A Meta-model Framework for Long-term Adaptation Planning in Korea

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1. Analysis of Korea's Adaptation Implementation Plans of Local Governments (1st Plan, 2014~2018)

Challenges in identifying, prioritizing, and implementing adaptation plans are intensified according to spatial-temporal conditions but there is little to no guidance on which approach is appropriate for tackling each of these challenges. Ever since South Korea enforced the implementation plan for national, regional and local adaptation in accordance with the "Act on Low Carbon Green Growth", Korean local governments have had the difficult task to understand climate science in its depth and breadth. The purpose of this study is to suggest strategies for decision-support tool developments that can enhance the effectiveness of climate adaptation plans.

First, a review of local "Implementation Plan for Climate Change Adaptation" from each province, identified factors that inhibit effective implementation of adaptation plans were analyzed. Currently, local governments are provided an online support tool for vulnerability assessment, VESTAP. However decision makers did not translate the vulnerability and impact assessments into shaping their goals for adaptation. Instead, the selection process for implementing adaptation measures was based on current policies with no evaluation on the actual effectiveness. Further, prioritization of adaptation measures were decided based on stakeholder input but without an objective and quantified method (Table 1).

These bottlenecks to effective adaptation plan implementation can be interpreted into the following categories identified in previous literatures:

1. Limited assessment of local context (Cash et al., 2002; Dessai et al., 2009)
2. Lack of scientific evidence measuring effect of adaptation measures (Rapley et al., 2014)
3. Inadequate consideration of uncertainties, especially for long-term planning (Vij et al., 2017)

Table 1. Methods for Determining Adaptation Priorities by Sampled Municipalities

Municipality	Vulnerability Assessment	Citizen Survey	Civil Servant Survey	Past Climate Impacts	Expert Evaluation	Other
Gwanak-gu, Seoul	80%		20%			
Dalsung-gun, Daegu	50%	30%	20%			
Namdong-gu, Incheon	√*	√	√	√		
Dong-gu, Gwangju	√				√	√
Seo-gu, Daejeon	√			√	√	√
Dong-gu, Ulsan	√	√	√	√	√	
Pocheon, Gyeonggi	20%	30%	30%	20%		
Taebaek, Gangwon	√	√	√	√	√	√
Hwacheon-gun, Gangwon	√	√	√	√	√	
Cheongju, Chungbuk	√	√	√	√		
Goesan-gu, Chungbuk	20%	25%	25%	10%		20%
Asan, Chungnam	√	√	√			
Yaesan-gun, Chungnam	20%	30%	30%	20%		
Gwangyang, Jeonnam	20%	30%	30%	20%		
Hwasun-gun, Jeonnam	√	√	√	√		
Pohang, Gyeongbuk	√	√	√	√	√	√
Youngyang-gun, Gyeongbuk	√	√			√	√
Gimhae, Gyeongnam	√	√	√			
Sanchung-gun, Gyeongnam	√			√		

* Represents a ratio only if weights are specified. √ is the actual ratio not specified

2. Review of Successful Cases of Adaptation Planning Decision-Support Tools

Strategies to improve adaptation planning includes:

1. Designing methods that identify local adaptive capacity, objectives and priorities adequately
   - *ex) California's adaptation capability advancement toolkit; Adapt-CA*
2. Develop tools that measure the effects of adaptation measures at the local level
   - *ex) PLASK(Project on Local Analysis of the Social-Economics of Climate Adaptation), Denmark*
3. Incorporate scenario-based long-term planning models
   - Below is a review of approaches used for effective long-term planning to incorporate uncertainties

Table 2. Adaptation policy approaches to support long-term climate decision-making

Approaches	Description	Main Characteristics	Key references
Scenarios-based	Key focus on alternatives within a system and set process	Inflexible; case focused, Local, national and global scale	Moss et al., 2010; Vervoot et al., 2014
Real option analysis	Treating a range of adaptation options as 'real options' in the face of uncertainty and evaluating the merits of both action and inaction in this context	Flexible; uncertainty; case focused	Yang &Blyth , 2007; Woodward et al., 2013
Portfolio analysis	Selecting a portfolio of adaptation options rather than single options and exploring which is most effective in terms of return and uncertainty	Flexible; experimental; uncertainty	Beh et al., 2015
Robust Decision Making	Quantitative decision-analytic approach for supporting decisions under conditions of deep uncertainty and informed by stakeholder driven processes	Flexible; uncertainty; stakeholder engagement	Lempert and Groves, 2010; Weaver et al., 2013
Adaptation Pathways	Key focus on policy reflexivity and adaptive nature of it. Emphasizes policy and transformational change; conceptually and theoretically in experimental phase, but some empirical evidences at local scale available	Flexible; reflexive; time-oriented; experimental; focuses on incremental change; deep uncertainty	Butler et al. 2016; Wise et al., 2014; Hassnoot et al., 2013

Adapted from Vij et al. (2017) and McDermott and Surminski (2018)

3. Meta-Model Framework: Identify optimal adaptive pathways using quantified assessments of adaptation options

For t = 2010

A. Identification of optimal adaptation sequence pathways

1a. Goal Setting

- Climate Impacts → *39 days of extreme heat × 0.02 increase annually*
- Local Adaptive Capacity → *Limited budget, 4 climate change experts*
- Adaptation Goals → *Identified based on risk +/or vulnerability assessment*

2. Problem Formulation

I. Planning horizon, t = 90 years
II. Staging interval, *20 years*
III. Objective functions
   - *ex) Min. damage (50%) from multi-hazards, Min. deaths (30%) from extreme heat*

IV. Constraints, *budget = $50M*
V. Prioritization of goal, *multi-hazard 80%, extreme heat 20%*

1b. Assessment of Adaptation Options

Location × Time

Implementation degrees of Adaptation Option A

Implementation degrees of Adaptation Option B

×

- Environmental Assessment Model
- Safety Assessment Model
- Health Assessment Model
- Cost-benefit Analysis Model

→ Landslide risk change by option, location, time

→ Heat stroke patients change by option, location, time

3. Determine Optimal Sequence

There are 8 scenarios that satisfy the constraint function and objective. However the constraint and objective function have a tradeoff relationship where lower cost options may be less effective. These relationships can be explored using heuristics based multi-objective optimization algorithms. Recent applications of these algorithms for adaptation planning include Kwakkel et al. (2015) and Beh et al. (2017)

B. Performance assessment of optimal adaptation pathways

4. Performance Assessment using metrics

The reliability of each scenario's adaptation effect is evaluated using a performance metric. An example of a performance metric includes, the probability of an adaptation option successfully adapting to impacts

5. Assessment of the sustainability and macro-economic effects of Adaptation Pathways

Long-term plans should incorporate the principles of sustainability, for both socio-economic benefit and equitable planning. Sustainability of adaptation plans can be assessed using the SDG framework, and ensure that benefits are distributed equally with attention to most vulnerable groups.

$t = t + 10$

Is t = 2100? — No → $t = t + 10$; Yes → STOP

C. Selection of Adaptation Pathway

Pathways must be assessed against their different uncertainties, a methodology and strategy for expressing the data must be developed in further research

4. Expected Results: Adaptation pathways

Problem Formulation

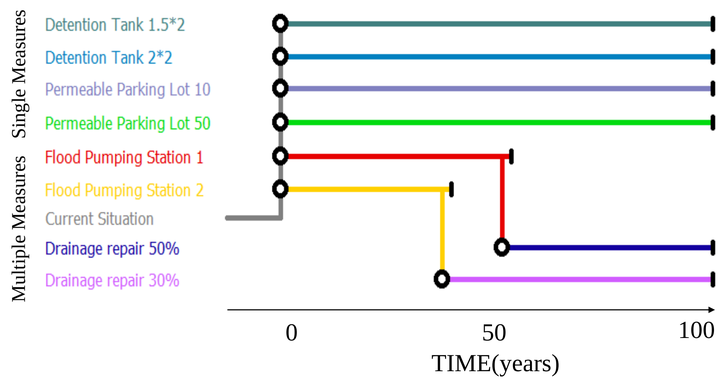
For municipality A = $w_1\left(\alpha_{1_{ij}}, \alpha_{2_{ij}} \ldots \alpha_{n_{ij}}\right) + w_2\left(\beta_{1_{ij}}, \beta_{2_{ij}} \ldots \beta_{n_{ij}}\right) + w_3\left(\gamma_{1_{ij}}, \gamma_{2_{ij}} \ldots \gamma_{n_{ij}}\right)$

α, β, γ = *Flood pumping, Drainage repair, Permeable parking lot*

$i = cost$, j = adaptation option's effect

w_1, w_2, w_3 = priority weights between options

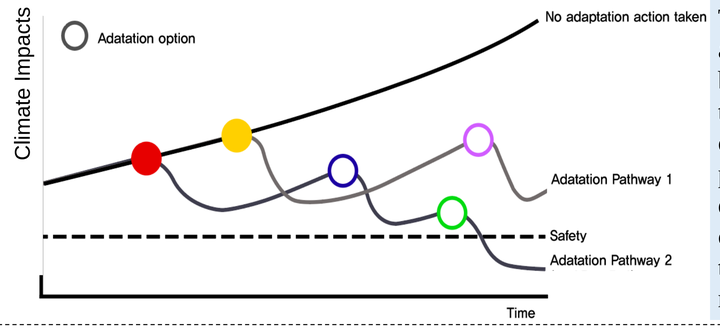
Assessment of Adaptation Options and Sequencing



	discharge	cost
Detention Tank 1.5*2	-20%	10
Detention Tank 2*2	-30%	15
Permeable Lot 10	-35%	25
Permeable Lot 50	-50%	50
Flood Pumping 1	-10%	8
Flood Pumping 2	-15%	15
Drainage repair 50%	-10%	5
Drainage repair 30%	-5%	3

A scorecard of each adaptation options cost and effect

Selection of Adaptation Pathway



The final product of this approach is not a single best solution, but a map that shows the diverse set of robust candidate pathways. The actual decision-making process can then focus on translating this adaptation map into a plan of action.

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