Public Flat in Indonesia, Their Role in Highly Densed City:
Legal Aspect Review and Prototype Assessment

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Abstract. An affordable vertical house, which is known as rusun in Indonesian term becomes the utopia of a compact city. The rusun to be the main actor contributing to the creation of liveable comfort in dense areas by relocating squatters and slum inhabitants to better living places. Technical guidelines and building standards play a major role in a building’s environmental impact. These standards will be reviewed based on their impact on building performance. There are two prototypes of rusun referenced in 05/PRT/M/2007, and the assessment of these prototypes has been done by using ENVI-met. The meteorological data for the ENVI-met configuration input is adapted to the same weather and climate conditions taken from the data measured on June 13th, 2012. The analysis of this assessment will focus on building orientation, building length, building height, and also the microclimate which is impacted by these prototypes. Based on the assessment, it is recommended that the layout of outdoor space on the north side should provide as much green coverage as possible, either for shadowing or for the benefit of its albedo. The simulation shows that building ratio of 1:3 produces higher wind speed, which also controls air temperature and humidity.

1. Introduction
High population densities increase exposure to the effects of microclimates. Also, high population densities are vulnerable to climate change, as they can potentially localize climatic effects, such as increased local temperatures, urban heat island effects and high levels of outdoor temperatures. Therefore, density has become one of a variety of factors that influence the sustainability of urban form. Furthermore, density has an effect of compactness, the need to travel, and the feasibility of public transport in reducing emissions. In a broader sense, sustainable cities are a matter of density. Based on the data from BPS Indonesia, there are twelve cities in Indonesia with the population of more than 10,000 people / km² [1] not only causing demographic problems for the social economic but also giving burdens to the urban living environment. The excess of population in big cities in Indonesia creates slum and squatter pockets nearby the downtowns. Thus, the program of 1000 towers was set by the Indonesian Government to replace the over-crowded settlement by providing vertical housing, which in Indonesian term is called rusunawa (rent) and rusunami (owned).
The national government runs the program of *rusun*. Previously, two ministries take responsibility for *rusun* construction that is the ministry of public works and the ministry of public housing. Starting from 2014, these two ministries have been joined as the ministry of public works and housing (PUPR). The demand of *rusun* as affordable housing in Indonesia is rising year by year. The amount of backlog based on the concept of residential in 2014 is 7.4 million unit house. Therefore, the development and construction of *rusun* will be further carried out in the following years to handle the high density in the slum areas, which is essential for city planning and design. The legal aspect is then a primary strategy for *rusun* planning and design. Technical guidelines and building standards play a major role in a building’s environmental impact, and they are also related to building performance, a factor correlated with urban built environments. Therefore, the actual and strategic positions of legal aspects are the driving force in examining the technical guidelines and building standards of *rusun*.

### 2. Legal Aspect of *Rusun*

Legal aspects discussed here refer to the result of a legal product when Kemenpera and PU were yet in the same ministry. The hierarchy of legal aspects of *rusun* includes technical requirements, guidelines, and standards, shown in figure 1. The focus of the discussion is the content of the guidelines. Thus, the hierarchy of the legal aspect will not be necessary to discuss. Specific discussions of the technical guidelines in this paper can be seen in the following:

a. 60/PRT/1992 about Technical Requirements of *rusun* construction [2]

b. 05/PRT/M/2007 about Technical Guidelines of high-rise *rusun* [3]

An explanation of the above legal aspects is as follows:

**60/PRT/1992 CHAPTER VII: DENSITY AND LAYOUT OF BUILDING**

- Article 48
  1. Public flats with five floors and the maximum density of the dwellers is 1,736 persons and the BCR is 25% and FAR is 1.25
(4) The use of land is the ratio of total land area for building flats, which is 50% and for infrastructure is 20%.

Article 50

(1) The distance between buildings required for fire safety, daylighting and air circulation

CHAPTER III: THE REQUIREMENTS OF BUILDING FORM AND CONFIGURATION

III.1. (4) d. The building distances (clearances) are set from the ground floor as far as 4m, with an augmentation of 0.5m for each additional floor or building level until it reaches the furthest distance of 12.5m.

III.2. (1) b. Building blocks with T, L or U shapes which have the building length of more than 50m need to make a dilatation to prevent damages caused by an earthquake or subsidence as seen in Figure 2.

Building plans with centric shapes such as squares, polygons or circles are better than elongated shapes to prevent earthquake-related damages.

As described above, there is an absence of building forms and configurations regarding passive design needed to accommodate the urban microclimate aspect. Furthermore, the low availability of detailed dimensions and the lack of specific explanations make this guideline open to multiple interpretations. Since this guideline is so general, developers will not comply with these rules which in turn put the law enforcement of building regulations in a difficult position.

Additionally, an important part of this legal aspect is the rusun prototypes, which have two main building plan types. These include symmetric parallel (SP) and symmetric cross (SC), and they can be used for eight, fifteen and twenty floors. To accommodate subsequent discussions, the assessment of these flats will then be referred to as the prototype of rusun.

2.1. Legal Aspects Review

The legal aspect here refers to 60/PRT/1992 CHAPTER VII, article 48 and 50; 05/PRT/M/2007 CHAPTER III, verses III.1 and III.2, which are included in the Indonesian National Standard (SNI) for rusun construction. The realization of legal aspect aforementioned seems to overlap each other, and also there are some inconsistencies in the statements which are described in Table 1.

| Legal Aspect | Realization of Prototype |
|--------------|--------------------------|
| 60/PRT/1992 : | SPModel: BCR 25%, FAR 2.0, density 1,024 persons. |
| Public flats with five floors and the maximum density of the dwellers is 1,736 persons, the BCR is 25% and FAR is 1.25 | SCModel: BCR 37%, FAR 2.96, density 1,120 persons |
| Max uses of land for building is 50%; environmental infrastructure 20% and environmental facilities 30% | 8 floors |
| 05/PRT/2007 : | SPModel: BCR 25%, FAR 3.85, density 1,920 persons. |
| Building distance from the ground floor as far as 4m, and the farthest is 12.5m | SCModel: BCR 37%, FAR 5.55, density 2,040 persons. |
| SN1 03-2846-1992 : [4] | 20 floors |
| 8 floors \( \rightarrow \) BCR 17.5%, FAR 1.375 and density 1,909 persons | SPModel: BCR 25%, FAR 6.42, density 2,560 persons. |
| The number of floors allowed are 11- | SCModel: BCR 37%, FAR 7.4, density 2,720 persons. |
| 05/PRT/2007 : | 05/PRT/2007 |
| The distance between the building is not synchronous with the availability of prototype, which is only for a single building. In case applied in the building groups, it will have an impact on the availability of daylighting and possibility of wind turbulence | The distance between building 12.5m so H/W = 30/12.5 = 2.4 |
12 floors  
15 floors tower → the distance between building 12.5m so  
H/W = 51/12.5 = 4.08  
20 floors tower → the distance between building 12.5m so  
H/W = 66/12.5 = 5.28

3. Assessment of Rusun’s Prototypes
The assessment of building forms and configurations for the two models of the prototype was done by using ENVI-met. The meteorological data for the ENVI-met configuration input was adapted with the weather and climate conditions taken from the data measured on June 13th, 2012. Since the prototype only provides a single building for the site, the analysis of this assessment focuses on building orientation, building length, building height, also the microclimate which is impacted by the prototypes. There are two prototypes of rusun referenced in 05/PRT/M/2007. The first model is a symmetric parallel model (SP), as shown in figure 3a and figure 3b. The second model is a symmetric cross model (SC), as shown in figure 3c and figure 3d.

Figure 3(a). Plan of Symmetric Parallel (SP) Model; (b). Section of Symmetric Parallel (SP) Model; (c) Plan of Symmetric Cross (SC) model and (d) Section of Symmetric Cross (SC) Model  
Source: Legal Aspect of Rusun 05/PRT/M/2007

3.1 Microclimate Assessment
ENVI-met is a three-dimensional microclimate model designed to analyze the small scale interaction between urban design and the microclimate. The model combines the calculation of fluid dynamic parameters such as wind flow or turbulence with the thermodynamic processes taking place on the ground surface, at walls and roofs or at the plants. With a typical resolution between 0.5m and 10m, the model is
able to simulate even complicated geometric forms, such as terraces, balconies or complex quarters. [5][6]

The model includes the simulation of:
1. flow around and between buildings;
2. exchange processes of heat and vapour at the ground surface and at walls;
3. turbulence;
4. exchange at vegetation and vegetation parameters.

This simulation will help architects and planners predict the quality of urban areas in the complexity of urban microclimate, understand the better living area or give the optimum decision before the construction is held.

### Table 2. General Condition for Simulation

| Location          | Bandung, Indonesia -6.54S; 107.37E |
|-------------------|------------------------------------|
| Climate type      | Hot humid climate                  |
| Simulation day    | 13\textsuperscript{th} June, 2013 24hours |
| Meteorological Data | Initial Temperature 298.35 K     |
| Specific Humidity | 13 gWater/kg air RH 63%           |
| Indoor 296.34 K   | Heat transmission                  |
| Walls: 0.41 W/m\textdegree K |
| Roofs: 0.157 W/m\textdegree K |
| Albedo            | 0.2                                |
| Wind speed 2.29m/s |                                      |
| Direction 321NW   |                                      |
| Energy Exchg : 116W/m\textdegree |
| Clo : 0.7         |                                      |

As mention above, there are two models, which are SP and SC. These two models have tilted from the west-east 20 degrees toward north. Accordingly, there is SP_20 for the SP Model titled 20 degrees, and SC_20 for the SC Model titled 20 degrees. Therefore, in this simulation, the total number of building models is four models. The general condition for simulation, like the geographic location and meteorological condition, is described in table 2. The model of SP Model can be seen in Figure 4(a) and the SP_20 Model is shown in Figure 4(b). Also, the SC Model can be seen in Figure 4(c) and the SC_20 Model is shown in Figure 4(d).

In this study, the assessment is limited to prototypes of only eight floors, as fifteen and twenty floor prototypes are not included in the study. The consideration of the impropriety of fifteen and twenty floor prototypes has explained in Table 1.

The building form and massing, including their different height to width ratio, distances between building and green open space are the most significant aspects to influence the wind speed and the penetration of radiation within the urban area. Here, the interaction between urban form and microclimate from ENVI-met simulation has been shown by air temperature (Ta), humidity (RH), velocity (v) and the most important part is the mean radian temperature (Tmrt) value, as an expression of radiation flux and parameter with high variability in urban area, at least by the modification of the global radiation. Later, table 3 shows microclimate condition of Rusun’s prototype and the diagram of this assessment shown at table 4.

Figure 5 as a chart from table 3 presents the microclimate for each prototype. These results indicate that the south west orientation of this model reached the lowest temperature (Ta), but did not reach low values in other meteorological parameters. The north west orientation has the highest Ta, but the other parameters (Tmrt, Tg and RH) show the lowest value. By tilting the building orientation of west to east to N 20\degree, the SC Model does not seem to significantly reduce the gap of maximum meteorological parameters.
Figure 4. Area input for ENVI-met a. SP Model b. SP-20 model; c. SC Model d. SC-20 Model

Table 3. Microclimate assessment of Rusun’s Prototype

| Orientation | Ta  | Tmrt | Tg  | RH  | v   |
|-------------|-----|------|-----|-----|-----|
| N           | 30.1| 76.37| 65.35| 53  | 1.74|
| S           | 28.48| 25.96| 26.55| 59  | 1.64|
| W           | 29.31| 52.91| 47.89| 56  | 1.3 |
| E           | 28.83| 29.88| 29.82| 57.3| 0.07|

Symmetric Parallel Model titled 20° (SP_20)

| Orientation | Ta  | Tmrt | Tg  | RH  | v   |
|-------------|-----|------|-----|-----|-----|
| N           | 28.31| 63.13| 57.37| 80.2| 0.7 |
| S           | 28.03| 54.09| 49.78| 76.32| 0.7 |
| W           | 27.95| 50.8 | 46.01| 80.08| 1.25|
| E           | 28.27| 50.78| 45.85| 77.66| 1.4 |

Symmetric Cross Model (SC)

| Orientation | Ta  | Tmrt | Tg  | RH  | v   |
|-------------|-----|------|-----|-----|-----|
| NE          | 29.5| 61.77| 55.05| 59.5| 1.23|
| SW          | 29.78| 75.25| 65.4 | 55.43| 1.36|
| NW          | 30.15| 62.46| 56.61| 55.36| 0.87|
| SE          | 28.99| 77.05| 70.72| 57.41| 0.41|

Symmetric Cross Model titled 20° (SC_20)

| Orientation | Ta  | Tmrt | Tg  | RH  | v   |
|-------------|-----|------|-----|-----|-----|
Referring to the previous research [3], building form and massing have an important effect on the microclimate through modifying ground surface temperature with vegetation ratio which is proven to offer lower isolation and bring the optimum outdoor thermal comfort.

The result of ENVI-met simulation of building prototypes: SP; SC; SP_20; SC_20 from 06.00 am to 07.00 pm are shown in figure 5 as a chart from table 3. This value presents the Tmrt value for each prototype, in which all the prototypes reached the highest Tmrt value at 2pm. The SC_20 Model reached the lowest Tmrt value at 50.97 °C, meanwhile the SC Model reached the highest Tmrt value at 52.7 °C.

This simulation provides the information that four of the building prototypes, building form and massing, including their orientation, length, and height give similar responses to the microclimate situation.

3.2 Living Quality based on human perception of outdoor thermal comfort.

The living quality is determined by many aspects. However, it cannot be denied that meteorology and atmospheric conditions have a significant impact on the quality of urban environments, which depend on their physical aspects. Thus, it is a logical correlation that air temperature, humidity, wind speed and insolation within the urban space strongly impact on human health.

| Model | Tmrt value for four models |
|-------|---------------------------|
|       | Diurnal Mean Radiant temperature (Tmrt in °C) |
|       | 06.00 | 07.00 | 08.00 | 09.00 | 10.00 | 11.00 | 12.00 | 13.00 | 14.00 | 15.00 | 16.00 | 17.00 | 18.00 | 19.00 |
| SP    | 15.73 | 28.30 | 43.20 | 47.76 | 49.54 | 49.89 | 50.29 | 51.08 | 51.50 | 50.30 | 45.20 | 25.47 | 17.67 | 16.97 |
| SC    | 15.74 | 28.72 | 43.10 | 48.45 | 50.35 | 51.00 | 51.55 | 52.29 | 52.67 | 50.76 | 45.62 | 27.75 | 18.04 | 17.41 |
| SP_20 | 15.73 | 28.28 | 42.94 | 47.77 | 49.62 | 50.09 | 50.58 | 51.46 | 51.93 | 50.34 | 44.90 | 26.18 | 17.99 | 17.35 |
| SC_20 | 15.74 | 28.22 | 42.85 | 47.81 | 49.72 | 50.12 | 50.31 | 50.88 | 50.97 | 49.40 | 44.34 | 24.66 | 17.15 | 16.61 |
As previously described, with respect to the idea of microclimate improvement in the frame of building groups, a passive design gives better outdoor thermal comfort.

Table 5. Thermal sensation classification for Taiwan and Western/Middle Europe

| Thermal sensation  | PET in Taiwan (°C) | PET range for Western/Middle Europe (°C) |
|-------------------|--------------------|----------------------------------------|
| Very cold         | <14                | <4                                     |
| Cold              | 14-18              | 4-8                                    |
| Cool              | 18-22              | 8-13                                   |
| Slightly cool     | 22-26              | 13-18                                  |
| Neutral           | 26-30              | 18-23                                  |
| Slightly warm     | 30-34              | 23-29                                  |
| Warm              | 34-38              | 29-35                                  |
| Hot               | 38-42              | 35-41                                  |
| Very hot          | <42                | <41                                    |

In this research, the assessment focuses on the human perceptions of outdoors, which in this step is merely based on measurement and simulation, not through interviews or personal contacts. Studies on thermal comfort of humans in urban areas require meteorological parameters, such as air temperature, humidity, air velocity, short and long wave fluxes. The quality of urban environment as a living area then will be stated as PET (Physiological Equivalent Temperature), which is an index of human well-being or comfortability based on the thermal environment. The PET can make estimations using a free software package called RayMan. In their study, Lin, et.al [7] looked at 1644 interviews in Taiwan and developed PET ranges for Taiwan in their hot and humid climate. This is shown in table 4. The PET indices based on microclimate data from ENVI-met simulation which is shown in table 5. From those tables, it shown that rusun prototypes offer the outdoor thermal comfort in the perception of “warm”, which is stated in the range of 34.7°C – 37.4 ºC. As mentioned above, the prototypes give similar responses to the microclimate. This also means that the outdoor thermal comfort gives the similar value in PET indices.

4. Conclusion
In order to compile comprehensive and complete building regulations, a holistic and complicated approach needs to be utilized. Thus, it must be acknowledged that this research has a huge limitation regarding the implementation of the legal aspects above. Nevertheless, the important finding of this study can be considered as an improvement of the current regulatory recommendations. This is true especially regarding the building form and configuration. The most important facets of the study’s results are as follows:

Table 6. Outdoor thermal perception for Rusun’s model

| Model | Tmrt max | Ta (°C) | Va (m/s) | RH (%) | PET | Perception |
|-------|----------|---------|----------|--------|-----|------------|
| SP    | 51.50    | 27.50   | 1.86     | 83.13  | 34.7| Warm       |
| SC    | 52.67    | 29.70   | 1.76     | 56.75  | 37.4| Warm       |
| SP_20 | 51.93    | 28.28   | 1.80     | 77.18  | 35.8| Warm       |
| SC_20 | 50.97    | 27.55   | 1.47     | 84.28  | 35.4| Warm       |
Based on the four models, it was determined that the northern face receives more insolation compared to other directions such as the west, east or south. Therefore, the layout of outdoor space on the north side should provide as much green coverage as possible, either for shadowing or for the benefit of its albedo.

The building ratio of 1:3 produces higher wind speed, which also controls air temperature and humidity. However, this is difficult to apply due to the limited availability of land.

The given prototypes of eight, fifteen and twenty floors provide the possibility of opening it up to *rusun* construction unwell planned. Instead of creating bounds with this prototype, it would be better to carefully measure and accommodate the number of people who live in a certain area.

The strategy of building group passive design is summarized as follows: the first priority is to accommodate or to determine the population density. It must also consider the environmental load in terms of infrastructure. The urban form characteristic due to the high values of FAR, DU, and high population seems to be a good concept for the urban built environment. They can be very livable and comfortable environments if an efficient development pattern is used.

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