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Abstract

This manuscript was concerned with the reasons for the lateness of completion of building projects, highway projects, and other infrastructures in Mosul City that were hugely damaged due to the occupation of the terrorist ISIS gangs from 2014 to 2018. The questionnaire survey was launched in a very critical period of time (i.e. during the spread of the coronavirus pandemic), It was during a couple of months Oct. and Nov. of the year 2020. The neutrosophic theory has very flexible tools for analyzing the vagueness, hesitancy, and incomplete data, therefore, the author tried to partition the delay reasons into three major causes depending upon the probability bias of occurrence (i.e. truth, indeterminacy, and falsity), We figured out a good innovative approach to sort the importance of thirty-one causes of delay the construction projects.

Keywords: Neutrosophic Relative Importance; Construction Projects; Delay Causes; ISIS Occupation; Mosul City; Building Projects; Highway Projects; Infrastructure Projects.

1. Introduction

To gain a good insight into the causes and how to therapy the construction delay in the Infrastructure of Mosul city after a hugely damaged city faced by the ISIS terrorist gangs' occupation

of the city in 2014 for about three years. The researcher launched 1500 local questionnaires, exactly a national survey. This survey consists of thirty-one scopes of causes (thirty causes already exist in the literature, while the last cause was added by the author which is the delay of finishing the project caused by the Coronavirus pandemic spreading in Iraq for the period from Feb 2020 to Jan. 2022) [1].

The following table illustrates the definition of each delaying cause with its mathematical symbol accompanied by its grade of intense in view of neutrosophic theory, that is there are nine grades of intense (the gradations 9-8-7 have been dedicated to the truth bias, and the grades 6-5-4 went for indeterminate bias, and 3-2-1 have been specified for falsity bias). The survey has been targeted at 1,500 of experience, but unfortunately, the persons responding were just 250 individuals whose expertise is diverse between Project owners, Project designers (i.e. Consulting offices), Contractors…etc.

Table (1): The degrees of the intense in the construction delay reasons from the neutrosophic point of view.

Problem Math. Code	Definition of the problem	Falsity bias			Indeterminate bias			Truth bias		
		1	2	3	4	5	6	7	8	9
R1	Unrealistic schedule (bid duration is too short)	14	0	4	1	6	25	81	26	93
R2	Ineffective delay penalty provisions in the contract	92	86	17	13	5	22	12	1	7
R3	Errors in contract documents	13	2	9	101	18	98	4	2	3
R4	Selecting an inappropriate project delivery method	65	90	66	3	4	13	3	3	3
R5	Excessive change orders by the owner during construction	19	26	7	43	93	17	10	16	19
R6	Delayed payments by the owner	0	1	1	16	15	3	14	100	100
R7	Delay in approving design documents by the owner	11	9	15	19	22	27	53	50	44
R8	Time-consuming decision-making process of the owner	72	30	88	10	0	13	0	12	25
R9	Unnecessary Inference by the owners	30	10	60	48	34	20	0	4	39
R10	Delay to furnish and deliver the site to the contractor	80	20	80	15	10	60	4	50	3

R11	Poor communication and coordination of the owner with designer and/ or contractor	25	0	146	9	27	31	2	10	0
R12	Poor Quality Assurance (QA) plan of the owner	31	13	37	0	22	59	0	11	77
R13	Lack of management staffs of the owner	64	79	0	8	74	14	2	4	5
R14	Inappropriate construction methods	86	13	41	1	0	0	39	0	70
R15	Contractor inefficiency (in providing the labor, equipment and material and handling sub-contractors)	12	18	51	10	36	29	18	27	49
R16	Poor communication and coordination of the contractor with owner and/ or designer	80	17	4	3	16	9	24	21	76
R17	Inadequate contractor experience	15	12	13	29	23	35	21	38	63
R18	Financial difficulties and mismanagement by the contractor	12	14	15	23	19	31	39	41	56
R19	Poor site management and Quality Control (QC) by the contractor	8	11	19	21	31	29	46	43	42
R20	Legal disputes between the designer and the owner	5	71	13	21	19	12	47	59	67
R21	Design errors	10	13	17	17	21	22	45	52	53

R22	Complexities and ambiguities of project design	8	21	14	27	42	39	29	37	33
R23	Delays in providing the design documents by the designer	53	7	26	32	40	47	15	17	13
R24	Inadequate experience of the designer	17	18	0	57	99	12	9	28	8
R25	Inadequate site assessment by the designer during the design phase	4	39	70	23	10	3	57	33	11
R26	Misunderstandings between owner and designer about the scope of the work	36	64	57	25	15	29	8	16	0
R27	Financial difficulties with the designer	6	3	9	67	51	64	17	10	23
R28	Poor communication and coordination of the designer with the owner and/ or contractor	12	0	17	53	57	61	0	19	31
R29	Legal dispute between the designer and the owner	56	60	71	7	22	9	12	13	0
R30	Delay in getting permits and acquisitions (Environmental, building, right of way, utilities, etc.)	0	5	2	6	8	19	81	37	92
R31	The coronavirus pandemic spreading in Iraq from Feb 2020 to Jan. 2022	7	10	3	12	3	15	69	48	83

It is worth mentioning that the grades from 1 to 9 have different neutrosophic linguistic meanings [2-11], as forthcoming table (2) demonstrates the grade linguistic meaning of the impact of the reason on delaying the completion of the project:

Table (2): 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

2.

3. Analyzing the Results of Survey (A)

The local survey (A) attached at the end of this manuscript, achieves some important aims such as investigating the effectiveness of the most popular causes of construction delay, determining the scale of riskiness for every probable cause of delay, and confinement the list of the most critical delay causes.

Because of the situation of quarantine during the period of coronavirus spreading, we tried to avoid doing the paper survey, and an online survey was launched via Google form within a couple of months Oct. and Nov. 2020, This needed to invite 1500 experts, especially the Officials in Nineveh Governorate, and some civil society organizations who had projects for the reconstruction of Nineveh as a UNDP organization, TEKA organization...etc. we gained just 250 completed surveys.

The following subsections contain traditional statistical percentages categorized as the kinds of projects, the ownerships of the projects, how delivery method of the project, the role of the respondents worked in the project, the accumulation experience of the respondents, the impacts of different causes of delay.

3.1 Projects' Kinds Subject to Respondents' Answers

The 250 answers gained out of 1,500 issued questionnaires confirm that 117 equivalently to (46.8%) of the projects were building projects, while 100 of them were infrastructure projects (i.e. it is 40% of the projects), wherein the highway projects were 33 projects out of 250 (i.e. 13.2%). The below figure (3.2) illustrates the pie chart of the distributed percentages figured out using MATLABR 2023a.

```
% plot the Pie chart of distributed percentages of projects type
clc;
clear;
close;
numberofbuildingstype=[117 100 33];
percentage=numberofbuildingstype./250;
% Create Pie Chart
```

```
ax1=nexttile;
pie3(ax1,percentage)
title(' Types of Projects')
labels={'buildings projects','infrastructure','highway projects'};
% Create legend
lgd=legend(labels);
lgd.Layout.Tile='east';
```

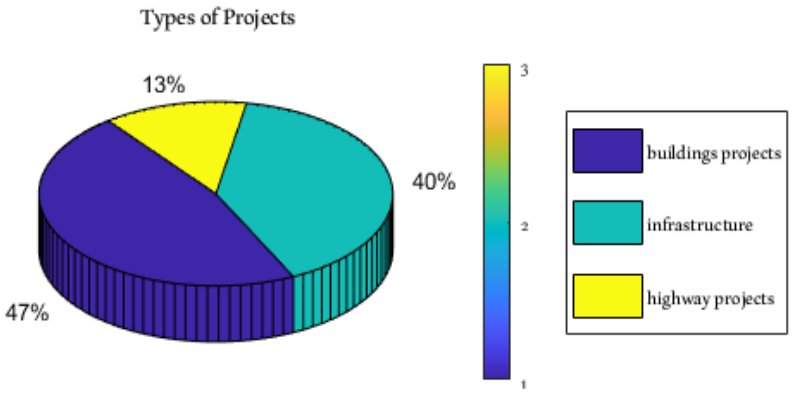

Figure (1): Percentages of Project Types

3.2 The Ownership Categories

Again, after completing the surveys, we concluded that 170 projects out of 250 belong to government projects (public projects) which represent the percentage (68%), whilst 50 projects are in the private sector (i.e. 20%). Finally, the remaining 30 projects have been done by civil society organizations, that is, 12%. The following figure (3.2.2) demonstrates the distributed percentages figured out by Pie chart using MATLAB R2023a.

```
% plot the Pie chart of distributed percentages of ownerships type
clc;
clear;
```

```
close;
numberofownershipstype=[170 50 30];
percentage=numberofownershipstype./250;
% Create Pie Chart
ax1=nexttile;
pie3(ax1,percentage)
title(' Types of Projects')
labels={'public projects','private sector','civil society organizations'};
% Create legend
lgd=legend(labels);
lgd.Layout.Tile='east';
```

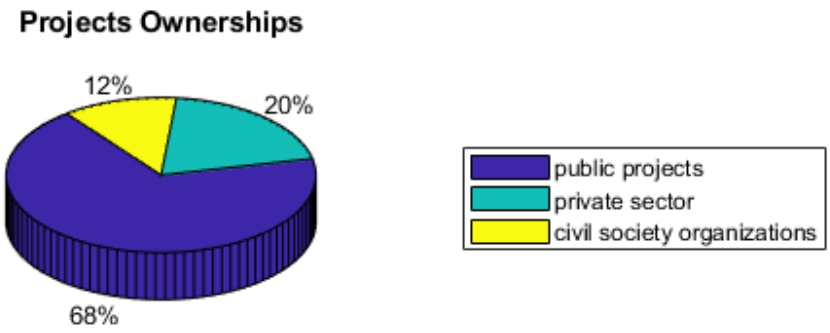

Figure (2): Types of Ownerships

3.3 Choosing the Method of Delivering the Project to the Beneficiary

It is well known that there are four methods of delivering the projects in Iraq country, they are: [11-13]

1- Traditional Approach (TA).
2- Direct Labor (DL).
3- Design Build (DB).
4- Turn Key (TK).

Hence, we should not forget that our studying is focused on the projects that already completed but they were suffered from delays in the completion in some implementation stages for critical causes [14,15]. Our database of survey results showed that (145) projects were of the type of (TA) delivered method, while (55) projects went in favor of the (DL) method, and (30) projects were delivered by the (DB) method, finally, there were (20) projects of (TK) delivery method. The following MATLAB program and figure (3.2.3) clarify the statistical categories of the above-mentioned information:

```
% plot the Pie chart of the projects delivery method
clc;
clear;
close;
numberofdeliverymethods=[145 55 30 20];
percentage=numberofdeliverymethods./250;
% Create Pie Chart
ax1=nexttile;
pie3(ax1,percentage)
title(' Statistical Categories of Delivery Methods')
labels={'TA approach','Dl approach','DB approach', 'TK approach' };
% Create legend
lgd=legend(labels);
lgd.Layout.Tile='east';
```

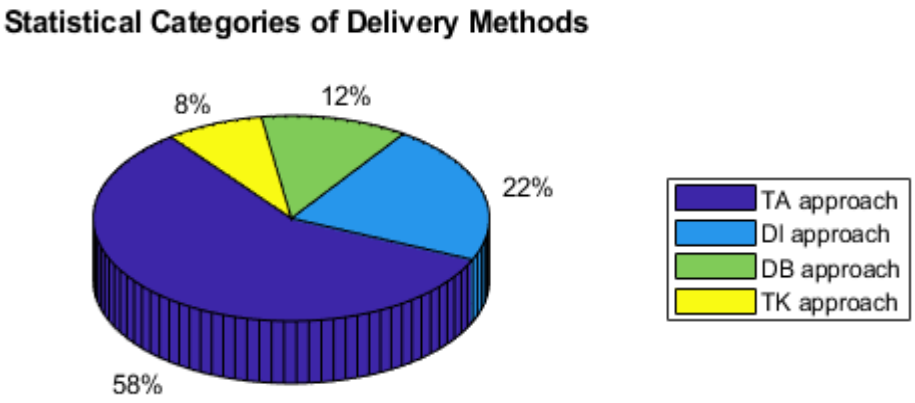

Figure (3): Categories Percentage of Delivery Methods

3.4 Respondents' Role in Project

In this study, we are dependent on three main kinds of respondents' roles, the owners of the projects are 33 respondents, the contractors are 52, and 79 of the consulting offices, while other kinds of respondents such as architects, safety directors, foremen…etc, all of them counting together were 86. Hence the forthcoming program and figure (4) are simply illustrate the percentage of them:

```
% plot the Pie chart of the respondents' role in the Project
clc;
clear;
close;
numberofrespondentsrole=[33 79 52 86];
percentage=numberofrespondentsrole./250;
% Create Pie Chart
ax1=nexttile;
pie3(ax1,percentage)
title(' Respondents' Role in Project')
labels={'projects owners','Projects designers','Contractors', 'Others' };
```

```
% Create legend
lgd=legend(labels);
lgd.Layout.Tile='east';
```

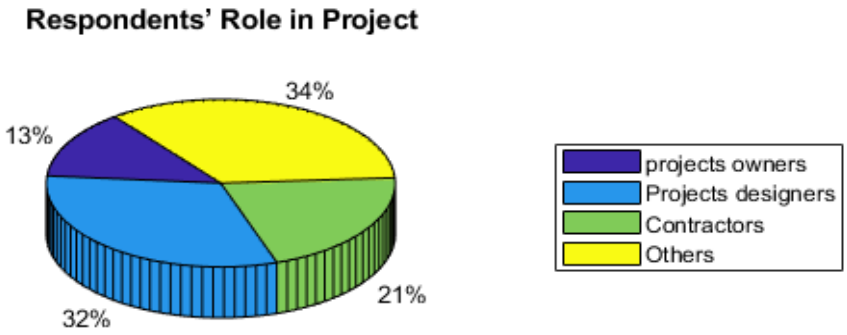

Figure (4): Categories Respondents' Role in Projects

4. Neutrosophic Perspective-Based Impact Delay Causes

It is important to determine the impishness of the 31 potential causes of the occurrence of delay. the participants during the launched survey were requested to evaluate the impact of each cause by ranking the effectiveness using numbers from 1 to 9, where the number one shows the least impishness, on the other hand, the no. nine means the severest cause. By using neutrosophic theory, we will cover the vagueness of the data, the hesitancy in the decisions because there are some reasons that cannot be determined with certainty whether they have an impact on delaying the project or not! or they may have some impact on delaying the completion of some projects and not others, and some of the reasons may have an impact on a particular project at certain times, while at other times they have no effect. All this confusion may affect the process of making the correct decision, which consequently leads to the emergence of an urgent need to use neutrosophic logic, which is an ideal generalization of fuzzy logic

because in all complicated cases, it has the appropriate mathematical tools to represent all cases of ambiguity, vagueness, and incomplete information [4-7].

This section will be dedicated to analyzing the questions raised by the survey (A) using the newly suggested neutrosophic mathematical concept named as Neutrosophic Relative Importance Index (NRII) which has the ability to partition the causes' effects of delay the projects into three categories:

1-Truth Relative Importance Index (RIItruth).

2- Indeterminate Importance Index (RIIindeterminate).

3- Falsity Importance Index (RIIfalsity).

For the above three neutrosophic components, the authors suggested the following mathematical formulas:

$$RIItruth, RIIindeterminate, RIIfalsity = \frac{\sum_{i=1}^{31}\sum_{j=1}^{3} m_j r_{ij}}{M*250}, \quad (3.1)$$

Where $i = 1,2,3, \dots ,31$, for truth bias $M = 9, m_1 = 9, m_2 = 8, m_3 = 7$, that is mean:

$$RIItruth = \frac{9*r_{i9}+8*r_{i8}+7*r_{i7}}{9*250}, \quad (3.2)$$

Again, for indeterminacy bias, $M = 6, m_1 = 6, m_2 = 5, m_3 = 4$, which implies to

$$RIIindeterminacy = \frac{6*r_{i6}+5*r_{i5}+4*r_{i4}}{6*250}, \quad (3.3)$$

Finally, for falsity bias, $M = 3, m_1 = 3, m_2 = 2, m_3 = 1$, hence

$$RIIfalsity = \frac{3*r_{i3}+2*r_{i2}+1*r_{i1}}{3*250}, \quad (3.4)$$

It should be noticed that the values of r_{ij} represent the intensity of the (31) causes, the index i is the number of the (31) rules, and the index j is the number of the nine columns stated in table (1).

The reader should be notified the number 250 that has been embedded in the denominator of the formulas $(3.2, 3.3, 3.4)$ is the total number of respondents that have been received after launching the survey (A).

The upcoming MATLAB program with its graph consisting of three pie charts represents the severity of each cause in terms of truth-biasing, indeterminacy-biasing, and falsity-biasing:

```
% Three Graphs categorizing the cause's severity according to their relative importance
```

```
clc;
clear;
close;
Z1=[93 26 81;7 1 12;3 2 4;3 3 3;19 16 10;100 100 14;44 50 53;25 12 0;39 4 5;3 50 4;0 10 2;77 11 0;5 4 2;70 0
39;49 27 18;76 21 24;63 38 21;56 41 39;42 43 46;67 59 47;53 52 45;33 37 29;8 28 9;13 17 15;11 33 57;0 16
8;23 10 17;31 19 0;0 13 12;92 37 81;83 48 69];
M1=[9 8 7];
F1=M1';
RIItruth=(Z1*F1)./(9*250)
% Create Pie Chart
ax1=nexttile;
pie3(ax1,RIItruth)
title('Relative Importance Index for Truth')
Z2=[25 6 1;22 5 13;98 18 101;13 4 3;17 93 43;3 15 16;27 22 19;13 0 10;20 34 48;60 10 15;31 27 9;59 22 0;14
74 8;0 0 1;29 36 10;9 16 3;35 23 29;31 19 23;29 31 21;12 19 21;22 21 17;39 42 27;12 99 57;47 40 32;3 10 23;29
15 25;64 51 67;61 57 53;9 22 7;19 8 6;15 3 12];
M2=[6 5 4];
F2=M2';
RIIindeterminacy=(Z2*F2)./(6*250)
% Create Pie Chart
ax2=nexttile;
pie3(ax2,RIIindeterminacy)
title('Relative Importance Index for Indeterminacy')
Z3=[4 0 14;17 86 92;9 2 13;66 90 65;7 26 19;1 1 0;15 9 11;88 30 72;60 10 30;80 20 8;146 0 25;37 13 31;0 79
64;41 13 86;51 18 12;4 17 80;13 12 15;15 14 12;19 11 8;13 7 5;17 13 10;14 21 8;0 18 17;26 7 53;70 39 4;57 64
36;9 3 6;17 0 12;71 60 56;2 5 0;3 10 7];
M3=[3 2 1];
```

```
F3=M3';
RIIfalsity=(Z3*F3)./(3*250)
labels={'R1','R2','R3','R4','R5','R6','R7','R8','R9','R10','R11','R12','R13','R14','R15','R16','R17','R18','R19','R
20','R21','R22','R23','R24','R25','R26','R27','R28', 'R29', 'R30', 'R31'};
% Create Pie Chart
ax3=nexttile;
pie3(ax3,RIIfalsity)
title('Relative Importance Index for Falsity')
% Create legend
lgd=legend(labels);
lgd.Layout.Tile='east';
```

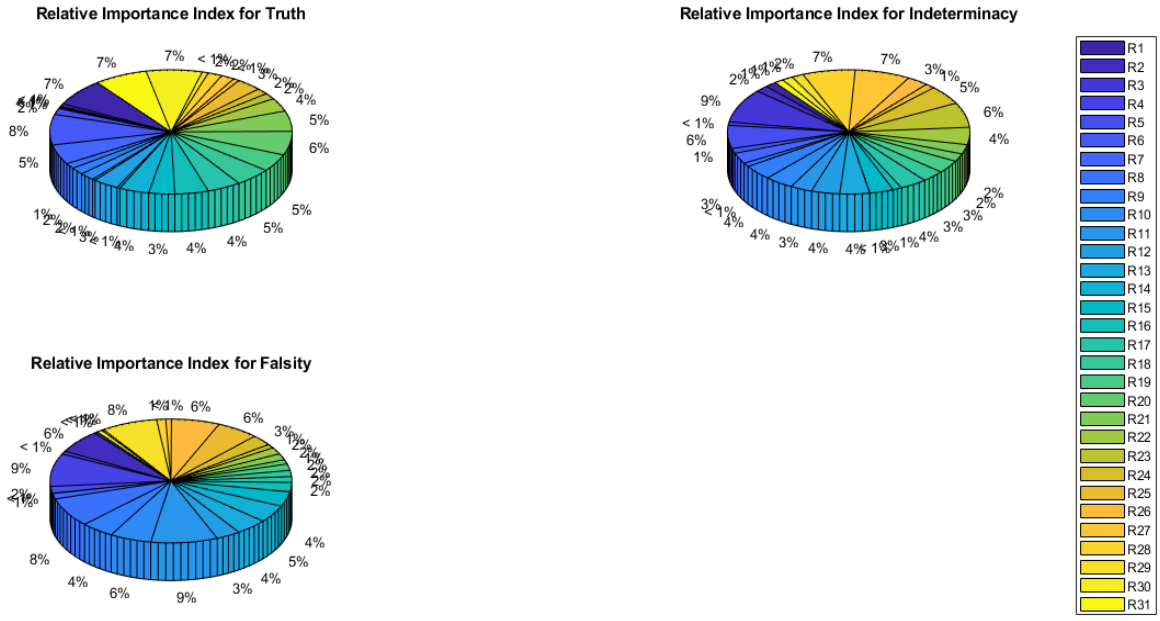

Figure (5): Neutrosophic Relative Importance Index (NRII)

Now to make a fair analysis of the most important causes that are expected to be ranked due to their effectiveness, we need to calculate the accumulated Neutrosophic Relative Importance values:

$$RIItotal = RIItruth + RIIindeterminacy + RIIfalsity \quad (3.5)$$

The following table shows all $RIItotal$ depending upon the number of Ri reason.

Table (3): Total Neutrosophic Relative Importance

$RIItotal$	Corresponding Ri
0.8738	$R1$
0.6282	$R2$
0.8116	$R3$
0.6960	$R4$
0.7793	$R5$
0.9104	$R6$
0.8493	$R7$
0.7493	$R8$

0.8138	$R9$
0.8996	$R10$
0.8971	$R11$
0.8804	$R12$
0.6604	$R13$
0.7173	$R14$
0.8787	$R15$
0.7187	$R16$
0.8504	$R17$
0.8531	$R18$
0.8553	$R19$
0.8687	$R20$
0.8562	$R21$
0.8444	$R22$
0.7602	$R23$
0.7591	$R24$
0.8347	$R25$
0.7611	$R26$
0.8371	$R27$
0.8509	$R28$
0.7302	$R29$
0.8916	$R30$
0.8673	$R31$

The above table need to sort the total RII in descent order using the following MATLAB commands.

```
% Sorting the Neutrosophic Relative Importance in Descend Order
clc;
clear;
close;
RIItotal=[0.8738 0.6282 0.8116 0.6960 0.7793 0.9104 0.8493 0.7493 0.8138 0.8996 0.8971 0.8804 0.6604
0.7173 0.8787 0.7187 0.8504 0.8531 0.8553 0.8687 0.8562 0.8444 0.7602 0.7591 0.8347 0.76110.8371 0.8509
0.7302 0.8916 0.8673];
S=sort(RIItotal,'descend');
W=S'
```

Table (4): Sorting Neutrosophic Relative Importance in descend Order

Importance Order	$RIItotal$	Corresponding Ri
1	*0.9104*	$R6$
2	*0.8996*	$R10$
3	*0.8971*	$R11$
4	*0.8916*	$R30$
5	*0.8804*	$R12$
6	*0.8787*	$R15$
7	*0.8738*	$R1$
8	*0.8687*	$R20$
9	*0.8673*	$R31$
10	*0.8562*	$R21$
11	*0.8553*	$R13$
12	*0.8531*	$R18$
13	*0.8509*	$R28$

14	*0.8504*	$R17$
15	*0.8493*	$R7$
16	*0.8444*	$R22$
17	*0.8371*	$R27$
18	*0.8347*	$R25$
19	*0.8138*	$R9$
20	*0.8116*	$R3$
21	*0.7793*	$R5$
22	*0.7611*	$R26$
23	*0.7602*	$R23$
24	*0.7591*	$R24$
25	*0.7493*	$R8$
26	*0.7302*	$R29$
27	*0.7187*	$R16$
28	*0.7173*	$R14$
29	*0.6960*	$R4$
30	*0.6604*	$R13$
31	*0.6282*	$R2$

5. Conclusion and Results Analysis

The descending sorting of the neutrosophic RII shows in table (3.3.2) that the reason R6 (i.e. Delayed payments by the owner) comes in the first order due to its importance, whereas the cause R10 (i.e. delayed preparation and delivery of the site to the contractor) comes in the second order, while the reason of spreading the coronavirus and the quarantine situation that Nineveh province suffered from was in ninth order according to its importance. Consequently, we are convinced that these results are very harmonized with the obstacles and situations of Mosul Province in the period 2020

to the end of 2022 where the federal general budget did not Endorsed in those years, and there was a budget deficit and there was austerity has been conducted by the central government and local governments. We should state that all projects that were studied have been finished and completed but they had suffered from delays.

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 and 7 mean the grades of truth's state. The numbers 6, 5 and 4 are of indeterminate bias levels of the delays' causes. While the numbers 3, 2 and 1 are the gradation of the falsity states. The definitions of all numbers (9 to 1) are specified through the table (2).

Table (5): The Gradations of the 31 Reasons for the Construction Project 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 work scope									
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									

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