

**PHYLLOTAXY AS A PROBLEM SOLVING FOR VERTICAL INTEGRATION OF  
AGRICULTURE IN DESIGNING TRANSITORY HOUSING**

**AWFAR RUSYDI AHDA<sup>1</sup>**

Master Student,  
Department of Architecture,  
Sepuluh Nopember Institute of Technology,  
Surabaya, Indonesia  
**Email : *awfar.rusydi.a@gmail.com***

**DR. ING. IR. BAMBANG SOEMARDIONO<sup>2</sup>**

Lecturer,  
Department of  
Architecture,  
Sepuluh Nopember Institute of Technology,  
Surabaya,  
Indonesia  
*bbsoem@arch.its.ac.id*

**DR. IMA DEFIANA, ST, MT<sup>3</sup>**

Lecturer,  
Department of  
Architecture,  
Sepuluh Nopember Institute of  
Technology.  
Surabaya,  
Indonesia  
*may\_d@arch.its.ac.id*

**Abstract**

This paper describes biomimetic features related to vertical integration of agriculture by optimizing natural light in transitory housing for street children. Increasing the capacity of transitory housing which have not accommodated yet is demanded very much, there are seventy-seven percent of street children. Transitory housing is a center of resocialization and a respond to the diminishing land food in Riau, because of the conversion to oil palm plantation. Vertical integration of agriculture in transitory housing is a design solution to improve street children economy and sustainable land food system. Challenge related to vertical integration of agriculture is optimizing the natural lighting for plant productivity. Phyllotaxy Feature is deemed responsive to climate, as a solution to optimize natural lighting for vertical integration of agriculture in transitory housing. The result of this paper shows the potential of phyllotaxy feature to optimize natural lighting in transitory housing.

**Key Words :** *Phyllotaxy, Transitory Housing, Biomimetic, Vertical-Agricultur*

## **1. INTRODUCTION**

The number of street children in 2013 in Pekanbaru, the capital of Riau – Indonesia is recorded 522 children (Hidayatullah, 2014). Data Pekanbaru in Figures 2014, The capacity of Panti Sosial Bina Remaja is able to accommodate 260 people, which occupies Panti Sosial Bina Remaja in 2015 they are 70 people (Andi, Jumaini, & Wasisto, 2015). Capacity of Loka Bina Karya (LBK) is able to accommodate 30 people (Langgeng, 2016). In conclusion, the capacity of Panti Sosial Bina Remaja and LBK are able to accommodate 23% of street children, and the remaining 77% of the children have not been accommodated yet. Therefore, Pekanbaru is required to add facilities of transitory housing for street children.

Fulfilling the needs of street children as claimed in Maslow's "hierarchy of need" saying, the level of basic needs must be satisfied or relatively satisfied before higher-level needs. The statement is such as that written by Brink (1997) in his research, biggest indicator of basic needs of the street children are food and clothing (Ayuningtiyas, 2010). On the other hand, transitory housing as a center of resocialization is also able to improve the economics.

Transitory housing presents the atmosphere of resocialization from the values and norms of local community (BKSN, 2000). Realizing a built environment always connects among people, communities and natural surroundings. In this case, transitory housing is also responding to the diminishing land of food in Riau. Visible impact on food production that mentioned in BPS Riau data, the number of food production in January-December 2013 climbed down between 10% -47% (Rio, 2014).

Currently, vertical-agriculture has attracted attention from all circles, new concepts in agriculture is currently appearing in various forms around the world after Dickson Despommier introduced vertical-agriculture for the first time in 1999. Many participants of multidisciplinary produce a wide range of new concepts: how to increase crop productivity by minimizing the use of water and chemicals (fertilizers, pesticides, fungicides and herbicides) with low carbon levels. Dickson Despommier's book 'The Vertical Farming', strongly argues that the agricultural world is currently in crisis and in need of radical and innovative approaches (Griffiths, 2014).

Though not a new concept, greenery aspects in the building has increased the percentage of greenery in urban built-up area and bring back the vanishing urban green space (Wong et al. 2003). The benefit of integrating transitory housing with vertical-agriculture is able to stimulate occupants to create a biodiversity in the narrow yard though. Other beneficial things of integrating vertical-agriculture are (Ratih, Eddy, & Revelation, 2014): improving air quality, solution to urban heat island, creating a great microclimate, as building insulation.

The challenge of vertical-agriculture is optimizing natural lighting on the productivity of the plant. Features phyllotaxy is deemed responsive to the climate as a solution to optimize natural lighting. Phyllotaxy or configuration of leaves is influenced by the reception of sunlight (Mukminin, 2014). The scope of this paper is to discuss the transitory housing for street children which is integrated with vertical agriculture by optimizing natural light. Biomimimetic approach is employed to identify the characteristics of phyllotaxy in relation to the use of conventional lighting systems.

## 2. THEORITICAL REVIEW

Biomimetic has two design processes written on biomimicry guild (2007): "looking to biology" defines a design issue and see how organisms or ecosystems to cope and "biology Influencing design" identifies the characteristics of shape, behavior or ecosystem of certain organisms and move them into the design (Zari, 2007). On biomimicry Guild (2007) identifies three levels of mimicry (Nelly, 2015); organism, behavior, and ecosystem. Each individual level, there are five aspects to explore mimicry, namely: form, materials, construction, process, and function (Zari, 2007).

On the behavior level, the building mimics how an organism interacts with its environment by means of a structure that can fit in without resistance in its surrounding environment, or a specific type of behavior that the organism does or replicates on a regular basis to survive or adapt with its context (Nelly, 2015). Behavior level must have eligibility conformity of what will be replicated in the context of the design, because not all organisms exhibit behaviors that are feasible and appropriate for the emulated (Zari, 2007).

### **3. METHODOLOGY**

A large number of design problems can be completed with nature as a mentor. If the application is correct, it is able to create new technologies and innovations. Biomimetic design method does not only perceive nature as a solution, but also try to imitate and apply the value of sustainability contained. For example, the results of bottom-up process, optimization, diversity, adaptation and evolution, as well as shapes and materials. Criteria used in biomimetic in degree consist of two aspects, functions and strategies: functions are related to issues while the strategy is the solution.

Associated with this paper, phyllotaxy or configuration of the leaves as strategy in plants in response to receipt sunlight will be explained further. Several steps performed in biomimetic method starting from the main issues in optimizing natural lighting, searching criteria and implementation of phyllotaxy.

### **4. RESULT AND DISCUSSION**

#### **4.1 Analysis of users and capacity transitory housing**

Occupancy is the primary facility in a transitory housing. The capacity of street children to be accommodated obtained through the assumption of street children in 2013 and the number of street children today. The following is the assumption of street children to be accommodated in transitory housing Pekanbaru.


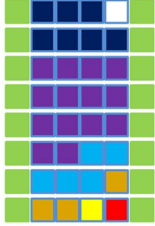
- The number of street children in 2013 in Pekanbaru is as many as 522 children, of whom 77% have not been accommodated about 402 children.
- The increasing of street children in Pekanbaru from 2000-2012 is about 13%, then the assumption of the number of street children by 2015 as many as 68 people.
- The number of street children by gender, women 27% and men 73%.
- The number of street children by age, 0-6 years as many as 6%, 7-12 years 33% and 61% aged 13 and older (Hidayatullah, 2014)

The cumulative of street children who have accommodated is as many as 470 children. Grouping of street children which will be accommodated at the transitory housing by age and sex, grouped into 2 units.

**Table 1:** The grouping of user (Source: Author, 2016)

Age/year	Unit A		Unit B
	Male	Male	Female
0-6		20	8
7-12		113	42
13 over	210		77
Total	210	133	127

**Table 2:** Zoning (Source: Author, 2016)

Pembagian Zona			
<p><b>Unit B.</b>                      Age 0-6 (1 room for female and 3 room for male).                      Age 7-12 (5 room for female, 14 room for male)                      Age 13 over (7 room for female)</p> <p><b>Unit A.</b>                      Age 13 over ( 26 room for male)</p>			<ul style="list-style-type: none"> <li><span style="color: green;">■</span> Koridor</li> <li><span style="color: blue;">■</span> Umur &gt;13 th (PR)</li> <li><span style="color: purple;">■</span> Umur 7-12 th (LK)</li> <li><span style="color: cyan;">■</span> Umur 7-12 th (PR)</li> <li><span style="color: orange;">■</span> Umur 0-6 th (LK)</li> <li><span style="color: yellow;">■</span> Umur 0-6 th (PR)</li> <li><span style="color: magenta;">■</span> Umur &gt;13 th (LK)</li> <li><span style="color: red;">■</span> Publik, ME</li> </ul>

**4.2 Analysis features biomimetic of phyllotaxy**

Stages analysis biomimetic features integrated by vertical-agriculture in designing transitory housing, where phyllotaxy as a solution in search of patterns and forms of integration vertical-agriculture in transitory housing. Start from identifying characteristics of phyllotaxy to obtain characteristics as a design proposal. The following criteria related to the integration of imitating phyllotaxy vertical-agriculture in transitory housing.

**Table 3:** The applications of biomimetic (Source: after Zari, 2007)

Behaviour level of phyllotaxy (Mimicry of how an organism behaves or relates to its large context)	
Form	The building looks like a leaf arrangement; terraced, with a radial pattern
Construction	Shape of the building where most of the buildings that seem to pile on the other the same building as the leaves; attached to the trunk.
Process	The building with the same process as the process of leaf growth; leaf arrangement has a pattern to form the corners of strategic response to sunlight
Function	he building with the same functionality as a priority productive space; leaf arrangement has the optimal dose to capture power of sunlight and do not cover (overshadow) the arrangement of leaves underneath for photosynthesis needs.

Phyllotaxy greatly influences the acceptance of sunlight by the leaves (Mukminin, 2014). Several characteristics of phyllotaxy based on the number of leaves on each stem books, phyllotaxy can be spread into three groups, in which each group consists of four kinds (Stoma, 2007) can be seen in table 4. To demonstrate the advantages of adaptive phyllotaxy, then indirectly in phyllotaxy feature implementation will

be influenced by local climatic factors. Searching for the arrangement of the area vertical-agriculture by analyzing the 12 pattern of phyllotaxis strategic angles associated to orbits the sun of site locations in the city of Pekanbaru reviewed with Sketchup software with -07.00 UTC shadow settings, with the following results:

**Table 4:** Analysis shadowing (Source: Author, 2016)

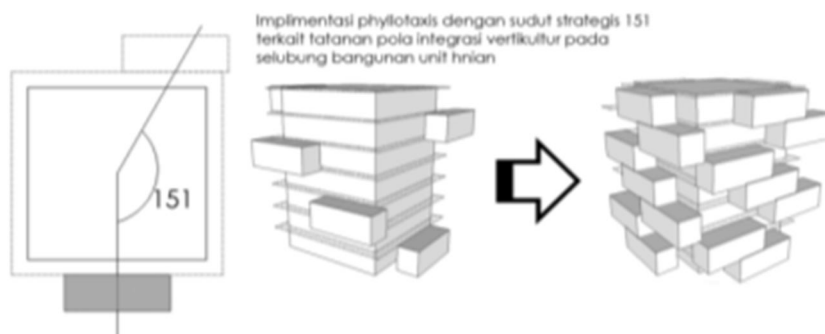
Strategic angle phyllotaxis	Analysis
a. Spiral (Monostichous 1.7) strategic angle = 47.3°	Direct sunlight 81,25%
b. Spiral (Lucas 3.4) strategic angle = 99.5°	Direct sunlight 78,75%
c. Spiral (Fibonacci 3.5) strategic angle = 137.5°	Direct sunlight 81,25%
d. Spiral (Anomalous 5.7) strategic angle = 151.1°	Direct sunlight 85,625%
e. Alternate (Spiro-distichous 2.13) strategic angle = 167.4°	Direct sunlight 80%
f. Alternate (Distichous) strategic angle = 180°	Direct sunlight 76,25%
g. Alternate (Bijugate 2x2.3) strategic angle = 68.8°	Direct sunlight 85%
h. Alternate (Spiro-descussate 2x2.13) strategic angle = 83.7°	Direct sunlight 80%
i. Whorled (Descussate) strategic angle = 90°	-
j. Whorled (Multijugate 3x1.2) strategic angle = 45.8°	-
k. Whorled (Tricussate) strategic angle = 60°	-
l. Whorled (whorled) strategic angle = 45°	-

Analyzing 12 strategic angle phyllotaxis patterns related to the orbit of sun, some similarities pattern. From various strategic angle phyllotaxis pattern shown, Spiral pattern (Anomalous 5.7) had the highest percentage of 85.625% in direct sunlight associated to the orbit of sun at an angle of 151.1 ° and it strategically became the choice of the pattern that will be applied.

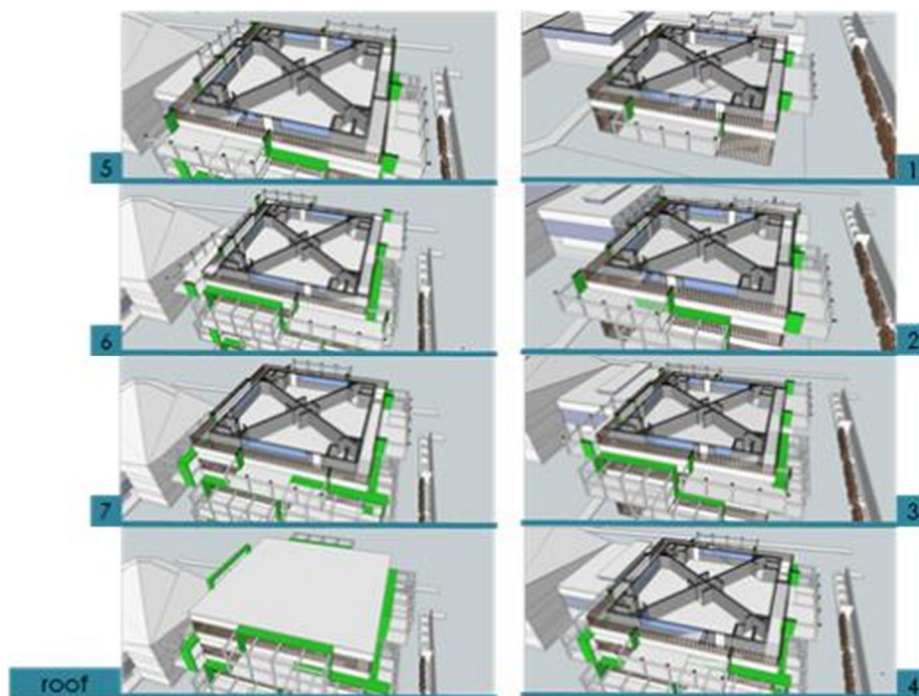
**4.3 Implementation of phyllotaxy**

From the analysis, it is obtained design criteria: multilevel pattern and radial; Adapting from one of the 12 strategic angle phyllotaxis patterns i.e. 151.1 ° angle; The arrangement rested on other buildings; Can be applied vertically, in this case that the dwelling unit. Phyllotaxis forms and implementations can be seen in Figure 1.



**Figure 1:** Implementation phyllotaxy with angle of strategic 151,1° (Source: Author, 2016)

From the implementation of phyllotaxy above obtained fabric of space agriculture optimal utilization of natural lighting in which it has optimal dose to capture power of sunlight and does not cover (shadowing) that are below the arrangement, shown in Figure 2.



**Figure 2:** Setting the agricultural space in the building envelope (Source: Author, 2016)

Orbit the sun of site locations in the city of Pekanbaru reviewed with Sketchup software with -07.00 UTC shadow settings, tend to east-west. Related to orbit the sun orientation of the layout 2 units dwelling are not arranged in parallel with the east-west line, avoid mutual shadowing between the two. The layout of the two residential units can be seen in layout plan, figure 3.



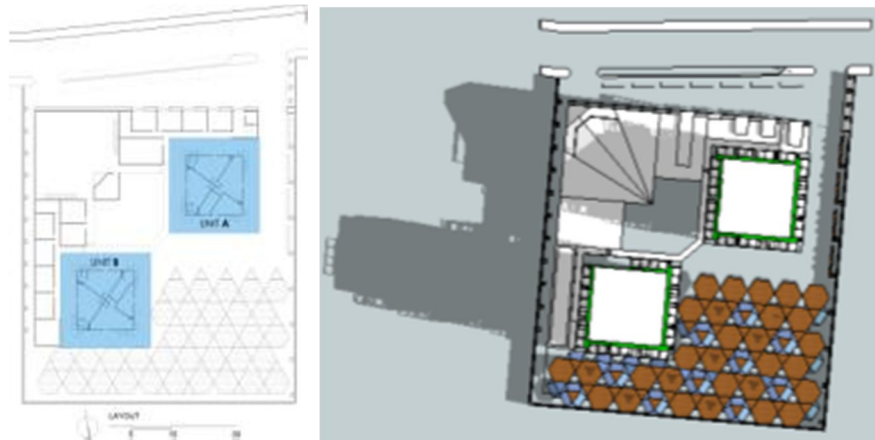


Figure 3: Ground floor (right) Shadowing (Source: Author, 2016)

Structuring space room space seeking direct view of the outdoor space and optimizes natural lighting, the room configuration can be seen in Figure 4 and 5. Grouping in this dwelling unit, i.e. the unit A is for men aged 13 years and older, while the unit B reserved for men and women aged 0-13 years overall.

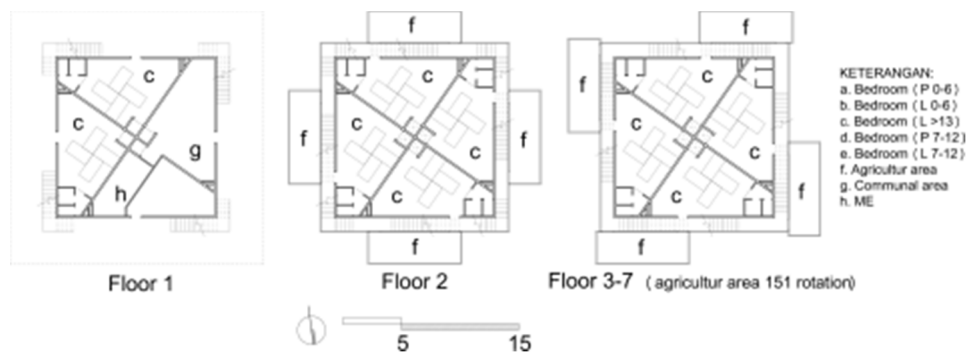


Figure 4: Floor plan unit A (Source: Author, 2016)

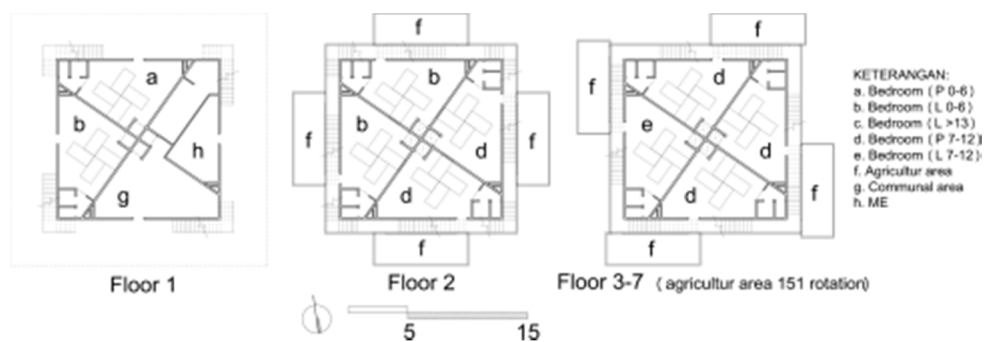
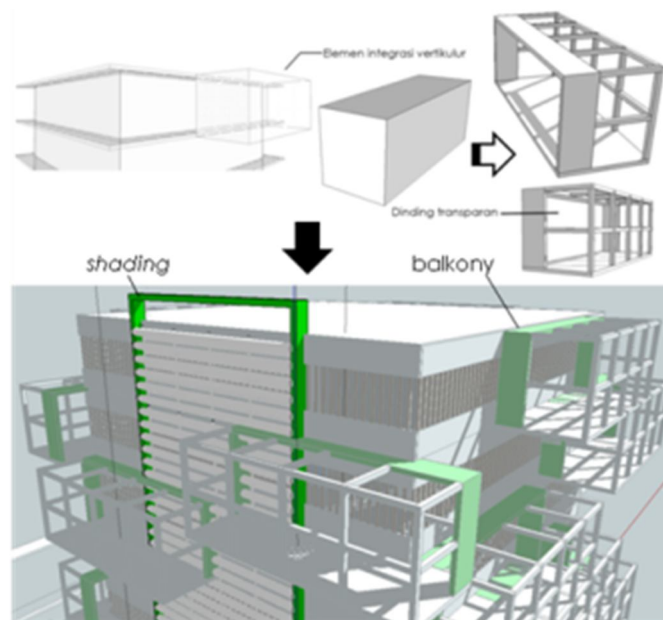


Figure 5: Floor plan unit B (Source: Author, 2016)

Configuration space for integration of vertical-agriculture in transitory housing is referring to Francis DK Ching, in his book says there are fundamental ways of linking the space of a building (Ching, 2009), namely: a) The space in the room, b) Space mutual relates, c) contiguous space, d) the room is connected by a common room. The following are criteria of vertically-integrated agriculture in transitory housing:

- Vertical-agriculture integration of space has the potential of natural lighting and air circulation is sufficient to support the productive process plant.
- Area integrated vertikultur, namely the building envelope.
- The sides were affected by exposure to the sun more often a permanent element of the balcony, while the side that is rarely exposed to the sun in the form of its moveable shading elements

Configuration space-related criteria may be seen on the picture floor plan and perspective view can also be seen in Figure 6.



**Figure 6:** Detail (Source: Author, 2016)

## 5. CONCLUSION

Integrating of agriculture space on the building envelope by adapting the shape of one typology phyllotaxy with the results: the acquisition of room setup agriculture for optimal utilization of natural lighting in which dose optimized to capture power of sunlight and do not cover (overshadow) the composition of which are below, implementation phyllotaxy in the shape of a square building, where the typology of phyllotaxis are able to demonstrate an adaptive advantage to the acceptance of most of natural lighting is spiral (anomalous 5.7) at an angle of  $151.1^\circ$  located approximately 85.625%.

**6. REFERENCES**

- Ching, F. D. (2009), *Arsitektur: Bentuk Ruang dan Tataan*, Erlangga, Jakarta
- Andi, V. O., Jumaini, & Wasisto, U. (2015), Konsep Diri Remaja Putus Sekolah Di Panti Sosial Bina Remaja Rumbai, *JOM*, **2(2)**, 935-943, Pekanbaru
- Hidayatullah, R. (2014), Analisis Kinerja Dinas Sosial Dan Pemakaman Kota Pekanbaru, *Jom FISIP*, **1(2)**, Pekanbaru
- Nelly, R. (2015), Sustainable Spaces With Psychological Connotation: Historical Architecture As Reference Book For Biomimetic Models With Biophilic Qualities, *Archnet-IJAR*, **9(2)**, 248-267, International Journal of Architectural Research: ArchNet-IJAR
- Ratih, W., Eddy, P., & Wahyu, S. B. (2014), Performance Evaluation of Vertical Gardens. *IJAEC*, **8(1)**, 13-21, IASDM
- Ayuningtiyas, A. M. (2010), *Perancangan Sekolah Anak Jalanan Pendekatan Fleksibilitas Arsitektur*, Thesis, Department of Architecture, ITS, Surabaya.
- Griffiths, S. (2014), *Vertical and urban farming*, <<http://www.fstjournal.org/features/28-4/vertical-farming>> (Accessed on 5 April 2016)
- Mukminin, A. (2014), *Laporan Praktikum Struktur Perkembangan Tumbuhan (Spt) I Tata Letak Daun (Phyllotaxis)*, <[http://biomukmin.blogspot.com/2014/03/v-behaviorurldefaultvmlo\\_6.html](http://biomukmin.blogspot.com/2014/03/v-behaviorurldefaultvmlo_6.html)> (Accessed on 16 Maret 2016)
- Rio, S. P. (2014), *Alih Fungsi Lahan, Sektor Pertanian Di Riau Makin Tergusur*, <<http://sumatra.bisnis.com/read/20140423/13/50300/alih-fungsi-lahan-sektor-pertanian-di-riau-makin-tergusur>> (Accessed on 23 April 2016)
- Sawit watch/admin (2014), *Kedaulatan pangan, hanyalah mimpi, bila konversi lahan pangan tidak dihentikan*, <<http://sawitwatch.or.id>> (Accessed on 29 February 2016)
- Stoma, S. (2007), *Phyllotaxis*, <<http://openalea.gforge.inria.fr/wiki/doku.php?id=documentation:demo:phyllotaxy>> (Accessed on 16 November 2015)

Taufik, R. (2015). *Alih Fungsi Lahan Pertanian Mencapai 100 Ribu Hektare per Tahun.*, 2016,

<<http://nasional.republika.co.id/berita/nasional/umum/15/11/16/nxwc53219-alih-fungsi-lahan-pertanian-mencapai-100-ribu-hektare-per-tahun>> (Accessed on 29 February 2016)

Zari, M. P. (2007), *Biomimetic Approaches To Architectural Design For Incresed Sustainability*, Auckland, New

Zealand, <[www.cmnzl.co.nz/assets/sm/2338/61/16300MaibrittPedersenZari.pdf](http://www.cmnzl.co.nz/assets/sm/2338/61/16300MaibrittPedersenZari.pdf)> (Accessed on 2016)

Badan Kesejahteraan Sosial Nasional (BKSNN, 2000), *Modul Pelatihan Pekerja Sosial Rumah Singgah*, Jakarta

Langgeng. (2016), *Interview of "Masalah Kesejahteraan Sosial Anak Jalanan" on Dinas Sosial dan Pemukiman Kota*

*Pekanbaru, Jl. Jend. Sudirman No.239* (Interview on 2 February 2016)