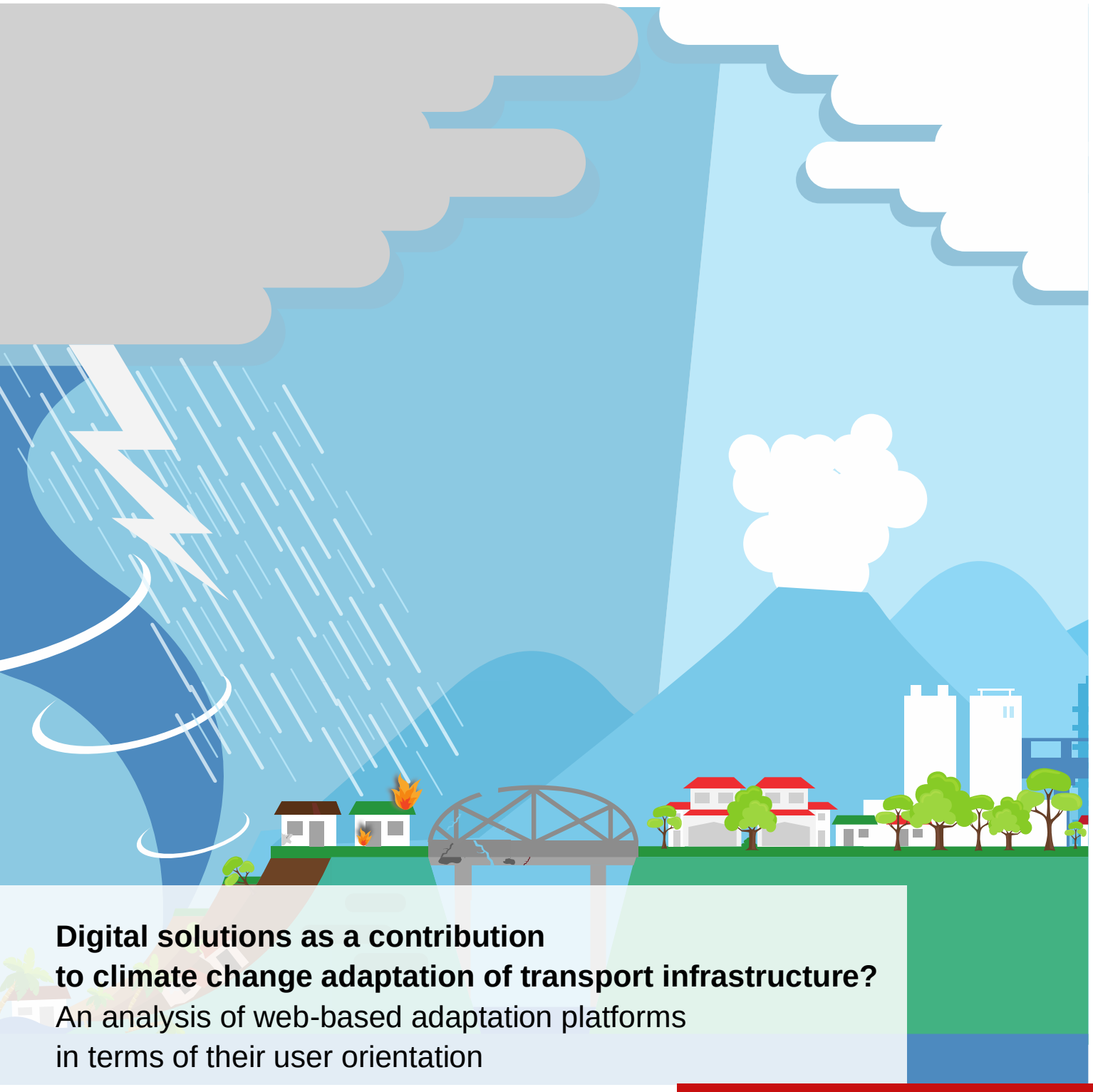

Digital solutions as a contribution to climate change adaptation of transport infrastructure?

An analysis of web-based adaptation platforms in terms of their user orientation

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Preface

The project "Enhancing Climate Services for Infrastructure Investments (CSI)" is part of the International Climate Initiative (IKI), which is the central element of Germany's financing commitments to the UN Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD). In accordance with a resolution of the German Bundestag, the IKI is funded by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The BMU in turn has commissioned the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH to implement the CSI project with the partner countries Brazil, Costa Rica and Vietnam and the Nile Basin Initiative (NBI) for the period 2017 to 2020. GIZ's main international implementing partners include the German Weather Service (DWD) and Engineers Canada.

The CSI project aims to encourage decision-makers to make greater use of Climate Services when planning infrastructure investments, thereby helping to increase the resilience of the infrastructure. At the same time, CSI promotes the achievement of goal 9 of the Sustainable Development Goals (SDG) by bringing together all relevant actors from the private and public sectors along the value chain of Climate Services. These include providers of climate data, policy makers and engineers who work with these data. Various activities within the CSI project drive the development and implementation of the National Adaptation Plan (NAP) and the Nationally Determined Contributions (NDC). Besides strengthening the international knowledge transfer, the focus lies on the sustainable establishment of an interface between users and providers of Climate Services. This so-called Climate Service User Interface should enable close interaction between providers and users of Climate Services and thus lead to evidence-based adaptation decisions and correspondingly effective adaptation measures.

This study is part of the CSI project and examines the global landscape of Climate Service User Interfaces in form of web-based adaptation platforms and the functionality of these already existing virtual areas. The study aims to update and extend existing studies on the global landscape of web-based adaptation platforms. Furthermore, essential elements of these existing platforms are identified, which support the process of making evidence-based adaptation decisions and developing user-specific adaptation measures. The identification of these elements will enable the design of an ideal requirement profile for a web-based adaptation platform, which takes into account user needs as well as provider capacities, and should be seen as a trend-setting basis for the development of future Climate Service User Interfaces.

Executive Summary

Climate change is one of the most urgent future issues politicians and scientists are currently facing. In addition to mitigating the causes, the aim is also to adapt to the expected and often unavoidable consequences of climate change. Especially, in areas of life that build the foundation for the supply of a society and the growth of a country's economy (e.g. the road sector), it is crucial to provide effective decision support in climate change adaptation. Against the background of the digital age, so-called Climate Service User Interfaces are becoming increasingly important. Climate Services comprise the creation, translation, dissemination and use of climate data and information and are offered in a wide range of formats. Climate Service User Interfaces in form of web-based adaptation platforms create virtual spaces that bridge geographical distances between actors from different countries and continents in the field of climate change and promote the exchange of knowledge about adaptation options.

For evidence-based adaptation decisions, the identification of correspondingly effective measures and thus the success of an adaptation platform, a close process of coordination, a so-called co-production, between user needs and provider capacities is essential. But how does the global landscape of web-based adaptation platforms currently look like? To what extent do adaptation platforms take the principle of co-production into account? Which elements of an adaptation platform contribute to the specific needs of the user? And what is the fundamental role of digital solutions in climate change adaptation in specific sectors, such as the road sector? To answer these questions, the study examines and analyses the global landscape of web-based adaptation platforms and takes a critical look at their functionality. In addition, elements, which consider user needs and provider capacities, are identified and recorded in a catalogue of criteria. A subsequent validation of these results within a specific sector (here: road sector) completes the analysis. The study aims to support future providers in the development of Climate Service User Interfaces.

Background

The topic of global warming is one of the most urgent future issues actors worldwide need to deal with. Numerous independent sources have been reporting for several years now that a global trend towards global warming and thus a significant change in the global climate is taking place. These include analyses by the Intergovernmental Panel on Climate Change (IPCC) and by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) (BMU 2019; IPCC 2018: 6), as well as measurement series by numerous other institutions (NASA 2019, PALMER ET AL. 2007, LEVITUS ET AL. 2012, NIKOGOSIAN 2019: 3, KLIMAFAKTEN 2019). They all emphasize that the consequences of climate change are unstoppable at the global level and confirm this by using facts such as the worldwide increase in forest fires by up to 50 percent, an expected number of about 500,000 additional deaths by 2050 due to a deteriorating food supply, financial costs worldwide of about 12 billion dollars per year for a secure drinking water supply and damage of up to 15 billion dollars due to flood events. In general, it can be seen that total expenditure is rising as a result of extreme weather events and is estimated to increase by up to 20 percent by 2050 (COACCH 2018: 13). This trend of global warming and the increase in extreme weather events gives rise to various risks to which the world is currently and in future exposed and which are confirmend in the current Global Risk Report. Only a few years ago, growing income inequalities or geopolitical conflicts topped the list of risks that are most likely to occur in the next ten years. In the Global Risk Report 2020, for the first time, all five of these global risks exclusively cover environmental issues: extreme weather events, the failure of climate protection, man-made environmental disasters, the collapse of ecosystems and natural disasters (WORLD ECONOMIC FORUM 2020: 7).

Particularly in areas of life that form the foundation for the supply of a society and the social and economic development of a country, there is a growing awareness of the increasing risk of extreme weather events and their effects. An example of such a risky and endangered area of life is the so-called critical infrastructure. According to the Federal Office of Civil Protection and Disaster Assistance (BBK), critical infrastructures are defined as follows: "Critical infrastructures are organisations or institutions with important significance for the state community. Their failure or impairment would result in lasting supply bottlenecks, considerable disruptions to public security or other dramatic consequences" (BBK 2019). They thus represent a complex and highly interconnected system of different functions, whose interdependencies usually only become apparent in crises. Extreme weather events can cause the failure of one sector and thus cascade effects in numerous other areas.

A critical infrastructure sector that is not only essential for the functioning, but also for the development of a society is the transport sector, especially the road transport. Within this sector, only traffic and tunnel control centres are critical infrastructures, as traffic safety can no longer be guaranteed in the event of disruptions or failures. All other road equipment and measures, such as traffic signs, direction signs, road markings, vehicle restraint systems, traffic light systems and street lighting (NATZSCHKA 2011: 423) are therefore not defined as critical infrastructure. Nevertheless, it must be considered that climate change and its effects endanger the roads that "[...] are as essential for mobile life as the blood vessels are for the human body"[...] (StN 2019). This dependence of society on road infrastructure and the network of economic, ecological and social areas of life can be illustrated by various examples. These include the basic mobility of

people, the creation of jobs through the construction and maintenance of road infrastructures, such as bridges or tunnels, or the connection between locations as the basis for economic activities. In addition, the provision of public transport on the one hand leads to an increased participation of disadvantaged social groups and on the other hand contributes to reducing individual transport and air pollution as well as the production of greenhouse gases through the reduced use of cars (THE ECONOMIST INTELLIGENCE UNIT LIMITED 2019). Thus, road infrastructure not only provides the basis for social interaction, but also contributes to the achievement of higher development policy goals, such as the SDGs.

Against the background of global warming and its effects on vulnerable sectors, countless governments and institutions worldwide are therefore pursuing the goal of mitigating the causes of climate change on the one hand, while on the other hand focusing increasingly on appropriate adaptation to the expected and often unavoidable consequences of climate change (HÜTTL ET AL. 2012: 8). Thus, numerous adaptation projects in various areas of life are already being carried out worldwide and decision-making support is made available to varying degrees with different purposes (FICHTNER ET AL. 2014: 14). In this process, so-called Climate Services are becoming increasingly important. They include the production, translation, dissemination and use of climate data and information and thus represent the production and provision of climate data on the one hand. On the other hand, they comprise processed products of this climate information. Climate Services pursue the goal of enabling relevant actors to make evidence-based decisions on climate change adaptation by including specific information. In this way, the resilience of societies is to be strengthened by identifying current climate variability and future climate impacts, identifying potential options for action, formulating and implementing concrete adaptation measures and evaluating their respective effectiveness (STREET ET AL. 2018: 30).

Climate Services can be offered in a variety of formats and range from the provision of climate data and trends in databases, through analogous advisory services in project format and the production of publications (such as synthesis reports, guides and manuals, case studies and strategy papers), to products such as information platforms, interactive visualisations like maps and tools. Against the background of the advancing digital age, those formats of Climate Services, which offer people quick and easy access to relevant and high-quality information, are trendsetting. Climate Services in form of web-based adaptation platforms are therefore playing an increasingly important role as an effective method of collecting and sharing experiences (EEA 2015: 6). With the help of such virtual spaces, geographical distances between actors from different countries and continents in the field of climate change can be overcome effortlessly, their cooperation simplified, sector-relevant knowledge about adaptation options exchanged more quickly and climate-compatible decision-making processes supported (PALUTIKOF ET AL. 2019: 472). Climate Service User Interfaces are defined by the World Meteorological Organization (WMO) as a "structured means for users, climate researchers and climate information providers to interact at all levels" (WMO 2014: 8).

A dynamic landscape of various web-based adaptation platforms already exists, but it is noticeable that these are mainly standard products and only a few web-based Climate Service User Interfaces take user needs and provider capacities into account. However, in order to make evidence-based adaptation decisions and implement effective measures, it is essential to include specific data. This close interaction between users and providers required for this is also known as co-production

and follows six different principles. These include that the process "[...] should be inclusive, collaborative and flexible, and that the final product, in this case web-based adaptation platforms, is characterised by the fact that it is [...] decision-driven, process-based and time-managed" (VINCENT ET AL. 2018: 48 ff.). Only when these principles have been considered it can be entitled as an adequate interface between user needs and provider capacities and an effective Climate Service User Interface.

Facing the fact that there is already a large variety of web-based adaptation platforms, some central questions arise: How many adaptation platforms exist on global scale? Which of them enable co-production between providers and users? Which elements favour this interaction? Which other components may influence a decision process for user-oriented adaptation?

Methodology

To answer this question, the methodology of Grounded Theory was applied in order to do justice to the exploratory character of the research. The two individual techniques used include a comparative platform analysis and a guideline-guided expert interview. The results of the platform analysis consist of a review and analysis of the global landscape of web-based adaptation platforms. These were performed by means of a systematic keyword search (using Boolean operators). Subsequently, this well-founded selection of platforms was subjected to a binary subdivision and assigned the two attributes "unidirectional" and "bidirectional" depending on the functionality. In addition, the years of origin and the actors who hold responsibility for the platform were analysed in only a brief review. In the final step of the comparative platform analysis, only the bidirectional web-based adaptation platforms were taken as a basis and recurring elements in the interactive query of user-oriented data were identified, which were listed and categorized thematically. In order to find out whether the rather theoretical results generated up to this point also find practical application in a concrete sector, an exemplary expert interview was conducted as a second individual technique. The intention of this interview was to to validate the results and to obtain further valuable information on the role of digital solutions in climate change adaptation by means of open questions. The road sector was selected as a concrete infrastructure sector because road infrastructure is an omnipresent and essential component of a society and the development of a country (see above). The semi-structured guide was mainly oriented towards the questions whether the elements identified in the platform analysis can be confirmed or complemented and to what extent digitalisation can contribute to climate change adaptation in the road sector. As expert for this exemplary interview an employee of the Federal Highway Research Institute (BASt) was selected, who had already been in contact with the CSI project of GIZ before.

Results

Outcome 1: Review of the global landscape of web-based adaptation platforms (last updated August 2019)

Outcome 1a: 107 continent-specific adaptation platforms

Continent	Acronym	Web-based platforms for climate change adaptation	Link
Asia (10)	AKP	Adaptation Knowledge Platform	http://www.climateadapt.asia
	APAN	Asia Pacific Adaptation Network	http://www.asiapacificadapt.net/
	AP-PLAT	Asia Pacific Climate Change Adaptation Information Platform	http://www.adaptation-platform.nies.go.jp/en/ap-plat/
	BBC-C	BBC Climate	https://www.bbc.co.uk/climateasia
	CAMP4ASB	Climate Adaptation and Mitigation Program for Aral Sea Basin	http://ca-climate.org/eng/
	CANSA	Climate Action Network South Asia	https://www.cansouthasia.net
	CST	Climate Smart Tools for Asia	http://exchange.growasia.org/climate-smart-tools-asia
	GAINS	Greenhouse Gas – Air Pollution Interactions and Synergies	https://gains.iiasa.ac.at/gains/ASN/index.login?logout=1&switch_version=v0
	RCCAP	Regional Climate Consortium for Asia and the Pacific Southeast	http://www.rccap.org/
	SEA-START	Asia START Regional Center	https://start.org/programs/sea-start/
Africa (11)	AfAd	AfricaAdapt	http://www.africa-adapt.net/en-us/
	ARC	African Risk Capacity	https://www.africanriskcapacity.org
	CARD	Climate Adaptation in Rural Development	https://www.ifad.org/en/web/knowledge/publication/asset/41085709
	CCAPS	Climate Change and African Political Stability	https://www.trendradar.org/de/case/ccaps-mapping/
	CSIR	Council of Scientific & Industrial Research	https://www.csir.co.za
	FCFA	Future Climate For Africa	https://futureclimateafrica.org/resource/fonerwa-climate-risk-screening-tool/
	FRACTAL	Future Resilience for African Cities and Lands	http://www.fractal.org.za/
	GreenB	The Green Book: Municipal Planning Support	https://www.greenbook.co.za/
	OADC	Open Access Data Center von SASSCAL	http://www.sasscal.org/
	TAN	The Adaptation Network	http://www.adaptationnetwork.org.za
	WADI	Data Portal von WASCAL	https://www.wascal.org/
North America (35)	ActA	ActAdapt des Pacific Water Research Center	https://act-adapt.org/
	ACASA	Atlantic Climate Adaptation Solutions Association	https://atlanticadaptation.ca/
	AdWest	AdaptWest: Ecoregion Climate Data Explorer	https://adaptwest.databasin.org/app/ecoregion_climate_explorer
	AgClim	AgroClimate	http://agroclimate.org/tools/
	ARC-X	Climate Change Adaptation Resource Center von U.S. EPA	https://www.epa.gov/arc-x
	BUAKP	Bottom-Up Approaches Knowledge	https://agwaguide.org/
	CAC	Climate Atlas of Canada	https://climateatlas.ca/
	CAL-adapt	Exploring California's Climate Change Research	https://cal-adapt.org/tools/
	CALP	Collaborative for Advanced Landscape Planning	https://calp.forestry.ubc.ca/
	CAKE	Climate Adaptation Knowledge Exchange	https://www.cakex.org/
	CAT	Massachusetts Wildlife – Climate Action Tool	https://climateactiontool.org/
	CCC	Government of Canada	https://climate-change.canada.ca/climate-data/#/
	CCDST	Canadian Climate Data Scraping Tool	https://www.sciencedirect.com/science/article/pii/S009830041400243X
	CEC	Commission for Environmental Co-Operation	http://www.cec.org/our-work/climate-change
	CIRC	Climate Impacts Research Consortium (Oregon University)	https://pnwcirc.org/climatetools

	CSF	Climate Smart Farming	http://climatesmartfarming.org/tools/
	CRAVe	Climate Registry for the Assessment of Vulnerability	https://www.usgs.gov/media/videos/crave-climate-registry-assessment-vulnerability https://toolkit.climate.gov/
	CRT	U.S. Climate Resilience Toolkit Platform	
	CVT	Climate Visualization Tools	https://mashable.com/2014/02/23/climate-science-tools/?europe=true
	EcoA	EcoAdapt von National Resource Canada	http://www.ecoadapt.org/
	GCC	Georgetown Climate Centre	https://www.georgetownclimate.org/
	GL-LCI	Great Lakes and St. Lawrence Cities Initiative	https://glslcities.org/topic/climate-change-tools-guides/
	GOC	Governor's Office - Clearinghouse	http://www.opr.ca.gov/clearinghouse/adaptation/tools-research.html
	ICCA	Intact Centre Climate Adaptation	https://www.intactcentreclimateadaptation.ca/
	NCT	The Northwest Climate Toolbox	https://climatetoolbox.org/
	NRC	Natural Resource Canada	https://www.nrcan.gc.ca/home
	NOAA	National Oceanic and Atmospheric Administration	https://www.climate.gov/maps-data/data-snapshots/start
	OCCIAR	Ontario Center for Climate Impacts and Adaptation Resources	http://www.climateontario.ca/
	OcAd	OceanAdapt	https://oceanadapt.rutgers.edu/
	PCIC	Pacific Climate Impacts Consortium	https://services.pacificclimate.org/pcex/app/#/data/climo/ce_files
	PIEVC	Public Infrastructure Engineering Vulnerability Committee	https://pievc.ca/
	ResCA	Resilient Canada	https://resilientca.org/
	SCEIC	Southwest Climate and Environmental Information Collaborative	https://wrcc.dri.edu/csc/scenic/
	TACCIMO	Template for Assessing CC Impacts and Management Options	https://taccimo.info/tbl_sector_list.php
	US-CCCT	USDA's Climate Change and Carbon Tools	https://www.fs.usda.gov/ccrc/index.php?q=tools
South America (8)	AdClim	AdaptaClima	http://adaptaclima.mma.gov.br/
	CCCCC	Caribbean Community Climate Change Center	https://www.caribbeanclimate.bz/
	CCORAL	Caribbean Climate Online Risk and Adaptation Tool	http://ccoral.caribbeanclimate.bz/
	CRC-SAS	Centro Regional del Clima para el Oeste de Sudamérica	http://www.crc-sas.org/en/
	ELDIS	ELDIS Programme – Sharing Knowledge for 20 Years	https://www.eldis.org/
	LAPC	Latin American Platform on Climate	https://www.intercambioclimatico.com/en/
	LC	LatinClima	http://latinclima.org/palabra-clave/adaptacion
	REGATTA	Regional Gateway for Technology Transfer and Climate Change Action in Latin America and the Caribbean	http://www.cambioclimatico-regatta.org/index.php/en/
Antarctica (4)	AEP	Antarctic Environments Platform	https://www.environments.aq/?locale=en_GB
	BAS	British Antarctica Survey	https://www.bas.ac.uk/science/our-research/topics/climate-climate-change/
	BPP	Belgian Polar Platform	http://www.belspo.be/antar/
	DSNSC	Deep South National Science Challenge	https://www.deepsouthchallenge.co.nz/
Europe (27)	AdapteCCa	Platform for the Exchange of Information on Climate Change	https://www.adaptecca.es/en
	C-ADAPT	Climate-ADAPT	https://climate-adapt.eea.europa.eu/
	CARAVAN	Regional Assessment of Vulnerability and Adaptive Capacity	https://www.iav-mapping.net
	CCA DK	Climate Change Adaptation Denmark	https://en.klimatilpasning.dk/
	ClimBiz	Black Sea Climate and Business Initiative	http://www.climbiz.org/30-0-HOME.html#.XRD01o_gqWs
	C-Ireland	Climate Ireland	https://www.climateireland.ie/#!/
	CDLP	Climate and Development Learning Platform	https://www.climatelearningplatform.org/
	CI	CIrcle - Critical Infrastructur	https://circle.deltares.org/
	CIT	Climate Impacts Tool	https://www.gov.uk/government/publications/climate-impacts-tool
	CLAR	CLARITY	http://clarity-h2020.eu/
	CMTool	Multi-Lead Time Climate-Mortality Prediction Tool	http://cmtool.euporias.eu/

	COP	Copernicus' Climate Data Store	https://cds.climate.copernicus.eu/#!/home
	DAKP	Dutch Adaptation Knowledge Portal	https://ruimtelijkeadaptatie.nl/english/
	EEA	European Environment Agency	https://www.eea.europa.eu/
	EMP	European MSP Platform	https://www.msp-platform.eu/
	EU-MS	EU Met Sat	https://www.eumetsat.int/website/home/index.html
	GERICS	GERICS' Toolkits	https://www.climate-service-center.de/products_and_publications/toolkits/index.php.en
	JPI	JPI Climate	http://www.jpi-climate.eu/home
	KLiVo	German Climate Preparedness Portal	https://www.klivoportal.de/DE/Home/home_node.html
	MasterAdapt	Mainstreaming Experiences at Regional and Local Level for Adaptation to Climate Change	https://masteradapt.eu/
	MEDIATION	Methodology for Effective Decision-Making on Impacts and	http://mediation-project.eu/
	PLACARD	Adaptation	https://www.placard-network.eu/
	RESIN	Climate Risk Typology	http://www.resin-cities.eu/resources/tools/
	ToPDAd	Tool-Supported Policy-Development for Regional Adaptation	http://topdad.services.geodesk.nl/
		Platform for Climate Adaptation and Risk Reduction	
	UBA	Federal Environment Agency of Germany	https://www.umweltbundesamt.de/en
	UK CIP	United Kingdom Climate Impacts Programme	https://www.ukcip.org.uk/
	UK CG	UK Global Calculator	http://tool.globalcalculator.org/
Oceania (12)	AdaptNRM	Adaptation for National Resource Management	https://adaptnrm.csiro.au/
	CoastAd	CoastAdapt	https://coastadapt.com.au/
	CChangeAP	Climate Change Adaptation	http://cchangeap.com.au/
	CFET	Climate Futures Exploration Tool	https://www.climatechangeinaustralia.gov.au/en/climate-projections/
	CliMate	Climate Analysis for Decision Makers	https://climateapp.net.au/
	MoE NZ	Ministry for the Environment of New Zealand	https://www.mfe.govt.nz/
	NCCARF	National Climate Change Adaptation Research Facility	https://www.nccarf.edu.au/
	NIWA	Taihoro Nukurangi	https://www.niwa.co.nz/
	PACCSAP	Pacific-Australia Climate Change Science and Adaptation Planning	https://www.terranova.org.au/repository/paccsap-collection
	PCCP	Pacific Climate Change Portal	https://www.pacificclimatechange.net/climate-tools
	PCCST	Pacific Climate Change Science Tools	https://www.pacificclimatechangescience.org/climate-tools/
	SPREP	Secretariat of the Pacific Regional Environment Programme	https://www.sprep.org/

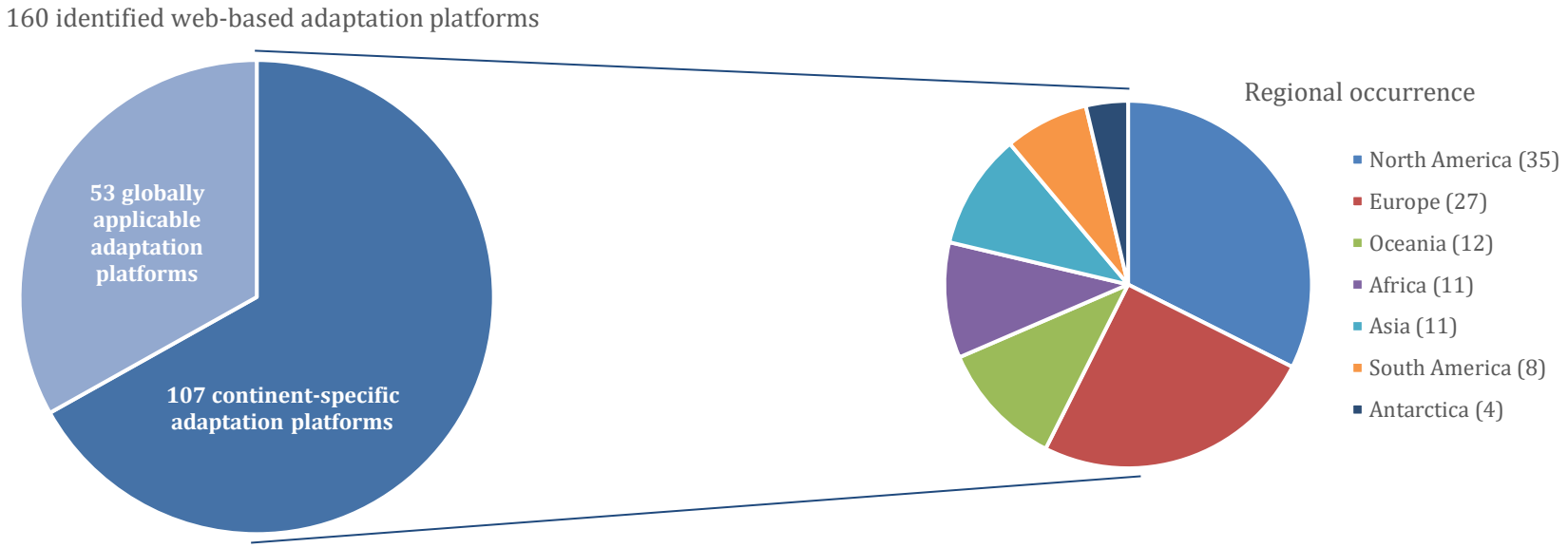
Outcome 1b: 53 globally applicable adaptation platforms

Acronym	Web-based platforms for climate change adaptation	Link
ALM	Adaptation Learning Mechanism	http://www.adaptationlearning.net/
ATLA	Climate-KIC's ATLA Tool	https://www.climate-kic.org/projects/adaptation-tool-for-local-authorities-atla/
AW	AdaptationWatch	http://www.adaptationwatch.org/
CA	ClimateAnalytics	https://climateanalytics.org/tools/
CAT	Climate Action Tracker	https://climateactiontracker.org/

CDCW	Climate-Data.org	https://en.climate-data.org/
CDKN	Climate and Development Knowledge Network	https://cdkn.org/resources/?loclang=en_gb
CGIAR-CCAFS	Research Program on CC, Agriculture & Food Security	https://ccafs.cgiar.org/tool-climate-analogue-tool
CIL	Climate Impact Lab	http://www.impactlab.org/map/#
Clim-In	Climate Interactive	https://www.climateinteractive.org/tools/
ClinfoMATE	Platform for Tailor-Made Climate Services	https://clinfomate.nozilla.de/about/
CT	Climate Tool – Planungswerkzeug für das internationale Bauen	http://www.climate-tool.com/en/home.html
DDC	IPCC Data Distribution Centre	http://www.ipcc-data.org/
FW-WCT	Frontier Weather's Weather and Climate Tools	https://www.frontierweather.com/climateandtools.html
GECO	GECOsistema	http://climate-tools.com/#one
GCA	Global Center on Adaptation	https://gca.org/home
GCAP	Global Adaptation Patnership	https://www.climateadaptation.cc/our-work/knowledge-space
GEF	Global Environment Facility	https://www.thegef.org/topics/climate-change-adaptation
ICLEI	Local Governments for Sustainability	https://www.iclei.org/
KNMI-CE	Climate Explorer	https://climexp.knmi.nl/start.cgi
NAP-GSP	National Adaptation Plan Global Support Programme	https://www.globalsupportprogramme.org/nap-gsp
NASA-CTM	NASA's Climate Time Machine	https://climate.nasa.gov/interactives/climate-time-machine
NI	Nautilus Institute	https://nautilus.org/
NCI-CPGS	New Climate Institute for Climate Policy and Global Sustainability	https://newclimate.org/expertise/tools-and-models/
NDC-CT	NDC Partnership's Climate Toolbox	https://ndcpartnership.org/ndc-toolbox
NDGAI	Notre Dame Global Adaptation Initiative	https://gain.nd.edu/our-work/country-index/
PPP-KL	PPP Knowledge Lab	https://pppknowledgelab.org/
SAGA-TL	SAGA-GIS Tool Library	http://www.saga-gis.org/saga_tool_doc/7.0.0/climate_tools.html
SDG-CANT	SDG Climate Action Nexus Tool	http://ambitiontoaction.net/scan_tool/
SSW	SamSamWater	https://www.samsamwater.com/climate/
UC-CSMR	University of Colombia: Climate and Society Map Room	http://iridl.ldeo.columbia.edu/maproom/
UC-SEDAC	University of Colombia: Socioeconomic Data and Application Centre	https://sedac.ciesin.columbia.edu/tools
UN-AKP	UNFCCC's Adaptation Knowledge Portal	https://www4.unfccc.int/sites/nwpstaging/Pages/Home.aspx
UN-CCA	UNDP's Climate Change Adaptation	https://www.adaptation-undp.org/
UN-CCT	UN FAO's Climate Change Tools	http://www.fao.org/tc/exact/review-of-ghg-tools-in-agriculture/other-climate-change-tools/en/
UN-CIP	UNEP's Climate Initiatives Platform	http://climateinitiativesplatform.org/index.php/Welcome
UN-CIP_2	UNITAR's Climate Information Platform	http://cip.csag.uct.ac.za/webclient2/app/
UN-CIT	UN FAO's Climate Information Tool	http://www.fao.org/nr/water/aquastat/climateinfotool/index.stm
UN-EP	UNEP's Environment Programme	https://www.unenvironment.org/explore-topics/climate-change
UN-EPIC	UN FAO's EPIC Programme	http://www.fao.org/in-action/epic/background/en/
UN-GAN	UN Global Adaptation Network	https://sustainabledevelopment.un.org/
UN-GRDP	UNISDR Global Risk Data Platform	https://preview.grid.unep.ch/index.php?preview=map&lang=eng
UN-L	UN CC: Learn	https://www.uncclearn.org/
UN-PT	UNDP's CCA Practitioner Toolkit	https://www.adaptation-undp.org/resources/training-tools/designing-climate-change-adaptation-initiatives-toolkit-practitioners
UN-WCW	UN WMO Weather, Climate, Water	https://public.wmo.int/en

US-CLTS	US AID's Climate Links, Tools & Support	https://www.climatelinks.org/tools?page=1
US-REC	US AID's RECOFTC e-Learning Platform	https://www.recoftc.org/learning/online
WeAdapt	Climate Adaptation Planning, Research and Practice	https://www.weadapt.org/
WB-CAUS	World Bank's Climate Action for Urban Sustainability	https://www.worldbank.org/
WB-CDST	World Bank's Climate and Disaster Screening Tools	https://climatescreeningtools.worldbank.org/
WB-CKP	World Bank's Climate Knowledge Portal	https://climateknowledgeportal.worldbank.org/
WC	Wilson Centre	https://www.wilsoncenter.org
WWF	WWF Adapt	http://wwfadapt.org/

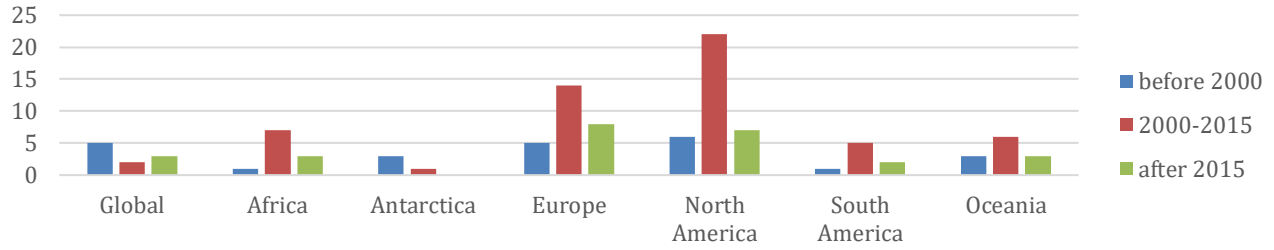
Outcome 1c: Analysis of the global landscape of web-based adaptation platforms



Regional occurrence
Despite significant results for African or South American countries, there is a regional accumulation of already existing adaptation platforms on Western industrialized nations, such as the United States of America, European countries, Australia and New Zealand.

Outcome 2: Analysis of the years of origin and the stakeholders of the 160 adaptation platforms

Outcome 2a: Results of the Analysis "Years of origin" (107 continent-specific adaptation platforms)



Years with high accumulation	
Year(s) of origin	Number of platforms
1985/86	4
1992-98	12
2009	8
2013	8
2014	8
2015	10
2017	8

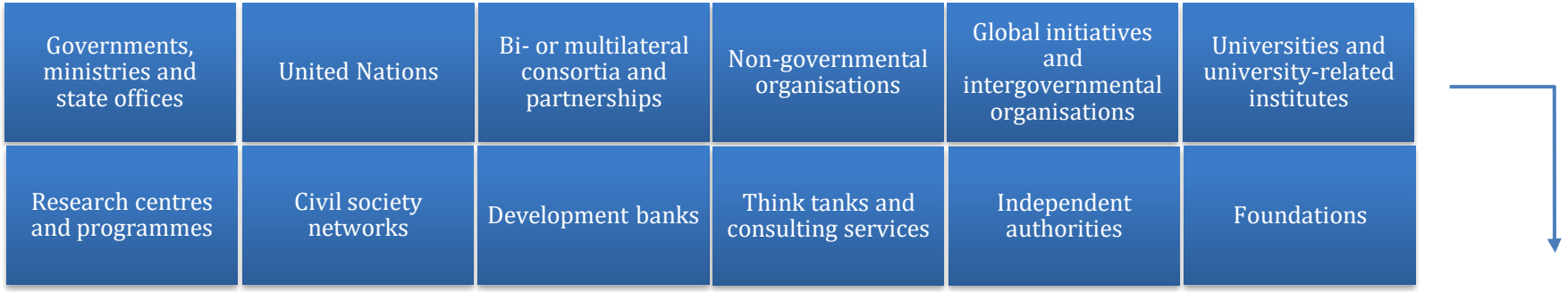
Years of Origin	Asia	Africa	Antarctica	Europe	North America	South America	Oceania
Before 2000	1996: SEA-START	1945: CSIR	1962: BAS 1985: BPP 1998: AEP	1971: CCA DK 1986: EU-MS 1992: MasterAdapt 1993: EEA 1997: UK CIP	1980: GOC 1986: SCENIC 1994: CALP, CEC 1995: NRC 1998: AgClim	1996: ELDIS	1986: MoE NZ 1992: NIWA 1993: SPREP
2000 – 2015	2005: GAINS 2009: AKP, APAN 2013: BBC-C 2015: CST, RCCAP	2009: CCAPS, TAN 2010: OADC, WADI 2012: AfAd, ARC 2013: FCFA 2016: FRACTAL	2014: DSNSC	2007: MEDIATION 2008: CARAVAN 2009: GERICS 2010: ClimBiz 2011: JP 2012: C-ADAPT, CMTool, ToPDAd 2013: AdapteCCA, UBA 2014: DAKP 2015: PLACARD, RESIN, UK CG	2003: GL-LCI 2005: PIEVC 2006: ActA 2008: ICCA 2009: ACASA, GCC 2010: CAKE, EcoA, OCCIAR 2011: CAL-adapt 2013: NOAA, PCIC, TACCIMO 2014: AdWest, CCDST, CRT, CVT, OcAd 2015: CIRC, CSF, CRAVe, ResCA	2005: CCCCC 2009: LAPC 2012: REGATTA 2013: CCORAL 2015: LC	2007: CFET 2008: NCCARF 2011: PACCSAP, PCCP, PCCST 2014: AdaptNRM
After 2015	2017: CAMP4ASB, CANS 2019: AP-PLAT	2019: GreenB, CARD	-	2015: C-Ireland 2016: EMP 2017: CLAR 2018: CDLP, CI, COP, KliVO 2019: CIT	2016: ARC-X 2017: BUAKP, CAT, CCC 2018: CAC, NCT, US CCCT	2017: AdClim, CRC-SAS	2016: CoastAd, CChangeAP, CliMate

Years with high accumulation of the 107 continent-specific adaptation platforms

With the development of 61 adaptation platforms, the largest increase in numbers occurred between the years 2000 and 2015.

A comparatively small proportion, only 20 adaptation platforms, had been developed before the turn of the millennium, while the development of 26 adaptation platforms since 2015 demonstrates the on-going relevance of web-based adaptation platforms (start of the digital age?)

Outcome 2b: Results of the Analysis "Stakeholders" (107 continent-specific adaptation platforms)

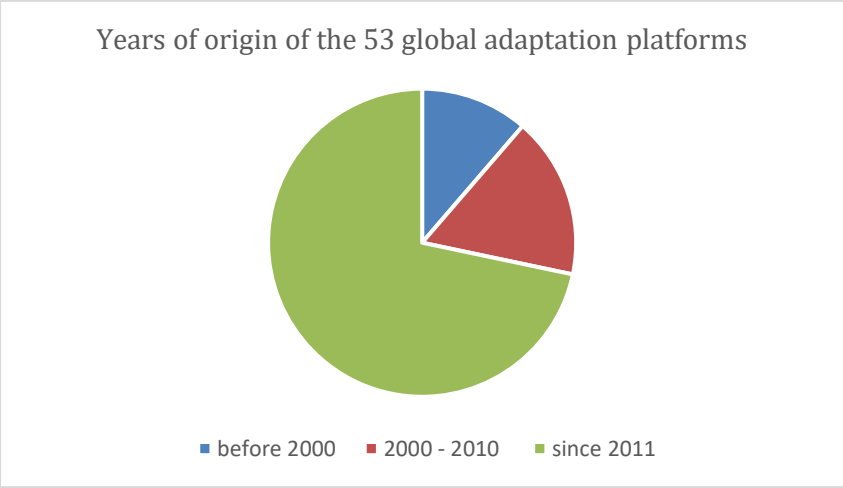


Stakeholders	Asia	Africa	Antarctica	Europe	North America	South America	Oceania
Government-related authorities as well as bi- or multilateral government partnerships	AP-PLAT, CST	ARC, SASSCAL, WASCAL	BPP, SDNSC	C-Adapt, CARAVAN, CCA DK, COP, CIT, CLAR, CMTool, DAKP, EEA, EMP, JPI, KLiVO, MasterAdapt, MEDIATION, PLACARD, RESIN, ToPDAd, UBA	ACASA, ARC-X, CCC, CEC, CRT, GCC, GL-LCI, GOC, NRC, NOAA, PIEVC, ResCA, TACCIMO, US CCCT	AdClim, CCCCC, CCORAL, LC	AdaptNRM, CoastAd, CFET, MoE NZ, NCCARF, PACCSAP, PCCP, PCCST, SPREP
United Nations	APAN			ClimBiz		CRC-SAS, REGATTA	
Research centres & university-related institutes	BBC-C, GAINS, SEA-START	AfAd, CCAPS, CSIR, FCFA, FRACTAL, GreenB, TAN	AEP, BAS	C-Ireland, CDLP, CI, EU-MS, UK CIP, UK CG	ActA, AdWest, AgClim, CAC, CAL-adapt, CALP, CAT, CCDST, CIRC, CSF, CRAVe, CVT, ICCA, NCT, OCCIAR, OcAd, PCIC, SCENIC	ELDIS	CliMate, NIWA
Civil society networks & non-governmental organisations	CAMP4ASB, CANSA	CARD			BUAKP, CAKE, EcoA	LAPS	
Other (Think tanks, development banks, consulting services, foundations)	AKP, RCCAP			AdapteCCa, GERICS			CChangeAP

Trends in terms of the stakeholders of the 107 continent-specific adaptation platforms

Apart from country-specific institutions, there is an enormous variety of institutions developing web-based adaptation platforms (including the United Nations, governments, ministries, state authorities and offices, bilateral or multilateral consortia and associations, global initiatives and intergovernmental organisations, development banks, research centres and programmes, universities and university-related institutes, independent authorities, strategic project partnerships, civil society networks, non-governmental organisations, consultancy services, think tanks and foundations).

Outcome 2c: Results of the Analysis “Years of origin” & “Stakeholders” (53 globally applicable adaptation platforms)



Trends in terms of the years of origin		
	Number of platforms	Name of platforms
Before 2000	6	DDC, KNMI-CE, NI, UN-EP, UC-SEDAC, WC
2000 - 2010	9	ATLA, CA, CAT, CDCW, FW-WCT, NASA-CTM, SSW, UN-L, WeAdapt
Since 2011	38	ALM, AW, CDKN, CIL, CGIAR-CCAFS, Clim-In, ClinfoMATE, CT, GCA, GCAP, GECO, GEF, ICLEI, NCI-CPGS, NDGAI, NAP-GSP, NDC-CT, PPP-KL, SAGA-TL, SDG-CANT, UC-CSMR, UN-AKP, UN-CCA, UN-CCT, UN-CIP, UN-CIP_2, UN-CIT, UN-EPIC, UN GAN, UN_GRDP, UN-PT, UN-WCW, US-CLTS, US-REC, WB-CAUS, WB-CCDST, WB-CKP, WWF Adapt

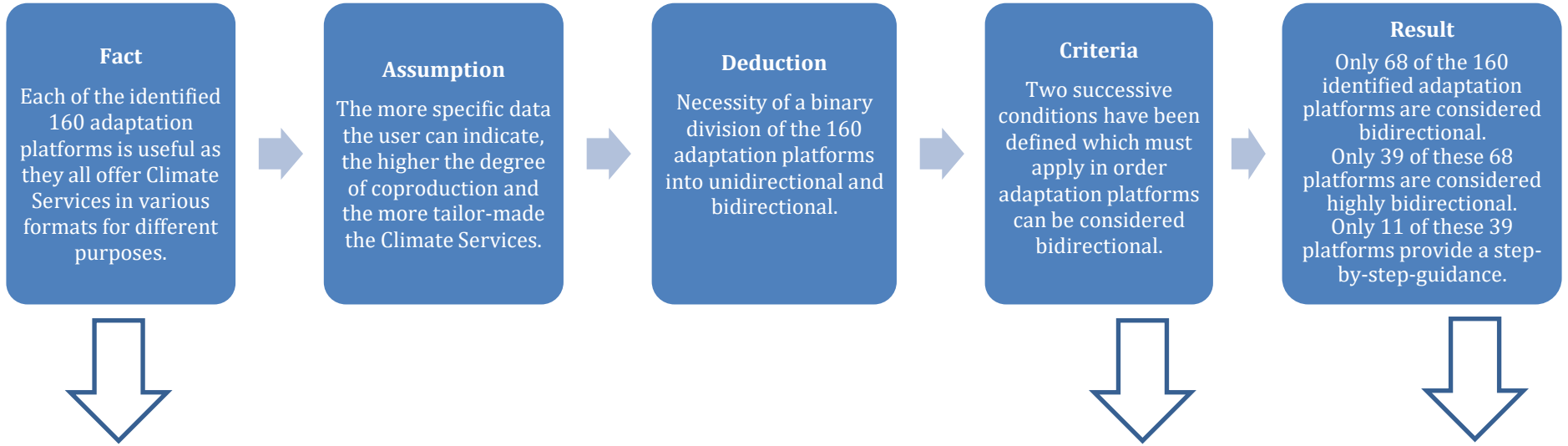
Stakeholders	
Governments, government-related authorities, state offices	GCA, NDC-CT, ICLEI
Bi- or multilateral initiatives & partnerships	ATLA, AW, GCAP
United Nations	DDC, NAP-GSP, UN-AKP, UN-CCA, UN-CCT, UN-CIP, UN-CIP_2, UN-CIT, UN-EP, UN-EPIC, UN GAN, UN-GRDP, UN-L, UN-PT, UN-WCW
Research centres & univerity-related institutes	CIL, NCI-CPGS, NDGAI, UC-CSMR, UC-SEDAC, WC
Civil society networks & NGOs	ALM, CA, CDKN, US-CLTS, US-REC
World Bank/ Development banks	WB-CAUS, WB-CCDST, WB-CKP
Foundations	FW-WCT, GEF, PPP-KL, SSW, WeAdapt, WWF Adapt
Online tool	CAT, CDCW, Clim-In, ClinfoMATE, CT, KNMI-CE, NASA-CTM, SAGA-TL, SDG-CANT
Other (Think tanks, consulting services)	CGIAR-CCAFS, GECO, NI

Summary

- 160 adaptation platforms were identified of which:
  - 107 platforms had been developed for the individual continents with a regional accumulation on the U.S., Europe and Oceania
  - 53 platforms exist at global level without considering specific climatic characteristics of the continents
- each region or country aims for specific activities, but also considers global strategies
- significant increase of adaptation platforms after major climate conferences (1992 & 2015) and since the start of the digital age
- large number of various stakeholders from both governmental and civil society as well as independent institutions

Outcome 3: Identification of bidirectional adaptation platforms

Outcome 3a: Selection process of bidirectional platforms



Including:

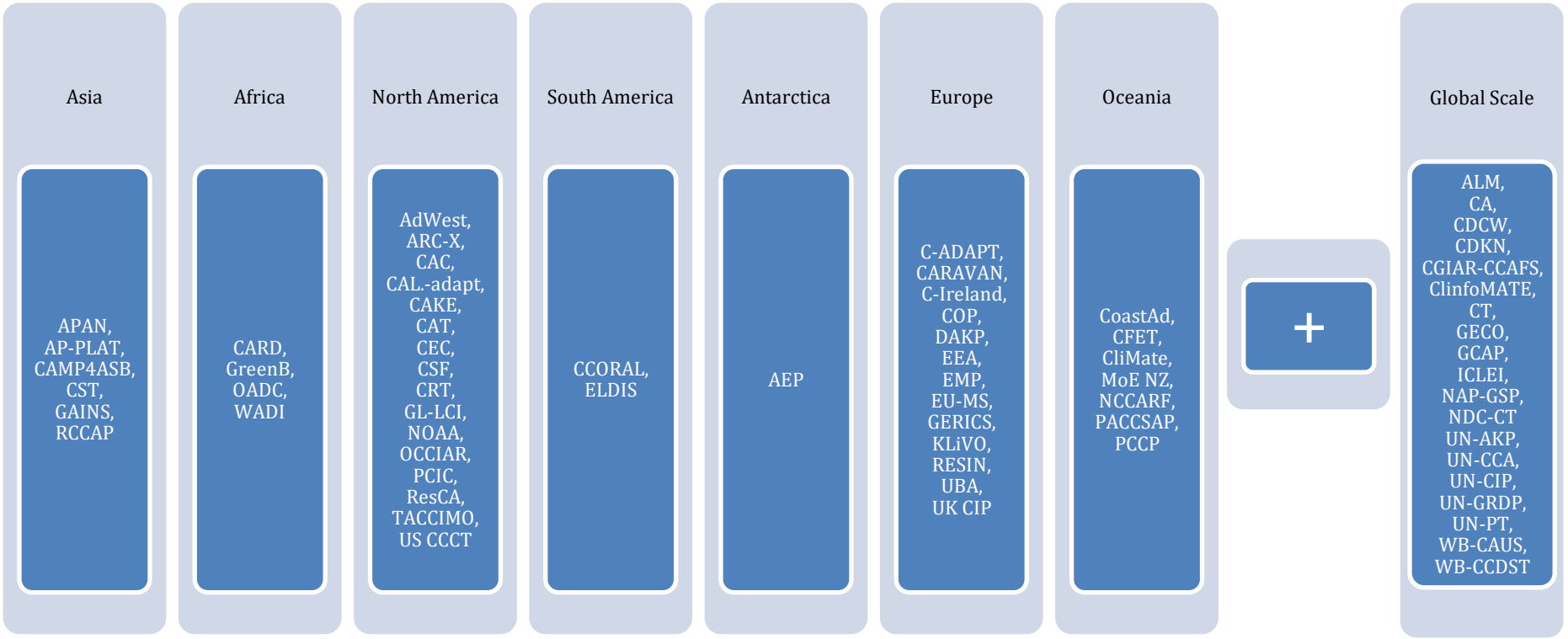
- Publications
- Background papers on climate change & climate negotiations
- Strategy papers, reports & research articles
- Brochures & fact sheets
- Guides, manuals & instructions
- Blog entries, podcasts & webinars
- Informative videos
- Case studies & best practices
- Databases for climate trends
- Interactive map modelling
- Step-by-step guided tools

1) Platforms are considered bidirectional if they allow the user to interact in formulating his specific needs

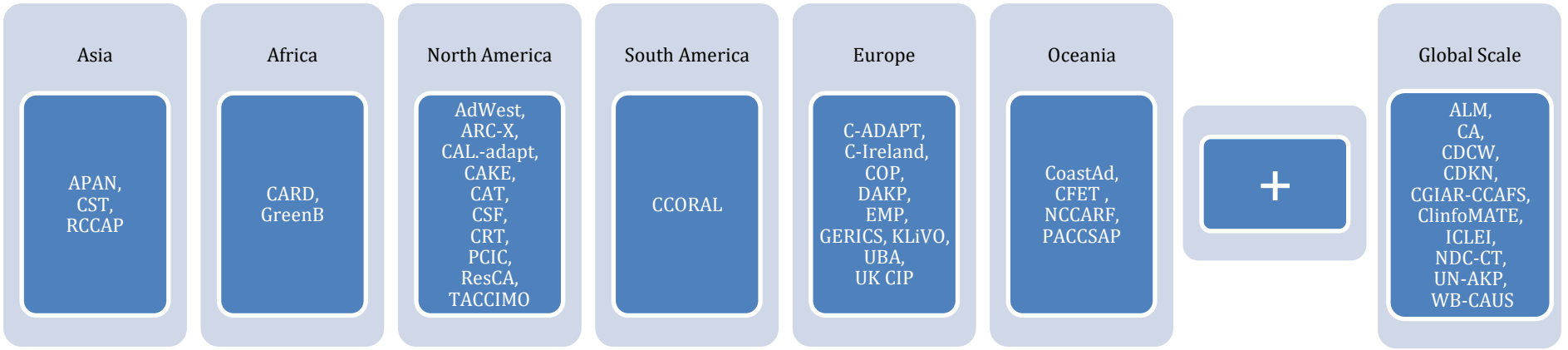
2) Platforms are considered to be highly bidirectional if the user can select at least two criteria that characterise his object-specific needs

For more detailed results: see Outcome 3b, 3c & 3d

Outcome 3b: 68 adaptation platforms that can be considered bidirectional



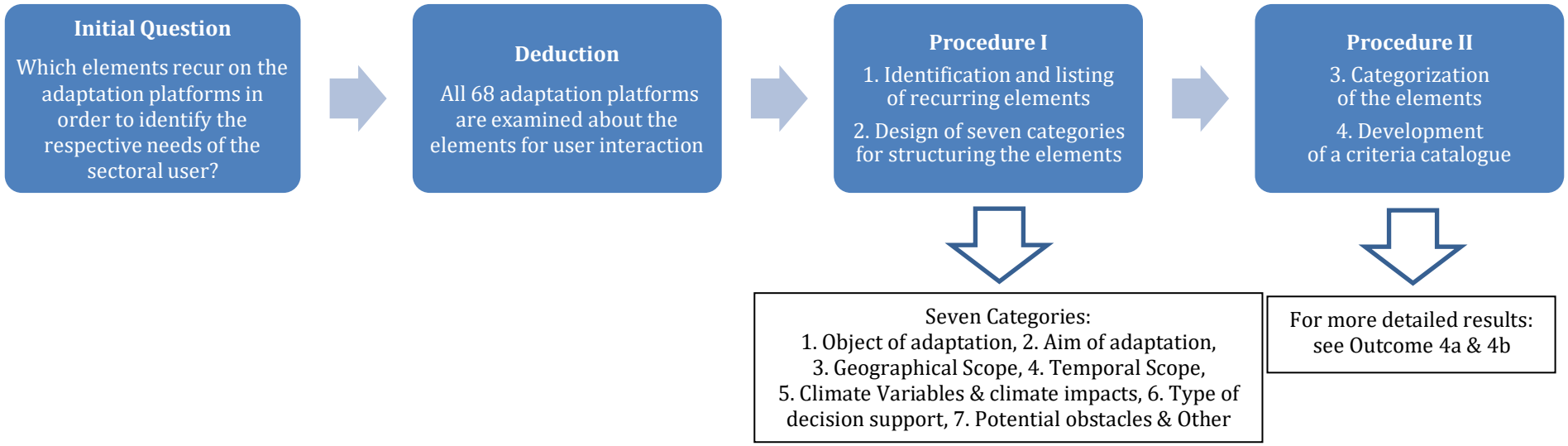
Outcome 3c: 39 adaptation platforms that can be considered highly bidirectional



Outcome 3d: 11 tools with a high degree of user orientation through step-by-step-guidance

North America	•CRT: U.S. Climate Resilience Toolkit
South America	•CCORAL: Caribbean Climate Online Riskt and Adaptation Tool
Europe	•C-ADAPT: Adaptation Support Tool •C-Ireland: Sectoral Adaptation Tool •KLiVO: KLiVO-Portal •UBA: Klimalotse •UK CIP: Adaptation Wizard
Oceania	•CoastAd: C-CADS-Tool
Global Scale	•ClinfoMATE: ClinfoMATE-Prototype •ICLEI: Interactive Adaptation Participatory Process Toll •NDC-CT-Climate Toolbox

Outcome 4: Elements of user interaction



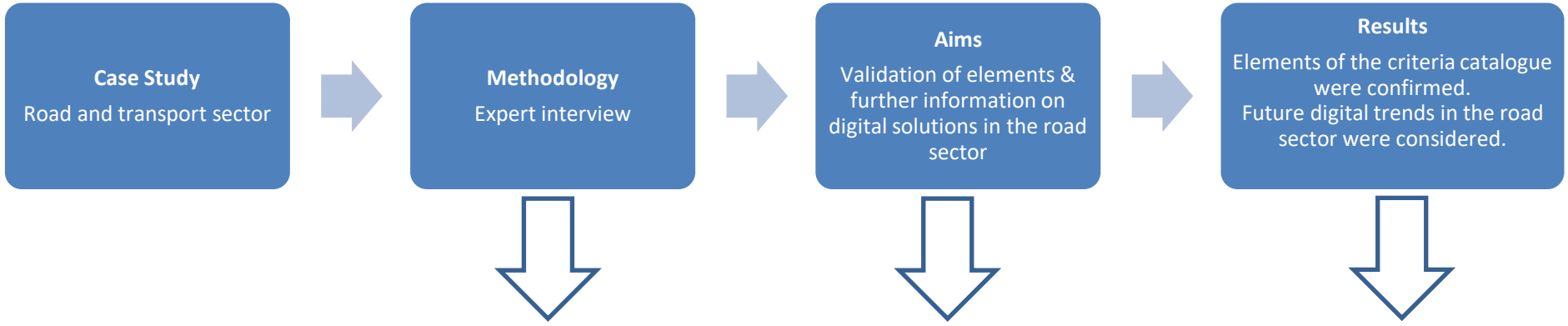
Outcome 4a: Categorization of recurring elements on adaptation plattforms

Object of adaptation	•Adaptation Element, Adaptation Sector, Adaptation Themes, Agriculture, Crop/Crops, Elderly, Field of Action, Key Sector, Sector, Subject, Theme/Themes, Topic/Topics
Aim of adaptation	•Adaptation Phase, Adaptation Planning, Expertise Level, Planning Function, Steps to Resilience, What are you planning?, What are you trying to do?, Adaptation Strategies, Explore by Steps, Explore by topics, Mitigation Strategies
Geographical scope	•Area of Interest, City/Cities, Continent, Country/Countries, Federal State, Geographic Focus, Geographic Region, Geographical Scope, Habitat, Location, Region/Regions/Region of Interest, Sea Basin, Scale, Spatial Coverage, Target Area
Temporal scope	•Year, Date, Date when published, Experiment, Period, Target Year, Temporal Coverage, Time Period, Timing
Climate variables & climate impacts	•Climate Hazard, Climate Impacts, Core Issues, Frequency, Hazard & Climate Impacts, Number of Days in Extreme Weather Events, Scenario, Threshold Temperature, Variables/Climate Variables/ECVs, Variable Domain, Vulnerability Types
Type of decision support	•Best Practice Types, Climate Model, Content Type, Data Set, Data Types, Document Type, Information Type, Media Type/Media Types, Model, Publication Date, Publication Type, Product Type, Resource Type/Resource Types, Tool Type, Tool Use, Type of Publication, Type of Practice, Type/Types
Potential obstacles & Other	•Costs, Factor, Funding Range, Index, Jurisdictional Constraints, Keyword, Keyword Search, Language, Public Agencies, Search, Target Group, Transparency

Outcome 4b: Development of a criteria catalogue for user-oriented climate services

Context	Element	Specific Issue
User context	Phase of adaptation	What is the aim of the user?
	Target group	To which target group does the user belong?
	Level of expertise	What previous knowledge and (technical) capacities does the user have?
Object context	Sector	To which sector does the object to be adapted belong?
	Object type	Is a single object or a network of objects going to be adapted?
	Geographical scope	Where is the object located?
	Temporal scope	What is the project horizon? Does a certain life cycle for the object exist?
	Climate variables & climate impacts	Does the user can select specific climate variables and climate impacts?
	Level of experience	Does the user can specify the impact threshold of the infrastructure?
Technical context	Accessibility	Does the user have free access to the decision support?
	Language	Does the user can choose the language of the decision support tool?
	Help Desk	Is it possible to contact the provider for further advice?

Outcome 5: Validation of the elements in the criteria catalogue



Fore exemplary statements: see Outcome 5a

For more detailed results (e.g. that every element was confirmed): see Conclusion

Outcome 5a: Selection of quotations from the expert interview

"What are the threats to my structure? Where are the vulnerabilities? What are the resulting risks? How can I act? In principle, it's always these four steps."

"In order to prevent threats and ensure the safety of all road users as a top priority, the introduction of speed limits is therefore an applied consequence in the road sector. Although this does not significantly change the probability of a hazard occurring, the risk of personal injury and damage to property is contained."

"[...] in my experience [...] this must come from a native speaker who is also in the context, for example either an engineer or a climatologist, who must at least check. Because if you have a couple of wrong engineering terms there, the engineer is dead. The technical terms must fit 100 percent, otherwise it's not acceptable."

"Analyses and tools regarding adaptation to climate change are only meaningful if existing road infrastructures are categorized and examined about their specific hazards and risks. "

"... and I need object-specific solutions. I can't do that by rules and regulations, I have to look at each tunnel or major bridge separately."

Much is on the emotional level. If I have already open the tool and I have a feeling "This is semi-professional or does not play in my world", then this does not lead to acceptance [...]"

But such a PIARC (Permanent International Association of Road Congresses) is of course also a giant tanker. Once it is in motion, you won't turn it around in a confined space. But we have realized that we can't get anywhere without these topics [...] if we don't deal massively with digitalization."

"Our road will be very much become more digital. "

Conclusion

Neither the trend of global warming can be longer denied, nor the increase in extreme weather events associated with significant changes in the global climate. Numerous scientific studies, historical series of measurements and climatological analyses generated by a wide range of international institutions confirm this development and making need for action unavoidable. Therefore, it is crucial not only to aim for the prevention of global warming pursued by reducing harmful greenhouse gases, but also to develop and follow strategies for adapting to the unavoidable negative effects of climate change. Such measures are particularly important in areas of life which create the basis for the function, the supply and the social and economic development of a society. An example of such an area is the transport and traffic sector. It is assigned a special role, since the effects of climate change endanger existing road infrastructure, which is also compared with the bloodstream for the human body in terms of its elementary functions for the supply, development and mobility of societies. Functioning traffic routes and available means of transport connect the economic, ecological and social spheres of life by linking locations and people. In this way, processes of participation of disadvantaged social groups in economic and political developments are enabled, basic mobility is promoted and the prerequisites for economic activities are created through road infrastructure.

Against the background of climate change, concrete threats to road traffic and its function arise from heat waves or extreme precipitation. These lead to direct damage such as blow-ups and cracks in the road infrastructure, from which indirect risks result such as limited usability or even the impairment of road safety. In addition to speed restrictions, which are considered promising to reduce the probability of risks occurring, further concrete adaptation strategies must be developed. Especially, the large number of existing road structures must be made more resilient in upcoming years. To sum up, the tunnel and traffic control centres in the road infrastructure can be considered robust and not endangered by the negative consequences of extreme weather events. At the same time, a large stock of road infrastructure needs rehabilitation, for which object-specific adaptation solutions must be developed. Aware that the climate is changing and that this is having a negative impact on infrastructure, debates on adaptation strategies have been taking place since the early 1980s and numerous political agreements have been reached since then. These include various framework agreements as well as the Global Framework for Climate Services. This framework is intended to improve access to relevant and high-quality climate information, as well as to promote the user-friendly processing of climate data and the provision of case-specific Climate Services. These Climate Services include the production, translation, dissemination and use of unprocessed climate information and exist in a wide range of formats. Especially, digital Climate Services in form of web-based adaptation platforms represent an increasingly important method for collecting and sharing experience and knowledge and can be considered an important decision support tool by providing sector-relevant climate information.

Regarding the existing landscape of adaptation platforms, it turned out that an almost confusing variety of web-based solutions for decision-making processes in climate change adaptation is offered worldwide (Outcome 1). A total of 160 platforms was identified, 107 of them for the individual continents, with a focus on the USA, Europe and Oceania, and a further 53 platforms at the global level, which also showed the dominance of Western institutions. The strongest increase in the number of web-based adaptation platforms for the 107 platforms occurred between 2000

and 2015, while the number of globally applicable adaptation platforms has been increasing especially since 2011. This implies that although the issue of knowledge platforms was addressed early on, but simultaneously the demand for Climate Service User Interfaces increased and thus more and more web-based platforms have been developed as a means of knowledge transfer. Regarding the actors who are the driving forces behind the platforms, a confusing variety of governmental, civil society and independent institutions can be identified, which need to be investigated further (Outcome 2). Furthermore, it was found that the adaptation platforms differ significantly from one another in terms of their degree of user orientation and only a comparatively small proportion of them respond to the needs of the users: of the 160 platforms identified, only 68 fulfilled the conditions of user-oriented design and only 39 of thes 68 platforms were considered highly user-friendly (Outcome 3).

During the expert interview it was also confirmed that the level of understanding between users and providers is often missing and that only very few adaptation platforms can react flexibly and spontaneously to user needs due to their rigid structure. Thus, the basis for the formulation of these very requirements for effective adaptation options is missing. Furthermore, there is often a lack of contact opportunities for a long-term and continuous exchange and for building mutual trust. Based on the 68 bi-directional platforms, which implement the coproduction principles to varying degrees, various interactively selectable elements were identified, listed and categorised, which help to identify the needs of the corresponding sectoral users. The elements contained in the catalogue of criteria derived from this were confirmed in the expert interview: when developing new web-based adaptation platforms, it is important considering the adaptation phase, the target group and the level of the user's competence. In addition, crucial elements to determine user-oriented needs are the sector, the type of object, the geographical and temporal coverage, important climate variables and consequences as well as empirical values which must be defined (Outcome 4). Furthermore, access to the web-based decision support should be easy to understand, offered in different languages and the possibility of contacting the user in an analogue way should be provided. It was added that it makes sense to state the year of construction of the infrastructure in order to establish a link to regulations. It was also confirmed that links to relevant background information, providers or other tools could be provided in suitable places in order to give the user the opportunity to inform himself without presenting an unclearly large number of and possibly superfluous aspects.

The main obstacle to the success of a web-based customization platform was security reasons. This means that sectoral users do not enter sensitive data about an infrastructure object on a digital platform, as they could fall into the wrong hands and become vulnerable. The confusing variety of web-based solutions and the more research-oriented and less practice-oriented approach were also criticised. Regarding the question, to what extent Climate Service User Interfaces in form of web-based adaptation platforms can contribute to the climate change adaptation of infrastructure, it can be summarised that they should respond to the needs of the user by means of various elements. At the same time, web-based adaptation platforms can only ever act as a decision support in an adaptation process up to a certain point, since analogue consultations are still very important and, for security reasons, no digital solution can and should cover all needs.

Regarding the importance of digitisation in the road sector, it can be added, apart from road sector-specific adaptation platforms, that digitalization will play an increasingly important role in the future. Individual pilot projects are already using digital technologies such as sensors, drones, 3D models and scanners to obtain information that can be useful in the climate change adaptation of road infrastructure. Overall, there is a tension in the road sector between ensuring road safety and innovations through digitalization. However, global institutions have recognised that while existing regulations are useful in legal matters, they often act as a brake on innovation. Therefore, the demand for the future is a combination of old and new technologies that are promising for the climate change adaptation of infrastructures.

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