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Design of a Low-Volume Waiting Unit for Airports Using Biomimetic Approaches

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Abstract

Air transportation delays due to weather conditions, failure of transportation vehicles and flight density on special days cause the passenger capacity of the airport to be exceeded and the lack of common areas. The existing waiting areas at the airports are not comfortable enough for long-term expectations and can disturb the individuals ergonomically. In this study, a low volume ergonomic waiting unit was designed with a hexagonal structure, inspired by honeycomb model. The planning of the waiting unit in the modular system enables the number of units to be increased according to the need and the ease of installation.

1. INTRODUCTION

Travelling by air is a unique experience where passengers feel the sense of reaching the summit [1]. The fact that it takes shorter compared to other means of transport and low accident rates increases the preferability of travel by air. Journey being as comfortable as possible depends on the quality of the time spent during the flight as well as the time spent at the airport, as well. Therefore, it is significantly important that the airports be designed in compliance with the needs of the passengers [2]. In addition, the fact that the airports are the door of a country to the World, this causes investments made on airports to be increased [3]. However, many airports nowadays, have many uncertainties in terms of design as well as management [4]. For the sake of the airports running properly and having a contemporary looks, investments made in this field should be increased. Arrangements and implementations to be carried out should user-oriented, functional, open to improvement, renewable and aesthetic at the same time [5].

People's wanting, these days, to spend less time for transportation and have a journey as problem-free as possible have caused an increase in the use of airways. Thousands of domestic and international airway journeys are realised during the day. The airports in the cities with a large population may in fact get, in some special days, over their passenger-carrying capacities due to heavy flight-loads. This causes waiting lounges at the airports to be insufficient and many passengers to wait standing for hours. Disruptions on the flights and long-lasting delays may require passengers to remain at the airports for hours. In some extraordinary situations, they may have to wait for longer than a day and this causes passengers to go out and find an accommodation place near by the airport. The stopovers that are unwillingly made at the airports due to such unforeseen reasons uncover very uncomfortable even unpleasant situations for the passengers (Figure 1 – 3).

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Figure 1. *Waiting lounges at airports [6]*

Figure 2. *Using tents at airports for sleeping purposes [7]*

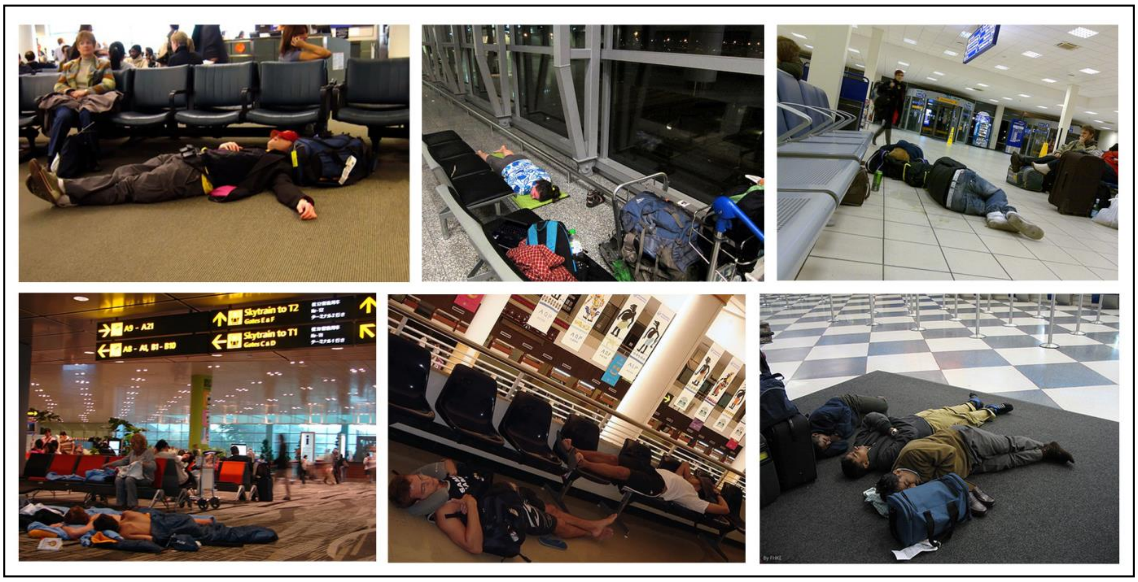


Figure 3. *People sleeping at airports [8]*

In this study, a design was made, using the honeycomb model, for a modular waiting unit, taking up a minimum space at the airports, through biomimetic approach, intended for the needs mentioned above. It was aimed, with the ergonomic design created, that the passengers could spend their waiting up comfortably and satisfy their needs easily.

2. BIOMIMICRY AND DESIGN

Nature has been a source of inspiration for humans at every stage of the life. People living in caves to satisfy their needs, built shelters afterwards for defence and protection purposes mimicking the caves they used to stay in [9]. Getting an idea about the natural forms then creating new structures in line with their needs is one of the fundamental steps of the production process for humans. In biomimetic approach, too, using the structures available in nature in development of ideas and products is essential.

The concept of biomimetic is also known as different terms such as biomimesis, biomimicry or bionic in literature. The term Biomimetic comes from the combination of the Greek words “Bio” (Life) and “mimesis” (mimicking). Otto H. Schmitt was the first one to mention this term in 1969 [10]. It is a new discipline of science used to create solutions for the problems of individuals by being inspired by or mimicking the characteristics of the living things in nature. Characteristics of living creatures in nature such as their functions, shapes and even colours and fabrics, may in fact be mimicked by people and used in the processes of design [11].

Following the coming into existence of the term biomimetic, a period in which biologists tried to consubstantiate the engineering methods with biological instances was passed through and the term biomimetic was fully born at a meeting in Seattle in late 1980s. In late 1990s, the term biomimicry came into existence and became a new field for scientific researches. With the studies made in this field, the number of patents in this field have also gradually increased [12-15].

Successful solutions to many problems in science and technology were brought by the designs and strategies inspired by the biology. Use of biomimetic approaches is quite effective in functional systems in particular (signal transmission, storage and process of data and transformation of energy etc.). It is also significant in analysis of biological structures and designation of the mechanical characteristics of the design such as self-repairing or repeatability [16].

Biomimetic approaches fall into two in design process; in the first approach, following the determination of the needs of the humans and the design problems, the way the organisms and ecosystems solve this problem is sought after. In the second approach, a specific characteristic, behaviour or the shape of ecosystem or organism is applied on the design to be made [17].

In this study, design of a new waiting unit was made to find a solution to the accommodation problems at airports. For the design the honeycomb model was inspired by, which consists of same units being repeated one after the other. The hexagonal structure in honeycomb was mimicked in the design of the airport waiting units and functional units taking up a minimum space were studied on to be created.

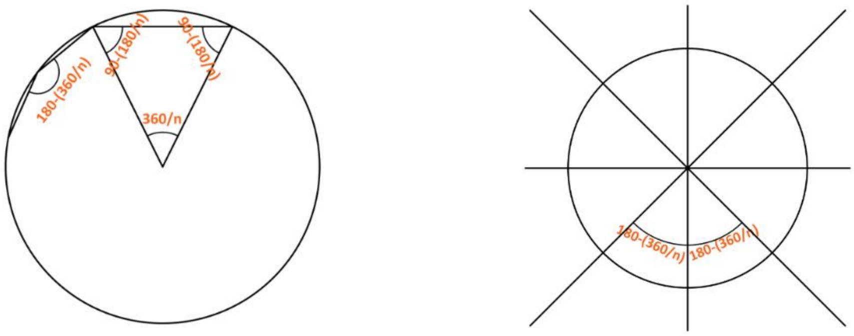
3. HONEYCOMB MODEL

Structure of the honeycomb was used in many applications in different fields such as mechanical engineering, chemical engineering, architecture, transport and nanofabrication [18]. The structure of the honeycomb, which consists of hexagons coming one after the other without any voids is used in architectural designs because of the reason it provides high strength (Figure 5). The VTB Arena Park Stadium designed by the Dutch Architect E. Van Egeraat is one of those designs [19].

(a) (b)

Figure 5. *(a) Structure of a natural honeycomb, (b) VTB Arena Park Stadium designed by E.van Egeraat*

The structure of the honeycomb, consisting of hexagons with a wall thickness of 0.1 mm aligning next to one another has drawn attention throughout the history. How ideal the geometrical shapes are in the forming of this shape, which is quite delicate, is presented in Figure 5.



(a) (b)

Figure 5. *(a) Demonstration of angles in a polygon with n sides (b) Adjacent polygons whose angles sum up to 360° [21]*

Geometrical shape that has the shortest perimeter encircling a specific area is the circle. When the perimeter of a circle and the perimeter of a square encircling a fixed area are compared, the circumference of circle would be shorter. However, it is different in the structure of the honeycomb. The perimeter of the honeycomb will be divided into equal and smaller areas and the shape with the shortest perimeter will be analysed (Figure 6). When the frame of the structure is divided into smaller combs in the shape of a circle; even though the shortest circumference property is provided, more materials would have been wasted for the voids in between the structures [21].

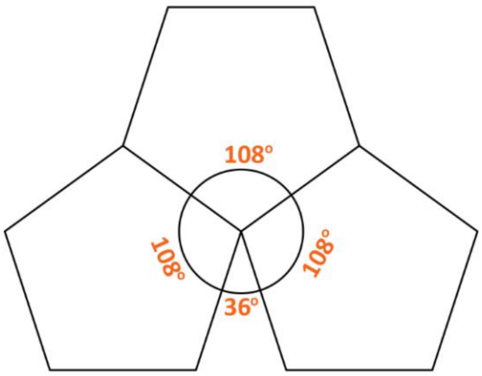


Figure 6. *Sample of a honeycomb structure [21]*

When principles of geometry is analysed, it will appear that the polygons will have to be used to use the minimum materials between the structures while ensuring the shortest circumference properties. When polygons with the same area having an “n” number of sides were compared, it would be seen that the geometrical shape having the shortest perimeter/circumference would be the regular “n-gon”. This geometrical shape, defined as regular, can be drawn in a circle and the edges will fall on the circumference of the circle. Due to the reason that the shape of this structure is rather close to the shape of an ideal circle, the perimeter would be the shortest [21].

Considering that this phenomenon would be experienced in a number of ways in design, hexagons, pentagons, tetragons and circles with different areas, whose heights were taken to be 200 cm as per the ergonomically average height of men-women, were placed in a square of 60 m by 60 m (Figure 7).

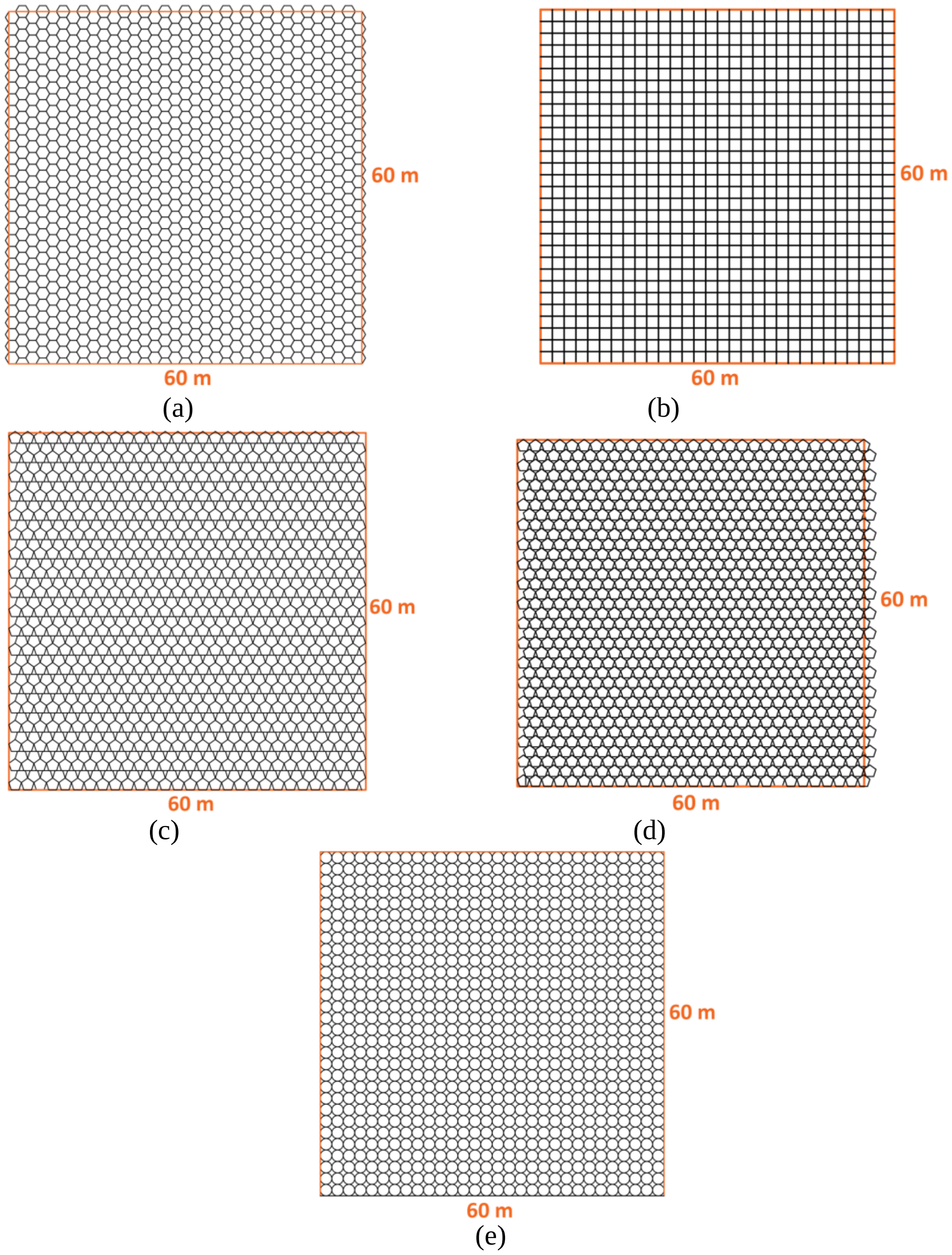


Figure 7. *(a) Positioning of hexagons in a fixed area, (b) Positioning of tetragons in a fixed area, (c) Irregular positioning of pentagons in a fixed area, (d) Regular positioning of pentagons in a fixed area, (e) Positioning of regular circles in a fixed area*

The number of modules that could be placed in the area of the square sized 60 m by 60 m, if the height of each module is taken to be 2 meters within ergonomic limits, as per this placement is given in Table 1.

Table 1. *Number of modules that could be fitted in depending on the geometrical shape.*

Regular hexagon	Figure 7 (a)	1050 Modules	
Regular Tetragon	Figure 7 (b)	900 Modules	
Regular Pentagon (1)	Figure 7 (c)	1036 Modules	(When inside of the pentagon is considered a room; as the floor of the 518 modules would be on an incline, it could not be used as a dwelling)
Regular Pentagon (2)	Figure 7 (d)	998 Modules	
Çember	Figure 7 (e)	1032 Modules	

Among these shapes, regular hexagons and regular tetragons are the ones that were placed without a gap in between (Figure 8). It provides advantages such as positioning without a gap in between the modules, providing strategical advantages during connection of the modules and statistical advantages.

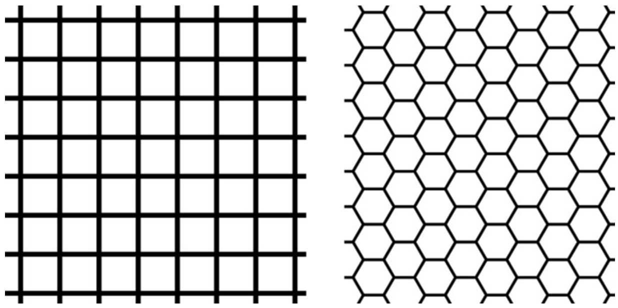


Figure 8. *Voids in positioning of regular tetragons and hexagons*

In other positioning patterns however, there gaps in between module boundaries (Figure 9).

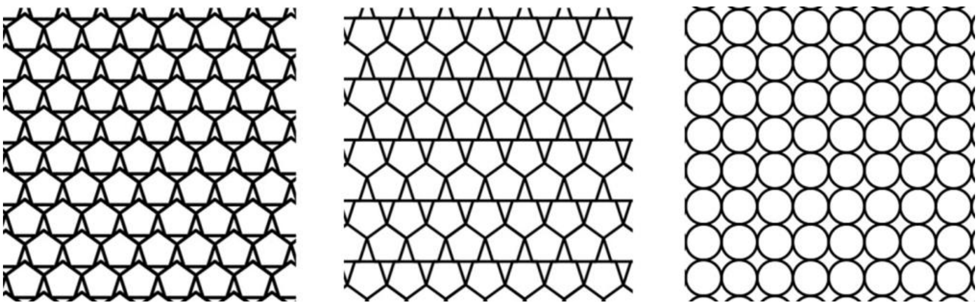


Figure 9. *Voids in positioning of regular pentagons and circles.*

Considering that the positioning is made ideally, when the efficiency is calculated dividing the 3.600 m^2 by module areas (60 x 60) and utilising the independency of the shape from the positioning, and when it is accepted that the agricultural efficiency is 95 %, it follows that the most suitable shapes for design are hexagon and tetragon.

$$\text{Ideal number of modules} = \frac{\text{Unit area}}{\text{Module area}}$$

$$\text{Efficiency \%} = \frac{\text{Number of modules per unit area}}{\text{Ideal number of modules}} \times 100$$

- Regular hexagon;

Unit area = 3,40 m^2

$$\text{Ideal number of modules} = \frac{3600}{3,40} \cong 1058$$

$$\text{Efficiency } \% = \frac{1050}{1058} \times 100 = \%99,2$$

- Regular tetragon;

Unit area = 4 m^2

$$\text{Ideal number of modules} = \frac{3600}{4} \cong 900$$

$$\text{Efficiency } \% = \frac{900}{900} \times 100 = \%100$$

- Regular pentagon (1);

Unit area = 2,9 m^2

$$\text{Ideal number of modules} = \frac{3600}{2,9} \cong 1241$$

$$\text{Efficiency } \% = \frac{1036}{1241} \times 100 = \%83,5$$

- Regular pentagon (2);

Unit area = 2,9 m^2

$$\text{Ideal number of modules} = \frac{3600}{2,9} \cong 1241$$

$$\text{Efficiency } \% = \frac{998}{1241} \times 100 = \%80,4$$

- Circle;

Unit area = 3,14 m^2

$$\text{Ideal number of modules} = \frac{3600}{3.14} \cong 1146$$

$$\text{Efficiency } \% = \frac{1032}{1146} \times 100 = \%90$$

Regular tetragon fits in with an efficiency of 100 % and hexagon of 99 %. In the selection to be made between the two, however, the selection is made based on the number of excessive modules falling into a unit area (3.600 m^2). When it is considered that, the numbers of modules are 1050 in regular hexagons and 900 in regular tetragons, it appears that the ideal shape is hexagon. The reason for areas of the modules being different is that the height and the width are ergonomically taken as 2 meters. Hence the difference in unit areas. This entitles hexagon modules with numerically more positions due to structural positioning attributes.

4. DESIGN OF MODULAR WAITING UNITS

People are sometime obliged to wait at the airports for a long time due to adverse weather conditions, connecting flights and technical faults. In these long lasting waits, which may require stopping over at the airports, the waiting lounges are numerically insufficient as well as not suitable for accommodation purposes.

In this study, a modular new waiting unit, which would not take up as much room and which could be a solution to stopover problems at airports, was designed. In this design, structure of a honeycomb was inspired by through biomimetic approach. In the calculations made, it was confirmed that the hexagonal shape of the honeycomb took the least room in a unit area and implemented on the design, as well. The forms coming one after another in a hexagonal structure were considered to come together in a modular system and thus ease of installation was provided for. Drawings made in the development stage of the product are presented in Figure 10.

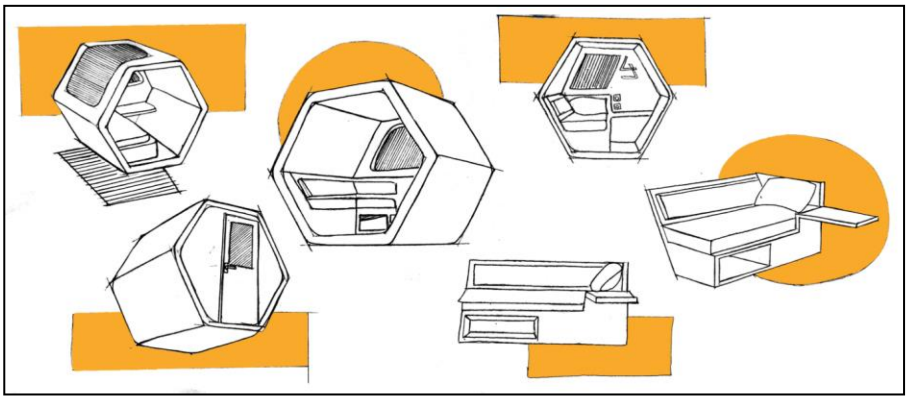


Figure 10. *Drawings made at development stage of the product*

Each unit repeating itself on the nest one is identical and consists of steel construction with doweled connection (Figure 11). With this attribute, the number of these waiting units designed can be reduced or increased depending on the need or number of people waiting.

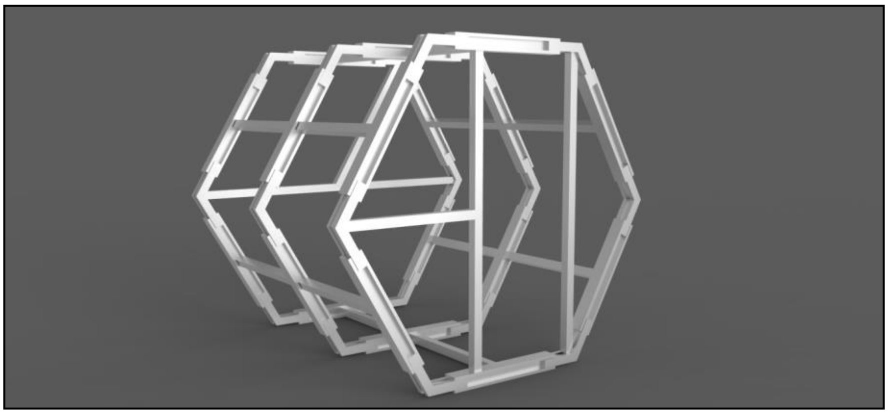


Figure 11. *Steel construction of the waiting unit*

Timber veneer was deemed suitable over the steel construction designed because of its warm look and it reflects a comfortable home. The waiting unit was designed simple and plain with a minimalist approach (Figure 12). The colours used in the design could vary depending on the interior design of the airport the application will be made in.

Figure 12. *External view of the waiting unit*

The interior design of the waiting unit was also approached with a minimalist insight and was planned based on the fundamental needs of passengers. These fundamental needs are listed:

- A suitable place for the hand luggage, if available, that would remain after handing in of the main luggage.
- A table/bench to place technological gear such as laptops or mobile phones and two power outlets to charge them.
- A bed that could be used for sitting as well as for sleeping positions.
- An energy saving bulb for lighting purposes.
- A wall-mounted hanger to hang clothing such as hats and coats.
- A small cabinet to place shoes in.

The colours used in the design were chosen to be in non-destructing soft tones. Interior design visuals of the waiting units are presented in Figures 13 and 14.

Figure 13. *Interior design of waiting unit*

Figure 14. *Interior design of waiting unit*

The units designed were assembled through a modular system in steel construction stage (Figure 15).

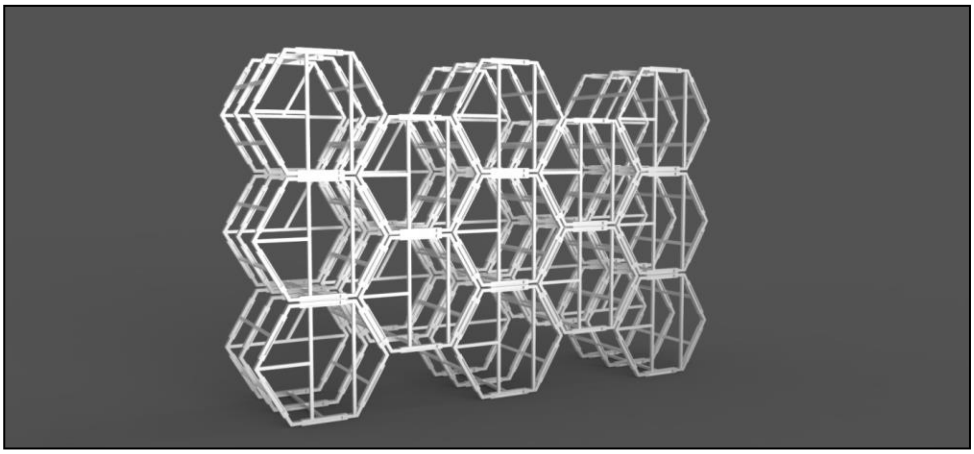


Figure 15. *Steel construction of the waiting units assembled in a modular system*

The fact that the structure is assembled in a modular system makes the transport and installation processes easier. Access to the upper floors of the waiting units is provided through lifts. In order to use the lifts, the directions of the floors vary in each floor (Figure 16 and 17). The lift has an attribute to stop at each half-floor. The structure is covered in timber veneer after completion of the steel construction.

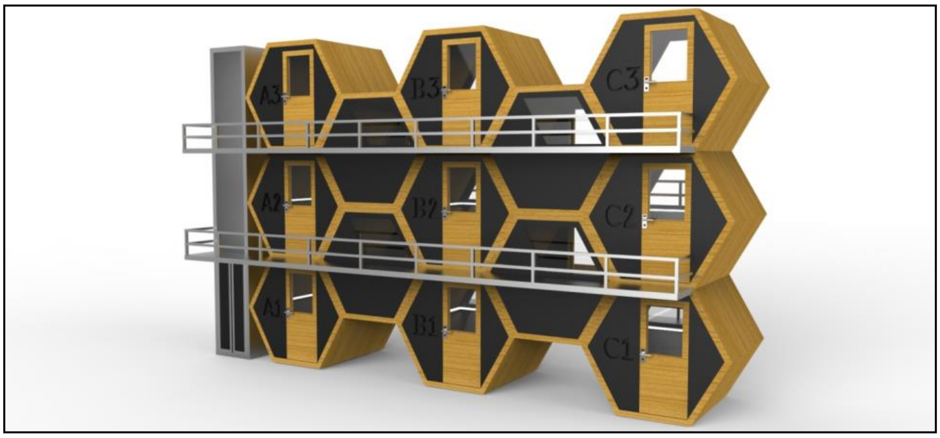


Figure 16. *External view of the waiting units assembled in modular system*

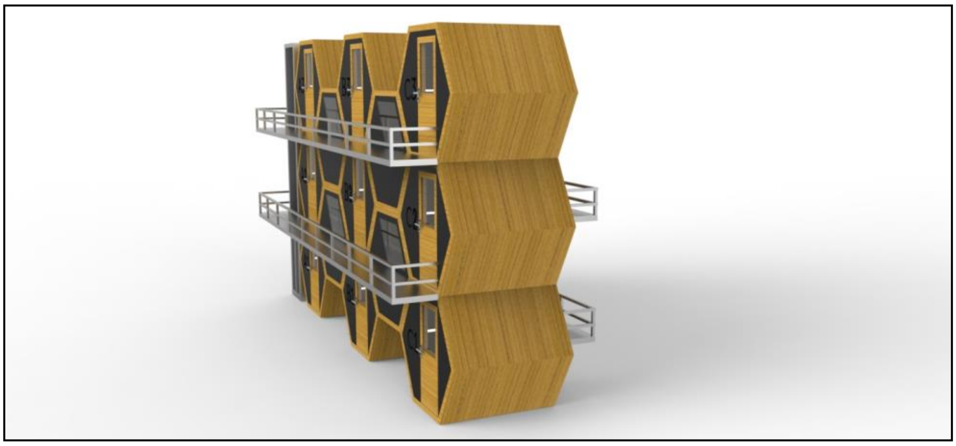


Figure 17. *Unit facing directions to provide access through lifts.*

Use of the waiting units are planned to be through a card system. A card that will be valid for the duration of the stay will be given to the passenger and the passenger will use this card on the card reading system on the door of the unit. The letters and figures on the waiting unit will match the ones on the card to be given to the passenger and thus the passenger will be able to locate the unit easily.

5. CONCLUSION

New waiting units were designed in this study for a purpose to find a solution to inefficiency of the waiting lounges and to the problem that the passenger have to wait in non-ergonomic conditions. In the design made, maximum number of units were provided to be fitted in a unit area with biomimetic approach utilising the structure of the honeycomb model. Unit being assembled were designed suitable for modular system and the installation process was made easy. The needs of the passengers that would arise during the waiting period are listed and the interior design of the waiting units was approached in a minimalistic manner. The fact that the hexagonal shape of the honeycomb could be fitted numerically fitted more in a unit area was confirmed through calculations made, as well.

With the waiting units designed being inspired by the honeycomb, a solution was brought to problems of passengers stopping over on seating units or on the floor at the airports during the long lasting waiting periods. During the design process developed with a maximum comfort in minimum unit area, all requirements that passengers would need during the stay were designated. Thus, the passengers would be able to rest in a quiet and comfortable place during the stay.

CONFLICT OF INTEREST

No conflict of interest was declared by the authors

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