# ANALYSIS AND CLASSIFICATION OF ADAPTATION TOOLS FOR TRANSPORT SECTOR ADAPTATION PLANNING

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**Abstract.** Climate change is an upcoming and unavoidable challenge that all critical infrastructures including transport sector will have to face. Although transport sector and its network substructures are typically designed to withstand weather-related stressors, shifts in climate patterns will greatly increase potential risks. The area of climate adaptation planning is relatively new, however a variety of processes and methodologies for assessing and reducing the vulnerability to climate change are currently being developed. These processes require and benefit from the use of geo-spatial analyses, software tools and web portals. In this paper, we have focused on climate-related adaptation planning. We provide detailed classification of a set of tools that can facilitate adaptation assessment and risk planning. Our goal is to present a multi-faceted taxonomy and analysis of available Climate Change Adaptation tools that can support Transport Sector develop risk management policies.

**Keywords:** Adaptation planning, transport adaptation tools, climate change, tools classification.

## 1 Introduction

Recent modeling studies indicate that climate change is inevitable and our society will have to deal with over coming decades. According to IPCC [1], global warming will have significant implications in climate, population and ecological health, economic development and social stability. Gradual global temperature increase, sea level rise and rainfall regimes along with the projected increase in frequency and intensity of extreme weather events will seriously challenge transportation substructures.

Transport is characterized as a Critical Infrastructure (CI) that supports the smooth functioning of society's prosperity and economy's viability worldwide [2]. Most transport substructures being built today are expected to last for decades or even centuries. Integrating adaptation into the design of new and upgraded substructure can enhance stability and life span, while minimizing unplanned outages, failures and maintenance costs [3].

In this research, we have focused on climate-related adaptation planning and we provide detailed information about a set of tools that facilitate adaptation assessment and risk management. We have examined available Climate Change Adaptation tools, with a goal

to present a detailed classification and analysis for tools which can support transport sector. The term "tool" has been used to describe a wide variety of planning processes, policies, and analytical approaches, focusing on software and web-based applications that help incorporate data geophysical, environmental or socioeconomic into the planning process.

The rest of this paper is structured as follows. Climate adaptation and planning process is presented in Section 2. Adaptation tools analysis takes place in Section 3, followed by a sort description for each one. The main contribution of our paper, is in section 4 where adaptation tools are analyzed and classified in several ways: i) according to type categories and target audience; ii) according to Sectors affected and Climate Impacts; iii) Adaptation Planning Steps; iv) Software Tools Functionality & Mode of Use; v) Strengths and Weaknesses analysis. Section 5 concludes with the analysis of classification results.

## 2. Climate Change Adaptation

*Climate Change Adaptation* is the evolutionary process of adjusting to new conditions, stresses and natural hazards that result from global warming effects. Thus, adaptation consists of actions responding to current and future climate impacts and vulnerabilities, not only protecting against negative impacts of climate change, but also building resilience and taking advantage of any benefits, it may bring. [1]

Either adaptation can be a spontaneous, autonomous process that takes place depending on existing capacity which is-called '*adaptive capacity*', or it can be well planned and designed. Planned adaptation can take many forms and be driven by decision makers and by policies on a macro scale as well as locally by stakeholders involved. Both autonomous and planned adaptation may require additional outside support in terms of knowledge, financing and technology. According to UKCIP [4] adaptation responses and decisions can be categorized as measures and strategies that contribute to: (i) Build adaptive capacity with knowledge spread (i.e. research, data collection and monitoring, awareness raising); (ii) Create supportive social structures (i.e. organizational development, working in partnership), and supportive governance (i.e. regulations, legislations, guidance); (iii) Identify adaptation actions which help to reduce vulnerability to climate risks, or to exploit opportunities. These three categories reflect the range of adaptation strategies from which a good adaptation assessment can be developed.

Although the field of climate adaptation planning is still relatively new, a variety of processes and approaches are emerging in order to assess and reduce vulnerabilities of CIs to climate change. These processes and approaches require or benefit from the use of geospatial analyses and methodology tools. Basic steps of Adaptation planning processes, as depicted in Figure 1, involve:

1. Scope problems, stressors and planning area, information gathering and data inventorying, build working groups and gain stakeholder involvement.
2. Analyze information to elucidate patterns, relationships and potential future outcomes, conduct vulnerability, impact and risk assessment and set priorities.
3. Establish vision and prioritize adaptation strategies, create action plan based on priorities and schedule implementation.
4. Implement and evaluate the effectiveness of plan, seek funding, adjust to unexpected or novel issues or stressors, revise strategies and priorities as needed.


Figure 1: Adaptation Planning Process

Conducting vulnerability and risk assessment is a key analytical step not only for CI protection, as already presented in [5, 6], but also for adaptation planning. Climate change vulnerability assessments identify assets, which may be impacted. In addition, potential sources of vulnerability, risk assessments also consider the likelihood and consequences of potential climate change impacts. Due to the predictive nature of vulnerability and risk assessments, there is a degree of uncertainty in the results [7]. It is important to understand and account for this uncertainty when considering management actions of adaptation, so decision support tools and related software can incorporate data, analyze trends, project evolution and minimize uncertainty issues.

Transport has already dealt with extreme events causing interruptions, stemming from natural hazards and developed strategies to maintain resilience. In previous work [8] we have analyzed adaptation options for transport sector applied worldwide. Moreover US-TRB [9] made the following recommendations: i) Transportation officials should inventory potentially vulnerable critical assets and incorporate climate change into long-range plans for new facilities ii) They should rely on probabilistic techniques to guide decisions and protect assets against the risk and consequences of failure; iii) Research programs should invest in the development of monitoring technologies that can measure stresses and provide warning of potential failures; and iv) Transportation stakeholders should develop procedures to identify and share best practices in managing assets.

The above recommendations highlight the need for mainstreaming available adaptation tools into planning and critical infrastructure protection, as an essential component of a successful and comprehensive climate adaptation.

## 3. Climate adaptation Tools Analysis

The purpose of Adaptation Tools development is to provide the information necessary for stakeholders involved to select appropriate measures and manage risk of their projects. Since there has been an increased demand by governments and international agencies for practical guidance on methods for adaptation assessment, there is a huge development of

analytical tools, which are available to support communities, decision makers and stakeholders [7]. The emerging need for multi-model analysis has driven the creation of adaptation toolboxes, which describe the steps to be undertaken for adaptation and risk management process. They also provide access and information on available methods and models to use in such an analysis. The number of tools and guidelines pertaining to climate change has skyrocketed, driven mostly by international aid agencies and NGO.

In our paper, we have extensively searched for open literature adaptation tools, in order to create a useful pool of tools that can be used for CIs adaptation assessment. Although this selection of tools is not exhaustive, we have distinguished the ones who incorporate transport networks and related critical infrastructures. As a result, 17 tools have been selected and analyzed in our paper. They allow for a broad range of aspects to be evaluated and provide supportive information for adaptation planning projects in transport sector. These seventeen tools are shortly presented below:

1. **BalticClimate Toolkit**: A methodology tool that guides the process of identifying vulnerabilities in the Baltic countries and properly mitigating them [10]. Typical pattern is problem recognition, vulnerability assessment and the mitigation planning. Abbreviation used in our analysis: BALTIC_CLIM_TOOL
2. **Blue Spot Model:** An analysis methodology used to identify roadways vulnerable to flooding [11]. The method is using Geographical Information System environment and has a complete methodology for vulnerability and risk assessment. Abbreviation: BLU_SPOT_MODE
3. **Climate Vulnerability Monitor:** A monitoring tool that assesses vulnerabilities and risks and contains detailed information for projected climate related economic damages, deaths, environmental disasters on 184 countries [12]. Additionally, the tool has aggregated findings and recommendations to support decision makers. Data can be viewed either graphical (world map view) or through a monitor table. Abbreviation: CLI_VULN_MONITOR
4. **Climate Guide: Climate Change Impacts in Finland:** Developed for Finland, where scenarios are built concerning the water resources, potential energy demand and natural ecosystems range from baseline years of 1961-90 to 2099 [13]. Specific climate scenarios are being examined, where observed and projected data are provided for temperature and precipitation, based on different scenarios of carbon emissions. Abbreviation: CLIMATE_GUIDE_FIN
5. **Climada**: A software tool available on Github which uses numerical functions to model economic damages from natural hazards [14]. It is based on scenario building and examines type of hazards, related variables, implemented counter measures etc. It uses natural catastrophe modeling to calculate the impacts and using a simple GUI, it plots assets, damage and benefits on a map. Abbreviation: CLIMADA
6. **ECONADAPT- Toolbox**: A European project, whose purpose is to support adaptation planning, build the knowledge base on the economics of adaptation and provide practical information for decision makers [15]. It is a library of knowledge related to economics of climate adaptation and methodologies used to assess the economic risks and adaptation strategies. Abbreviation: ECONADAPT
7. **Ecocities Spatial Portal:** An interactive platform that displays spatial data and information for understanding climate change vulnerabilities in Manchester area [16]. It provides decision support making and what-if scenarios. Abbreviation: ECO_SPAT_-PORTAL

8. **MACC**: A tool developed by GIZ, which leads project managers through the five steps of the guidebook Adaptation [17]. Each of these steps is monitored by the Excel MACC tool, which provides a spider chart that measures the overall progress of a project of climate adaptation. Abbreviation: MACC
9. **ND-GAIN** (Notre Dame Global Adaptation Index) follows a data-driven approach to show which countries are best prepared to deal with global changes [18]. It informs strategic and operational decisions using data since 1995, to create a rank of 181 countries, measuring vulnerability and readiness. The second part of the tool is a matrix that highlights the relative position of the countries' readiness for adaptation. Abbreviation: ND_GAIN
10. **MOWE-IT:** A project that identified best practices and methodologies to assist transport operators and authorities mitigating the impact of natural disasters and extreme weather phenomena on transport system performance [19]. It is a knowledge database-repository and visualization tool, which includes visualization of climatic scenarios, comparison with various cities climatic scenarios and impact on passenger flows. Abbreviation: MOWE_IT
11. **Stocktaking for National Adaptation**: A tool providing test questions for assessing the country's capacity to perform adaptation [20]. It works as a decision support tool. Abbreviation: SNAP
12. **Sea Level Rise and Coastal Flooding Impacts Viewer**: A visualization tool creating simulations and graphics of current and potential future conditions to understand and envision consequences of different management decisions [21]. It visualizes potential impacts of sea level rise. Abbreviation: SLR_CFI_VIEWER
13. **HAZUS-MH (Hazards US Multi-Hazard): A** risk-assessment methodology for analyzing potential losses from floods, hurricane winds, coastal surge, and earthquakes [22]. Loss estimates can be performed anywhere in USA through damage functions and fragility curves. It uses GIS software to map and hazard data and results of damage and economic loss estimates for buildings and infrastructure. Vehicle and traffic data for transportation sector are available. Abbreviation: HAZUS-MH
14. **NatureServe Vista:** A spatial decision support system for conducting cumulative effects assessment, mitigation planning, and conservation planning [23]. It can help integrate conservation with land use, transportation, energy, and natural resources assessment. Abbreviation: NATURE_VISTA
15. **CommunityViz:** A decision support tool that integrates a variety of analytical models as well as visualization and mapping capabilities to support a variety of planning activities [24]. The software visualizes and analyzes planning and design alternatives and their impacts. It supports scenario building, sketch planning and geodesign, 3-D visualization, suitability analysis, impact assessment, growth modeling etc. It also works as an integration framework connecting to other tools such as Hazus-MH and NatureServe Vista. Abbreviation: COMMUN_VIZ
16. **The Urban Adaptation Support Tool**: A methodology-guide that takes decision makers gradually through the adaptation process [25]. It provides a quick access guide to data relevant to the process and serves as a decision-making support index. Abbreviation: URBAN_ADAPT_TOOL
17. **UKCIP Adaptation Wizard:** A tool for adapting to climate change, by using a 5-step process that will help assessing vulnerability to current and future climate change. It identifies options for adapting to climate risks, and helps developing and implement adaptation strategy [26]. Abbreviation: UKCIP_WIZARD

## 4. Classification of Adaptation Tools

In this section, the main contribution of our paper is presented, where adaptation tools are analyzed and classified in several ways, aiming to facilitate stakeholders to understand which ones better fit to their adaption planning needs. In 4.1 tools are classified according to typology and target audience, in 4.2 classification is dealing with climate impacts and economy sectors affected, then in 4.3 tools are categorized according to adaptation planning steps. In subsection 4.4, software tools are further classified according to their functionality & mode of use. Finally, in 4.5 Strengths and Weaknesses are evaluated.

### 4.1. Classification according to Type of tool and Target Audience

The selected adaptation tools are classified, based on the following three broad categories:

i. *Informative Guidelines:* Tools that offer informational databases on climate change and adaptation planning, through open libraries and repositories, supporting research and knowledge spread.
ii. *Methodologies and Assessments:* Tools that describe climate adaptation though a sequence of steps, which should be followed in order to accomplish a specific task within a larger framework. Vulnerability and risk assessments are also included in this category, to evaluate threats and vulnerabilities.
iii. *Software Tools*: Tools that offer a calculating platform to facilitate user perform a specific task, model a problem, and enhance his experience by visualizing provided information.

Each tool is designed to support different target audience and this information is presented in Table 1. The three main target groups are: (i) Designers & Engineers (D); (ii) Operators & Managers (O); (iii) Policy Makers (P).

| No | Name | Tool Category | | | Target Group |
|---|---|---|---|---|---|
| | | Informative Guidelines | Methodology Assessment | Software Tools | |
| 1 | BALTIC_CLIM_TOOL | X | X | | P-D-O |
| 2 | BLU_SPOT_MODE | | X | | O |
| 3 | CLI_VULN_MONITOR | | | X | P-O |
| 4 | CLIMADA | | | X | D-O |
| 5 | CLIMATE_GUIDE_FIN | | | X | O |
| 6 | COMMUN_VIZ | | | X | P-O |
| 7 | ECO_SPAT_PORTAL | | | X | P |
| 8 | ECONADAPT | X | X | | D-O |
| 9 | HAZUS-MH | | | X | D-O |
| 10 | MACC | | | X | O |
| 11 | MOWE_IT | X | | X | P-O |
| 12 | NATURE_VISTA | | | X | P-D-O |
| 13 | ND_GAIN | | | X | P |
| 14 | SLR_CFI_VIEWER | | | X | P |
| 15 | SNAP | | X | | P-O |
| 16 | UKCIP_WIZARD | | | X | P-O |
| 17 | URBAN_ADAPT_TOOL | X | X | | O |

Where: P = Policy Makers, D= Designers/Engineers/Developers, O= Operators & Managers

**Table 1**: Tools Categories and Target Audience

### 4.2. Classification of Adaptation Tools according to Sectors and Climate Impacts

In Table 2 examined tools have been classified based on geographic scope, affected economy sector and climate impacts. In terms of geographical coverage, there are tools that cover a single state or location, multiple states (e.g., counties belonging to the same continent, like EU, USA, etc.), and finally those who have a global geographic scope. Sectors affected may be urban areas and communities, agricultural activity, transport or energy sector and earth resources with water and other natural assets. In terms of climate impacts, there are various weather-related stressors that may impact transport substructure.

| No | Tool Name | Geographic Scope | Vulnerable Sector | | | | | Climate Impacts | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Urban | Transport | Agriculture | Energy | Water & Resources | Flood | Heat | Cold | Storms | Drought |
| 1 | BALTIC_CLIM_TOOL | MS | X | X | X | X | X | X | X | | | X |
| 2 | BLU_SPOT_MODE | G | | X | | | | X | | | X | |
| 3 | CL_VULN_MONITOR | G | | X | X | X | X | X | | | X | X |
| 4 | CLIMADA | G | X | X | | X | X | X | | X | X | |
| 5 | CLIMAT_GUIDE_FIN | S | | X | X | X | X | X | X | X | X | X |
| 6 | COMMUN_VIZ | MS | X | X | X | X | X | X | X | X | X | X |
| 7 | ECO_SPAT_PORTAL | MS | X | X | | X | X | X | X | | | X |
| 8 | ECONADAPT | G | X | X | X | X | X | X | X | X | X | X |
| 9 | HAZUS-MH | MS | X | X | | | X | X | | | X | |
| 10 | MACC | G | X | X | X | X | X | X | X | X | X | X |
| 11 | MOWE_IT | MS | | X | | | | X | X | X | X | |
| 12 | NATURE_VISTA | G | X | X | X | X | X | X | X | X | X | X |
| 13 | ND_GAIN | G | X | X | X | X | X | X | | | | X |
| 14 | SLR_CFI_VIEWER | MS | X | X | | | X | X | | | | |
| 15 | SNAP | G | X | X | X | X | X | X | X | X | X | X |
| 16 | UKCIP_WIZARD | G | X | X | X | | | X | X | X | X | X |
| 17 | URBAN_ADAPT_TOOL | MS | X | X | | X | | X | X | X | X | X |

Where: G = Global Scope, MS= Multi State Area, S= State

**Table 2**: Tools Categories and target audience

We can distinguish that the majority of tools deal with all climate change impacts and all sectors approach. In addition, the most elaborated weather impact is flood. It is evident that multi sector combined with multi hazard approach tools are most developed, since they provide a holistic support for stakeholders to adaptation planning process.

### 4.3. Classification of Adaptation Tools according to Adaptation Planning Steps

Another key characteristic of tools is how they support their users to planning process. Different tools perform different functions and are useful at different steps in climate adaptation planning, which are: (i) Information, Engagement and Scoping, (ii) Vulnerability Assessment, (iii) Scenario Building, (iv) Adaptation Planning, and (v) Implementation &

Monitoring. A key element for selecting the proper tool for a task is to have a well-identified planning process, so for each tool, we have examined which step of adaptation planning serve and results are listed in Table 3.

| No | Tool Name | Climate Adaptation Steps | | | | |
|---|---|---|---|---|---|---|
| | | Information Engagement, Scoping | Vulnarability Assesment | Scenario Building | Adaptation Planning | Implement & Monitor |
| 1 | BALTIC_CLIM_TOOL | X | X | | X | |
| 2 | BLU_SPOT_MODE | | X | | | |
| 3 | CLI_VULN_MONITOR | X | X | | | |
| 4 | CLIMADA | | X | X | X | |
| 5 | CLIMATE_GUIDE_FIN | X | X | X | | |
| 6 | COMMUN_VIZ | X | X | X | X | |
| 7 | ECO_SPAT_PORTAL | X | X | X | | |
| 8 | ECONADAPT | X | X | | | |
| 9 | HAZUS-MH | | X | X | | |
| 10 | MACC | | | | X | X |
| 11 | MOWE_IT | X | | X | | |
| 12 | NATURE_VISTA | | | X | X | |
| 13 | ND_GAIN | X | X | | | |
| 14 | SLR_CFI_VIEWER | X | X | X | | |
| 15 | SNAP | | | | X | X |
| 16 | UKCIP_WIZARD | X | X | X | X | X |
| 17 | URBAN_ADAPT_TOOL | X | X | X | X | X |

**Table 3:** Tools Classification according to Adaptation Planning Steps

Results showed that the tools which have all steps planning approach are rather limited. In our research, we have found only two tools able to cover all five steps. These tools are Urban Adaptation Support tool and UKCIP Adaptation Wizard.

### 4.4. Software tools classification

Software tools are further classified according to functionality, mode of use and modeling algorithms, as presented in Table 4. They are web-based or standalone applications and they are further classified into three broad categories according to their functionality [7]:

- **Visualization Tools** create simulations based on GIS and graphics of current and potential future conditions to help stakeholders understand and envision potential consequences of different management decisions. They are generally easy to use and do not require specialized software or hardware. Increasingly, they are available via Internet.
- **Modeling Tools** model current and potential future conditions of geophysical and socioeconomic processes. These are generally the most technically challenging tools to use and often require GIS software and appropriate hardware, topical expertise, and training. Models also generally require local data on the process being investigated.

- **Decision Support Tools (DSS)** help develop scenarios of future conditions resulting from potential climate change effects and management decisions. They can help develop "what if" scenarios that allow users investigate a wide variety of management outcomes.

| No | Tool Name | Software Tools | | | Mode of Use | | Modeling algorithms used |
|---|---|---|---|---|---|---|---|
| | | Visualize | Modeling | DSS | Web Based | Download | |
| 1 | CLI_VULN_MONITOR | X | | | X | | Data visualization, WordPress, Javascript Framework (jquery) |
| 2 | CLIMADA | | X | | | X | Probablistic model, Matlab functi-ons |
| 3 | CLIMATE_GUIDE_FIN | X | | | X | | Environmental Data Visualization, OpenLayer maps and Javascript Frameworks (AlloyUI, YUI, jquery) |
| 4 | COMMUN_VIZ | X | | X | | X | 3D Visualization, Realtime predicti-ve model, decision tree |
| 5 | ECO_SPAT_PORTAL | X | | | X | | Environmental and Geophysical spatial data visualization on map, openlayer map, jquery |
| 6 | HAZUS-MH | | X | | | X | Predictive model |
| 7 | MACC | | X | | | X | Excel based tool |
| 8 | MOWE_IT | X | | | X | | Data Visualization, Javascript Fra-meworks and Google Maps |
| 9 | NATURE_VISTA | | | X | | X | Decision tree, predictive model |
| 10 | ND_GAIN | X | | | X | | Data visualization on maps, Java-script Framework (jquery, node.js, D3, backbone.js, underscore.js) |
| 11 | SLR_CFI_VIEWER | X | | | X | | Environmental Data Visualization on map |

**Table 4:** Software Tools classified according to Functionality and Mode of Use

The majority of software applications integrate with existing GIS software and provide user-friendly interfaces and pre-assembled modeling functions. Most visualization tools are web based, while modeling and DSS tools are downloaded applications.

### 4.5. Strengths and Weaknesses of adaptation tools

Finally, after examining tools operation and technical characteristics, we have evaluated strengths and weaknesses of these selected tools, and results are presented in Table 5:

| No | Tool name | Strengths | Weaknesses |
|---|---|---|---|
| 1 | Baltic Climate Toolkit | •It describes guidelines and methodology easy to understand.<br>• Can be used as a model of regional adaptation planning | • Not enough data to make informed decisions.<br>•Example links stopped working. |
| 2 | Blue Spot Model | •Complete protection for any sector and type of hazard.<br>•It can be used for new roads the planning phase.<br>• Potential to expand to other counties | •It requires extensive data related to precipitation, elevation etc. around the targeted road networks |
| 3 | Climate Vulnerability Monitor | •Valuable information for all countries worldwide.<br>• Financial analysis and communication on clim.change.<br>• Policy development guidance & resource allocation | •Data classifications of confidence levels<br>• Uncertainty factor |
| 4 | Climada | • Wide variety of simulated hazards.<br>• Simulation for natural catastrophes, quantifies costs and damages. •The tool is open source<br>• Allows users to write their own modules | •Some modules might not have been thoroughly tested, but core climada works without limitations.<br>• Uncertainty factor |
| 5 | Climate Guide: Clim. Change Impacts | •Comprehensive tool offers a wide range of climate related information.<br>•Can be used in conjunction with the BalticClimate Tool | •Some parts of the tool are available in Finnish only.<br>•Local scope, only for Finland. |
| 6 | CommunityViz | • Interactive and highly visual decision-support tool<br>• Versatile, widely used well supported, and updated<br>• Works as an integration framework connecting to Hazus-MH and NatureServe Vista. | • No built-in data and relatively little built-in modeling.<br>• Uncertainty factor<br>• High cost to obtain |
| 7 | Ecocities Spatial Portal | •Wide variety of scenarios presented on a map<br>• Used as a template to assist vulnerability assessment.<br>• Can be combined with Urban Adaptation tool. | • Very limited scope, covering only the region of Manchester.<br>• Uncertainty factor |
| 8 | EconAdapt | •Rich library of economics of climate change adaptation<br>•Detailed deliverables support decision makers in adaptation process<br>•Easy accessible info on adaptation economic assessment | •Some aspects of the toolbox do not seem to work properly<br>• Uncertainty factor |
| 9 | HAZUS-MH (Hazards-United States-Multi-Hazard) | • Results for large-scale events for planning, mitigation, emergency preparedness and response<br>• Intuitive graphic and tabular formats<br>• GIS software to map hazard and economic loss<br>• Vehicle & traffic data<br>• Allows users to estimate the impacts on populations | • Components of default inventory data may not line up on maps, e.g. bridges and roads<br>• Can run out of memory and fail during coastal floodplain delineation for complex regions |
| 10 | MACC | •Useful manual and tutorial videos<br>•The auto-generated indicator and progress charts<br>• The charts and monitoring data can be exported | • Formula can be deleted or altered<br>• Uncertainty factor |
| 11 | MOWE-IT | •Wide variety of information for different stakeholders<br>•There is a library of good practices and methodologies • Visualization tool offers details for transport network | • Not very detailed analysis on results calculations<br>• Uncertainty factor |
| 12 | NatureServe Vista | • Integrates information from other tools<br>• Covers integration and modeling assessment | • Raster-based platform<br>• Limited scale |

| | | | |
|---|---|---|---|
| | | • Works well with a variety of other tools<br>• Number of conservation elements, objectives, & multiple land-use | • The breadth of functions provided may lead to a slow learning curve<br>• Uncertainty factor |
| 13 | ND-GAIN | •A wide variety of sectors on almost every country.<br>•Comparison methods of countries and explanation.<br>•The tool is updated bi-annually | • Incomplete measures of institutional and governmental capacity.<br>• Uncertainty factor |
| 14 | Sea Level Rise and Coastal Flooding Impacts | • User friendly - GIS analysis for coastal areas<br>• Contains photos and visualize impacts of sea<br>• Diversity of information for different stakeholders. | • Deficient inundation scenarios<br>• Cannot customize outputs |
| 15 | SNAP | •It can be used by a variety of stakeholders and in different projects<br>•It can both lay the groundwork for adaptation as well as assess the adaptation process | •Requires preparation that must be conducted outside the tool and is not supported by it |
| 16 | UKCIP Adaptation Wizard | • Captures information on weather events<br>• It assesses organization vulnerability to climate<br>• Range of tools to help user plan his adaptation strategy | • Does not produce a tailor made climate adaptation strategy at the click of a button |
| 17 | Urban Adaptation Support Tool | •A complete methodology covering all steps<br>•Feedback system helps tool evolution<br>• Covers a wide range of different regions | •It is more focused on municipality-urban levels |

**Table 5**: Strengths and Weaknesses analysis

## 5. Conclusions

Climate change is already occurring, seriously affecting weather stressors. Adaptation has become a necessity for critical infrastructures. Research work has been done to investigate adaptation tools, suitable for transport sector, with emphasis on methodology assessments and supportive applications, that help stakeholders, make prudent decisions about adaptation planning.

Tools are classified based on typology and target audience, activity sectors, climate impacts and adaptation planning steps. Moreover, the software tools are classified according to their functionality and mode of use. The majority of tools are developed to deal with all climate change impacts and have an all sectors approach, in order to provide a holistic support for stakeholders to adaptation planning process.

GIS functionality is incorporated into many decision-making and climate adaptation processes. Seeing that many of the questions raised by climate change planning are landscape-based, they are better addressed by geospatial visualization tools. Stakeholder input throughout the process, is quite critical, since adaptation actions and plans can affect economic prosperity and society's critical services.

Out of the methodology tools examined, the 'Urban Adaptation Support Tool' is a complete methodology-guide, which leads policy makers throughout all adaptation steps, covering all possible climate impacts and the majority of vulnerable sectors. It provides a comprehensive literature database for each step of the adaptation cycle. Also, 'UKCIP Wizard' is effective, as it provides a variety of functionalities to help user plan his adaptation strategy and evaluate organization vulnerability to current and future climate.

As far as software tools are concerned, 'Climada' is the most advanced among European initiatives. It uses probabilistic modeling and projects vulnerabilities along with effective-

ness evaluation of adaptation measures. Moreover, it is an open source tool, so it can be modified to adjust to specific needs.

From the US developed tools, we have distinguished the 'CommunityViz' software which provides 3D real-time visualization, covers all steps in planning process and works as an interactive decision support tool. It is well maintained and can cooperate with other tools, like 'Hazus' and 'NatureServeVista', which adds up in building adaptive capacity. However, it has a high purchasing cost that limits access to only those who can afford it.

Finally, having examined strengths and weaknesses for each tool, we have collected main strengthful attributes like usability, modeling competencies, future projections and data visualization. On the other hand, scope limitations, missing data, broken links and information robustness are listed as main weaknesses. Last but not least, the uncertainty factor, which deals with climate projections, along with impact assessment ambiguity, can be proved as tools' main shortcoming with a decisive role in effective adaptation planning.

As a result, adaptation tools should constantly improve their data robustness and modeling algorithms to avoid driving stakeholders to unnecessary measures, costs and complexity on adaptation policies and actions.

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