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Building and Analyzing a Crisis Management Model Using Fuzzy DEMATEL Technique

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ABSTRACT
Iraq is witnessing many ongoing crises that have affected the performance of the infrastructure and the development of the construction field. Therefore, it is necessary to devise and develop effective crisis management strategies during the three phases of crises before, during, and after the crisis, which makes the development of such a system extremely important. This study focuses on developing and analyzing a framework for crisis management in construction projects. Our view is based on the work of several previous crisis management researchers. This research aims to provide an appropriate crisis management approach to the Iraqi construction industry. This study proposed an integrated crisis management model, based on a comprehensive examination of the crisis management literature and extracting crisis criteria in three phases: before, during, and after the crisis. The researcher, using the **Fuzzy DEMATEL** method, analyzed the relationships between the criteria. In addition to devising an integrated crisis management model, crisis criteria are categorized by measuring the weights of key components, and finally by ranking criteria according to their importance, enabling managers to respond to threats quickly.

Keywords: Crisis, Crisis Management,FuzzyDEMATEL, ConstructionProjects, Iraq

1.Introduction:

A crisis is one of the real-life events that might occur during the construction phase of a project [1]. Criseswill influence existing projects, resulting in project destruction and massive time, money, and quality losses [1].As a result, countries seek to develop standard crisis response procedures by defining the processes andregulationsthatmustbefollowedduringtherecoveryphase. Regardlessoftheirsuccess,allorganizationsarelikely to suffer a crisis, and all crises display warning signals. Organizations, on the other hand, rarely notice the warnings in time to learn and adapt to avoid disaster [2]. Crisis management is difficult, and it involves the integration of activities across many organizational functional subsystems, providing more opportunitiesfor symptom recognition and successful resolution. Management decisions made before, during, and after a crisis are important to an organization's survival [3, 4]. [2] It was previously believed that excellent managers regularly set and prioritize strategic goals, which constitute the bedrock of every organization's strategic plan. [5] Complexity-based approaches to corporate strategy have been proved to be particularly relevant at times of widespread environmental uncertainty when the impact of crises on businesses and individuals is higher than ever. [6] Demonstrate that essential and big decisions are always required in theearly stages of a crisis; the earlier the crisis management makes a decision, the faster the situation will becontrolled. Identifying and prioritizing crises based on need, identifying and prioritizing factors affecting theoccurrence of crises, providing the necessary facilities and foundations to solve the crisis, control or reduce it. In addition, choosing appropriate solutions are some of the actions that organizations can take when crises occur [6]. Decision-makersfacedifficultywhenitcomestocrisismanagementsinceitnecessitatesactioninuncertainsituations when there is a lack of proven and trustworthy information and the repercussions are not alwayscompletely analyzed (Brändström, 2016) [7]. The primary decisions are considered one of the fundamentalsof the crisis in its early stages; the faster managerial decision-making, the faster the crisis may be controlled[8]. [9] This work creates anticipatory models for construction project crises by identifying and categorizingtheprimarydiversevariablesthataffectconstructionprojectobjectivesandsignaltimeoverrun,costoverrun,and poor quality before crises occur. The activities and actions conducted when a crisis develops should notberelieduponsimplyforcrisismanagement.

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1.1 ResearchObjectives:

1. Developinganintegratedandcomprehensivemodelthatconsidersallcrisismanagementcriteriainbuildingprojects.
2. CrisiscriteriaClassification according topriorities.
3. The correlations between the major and sub-criteria are determined using the Fuzzy DEMATEL approach.
4. Determine the weights of the main and sub-criteria based on their relative importance.

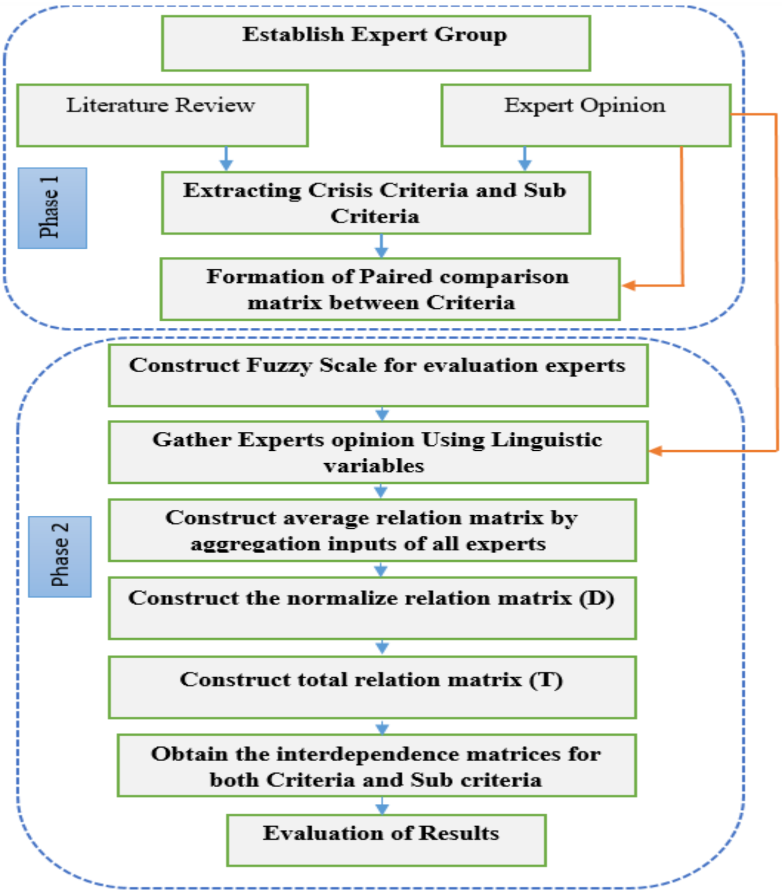
1.2 Research Hypothesis

Theresearchhypothesiswas builtasfollows:"There is a need to build and analyze a crisis management model to the ability ofdecision-makerstoidentifymajorandminorcriteriathatcontributetothecrisismanagementprocessinIraqi construction projects."

2. Amethodologyforbuildingandanalyzingtheproposedcrisismanagementmodel

The study's major goal is to develop and examine a complete crisis management model. Thisconceptdividesthecrisisinto3phases:pre-crisis,crisis,andpost-crisis.Thepopulationconsistsoffivecrisisprofessionalswithmorethan15 yearsofexperienceincrisismanagement(experts). To the Crisis management model, this study also uses expert perspectives. Based on thestandardprocessofevaluatingtheproposedcrisismanagementmodel,theresearcherusedtheFuzzyDEMATEL method to determine the main points of the proposed crisis management model andexamine the internal causal relationships of the main and secondary criteria, as well as find theweightsofthecriteria.Figure(1)showstheproposedmethodologyforapplyingtheFuzzyDEMATEL technique in the analysis and evaluation of the main and secondary criteria in theproposedcrisis management model.

Figure (1):A methodologyfor buildingandanalyzingacrisis managementmodel



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2.1 Theoreticalframeworkandliteraturereview

A crisis is a circumstance in which a group or organization is unable to deal with using standardoperating procedures [10]. It can happen because of unexpected circumstances with unknownrepercussions.Due to the nature of projects, they are usually long-term;bothareprevalentfeaturesofconstructionorganizations [11]. As a result, it necessitates their competent management in preventing crises andresolving them when they do occur. A crisis, according to Coombs (2012) [12], is "the perception ofan unexpected incident that threatens significant beneficiary expectations and can seriously damagethe organization's performance and cause negative effects." A crisis is those internal and/or externaleventsthatcausepressureonorganizationalresources(financialresources,humanresources,contracts, communications, and others) and constitute the biggest threats to the security and vitalityof any company or construction project. Therefore, it is necessary to know and follow the stages ofthe crisis life of e cycle of the decision-makers as Coombs wrote, “a crisis does not just happen,it evolves” [13]. (Jose M Sarriegi) identifiedthere is a group of researcherswho determined the stages of the crisis and among these researchers are (Fink, Coombs, Augustine,Mitroff,and Olson) [12].Table(1)showsthecrisisstagesaccordingtosomeresearchers:

Table1: CrisisStages(**Researcher**)

Researcher	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Fink (4 Stages) (2002)	Prodromal Crisis	Acute Crisis	Chronic Crisis	Crisis Resolution		
Coombs (3stage) (2007)	Pre-Crisis	Crisis Event	Post Crisis			
Mitroff (5 Stage) (1996)	Pre-Crisis (Detecting Signs)	Prevention Preparation Research and Reduction of risk factors	Prevention Crisis Damage-isolate contain the Crisis	Crisis Restoration-Repair	Crisis Retrospection–Assessment-Learning	
Augustine (5 Stage) (1995)	Avoiding the Crisis	Preparation to manage the crisis	Recognizing the crisis	Containing the crisis	Resolving the crisis – Profiting from the crisis	
Burentt (6 stage) 2007	Identification goal formation	Identification Environmental analysis	Confrontation strategy formulation	Confrontation strategy evaluative	Confrontation strategy implantation	Reconviction strategy control
Olson (4 Stages) (2009)	Crisis Prevention phase	Crisis Preparation phase	Crisis Response phase	Crisis Retrieval Phase		

Early warning, survey, problem management, planning procedures, manuals, training, andsimulation are among the criteria mentioned by (**Jaques**2007) [14] for each of these three primarystages.Theactivation/reactionofacrisisrecognitionsystem,emergencyresponse,andcrisismanagement are all included in a crisis [15]. Assessment, adjustment, post-crisis issue implications,recovery,andbusinessresumptionareallpartofthepost-crisisprocess.InFigure(2),theresearcheridentified the main stages of the crisis according to (**Coombs** 2007) [12], in addition to identifyingthemain elements for each stage, as shown below. Sarafrazi (2013) [16] used MCDM techniques and the DEMATEL method to establish a set of criteria for each of the "three crisis stages." Signal detection, crisis planning, organizational and managerial structure, training, and maneuvering are examples of pre-crisis activities; crisis event activities include crisis detection, rapid response data collection, and reducing negative consequences; and post-crisis activities include removing negative consequences, ensuring security, and learning and reflection are examples of post-crisis activities.

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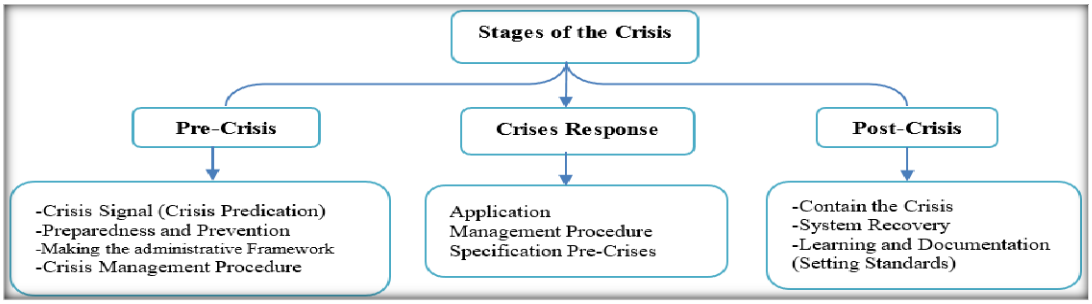
Figure 2: Stages oftheCrisis(**Researcher**)



Crisis management includes planning ahead of time for a crisis, responding quickly to minimize harm during a crisis, and providing feedback afterward. Rabiee et al (2013) to identify and assess the interdependencies of decision-making criteria during crises [8] used the fuzzy DEMATEL technique. The findings of this study showed that the criteria and sub-criteria of the organizational crisis decision-making model are connected.Furthermore, the most important criteria at the pre-crisis stage are signal detection, crisis preparedness, and prevention; at the crisis stage, the most important criterion is 'prevention from crisis damage (crisis control); and at the post-crisis stage, the most important criterion is 'identifying factors causing the crisis. [17]Highlight several approaches for crisis management, including organizational readiness, crisis leadership, and organizational learning.

2.2 Proposedcrisismanagementmodel

Afterreviewingpreviousstudiesaswellasinterviewswithexperts,theresearcherdividedthecrisis management structure into three areas, the first representing the crisis, which theresearcherrepresented(organizationalculture).In addition,thesecondregionduringtheoccurrenceofthecrisis,which the researcher considered (Executive Culture), and finally the post-crisis stage represented bythe researcher (Recovery, assessment, and learning). It includes each stage of the main activities orthe main and sub-criteria. **Appendix (1)** illustrated proposed crisis management. In this model,the researcher focused on the first stage, which is the stage before crises occur, as the researcherconsidereditthemostimportantstageincrisismanagementbecauseitinvolvesidentifying,diagnosing,predicting crises, and responding.

2.3 Fuzzy DEMATEL Method

The DEMATEL method [18] is a good way to look into cause-and-effect relationships between evaluation criteria. Using matrices or digraphs, an intelligible structural model may be created that contains interactions between criteria as well as degrees of influential influence. To show such concerns, graph theory [19] can be used to build complicated causal links between criteria. The standard technique should be adjusted to account for experts' confusing assessments by including fuzzy logic theory. In real-world MCDM situations, thefuzzy DEMATEL approach is provided as a solution to fuzziness in decision-making. In decision-makinginformation,fuzzylinguisticvariablescanbe usedtoderivesubjective perspectives on various interactions rather than precise numerical values. The fuzzy-DEMATEL model blends fuzzy theory's fuzzy linguistic component with DEMATEL [20]. Researchers can study the causal linkages between fuzzy variables and determine the extent of interactive influence between variables using the DEMATEL in a fuzzy environment. As a result, the broader method is being used to investigate the causal structure of SMEs' energy efficiency financing issues. The following are the steps in the calculation:

2.3.1 TheStepsofthe FuzzyDEMATELMethod

Step1:Generatethefuzzydirect-relationmatrix

An n*n matrix is first built to define the model of the relationships among the n criteria. A fuzzy number can be used in this matrix to show the impact of each row's element on each column's element. If more than one expert's opinion is needed.All specialists are required to fill out the matrix. The direct relation matrix z is constructed using the arithmetic mean of all of the experts' assessments. Table 2 shows the fuzzy scale for compare

ng assessment criteria in pairs.

$$z=\begin{bmatrix} 0 & \cdots & \tilde{z}_{n1} \\ \vdots & \ddots & \vdots \\ \tilde{z}_{1n} & \cdots & 0 \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ (1)}$$

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Table (2) shows the fuzzy scale that was utilized in the model.

Table(2): FuzzyScaleforpairwise comparisonofevaluationcriteria

Code(CrispValue)	DegreeofInfluence	Linguisticterms	Fuzzy Value(TFNs)		
			L	M	U
1	Noinfluence	No	0	0	0.25
2	Verylow influence	VL	0	0.25	0.5
3	Lowinfluence	L	0.25	0.5	0.75
4	Highinfluence	H	0.5	0.75	1
5	Veryhigh influence	VH	0.75	1	1

Step2:Normalizetheambiguousdirect-relationmatrices.
Thefollowing formulacan be used to calculate the normalized fuzzydirect-relation matrix:
$\tilde{x}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r}\right)$ ……………………………. (2)
Where: $r = \max_{i,j}\left\{\max_{i} \sum_{j=1}^{n} u_{ij}, \max_{j} \sum_{i=1}^{n} u_{ij}\right\}$ $i, j \in \{1,2,3, \ldots, n\}$……………… (3)
Step3:Calculatethefuzzytotal-relationmatrix

In step 3, use the formula to compute the Fuzzy total-relation matrix:

$\tilde{T} = \lim_{k\to+\infty}(\tilde{x}^1 \oplus \tilde{x}^2 \oplus \ldots \oplus \tilde{x}^k)$ ………… (4)
If each element of the fuzzy total-relation matrix is expressed as $\tilde{t}_{ij} = (l''_{ij}, m''_{ij}, u''_{ij})$, it can be calculated as follows:
$[l''_{ij}] = x_l \times (I - x_l)^{-1}$ …………….... (5)
$[u''_{ij}] = x_u \times (I - x_u)^{-1} \ldots\ldots\ldots\ldots..(6)$

To put it another way, the inverse of the normalized matrix is computed first, then subtracted from matrix I, followed by the normalized matrix being multiplied by the resulting matrix. The table below shows the fuzzy direct-relation matrix.
Step4:Defuzzifyintocrisp values

The converting fuzzy data into crisp scores **CFCS** method proposed by "**Opricovic and Tzeng**" [21] has been used to obtain a crisp value of the total-relation matrix. The steps of the CFCS method are as follows:
$l_{ij}^{n} = \frac{\left(l_{ij}^{t} - \min l_{ij}^{t}\right)}{\Delta_{min}^{max}} \ldots\ldots\ldots\ldots..(7)$
$m_{ij}^{n} = \frac{(m_{ij}^{t} - min\ l_{ij}^{t})}{\Delta_{min}^{max}} \ldots\ldots\ldots\ldots..(8)$
$u_{ij}^{n} = \frac{(u_{ij}^{t} - min\ l_{ij}^{t})}{\Delta_{min}^{max}}$………….. (9)
So that: $\Delta_{min}^{max} = \max u_{ij}^{t} - \min l_{ij}^{t}$……………..(10)
Calculating the upper and lower bounds of normalized values:
$l_{ij}^{s} = {m_{ij}^{n}}\big/{(1 + m_{ij}^{n} - l_{ij}^{n})} \ldots\ldots\ldots\ldots..(11)$
$u_{ij}^{s} = {u_{ij}^{n}}\big/{(1 + u_{ij}^{n} - l_{ij}^{n})} \ldots\ldots\ldots\ldots..(12)$

The output of the CFCS algorithm is crisp values.
Calculating total normalized crisp values:

$$x_{ij} = \frac{[l_{ij}^{s}(1-l_{ij}^{s})+u_{ij}^{s}\times u_{ij}^{s}]}{[1-l_{ij}^{s}+u_{ij}^{s}]} \ldots\ldots\ldots\ldots\ (13)$$

Step5:Setthethreshold value

Before the internal relations matrix can be calculated, the threshold value must be met. As a result, incomplete relationships are ignored and a Network Relationship Map (NRM) is produced. The NRM only shows associations with values in matrix T greater than the threshold value. Calculating the threshold value for relationships is as easy as calculating the matrix T's average values. After finding the threshold intensity, all values in matrix T that are smaller than the threshold value are set to zero, disregarding the previously established causal relationship.

Step6:Createacausalrelationship diagramusingthefinaloutput.

The total of each row and column in T will be calculated next (in step 4). The sum of rows (D) and columns (R) can be calculated using the formula below:

$$D=\sum_{j=1}^{n} T_{ij} \ldots\ldots\ldots\ldots(14)$$

$$R=\sum_{i=1}^{n} T_{ij} \ldots\ldots\ldots\ldots(15)$$

D and R can then be used to calculate the values of D+R and D-R, where D+R signifies the degree of importance of factor I in the overall system and D-R denotes the net impacts of factor I on the entire system.

3. Statisticalanalysisandinterpretationofresults

The questionnaire was divided into two main parts, as mentioned earlier. This step isintendedto simplifyandfacilitate thesurveyresults, as shown below:

3.1 **Part(I):**PersonalInformation

Five evaluators who were actively working on construction sites examined major and minorcriteriaforcrisismanagementinconstructionbeforeimplementingthisapproach.Residentsofvariousages(45-57years)andprofessionalexperience(19-28years)werechosenasindicatorsoftheirdegreeofexperience,aswellastheassessor'seducationallevel,jobtitle,andjobresponsibilities. The evaluators shared theirperspectives on r own knowledge, experience, and expertise. In this stage, you will go over themajorand minor criteria you found in Appendix**(1)**.

3.2 Part(II):TheFuzzyDEMATELtechniqueresults

According to the closed questionnaire, five experts' knowledge and information in theIraqi construction sector were gathered in a Fuzzy DEMATEL model. As a result, the Fuzzy DEMATELmodelcanbe developedasadecision-makingprovisionmeans.Thequestionnairewasdividedintotwomainparts.This step isintended to simplifyandfacilitate thesurveyresults,as shown below:

1. AnalysisandEvaluationof theMain Phases LevelsforCrisis

To obtain the resultsofFuzzyDEMATEL, the researcher identified a setofmain stepsand equationsrequired for the technology to analyze and evaluate the proposed crisis management model, as follows:

Step1: Definingthemainandsecondarycriteriafortheproposedcrisismanagementmodelforallstagesofcrises:Theresearchercollectedvariousliteratureonthesubjectofcrisismanagementaccordingto different points of viewand as shownin table (1).
Step2: PriorBefore mintingthisapproach,fiveevaluators,workingwithintheprojectmanagement,evaluated the proposed crisis management model. Their various experiences in the proposed crisismanagementtopicwere utilizedandthusthestructureofthecrisismanagementwas modelmodifiedaccordingto the opinions of the five experts. Finally, the various major and minor crisis criteria were raise extracted. Asshownin **Appendix(1)**.

Step 3: The assessors utilized a five-point scale (see Table 2) with no effect, very low influence, moderate influence, medium

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influence, strong influence, and very high influence as the categories.

Step4: Apairwisecomparisonwasperformedusingthelanguagevariables,andtheresultswerethenchanged to a numeric scale of 1 to 5 using the table's scale (2). Table (1) shows the average numerical scores for the assessors' opinions. (2). A first direct relationship matrix was created using the fuzzy scale shown in Table (3). The direct relation matrix for the average of the five respondent views is shown in Table (1). Table (4) shows the direct relation matrix for (Crisis Main Phases andLevels)

Table3: Linguisticassessmentofaprofessional'sopinion

Main Stages of Crisis	A1- Pre-Crisis	A2- DuringCrisis	A3- AfterCrisis
A1- Pre-Crisis	1	4	2
A2- DuringCrisis	3	1	3
A3- AfterCrisis	3	3	1

Table(4):thedirectrelationshipmatrix(average oftheopinionsofthefiverespondents)

	A1- Pre-Crisis	A2- DuringCrisis	A3- AfterCrisis
A1	(0.000,0.000,0.000)	(0.583,0.833,1.000)	(0.500,0.750,1.000)
A2	(0.250,0.500,0.750)	(0.000,0.000,0.000)	(0.583,0.833,1.000)
A3	(0.583,0.833,1.000)	(0.500,0.750,1.000)	(0.000,0.000,0.000)

Step 5: The normalized fuzzy direct-relation matrix "N" was generated using the presence of the initial direct connection matrix. Expressions (2 and 3) can be used to generate the normalized fuzzy direct-relation matrix (see table (5)).

Table(5): Thenormalized fuzzydirect-relationmatrix

	Pre-Crisis-A1	DuringCrisis-A2	AfterCrisis-A3
A1	(0.000,0.000,0.000)	(0.292,0.417,0.500)	(0.250,0.375,0.500)
A2	(0.125,0.250,0.375)	(0.000,0.000,0.000)	(0.292,0.417,0.500)
A3	(0.292,0.417,0.500)	(0.250,0.375,0.500)	(0.000,0.000,0.000)

Step 6: The total-relation fuzzy matrix was produced after getting the normalized direct-relation fuzzy matrix. The formulas (5, 6, and 7) can be used to calculate this, where n*n is the identity matrix. The relation fuzzy matrix is shown in Table 1 as a whole (6).

Table (6): Thefuzzytotal-relation matrix

	Pre-Crisis-A1	DuringCrisis-A2	AfterCrisis-A3
A1	(0.181,0.772,7.000)	(0.451,1.170,8.000)	(0.427,1.152,8.000)
A2	(0.267,0.889,6.667)	(0.181,0.772,7.000)	(0.411,1.072,7.333)
A3	(0.411,1.072,7.333)	(0.427,1.152,8.000)	(0.227,0.882,7.667)

Step 7: Defuzzify the values into crisp ones: The CFCS approach developed by (**Opricovic** and**Tzeng**) [21] for turning fuzzy data into crisp scores was utilized to produce a crisp value of the total-relation matrix. The crisp value was calculated using the questions (7, 8, 9, 10, 11, 13, and 14). Thecrisptotal-relation matrixis shown in Table (7).

Table(7): Thecrisptotal-relationmatrix

	Pre-Crisis-A1	DuringCrisis-A2	AfterCrisis-A3
A1	1.829	**2.317***	**2.301***

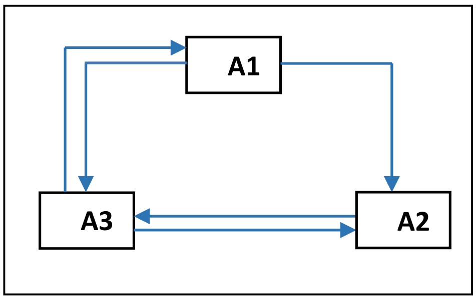
A2	1.877	1.844	**2.142***
A3	**2.123***	**2.301***	2.032

Step8:Determinethethresholdvalue: The threshold value in this investigation is equivalent to (2.085). All values in matrix T that are less than (2.085) are set to zero, indicating that the previously indicated causal relationship is not taken into account. The table below depicts a model of essential relationships (8). The ultimate form of the internal causal relationship between the various stages of crisis management is depicted in Figure (3).

Table(8): Thecrisp total-relationships matrixbyconsideringthethresholdvalue

	Pre-Crisis-A1	**DuringCrisis-A2**	**AfterCrisis-A3**
A1- Pre-Crisis	0	**2.317***	**2.301***
A2- DuringCrisis	0	0	**2.142***
A3- AfterCrisis	**2.123***	**2.301***	0

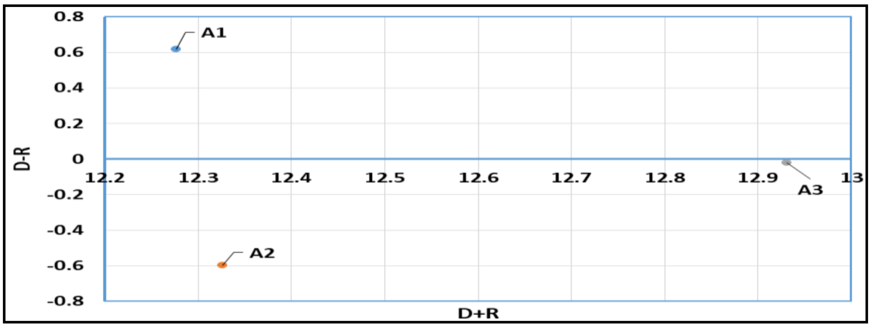
Figure(3): Representthefinalinternalcausalrelationship



Step9: ThenextstepistoaddeachTcolumnandrowtogether(instep7).Questions can be used to determine the total number of rows (D) and columns (R) (15 and 16). The values of D+R and D-R may then be determined, with D+R denoting the degree of importance of factor I in the overall system and D-R denoting the system's net impacts. The outcome is shown in Table (9).
Table(9): Thefinal output

	Code	**D**	**R**	**D+R**	**Rank**	**D-R**	**Identify**
Pre-Crisis	**A1**	6.447	6.447	12.276	**3**	0.618	Cause
DuringCrisis	**A2**	5.864	5.864	12.326	**2**	-0.599	Effect
AfterCrisis	**A3**	6.456	6.456	12.931	**1**	-0.019	Effect

Figure (4) depicts a model of relevant relationships. This model can be seen as a graph, with (D+R)values on the horizontal axis and (D-R) values on the vertical axis. Each factor's position andinteractionwith apoint in thecoordinates (D+R,D-R) is determinedbythecoordinatesystem.
Figure(4): Cause-Effect Diagram



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2. AnalysisandEvaluationoftheMainPhasesLevelsforPre-Crises

A. TheMainCriteriaforPre-Crisis

Table (10) shows the clear overall relationship matrix for the main criteria for the pre-crisisstage. This is after decoding the confusion into clear values, in addition to setting the limit value. Byapplying the **CFCS**method suggested by [21]. The threshold value was determined by applying thepreviouslymentionedequations.The value of the threshold is the same as (0.321). Because not all values in matrix T smaller than (0.321) are set to zero, the preceding causal relationship is taken into account. Using the aforementioned computing methodologies, a crisp total relation matrix for the key criterion group for pre-crisis was generated, as shown in table (10).Anasteriskdenotedsignificantinteractionassociations(*).

Table (10): shows the pre-crisis stage main criteria crisp total-relation matrix.

MainCriteria	B1	B2	B3	B4	B5	B6
B1	0.214	**0.388***	**0.408***	**0.38***	**0.487***	**0.495***
B2	0.245	0.221	**0.36***	0.303	**0.42***	**0.426***
B3	0.277	**0.355***	0.249	**0.332***	**0.439***	**0.458***
B4	0.257	0.299	0.311	0.209	**0.436***	**0.457***
B5	0.215	0.25	0.274	0.244	0.241	**0.407***
B6	0.198	0.246	0.255	0.232	**0.34***	0.234

(*)Indicates avaluegreaterthan orequal to(0.321)

Table (11), the final product of the study of the primary criteria before the crises, illustrates the relative importance of the main criteria, as well as determining the cause and impact of all of the criteria.

Table(11): FinalOutputformain criteriaforPre-Crisis stage

MainCriteria	Code	D	R	D+R	Rank	D-R	Identify
PlanningProcess	**B1**	2.371	1.405	3.776	**4**	0.966	**Cause**
Systems&Manuals	**B2**	1.974	1.759	3.733	**5**	0.216	**Cause**
Training&Simulation	**B3**	2.11	1.856	3.966	**3**	0.254	**Cause**
EarlyWarning	**B4**	1.969	1.7	3.669	**6**	0.269	**Cause**
ProblemriskManagement	**B5**	1.63	2.363	3.993	**1**	-0.733	**Effect**
EmergencyResponse	**B6**	1.504	2.477	3.981	**2**	-0.973	**Effect**

Figure (5) shows a causeand effect diagram based on the primary criteria. All of the primarycriteria's causal properties are shown in Figure 5a. The important relationships between the primarycriteriaaredepictedinFigure(5b).Black arrows represent significant mutual effects between two criteria,andlines represent apparent one-way causal effects.

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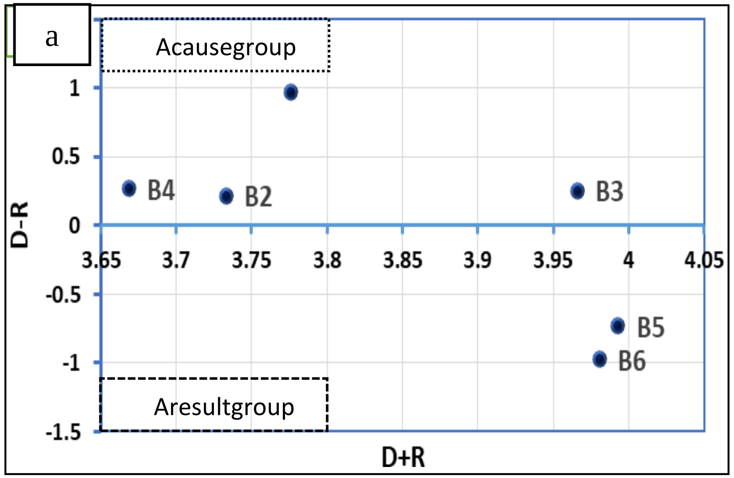

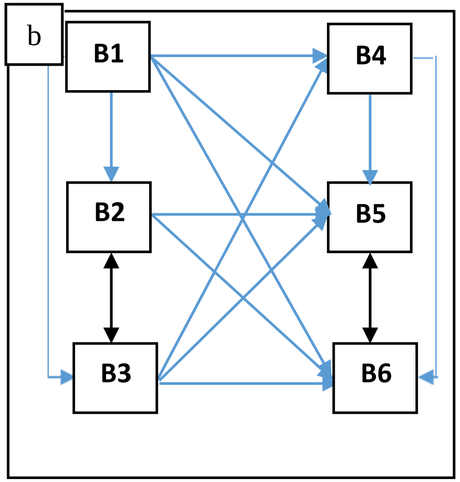

Figure(5): Diagramsofcauseandeffectamongmajorcriteria,displaying**a)**All-maincriterion'causalattributions and **b)**the main criteria'importantlinkages.

A. Sub-CriteriaforPre-Crisis

Table (12) shows the clear overall relationship matrix for the main criteria for the pre-crisis stage. This is after decoding the confusion into clearvalues, in addition to setting the limit value. By applying the **CFCS** method suggested by [18]. The threshold value was determined by applying thepreviously mentioned equations. The value of the threshold is equal to (0.073). The above causal link is taken into account since not all values in thematrix T lower than (0.073) are set to zero. As a result of the aforesaid computation methods, a crisp total relation matrix was constructed for the pre-crisis sub-criterion group, as shown in table (12). Asterisks were used to indicate significant interaction relationships (*).

Table (12): The crisp total-relation matrix for main criteria in the pre-crisis stage.

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	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
C1	0	0.082*	0.091*	0.098*	0.093*	0.095*	0.083*	0.09*	0.099*	0.09*	0.101*	0.089*	0.094*	0.092*	0.098*	0.096*	0.111*	0.122*	0.096*	0.118*
C2	0	0	0.096	0.098*	0.1*	0.095*	0.084*	0.091*	0.1*	0.084*	0.114*	0.096*	0.095*	0.099*	0.092*	0.096*	0.118*	0.128*	0.097*	0.119*
C3	0	0.087*	0	0.098*	0.093*	0.101*	0.077*	0.09*	0.1*	0.084*	0.114*	0.096*	0.101*	0.099*	0.092*	0.096*	0.118*	0.122*	0.097*	0.119*
C4	0	0	0	0	0.093*	0.088*	0	0.084*	0.093*	0	0.1*	0.083*	0.088*	0.092*	0.08*	0.083*	0.11*	0.114*	0.084*	0.11*
C5	0	0	0	0.087*	0	0	0	0	0.08*	0	0.092*	0.083*	0	0.073*	0	0	0.102*	0.105*	0	0.09*
C6	0	0	0	0	0	0	0	0	0	0	0.076*	0	0	0	0	0	0.079*	0.082*	0.076*	0.08*
C7	0	0	0	0	0.08*	0	0	0	0.078*	0	0	0.076*	0	0	0	0	0	0.075*	0	0
C8	0	0	0	0	0	0	0	0	0.091*	0	0.091*	0.075*	0.081*	0.078*	0	0.082*	0.087*	0.097*	0	0.094*
C9	0	0	0	0	0	0	0	0	0	0	0.088*	0.073*	0.079*	0.076*	0.076*	0.074*	0.092*	0.101*	0.074*	0.079*
C10	0	0	0	0	0	0.074*	0	0	0.078*	0	0.096*	0.075*	0.074*	0.077*	0	0.082*	0.093*	0.096*	0.076*	0.094*
C11	0	0	0	0.079*	0	0.075*	0	0	0	0	0	0.076*	0.075*	0.085*	0	0.076*	0.101*	0.104*	0.077*	0.102*
C12	0	0	0	0	0	0.075*	0	0	0.079*	0	0.092*	0	0.081*	0.078*	0.079*	0.089*	0.095*	0.098*	0.077*	0.096*
C13	0	0	0	0	0	0	0	0	0.082*	0	0.081*	0	0	0.075*	0.077*	0.074*	0.084*	0.094*	0.074*	0.085*
C14	0	0	0	0	0.085*	0	0	0	0	0.084*	0.096*	0.075*	0	0	0	0	0.093*	0.096*	0	0.093*
C15	0	0	0	0	0.074*	0	0	0	0.08*	0.079*	0.104*	0	0	0.079*	0	0.09*	0.102*	0.116*	0.077*	0.104*
C16	0	0	0	0	0	0	0	0	0.076*	0	0.088*	0.073*	0	0.075*	0	0	0.097*	0.1*	0.074*	0.103*
C17	0	0	0	0.077*	0	0	0	0	0.076*	0	0.081*	0	0	0	0	0	0	0.106*	0.08*	0.098*
C18	0	0	0	0	0	0	0	0	0.074*	0	0.079*	0	0	0.079*	0	0	0.088*	0	0	0.1*
C19	0	0	0	0	0	0	0	0	0	0	0.074*	0	0	0.081*	0	0	0.083*	0.093*	0	0.091*
C20	0	0	0	0	0	0	0	0	0.074*	0	0.079*	0	0	0.073*	0	0	0.088*	0.085*	0	0

(*)Indicates avaluegreaterthan orequal to(0.321)

Table(13)showsthefinaloutputoftheanalysisofthesub-criteriabeforethecrises,andthetableshowstherelativeimportanceofthesub-criteria,as well as determiningthe causeand effect ofall the criteria.A cause and effect diagram based on the key criteria is shown in Figure (6). Figure 6a depicts all of the causal features of the key criterion. Figure (6b) depicts the essential correlations between the primary criteria (6b). Black arrows represent significant mutual effects between two criteria, whereas lines represent apparent one-way causal effects.

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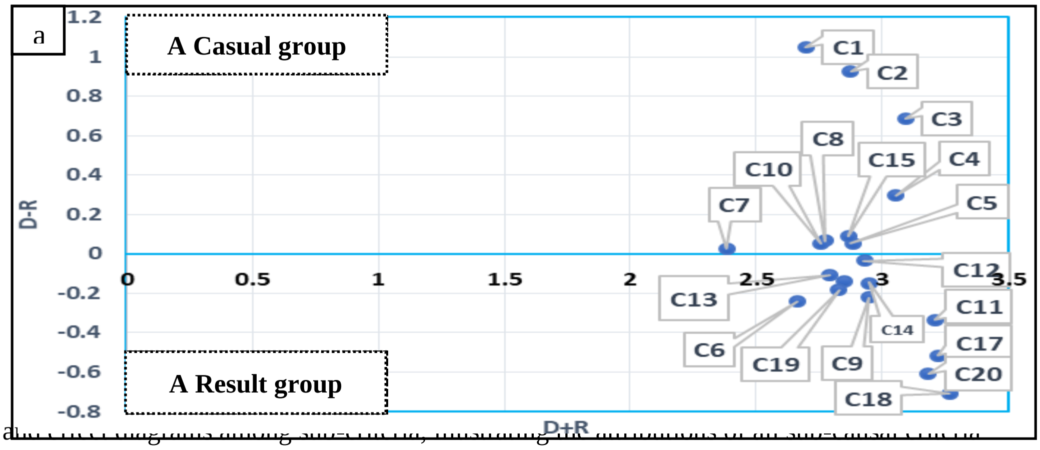
Table(13): FinalOutputforSub-CriteriaforPre-Crisisstage

Sub-Criteria	Code	D	R	D+R	Rank	D-R	Identify
Establishof Centralauthorityfor Crisis	**C1**	1.874	0.825	2.699	**18**	1.049	**Cause**
Formationofcrisismanagement Team	**C2**	1.9	0.976	2.876	**11**	0.924	**Cause**
Assigningrolesand responsibilities	**C3**	1.891	1.202	3.093	**5**	0.688	**Cause**
Createorganizedandtightplans	**C4**	1.676	1.378	3.054	**6**	0.297	**Cause**
Establishingalibraryof	**C5**	1.468	1.415	2.883	**10**	0.053	**Cause**
ContinuousCommunication	**C6**	1.212	1.455	2.667	**19**	-0.243	**Effect**
Createchecklist	**C7**	1.204	1.178	2.382	**20**	0.027	**Cause**
Establishmentofaneffective	**C8**	1.42	1.354	2.774	**16**	0.066	**Cause**
Buildinganeffectivemechanism	**C9**	1.364	1.584	2.948	**8**	-0.221	**Effect**
Crisismanagementteamtraining	**C10**	1.407	1.354	2.76	**17**	0.053	**Cause**
Preparing	**C11**	1.439	1.773	3.212	**3**	-0.334	**Effect**
Determinesourcesofinformation	**C12**	1.451	1.484	2.935	**9**	-0.034	**Effect**
Establishinganeffectivecontrol	**C13**	1.342	1.452	2.794	**15**	-0.11	**Effect**
Livesimulationof crises	**C14**	1.4	1.55	2.951	**7**	-0.15	**Effect**
Developanintegratedpredictive programforcrises	**C15**	1.479	1.388	2.866	**12**	0.091	**Cause**
Analyzetherisk factorsof crisesto determinepriorities	**C16**	1.356	1.497	2.853	**13**	-0.141	**Effect**
Developingplanstopreventcrisis	**C17**	1.353	1.87	3.224	**2**	-0.517	**Effect**
Formulateprocedures andcarry	**C18**	1.279	1.989	3.269	**1**	-0.71	**Effect**
Continuityofcommunication betweenstakeholders	**C19**	1.321	1.504	2.826	**14**	-0.183	**Effect**
Implementationandevaluationof rapidresponse	**C20**	1.288	1.895	3.183	**4**	-0.607	**Effect**



Figure(6): Cause and effect diagrams among sub-criteria, illustrating the attributions of all sub-causal criteria

3. AnalysisandEvaluationof the main phaseslevelsDuringCrises

A. TheMain Criteria forDuringCrises

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Table(14)showstheclearoverallrelationshipmatrixforthemaincriteriatheduringcrisisstage. The value for the threshold was determined to be equal to (0.966). The above causal link is taken into account since not all values in the matrix T lower than (0.966) are set to zero. Asterisksdesignatedsignificant interactiverelationships (*).

Table (14): This shows the crisp total-relation matrix for the important criteria in the crisis stage.

MainCriteria	B7	B8	B9
B7	0.53	**0.937***	**1.041***
B8	0.611	0.541	**0.916***
B9	0.546	0.634	0.535

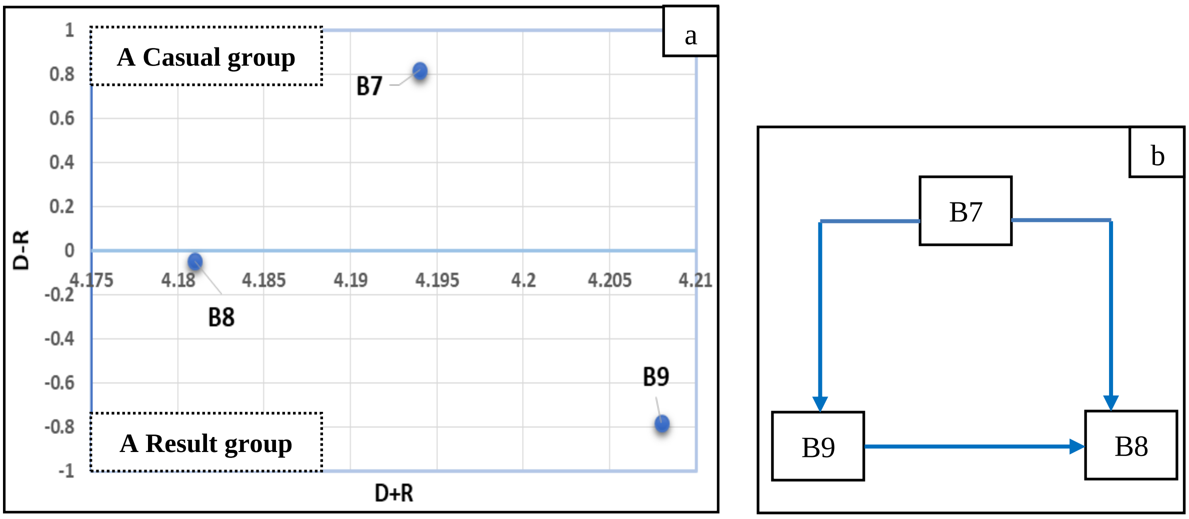
(*)Indicates avaluegreaterthanorequal to (0.966)

Table(15)showsthefinaloutputoftheanalysisofthemaincriteriaduringthecrisisoccur,andthetableshowstheimportanceofthemaincriteria,aswellasdeterminingthecauseandeffectof all the criteria.

Table(15): Final Outputformain criteriaDuringthe Crisisstage

MainCriteria	Code	D	R	D+R	Rank	D-R	Identify
Diagnose(recognize)crises	**B7**	2.508	1.686	4.194	**2**	0.822	**Cause**
Systemsactivation /response	**B8**	2.068	2.113	4.181	**3**	-0.045	**Effect**
CrisisManagement	**B9**	1.715	2.493	4.208	**1**	-0.778	**Effect**

The major criteria are depicted in Figure (7) as a cause and effect diagram. Figure 7a depicts all of the causal features of the key criterion. Figure (7) depicts the essential correlations between the primary criteria (7b). Bluearrows represent significant mutual effects between two criteria, whereas lines represent apparent one-way causal effects.



Figure(7): Cause andeffectdiagramsamong importantcriteria,showing**a)**thecausalattributionsofallmain criteriaand **b)** thesignificant relationships between them.

B. Sub-CriteriaforDuringCrisis

In the crisis stage, Table (16) displays a clear overall relationship matrix for the Sub-criteria. The threshold value was set to be equal to (0.219). The above causal link is taken into account since not all values in the matrix T lower than (0.219) are set to zero. Asterisksdesignatedsignificant interactiverelationships (*).Table (17) shows the final output of the analysis of the main criteria during the crisisoccur, and the table shows the importance of the main criteria, as well as determining thecauseandeffect ofall the criteria.

Table(16): Thecrisptotal-relation matrixforSub-criteriaduringcrisis

Sub-Criteria	C21	C22	C23	C24	C25	C26	C27	C28	C29
C21	0.154	**0.244***	**0.309***	**0.264***	**0.268***	**0.247***	**0.307***	**0.263***	**0.273***
C22	0.219	0.151	**0.299***	**0.264***	**0.258***	**0.265***	**0.307***	**0.282***	**0.293***
C23	0.159	0.155	0.169	0.199	0.202	**0.22***	**0.273***	**0.224***	**0.243***
C24	0.193	0.18	**0.287***	0.16	**0.248***	0.218	**0.275***	**0.242***	**0.271***
C25	0.171	0.168	**0.27***	0.193	0.148	**0.224***	**0.258***	**0.228***	**0.227***
C26	0.174	0.151	**0.219***	0.194	0.186	0.136	**0.236***	0.216	0.235
C27	0.127	0.142	0.207	0.173	0.185	0.183	0.155	**0.226***	0.214
C28	0.21	0.199	**0.255***	**0.225***	0.218	0.205	**0.281***	0.173	**0.268***
C29	0.189	0.167	**0.248***	0.211	0.204	0.192	**0.255***	0.215	0.166

(*)Indicates avaluegreaterthanorequal to (0.219)

Table(17): FinaloutputforSub-criteriaduringcrisisstage

Sub-Criteria	Code	D	RW	D+R	Rank	D-R	Identify
Preparingandmeeting	**C21**	2.327	1.596	3.923	**6**	0.731	**Cause**
Activatecommunications	**C22**	2.339	1.559	3.898	**7**	0.781	**Cause**
Activateresponsesystems	**C23**	1.845	2.264	4.108	**1**	-0.419	**Effect**
Activateeffectivemonitoring	**C24**	2.072	1.882	3.955	**5**	0.19	**Cause**
Activateassessmentsystems	**C25**	1.887	1.915	3.802	**8**	-0.028	**Effect**
Stakeholdermanagement	**C26**	1.747	1.89	3.637	**9**	-0.144	**Effect**
Mitigatingdamage	**C27**	1.611	2.346	3.957	**4**	-0.735	**Effect**
Crisischecklists	**C28**	2.034	2.067	4.101	**2**	-0.033	**Effect**
Pursuehighlydetailedaction	**C29**	1.846	2.189	4.035	**3**	-0.343	**Effect**

The major criteria are depicted in Figure (8) as a cause and effect diagram. Figure 8a depicts all of the causal features of the key criterion. Figure (8b) depicts the essential correlations between the primary criteria (8b). Black arrows represent significant mutual effects between two criteria, whereas lines represent apparent one-way causal effects.

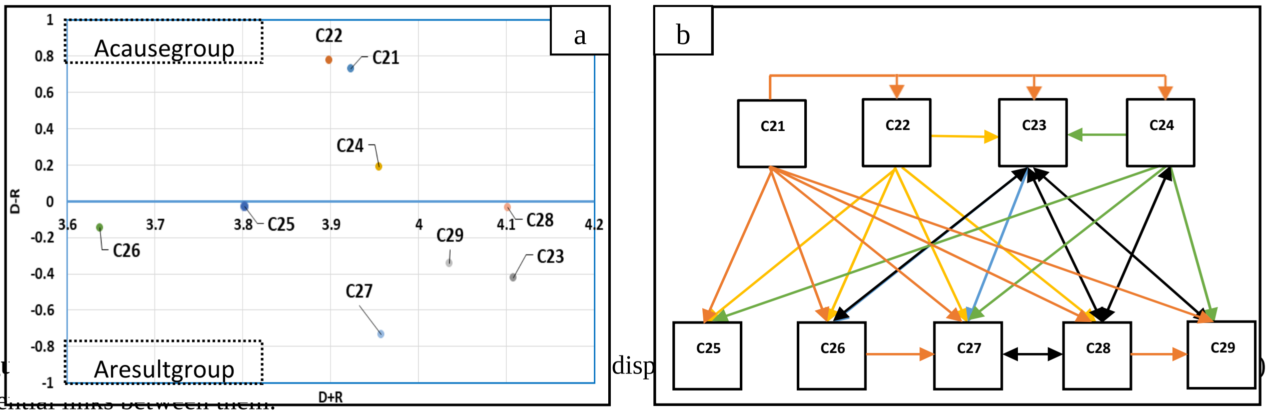


Fig disp) the essential links between them.

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4. AnalysisandEvaluation betweenthemain phaseslevelsforAfterCrises

A. TheMain CriteriaforAfterCrisis

The clear overall relationship matrix for the main criteria for the post-crisis stage is shown in Table(18).Thevalueofthethresholdwasdeterminedtobeequalto(0.202).Theabovecausallinkistakeninto account since not all values in the matrix T lower than (0.202) are set to zero. Significantinteractionrelationships (*) weredenoted with asterisks.

Table18: Thecrisp total-relationmatrixforafter-crisis stageprimarycriterion

MainCriteria	B10	B11	B12
B10	0.115	0.131	**0.475***
B11	0.163	0.041	**0.493***
B12	**0.203***	0.058	0.117

(*)Indicates avaluegreaterthanorequal to (0.202)

The result of the key criterion analysis after crises occurs is shown in table (19), whichdemonstratestherelativerelevanceof themaincriteriaas wellasdefiningthecause andeffectofallthecriteria.

Table(19): FinalOutputformaincriteriaaftercrisis stage

MainCriteria	Code	D	R	D+R	Rank	D-R	Identify
Crisismanagementplan	**B10**	0.721	0.481	1.202	**2**	0.24	**Cause**
Negativeeffectsafter crises	**B11**	0.697	0.23	0.927	**3**	0.467	**Cause**
Learningfromcrises	**B12**	0.378	1.085	1.463	**1**	-0.707	**Effect**

Figure (9) depicts a cause and effect diagram for the primary criteria. All of the main criteria's causal qualities are depicted in the diagram (9a). The graph displays the primary criteria's essential relationships (9b). Blue arrows represent significant mutual effects between two criteria, while lines represent apparent one-way causal effects.

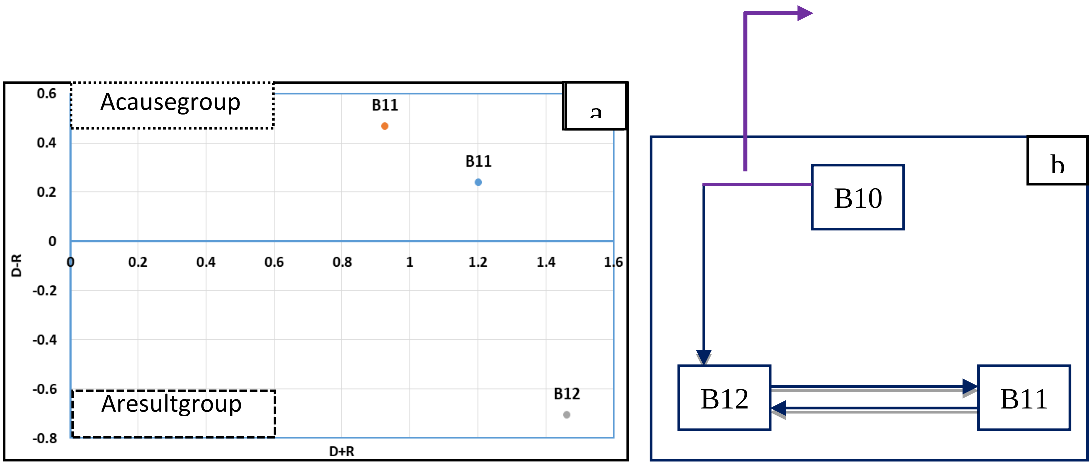

Figure (9): Cause and effect diagrams for important criteria, displaying **a)** Causal attributions for allmaincriteriaand **b)**Significant correlations between them.

B. TheSub-CriteriaforAfterCrisis

Table (19) shows the clear overall relationship matrix for the main criteria for the after-crisisstage. The value for the threshold was determined to be equal to (0.202). The above causal link is taken into account since not all values in the matrix T lower than (0.202) are set to zero. Asterisksdesignatedsignificant interactiverelationships (*).

Table(19): Sub-criteriatotal-relationmatrixforpost-crisisstage

Sub-Criteria	C30	C31	C32	C33	C34	C35	C36
C30	0.082	**0.261***	0.107	0.15	**0.229***	**0.252***	**0.232***

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C31	0.128	0.141	0.098	0.144	**0.289***	**0.3***	**0.266***
C32	0.112	0.163	0.096	**0.271***	**0.253***	**0.262***	**0.274***
C33	0.095	0.172	0.143	0.121	**0.257***	**0.267***	**0.277***
C34	0.148	**0.245***	0.136	0.197	0.18	**0.3***	**0.293***
C35	0.124	**0.215***	0.127	0.184	**0.23***	0.169	**0.275***
C36	0.167	**0.242***	0.184	**0.211***	**0.315***	**0.313***	**0.203***

(*)Indicates avaluegreaterthanorequal to (0.202)

Table (20) shows the final output of the analysis of the Sub-criteria after the crises occur,and the table shows the importance of the Sub-criteria, as well as determining the cause andeffectof all the criteria.

Table(20): FinalOutputforSub-criteriaaftercrisisstage

Sub-Criteria	**Code**	**D**	**R**	**D+R**	**Rank**	**D-R**	**Identify**
Establish anindependentthird	**C30**	1.312	0.856	2.168	**7**	0.457	**Cause**
Activatingasystemforevaluating	**C31**	1.367	1.438	2.805	**4**	-0.072	**Effect**
Analysisoftherootcause	**C32**	1.43	0.891	2.321	**6**	0.539	**Cause**
Assessmentofthenegativeeffects	**C33**	1.331	1.277	2.608	**5**	0.054	**Cause**
Addressshortcomings inthe response	**CtThe4**	1.499	1.753	3.252	**2**	-0.254	**Effect**
Developaneffectivemechanism	**C35**	1.324	1.863	3.187	**3**	-0.539	**Effect**
Continuingcommunication	**C36**	1.634	1.82	3.454	**1**	-0.185	**Effect**

A cause and effect diagram for the Sub-criteria is shown in Figure (10). In Figure,every Sub-causal criteria's features are depicted (10a). Figure(10b) depicts the main links among the Sub-criteria.The lines depict apparent one-way causal effects, while the black arrows represent strong mutual effects between the two criteria.

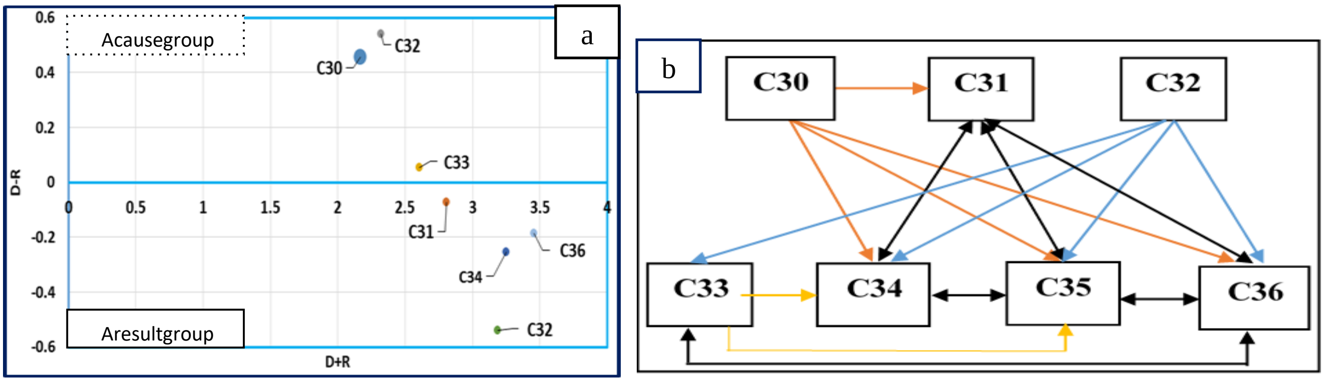

Figure (10): Cause and effect diagrams among sub-criteria, displaying a) all sub-causal criteria'attributionsand b)the essential relationships between them.

4.Conclusions

Throughtheresults presentedinthis paper,thefollowingconclusionscan bereached:

1. Throughastudyoftheliteratureandtheopinionsofexpertsinconstructionprojectmanagement in Iraq, a crisis management model in construction projects was proposed, thepurpose of which is to help decision-makers take the optimal decision in the event of crisesduringtheirthreephases.

2. **AnalysisandEvaluationof theMainPhasesLevelsforCrisis:**Whenitcomestosignificance,A3- after crisis ranked in the first place and A2- during Crisis, and A1-Pre-crisis, ranked inthe next place. In addition**,** in this study, A1- Pre- Crisis is considered a causal variable, A2-duringthe crisis, and A3-aftera crisis isregarded as an effect.

3. **AnalysisandEvaluationoftheMain PhasesLevelsforPre-Crises**

a. **The Main criteria for Pre-crisis:** In terms of importance, B5 ranked first place andB6, B3, B1, B2, and B4, ranked next place. On the other hand, B1, B2, B3, and B4 areconsideredcausal variables, andB5andB6 areregarded aseffect variables.

b. **Sub-criteria for Pre-Crisis:** When it comes to significance, C18, C17, C11, C20, C3, C4,C14, C9, C12, C5, C2, C15, C16, C19, C13, C8, C10, C1, C6, and C7, are ranked in the nextplaces. And In this study, C1, C2, C3, C4, C5, C7, C8, C10, C15 are considered to be a causalvariables, C6, C9, C11, C12, C13, C14, C16, C17, C18, C19, C20 are regarded as an effectvariable.

4. AnalysisandEvaluationofthemain phaseslevels DuringCrises

a. **The Main Criteria for During Crises:** When it comes to significance, B9, B7, and B8,rankedinthenextplace.Inthisstudy,B7isacausalvariable,and B8,ad B9areregardedaseffectvariables.

b. **Sub-Criteria for During Crisis:** When it comes to significance, C23is ranked in the firstplace and C28, C29, C27, C24, C21, C22, C25, and C26, are ranked in the next place. In thisstudy, C21, C22, and C24 are considered to be the causal variables. While,C23, C25, C26,C27,C28, and C29 areregarded aseffectvariables.

5. AnalysisandEvaluation betweenthemain phaseslevelsforAfterCrises

a. **TheMainCriteriaforAfterCrisis:**Intermsofthelevelofsignificance,B12rankedfirstplaceandB10andB11rankedthenext place.Inthisstudy,B10,andB11consideredbeingascausal variables,andB12 regardedasaneffectvariable.

b. **The Sub-Criteria for After Crisis:** In terms of importance, C36 ranked in the first placeand C34, C35, C31, C33, C32, and C30 ranked in the next place.In this study, C30, C32, andC33areconsidered causal variables,and C31,C34,C35,andC36areregardedaseffectvariables.

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