

**MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT
VIETNAM INSTITUTE OF
METEOROLOGY, HYDROLOGY AND CLIMATE CHANGE**

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**RESEARCH ON ASSESSING THE ROLE OF DETERMINANTS
AFFECTING CLIMATE CHANGE ADAPTIVE CAPACITY OF
DA NANG CITY BY STRUCTURAL EQUATION MODELING
(SEM)**

Subject: Climate change

Code number: 9440221

SUMMARY OF DOCTORAL THESIS ON CLIMATE CHANGE

HA NOI – 2022

The thesis was completed at:

Viet Nam Institute of Meteorology, Hydrology and Climate Change

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The thesis will be defended before the Doctoral Dissertation Judging Committee at the Viet Nam Institute of Meteorology, Hydrology and Climate Change in a meeting at:

Time:

Date: 2022

The thesis can be found at:

PRE-FACE

1. Importance of carrying out the research

According to the Report of the Global Climate Risk Index 2020 of “Germanwatch” [53], Viet Nam ranks 6th in the 10 countries most affected by climate risks from 1999 to 2018. Climate change is one of the biggest global challenges for humanity in the 21st century. It is an existential threat to the sustainable development goals (SDG) of all countries and regions. In Viet Nam, the coastal area is the area most at risk and vulnerable due to climate change. Increasing climate risks are creating great pressures on the resource-based livelihoods of coastal communities. Therefore, improving the capacity to adapt to climate change for the most vulnerable communities, regions and countries is a necessary condition to reduce the vulnerability and a foundation of sustainable development [69]. It helps develop a sustainable society to ensure the livelihoods of communities with the capacity of adapting to climate change. Therefore, the relationship between sustainable livelihoods and abilities of climate change adaptation of coastal urban areas is close. Determining the role of livelihood resources on abilities of climate change adaptation of coastal urban areas needs to be built based on the perspective of climate change adaptation associated with sustainable development. It is necessary to develop abilities of climate change adaptation based on livelihood resources since livelihood resources are the "internal resources" of people, which is the central factor and the core basis for livelihood activities to adapt to climate change. Currently, the Structural Equation Modeling (SEM) is popularly applied in research around the world and Viet Nam in the fields of psychology, sociology, education, and management, and customer needs of the service industries to analyze and evaluate the relationship and the influential role of indicators and factors in these fields [15], [18], [33], [63], [74]], [79]. With the advantage of being able to calculate measurement bias in a combination of measurement bias analysis techniques in one model [29], [30] the SEM has overcome the limitations of the traditional calculation methods to improve and enhance the reliability of the calculation results [30]. Therefore, it is essential to conduct a research namely "Research on assessing the role of factors affecting the capacity to climate change adaptation of Da Nang city by the Structural Equation Modeling (SEM) method" because of scientific and practical urgency to respond to climate change and sustainable socio-economic development in coastal areas.

2. Research objectives

(1) Research and propose a set of indicators affecting the abilities of climate change adaptation of Da Nang city based on sustainable livelihoods;

(2) Research and select SEM to assess the role of determinants affecting the abilities of climate change adaptation of Da Nang city;

(3) Evaluation of the role of determinants affecting the abilities of adaptation of Da Nang city, the high and middle-income households, and the poor and near-poor households with climate change.

3. Objects and scope of research

The object is determinants affecting the capacity of climate change adaptation of Da Nang city.

The scope of the geographical study is the entire 7 district units of Da Nang city including Hai Chau district, Lien Chieu district, Son Tra district, Ngu Hanh Son district, Thanh Khe district, Cam Le district, Hoa Vang district;

The scope of the research time is 2014 based on the survey results of a research on the National Science and Technology.

4. Research questions

(1) What is the scientific and practical basis for proposing a set of climate change adaptation indicators of Da Nang city?

(2) What is the scientific and practical basis for selecting the SEM method to assess the role of determinants affecting the climate change adaptation of Da Nang city?

(3) What are the results of the assessment of the role of determinants affecting the climate change adaptation of Da Nang city, the high and middle-income households, and the poor and near-poor households with climate change?

5. Defensive points

(1) Point 1: The set of indicators affecting the adaptation capacity of Da Nang city is proposed based on the approach of IPCC 2014, DFID's livelihood resources including infrastructure, society, nature, finance, human resources, and 17 indicators for the city's natural - economic - social - livelihood development conditions.

(2) Point 2: The SEM method can ensure the calculation of the role of determinants affecting the adaptation capacity to climate change and at the same time, minimize the calculated measurement bias. The assessment results using this method show that infrastructure and natural determinants have a great impact on the adaptation capacity of Da Nang city and the high and middle-income households. Financial determinants have a significant impact on poor and near-poor income households.

6. Research content

To achieve the set objectives, the research contents of the thesis include:

- Research overview on the set of adaptation indicators and the set of indicators on adaptation capacity with climate change (including determinants affecting the capacity of climate change adaptation), methods to assess the role of determinants affecting adaptation capacity to identify the determinants affecting the capacity of climate change adaptation, experience in the selection of determinants and indicators; identify domestic and international experiences in using methods to assess the role of impact determinants on climate change and the applications of SEM methods;
- Research and propose a set of indicators on the capacity of climate change adaptation of Da Nang city;
- Research and select SEM method to evaluate the role of determinants affecting the capacity of climate change adaptation of Da Nang city;
- Assess the role of determinants affecting the capacity of climate change adaptation of Da Nang city, the high-middle income households and the poor and near-poor income households and climate change;
- Propose interventions to improve the capacity of climate change adaptation.

7. Scientific and practical significance of the thesis

Scientific significance: Establish a scientific and practical basis in proposing a set of indicators on the capacity of climate change adaptation of Da Nang city based on sustainable livelihood resources; Improve the reliability of the calculation results to identify the role of determinants affecting the capacity of climate change adaptation of Da Nang city and minimize measurement bias in the calculations; Prove that the SEM method is an effective, objective and reliable method in quantifying the role of determinants affecting the capacity of climate change adaptation of Da Nang city.

Practical significance: Propose a set of indicators on the capacity of climate change adaptation of Da Nang city to consider and evaluate the role of determinants affecting the city's capacity of climate change adaptation, and to apply to other coastal cities; Assessing the role of determinants affecting the capacity of climate change adaptation of Da Nang city, the high - middle-income households and the poor and near-poor income households and climate change. This result creates the basis for the development of strategies, policies, and solutions to climate change adaptation proper to the local natural - economic - social - livelihood conditions.

8. Novel contributions of the thesis

- Propose a set of indicators on the capacity of climate change adaptation of Da Nang city based on integrating sustainable livelihoods with climate change and under the natural - economic - social - livelihood characteristics of the city.

- Select and apply the SEM method on climate change to assess the role of determinants affecting the capacity of climate change adaptation of Da Nang city.

- Assess the role of determinants affecting the capacity of climate change adaptation of Da Nang city, the high-middle income households and the poor and near-poor income households, and climate change.

9. Structure of the thesis

The thesis is organized as follows:

Pre-face

Chapter 1. Overview of impact determinants, set of indicators on adaptability to climate change. This chapter will introduce some concepts related to the research; overview of studies in the world and Viet Nam on climate change adaptation indicators; the determinants affecting the capacity of climate change adaptation; method to evaluate the role of impact determinants in the field of climate change and some applications of the SEM method.

Chapter 2. Research methods, research area, and database. This chapter will introduce the research methods used in the thesis, the study area, and the data used in the study.

Chapter 3. Assess the role of determinants affecting the climate change adaptation of Da Nang city. This chapter will present the main research results achieved by the thesis, including the scientific and practice basis for proposing a set of indicators on climate change adaptation for Danang city; the scientific and practical basis for selecting the SEM method to assess the role of determinants affecting the city's central economy with climate change. The results of the assessment of the role of determinants affecting the city's capacity of climate change adaptation results on accessed roles of the high-middle income households and the poor and near-poor income households and climate change; proposing solutions to improve the city's capacity of climate change adaptation, high - middle-income households and the poor and near-poor income households and climate change.

Conclusions and recommendations

References and Appendix

CHAPTER 1. OVERVIEW OF IMPACT DETERMINANTS, SET OF INDICATORS ON CAPACITY OF CLIMATE CHANGE ADAPTATION

1.1. Some concepts

- "Climate change is a change in the climate state in comparison to the middle and/or climate variability that persists over a long period, often decades or longer" [69]. Climate change manifests in many different forms, but the common feature is the change of climate compared with the previous relatively stable state in a certain trend. Specific manifestations of climate change include increased temperature, changes in humidity, rainfall, sea-level rise, and more frequent extreme weather events with greater intensity.

- Capacity of climate change adaptation is the ability of a system to self-adjust to climate change to mitigate potential damages, take advantage of opportunities, or cope with consequences [69]; or an adjustment of a natural or human system to a changing situation or environment to reduce vulnerability and take advantage of the opportunities it brings [2], or society's capacity to change in a way that makes it better equipped to manage risks or sensitivities from the effects of climate change [87].

- Sustainable livelihoods are livelihoods that can respond to and recover from impacts or can promote capabilities and assets both now and in the future, while not eroding the foundation of natural resources [57], [58].

- Criteria/determinants of the capacity of climate change adaptation are the quantities constituting the capacity of climate change adaptation, therefore the criteria/determinants of the capacity of climate change adaptation must reflect the characteristics of the capacity of climate change adaptation in a clear, non-abstract, easy-to-read manner, understandable and appropriate with international standards.

- Indicators of the capacity of climate change adaptation are quantitative values of the capacity of climate change adaptation and are described with the content and natural nature of the determinants constituting the capacity of climate change adaptation.

1.2. Status of research on climate change adaptation indicators

1.2.1. In the world

Indicators related to climate change adaptation are used to monitor and evaluate the effectiveness of climate change adaptation activities and climate change adaptation-related policies [13].

Indicators can serve different purposes of monitoring and evaluation. According to the literature review, it is not possible to measure the adaptation of a natural environment or a natural system directly, it should be measured through adaptation indicators and based on the *characteristics of the natural system which is resilienced to climate change* [77].

The study on "Indicators of Climate Change Adaptation for the Natural Environment" of the UK Environment Commission indicates a set of climate change adaptation indicators for the natural environment including indicators of crop diversity and land cover, common bird species, landslides, coastal habitat creation, natural ecological status, surface and groundwater, air quality, urban green space [77].

The study on "Tracking the adaptation process in the agricultural sector by climate change adaptation indicators" of the United Nations Food and Agriculture Organization has shown a set of indicators to monitor the adaptation process in the agriculture field including determinants of natural resources and ecosystems, a system of agricultural products, socio-economic determinants, and institutional and policy [61].

Research on "Indicators to Guide and Monitor Climate Change Adaptation in the US Pacific Northwest" by Annie Doubleday has developed a set of climate change adaptation indicators to monitor climate change adaptation activities at local and national health agencies in the United States. The set of indicators includes elements such as cooperation and sharing; information system; justice; resources; ability to prevent and respond to climate change [43]

1.2.2. In Viet Nam

In the study on "Development of a set of indicators of climate change adaptation to serve the state management on climate change" by Huynh Thi Lan Huong, the set of indicators to assess the current status of adaptation and the effectiveness of adaptation activities including indicators of the resilience of the natural environment, indicators of vulnerability, indicators of risk reduction due to climate change [13].

The report on "Climate-adapted livelihoods for Viet Nam, assessment criteria and case studies" introduced a climate change response model that was evaluated based on four criteria including climate change adaptation, mitigation of greenhouse gas emissions, sustainability, reproducibility [6].

A study on "Developing a set of criteria to evaluate the effectiveness of district-level economic models adapting to climate change in the Mekong

Delta, a case study at a typical district" [8] has pointed out six evaluation criteria. including socio-economic efficiency, socio-culture, climate change adaptation ability, environmental protection, management, and replication [8].

1.3. Research status on determinants affecting the capacity of climate change adaptation

1.3.1. In the world

The set of indicators on the capacity of climate change adaptation has not been developed universally worldwide for national, regional, and household scales. Recent studies have shown as follows:

For the national scale, the capacity of climate change adaptation depends on the determinants as follows: welfare and stability of the economy, demographic structure, general connectivity, resource dependence, stability of education and welfare [41]; adaptive motivations, nature, technology, economic, human and institutions [72]; finance, technology, knowledge, infrastructure, and institutions [83].

For the city scale, the capacity of climate change adaptation depends on the determinants including the economy, technology, information - management - skills, infrastructure, network and institutions, social justice [54]; economic, society, culture, infrastructure - institutional determinants which depend on physiological conditions to be suitable for cereals [82]; ability, willingness, and permission [68];

For the household scale, the capacity of climate change adaptation depends on the following determinants: welfare and stability of the economy, demographic structure, general connectivity, dependence on resources, and quality of households [41]; economic activity, information, technology, society, knowledge, infrastructure [86]; human resources, material resources, financial resources, information and livelihood [56]; economic, social factor, technology, institution, infrastructure, and training - cognitive determinants [87].

1.3.2. In Viet Nam

In Vietnam, in-depth studies on the set of indicators on the capacity of climate change adaptation are still limited, most of the indicators are approached through a set of indicators for assessing vulnerability due to climate change and are considered as a part of this set.

However, recently, research on the model of coastal urban areas with a capacity of climate change adaptation in Viet Nam has focused on the capacity of climate change adaptation and proposed a set of indicators of capacity of climate change adaptation for a city scale. The research's results

have shown that the city's capacity of climate change adaptation is the resilience ability to nature, society and take advantage of development opportunities (transforming challenges into opportunities for development, and mitigating when facing natural disasters climate change) [23].

Research on the determinants affecting the capacity of climate change adaptation of the Tam Giang - Cau Hai Lagoon area, Thua Thien Hue city has shown that the set of indicators on the capacity of climate change adaptation include human, infrastructure, social, natural, and financial determinants [38].

1.4. Overview of methods to assess the role of impact determinants in the field of climate change

1.4.1. Methods for assessing the role of impact determinants in the field of climate change

Until now, the assessment of the relationship of determinants and indicators in the field of climate change has been studied at home and abroad in two directions: 1) Direct - qualitative; 2) Indirect - quantitative.

1.4.1.1. In the world

The study "Using social indicators to measure community vulnerability to the effects of natural hazards" used economic and social survey results to assess vulnerability based on the set of indicators and collected data, then conduct a descriptive analysis of all indicators through survey questionnaires and interviews [71].

Research on "the capacity of climate change adaptation of farmer households in the Philippines" using the Analytical Hierarchy Process (AHP) method with 9 point scales to determine the weights of the components, main indicators, and sub-indicators of the capacity of climate change adaptation in which these components and indicators are transformed into a structure with multiple hierarchies for pairwise comparison at each level [56].

A study by the group of authors from the University of South Africa on "Using AHP analysis method to establish a climate change response model of enterprises" used the AHP method as a multi-criteria decision support method. criteria to respond to climate change of enterprises in South Africa and identify priority issues in addressing climate change of enterprises [50].

A study on "Application of Iyengar - Sudarshan method to assess social vulnerability to drought in South Africa" used the Iyengar - Sudarshan method to calculate weighted values of social vulnerability indicators which have been set [46].

A study on “Vulnerability of farmers household livelihoods due to the effects of extremes and fluctuations of climate change: a livelihood-based approach in the highlands of northeastern Ethiopia” used Iyengar – Sudarshan method with unequal weights to calculate the weights of the vulnerable indicators [39].

The Principal Components Analysis (PCA) method has been used by some authors to make a vulnerability map the of socio-ecosystems in South Africa [23] and to assess the capacity of climate change adaptation of farmer households to climate change for northern Ghana [38]; identify the determinants affecting the selection of private university in Sarawak, Malaysia [45].

1.4.1.2. In Viet Nam

In Viet Nam, the PCA and AHP methods are applied in the authors' studies [8], [16], [23], [22], [27]. In addition, many other studies also used the equal weighting method according to Iyengar - Sudarshan [14], [21], [36] to calculate the impacts of indicators on vulnerability and capacity of climate change adaptation.

1.4.2. Applications of the structural modeling method

1.4.2.1. In the world

Currently, the SEM has been used widely in fields of psychology, sociology, education, and management, especially SEM is also applied in research on psychology and customer needs of the service industries in many countries in the world [15], [18], [33] [60], [63], [79].

The study on "Application of Structural Equation Modeling to develop good teaching forms with Ontogy technique" used the SEM to identify 6 main factors related to teaching including knowledge, materials, presentation skills, teaching equipment technology, analysis, preparation, and 12 indicators describing these factors [79]

The study on "Application of Structural Equation Modeling in ecological studies" used SEM to evaluate complex assumed relationships on cause and effect of ecosystems [60]

The study on "Application of Structural Equation Modeling in the industry: some trends" used the SEM to overcome the limitations of using regression techniques when the dependent and independent variables are continuous. and can be measured [63].

1.4.2.2. In Viet Nam

The study on "Brand's value components: a case study for dragon fruit" used SEM to demonstrate the relationship of brands' value components of dragon fruit in Binh Thuan province. [15]

The study on "Analysis of factors affecting the decision to reuse passenger transport services by routes in Can Tho city" used exploratory factor analysis, confirmatory factor analysis, and linear structural model to show the convenience satisfaction factors that directly and positively affect the decision to reuse [33].

Research on "Assessment of factors affecting strategic management of the Viet Nam's Commercial Banks - An empirical study at the Joint Stock Commercial Bank of Investment and Development of Viet Nam" using SEM with the least-squares approach to indicate that reputation has the greatest influence on strategic management in banks [18].

Through an overview study on the set of indicators of climate change adaptation, the set of indicators of capacity of climate change adaptation, and methods of assessing the role of impact determinants in the climate change field, it has found as follows:

The set of adaptation indicators to monitor and evaluate the effectiveness of climate change adaptation activities and policies related to climate change adaptation includes basic elements constituting adaptation and indicators which reflect the influence between determinants in the concept of climate change adaptation.

The capacity of climate change adaptation is complex quantities and difficult to define absolutely. The determinants and indicators that reflect the capacity of climate change adaptation will vary among countries, regions, localities, communities, and households. The selection of a set of indicators of capacity on climate change adaptation depends on the objectives, objects, and scope of the research space.

Studies have used different methods either directly or indirectly to assess the role of impact determinants in the field of climate change. The experience of the authors has shown that selecting methods to calculate the role of impact determinants should depend on the research's objectives and problems with appropriate adjustments if needed to improve the reliability of the bias calculations in the evaluation methods.

The SEM method is effective in evaluating complex relationships between determinants and indicators with high reliability. However, until now, this method has not been studied and applied in the field of climate change.

The analysis shows that there are still some shortcomings that the thesis will focus on solving as follows:

- The scientific and practical basis based on the sustainable livelihood approach has not been established to propose a set of indicators on the capacity of climate change adaptation of Da Nang city, the high-middle income households, and the poor and near-poor income households and climate change.

- The role of determinants affecting the capacity of climate change adaptation of Da Nang city, the high-middle income households and the poor and near-poor income households and climate change has not been assessed by the SEM method.

CHAPTER 2. RESEARCH METHODS, RESEARCH AREA, DATA USED

2.1. Research Methods

2.1.1. Structural Equation Modeling method

Recently, the SEM method is an effective method to evaluate complex relationships between determinants and indicators with high reliability. However, until now, this method has not been studied and applied in the field of climate change. Therefore, the author used the SEM method to analyze the relationship of the indicators and factors and the relationship among the factors affecting the capacity of climate change adaptation of Da Nang city. Thereby assessing the role of factors affecting the capacity of climate change adaptation of Da Nang city, the high-middle income households and the poor and near-poor income households and climate change. Based on the results of weighted regression estimation of infrastructure, natural and social factors, financial and human resources for the city, the high-middle income households, and the poor and near-poor income households to build a linear regression equation describing the relationship between the factors affecting the capacity of climate change adaptation of these subjects.

2.1.2. Exploratory Factor Analysis method

Exploratory Factor Analysis (EFA) belongs to the group of interdependent multivariate analysis, ie there is no dependent variable and independent variable, but it relies on the correlation between variables. The EFA method helps the researcher to evaluate to select indicators.

2.1.3. Confirmatory Factor Analysis method

The Confirmatory Factor Analysis (CFA) method is one of the techniques that allow testing how well the indicators represent the factors. CFA is the next step of EFA. CFA method is one of the techniques that allow testing representative indicators for factors. The methods of EFA and CFA are used to identify indicators of capacity on climate change adaptation which can explain and describe their correlation relationships.

2.1.4. Methods of data collection, statistics, and synthesis

Methods of collecting, statistic, and synthesizing documents are used to review domestic and international studies on the contents related to the factors and indicators of capacity on climate change adaptation.

2.1.5. Expert consultation

The expert consultation method is considered an important and effective method to mobilize the experience and knowledge of an interdisciplinary group of experts in the field of research, thereby giving appropriate practical and scientific results.

2.1.6. Interview method

The purpose of the interview method is to collect information about the study area to make a preliminary assessment of the study area and information from representatives of households in Da Nang city randomly selected for developing the scale, completing the questionnaire and analyzing, evaluating, and explaining the research problems more specifically.

2.2. Research area

Da Nang city is a coastal city in the Central region that is developing very strongly both in terms of urban space expansion and socio-economy. But the city is also strongly affected by climate change such as widespread flooding, increasing salinity, and prolonged drought. The livelihoods of most of the city's population are in the field of agriculture, aquaculture, fishing, tourism, etc. Therefore, the author selected Da Nang as the representative city for the research area.

2.3. Used database

The thesis used labor rate, population structure, labor productivity, geographical location, infrastructure, natural conditions, total middle income, the economic structure of the city [7] to serve the introduction of the study area. Survey information and data in household representatives for communes in districts are used to propose and modify the set of indicators of and evaluate the role of factors affecting the capacity on climate change adaptation of Da Nang city, the high and middle-income households, and the poor and near-poor income households with climate change. The selection of households is surveyed based on population density, districts with a high density of households will be selected more samples. The selection of wards/communes and households and interviewers ensures objectivity by drawing lots or selecting a random list.

CHAPTER 3. ASSESSMENT OF THE ROLE OF FACTORS AFFECTING TO DA NANG CITY'S CAPACITY OF CLIMATE CHANGE ADAPTATION

3.1. Scientific and practical basis for proposing the indicators of capacity on climate change adaptation of Da Nang city

3.1.1. Scientific basis for proposing a set of indicators of the city's capacity on climate change adaptation in Da Nang city

The policies of the Viet Nam's Party and Government have been strongly affirmed in their guiding documents on "Perspectives on responding to climate change to ensure sustainable livelihoods" specifically: Directive No. 05-CT/ TW dated on June 23, 2021, Resolution No. 25/2021/QH15 dated on July 28, 2021, Resolution No. 120/NQ-CP dated November 17, 2017. Previous studies have also shown that climate change is strongly affecting livelihoods and causing serious vulnerabilities to livelihoods, especially the livelihoods of the poor and people in coastal cities. Therefore, climate change adaptation is associated with sustainable development and development of climate change adaptation abilities towards changing the behavior of society to ensure sustainable livelihoods of the city. Climate change adaptation capacities need to rely on livelihood resources. Through livelihood resources, a close dependence relationship between sustainable livelihoods and climate change adaptation abilities of the city will be seen. The thesis has based on the approach of IPCC 2014 and DFID 2007 on factors affecting climate

change adaptation abilities, impacts of climate change on livelihoods, and sustainable livelihood resources [58], [70]. Five factors of climate change adaptation abilities were chosen including infrastructure, nature, human, society, and finance. To select the indicators on climate change adaptation abilities, the thesis has relied on the characteristics of nature, socio-economic, vulnerable livelihoods of Da Nang city and practical experiences in developing indicators on climate change adaptation abilities developed and tested by prestigious organizations in some studies [23], [58], [82]. The detailed explanations on the selection of the city's indicators on climate change adaptation abilities are presented in Section 3.1.2.

3.1.2. Practical experience to propose a set of indicators on the capacity of climate change adaptation for Da Nang city

International and domestic experience has shown that capacity on climate change adaptation are complex quantities and it is difficult to define it. Indicators reflecting the elements that make up the capacity for climate change adaptation will vary across countries, regions, localities, communities, and households. The proposal of a set of indicators on adaptive capacity on climate change depends on the size, object, and scope of the research space.

The studies on the indicators of climate change adaptation abilities for the city scale [23], [82] show that the technical infrastructure is reflected through the electricity system indicators including the supplied amount of electricity, the capacity of electricity; the water system includes supplied quantity of water and the quality of supplied water [82].

Social factors can be reflected through indicators of support of the community and local government [42], [82].

The human factor is reflected through the exchange of experience and information to respond to climate change [knowledge 23], [82], skills [58].

The financial factor is reflected by the income and livelihood diversity and the livelihood index [23], [82].

Natural factors are reflected through livestock production, cultivation, fishing, and aquaculture in response to changes in the natural environment under the impact of climate change [23].

The scientific and practical based on those factors and indicators show that the city's adaptive capacity will include infrastructure, natural, social, human, finance factors. 17 indicators from I1 to I17 are summarized in Table 3.1.

Table 3.1: The set of indicators of climate change in Da Nang city

| Determinants | Indicators | Definition | Source |
|---------------------|----------------------------------|---|-------------------------|
| Infrastructure | I7: Water supply | Level of meeting water demand | Remy Sietchiping (2007) |
| | I8: Water quality | Level of satisfaction on water quality | Remy Sietchiping (2007) |
| | I9: Electricity supply | Level of stability of electricity source | Remy Sietchiping (2007) |
| | I10: Electricity Capacity | Level of electricity capacity assurance | Remy Sietchiping (2007) |
| Production /Nature | I11: Cultivation | The role of cultivation in climate change adaptation | Mai Trong Nhuan (2015) |
| | I12: Livestock Production | The role of livestock production in climate change adaptation | Mai Trong Nhuan (2015) |
| | I13: Aquaculture | The role of aquaculture in climate change adaptation | Mai Trong Nhuan (2015) |
| | I14: Fishing | The role of fishing in climate change adaptation | Mai Trong Nhuan (2015) |
| Society | I4: Community's Support | Community's Support to Respond to Climate Change | Remy Sietchiping (2007) |
| | I5: Government's support | Social support to respond to climate change | Remy Sietchiping (2007) |
| | I6: Participation | Involvement in idea contribution to local policies on climate change response | Remy Sietchiping (2007) |
| Finance | I15: Household Income | Role of household income in Climate Change Adaptation | Remy Sietchiping (2007) |
| | I16: Livelihoods Diversification | The role of Livelihoods Diversity on Climate Change Adaptation | Remy Sietchiping (2007) |
| | I17: Livelihoods | Role of Livelihoods with adaptive capacity on Climate Change | Mai Trọng Nhuan (2015) |

| | | | |
|-------------------------------------|--------------------------|---|--|
| Human Resources | I1: Knowledge | Tracking information on Climate Change Response | J. Hamilton-Peach & P. Townsley (2002) |
| | I2: Experiences Exchange | Exchange of information on climate change response | J. Hamilton-Peach & P. Townsley (2002) |
| | I3: Skills | Climate Change Adaptation Skills | J. Hamilton-Peach & P. Townsley (2002) |
| Adaptive Capacity on Climate change | I18 Knowledge of nature | Feelings when hearing information about weather and natural disasters | Mai Trong Nhuan (2015) |
| | I19 Adaptive Capacity | Feelings of Adaptability | Mai Trong Nhuan (2015) |
| | I20 Knowledge on society | Perceptions of the city's policies | Mai Trong Nhuan (2015) |

3.2. Scientific and practice basis of selecting the SEM method to assess the role of factors affecting the climate change the adaptive capacity of Da Nang city

The basis for conducting the tests in the EFA and CFA methods to ensure the reliability of the research hypothesis is the set of indicators on the adaptive capacity on climate change of Da Nang described in Section 3.1. That set of indicators includes infrastructure, nature, society, human, finance factors, and 17 indicators from which to see the scientific basis of the hypothesis on the relationship between factors and the adaptive capacity of Da Nang city with climate change.

The characteristics of the measurement model and the SEM are as follows: The measurement model to show the statistical relationships among climate change adaptive capacity indicators. The SEM identifies the links and relationships of factors and climate change adaptive capacity.

Experience of many studies of Viet Nam and foreign countries on the evaluation of the relationship of factors and impact indicators has also shown that it is necessary to limit measurement bias in the calculation process and improve reliability in determining the role of impact factors.

3.3. Assess the role of factors affecting the adaptability of the city to climate change

3.3.1 The EFA for infrastructure, natural, social, human, financial factors and adaptive capacity to climate change of the city

3.3.1.1. The EFA for infrastructure, natural, social, human, and financial factors

KMO test results in EFA analysis with KMO coefficient = $0.755 > 0.5$. Bartlett's test results are: 11,374 with significance level of $\text{sig} = 0.000 < 0.05$. Total variance extracted = $76.017\% > 50\%$. Eigenvalues > 1 for 5 factors including infrastructure, natural, social, human, and finance. Therefore, the results of EFA analysis show that the research data used for EFA analysis is completely appropriate and the observed variables are convergent. By continuing to check the reliability of EFA analysis by Cronbach's Alpha analysis for 5 factors including infrastructure natural, social, human, financial, and 17 indicators from I1 to I17, the results of Cronbach's reliability analysis alpha indicates that the indicators on adaptive capacity on climate change are arranged into each group of factors, which is appropriate. All the indicators of adaptive capacity with climate change are accepted and used.

3.3.1.2. The EFA for adaptability factor

KMO test results in EFA analysis with the KMO coefficient is $0.663 > 0.5$. The result of Bartlett's test is 1341.496 with a significance level of $0.000 < 0.05$. The total variance extracted is $73.289\% > 50\%$, showing that the research data used for EFA analysis is completely appropriate and the observed variables are convergent. By continuing to test the reliability of Cronbach's Alpha for adaptive capacity, the results show that the scale used for 3 variables I18, I19, I20 to study the factor of adaptive capacity is appropriate and all observed variables are accepted and used.

The results of EFA analysis for the above 5 factors including infrastructure, natural, social, human, financial, and adaptive capacity factors, show that the data used in the study is completely consistent and ensures convergence. Therefore, the data can continue to use CFA analysis based on the AMOS software to test the relationship between the indicators with 5 factors and the adaptive capacity.

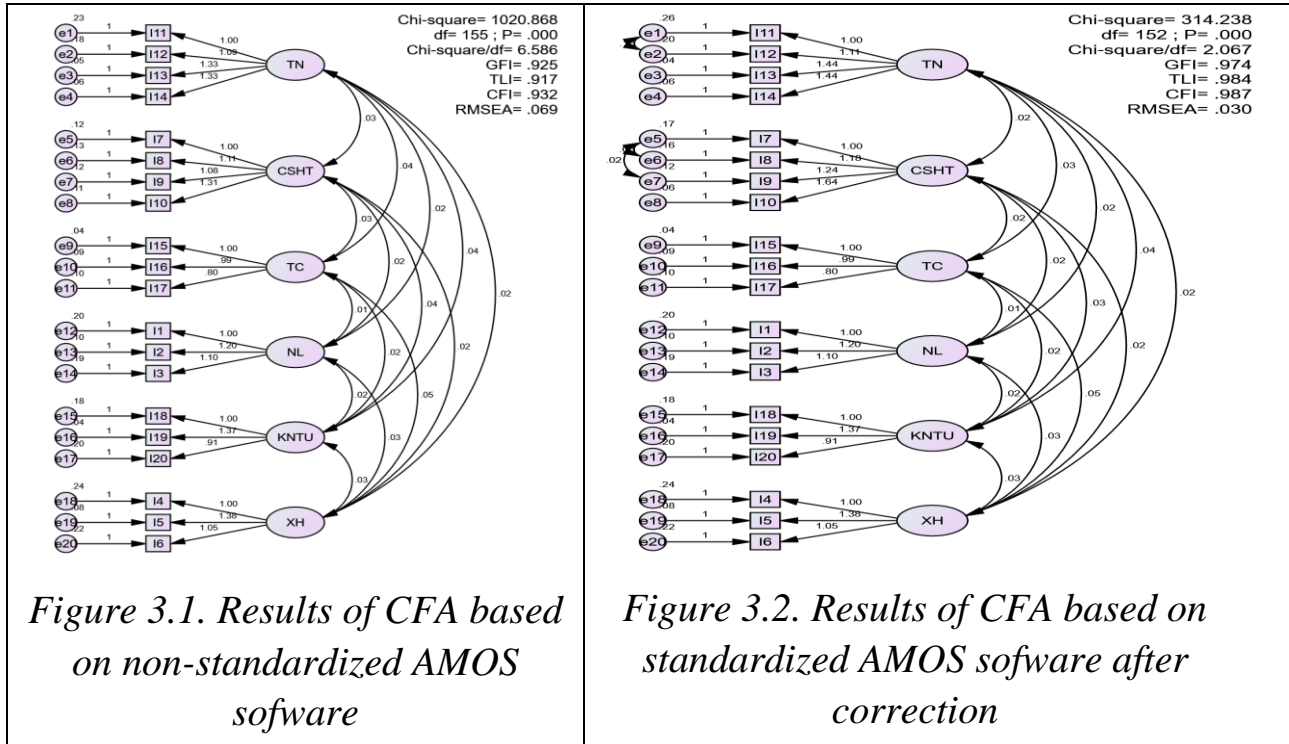
3.3.2. The CFA based on AMOS software for infrastructure, natural, social, human, financial, and climate change adaptive capacity factors

3.3.2.1. CFA on the unnormalized structural model

The results of the CFA analysis on AMOS software (Figure 3.2) show that the RMSEA index = $0.069 > 0.05$ and the Chi-square/df (cmin/df) = 6.586

> 5, the CFA analysis results from this model are not really good (for test details in Appendix 2). Therefore, the author uses the MI index to improve the fit of the model, with the pair with the highest MI then re-estimates the model until the inspection criteria followed [51] are satisfied (Figure 3.3).

3.3.2.2. The CFA based on standardized AMOS software



The results (Figure 3.3) show: Chi-square = 314,238 (p-value = 0.000); Chi-square/df = 2,067 < 5; GFI = 0.974, TLI = 0.984, CFI = 0.987 are all greater than 0.9 and RMSEA = 0.03 < 0.08. Thus, the model is suitable with the collected data and can continue to be used to quantify the role of factors affecting the city's adaptive capacity on climate change using the SEM.

3.3.2.3. Assess the role of factors affecting the adaptability of Da Nang city to climate change

The standardized CFA analytical indicator framework is used to calculate the role of factors affecting the city's adaptive capacity on climate change in the SEM. The results (Figure 3.4) show: the Chi-square/df index is 2,888 < 5; The GFI of 0.96, the TLI of 0.972, the CFI of 0.976 are all greater than 0.9, and the RMSEA value is 0.4 < 0.5. The results of the combined reliability test (Table 3.8) show that the combined reliability values are all greater than 0.7 and the extracted variance is greater than 0.5. These results indicate that the model has convergent validity. Thus, the calculation results of the SEM can also conclude the role of factors affecting the city's adaptive

capacity on climate change, respectively in the order of infrastructure, natural, or production. However, to ensure the reliability of the SEM's calculation results, the author continues to use Bootstrap test to test 300 different samples in an iterative and alternative manner. From these 300 samples, the computer will estimate 300 pairs of estimated coefficients and calculate the middle of those estimates. The difference between the estimate from the original sample and the mean value of the estimates from Bootstrap is called the deviation. The smaller the deviation is, the better accuracy is achieved.

The result of the difference between the estimated value and the mean value has very small and the absolute value and the reliability critical value is less than or equal to 2 (Table 3.9). The results of the very small deviation have shown that the model has 95% confidence.

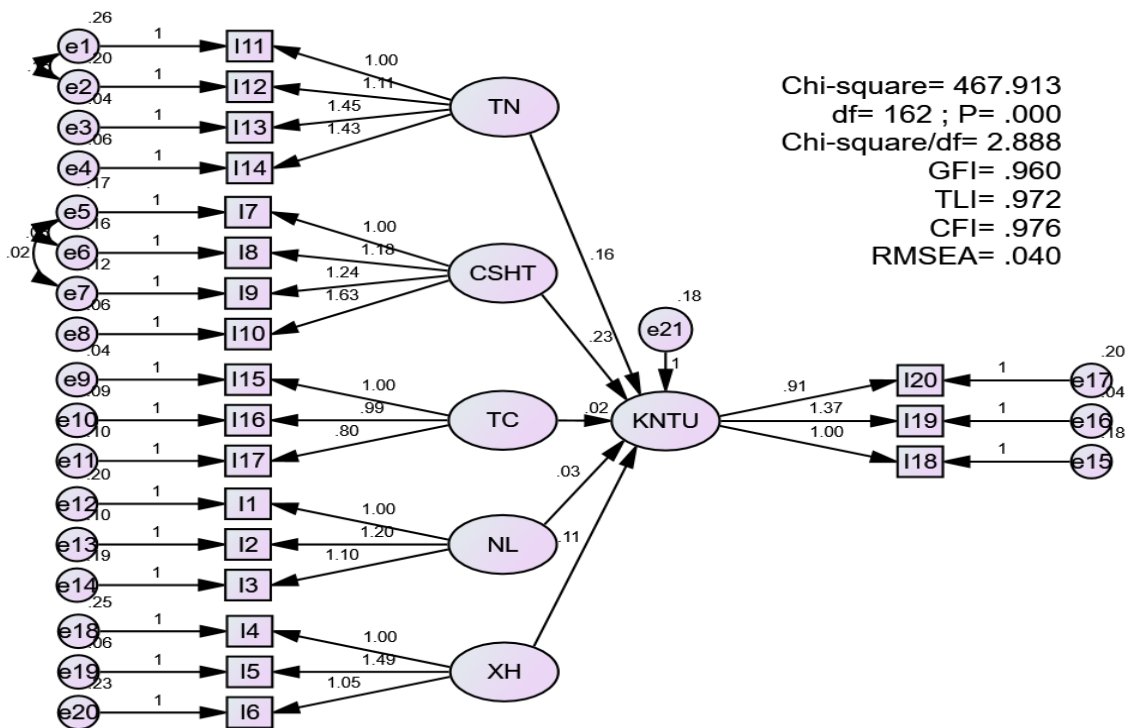


Figure 3.3. Results evaluating the influence of factors on the city's capacity on climate change adaptation in the SEM.

Infrastructure and natural factors have a great influence on the city's capacity for climate change adaptation. The results of calculating the weights of the factors affecting the city's capacity on climate change adaptation from the SEM (Table 3.10), the author has built a linear regression equation showing the role of influencing factors as follows:

$$\text{Adaptive Capacity (city)} = 0,182 \times \text{Infrastructure} + 0,152 \times \text{Nature} + 0,091 \times \text{Society} + 0,035 \times \text{Human resources} + 0,020 \times \text{Finance} \quad (3.1)$$

3.3. Assessing the role of factors affecting the adaptive capacity of the high and middle-income households in the city

In this part, the author continues to test EFA, CFA, SEM, and the city's set of indicators on climate change adaptation (Table 3.1) to evaluate the role of factors affecting the adaptive capacity on the high and middle-income households.

The data are selected from a survey of 948 households in the city based on the local criteria of the high and middle-income households in 2014 and self-assessed by households. The survey questionnaires were conducted in June 2014. The calculation results show as follows:

The results of developing a linear regression equation to assess the adaptive capacity of the high and middle-income households are as follows:

Adaptive Capacity (the high and middle-income households) as follows:

$$= 0,178 \times \text{Infrastructure} + 0,169 \times \text{Nature} + 0,113 \times \text{Society} + 0,021 \times \text{Human resources} + 0,024 \times \text{Finance} \quad (3.2)$$

The EFA, CFA, and tests in the SEM obtained the results that the infrastructure and natural factors (production is consistent with nature) have a great influence on the adaptative capacity on climate change of the high and middle-income households. The role of factors affecting the adaptative capacity on climate change of the city and the high and middle-income households tends to be almost the same since most of the interviewed households in Da Nang city thought that they were high and middle-income households and this perception of the household was consistent with the results of the socio-economic report in the 2014 Statistical Yearbook of the city.

3.4. Assessing the role of factors affecting the adaptability of the poor and near-poor households in the city to climate change

In this section, the author continues to use the EFA, CFA, SEM, and the set of indicators on the capacity of climate change adaptation (Table 3.1) to evaluate the role of factors affecting the adaptive capacity on climate change of the poor - near-poor households of the city.

The data are selected from a survey of 220 city households based on the local criteria of near-poor and poor households in 2014 and are self-assessed by the households. The survey questionnaires were conducted in June 2014 to the city.

The results of developing a linear regression equation to assess the adaptive capacity of poor - near-poor households with climate change are as follows:

Adaptive capacity (poor - near-poor households) = $0,152 \times \text{Finance} + 0,096 \times \text{Human resources} + 0,055 \times \text{Infrastructure} + 0,031 \times \text{Nature} + 0,006 \times \text{Society}$ (3.3)

The tested EFA, CFA, and calculated SEM obtained the results that financial factors have a great influence on the adaptive capacity on climate change of poor - near-poor households in the city.

The results of the linear regression equations (3.1), (3.2), (3.3), the results of the SEM model parameters (Figure 3.4, Figure 3.7, Figure 3.10) show that: infrastructure and nature factors have a great impact on the adaptive capacity on climate change of high and middle-income households. Financial factor has an important role in the adaptive capacity of climate change in poor - near-poor households.

3.5. Proposing some solutions to improve adaptability to climate change

3.5.1. Solutions for development and usage of infrastructure

The target group is Da Nang city, high and middle-income households. They need to apply solutions to develop and use infrastructure including 1) Exploiting and using effectively electric energy and groundwater by seasons, regions, and population groups; 2) Transforming operation model of electricity and clean water supply services; 3) Sustainable development of household water supply activities suitable to each type and group of communities. Based on the research results, the infrastructure factor has a great influence on the capacity on adapting to climate change of the city and the middle-income households. Therefore, for this target group, infrastructure solutions need to be more focused and prioritized. Local authorities need to have preferential policies to support capital, technology, and resources to create incentives for this target group to actively invest in equipment that uses water efficiently, uses energy effectively, and renewable energies. For production enterprises, private seafood production, and processing enterprises, small-sized household shrimp farms can invest in clean electricity production systems and water filtration and recycling systems, etc

3.5.2. Solutions to develop nature-based production

The solution to developing nature-based production is also proposed to be applied to cities and high and middle-income households, including 1) Developing fisheries to adapt to climate change, including offshore fishing fleets with large capacity and modern techniques; 2) Developing production processes to adapt to climate change, clean production towards applying organic production processes;

3.5.3. Financial Solutions

For the poor and near-poor households, financial solutions are important solutions that need to be proposed in the city's policies including 1) Ensuring stable livelihoods with a focus on climate change adaptation through loan support, resource support, seed and seedling technology, preservation technology, freezing, and farming techniques, land, boats, cages to create motivation to help the poor and near-poor households to develop cultivation, husbandry, fishing and aquaculture activities based on high technology to increase the proportion of food production, clean and high-quality food; building and investing in smart technologies with climate change; converting plant varieties that are resistant to climate change, applying effective irrigation measures, and developing linkage models in the production and supply chain of agricultural products. Transforming forms of fishing and aquaculture; improving means of fishing, aquaculture, etc; 2) Diversifying livelihood activities to adapt to climate change by supporting initial loan sources and supporting information on business methods and professional experiences; increase training and vocational classes for laborers; carry out migrations and labor export; create conditions and encourage the participation of poor and near-poor households in the development of services, local tourism, etc.; 3) Promote the increase of people's income to diversify their livelihoods; supporting loans to focus on investment and production recovery is a direct, timely and effective solution for people when natural disasters occur; limit spending to have proactive savings to prevent natural disasters and respond to climate change.;

3.5.4. Solutions to develop human resources and improve skills

Likewise, the solution to developing human resources and improving skills is also an important solution to improve the adaptive capacity of the poor and near-poor households including 1) Monitoring and forecasting; 2) Exchange and providing information; 3) Adaptive practice; 4) Sharing experiences in production to adapt to climate change.

3.4.5. Social solutions

The adaptive capacity of the high and middle-income households with climate change is improved when more social solutions are applied, namely: 1) Access to local government support; 2) Community solidarity and mutual support; 3) Enhance participation and comments on local policies on climate change response.

CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSION

1. The set of indicators of capacity on climate change adaptation of Da Nang city is determined based on scientific and practical materials as follows: IPCC's approach on adaptive capacity with climate change 2014, and DFID 2007; National and international experience in determining the city's factors and indicators on the capacity of climate change adaptation; Natural - economic - social - livelihood characteristics of Da Nang city. The proposed set of indicators on the capacity of climate change adaptation of Da Nang city includes 5 factors consisting of infrastructure, nature (nature-based production), human resources, finance, society, and 17 indicators.

2. The SEM method was selected based on the structure of the indicator set on the capacity of climate change adaptation in Da Nang; Scientific basis of the SEM method; The experience of studies of Viet Nam and foreign countries on assessment of the relationship of factors and indicators affecting climate change. The SEM method has been selected to evaluate the role of factors affecting the adaptive capacity of Da Nang city, the high and middle-income households, the poor, and near-poor income households with climate change.

3. The results of applying the set of indicators on the capacity of climate change adaptation of Da Nang city and the EFA, CFA, and SEM show that:

- Infrastructure and natural factors (nature-based production) have a great influence on the adaptive capacity of Da Nang city with climate change and are expressed through the linear regression equation as follows:

$$\text{Adaptive Capacity (city)} = 0,182 \times \text{Infrastructure} + 0,152 \times \text{Nature} + 0,091 \times \text{Society} + 0,035 \times \text{Human resources} + 0,020 \times \text{Finance}$$

- The infrastructure factor, natural factor (production is suitable for nature), has a great influence on the adaptive capacity of the high and middle-income households in Da Nang city with climate change and is shown by the linear regression equation

$$\begin{aligned} &\text{Adaptive Capacity (the high and middle-income households) as follows:} \\ &= 0,178 \times \text{Infrastructure} + 0,169 \times \text{Nature} + 0,113 \times \text{Society} + 0,021 \times \\ &\text{Human resources} + 0,024 \times \text{Finance} \end{aligned}$$

- The financial factor has a great influence on the adaptive capacity of the poor and near-poor income households in Da Nang city with climate change and is shown by the linear regression equation as follows:

Adaptive Capacity (poor and near-poor households) = $0,152 \times \text{Finance} + 0,096 \times \text{Human resources} + 0,055 \times \text{Infrastructure} + 0,031 \times \text{Nature} + 0,006 \times \text{Society}$

4. It is necessary to apply some of the following solutions to improve the economic growth of Da Nang city, and high and middle-income households with climate change including 1) Development and use of infrastructure to i) Exploiting and using effectively electricity and groundwater between seasons, regions and population groups; ii) Transforming the operating model of electricity and clean water supply services; iii) Sustainable development of household water supply activities suitable to each type and group of population communities; 2) Development of nature-based production including i) Development of climate change adaptation fisheries, including a large and modern offshore fishing fleet; ii) Development of production processes adapted to climate change, clean production, and then apply organic production processes; In addition, it is necessary to apply more social solutions. Indeed, the development of an infrastructure network providing stable electricity and water, and at the same time gradually shifting the structure of agricultural and fishery products from small to industrial scale will also contribute to maintaining livelihoods and improve the climate change adaptation capacity of the city, the middle and high-income households, which is a key driver for the development of society, economic growth and innovation.

The adaptive capacity of the poor and near-poor income groups is improved through financial solutions including i) Ensuring stable livelihoods with a focus on climate change; ii) Diversifying livelihood activities to adapt to climate change; iii) Promoting the increase of people's income.

B. RECOMMENDATIONS

Within the framework of the thesis, limited in time and collected data, therefore, the author could not test and evaluate the linear regression equations describing the influence of factors on the city's adaptive capacity, the high and middle-income household, and the poor and near-poor income households of Da Nang city with climate change and test the application of SEM method to assess the role of factors affecting the climate change in other coastal cities, economic zones, coastal tourist area, etc. Therefore, several trials need to be continued in further studies.

LIST OF PUBLICATIONS

1. **Nguyen Bui Phong**, Mai Trong Nhuan, Do Dinh Chien (2020), “Identifying the Role of Determinants and Indicators Affecting Climate Change Adaptative Capacity in Da Nang City, Viet Nam”, *VNU Journal of Science: Earth and Environmental Sciences*, Vol. 30, No.3, pp.70-80.

2. **Nguyễn Bùi Phong**, Mai Trọng Nhuận (2020), “ Researching and recommending the Indicators of Change Adaptative Capacity in Da Nang City, Viet Nam.”, *Journal of Climate Change Sciences*, No 16, pp.76-82

3. **Nguyễn Bùi Phong**, Mai Trọng Nhuận (2021), “Identifying the Role of Determinants and Indicators Affecting Climate Change Adaptative Capacity in poor – nearpoor ‘s Da Nang City, Viet Nam”’, *Viet Nam Journal of HydroMeteorology*, No 721, pp.21-30.