Factors Analysis Affecting Low Productivity in High-Rise Building Projects in Surabaya City

Aileen Indonesia[a*], I Putu Artama Wiguna[a]

Correspondence

[a]Department of Civil Engineering, Institut Teknologi Sepuluh Nopember, ITS Campus Sukolilo, Surabaya 60111, Indonesia.

Corresponding author email adress: aileenindonesia67@gmail.com.

Submitted : 30 June 2023
Revised : 06 June 2024
Accepted : 14 June 2024

Abstract

High-rise building construction projects are characterized by significant risks and numerous challenges, which frequently lead to low productivity, causing delays and hindering project completion. One way to address these problems is to analyze the risk factors of low productivity in construction projects using a clustering method based on their probability and impact. This approach helps determine the dominance level of each cluster and provides insights into the occurrence of risk factors that affect low productivity in high-rise building projects in Surabaya City. This research was conducted with surveys filled out by 37 respondents involved in four high-rise building projects in Surabaya City. The aim of this study is to analyze risk factor clustering and determine the dominance of each cluster affecting low productivity in high-rise building projects in Surabaya City by employing the Agglomerative Hierarchical Clustering method to identify clusters and determine the most dominant cluster using Euclidean Distance. From the literature review, 33 risk factors were identified as the variables of this research. The AHC method was carried out based on the mean probability and impact of each cluster obtained from the survey. The result of AHC is that Cluster 1 consists of 23 factors, Cluster 2 consists of 5 factors, and Cluster 3 consists of 5 factors. For the dominance level of each cluster, the Euclidean distance method was carried out, and the result was that Cluster 2 emerged as the highest overall risk, and Cluster 3 represented a low overall risk.

Keywords

Construction projects, high rise building, low productivity, agglomerative hierarchical clustering, euclidean distance

INTRODUCTION

A construction project is required to be completed on time according to the initial planning made at the beginning of the project. The completion time of a project is closely related to the productivity achieved by the project. Low productivity in a construction project can result in project delays that can cause negative impact for the owner, consultant, and contractor involved in the construction project. Surabaya, as one of the largest cities in Indonesia, is actively engaged in ongoing development to meet the needs of its population, including the construction of high-rise buildings. However, the construction of high-rise buildings carries the potential risk of project delays [1], due to the magnitude of work involved, the complexity of the structures being built, and the time constraints imposed to complete them compared to other construction projects. Low productivity stands as a significant risk factor that can impact project quality and completion time and cause project delays, ultimately leading to increased costs and reduced efficiency.

Based on previous research, low productivity is a significant risk that can affect the quality and timeliness of project completion, leading to project delays and subsequent impacts on costs and efficiency [2], [3]. The presence of low productivity is attributed to various risk factors. After conducting a literature review, the researcher identified a total of 33 risk factors that could cause low productivity. To determine the most dominant risk factors causing low productivity in high-rise building projects in Surabaya, further analysis is required [4]. This analysis aims to assess and categorize the low productivity risk factors, allowing for appropriate handling. One way to conduct risk assessment and categorization is by evaluating the probability and impact value of each risk factor.

The Agglomerative Hierarchical Clustering (AHC) method [1], [2] is employed to cluster the 33 risk factors, Agglomerative Hierarchical Clustering was chosen due to the nature of this method, which clusters factors based on their similarity, in this case both the probability and impact values of each factor. Previous research has demonstrated the effectiveness of Agglomerative Hierarchical Clustering in studying the risks associated with low productivity in construction projects [2].

After obtaining the clusters of causal factors related to low productivity in high-rise building projects in Surabaya, the Euclidean Distance method was used to determine the dominance of each cluster. The dominant cluster signifies the cluster that encompasses the primary risk factors that contribute to low productivity in high-rise building projects in Surabaya. The selection of the Euclidean Distance method is based on previous research, which has demonstrated its efficacy in determining the level of dominance of a cluster of factors [6]. The aim of this research is to analyze the clusters of causal factors and determine their dominance in causing low productivity in high-rise building projects in Surabaya city.

RESEARCH SIGNIFICANCE

This study effort is highly valuable because it adds to the body of knowledge already known and because it may be used as a useful resource for future academic studies on the subject of low productivity in high-rise construction projects. It provides a thorough grasp of the underlying issues that impede productivity in such construction undertakings by digging into the intricacies and problems involved with this particular field of research.

The practical implications of this research extend beyond academia and affect experts in the building industry as well as practitioners. The conclusions and suggestions provide a useful manual for managing high-rise construction projects successfully, helping professionals recognize and reduce the risks that lead to poor productivity. The conclusions of this study can help guide decision-making processes, resource allocation strategies, and project management techniques in order to enhance overall productivity and project success rates.

METHODOLOGY

The methodology used in this research is Agglomerative Hierarchical Clustering (AHC) to obtain clusters of risk factors, and Euclidean Distance calculation to determine the dominant cluster as the cause of low productivity in high-rise building projects in Surabaya.

The flow of this research begins with the research background, followed by problem formulation and research objectives. Subsequently, a literature review is conducted on the factors affecting low productivity in high-rise building projects. Next, the identified risk factors are assessed for their mean probability and impact. These factors are then analyzed using Agglomerative Hierarchical Clustering (AHC) to determine the formed risk factor clusters. Afterwards, Euclidean distance calculations are performed on these clusters to identify the most dominant cluster, which serves as the primary cause of low productivity in high-rise building projects in Surabaya City.

This research was conducted with research variables obtained from the results of literature review, namely 33 risk factors affecting low productivity in high-rise building projects. The research variables that will be used are as follows Table 1 Risk Factors from Literature Review.
Furthermore, variable assessment is carried out with a questionnaire survey using a five-point scale to assess the probability and impact of each risk factor. The five-point scale is used to analyze the extent to which the identified risk factors have the potential to affect the productivity of high-rise building construction projects [14]. The five-point scale for probability and impact can be seen in Table 2 Five-point Scale.

The distribution of questionnaires assessing the probability and impact of each factor was carried out with a research population of high-rise building projects in Surabaya City with building specifications of more than 25 meters that are still in the under-construction stage in Surabaya City. The respondents selected were the project manager, operational division, and engineer division of the contractor on the high-rise building project in Surabaya City. Research respondents were obtained through sampling techniques using snowball sampling. In snowball sampling, the sample continues to grow through social networks or relationships owned by respondents who have been selected. Like the analogy of a snowball, which is initially small, but after that it swells gradually as it accumulates [15].

From the distribution of risk assessment questionnaires to research respondents, the mean probability and impact values used for AHC analysis were obtained. The mean probability and impact of each risk factor were calculated using the following formula [16]:

$$\bar{x} = \frac{\sum_{i=1}^{n} xi}{n} \quad (1)$$

Explanation:
$\bar{x}$ = mean value
$\sum_{i=1}^{n} xi$ = sum of the obtained data
n = number of the data

The mean probability and impact values from the risk assessment results are then used as input in the Agglomerative Hierarchical Clustering (AHC) analysis. The output of this AHC analysis is a dendrogram diagram that shows the cluster of risk factors affecting low productivity in high-rise building projects in Surabaya City. The steps taken from the AHC analysis are:

1. Preparing the data to be analyzed using Agglomerative hierarchical clustering. The data used for Agglomerative hierarchical clustering in this research is obtained from the mean values of each factor contributing to low productivity in high-rise building projects in Surabaya. These mean values are derived from probability and impact questionnaires distributed to the respondents.
2. Iterating the distance matrix using Euclidean distance calculations and centroid linkage. The distance matrix is computed using the Euclidean distance formula as follows [3]:

$$d(x,y) = \sqrt{\sum_{(i=1)}^{k} (x_i - y_i)^2} \quad (2)$$

In the equation above, xi represents the ith variable of object x, yi represents the i-th variable of object y, and k denotes the number of variables. Subsequently, the calculated distances or similarities between the data points formed into a Distance Matrix. This Distance Matrix then be processed to construct the dendrogram.
In addition to using the Euclidean distance formula, the centroid linkage approach is employed to merge clusters. The centroid linkage formula is as follows [17]:

$$d_{(UV)W} = \frac{n_u d_{(UW)} + n_V d_{(VW)}}{n_{(UV)}} - \frac{n_U n_V d_{(UV)}}{n_{(UV)^2}} \quad (3)$$

Table 1 Risk Factors from Literature Review

Risk Group	Code	Risk	References
Technical	T1	Deviation from the sequence of work	[2]
	T2	Poor condition and quality of outdated/damaged equipment	[5]
	T3	Lack of availability of equipment and/or materials	[2], [5]
	T4	Complex design	[6]–[9]
Worker	P1	Poor relationships between workers, foremen, supervisors, and site managers	[10]
	P2	Rework	[2], [10]
	P3	Lack of worker discipline regarding time (arrival, breaks, and departure according to schedule)	[10]
	P4	Personal issues	[10]
	P5	Workers have difficulty adapting to technological advancements	[6], [7], [9]–[11]
	P6	Decreased learning curves	[2]
	P7	Low worker motivation	[5]–[11]
	P8	Low skills/abilities of the workers	[2], [5]–[7], [9], [10], [12], [13]
	P9	Unhealthy working conditions for the workers	[5]–[7], [9], [10]
Manage-ment	M1	Delayed inspections by Quality Control	[6], [7], [9], [11]
	M2	Imbalanced distribution of worker groups	[2], [5]
	M3	Lack of worker supervision	[2], [6]–[9]
	M4	Incompetent project managers	[6]–[9], [11]
	M5	Insufficient site planning	[5]
	M6	Excessive overtime work frequency	[2], [5], [10]
	M7	Unclear and changing instructions during the execution of work	[10]
	M8	Lack of coordination between the owner, consultant, and contractor	[6], [7], [9]–[11]
	M9	Delayed wage payments	[8]
Site	L1	Workplace accidents	[10]
	L2	Overcrowded (too many workers in one location)	[2], [5]
	L3	Project location far from workers' residences	[5]
	L4	Unsafe working conditions	[5]
External	E1	Poor weather conditions	[6]–[11]
	E2	Inflation/price fluctuations of materials	[8]
	E3	Inappropriate government policies	[6]–[11]
	E4	Slow approval from local government authorities	[6]–[11]
	E5	Insufficient supply or high cost of required resources	[6]–[11]
	E6	Excessive client interference in the construction process	[6]–[11]
	E7	Design changes	[6]–[11]

Table 2 Five-point Scale

Score	Probability	Impact
1	Very low frequency	Insignificant
2	Low frequency	Minor
3	Moderate frequency	Moderate
4	High frequency	Major
5	Very high frequency	Severe

3. Creating a dendrogram from the resulting distance matrix. The dendrogram is constructed based on the cluster merging or distance matrix iterations performed in the previous step. An example of a dendrogram in AHC can be seen in the following image [4]:

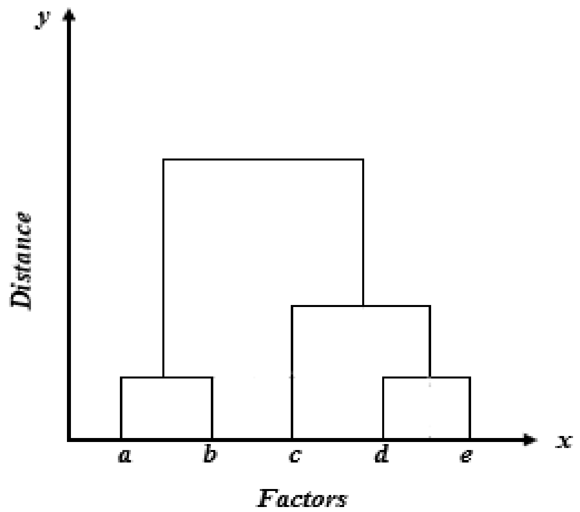

Figure 1 Example Dendrogram of Agglomerative Hierarchical Clustering (AHC)

In the dendrogram example above, the x-axis is the factor under review, and the y-axis is the distance between the factors. The way to read the dendrogram is to look at the line connecting the factors or clusters and then draw it to the left on the y-axis to find out the distance.

4. Cutting the tree to achieve the desired number of clusters. The tree is cut based on the researcher's subjective determination of the final desired number of clusters and how the inter-cluster distances are obtained from the generated dendrogram.
5. Interpreting the obtained dendrogram

After obtaining the clusters, the next step is to determine the dominant cluster as the cause of low productivity in high-rise building projects in Surabaya using Euclidean distance. The steps for calculating the Euclidean distance are as follows:

1. Calculating the centroid points for each cluster. The centroid point of a cluster is determined by calculating the centroid, or mean value, of each probability and impact within the members of that cluster. The formula to be used can be seen below [18], [19].

$$\bar{x} = \frac{\sum_{i=1}^{n} xi}{n} \quad (3)$$

Explanation:

$\bar{x}$ = mean value

$\sum_{i=1}^{n} xi$ = sum of probability/impact values from cluster members

n = number of cluster members

The output obtained from the centroid linkage calculation is the centroid point represented by the coordinates (x,y) of the mean probabilities (x) and impacts (y) of each cluster.

2. Calculating the Euclidean Distance value. The Euclidean distance value for each cluster is determined by calculating the Euclidean distance value from the cluster centroid to point (0,0). The formula used is as follows [3].

$$d(x, y) = \sqrt{\sum_{(i=1)}^{k} (x_i - y_i)^2} \quad (4)$$

Explanation:

xi = i-variable in x object

yi = i-variable in y object

k = number of variables

from the results of this step, the largest Euclidean Distance value will be determined, which represents the dominant cluster as the cause of low productivity in high-rise building projects in Surabaya.

The final result of this series of methods represents the level of dominance of clusters consisting of factors affecting low productivity in high-rise building projects in Surabaya.

ANALYSIS AND DISCUSSIONS

The respondents in this study consisted of project manager, operational division, and engineering division from high-rise building projects in Surabaya City. The projects included in this research were the UPT Vertikal Surabaya Hospital, KYO Society Apartment, Grand Shamaya Apartment, and AMP Intiland Building Development Project. The total number of respondents in this study was 37. The majority of the respondents had a bachelor's degree and had 6 to 10 years of experience working in construction projects.

A total of 33 risk factors were identified and evaluated based on probability and impact by 37 respondents in this study. These 33 risk factors were analyzed using the Agglomerative Hierarchical Clustering (AHC) method, resulting in factor grouping (clustering). Subsequently, Euclidean Distance calculation was performed to determine the dominant cluster as the cause of low productivity in high-rise building projects in Surabaya.

A. LOW PRODUCTIVITY RISK FACTORS

Table 1 presents the risk factors causing low productivity in high-rise building projects in Surabaya, based on risk identification and assessment conducted by 37 respondents from four high-rise building projects in Surabaya. It includes 33 risk factors along with their respective mean values used as input data for the AHC analysis.

Table 3 Risk Factors and Mean Values of Probability and Impact

Risk Group	Code	Risk	Mean Value	
			Probability	Impact
Technical	T1	Deviation from the sequence of work	3.76	3.57
	T2	Poor condition and quality of outdated/damaged equipment	2.97	3.24
	T3	Lack of availability of equipment and/or materials	3.00	3.14
	T4	Complex design	3.00	3.19
Worker	P1	Poor relationships between workers, foremen, supervisors, and site managers	3.03	3.14
	P2	Rework	2.97	3.14
	P3	Lack of worker discipline regarding time (arrival, breaks, and departure according to schedule)	3.03	2.84
	P4	Personal issues	2.16	2.76
	P5	Workers have difficulty adapting to technological advancements	2.95	3.00
	P6	Decreased learning curves	2.86	3.08
	P7	Low worker motivation	3.05	3.49
	P8	Low skills/abilities of the workers	2.92	3.43
	P9	Unhealthy working conditions for the workers	2.97	2.97

Risk Group	Code	Risk	Mean Value	
			Probability	Impact
Manage-ment	M1	Delayed inspections by Quality Control	2.08	2.76
	M2	Imbalanced distribution of worker groups	3.00	3.19
	M3	Lack of worker supervision	3.68	3.62
	M4	Incompetent project managers	2.92	3.05
	M5	Insufficient site planning	3.86	3.41
	M6	Excessive overtime work frequency	2.86	3.35
	M7	Unclear and changing instructions during the execution of work	3.59	3.32
	M8	Lack of coordination between the owner, consultant, and contractor	3.08	3.08
	M9	Delayed wage payments	2.81	3.16
Site	L1	Workplace accidents	3.05	2.84
	L2	Overcrowded (too many workers in one location)	2.73	3.03
	L3	Project location far from workers' residences	2.76	2.97
	L4	Unsafe working conditions	2.92	3.19
External	E1	Poor weather conditions	2.73	2.84
	E2	Inflation/price fluctuations of materials	1.97	2.49
	E3	Inappropriate government policies	2.03	2.54
	E4	Slow approval from local government authorities	2.03	2.51
	E5	Insufficient supply or high cost of required resources	3.11	3.05
	E6	Excessive client interference in the construction process	2.92	3.08
	E7	Design changes	3.73	3.41

B. AGGLOMERATIVE HIERARCHICAL CLUSTERING (AHC) ANALYSIS

In AHC analysis, the process of calculating Euclidean distance and centroid linkage results in a distance matrix with 32 iterations. The Agglomeration Schedule in Table 2 presents the sequence of merging each leaf (factors/clusters with only one member) and nodes (clusters larger than leaf) until eventually forming the root (main/large cluster). The merging of factors from the distance matrix is then used to construct a dendrogram, resulting in factor clusters/groups (Table 4).

As an example, in the first iteration, there is a merger between risk factors T4 and M2 (nodes) with a distance of 0. Subsequently, in the second iteration, the merger continues with risk factors E3 and E4 (nodes) with a distance of 0.027. The iteration process continues until the 32nd iteration, resulting in one large cluster. From the iteration of the distance matrix, a complete dendrogram is formed as shown in Figure 5 with the x-axis representing the distance and the y-axis representing the risk factors.

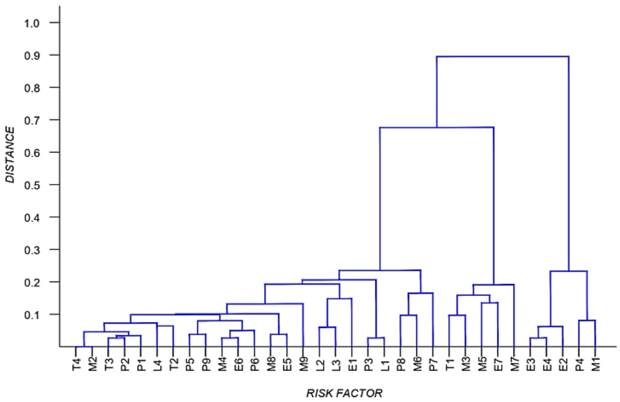

Figure 2 Dendrogram of Agglomerative Hierarchical Clustering (AHC)

Next, the tree is pruned by selecting a subjective distance value based on the author's preference regarding the desired number of final clusters and considering the dissimilarity/boundary of each cluster. The chosen distance value for tree pruning is 0.5, resulting in three main clusters from the AHC analysis. The first cluster comprises 23 members: T4, M2, T3, P2, P1, L4, T2, P5, P9, M4, E6, P6, M8, E5, M9, L2, L3, E1, P3, L1, P8, M6, and P7. The second cluster has 5 members: T1, M3, M5, E7, and M7. The third cluster consists of 5 members: E3, E4, E2, P4, and M1.

C. EUCLIDEAN DISTANCE

Once the clusters are formed, the next step is to determine the dominant cluster that causes low productivity in high-rise building projects in Surabaya. The first step is to calculate the centroid linkage to obtain the centroid points of each cluster according to Formula 3, which are as follows:

Cluster 1: The centroid point of Cluster 1 is located at coordinates (2.941, 3.108) on the x-y axis.

Cluster 2: The centroid point of Cluster 2 is located at coordinates (3.724, 3.465) on the x-y axis.

Cluster 3: The centroid point of Cluster 3 is located at coordinates (2.054, 2.611) on the x-y axis.

The positions of the centroid points for each cluster can be observed in the scatter plot of mean probability and impact in Figure 5.

The second step is to calculate the Euclidean Distance values according to Formula 1. The Euclidean Distance for each cluster is calculated by measuring the distance from the coordinate point (0,0) to the centroid point of each cluster. Here is an example of the Euclidean distance calculation. The centroid of Cluster 2 is located at the coordinates (3.724, 3.465), therefore the Euclidean Distance value for Cluster 2 is:

$$\sqrt{(P_2 - 0)^2 + (I_2 - 0)^2}$$

$$\sqrt{(3.724 - 0)^2 + (3.465 - 0)^2} = 5.087$$

Table 4 Agglomeration Schedule

Iteration	Action	Distance
1	T4 and M2	0.000
2	E3 and E4	0.027
3	P3 and L1	0.027
4	T3 and P2	0.027
5	M4 and E6	0.027
6	T3, P2 and P1	0.034
7	P5 and P9	0.038
8	M8 and E5	0.038
9	T3, P2, P1 and T4, M2	0.046
10	P6 and M4, E6	0.050
11	L2 and L3	0.060
12	E2 and E3, E4	0.062
13	T3, P2, P1, T4, M2 and L4	0.073
14	T2 and T3, P2, P1, T4, M2, L4	0.064
15	P5, P9 and P6, M4, E61	0.080
16	P4 and M1	0.081
17	P8 and M6	0.097
18	T1 and M3	0.097
19	T2, T3, P2, P1, T4, M2, L4 and P5, P9, P6, M4, E6	0.099
20	T2, T3, P2, P1, T4, M2, L4, P5, P9, P6, M4, E6 and M8, E5	0.101
21	T2, T3, P2, P1, T4, M2, L4, P5, P9, P6, M4, E6, M8, E5 and M9	0.132
22	M5 and E7	0.135
23	L2, L3 and E1	0.148
24	T1, M3 and M5, E7	0.159
25	P7 and P8, M6	0.165
26	T1, M3, M5, E7 and M7	0.191
27	T2, T3, P2, P1, T4, M2, L4, P5, P9, P6, M4, E6, M8, E5, M9 and L2, L3, E1	0.193
28	T2, T3, P2, P1, T4, M2, L4, P5, P9, P6, M4, E6, M8, E5, M9, L2, L3, E1 and P3, L1	0.206
29	P4, M1 and E2, E3, E4	0.233
30	T2, T3, P2, P1, T4, M2, L4, P5, P9, P6, M4, E6, M8, E5, M9, L2, L3, E1, P3, L1 and P7, P8, M6	0.235
31	T1, M3, M5, E7, M7 and T2, T3, P2, P1, T4, M2, L4, P5, P9, P6, M4, E6, M8, E5, M9, L2, L3, E1, P3, L1, P7, P8, M6	0.676
32	T1, M3, M5, E7, M7, T2, T3, P2, P1, T4, M2, L4, P5, P9, P6, M4, E6, M8, E5, M9, L2, L3, E1, P3, L1, P7, P8, M6 and P4, M1, E2, E3, E4	0.895

So, the Euclidean Distance value for Cluster 2 is 5.087. The same calculation was performed for all clusters, and here are the results of the Euclidean Distance values for the three clusters.

- Cluster 1, with members T4, M2, T3, P2, P1, L4, T2, P5, P9, M4, E6, P6, M8, E5, M9, L2, L3, E1, P3, L1, P8, M6, and P7, obtained a Euclidean Distance value of 4.279.
- Cluster 2, with members T1, M3, M5, E7, and M7, obtained a Euclidean Distance value of 5.087.
- Cluster 3, with members E3, E4, E2, P4, and M1, obtained a Euclidean Distance value of 3.322.

Therefore, it can be concluded that Cluster 2 ranks first because it has the highest Euclidean Distance value of 5.087, making it the dominant cluster referred to as High Overall Risk. Cluster 1 ranks second as moderate overall risk, and Cluster 3 ranks third as low overall risk. The High Overall Risk Cluster consists of 5 members: T1 = Deviation from the sequence of work, M3 = Lack of worker supervision, M5 = Insufficient site planning, E7 = Design changes, and M7 = Unclear and changing instructions during the execution of work. To provide a comprehensive understanding of the clustering result, the risk factor distribution graph based on probability and impact value, along with their clusters, is presented in Figure 5 below.

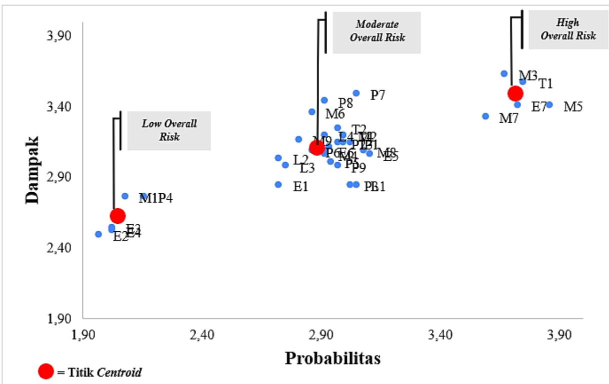

Figure 3 Risk Distribution Graph Based on Mean Probability and Impact

From Figure 5 above, it can be seen clearly that the risk factors affecting low productivity in high-rise building construction in Surabaya were clustered into three main clusters. Based on the distribution graph, it can also be observed that the most dominant cluster was cluster 2 (high overall risk), since it was located farthest from the (0,0) point on the risk distribution graph.

DISCUSSIONS

The results obtained from the AHC analysis reveal the presence of three major clusters, determined by setting a tree-cutting value of 0.5 distance. This outcome of three clusters differs from a previous study conducted [2], which identified two major clusters consisting of 16 and 4 factors, respectively. This disparity can be attributed to variations in the number of factors investigated and differences in the research context. Assaad et al.'s study focused on offsite construction in the United States, while the present research examines high-rise building construction projects in Surabaya city.

After obtaining the three clusters from the Agglomerative Hierarchical Clustering process, the researcher proceeded to measure the level of dominance for each cluster using the Euclidean Distance method with a centroid linkage approach. The results of this measurement provide a ranking of the dominance levels of the risk factor clusters that contribute to low productivity in high-rise building projects in Surabaya city. The cluster with the highest Euclidean Distance value, referred to as the High Overall Risk cluster, is Cluster 2, with a value of 5.087. The second-ranked cluster is Cluster 1, categorized as Moderate Overall Risk, with a value of 4.279. Lastly, Cluster 3 is identified as Low Overall Risk, with a value of 3.322. Based on these findings, it can be concluded that the High Overall Risk cluster, comprising factors such as improper sequencing of tasks (T1), lack of worker supervision (M3), insufficient site planning (M5), design changes (E7), and unclear and changing instructions during the execution of work (M7), is the most dominant cluster as a cause of low productivity in high-rise building projects in Surabaya city.

The risk factor "Deviation from the sequence of work" has a mean probability value of 3.76 and a mean impact value of 3.57. In a study conducted by [2] on risk factors causing low productivity using the AHC method, a dominant cluster was also obtained with one of its members being deviation from the sequence of work. In addition to [2] study, another research conducted by [23] also states that this factor has a significant impact on low productivity in a construction project. According to the project management team, this occurs because if the activities are not carried out in accordance with the initial sequence, there is a possibility that the work will need to be redone according to the sequence, which requires more time and leads to decreased productivity.

The risk factor "Lack of worker supervision" has a mean probability value of 3.68 and a mean impact value of 3.62. This risk factor belongs to the dominant cluster, as identified in the previous study by [2], which found a dominant cluster with one of its members being the lack of worker supervision. A study conducted by [24] also states that the lack of worker supervision can have a significant impact on the productivity of those workers. According to the project management team, this can occur because if workers are not adequately supervised, they may make mistakes, engage in laziness, or deviate from the initial planning by the management, resulting in longer work durations and decreased productivity.

The risk factor "Insufficient site planning" has a mean probability value of 3.86 and a mean impact value of 3.41. In this study, insufficient site planning is identified as one of the factors belonging to the dominant cluster that causes low productivity in high-rise building projects in Surabaya. According to a previous study conducted by [25], insufficient site planning can have a significant impact on productivity in construction projects. According to the project management team, this can occur because insufficient site planning hinders workers from performing efficiently due to inappropriate layout. For example, if the warehouse for materials and equipment is located far from the project site based on the site plan, workers will spend more time retrieving tools and materials. This will result in longer work durations and decreased productivity for the workers.

The risk factor "Design changes" has an mean probability value of 3.73 and an impact value of 3.41. Design changes are one of the dominant cluster members in this study. According to the project management team, this can occur because when design changes happen, workers are unable to proceed with their tasks or have to redo work that has already been completed. As a result, the work duration becomes longer, leading to decreased productivity for the workers. In a previous study conducted by [26], it was mentioned that design changes have an impact on project performance, affecting both time and the productivity of construction projects.

The risk factor "Unclear and changing instructions during the execution of work" has an mean probability value of 3.59 and an mean impact value of 3.32. Unclear and changing instructions during the execution of work are dominant factors that lead to low productivity among construction workers. Similar to the study conducted by [10], it is stated that unclear instructions are an important factor that can hinder the productivity of construction project workers. According to the project management team, when instructions and commands given to workers are unclear or constantly changing, it can cause confusion and uncertainty among the workers. Without clear guidance, workers may not have a proper understanding of what is expected of them, leading to errors in task execution. Additionally, changes in instructions and commands during work execution can disrupt workflow and cause unnecessary disruptions. Workers may have to pause the work they are doing to adapt to these changes, which consumes time and energy that could otherwise be used to continue work efficiently, resulting in low productivity for the workers.

Based on the results of this study, the managerial implications that can be implemented by contractors involved in high-rise building projects, particularly in Surabaya, are to pay extra attention and handle the five members of the high overall risk cluster. This is because the risk factors within this cluster are dominant contributors to the low productivity observed in high-rise building projects in Surabaya. In addition to addressing these five factors, project management should also continue to focus on and address other risk factors to ensure that the productivity of the workers reaches an optimal level.

From the results obtained in this study, it can be seen that the Agglomerative Hierarchical Clustering (AHC) method is capable of categorizing several factors into clusters based on the relative similarity of their values. In this research case, the values being considered are the probability and impact. This method differs from other risk analysis methods such as the Probability and Impact Matrix (PIM), which have specific value standards for categorizing risk factors, and factor analysis, which only provides rankings of factors without any grouping. The use of the Agglomerative Hierarchical Clustering (AHC) method can provide a fresh perspective in risk management related to productivity in a construction project.

CONCLUSIONS

Based on the analysis of data and discussions conducted regarding the factors causing low productivity in high-rise building projects in Surabaya, it can be concluded that there are three main clusters resulting from the analysis of Agglomerative Hierarchical Clustering (AHC) as the causes of low productivity in high-rise building projects in Surabaya. The Euclidean Distance calculation results indicate that Cluster 2 as High Overall Risk, with a Euclidean Distance value of 5.087, represents the dominant cluster causing low productivity in high-rise building projects in Surabaya. This cluster consists of Deviation from the sequence of work, Lack of worker supervision, Insufficient site planning, Design changes, and Unclear and changing instructions during the execution of work.

ACKNOWLEDGMENTS

The author would like to express gratitude to all parties who have assisted in the completion of this research.

REFERENCES

[1] K. Sasirekha and P. Baby, "Agglomerative Hierarchical Clustering Algorithm-A Review," International Journal of Scientific and Research Publications, vol. 3, no. 3, Jan. 2013.

[2] R. H. Assaad, I. H. El-adaway, M. Hastak, and K. LaScola Needy, "Key Factors Affecting Labor Productivity in Offsite Construction Projects," J Constr Eng Manag, vol. 149, no. 1, 2023.

[3] A. Nurseptiani, Y. Satria, and H. Burhan, "Application of Agglomerative Hierarchical Clustering to Optimize Matching Problems in Ridesharing for Maximize Total Distance Savings," in Journal of Physics: Conference Series, IOP Publishing Ltd, Mar. 2021.

[4] T. S. Madhulatha, "An Overview on Clustering Methods," ArXiv, vol. 02, no. 04, pp. 719–725, May. 2012, doi: 10.9790/3021-0204719725.

[5] A. Hartanto, "Faktor-Faktor Lapangan yang Mempengaruhi Produktivitas Pekerja pada Proyek Konstruksi," Jurnal Universitas Kristen Petra, vol. 1, no. 1, pp. 1–8, Jan. 2007.

[6] L. E. Bernold and S. M. AbouRizk, "Managing Performance in Construction,". Wiley, UK , 2010, ISNB 0470-171642.

[7] H. Doloi, A. Sawhney, and K. C. Iyer, "Structural Equation Model for Investigating Factors Affecting Delay in Indian Construction Projects," Journal of Construction Management and Economics, vol. 30, no. 10, pp. 869–884, Oct. 2012.

[8] S. Durdyev, S. Ismail, and N. Kandymov, "Structural Equation Model of The Factors Affecting Construction Labor Productivity," Journal of Construction Engineering and Management, vol. 144, no. 4, June. 2018.

[9] B.-G. Hwang, L. Zhu, and J. T. T. Ming, "Factors Affecting Productivity in Green Building Construction Projects: The Case of Singapore," Journal of Management in Engineering, vol. 33, no. 3, November 2017.

[10] Noviyasari, M. N. Yulius, Y. Bakar, and A. Ikhsan, "Identifikasi Faktor-faktor yang Mempengaruhi Produktivitas Kerja Proyek Konstruksi," in Seminar Nasional Riset & Inovasi Teknologi (SINARINT), 2022, pp. 353–362.

[11] D. T. Hai and N. Van Tam, "Application of the Regression Model for Evaluating Factors Affecting Construction Workers' Labor Productivity in Vietnam," The Open Construction and Building Technology Journal, vol. 13, no. 1, pp. 353–362, Dec. 2019.

[12] E. M. Sebayang, H. A. Rahardjo, and Dwi Dinariana, "Pengelolaan Risiko Proyek Gedung Bertingkat Pada PT. XYZ Di Jakarta Terhadap Kinerja Waktu," Jurnal Teknik Sipil, vol. 25, no. 3, p. 229, Dec. 2018.

[13] N. A. A. Mahat, H. Adnan, and N. Mohamad Yusuwan, "Analysing Factors Affecting Green Construction Productivity: Exploratory Factor Analysis Noor Aisyah," International Journal of Sustainable Construction Engineering and Technology, vol. 12, no. 5, Dec. 2021.

[14] V. Alireza, Y. Mohammadreza, R. M. Zin, N. Yahaya, and N. M. Noor, "An Enhanced Multi-Objective Optimization Approach for Risk Allocation in Public-Private Partnership Projects: A Case Study of Malaysia," Canadian Journal of Civil Engineering, vol. 41, no. 2, pp. 164–177, Feb. 2014.

[15] I. Lenaini, "Teknik Pengambilan Sampel Purposive dan Snowball Sampling," Jurnal Kajian, Penelitian dan Pengembangan Pendidikan Sejarah, vol. 6, no. 1, pp. 33–39, Jun. 2021.

[16] N. N. Watier, C. Lamontagne, and S. Chartier, "What Does The Mean Mean?," Journal of Statistics Education, vol. 19, no. 2, pp. 1–20, Jan. 2011.

[17] R. A. Johnson and D. W. Wichern, "Applied Multivariate Statistical Analysis," 6th ed., vol. 1. New Jersey: Pearson Prentice Inc, 2007.

[18] R. Silvi, "Analisis Cluster dengan Data Outlier Menggunakan Centroid Linkage dan K-Means Clustering untuk Pengelompokkan Indikator HIV/AIDS di Indonesia," Jurnal Matematika "MANTIK," vol. 4, no. 1, pp. 22–31, May 2018.

[19] A. M. Jarman, "Hierarchical Cluster Analysis: Comparison of Single Linkage, Complete Linkage, Average Linkage and Centroid Linkage," International Journal of Georgia Southern University, vol. 1, no. 1, pp. 1–13, 2020.

[20] I. S. Abotaleb, I. El-adaway, M. W. Ibrahim, A. S. Hanna, and J. S. Russell, "Causes, Early Warning Signs, and Impacts of Out-of-Sequence Construction: Expert-Based Survey Analysis," Journal of Management in Engineering, vol. 35, no. 6, pp. 1–17, Aug. 2019.

[21] R. Jimoh, L. Oyewobi, S. Suleiman, and R. Isa, "Influence of supervision on labour productivity on construction sites in Abuja-Nigeria," Independent Journal of Management & Production, vol. 8, no. 1, pp. 64–81, Mar. 2017.

[22] S. N. M. Zain et al., "Ineffective Site Management Practices and Their Impacts on Project Performance," in book: The 6th Proceeding of Civil Engineering, School of Civil Engineering, Universiti Teknologi Malaysia, Dec. 2021, pp. 501–518.

[23] H. A. Rahman, C. Wang, and J. B. H. Yap, "Impacts of Design Changes on Construction Project Performance: Insights from Literature Review," Journal of Quantity Surveying and Construction Business, vol. 7, no. 1, pp. 31–54, Mar. 2017.