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# Neutrosophic C-Mean Clustering Analysis of the Construction Projects Delay Causes

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## Abstract

This paper came in its concepts as a complement to our article entitled Ahmed A. "An Overview Neutrosophic relative importance Analysis the Construction Delays of Nineveh Province After Liberation from ISIS Occupation" where the two papers shed light on studying the reasons for delay causes of the projects in Mosul province that have been started at the end of 2018 exactly after the city's liberation from ISIS gangs occupation, those two papers are regarded as twins in its goal since both of them used the survey (A) that attached at the end of this paper. The novelty of this manuscript, in a nutshell, is using the notion of neutrosophic c-mean clustering as a mathematical tool for analyzing the results that the authors gained by the participants' answers for the survey (A) that had been released during months of October and Nov. of the year 2020, this survey has been targeted at 1500 individuals with experience, but unfortunately, the responses came from just 250 individuals whose expertise are diverse between project owners, project designers (i.e. consulting offices), contractors, etc. The sake of this paper is to use the neutrosophic c-mean clustering method for making nine comparisons between all opinions that biased to truth, indeterminacy, and falsity situations of the thirty-one delay reasons, those reasons adapted to be fit in its biasing from the gradations of truth to gradations of falsity. The MATLABR2023 toolbox was used in programming and analysis of the inferencing results, the traditional papers that had the same aims always used either classical or fuzzy mathematical tools, this is the first paper in its type using neutrosophic theory for this kind of application, which is related to project management in civil engineering and determining the risk factors in those construction projects that finished but suffered from delays in their implementation stages.

**Keywords:** Neutrosophic C-Mean Clustering; Neutrosophic Opinions; Linguistic Meaning of the Neutrosophic Delay Reasons; Truth Biasing; Indeterminate Biasing; Falsity Biasing.

## 1 | Introduction

It is well known that researchers who are interested in inference systems use questionnaires especially those questionnaires used for studying the causes of delay in the completion of construction projects, these

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questionnaires gather the experts' opinions about the reasons for delays, and these reasons are commonly used in literature. Many authors' attention has been attracted to delay causes of completing the construction projects in different ways [1, 3-7, 12 ], some of them used classical inference algorithms to analyze the gaining results [8-10], and others used fuzzy inference methods [2, 11], this article differs from the previous papers because the researcher conducted the comparisons between the 31 reasons using a new technique (he used neutrosophic theory and he put the neutrosophic opinions as centers of the clusters, while the intense of the 31 reasons of constructions delay were clustered around these opinions), whence their impacts and their importance. Again, the aim of this article and working strategy is: the researcher will focus on the 31 neutrosophic reasons and clustering them around neutrosophic nine opinions, these opinions have been demonstrated in Table 1.

**Table 1.** The grade linguistic meaning of the impact of the reason on delaying the completion of the project.

| Neutrosophic Grade | Neutrosophic Bias | Neutrosophic Linguistic Statement |
|---|---|---|
| **9** | Grade of Truth membership function | The reason always has an impact on delaying the completion of the project |
| **8** | Grade of Truth membership function | The reason usually has an impact on delaying project completion |
| **7** | Grade of Truth membership function | The reason generally has an impact on the delay in completing the project |
| **6** | Grade of Indeterminate membership function | The reason often has an impact on the delay in completing the project |
| **5** | Grade of Indeterminate membership function | The reason sometimes has an impact on the delay in completing the project |
| **4** | Grade of Indeterminate membership function | The reason occasionally has an impact on the delay in completing the project |
| **3** | Grade of Falsity membership function | The reason seldom has an impact on the delay in completing the project |
| **2** | Grade of Falsity membership function | The reason rarely has an impact on the delay in completing the project |
| **1** | Grade of Falsity membership function | The reason never has an impact on the delay in completing the project |

That is, we will distribute the 31 neutrosophic reasons of delaying the completion of construction project around the nine opinions (this is a kind of clustering where this study is dedicated to finding the problems positioned around the opinions, not the inverse), to simplify the concept of the work for the readers, we will take the nine opinions two by two (pairwise) to make them as centers, and finding the range of intense of the 31 reasons around these opinions in three directions:

- The first direction is the opinions of the truth grade with indexes 9, 8, and 7.
- The second direction is the opinions of the Indeterminate grade with indexes 6, 5, and 4.
- The third direction is the opinions of the falsity grade with indexes 3, 2, and 1.

Before implementing the suggested method, some of the preliminaries, and related basic concepts have been presented in the upcoming sections.

## 2 | Fundamentals

Generally, clustering term is known as grouping a set $N$ samples into $C$ clusters whose members are similar in some sense. This similarity between different samples is either a suitable distance based on numeric attributes, or directly in the form of pair-wise similarity or dissimilarity measurements.

Clustering can classify similar samples into the same group. The clustering process could be described as follows. Let $X = \{x_i, i = 1,2, \dots, N\}$ be a data set, and $x_i$ be a sample in n-dimensional space [13]. The problem of traditional clustering is to find a partition $P = \{p_1, p_2, \dots, p_c\}$, which satisfies:

$$X = \cup_{i=1}^{c} p_i \, , p_i \neq \Phi \;\; for \; i = 1,2, \dots, c \, , p_i \cap p_j = \Phi \;\; for \; i,j = 1,2, \dots c; i \neq j \dots \tag{1}$$

## 2.1 | Neutrosophic C-Mean Clustering [14]

Neutrosophic c-means clustering (NCM) is a newly proposed clustering algorithm, which can overcome the disadvantages of other algorithms on indeterminate points. In (NCM), the objective function and membership are defined as:

$$J(T_n, I_n, F_n, C) = \sum_{i=1}^{N} \sum_{j=1}^{C} (\varpi_1 T_{nij})^m \left\| x_i - c_j \right\|^2 + \sum_{i=1}^{N} (\varpi_2 I_{ni})^m \left\| x_i - \bar{c}_{imax} \right\|^2 + \sum_{i=1}^{N} \delta^2 (\varpi_3 F_{ni})^m \tag{2}$$

$$\bar{c}_{imax} = \frac{c_{pi} + c_{qi}}{2} \tag{3}$$

$$p_i = \arg max \, (T_{nij}) \quad j = 1, \dots C \tag{4}$$

$$q_i = \arg max \, (T_{nij}) \quad j \neq p_i \cap j = 1, \dots C \tag{5}$$

Where $m$ is a constant. $p_i$ and $q_i$ are the cluster numbers with the largest and second largest values of $T_n$. When the $p_i$ and $q_i$ are identified, the $\bar{c}_{imax}$ is calculated and its value is a constant number for each data point $i$ and will not change anymore. $T_{nij}, I_{ni}$ and $F_{ni}$ are the membership values belonging to the determinate clusters, boundary regions and noisy data set. Using Lagrange method to minimize the objective function, equations are updated as:

$$K = \left[ \frac{1}{\varpi_1} \sum_{j=1}^{C} (x_i - c_j)^{-\frac{2}{m-1}} + \frac{1}{\varpi_2} \, (x_i - \bar{c}_{imax})^{-\frac{2}{m-1}} + \frac{1}{\varpi_3} \, \delta^{-\frac{2}{m-1}} \right]^{-1} \tag{6}$$

$$T_{nij} = \frac{K}{\varpi_1} (x_i - c_j)^{-\frac{2}{m-1}} \tag{7}$$

$$I_{ni} = \frac{K}{\varpi_2} (x_i - \bar{c}_{imax})^{-\frac{2}{m-1}} \tag{8}$$

$$F_{ni} = \frac{1}{\varpi_3} \, \delta^{-\frac{2}{m-1}} \tag{9}$$

The membership functions $T_{nij}, I_{ni}$ and $F_{ni}$ with the cluster centers $c_j$ are updated by the equations (6)-(8) for each iteration. The $\bar{c}_{imax}$ is calculated according to indexes of the largest and second largest value of $T_{nij}$ at each iteration. The iteration will not stop until $\left| T_{nij}^{(k+1)} - T_{nij}^{(k)} \right| < \varepsilon$, where $\varepsilon$ is a termination criterion and $k$ is the iteration step.

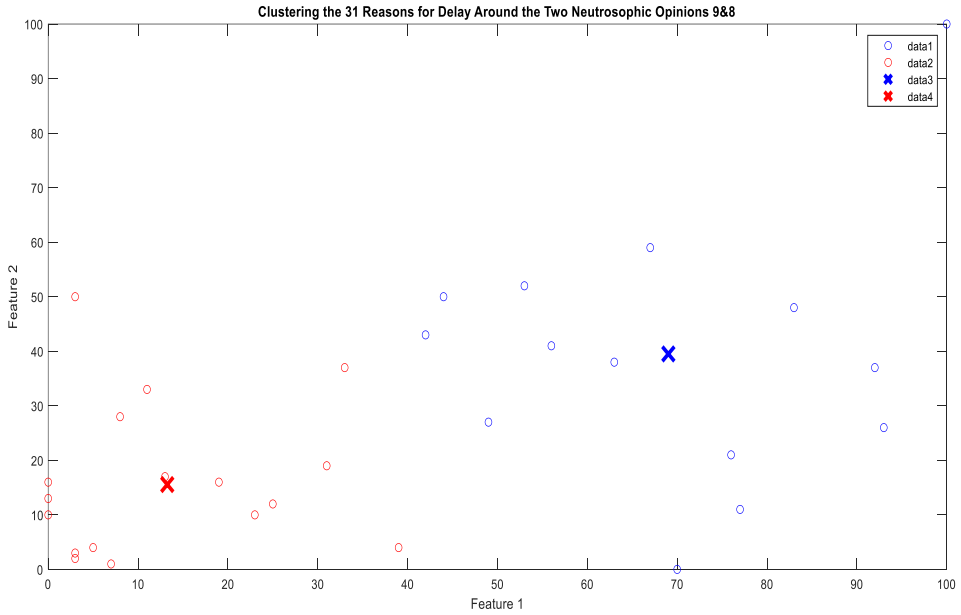
# 3 | Implement NCM on the Projects Delay Reasons

As stated in the introduction section, we will use two clusters with their two centers, each clustering MATLAB program uses pairwise neutrosophic opinions to infer how the 31 problems of delaying the construction projects are distributed around the two opinions, for the sake of the simplicity, we will not number the graphs, they will belong to their sections stated in it:

## 3.1 | First Comparison Among Truth Opinions

```
% using the neutrosophic c-mean clustering to specify the biasing of the 31 Reasons for the Delay Around the Two Neutrosophic Opinions 9&8
```

```
clc;
clear;
Z98=[93 7 3 3 19 100 44 25 39 3 0 77 5 70 49 76 63 56 42 67 53 33 13 8 11 0 23 31 0 92 83;26 1 2 3 16 100 50 12 4 50 10 11 4 0 27 21 38 41 43 59 52 37 17 28 33 16 10 19 13 37 48]';
save fcmdata1 Z98 –ascii
load fcmdata1
options=fcmOptions(NumClusters=2)
[centers,U]=fcm(fcmdata1,options)
maxU= max(U)
index1=find(U(1,:)== maxU);
index2=find(U(2,:)== maxU);
plot(fcmdata1(index1,1),fcmdata1(index1,2),"ob")
hold on
plot(fcmdata1(index2,1),fcmdata1(index2,2),"or")
plot(centers(1,1),centers(1,2),"xb",MarkerSize=15,LineWidth=3)
plot(centers(2,1),centers(2,2),"xr",MarkerSize=15,LineWidth=3)
xlabel("Feature 1")
ylabel("Feature 2")
hold off
```

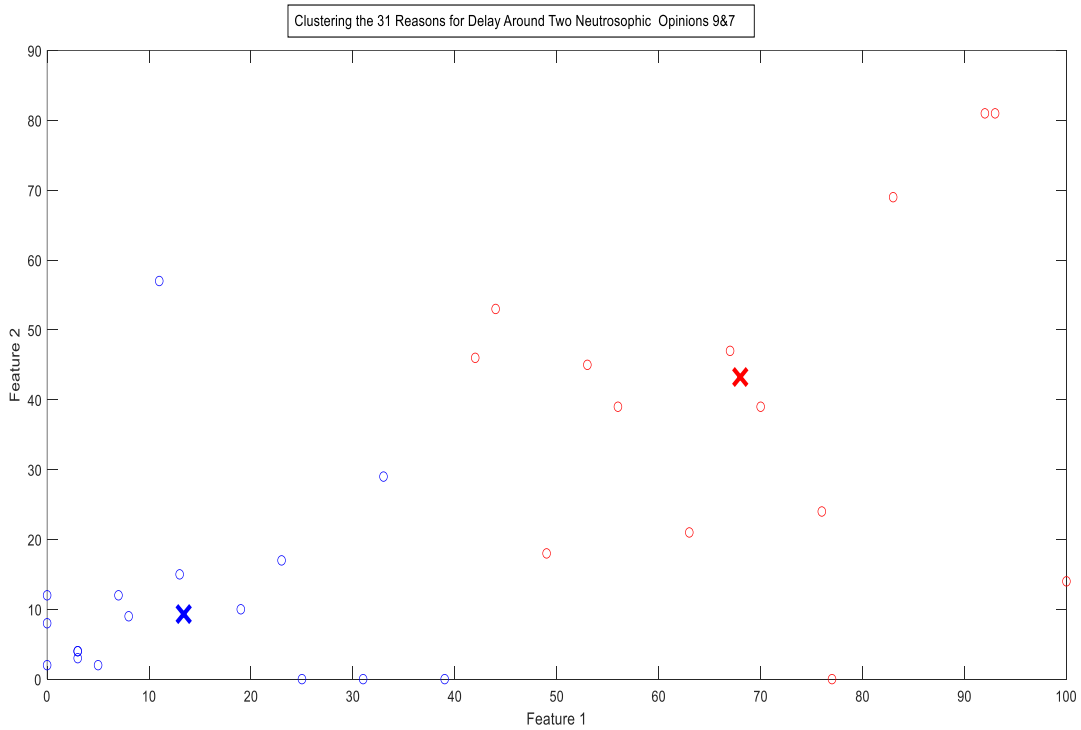



The blue colored data represent the index 1 (i.e. reasons for the delay in the construction projects) warping around the neutrosophic opinion 9=The problem always has an effect on the project. Hence, we noticed that there are fourteen reasons, in blue color are biased to the neutrosophic opinion 9. While the rest reasons (i.e. seventeen reasons in red color) are biased to the neutrosophic opinion 8= The problem usually has an effect on the project.

## 3.2 | Second Comparison Among Truth Opinions

% using the neutrosophic c-mean clustering to specify the biasing of the 31 Reasons for the Delay Around the Two Neutrosophic Opinions 9&7

```
clc;
clear;
Z97=[93 7 3 3 19 100 44 25 39 3 0 77 5 70 49 76 63 56 42 67 53 33 13 8 11 0 23 31 0 92 83;81 12 4 3 10 14
53 0 0 4 2 0 2 39 18 24 21 39 46 47 45 29 15 9 57 8 17 0 12 81 69]';
save fcmdata1 Z97 –ascii
load fcmdata1
options=fcmOptions(NumClusters=2)
[centers,U]=fcm(fcmdata1,options)
maxU= max(U)
index1=find(U(1,:)== maxU);
index2=find(U(2,:)== maxU);
plot(fcmdata1(index1,1),fcmdata1(index1,2),"ob")
hold on
plot(fcmdata1(index2,1),fcmdata1(index2,2),"or")
plot(centers(1,1),centers(1,2),"xb",MarkerSize=15,LineWidth=3)
plot(centers(2,1),centers(2,2),"xr",MarkerSize=15,LineWidth=3)
xlabel("Feature 1")
ylabel("Feature 2")
hold off
```

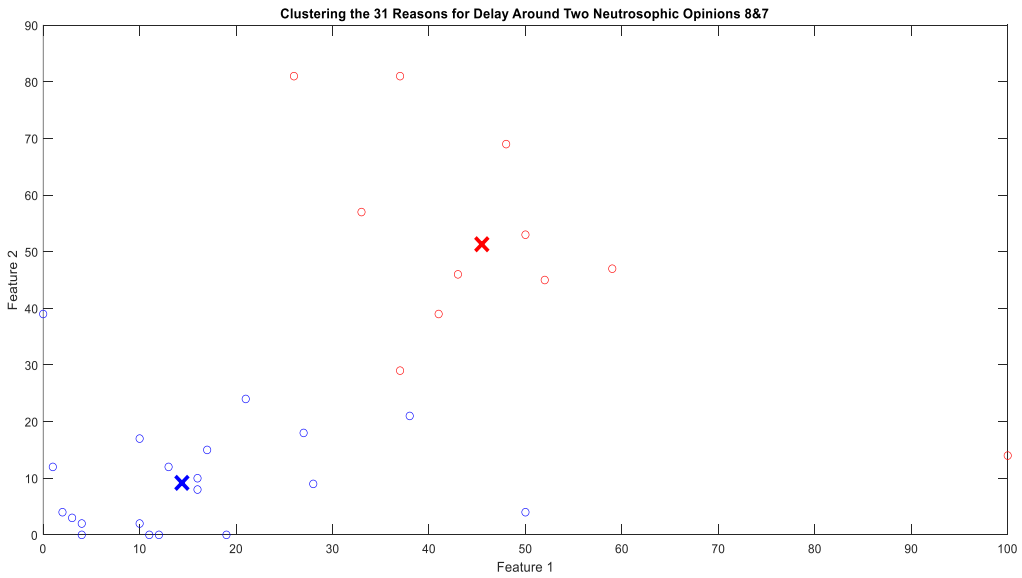



It should be noticed that, in the above MATLAB program, opinion 9 in the matrix data $Z_{97}$ has the priority in mentioning, so the blue represented data illustrates the range of reasons centered around the blue center x of the left cluster which is sixteen delay reasons. On the right-hand hand of the screenshot, the figure demonstrates that the red data represents those data centered around the neutrosophic opinion 7= The problem generally has affected the project and it is fourteen reasons.

## 3.3 | Third Comparison Among Truth Opinions

```
% using the neutrosophic c-mean clustering to specify the biasing of the 31 Reasons for the Delay Around the Two Neutrosophic Opinions 8&7
```

```
clc;
clear;
Z87=[26 1 2 3 16 100 50 12 4 50 10 11 4 0 27 21 38 41 43 59 52 37 17 28 33 16 10 19 13 37 48;81 12 4 3 10 14 53 0 0 4 2 0 2 39 18 24 21 39 46 47 45 29 15 9 57 8 17 0 12 81 69]'
save fcmdata1 Z87 –ascii
load fcmdata1
options=fcmOptions(NumClusters=2)
[centers,U]=fcm(fcmdata1,options)
maxU= max(U)
index1=find(U(1,:)== maxU);
index2=find(U(2,:)== maxU);
plot(fcmdata1(index1,1),fcmdata1(index1,2),"ob")
hold on
plot(fcmdata1(index2,1),fcmdata1(index2,2),"or")
plot(centers(1,1),centers(1,2),"xb",MarkerSize=15,LineWidth=3)
plot(centers(2,1),centers(2,2),"xr",MarkerSize=15,LineWidth=3)
xlabel("Feature 1")
ylabel("Feature 2")
hold off
```



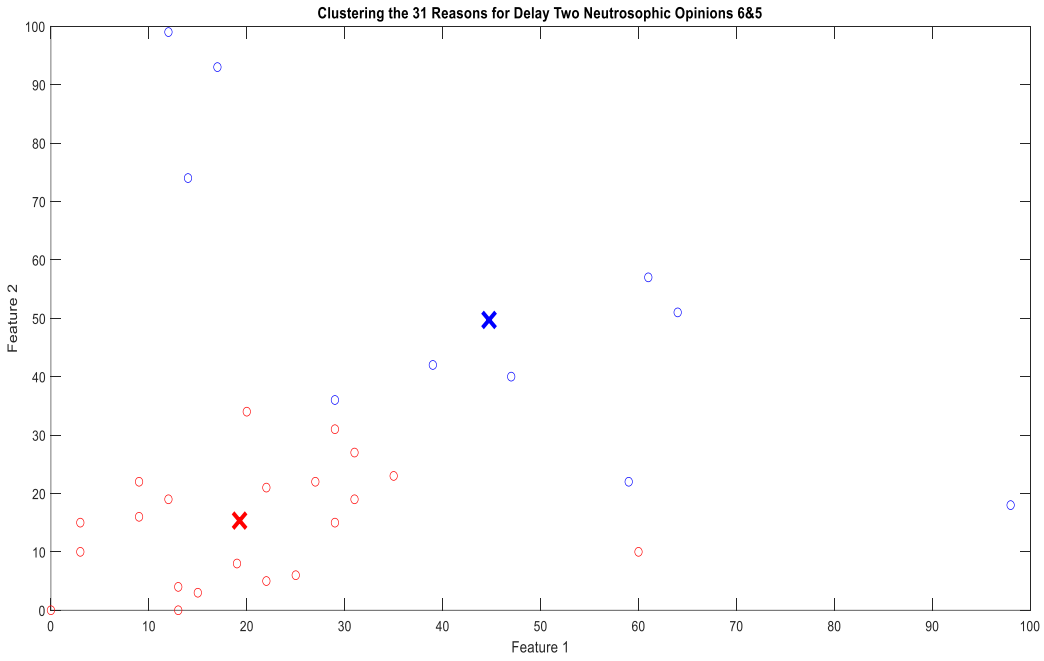

Again, in the above MATLAB program, opinion 8 in the matrix data $Z_{87}$ has the priority in mentioning, so the blue represented data illustrates the range of reasons centered around the blue center x of the left cluster which is twenty delay reasons centered around the neutrosophic opinion 8= The problem usually has an effect on the project. On the right-hand side of the screenshot, the figure demonstrates that the red data represents those data centered around the neutrosophic opinion (7= The problem generally has affected the project) and it is eleven reasons. Hence, we can say when we conduct an opinions comparison of a truth biasing of those problems that are causing the delay in the construction projects, we can use one of the data mining algorithms. The neutrosophic c-mean clustering has been used to do the analysis data clustering, where we noticed that

there are different degrees of intensity around a specific opinion. As well as the diversity of the amount of the causes around a specific neutrosophic opinion differs from one comparison to another.

## 3.4 | Fourth Comparison Among Indeteminate Opinions

```
% using the neutrosophic c-mean clustering to specify the biasing of the 31 Reasons for the Delay Around the Two Neutrosophic Opinions 6&5
```

```
clc;
clear;
Z65=[25 22 98 13 17 3 27 13 20 60 31 59 14 0 29 9 35 31 29 12 22 39 47 12 3 29 64 61 9 19 15;6 5 18 4 93 15 22 0 34 10 27 22 74 0 36 16 23 19 31 19 21 42 40 99 10 15 51 57 22 8 3]'
save fcmdata1 Z65 –ascii
load fcmdata1
options=fcmOptions(NumClusters=2)
[centers,U]=fcm(fcmdata1,options)
maxU= max(U)
index1=find(U(1,:)== maxU);
index2=find(U(2,:)== maxU);
plot(fcmdata1(index1,1),fcmdata1(index1,2),"ob")
hold on
plot(fcmdata1(index2,1),fcmdata1(index2,2),"or")
plot(centers(1,1),centers(1,2),"xb",MarkerSize=15,LineWidth=3)
plot(centers(2,1),centers(2,2),"xr",MarkerSize=15,LineWidth=3)
xlabel("Feature 1")
ylabel("Feature 2")
hold off
```

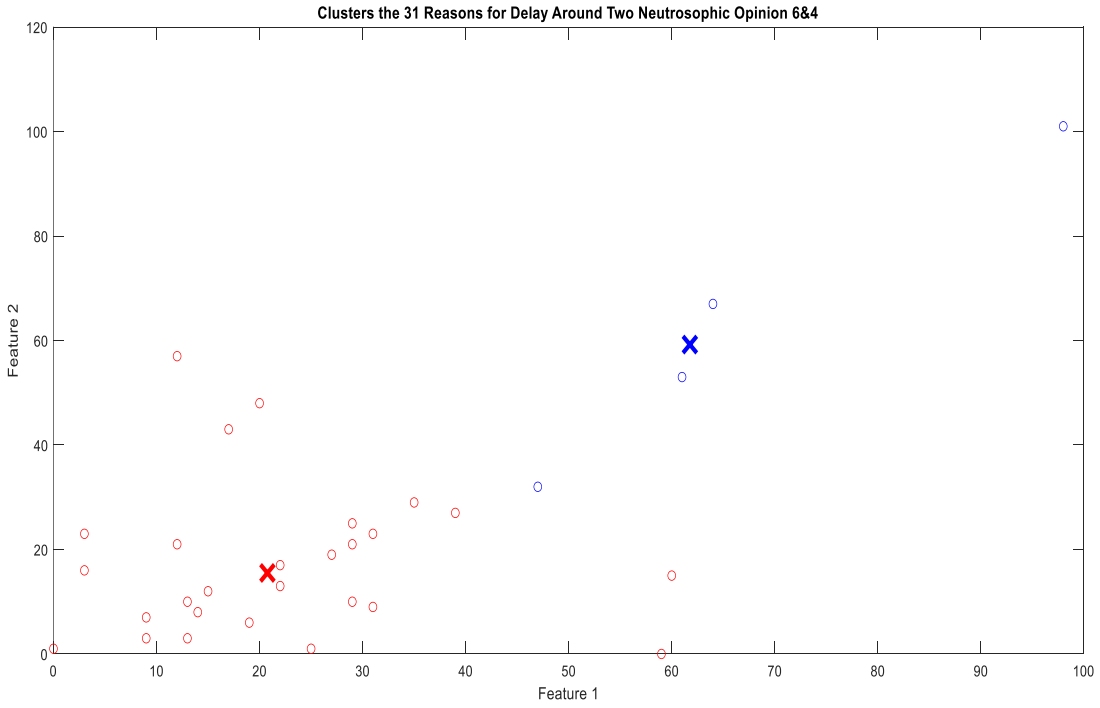



Again, for the indeterminate opinion (5=The problem sometimes affected the project) there are 21 causes have been clustered around it and demonstrated by red dots, while for the neutrosophic opinion (6=The problem often has affected the project), there are 10 reasons warping around it and they were determined by blue dots. Clearly, the reasons for the delay in the construction projects have been condensed around the neutrosophic opinion 6 more than those problems that wrapped around the neutrosophic opinion 5.

## 3.5 | Fifth Comparison Among Indeteminate Opinions

% using the neutrosophic c-mean clustering to specify the biasing of the 31 Reasons for the Delay Around the Two Neutrosophic Opinions 6&4

```
clc;
clear;
Z64=[25 22 98 13 17 3 27 13 20 60 31 59 14 0 29 9 35 31 29 12 22 39 47 12 3 29 64 61 9 19 15;1 13 101 3 43
16 19 10 48 15 9 0 8 1 10 3 29 23 21 21 17 27 32 57 23 25 67 53 7 6 12]'
save fcmdata1 Z64 –ascii
load fcmdata1
options=fcmOptions(NumClusters=2)
[centers,U]=fcm(fcmdata1,options)
maxU= max(U)
index1=find(U(1,:)== maxU);
index2=find(U(2,:)== maxU);
plot(fcmdata1(index1,1),fcmdata1(index1,2),"ob")
hold on
plot(fcmdata1(index2,1),fcmdata1(index2,2),"or")
plot(centers(1,1),centers(1,2),"xb",MarkerSize=15,LineWidth=3)
plot(centers(2,1),centers(2,2),"xr",MarkerSize=15,LineWidth=3)
xlabel("Feature 1")
ylabel("Feature 2")
hold off
```

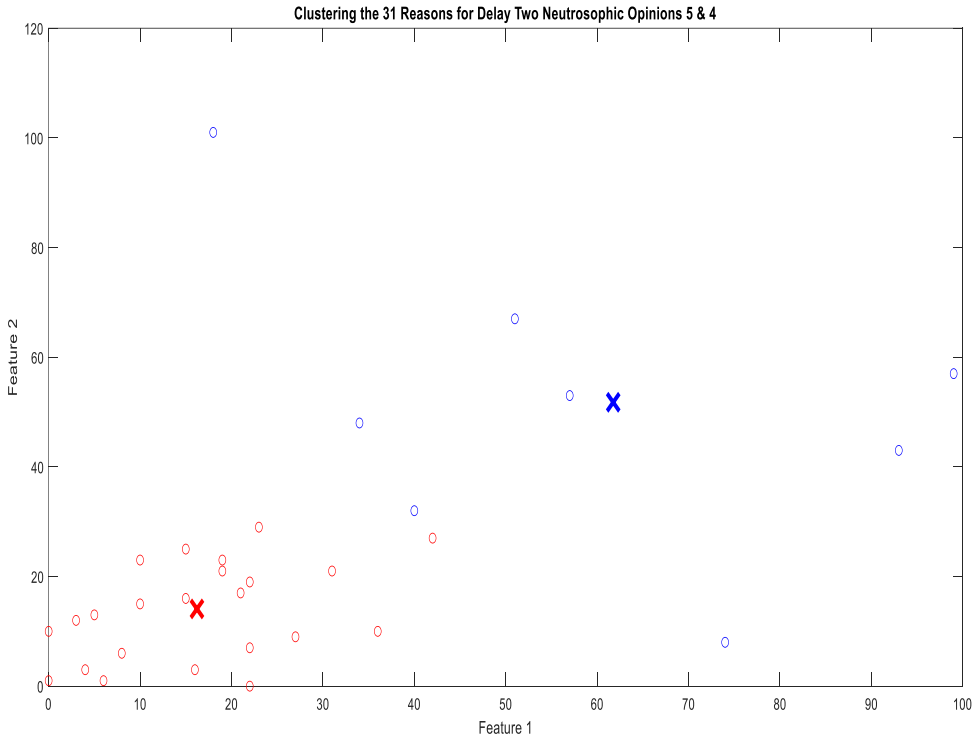



This fifth clustering significantly differs from those previous comparisons, since we noticed that most of the reasons (exactly 27 reasons) were biased to the neutrosophic reason (4), while there are just four reasons centered around the neutrosophic reason (6).

## 3.6 | Sixth Comparison Among Indeterminate Opinions

% using the neutrosophic c-mean clustering to specify the biasing of the 31 Reasons for the Delay Around the Two Neutrosophic Opinions 5&4

```
clc;
clear;
Z54=[6 5 18 4 93 15 22 0 34 10 27 22 74 0 36 16 23 19 31 19 21 42 40 99 10 15 51 57 22 8 3;1 13 101 3 43 16
19 10 48 15 9 0 8 1 10 3 29 23 21 21 17 27 32 57 23 25 67 53 7 6 12]'
save fcmdata1 Z54 –ascii
load fcmdata1
options=fcmOptions(NumClusters=2)
[centers,U]=fcm(fcmdata1,options)
maxU= max(U)
index1=find(U(1,:)== maxU);
index2=find(U(2,:)== maxU);
plot(fcmdata1(index1,1),fcmdata1(index1,2),"ob")
hold on
plot(fcmdata1(index2,1),fcmdata1(index2,2),"or")
plot(centers(1,1),centers(1,2),"xb",MarkerSize=15,LineWidth=3)
plot(centers(2,1),centers(2,2),"xr",MarkerSize=15,LineWidth=3)
xlabel("Feature 1")
ylabel("Feature 2")
hold off
```

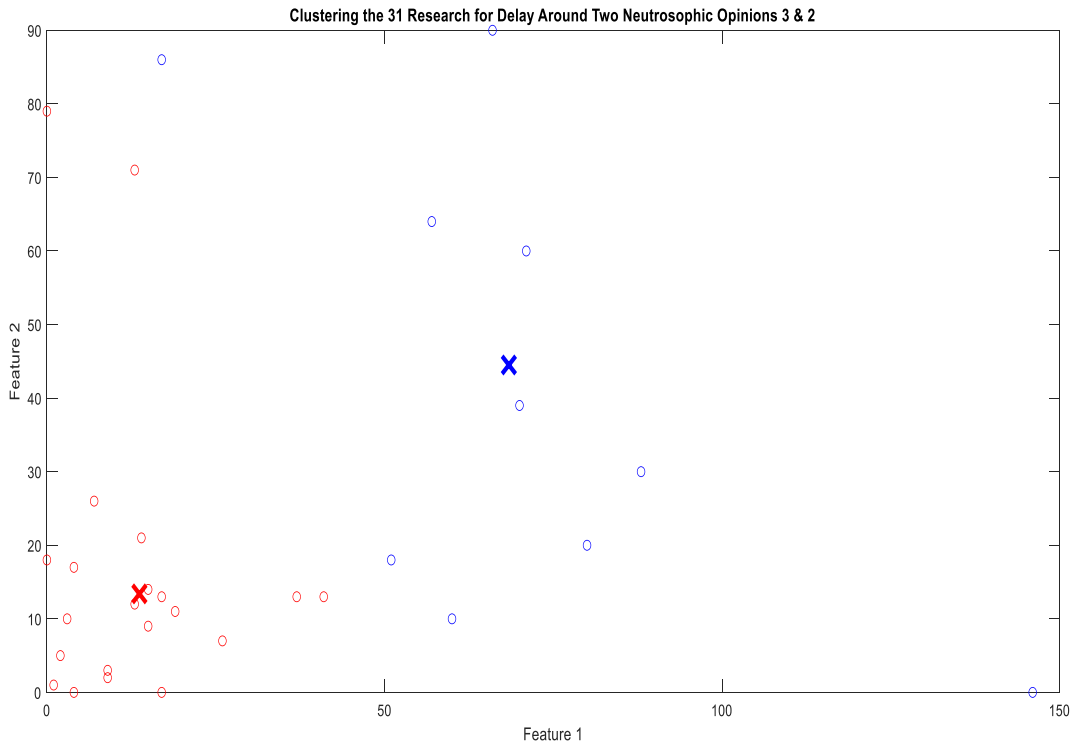



By taking a swift look at the above graph, it is very lightly that there are (23) delaying causes were biased to the indeterminate opinion (4= The problem occasionally has affected the project), while, the remaining reasons (exactly 8 reasons) were biased to the neutrosophic opinion (5=The problem sometimes affected the project).

## 3.7 | Seventh Comparison Among Falsity Opinions

% using the neutrosophic c-mean clustering to specify the biasing of the 31 Reasons for the Delay Around the Two Neutrosophic Opinions 5&4

```
clc;
clear;
Z32=[4 17 9 66 7 1 15 88 60 80 146 37 0 41 51 4 13 15 19 13 17 14 26 0 70 57 9 17 71 2 3;0 86 2 90 26 1 9 30
10 20 0 13 79 13 18 17 12 14 11 71 13 21 7 18 39 64 3 0 60 5 10]'
save fcmdata1 Z32 –ascii
load fcmdata1
options=fcmOptions(NumClusters=2)
[centers,U]=fcm(fcmdata1,options)
maxU= max(U)
index1=find(U(1,:)== maxU);
index2=find(U(2,:)== maxU);
plot(fcmdata1(index1,1),fcmdata1(index1,2),"ob")
hold on
plot(fcmdata1(index2,1),fcmdata1(index2,2),"or")
plot(centers(1,1),centers(1,2),"xb",MarkerSize=15,LineWidth=3)
plot(centers(2,1),centers(2,2),"xr",MarkerSize=15,LineWidth=3)
xlabel("Feature 1")
ylabel("Feature 2")
hold off
```

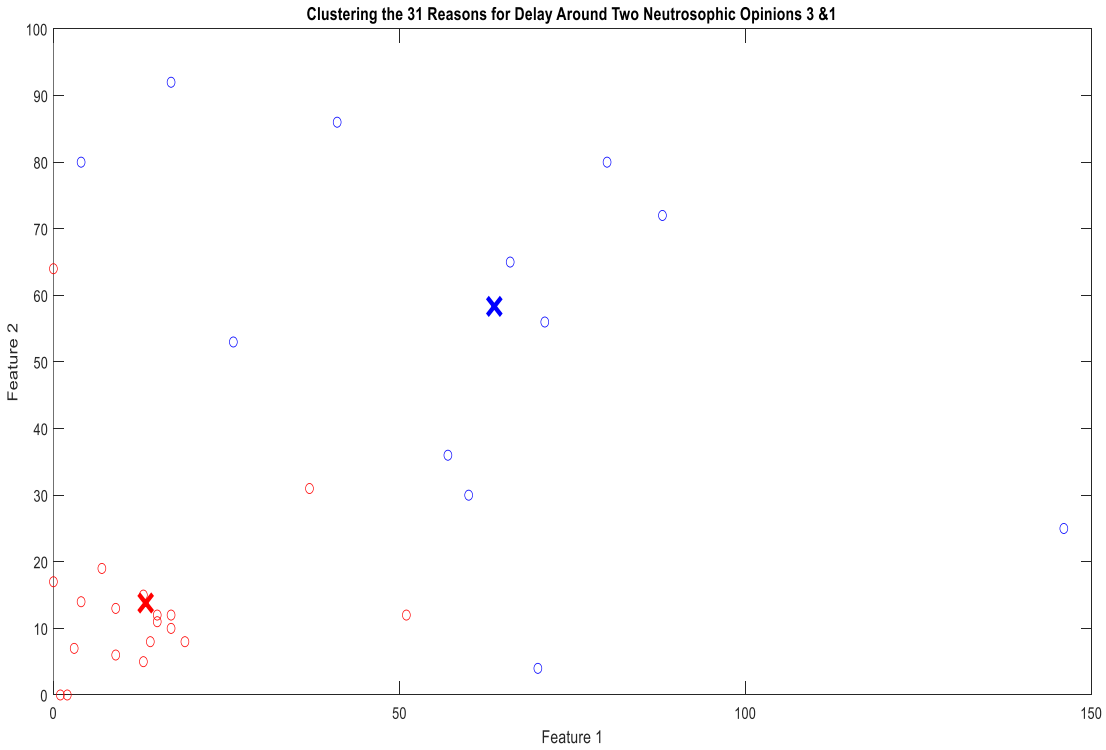



As noticed from the above figure, there are (21) causes that have been biased to the neutrosophic opinion (2= The problem rarely has affected the project). While (10) reasons that have been biased to the neutrosophic opinion (3= The problem seldom has affected the project).

## 3.8 | Eighth Comparison Among Falsity Opinions

% using the neutrosophic c-mean clustering to specify the biasing of the 31 Reasons for the Delay Around the Two Neutrosophic Opinions 3&1

```
clc;
clear;
Z31=[4 17 9 66 7 1 15 88 60 80 146 37 0 41 51 4 13 15 19 13 17 14 26 0 70 57 9 17 71 2 3;14 92 13 65 19 0
11 72 30 80 25 31 64 86 12 80 15 12 8 5 10 8 53 17 4 36 6 12 56 0 7]'
save fcmdata1 Z31 –ascii
load fcmdata1
options=fcmOptions(NumClusters=2)
[centers,U]=fcm(fcmdata1,options)
maxU= max(U)
index1=find(U(1,:)== maxU);
index2=find(U(2,:)== maxU);
plot(fcmdata1(index1,1),fcmdata1(index1,2),"ob")
hold on
plot(fcmdata1(index2,1),fcmdata1(index2,2),"or")
plot(centers(1,1),centers(1,2),"xb",MarkerSize=15,LineWidth=3)
plot(centers(2,1),centers(2,2),"xr",MarkerSize=15,LineWidth=3)
xlabel("Feature 1")
ylabel("Feature 2")
hold off
```

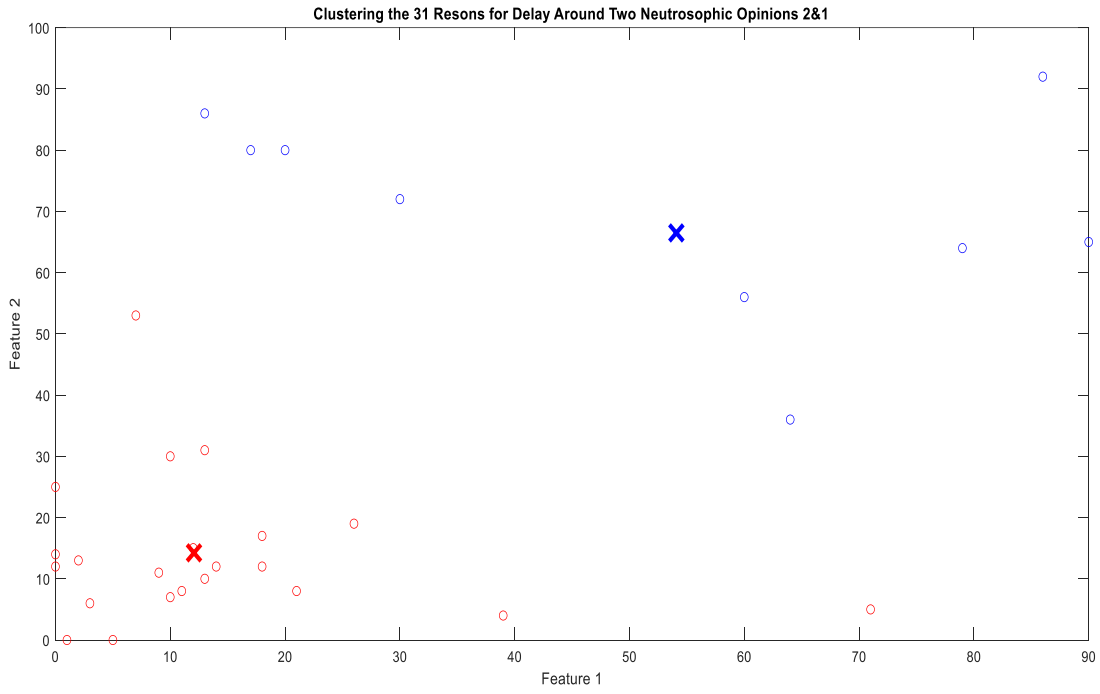



For the comparison between the two opinions (3&1), it is clear that there are (19) reasons biased to the opinion (3=The problem seldom has affected the project), and there are (11) causes biased to the neutrosophic opinion (1=the problem has never affected the project).

## 3.9 | Ninth Comparison Among Falsity Opinions

```
% using the neutrosophic c-mean clustering to specify the biasing of the 31 Reasons for the Delay Around the Two Neutrosophic Opinions 2&1
```

```
clc;
clear;
Z21=[0 86 2 90 26 1 9 30 10 20 0 13 79 13 18 17 12 14 11 71 13 21 7 18 39 64 3 0 60 5 10;14 92 13 65 19 0 11 72 30 80 25 31 64 86 12 80 15 12 8 5 10 8 53 17 4 36 6 12 56 0 7]'
save fcmdata1 Z21 –ascii
load fcmdata1
options=fcmOptions(NumClusters=2)
[centers,U]=fcm(fcmdata1,options)
maxU= max(U)
index1=find(U(1,:)== maxU);
index2=find(U(2,:)== maxU);
plot(fcmdata1(index1,1),fcmdata1(index1,2),"ob")
hold on
plot(fcmdata1(index2,1),fcmdata1(index2,2),"or")
plot(centers(1,1),centers(1,2),"xb",MarkerSize=15,LineWidth=3)
plot(centers(2,1),centers(2,2),"xr",MarkerSize=15,LineWidth=3)
xlabel("Feature 1")
ylabel("Feature 2")
hold off
```




The above figure illustrates that there are (22) red points that interpret those reasons that are biased to the neutrosophic opinion (1=the problem has never affected the project), while there are (9) causes biased to the neutrosophic opinions (2=The problem rarely has affected the project).

# 4 | Conclusion

From subsections (3.1 to 3.9), it is clear that the reasons for delay in the construction project can completely belong to some grades of the truth neutrosophic opinion, simultaneously, the same reasons can belong to some or all grades of indeterminacy neutrosophic opinions, these results, are delighting announcement that in neutrosophic theory, the same reason can have a kind of biasing to the truth opinion side by side to the falsity opinion side by side to the indeterminate opinions in fully consistent and with well definitions of the problems.

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## Author Contribution

All authors contributed equally to this work.

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## Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

## Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

## Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

# References

[1] Ahmed, S. M., Azhar, S., Castillo, M., & Kappagantula, P. (2002). Construction delays in Florida: An empirical study. Final report. Department of Community Affairs, Florida, US.

[2] Al-Humaidi, H. M., & Hadipriono Tan, F. (2010). A fuzzy logic approach to model delays in construction projects using translational models. Civil engineering and environmental systems, 27(4), 353-364.

[3] Alkass S, Mazerolle M, Harris F. Construction delay analysis techniques. Construction Manage Econ 1996; 14(5):375–94.

[4] Al-Momani, A. H. (2000). Construction delay: a quantitative analysis. International journal of project management, 18(1), 51-59.

[5] Assaf, S. A., & Al-Hejji, S. (2006). Causes of delay in large construction projects. International journal of project management, 24(4), 349-357. 101

[6] Baloi, D., and Price, A. D. F. (2003). "Modeling global risk factors affecting construction cost performance." Int. J. Proj. Manage. 21(4), 261–269. Okoroh, M. I., and Torrance, V. B. (1999). "A model for subcontractor selection in refurbishment projects." Construction Management Economics, 17(3), 315–327.

[7] Cheng, C. L., He, K. C., & Yen, C. J. (2008). Decision-making and assessment tool for design and construction of high-rise building drainage systems. Automation in Construction, 17(8), 897-906.

[8] El Razek, M. E., Basssioni, H. A., and Mobarak, A. M. (2008). "Causes of delay in building construction projects in Eygpt." J. Constr. Eng. Manage., 134(11), 831–841.
[9] Faridi, A. S., & El-Sayegh, S. M. (2006). Significant factors causing delay in the UAE construction industry. Construction Management and Economics, 24(11), 1167-1176.
[10] Frimpong, Y., Oluwoye, J., and Crawford, L. (2003). "Causes of delay and cost overruns in construction of groundwater projects in developing countries: Ghana as a case study." Int. J. Project Manage. 21(5), 321–326.
[11] George J, K. L. I. R., & Bo, Y. (2008). Fuzzy sets and fuzzy logic, theory and applications.
[12] Kazaz, A., Ulubeyli, S., and Tuncbilekli, N. A. (2012). "Causes of delays in construction projects in Turkey." J. Civ. Eng. Manage., 18(3), 426–435.
[13] Yanhui Guo, Abdulkadir Sengur, (2015)" NCM: Neutrosophic C-Means clustering algorithm", Pattern Recognition, http://dx.doi.org/10.1016/j.patcog.2015.02.018.
[14] Yanhui Guo, Rong Xia, Abdulkadir S¸engu, Kemal Polat, (2016) "A novel image segmentation approach based on neutrosophic c-means clustering and indeterminacy filtering" Neural Comput & Applic, DOI 10.1007/s00521-016-2441-2.

## Appendix

**Survey (A): Local Survey has been issued to experts in Nineveh Province during the couple of months Oct. and Nov. of the year 2020.**

1- What are the kinds of the projects you are/were enrolled in (you can choose all that applies):

◯ Building Projects. ◯ Highway Projects. ◯ Infrastructure Projects.

◯ Other please mention……..

2- Select the kind of ownership in the Projects, you were involved in (you can choose all that applies):

◯ Government Projects. ◯ Private Sector. ◯ Civil society organization.

◯ Other please mention……..

3- Select of project delivery method you are/were involved with (you can choose all that applies):

◯ Traditional Approach (TA).◯ Direct Labor (DL).

◯ Design Build (DB).◯ Turn Key (TK).

◯ Other please mention……...

4- Select which of the following parties you worked for (you can choose all that applies)

◯ Owner. ◯ Designer/ Consulting office. ◯ Contractor.

◯ Other please mention……

5- Years of experience in construction……

6- If you wish, provide us an email, and we will send you the studying results once it is completed.

Kindly, specify the intensity of the occurrence of the following problems that caused a delay in the project construction, where the numbers 9,8,7 mean the grades of truth's state. The numbers 6,5,4 are of indeterminate bias levels of the delays' causes. While the numbers 3,2,1 are the gradation of the falsity states. The definitions of all numbers (9 to 1) are specified through the Table 2.

**Table 2.**The gradations of the 31 reasons for the constructions projects delay.

| Definition of the problem | Falsity bias | | | Indet. bias | | | Truth bias | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Unrealistic schedule (bid duration is too short) | | | | | | | | | |
| Ineffective delay penalties provisions in contract | | | | | | | | | |
| Errors in contract documents | | | | | | | | | |
| Selecting inappropriate project delivery method | | | | | | | | | |
| Excessive change orders by owner during construction | | | | | | | | | |
| Delayed payments by the owner | | | | | | | | | |
| Delay in approving design documents by the owner | | | | | | | | | |
| Time-consuming decision-making process of the owner | | | | | | | | | |
| Unnecessary Inference by the owners | | | | | | | | | |
| Delay to furnish and deliver the site to the contractor | | | | | | | | | |
| Poor communication and coordination of the owner with designer and/ or contractor | | | | | | | | | |
| Poor Quality Assurance (QA) plan of the owner | | | | | | | | | |
| Lack of management staffs of the owner | | | | | | | | | |
| Inappropriate construction methods | | | | | | | | | |
| Contractor inefficiency (in providing the labor, equipment and material and handling sub-contractors) | | | | | | | | | |
| Poor communication and coordination of the contractor with owner and/ or designer | | | | | | | | | |
| Inadequate contractor experience | | | | | | | | | |
| Financial difficulties and mismanagement by the contractor | | | | | | | | | |
| Poor site management and Quality Control (QC) by the contractor | | | | | | | | | |
| Legal disputes between designer and the owner | | | | | | | | | |
| Design errors | | | | | | | | | |
| Complexities and ambiguities of project design | | | | | | | | | |
| Delays in providing the design documents by the designer | | | | | | | | | |
| Inadequate experience of the designer | | | | | | | | | |
| Inadequate site assessment by the designer during design phase | | | | | | | | | |
| Misunderstandings between owner and designer about scope of the work | | | | | | | | | |
| Financial difficulties with the designer | | | | | | | | | |
| Poor communication and coordination of the designer with owner and/ or contractor | | | | | | | | | |
| Legal disputed between designer and the owner | | | | | | | | | |
| Delay in getting permits and acquisitions (Environmental, building, right of way, utilities, etc.) | | | | | | | | | |
| The Coronavirus pandemic spreading in Iraq from Feb 2020 to Jan. 2022 | | | | | | | | | |