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# The Factors of Implementation Performance-Based Building Design on High Rise Residential Building in Indonesia

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**Abstract:** The complexity of the design in high-rise residential projects is a challenge for the construction industry in completing projects that fit the needs of user. Performance-Based Building Design (PBBB) appears as a design concept that can describe these needs into performance requirements. In this case designing a building can be considered as an iterative process of exploration, where desired functional properties can be created, the shapes are suggested, and evaluation processes is used, so as to bring together the shapes and functions of the building. This concept is a container for designers to produce high-performance buildings. This study aimed to identify the performance-based building design factors applied by architect designers and engineers in high-rise residential building in Surabaya. As part of this study, primary data was collected based on surveys conducted through observation and questionnaire distributed to designers who had or were involved in the high-rise residential design process in Surabaya. A total of sixty-eight respondents were included in this study. Descriptive analysis through a mean and standard deviation scatter plot was used to rank the application of PBBB. Meanwhile, factor analysis was used in the analysis of PBBB application factors. From the results of the analysis, four factors were obtained for the application of PBBB in high-rise residential buildings in Surabaya, namely; the interests of occupants, the sustainability of building operations, the design collaboration process, and the risk of loss. Future research is the influence relationships and measure the success model of PBBB at a higher level into BIM (Building Information Modeling) interoperability.

**Keywords:** performance-based building design; PBBB; high-rise residential.

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## 1. Introduction

Desired performance in the building is developed by the designer which is then processed and evaluated for its achievement. The performance approach is related to its use in buildings. The concept is then integrated in a design called Performance-Based Building Design (PBBB) [1]. The concept of performance-based design is not new many countries have implemented it gradually and are rapidly developing widely as a means for minimizing buildings against natural and man-made hazards. This can be analyzed at an early design stage [2]. The key concept of PBBB according to Meacham [3] are; (1) performance parameters that are clear and right on target (2) parameters can be monitored in terms of acceptance of performance (3) criteria are objective (4) if there are performance criteria not achieved, do not cause other problems (5) performance parameters are flexible so that they can be developed. Encouraging the application of PBBB, the task of the designer is not only to meet the building requirements that have been determined to suit the needs of the user/occupants, but also provides a mechanism so that the building can adapt to changes that will occur during the planned life cycle.

Surabaya is the second largest city in Indonesia with a population of 3,158,943 based on statistical bureau, 2019. The dynamics of population growth will continue to increase, because Surabaya has a strategic position regionally and nationally, that has business potential for economic development

for Indonesia. The phenomenon caused a lot of community migration to Surabaya, so that housing needs for new people will continue to grow. However, because land prices in the city of Surabaya are more expensive, and the availability of land is limited, then one of the best solutions to provide vertical housing is apartments. So far, based on international Colliers data 2018, the number of residential units in the city of Surabaya is 31,471 with an apartment occupancy rate of 52%. Residential is a basic need and as a long-term investment that can be adapted to the habits of residents. Therefore, high-rise residential development is important to ensure that the needs of residents can be handled properly where the performance of a building is also guaranteed [4]. Occupant satisfaction is a complex matter, it refers to residential units and satisfaction with the area and the environment. User/occupants who are satisfied with their occupancy can help the designer in achieving his goals [5].

The purpose of this study is to identify the factors in consideration of the application of PBBD that are applied by designers in high-rise residential buildings in the city of Surabaya. The study began with a literature review and continued with the distribution of the survey through a questionnaire distributed to 68 respondents experienced in designing high-rise residential buildings in Surabaya. This study is expected to support the development of PBBD research and its practice in achieving building performance in accordance with user/occupants requirements.

## 2. Literature Review on Performance-Based Building Design

The definition of performance in a dictionary is defined as an action or process of carrying out a task. Whereas in the world of construction, the performance of a building shows how well the building can perform its functions [6]. This is a key concept of a Performance-based Building Design (PBBD). The benefit of using the PBBD concept is to provide designers with innovations in produce alternative design solutions related to problems that arise in buildings. The most common problems are related to the safety and health of occupants. PBBD is known for the implementation of building design that focuses more on the results achieved by the building in accordance with its performance requirements, without specifying work methods and what the materials should be used. An example is the occupant's needs related to building safety. The building must have good structural stability related to the threat of fire, occupants can at least be protected during the evacuation process before the building is charred afterwards [2].

Performance-based design as a design concept that makes user/occupants requirements a measure of design success. Gopikrishnan and Paul [7] divided the user/occupants requirements related to buildings into three factors, namely; physical factor related to physical building condition, environmental factor related to healthy occupants and financial factor related to relationship between occupants and building. Therefore, by setting goals to be achieved at the beginning of the design, the step will focus the designer's efforts on aspects in improving performance considering the design is a complex process so that in producing products, it will involve the collaboration of many participants during the process [8]. In addition, design is an important factor for business success. This is a contribution in promoting design by increasing customers through products, product functionality and product quality [9].

It has been explained before, the implementation of building design based on performance is developed in accordance with the needs of user/occupants in several aspects of building. Some aspects of performance mentioned by researchers include; spatial, location, aesthetics, building costs [10] fire safety, noise, security, humidity, indoor air quality, durability [11,12], equipment and furniture, water, and disposal waste [13], all of which can be optimized to improve the quality of buildings. The emphasis on building quality drives building standards such as LEED in the US, BREAAAM in the UK, and GreenStar in the Australia which are applied by clients, architects, and engineers have focused on optimizing building performance. User/occupants who are satisfied with their occupancy are a measure of the success of their building helping achieve their goals. This can be done by evaluating building performance measurements based on various indicators, depending on the objectives [14]. Furthermore, performance measurement can also be a positive feedback where a

strong relationship between the physical environment with user satisfaction will be created and will be useful as learning in improving future designs [15].

Another important point in performance-based building design is that it supports the Building Information Modeling (BIM) approach throughout the life cycle in considering aspects of design performance levels [16]. BIM is a tool, process and technology facilitated by a digital machine whose documentation can be updated regarding buildings, performance, planning and operations. The use of technology tools on Performance-based design models can facilitate ideas in producing innovative designs by incorporating performance principles into design generations [17]. Exploring performance-based design provides user-friendly parameters in using sophisticated simulation-based software so that it helps designers to increase creativity, find good solutions to problems [18]. Until now, the development of BIM towards sustainable design is still a trend in construction. Both have a good potential relationship in integration of building. Bynum et al. [19] suggest that the use of BIM is most widely applied in companies as project coordination and project visualization. In addition, energy analysis, mechanical-electrical and plumbing analysis as well as lighting analysis, are the most widely performed types of building performance analysis in a sustainable project. Designer recognize that by understanding the potential benefits gained by using BIM, it will be an important tool in supporting sustainable design and construction practices. Of course, in achieving sustainability projects, the support of the parties to collaborate with each other must also be carried out optimally.

### 3. Research Method

Before distributing the questionnaire, the census must be carried out in advance related to the planning consulting firm incorporated in the Asosiasi Ikatan Nasional Konsultan Indonesia (INKINDO). Determination of the sample of respondents was done by using purposive sampling technique, which is a sampling technique with special conditions [20]. In this case, in order to obtain an informative sample, the selection of selected respondents was those who are experienced designers who have been or are involved in designing high-rise residential bulidings in Surabaya, namely design engineering at consulting firms.

In this study, respondents were asked to fill out a questionnaire in accordance with the instructions that have been mentioned. The questionnaire sheet contains general data on respondents and questions about indicators of the application of PBBD on a five-point Likert scale, where the numbers 1 to 5 each represent a level of agreement from very low to very high. Respondents were given a maximum of two weeks to fill out the questionnaire where respondents will then be contacted again to ascertain whether the questionnaire has been sent back by post to the address that was included in the reply envelope. Of the 255 questionnaires distributed, as many as 92 questionnaires were sent back, but only 68 questionnaires were declared valid and could be used.

Data were analyzed using a scatter plot of mean and standard deviation to rank the most important factor that need to be considered for application of PBBD by the designer in designing high-rise residential in Surabaya. Furthermore, factor analysis is used to validate and find out the factors applying the concept of PBBD based on the choice of respondents. Primary data obtained from the questionnaire were processed with the help of a computer. It is intended that information from many variables can be summarized into a number of factors, so that it will then be easily arranged and make conclusions easier. The extraction method used was principal component analysis where the main components extracted were based on the criteria for loading factors greater than 0.5.

### 4. Results and Discussion

#### 4.1. Profile of Respondents

General data collected from respondents covered information about their position, and work experience background in their respective organizations. Table 1 presents a summary of the demographic backgrounds of the respondents.

Table 1. Demographic background of respondents

Items	Sub-items	Frequency (N)	Cumulative frequency (%)
Position	Project Manager	5	7.3
	Project Officer	2	2.9
	Design Manager	3	4.4
	Design Engineer	48	70.5
	Others	10	14.7
Working Experience	< 1 years	13	19.1
	5 years	36	52.9
	6 – 10 years	19	27.9

In this study, the majority of respondents were designs engineering with a percentage of 70.5 percent. In general, it is known that design engineering is the expert of many professionals involved in the planning process, including architects and engineers. Their role in design is very important because they control and ensure the design process is carried out effectively and can be accounted for in terms of planning. In developing a performance-based building design framework, members of the design team must handle performance requirements derived from the needs of user/occupants without any aspects being solved at the expense of other aspects. The aspects described as performance requirements are implemented in every discipline whose processes are coordinated and collaborated [11]. Thus, the responses in the questionnaire can be relied upon. Furthermore, the majority of respondents with a percentage of 52.9 percent have work experience for five years, which means that the adequacy of respondents related to work experience is considered to be accurate and reliable.

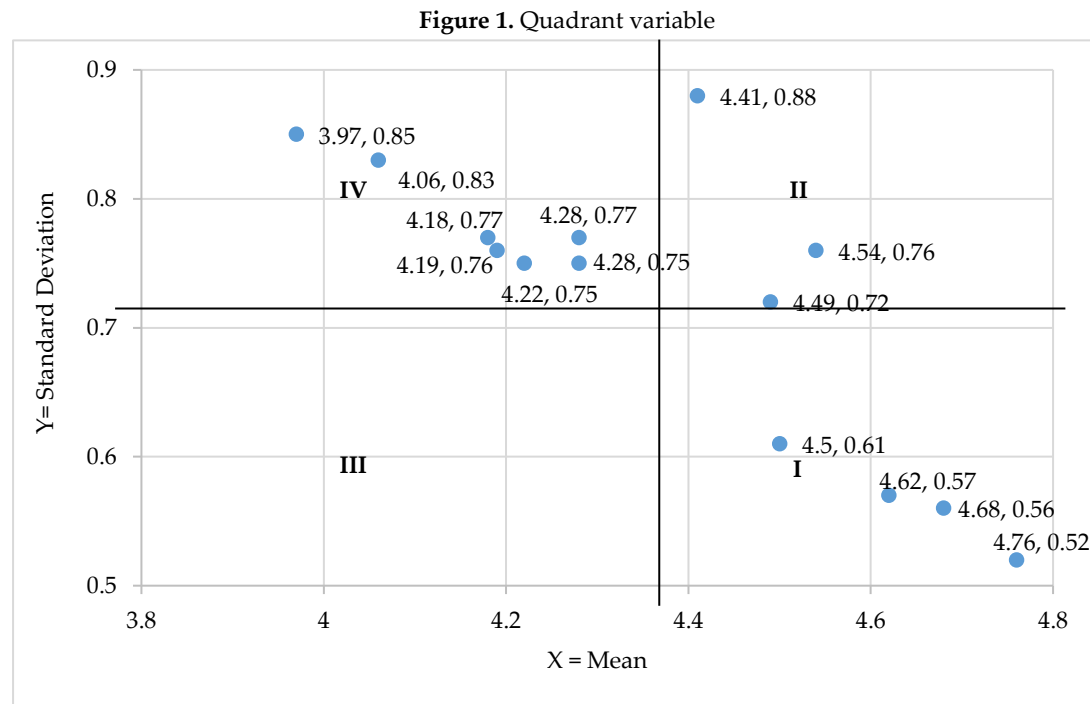
#### 4.2. Result of distribution data

The most influencing factors in the consideration of the application of PBBD in this study is by paying attention to the ranking based on the respondents' chosen score. In the following Table 2 explain the distribution of data using mean and standard deviations.

Table 2. Distribution data

(X) Variable	Mean	Standard Deviation
X1	4.49	0.72
X2	4.41	0.88
X3	4.18	0.77
X4	4.28	0.77
X5	4.76	0.52
X6	4.68	0.56
X7	4.19	0.76
X8	3.97	0.85
X9	4.06	0.83
X10	4.54	0.76
X11	4.28	0.75
X12	4.22	0.75
X13	4.62	0.57
X14	4.50	0.61

From the acquisition of the mean and standard deviation based on Table 2, in Figure 1 is shown about the position of each study variable in the cartesian diagram. In order to facilitate the assessment of the order of the variables that most influence, mapping is done in a diagram where the X axis shows the mean and the Y axis shows the standard deviation. Each research variable is divided into four quadrants based on the mean and standard deviation.



The variables that are considered the most influential are the variables with the position that are in quadrant one, namely variables with large mean and small standard deviations. Based on the results of the diagram above, we obtain a sequence of factors considering the application of PBBD to high-rise residential design as can be seen in Table 3.

**Table 3.** Ranking of variables based on quadrant position.

(X) Variable	Quadrant
X5	I
X6	I
X13	I
X14	I
X1	II
X2	II
X10	II
X7	IV
X12	IV
X4	IV
X3	IV
X8	IV
X11	IV
X9	IV

#### 4.3. Factor Analysis Results

There were fourteen variables considered as the application of PBBD analyzed using factor analysis. Before extracting the factors, the data suitability test was first performed using a Kaiser-Meyer-Olkin (KMO), Sample Adequacy Measure (MSA), and Bartlett test. KMO tested how much a partial correlation is to the original correlation. If the interconnected matrix value is the identity matrix and the KMO value  $<0.5$ , then the results indicate that the KMO value is small and shows that the correlation between pairs of variables cannot be explained by other variables [21]. The KMO index ranges from 0-1 where a value of 0.50 is considered suitable for factor analysis [22]. KMO approaching 0.80 or 0.90, shows an intercorrelation matrix which is almost ideal for factor analysis. MSA values indicate the adequacy of the sample. Bartlett's test is used to test whether the correlation matrix resembles the identity matrix, where the correlation coefficient is close to zero and must be significant 0.05 [23].

From the data processing, the KMO and Bartlett's test values were obtained for 0.729 with a significance of 0.000. In this case KMO and Bartlett have met the minimum criteria, but the communalities does not. Variable's communality is the proportion of its variance that is explained by each of the extracted factors, values ranging from 0.0 to 1.0. The closer the value is to 1.0, the greater the percentage of variance of a variable, so that, Mvududu and Sink [22] suggest to remove the attributes that have values less than 0.5 before other factor analyzes are carried out. That means one attribute was removed and then the remaining 13 attributes were analyzed. The KMO and Bartlett test results in this case then become 0.824. Anti image correlation test for all diagonal values was above 0.5, so that this value was declared to have met the minimum standard. Subsequent matrix rotations were calculated using varimax to get the grouping of variables for each factor, where eigen values which is greater than 1 will be extracted. The analysis produced four main factors with eigenvalues greater than 1. The results of the four factors were then labeled accordingly: factor 1 as "the occupants interest" (39.47 percent of the variance); factor 2 as "the sustainability of building operations" (11.93 percent of the variance); factor 3 as "the process of design collaboration" (10.29 percent of variance), and the last one, that is factor 4 as "the risk of loss" (9.06 percent of variance). Attributes of each of the four factors are shown in Table 4.

**Table 4.** Extraction of factors and attributes.

Factors	No	Factor Extraction	Factor Loading	Eigen value	Variance (%)
The occupants interest	X2	Indoor air quality	0.785	39.479	25.87
	X3	Visual comfort	0.746		
	X1	Accessibility	0.734		
	X4	Accoustic	0.692		
	X13	Building quality	0.683		
	X14	Facility of maintenance	0.663		
The sustainability of building operational	X8	Energy load	0.850	11.93	17.18
	X7	The sustainability of building	0.722		
	X9	Business process	0.647		
The process of design collaboration	X10	The involvement of another design consultant	0.871	10.29	15.03
	X11	Building operation	0.776		
The risk of loss	X5	Structure safety	0.822	9.06	12.66
	X6	Safety of fire	0.732		
Total					70.74

The four factors extracted explained 70.74 percent of the total variance. These results provide good validity. As such, these four components are defined as factors that apply performance-based design to high-rise residential buildings. Each factor will be further interpreted below.

#### 4.3.1. The Occupants Interest

The importance of this factor is shown by the percentage of variance in the factor analysis in Table 4 with a value of 25.87 percent. This factor consists of attributes that include indoor air quality, visual comfort, accessibility, Accoustic, building quality, and facility of maintenance. The purpose of building is to meet the expectations, needs and desires of user/occupants. Occupants become one of the significant factors and correlate in terms of building performance [12,24]. The term occupant's interests become a design requirement in producing high-performance and sustainable buildings. As a central figure related to residential comfort, buildings designed are important to prioritize occupant requirements as the final product. This is possible by providing buildings as products with good quality, will get the trust of occupants. Bragança et al. [25] also asserted that the interests of the occupants as the final result of the use of the building is a measure of success in meeting design objectives. Occupant satisfaction can be evaluated using a post-occupancy evaluation [24,26]. This is a structured process in evaluating the performance of buildings after they are built, occupied [25] and approach as a tool that can inform the designer about the need to make a building that matches the occupants' perceptions, preferences and abilities and in terms of ensuring that residents receive the return on investment they expect [27]. Furthermore, this approach is also the best way of evaluating certain aspects of the dweller's living environment that are related to the quality of the physical characteristics and functional characteristics of the dwelling [5].

#### 4.3.2. The Sustainability of Building Operational

This factor has a percentage variance of 17.18 percent in the application of performance-based building designs in high-rise residential building. This factor consists of three attributes which include: energy load, sustainability of building and business processes. Buildings are the biggest energy contributor, 80-90% in operation, while the energy contained in buildings is 10-20% [28]. However, in sustainability of building, there is an increased business focus on efforts related to managing energy consumption. The supply of renewable energy for residential buildings is the main case in building operations with the aim of improving facilities. This is at the same time a challenge for designers to ensure that their design is related to energy savings during the operational period [26]. For the example, energy needed to create comfort in a room with hot climates will require the use of substantial electricity load with associated environmental [29]. To reduce energy use and its impact on the environment, there are considerations that apply as a whole in residential design, namely; proper placement of buildings, the shape of the building that can adapt to the climate, separating the inside and outside thermally, the exchange of fresh air in the room, and choosing energy-efficient electrical equipment [30].

#### 4.3.3. The Process of Design Collaboration

This factor is the third factor in the application of performance-based building design with a variance of 15.03 percent. This factor consists of attributes; involvement of other design consultants and building operations. Performance-based building design creates designer collaboration in the process. Recently collaboration has increased because of the support of design tools to help designers share information, knowledge [31], and helping each other in decision making [32]. The availability of software allows multi-disciplinary designers to work together in managing information related to building products. However, in a complex project, many problems are not clearly defined and are beyond the ability of each individual to understand them, so that such problems can only be overcome by a group of people with various points of view that can provide the best solution [33]. Kalantari et al. [34] also highlights collaboration with facility managers who play a role in managing aspects of building operations. The designer must understand the role of the facility manager in applying the building use patterns intended by the designer [35]. Through good communication between designers and facility managers, the final product will be able to operate as efficiently as possible [36]. However, if the opposite happens, then only waste will result in higher operating costs, decreased building performance, and low satisfaction levels for building occupants [37].

#### 4.3.4. The Risk of Loss

This factor is the last factor with a variance value of 12.66 percent. In this factor there are structural safety and safety of fire attributes. Risk is uncertainty that occurs and is not desirable because it results in losses. Residential buildings with dense population, should be designed and built consider the appropriate structural characteristics. This is useful to minimize the risk of disaster that causes death. Thompson and Bank [38] divided risk factors related to the security and safety for occupants, there are; the risk of terrorist attacks, bomb threats, natural disasters and catastrophic fires. This affects the level of anxiety of occupants in occupying tall buildings. The three most critical building performance indicators highlighted by the study of Khalil et al. [39] namely structural stability, fire prevention, and building-related diseases. Designers who design structurally strong buildings have a good and reliable understanding of the risks of occupants' lives, buildings, and economic losses incurred due to natural disasters. This structural element is an important element in terms of occupant safety that must be guarded and maintained. Designing performance-based buildings facilitates the designer in creating scenarios of occupant movements during the process, with the aim of protecting occupants in the event of a disaster. Unfortunately, Mustafa [24] notes that the quality of buildings in terms of building safety and security is still at a low level among occupants.

## 5. Conclusions

Performance Based Building Design (PBBDD) needs strategic focus in integrating the building in accordance with the performance requirements. PBBDD provides the way of thinking which is more oriented on the user/occupants, and working in the design process. Based on the analysis, found four factors of PBBDD implementation in high rise building such as; the occupant interest, the sustainability of building operational, the process of design collaboration, and the risk of loss. Anyhow the approach of performance based design needs different attitude and different way of thinking about designing the building because performance based building is especially related to what must be done by the building for the owner and the user. Future research is the influence of relationships and measure the success model of PBBDD at a higher level into BIM (Building Information Modeling) interoperability.

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