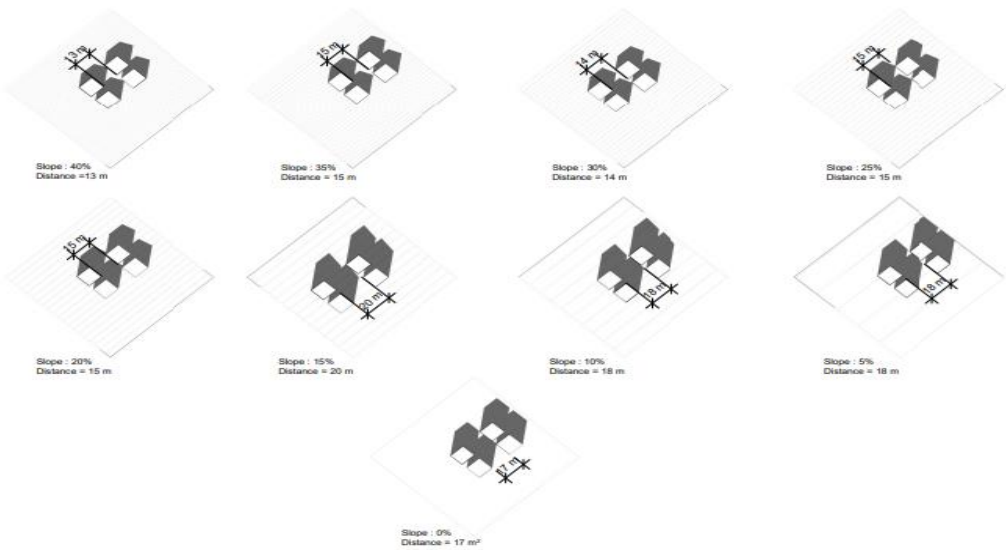


Figure 18: simulationof the correct distances of setbacks, based on Revit program.

(Source: the authors).

4. RECOMMENDATIONS

1. The legislation must consider the topography relationship with the setbacks; the contour degrees make changes to the setbacks.

2. Considering the setbacks and degrees with their relationship with the orientation of the building to the sun, the north orientation on the hills makes the distance with high degrees wider than the orientations to the south.

3. The building height makes the strong effect on the setbacks, the higher buildings need more distance between each other, so the ventilation becomes better.

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