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Solutions to minimize the impacts of climate change on bridge abutments in the Vam Co river downstream, Long An province, Vietnam

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ABSTRACT

Long An province, Vietnam, is one of the provinces in the Mekong Delta region, with the geographical location and natural conditions of dense rivers and canals, so it is easily affected by extreme weather phenomena, leading to impact on socio-economic issues in general and the field of traffic construction in particular. Especially, bridge works in the downstream area, in which the abutment and pier system is among the hardest impacted categories. This article uses the expert method by consulting experts and road managers in Long An province to identify the influencing factors. Then, the authors use SPSS20 software to build an econometric problem of regression analysis, assessing the influence of this factor on the management and exploitation of bridge abutments in the increasing conditions of climate change in Long An. After that, this study proposes solutions to minimize the impact of climate change on the bridge abutments in the Vam Co lower river, Long An province, Vietnam.

Keywords : Climate Change, Bridge Abutment, Solutions, Downstream, Impacts.

I. INTRODUCTION

Climate change is causing more frequent and severe floods, droughts, storms and heat waves as average global temperatures rise to new record levels. Scientists have warned that an increase in greenhouse gas emissions globally could lead to extreme weather conditions and higher risks from natural disasters [1].

Vietnam is one of the countries most heavily affected by climate change, in terms of politics, socio-economic, national defense and security. Therefore, proactively responding to climate change is an important and urgent issue [2].

Extreme weather events that occur abnormally, in which temperature increases, heavy rains, high tides, sea level rise, saline intrusion, etc., with increasing frequency and intensity, are specific examples of climate change, causing serious impacts on the system of road traffic works in Vietnam.

The morphologies of climate change affecting abutments and piers include 1) deformation of the river bed; 2) shoreline change in the downstream area; 3) downstream area and 4) sea level rise and saline intrusion to the downstream.

Management and exploitation of bridge abutments and piers in the context of climate change are activities of management, preparation, use and storage of records related to works in general, abutment and pier systems in particular; operating the system, checking, monitoring and updating changes; immediately dealing with damage and protecting the abutment and pier systems during the exploitation phase, especially in climate change conditions in order to reduce the impact on the abutment and pier systems by extreme weather phenomena such as rain, storm, flood, temperature rise, sea level rise, saltwater intrusion, etc. causing damage and destruction to abutments and piers. This work is carried out regularly and continuously to maintain the technical state, ensure the role and function of the abutment and pier systems in the overall operation of the bridge, promote its functions, save maintenance costs and improve exploitation efficiency.

Climate change and the impact of natural disasters is the change in characteristic values of the natural environment affecting bridge works in general, bridge abutments and piers in particular. If the design works is according to environmental conditions, it will not be safe enough for future responsiveness, potential risks and impacts will be very serious if no timely countermeasures are taken.

Therefore, the study identifies the effect of climate change factors on bridge abutments and piers including [3]:

- The increase in temperature rapidly destroys the protective layer of reinforced concrete structures, abutments, and causing cracks in the abutments.
- Reinforced concrete and bridge piers after a period of use often appear cracks, surface pits, abraded concrete flow, appearance of emulsions, or damage in the connecting parts between the piers. There are many causes of cracking and damage such as shrinkage, creep, strength of concrete or poor construction quality, resulting in the appearance of seepage, rust through the structure, reducing the capacity of the building and affecting the safety and the exploitation.
- Corrosion due to weathering: The surface is worn with rock or gravel only. The abutment material loses its original strength, resulting in cracking of the outer parts. If it is a reinforced concrete structure, the protective concrete part is broken, causing exposure and rusting of the reinforcement, the section is reduced.
- Types of cracks appearing on the abutments, cylinder body: Cracks appear on the surface - these cracks are usually horizontal cracks along the construction joints, at the adjoining positions of the pedestal and pier body, cylinder body, the millstones, and the helm beams. Longitudinal and deep cracks caused by the action of loads. These cracks usually originate from the position of the supporting stone growing deep below the cylinder body, possibly through the thickness of the cylinder body.
- Landslides caused by collisions of boats: Due to weathered concrete, when there are heavy rain or high tides, sea level rise, the river level rises, narrowing the clearance, causing accidents and collisions of boats to the piers. Those without supporting structures, have poor bearing capacity, easily causing bridge collapse.
- Landslide in the fourth part of the cone: Occurs due to the impact of rain and flood or the construction work does not meet the technical requirements.
- Damage to the foundation: Including local erosion; broken piles; submersible well wall cracking, partly erosion by floods, load development, appearance of slip arcs, and failure of foundations.
- Damage due to displacement: Too deep erosion at the abutment foundation; insufficient bearing capacity of the ground; horizontal pressure of the soil increases; deep sliding phenomenon; damage due to displacement of the movable bearing, expansion or contraction of the gap between the top of the span structure and the abutment to develop excessive displacements. If detected and suspected, detailed measurements should be carried out; damage the connection between the bridge and the road. If the slope of the abutment cone is too steep, landslides, sleeper settlement, rail settlement, deformation and stress in the rails can increase to dangerous levels.

Regarding the bridge construction system in Long An province, at present, the Department of Transport manages a total of 360 road and bridge works, with a total length of more than 23.5 km, including many types of structures such as reinforced concrete and pre-stressed; iron seamless and surface; iron seamless wooden surface; iron surface suspension bridge; wooden suspension bridge [4].

The Department of Transport of Long An province manages a total of 360 bridges, mainly pre-stressed reinforced concrete bridges (accounting for 91.67%), iron bridges (accounting for 6.94%) and a number of iron bridges, iron suspended bridges - wooden surface bridges temporarily built by localities in remote and isolated areas to meet people's needs [4].

Regarding the bridge system in the downstream area of Vam Co river, there is My Loi bridge located on the National Highway 50 connecting Phuoc Dong commune, Can Duoc district, Long An province with Binh Dong commune, Go Cong town, Tien Giang province. My Loi Bridge has a total length of about 2,691m, the main bridge is 1,422m long, the starting point is at Km33+650, the ending point is at Km36+543 on National Highway 50. Design load of HL93, design speed of 80 km/h. The cross section is 12m wide, ensuring the circulation of 2 lanes of motor vehicles and 2 lanes of rudimentary vehicles. Total investment is VND1,438 billion and 952 million [4].

Bridges on Vam Co Tay River route include: Tuyen Nhon Bridge (on National Highway N2): across Vam Co Tay River on National Highway N2, Thanh Hoa Town, Thanh Hoa, Long An; Ho Chi Minh City - Trung Luong Expressway Bridge; Tan An Bridge 1; Tan An Bridge 2;

Bridges on Vam Co Dong River route include: Duc Hue Bridge (connecting Hiep Hoa town, Duc Hoa district with Dong Thanh town, Duc Hue district - Long An); Duc Hoa Bridge (on National Highway N2); Ho Chi Minh City - Trung Luong Expressway Bridge; Ben Luc Bridge (Long An).

I. CURRENT STATUS OF IMPACTS OF CLIMATE CHANGE ON BRIDGE ABUTMENTS ON VAM CO RIVER, LONG AN PROVINCE

In recent years, climate change has affected many areas of Long An province, in which the transport sector is directly and comprehensively affected.

In particular, the situation of saline intrusion is complicated and tends to increase, causing negative impacts on agricultural production in Long An province. Especially the transportation industry is significantly affected, causing damage to agricultural production. destroying transportation infrastructure in general, bridge abutment and piers in particular, especially steel and reinforced concrete structures, causing traffic unsafety, incurring maintenance costs, etc.

In Long An, this study summarizes a number of incidents and damage to abutments due to impacts of climate change, especially in the lower Vam Co river, including erosion, damaged concrete abutment of Ben Luc bridge. Sea level rise has changed the navigability of the Duc bridge - Tan An; damage to bridge abutment and retaining wall of Tong Uan bridge - DT.833; change the water flow and damage the abutment, causing the collapse of Vinh Binh bridge; collapse of Tan Duc bridge - Tan Tru.

In addition to affecting the system of abutments and piers, climate change also affects many other items of transport works such as damage to the roof of Hau Thanh Tay bridge - provincial road No. 837; the main reinforced concrete girder of Kenh Ngang bridge - provincial road No. 837B bridge was damaged due to environmental impacts; Kenh 1 bridge - Thu Thua was damaged.

A. Impacts of climate change on the system of bridge abutments and piers in the downstream area of Vam Co river

Through the failures of the abutment and pier systems, it can be seen that climate change has a comprehensive impact on the bridge construction, not only the abutment and pier systems. On that basis, this study identifies the impacts of climate change factors on road and bridge works in Long An province as follows [4]:

- The sea level rise factor: sea level rise leads to more complicated saline intrusion, affecting seriously to bridge structures such as rusting of steel abutment structures, bridge piers, cracking of concrete structures, rapid degradation of reinforced concrete, broken protective layer.
- Temperature factor: for asphalt concrete structures of bridge decks and abutments, temperature increase will be a factor causing concrete cracking, rutting of the wheel tracks of asphalt concrete deck, reducing service life and increasing costs for maintenance work;
- Rain factor: according to climate change scenarios, the annual rainfall will increase, especially the maximum 1-month rainfall and the 5-day maximum rainfall may increase by over 10%, sometimes up to 70%, causing many risks and damages such as:

+ Bridge works are facing the risk of flooding and erosion because of the significant increase in the peak flow, flood water level, and flow velocity in the basins where the works are located.

+ Some existing bridges will be in danger of no longer being able to meet the traffic clearance, when the water level is high in floods, due to heavy rains.

In summary, the frequency and intensity of extreme weather events are increasing, not only causing delays to the traffic system, reducing service time, but also negatively impacting the bridge pier system, which is dangerous, creating chances of being hit by a ship or boat when there is heavy rain, storm, strong current, etc.

B. Identify the main causes that accelerate the failure rate of abutments in the context of climate change

Climate change causes a change in the characteristic values of the natural environment affecting the abutments. The potential risk of causing a very serious incident if timely action are not taken.

Causes of abutment damage in climate change conditions can be classified into the following basic groups (Figure 1) [5] [6] [7].

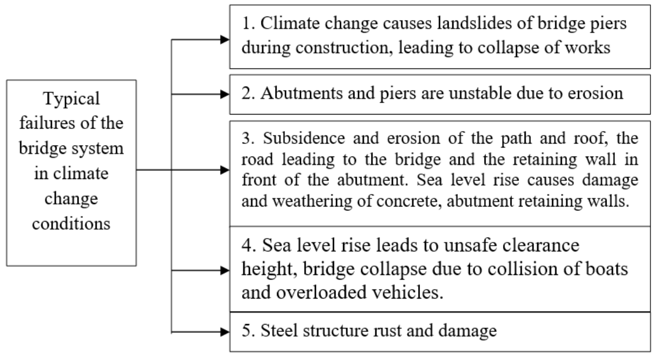

Figure 1. Typical failures of bridge system under climate change conditions

II. FORECASTING FACTORS AFFECTING THE MANAGEMENT OF THE BRIDGE ABUTMENT DUE TO CLIMATE CHANGE IN VAM CO RIVER LOWER AREA

A. Research process

In order to predict the factors affecting the exploitation and management of the bridge abutment in the increasing conditions of climate change in the lower Vam Co river, the authors evaluate the influence of these factors through two main stages [7] [8] [9]:

- Qualitative research to build questionnaires, organize interviews, collect opinions of experts and experienced managers working at road management agencies in Long An province.
- Quantitative research to complete questionnaires, collect official data, analyze data and test research models [10].

The research process is shown in Figure 2.

B. Research model and research hypothesis

Based on the results from expert consultation with an initial draft of 35 questions, after receiving comments from experts, the authors adjusted the terms and meanings of the questions, thereby preliminary determining 25 basic factors affecting the exploitation management of abutments in the increasing conditions of climate change in the lower Vam Co river area, classified into 06 groups as follows:

- Group of factors on the mechanism and policy of exploitation management of road and bridge works
- Group of factors on the management, organization and exploitation of the investors
- Group of factors related to maintenance contractors
- Group of factors on maintenance budget
- Group of factors related to consulting contractors
- Group of negative factors from climate change.

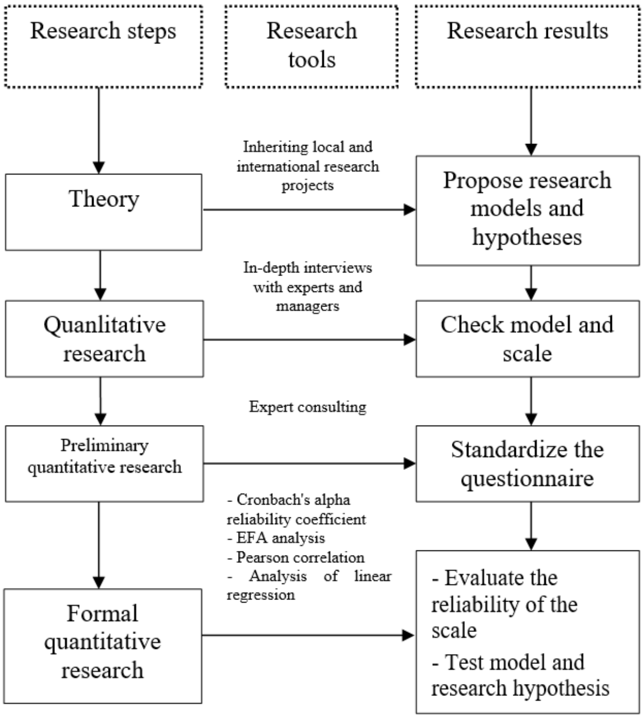

Figure 2. Research process

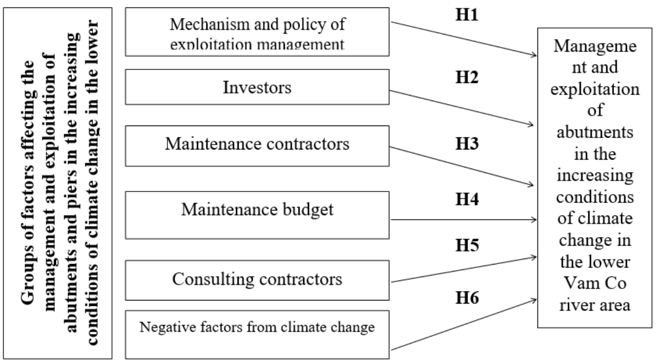

Figure 3. Research model

In order to determine the influencing factors, the question that needs to be answered is "The degree of influence of these factors on the exploitation management of the bridge abutment in the increasing conditions of climate change in the lower Vam Co river". Among them, the research hypotheses are as follows:

Hypothesis 1: Group of factors on mechanisms and policies that have an impact on the exploitation management of bridge abutments in the increasing conditions of climate change in the lower Vam Co river area.

Hypothesis 2: Group of factors on investors that have an impact on the exploitation management of bridge abutments in the increasing conditions of climate change in the lower Vam Co river area.

Hypothesis 3: Group of factors on maintenance contractors that have an impact on the exploitation management of bridge abutments in the increasing conditions of climate change in the lower Vam Co river area.

Hypothesis 4: Group of factors on maintenance budget that has an impact on the exploitation management of bridge abutments in the increasing conditions of climate change in the lower Vam Co river area.

Hypothesis 5: Group of factors on consulting contractors that have an impact on the exploitation management of bridge abutments in the increasing conditions of climate change in the lower Vam Co river area.

Hypothesis 6: Group of negative factors from climate change that have an impact on the exploitation management of bridge abutments in the increasing conditions of climate change in the lower Vam Co river area.

C. Scales

The scale of factors affecting the exploitation management of abutments in the increasing conditions of climate change in the lower Vam Co river area was adjusted and supplemented after getting expert consultation and measured by 6 following groups of factors.

- The group of factors about the investors (CĐT) is measured by 5 observed variables, with codes from CĐT1 to CĐT5.

- The group of factors about maintenance contractors (NT) is measured by 4 observed variables, with codes from NT1 to NT4.
- Group of factors of consulting contractors (TV) is measured by 3 observed variables, with codes from TV1 to TV3.
- The group of factors caused by climate change (KH) is measured by 4 observed variables, with codes from KH1 to KH4.
- The group of factors on maintenance budget (NV) is measured by 4 observed variables, with codes from NV1 to NV4.
- The group of factors on mechanisms and policies for exploitation management is measured by 5 observed variables, with codes from CC1 to CC5.

The scale of factors affecting the exploitation management of the bridge abutments in the increasing conditions of climate change in the lower Vam Co river area is the Likert scale (Rensis Likert 1932) with 5 rankings from 1 to 5. In which: (1) Not affected; (2) Very little influence; (3) Medium influence; (4) Great influence; (5) Huge influence.

TABLE I. TABLE OF SYMBOL OF OBSERVED VARIABLES

No.	Symbol	Factors
Group 1	**CĐT**	***Group of factors on the management, organization and exploitation of the investors***
1.1	CĐT1	The investors' model of exploitation management is not appropriate
1.2	CĐT2	The investors have not yet developed a process for management, exploitation and maintenance of abutments and piers in climate change conditions.
1.3	CĐT3	The professional capacity and experience of the investor staff is still weak. They do not have a deep understanding of climate change, and there is no full-time staff.
1.4	CĐT4	The work of patrolling, inspecting and detecting damage to bridge works of the investors is still procedural in nature, and testing equipment is outdated.
1.5	CĐT5	The investors have not yet boldly applied IT in the management and exploitation of bridge works.
Group 2	**NT**	***The group of factors about maintenance contractors***
2.1	NT1	Inappropriate maintenance plan, outdated construction technology, not yet applied new technologies, new materials in maintenance, repair of bridge abutments, piers.
2.2	NT2	The organization and assurance of traffic safety during maintenance and repair is not efficient.
2.3	NT3	The contractors' construction capacity is weak, the contractors' underwater construction equipment is still lacking in quantity, size and type.
2.4	NT4	Experience and professional ethics of technicians are weak
Group 3	**TV**	***Group of factors related to consulting contractors***
3.1	TV1	The survey and design work has not taken into account the impact of climate change
3.2	TV2	The supervision consultants lacks expertise, experience and awareness about the harmful effects of climate change to warn contractors.
3.3	TV3	Consultants do not fulfill their responsibilities, and there are interest groups.
Group 4	**KH**	***The group of negative factors caused by climate change***
4.1	KH1	The increase of temperature causes rapid destruction of the protective layer of reinforced concrete structures, abutments, piers, railings, pedestrian curbs, bridge bearings, ...
4.2	KH2	The increase in frequency and intensity of rain and storm surge causes local erosion and landslides of abutments.

No.	Symbol	Factors
4.3	KH3	The frequency and intensity of rain increase, the sea level rises, leading to the rise of river water level, narrowing the space for navigation, and easily causing accidents and collisions between boats and piers.
4.4	KH4	Saltwater intrusion causes rust and corrosion of steel structures and reinforced concrete abutments.
Group 5	**NV**	***Group of factors on maintenance budget***
5.1	NV1	Maintenance budget does not meet actual requirements
5.2	NV2	Capital allocation is slow
5.3	NV3	Prolonged payment and settlement procedures, slow administrative reform
5.4	NV4	Corrupted staff in charge of payment and settlement work
Group 6	**CC**	***The group of factors on mechanisms and policies for exploitation management***
6.1	CC1	Investment policy is too general, lacking key objectives
6.2	CC2	The system of legal documents regulating the exploitation management and maintenance of road bridges has not been completed yet
6.3	CC3	The mechanism and method of bidding in road bridge maintenance are still inadequate
6.4	CC4	The weak coordination between departments, agencies and sectors in exploitation management and maintenance of bridge works
6.5	CC5	The unit price applied to new materials, new technologies in maintenance, repair of road bridges are not practical.

D. **Data collection**

Within the scope of the research topic, the authors selected 125 votes to be distributed to experts and managers to create a database to include in the analytical model.

E. Data Analysis Methods

Quantitative data collected through the questionnaire survey will be considered, eliminating the responses that do not meet the requirements for the study. Satisfactory responses will be coded, entered and cleaned using SPSS20 software. This software also provides data analysis utilities for descriptive statistics, Cronbach Alpha scale testing, EFA factor analysis and regression correlation analysis.

The statistical features of the samples can be shown in Figures 4-7.

Descriptive statistics of the scale are summarized in Table II.

The results of Cronbach's Alpha test are shown in Table III.

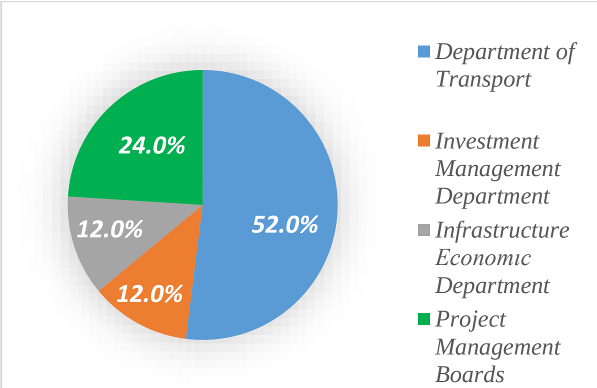

Figure 4. Statistics of working units of the samples

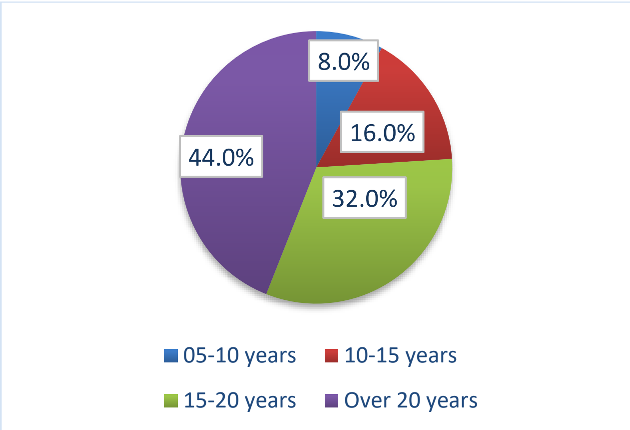

Figure 5. Statistics of sample's work experience

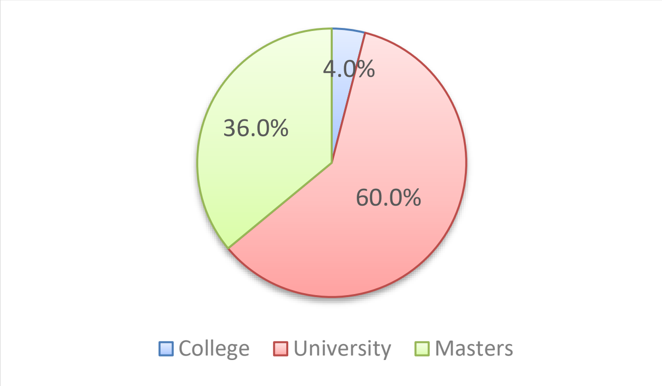

Figure 6. Qualification statistics

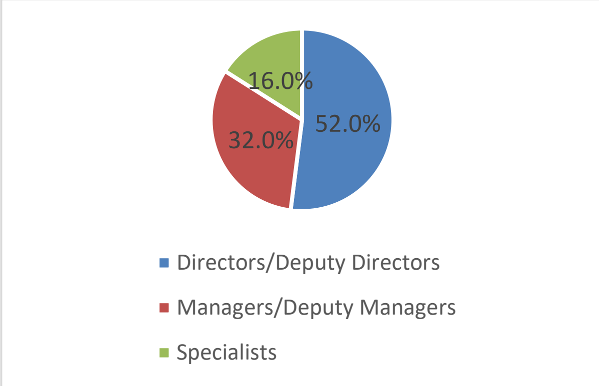

Figure 7. Positions of samples

TABLE II. DESCRIPTIVE STATISTICS OF THE SCALE

Observed variables	Number of samples	Smallest	Largest	Medium	Standard deviation
TV1	125	2	5	3.23	0.844
TV2	125	1	5	3.22	1.023
TV3	125	1	5	3.38	0.973
CĐT1	125	2	5	3.37	0.946
CĐT2	125	2	5	3.50	1.005
CĐT3	125	2	5	3.38	0.973
CĐT4	125	2	5	3.20	0.898
CĐT5	125	1	5	3.10	0.923
KH1	125	2	5	3.65	0.986
KH2	125	2	5	3.47	0.921
KH3	125	1	5	3.18	1.017
KH4	125	1	5	3.38	1.149
NV1	125	2	5	3.25	0.790
NV2	125	1	5	3.26	0.881
NV3	125	2	5	3.05	0.831
NV4	125	2	5	2.84	0.756
CC1	125	1	5	3.53	0.938
CC2	125	1	5	3.83	0.859
CC3	125	1	5	3.62	0.840
CC4	125	1	5	3.37	0.946
CC5	125	1	5	3.45	0.954
NT1	125	1	5	3.13	0.992
NT2	125	1	5	2.82	0.916
NT3	125	2	5	3.41	0.890
NT4	125	1	5	3.14	0.846

TABLE III. SUMMARY OF CRONBACH ALPHA COEFFICIENTS OF THE SCALES

Observed variables	**Scale average if eliminating variables**	**Scale variance if eliminating variables**	**Total variable correlation**	**Cronbach's Alpha if eliminating variables**
1. Group of factors on the management, organization and exploitation of the investors (CĐT), Cronbach's alpha = 0.847				
CĐT1	13.18	8.872	0.749	0.790
CĐT2	13.05	9.111	0.638	0.821
CĐT3	13.17	9.109	0.671	0.812

CĐT4	13.34	9.550	0.655	0.816
CĐT5	13.44	9.845	0.569	0.838
2. Group of factors related to maintenance contractors (NT), Cronbach's alpha = 0.8				
NT1	9.37	4.605	0.645	0.736
NT2	9.67	4.948	0.624	0.745
NT3	9.09	5.113	0.603	0.755
NT4	9.36	5.329	0.586	0.764
3. Group of factors related to consulting contractors (TV), Cronbach's alpha = 0.836				
TV1	6.60	3.339	0.667	0.806
TV2	6.61	2.595	0.749	0.722
TV3	6.46	2.879	0.692	0.779
4. The group of negative factors of climate change (KH), Cronbach's alpha = 0.778				
KH1	10.03	6.063	0.613	0.708
KH2	10.12	6.263	0.629	0.704
KH3	10.50	6.204	0.548	0.741
KH4	10.30	5.662	0.554	0.744
5. Group of factors on maintenance budget (NV), Cronbach's alpha = 0.785				
NV1	9.15	3.920	0.615	0.720
NV2	9.14	3.731	0.576	0.742
NV3	9.35	3.746	0.631	0.711
NV4	9.56	4.200	0.548	0.753
6. Group of factors on mechanisms and policies on management and exploitation of road and bridge works Cronbach's alpha = 0.855				
CC1	14.26	8.793	0.613	0.840
CC2	13.96	8.894	0.674	0.825
CC3	14.18	8.953	0.681	0.823
CC4	14.42	8.520	0.664	0.827
CC5	14.34	8.227	0.721	0.812

Evaluation results: All scales have Cronbach coefficient α > 0.7, total variable correlation coefficient > 0.3, so the observed variables have enough reliability needed to conduct factor analysis.

The results of the EFA exploratory factor analysis are summarized in Table IV. KMO and Bartlett's Test. 0.5 ≤ KMO = 0.723 ≤ 1, factor analysis is accepted with the research data.

Sig Barlett's Test = 0.000 < 0.05, factor analysis is appropriate.

TABLE IV. KMO VALUE AND BARLLET'S TEST

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.723
Bartlett's Test of Sphericity	Approx. Chi-Square	1545.772
	df	300
	Sig.	0.000

TABLE V. TOTAL VARIANCE EXTRACTION

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.639	22.558	22.558	5.639	22.558	22.558	3.445	13.781	13.781
2	3.607	14.428	36.986	3.607	14.428	36.986	3.317	13.268	27.049
3	2.195	8.781	45.767	2.195	8.781	45.767	2.638	10.554	37.602
4	1.951	7.803	53.571	1.951	7.803	53.571	2.523	10.091	47.693
5	1.825	7.300	60.870	1.825	7.300	60.870	2.415	9.660	57.353
6	1.457	5.829	66.699	1.457	5.829	66.699	2.336	9.346	66.699

7	.976	3.906	70.605						
8	.944	3.776	74.381						
9	.732	2.928	77.309						
10	.672	2.689	79.998						
11	.632	2.527	82.525						
12	.544	2.177	84.702						
13	.475	1.899	86.601						
14	.458	1.831	88.431						
15	.417	1.668	90.099						
16	.394	1.577	91.676						
17	.375	1.500	93.176						
18	.320	1.281	94.456						
19	.280	1.121	95.578						
20	.251	1.006	96.584						
21	.240	.962	97.546						
22	.141	.564	99.436						
23	.141	.564	100.000						

Extraction Method: Principal Component Analysis

- Eigenvalue = 1.457 ≥ 1 and extracted 6 factors that have the best information summary meaning.
- Total variance extracted = 66,699 ≥ 50% shows that the EFA model is suitable. Thus, 6 factors were extracted to summarize 66.19% of the variation of observed variables.

TABLE VI. ROTATION MATRIX OF FACTORS

	Factors					
	1	2	3	4	5	6
CC_3	.814					
CC_5	.809					
CC_2	.808					
CC_4	.754					
CC_1	.715					
CĐT1		.810				
CĐT4		.754				
CĐT2		.736				
CĐT5		.726				
CĐT3		.706				
NT_2			.800			
NT_1			.793			
NT_4			.732			
NT_3			.720			
NV_1				.822		
NV_3				.779		
NV_2				.758		
NV_4				.679		
KH1					.877	
KH2					.862	
KH4					.557	
KH3					.549	
TV3						.841
TV2						.813
TV1						.794

The results of the rotation matrix show that 25 observed variables are classified into 6 factor groups, all observed variables have Factor Loading coefficients greater than 0.5 (Table VII).

TABLE VII. CORRELATION MATRIX BETWEEN EXTRACTED FACTORS

		Y	CC	CĐT	NT	NV	KH	TV
Pearson Correlation	Y	1.000	.165	.370	.297	.272	.487	.282
	CC	.165	1.000	.000	.000	.000	.000	.000
	CĐT	.370	.000	1.000	.000	.000	.000	.000
	NT	.297	.000	.000	1.000	.000	.000	.000
	NV	.272	.000	.000	.000	1.000	.000	.000
	KH	.487	.000	.000	.000	.000	1.000	.000
	TV	.282	.000	.000	.000	.000	.000	1.000

Sig. (1-tailed)	Y	.	.033	.000	.000	.001	.000	.001
	CC	.033	.	.500	.500	.500	.500	.500
	CĐT	.000	.500	.	.500	.500	.500	.500
	NT	.000	.500	.500	.	.500	.500	.500
	NV	.001	.500	.500	.500	.	.500	.500
	KH	.000	.500	.500	.500	.500	.	.500
	TV	.001	.500	.500	.500	.500	.500	.
N	Y	125	125	125	125	125	125	125
	CC	125	125	125	125	125	125	125
	CĐT	125	125	125	125	125	125	125
	NT	125	125	125	125	125	125	125
	NV	125	125	125	125	125	125	125
	KH	125	125	125	125	125	125	125
	TV	125	125	125	125	125	125	125

Results of the correlation matrix between the extracted factors showed that no factors were excluded due to sig < 0.05

Testing the research model - the results of the regression analysis are summarized in Table VIII.

TABLE VIII. RESULTS OF REGRESSION ANALYSIS

Model		The coefficient is not yet normalized		Normalization coefficient (β)	t value	Sig.	Multicollinearity	
		b	Standard error				Tolerance coefficient	VIF coefficient
1	Constant	3.000	.035		86.349	.000		
	CC	.105	.035	.165	2.997	.006	1.000	1.000
	CĐT	.235	.035	.370	6.743	.000	1.000	1.000
	NT	.189	.035	.297	5.410	.000	1.000	1.000
	NV	.173	.035	.272	4.957	.005	1.000	1.000
	KH	.310	.035	.487	8.873	.000	1.000	1.000
	TV	.179	.035	.282	5.134	.000	1.000	1.000

The results of the regression analysis showed that Sig. of the normalized regression coefficients (β) of the variables CC and NV in the model ≥ 0.05, which means that the known CC and NV are not eligible to exist in the model.

The remaining variables include CĐT, NT, KH, TV with Sig. of the regression coefficient > 0.05, which means that there is not enough evidence to reject these independent variables in the model. In other words, these independent variables have statistical significance at 5% significance level. The variance exaggeration factor (VIF) of all the independent variables are < 10, so the phenomenon of multicollinearity, i.e. the phenomenon that the independent variables in the model are linearly correlated with each other, is not serious.

TABLE IX. FISHER TEST - FULL MODEL TEST

Model		Sum of squares	df	Average of squares	F	Sig.
1	Regression	32.196	6	5.366	35.564	**0.000**^{b}
	Residual	17.804	118	0.151		
	Total	50.000	124			

Analysis of variance for the whole model gives results Sig.=0.00 < 0.05, so there is not enough evidence to reject the model. In other words, the model has statistical significance at 5%.

TABLE X. MODEL FIT ASSESSMENT

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.802[a]	.644	.626	.388

Evaluation of the fit of the model shows that the regression model has adjusted R2 = 0.644 > 0.5, so the regression model can be used.

Thus, the multivariable regression analysis shows that the model is built in accordance with the research data and the obtained results are the management and exploitation of abutments in the increasing conditions of climate change in the downstream area of Vam Co river depends on 4 groups of factors. The results of testing and evaluating the model show that there is not enough proof to reject this model. So, the equation of multiple regression is as follows:

Unnormalized regression equation:

*QLKT = 3.000 + 0.235*CĐT + 0.189*NT + 0.310*KH + 0.179*TV* *(1)*

Normalized regression equation:

*QLKT = 0.487*KH + 0.370*CĐT + 0.297*NT + 0.282*TV* *(2)*

In which:

CĐT: Investors

NT: Maintenance contractors

TV: Consulting contractors

KH: Climate change

The multiple regression equation has confirmed the authors' hypotheses, specifically as follows:

- Confirming hypothesis 2: Coefficient β_2 = 0.370>0, so the group of factors about the investors has an impact on the exploitation management of the bridge abutment in the increasing conditions of climate change in the lower Vam Co river area;
- Confirming hypothesis 3: Coefficient β_3 = 0.297>0, so the group of factors about maintenance contractors have an impact on the exploitation management of the bridge abutment in the increasing conditions of climate change in the lower Vam Co river area;
- Confirming hypothesis 5: Coefficient β_4 = 0.282>0, so the group of factors about consulting contractors have an impact on the exploitation management of the bridge abutment in the increasing conditions of climate change in the lower Vam Co river area;
- Confirming hypothesis 6: Coefficient β_1 = 0.487>0, so the group of negative factors of climate change has an impact on the exploitation management of the bridge abutment in the increasing conditions of climate change in the lower Vam Co river area;

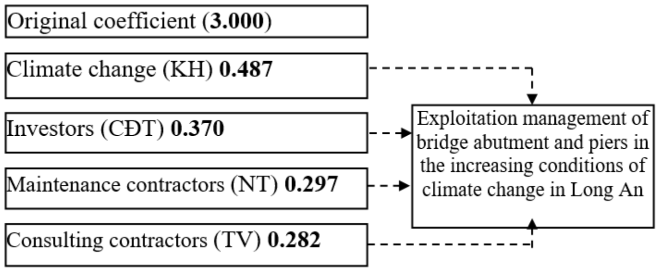

Figure 8. Regression model

In which:

- The factor of climate change (KH) has a coefficient of 0.487, indicating that when this factor increases by 1 unit, the exploitation management of abutments in the lower Vam Co river area will increase to 0.487 units.
- Factor of the investors (CĐT) has a coefficient of 0.370, indicating that when this factor increases by 1 unit, the exploitation management of abutments in the lower Vam Co river area will increase to 0.370 units.
- The construction contractor factor (NT) has a coefficient of 0.297, indicating that when this factor increases to 1 unit, the exploitation management of abutments in the lower Vam Co river area will increase to 0.297 units.
- The consulting contractor factor (TV) has a coefficient of 0.282, indicating that when this factor increases by 1 unit, the exploitation management of abutments in the lower Vam Co river area will increase to 0.282 units.

III. SOLUTIONS TO MINIMIZE THE IMPACTS OF CLIMATE CHANGE ON THE SYSTEM OF ABUTMENTS AND BRIDGES IN THE LOWER VAM CO RIVER AREA, LONG AN PROVINCE

A. Solutions to minimize the impact of climate change on the system of bridge abutments and piers in the downstream area of Vam Co river, Long An province

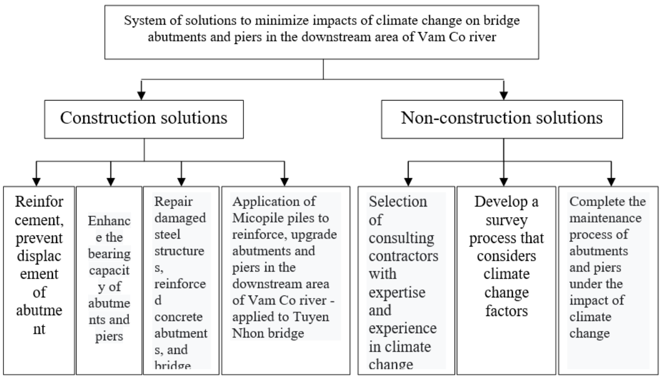

Figure 9. System of solutions to minimize impacts of climate change on abutments and piers in downstream area of Vam Co river

B. Construction solutions

1. Reinforcement, prevent displacement of abutment

The abutment displacement due to the impact of rain and storm can cause changes in flow, leading to abutment slippage. From practical experience and technical principles of anti-displacement abutment, some solutions are suggested as Figure 10 [11] [12].

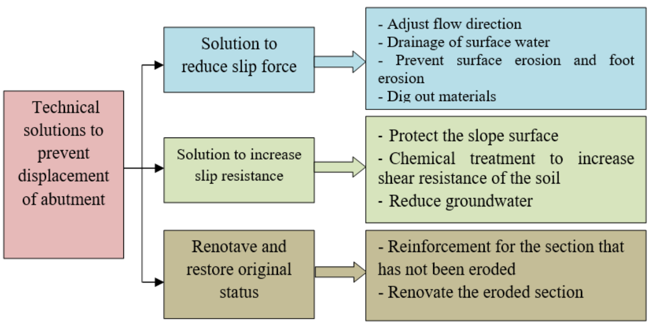

Figure 10. Technical solutions to prevent displacement of abutment

- Solution to reduce sliding force: According to the Southern Federation of Water Resources Planning and Investigation, the downstream area of Vam Co river has a characteristic that the flow is very complex. As a result, it is easy to wash away the riverbed sediment, riverbanks and around abutments, piers, causing local erosion in the area of bridge abutments and piers. Therefore, adjusting the flow direction to prevent local erosion leading to displacement of the abutment system can be considered if the actual site conditions can be implemented.

- Solution to increase slip resistance:

+ Protect the slope surface: in order to prevent the development of landslides, methods to protect the slope surface can be considered such as using gabion mats, tangled rock, melaleuca poles, bamboo, etc.

+ Underground drainage: it is possible to arrange more horizontal drainage pipes to increase the shear resistance and reduce the horizontal pressure acting on the retaining wall.

+ Chemical treatment to increase the shear resistance of the soil: it is possible to apply new materials for treatment to increase the shear resistance of the soil in the slip arc.

- Renovate and restore the current status: conduct surveys and assess the current status of the downstream area of Vam Co river to have information to propose solutions for reinforcement on the following principles:

+ For the section that has not been eroded, it is possible to consider keeping the current status and reinforce it in combination with the implementation of displacement monitoring.

+ For the part that has been eroded: consider restoring the current state or renovating the work.

Besides, in order to avoid the situation that the retaining wall in front of the abutment is missed or displaced, leading to the risk of collapse of the entire structure, the study proposes measures to strengthen the retaining wall in front of the abutment to ensure the stability of the system as follows [13]:

- Adding rows of piles to form cross-linked reinforced concrete in front of the abutment retaining wall.

- Add more fixed reinforced concrete piles to the reinforced concrete panels to keep the retaining wall in front of the abutment stable. It is noted that the reinforced concrete pile tip needs to be plugged into the good soil layer and the driving depth needs to be carefully calculated to ensure it can withstand lateral load from earth pressure behind retaining wall.

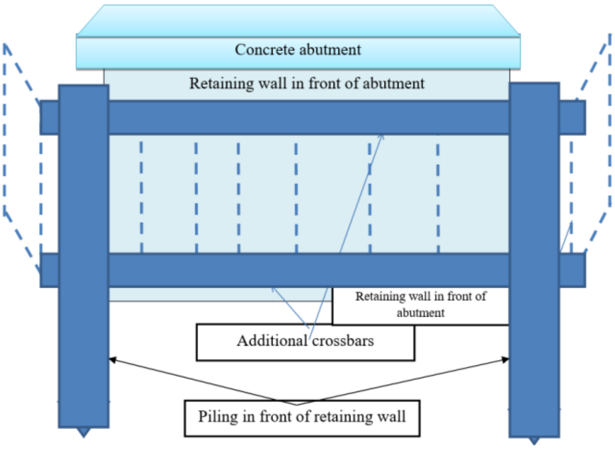

Figure 11. Simulation of abutment and retaining wall in front of abutment, avoiding abutment displacement

2. Enhance the bearing capacity of abutments and piers

a) Increase the bearing capacity of the abutment

Strengthen the abutment by placing rocks behind the abutment instead of the old soil [11] [12].

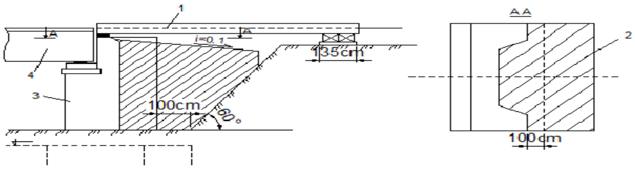

Figure 12. Strengthen the bearing capacity of abutment. 1) Temporary girder span structure for vehicles to pass through during repair; 2) New stone blocks are placed behind the abutment to reduce horizontal pushing pressure; 3) Walls in front of the abutment; 4) Span texture.

Strengthen the abutment by adding struts (a) adding a barrier in front of the abutment (b), (c).

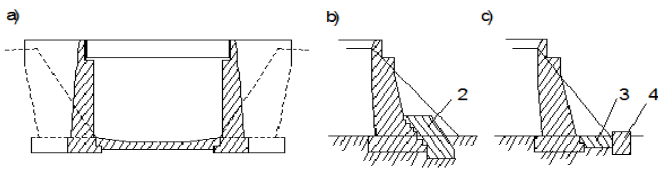

Figure 13. Strengthening the bearing capacity of abutment. 1) The strut between the foundations of two abutments; 2) Forts; 3) Struts; 4) Forts.

b) Increase the bearing capacity of the pier

Concrete wrapping method: This method is to create a layer of reinforced concrete with a thickness of 10-15 cm around the old cylinder body throughout the height of the cylinder body to increase the bearing area for the cylinder body.

Method of using high-strength FRP material: This method uses high-strength FRP material to wrap around the cylinder body vertically and horizontally to increase the bearing capacity of the cylinder body and inhibit hip expansion of concrete and increase the bearing capacity of the concrete body.

The method of using a steel cover: Increase the bearing capacity of the cylinder body by wrapping the steel shell around the cylinder body [11] [12].

c) Increase bearing capacity of pile foundation structure

Common types of damage to pile foundation structures include:

Figure 14. Strengthening the bearing capacity of the pile foundation structure

Concrete pile: Corrosion leads to damage to the protective concrete, reducing the bearing capacity of the pile.

Steel pile: Corrosion reduces the bearing cross-sectional area of the pile, reducing the bearing capacity of the pile.

- Method of covering concrete: creating a layer of reinforced concrete of 10-15 cm thick around the old pile body throughout the pile height to increase the bearing area for the pile. Augmented results in reality as shown in Figure 15.

Figure 15. Strengthening the bearing capacity of pile and column foundation

- Method of using prefabricated FRP sheet: using prefabricated FRP sheet as formwork, then pour epoxy-based concrete to fill the gap between the FRP sheet and the existing concrete of the pile. The bearing capacity of the pile is significantly increased due to the use of high-strength materials in the casing and the increase in the compressive capacity of the concrete by inhibiting the expansion of the concrete.

- Method of using prefabricated FRP sheet:

Figure 16. Using prefabricated FRP sheet (a). Prepare the FRP sheet; (b) Construction of FRP sheets; (c) Fixing and finishing the FRP sheet; (d) High strength grout pump, (e) After finishing

Figure 17. Actual results of using enhanced prefabricated FRP panels

- The method of adding piles applies to the case that the abutment foundation of the bridge is not capable of bearing the additional piles:

Figure 18. Addition of piles applies to the case that the abutment foundation of the bridge in the downstream area of Vam Co river is not able to bear the load and additional piles are needed.

d) Concrete is peeling, cracking, reinforcing steel is exposed and corroded

The general method to repair this phenomenon is: chisel away all damaged concrete, compensate reinforcement if necessary, clean the surface of both concrete and reinforcement then pour polymer mortar, polymer concrete or normal concrete. Based on the method as well as the material to decide whether to stop the vehicles or still allow the vehicles to circulate at a limited speed during the construction period.

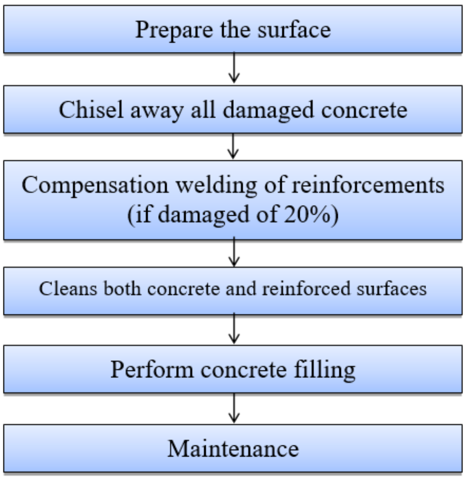

Figure 19. Steps to repair peeling and cracking of concrete

C. Non-construction solutions

1. Selection of consulting contractors with expertise and experience in climate

The authors recommend the following contents as Figure 20.

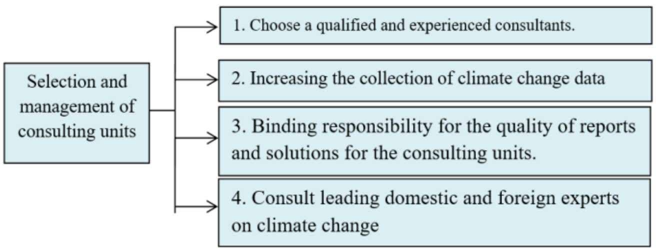

Figure 20. Selection and management of survey and design consultants [14]

2. Developing a survey process in the context of increasing climate change

The process of survey and maintenance in the exploitation phase is carried out similar to the normal survey. However, in order to further consider the impact of climate change on the abutment of the bridge during the exploitation phase, the authors propose to add the following tasks:

- The alignment needs to avoid landslides, floods, large flows, etc.
- The plan of bypass, temporary bridge to ensure traffic during construction or operation of works when there is an incident.
- Survey consultants must be responsible for the results of experiments and surveys.
- Solutions suitable for reinforcement for critical locations.
- Survey similar constructions nearby to prevent the impact factors from floods, landslides, etc.

3. Complete the maintenance process of abutments and piers under the impact of climate change

In order to maintain the abutment and pier systems in a timely manner under the impact of climate change, and at the same time to meet the objectives of effective management and exploitation activities, this study proposes a process as shown in Figure 21.

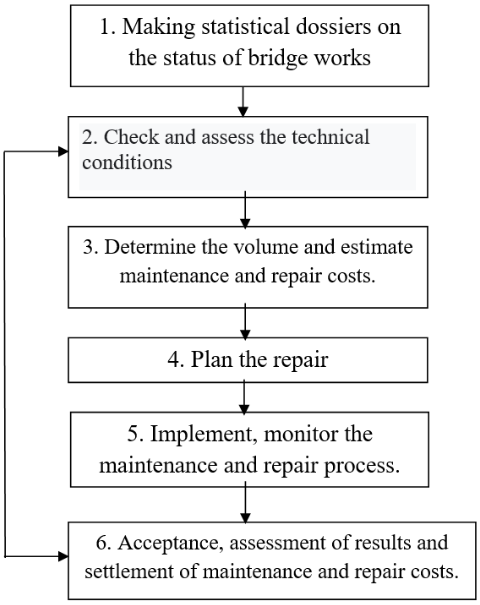

Figure 21. Process of management and repair of abutments and piers due to climate change impacts [15] [16]

IV. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

This study analyzed and evaluated the obtained results and drew the following conclusions:

1. Abnormally occurring extreme weather events, in which temperature increases, heavy rains, high tides, sea level rise, saltwater intrusion, etc., with increasing

frequency and intensity, have caused great influence on the abutment system during the exploitation phase.

2. This study has built an econometric model showing the influence of factors on the management of abutment exploitation in the context of increasing climate change in the lower Vam Co river with 6 groups of factors. The main influencing factors are mechanisms, policies, investors, maintenance contractors, maintenance capital sources, consulting contractors and negative impacts of climate change. Conduct a survey to evaluate their effects, obtain the standardized regression equation as:

*(Exploitation management) QLKT = 0.487*KH + 0.370*CĐT + 0.297*NT + 0.282*TV*

From the above equation, it can be seen that the variable KH (climate) has the greatest influence, followed by the variable CĐT (investors), NT (maintenance contractors) and TV (consulting contractors).

This helps the exploitation management units, the maintenance contractors and the consultants to re-evaluate their own capacity and experience, oriented to improve their capacity and experience in exploitation management in climate change conditions. Strongly apply management technology, advanced exploitation technology to the management and exploitation of abutments in order to improve the efficiency and quality of bridge construction management and exploitation in the downstream area of Vam Co river in Long An province.

3. On that basis, the authors have proposed structural and non-structural solutions to cope with and minimize damage to abutments caused by climate change impacts.

B. Recommendations

- Increase investment in construction, supplement and complete solutions to ensure smooth operation and traffic order and safety in the current climate change situation.
- Develop regulations on coordination between traffic management and operation agencies and the authorities of Long An province.

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