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Climate change and emerging risks. Innovative urban climate services as a strategy to improve resilience of human systems.

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Abstract. Climate change and extreme natural events are increasingly threatening human systems. Even if greenhouse gases emission were reduced to zero today, global warming and the consequent climate change would continue to affect future generations: as climate is changing, human systems must learn to adapt. This study focuses on the role, the use and the management of climate information to overcome the barriers to climate change adaptation action. The article first addresses the relationship between sustainable development and climate change, regarded as “two mutually reinforcing sides of the same coin”. After a short section on the complementarity of mitigation and adaptation strategies, it analyses the barriers to investments in climate adaptation action by public authorities: the uncertainty about the magnitude and the frequency of climate change-connected events, the common wrong perception of unlikelihood of global warming consequences and the intrinsic complexity characterizing human systems are identified as major constraints. These considerations lead to introduce the concepts of soft-resilience and low-regret adaptation strategies. The discipline of climate change adaptation based on soft-approach climate resilience strategies is closely linked to information management, information technologies, communications, logistics, geographic information services and good governance. Indeed, information management is here seen as the pillar of soft-approach strategies. Low-regret strategies are defined as measures that would generate net social and/or economic benefits both under current climate and a range of future climate change scenarios. Section 5 explores potential synergies between Climate Services (understood as any service, equipment, techniques, practical knowledge and skills that can be used to increase climate resilience of human system) and Urban Facility Management services. This study identifies Innovative Urban Climate Services, an integrated system of services addressing both climate and urban issues simultaneously, as an effective, soft-approach and low-regret strategy to overcome the barriers to adaptation action. These solutions provide a general framework allowing a flexible and customized support for human systems in adapting to unavoidable impacts of climate change.

1. Introduction

Earth’s climate has been relatively stable for the past 12000 years, and modern life is tailored to that climate [1]. In the last century, human systems face emerging physical and social risks arising from climate change, one of the biggest global challenges of modern world. Climate change has become a central theme in many political and public debates: in the last decade international and intergovernmental institutions and scientific community attention was increasingly drawn to this issue.



Climate change impacts on human systems are beginning to change how urban infrastructure is designed and located, how populations are settled, and their organization [2].

This paper summarizes the initial phase of a three-years research work on climate adaptation strategies for built environment funded by the Italian Ministry of Education (Ministero dell'Istruzione dell'Università e della Ricerca). After a rationale on the link between climate change and sustainable development, the issue of complementarity between mitigation and adaptation measures is approached, followed by an investigation on the barriers to climate adaptation action. Section 3 introduces the concepts of low-regret adaptation strategies and soft-resilience. The aim of the research is then stated: identifying effective strategies centred on the implementation of services to support human systems in coping with climate change. The next sections outline the potential synergies between Climate Services and Urban Facility Management. Lastly, the concept and implementation of Innovative Urban Climate Services, intended as an effective, soft-approach and low-regret strategy to improve resilience of human systems, is discussed.

The interest of this study, in line with the multidisciplinary nature of the issue itself, includes all the aspects of built environment management ranging from tangible to intangible infrastructures management, risk management, digitization and innovation in products and systems. It offers an original standpoint on the issue of sustainable built environment and climate change, exploring possible soft-adaptation solutions to improve resilience of human systems centred on the development of a set of urban services based on typical Urban Facility Management approaches.

2. Complementarity between climate change, sustainable development and built environment

The definition of sustainable development provided by the Brundtland Report in 1987 reads: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [3]. Even if greenhouse gases emission would be reduced to zero today, global warming will continue to affect future generations in the next centuries [1][4]. Climate change is the result of the unsustainable industrial production, unsustainable land use, unsustainable energy consumption, unsustainable resource use globally fostered and accepted by various stakeholders in the last two centuries.

In the UN agreement addressing climate change and promoting sustainable development are regarded as "two mutually reinforcing sides of the same coin" [5]: sustainable development cannot be accomplished without climate action and, vice versa, the Sustainable Development Agenda Goals tackle the main drivers of climate change by reducing greenhouse gases emissions. Climate change is the ultimate sustainable development issue [6].

Which role could built environment play in mitigation and adaption to climate change? The building sector is the main energy-consuming sector worldwide: almost 41% of final energy consumption and comparable contributions to greenhouse gases emissions are attributable to buildings life cycle [7]. Yet, this sector has great potential to significantly reduce GHG emissions [8], enable climate adaptation and enhance resilience of human systems.

3. Emissions mitigation and climate adaptation: adoption of national and local climate plans among European countries

As reported below, NASA stated that even if greenhouse gases emission would be reduced to zero today, global warming will continue to affect future generations in the next centuries [1]. Global climate models and IPCC climate projections support this statement [4]. Even assuming the efforts to reduce emissions demonstrate their effectiveness, climate change effects are inevitable, and complementary actions to adapt to its impacts are needed.

Climate adaptation, understood as "the process of adjustment to actual or expected climate and its effects" [4], seeks to mitigate or avoid climate-related impacts and, in the best-case scenario, to exploit their beneficial opportunities. The Paris agreement proposes a similar and inspiring definition of climate adaptation, identifying it as "changes to the socio-technical systems that support human living in light of inevitable climate change" [9].

So, ultimately, climate changes human systems must learn to adapt. Despite this evidence, data show that this commitment continues to be poorly implemented in practice: a voluntary survey launched by Eurostat and up-to-date as of January 2018 about adoption of national adaptation strategies and plans across 33 European countries reveals that climate change adaptation efforts have increased, particularly over the past decade, but only the 50% of the respondent countries dispose of a national adaptation plan at present (Eurostat, 2018).

What then are the barriers to adaptation action for public administrations and, more in general, for stakeholders? The next section seeks to examine the factors that interacts to impede adaptation planning and implementation.

4. Barriers to climate adaptation action

The IPCC identifies the uncertainties about projected climate change impacts as a major constraint, among others (e.g. limited financial and human resources; limited integration or coordination of governance; different perceptions of risks; competing values; absence of key adaptation leaders and advocates): they interact to impede adaptation planning and implementation [4].

Climate change is an extremely uncertain source of hazard and, thus, difficult to describe and model quantitatively. We need only think of the fact that an integral feature of IPCC reports is the communication of the strength of uncertainties in scientific understanding underlying assessment findings: the “IPCC AR5 guidance note on consistent treatment of uncertainties” was published, where a qualitative level of confidence is expressed for assessment findings (from very low to very high) and, when possible, they are probabilistically characterized with a quantified likelihood (from exceptionally unlikely to virtually certain).

Limitations of available measurements, especially for rare events, make the probability, the frequency of occurrence and the magnitude of such climate change-connected events still partially unknown. There is evidence from the literature of the lack of reliable statistics based on the past, as we are currently experiencing a transition phase of ecosystems. Limited knowledge leads to the common wrong perception of unlikelihood of global warming consequences.

Human systems are complex networks with very specific framework conditions, so the implementation of adaptation strategies is embedded in a complex frame that is influenced by internal and external factors. The issue of complexity should be therefore introduced: multiple communities of people, tangible and intangible infrastructures (built environment) and services characterized by high interdependency make up what we call a “human system”. Human systems are characterized by different geographical location, city structure, size and density, urban-rural relationships, socio-economic aspects, cultural habits and backgrounds, human resources, interests of the involved stakeholders, different exposure and vulnerabilities to climate change impacts, level of awareness of climate change, operational capability.

In conclusion, the uncertainty surrounding climate change impacts scenarios, the consequent common wrong perception of unlikelihood of global warming consequences and the intrinsic complexity of human systems are major obstacles to long-term, significant investments in adaptation actions by stakeholders.

In addition to the above constraints, information management-related barriers should be mentioned. Despite the growing availability of climate data, lack of actionable information can be observed: it may require tailoring, interpretation, or integration with other information before it can be useful [10]. In this paper, we seek to identify effective information management-based strategies that facilitate the implementation of adaptation measures.

5. Soft-resilience and low-regret strategies to overcome barriers to adaptation action

Facilitating the investments in climate adaptation action is a major challenge for the international scientific community. According to the outcomes of many studies carried out by the World Energy Council, addressing the issue of the reticence of policy makers to invest in climate adaptation measures would require a shift from the concept of hard-resilience (defined as the direct strengthening of

structures or institutions in relation to specific stresses, obtained through specific measures to reduce their probability of collapse) to an innovative soft-resilience approach [11]. Soft-resilience is here referred to as the ability of systems to absorb and recover from the impact of disruptive events without fundamental changes in function or structural-measures, relying on preparedness and systemic interventions [12].

The discipline of climate change adaptation based on soft-approach climate resilience strategies is closely linked to information management, information technologies, communications, logistics, geographic information services and good governance. Indeed, information management is here seen as the pillar of soft-approach strategies: it is the basis for the operation of Climate Services, as further explained in the next section.

Hard adaptation strategies rely predominantly on tangible built infrastructures, are resource-consuming and lack flexibility and adaptability to sudden changes in projections of climate change [13]. Given the high grade of uncertainty characterizing climate models, soft adaptation strategies present a great advantage considering their flexibility, reversibility and cost-effectiveness.

Table 1. Proprieties of soft-approach adaptation strategies and hard-approach adaptation strategies.

Propriety	Soft – approach adaptation strategies	Hard – approach adaptation strategies
Flexibility	Flexible, adaptable to sudden changes in climate conditions or projections	Inflexible in the short-term, non-adaptable to sudden changes in climate conditions or projections
Reversibility	Reversible in the short term without adverse impacts; do not narrow future choices	Reversible in the long time with impacts; narrow future choices
Technologies	Rely on simple, low-impact technologies and intangible infrastructures	Rely on complex technologies and human-built infrastructures
Time horizon	Short-medium term investments	Long-term investments
Scale	Small-scale measures	Large-scale measures; large-scale disturbances
Compatibility	Allow coexistence and synergies with other measures	Trade-offs with other measures; narrow future choices
Resources	Resource-saving; cost-effective	Resources-consuming; capital intensive
Type of interventions	Deal mainly with organizational, operational and institutional capacity	Mainly provide for physical interventions
Adjustability	Adjustable to stakeholders needs	Difficult to proportion on the basis of uncertain data
Environmental impact	No environmental drawbacks	Medium to high environmental drawbacks

Soft adaptation strategies may be regarded as low-regret solutions. It is worth introducing here the concept of low-regret adaptation: the IPCC defines it as measures that would generate net social and/or economic benefits both under current climate and a range of future climate change scenarios. Summarizing the UK Adaptation Sub-Committee definition this type of solutions can be described as adaptive measures for which the associated costs are relatively low and for which the benefits, although primarily realized under projected future climate changes, may be relatively large. The key is maximizing the positive impacts of climate adaptation measures.

Table 2. Proprieties of low-regret and high-regret adaptation strategies

Propriety	Low-regret adaptation strategies	High-regret adaptation strategies
Resources	Relatively low; resource-saving; cost-effective	High investments; resource-consuming; capital-intensive
Purpose	Often multi-purpose; address more than one societal objective	Specific purpose in specific conditions
Benefits	Benefits under current climate and a range of future scenarios	Benefits under current specific climate

Adjustability	Incrementable; often modular solutions	Rigid solutions
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Typical examples of low-regret strategies are restrictive land use planning; insurance, early warning and evacuation scheme; green infrastructures; improved building standards. As can be seen from the tables, soft solutions possess many proprieties that make them potential low-regret strategies.

The aim of this study is here declared: providing a methodology, a conceptual framework for the development of a set of strategies to enhance human systems resilience, taking into consideration the principles of soft-approach and low-regret solutions. The proposed strategies are centred on the enhancement of urban services. The next section first defines what Climate Services and Urban Facility Management are to then explore potential synergies arising from their integration.

6. Climate Services and Urban Facility Management

6.1 Climate Services

Interest in Climate Services has grown over the past decade, particularly with the launch of the Global Framework for Climate Services, a global partnership of governments and organizations that produce climate information and services, in occasion of the 3rd World Climate Conference. The aim was to turn scientific information into operationally available information and services that would help society to better cope with climate variability and change [11]. Later on the EU declared in the European Roadmap for Climate Services, published in 2015, its will to support the development of a market for Climate Services with and for diverse categories of users. In this direction numerous knowledge platforms and initiatives were launched, to foster the application of climate information into effective adaptation and mitigation actions: Copernicus Climate Change Services (C3S), that aims at providing open source climate information; Climate-ADAPT, presented as “a climate knowledge intelligent portal”; climate-knowledge and innovation communities like Climate-KIC, supported by the European Institute of Innovation and Technology (EIT); and many others.

As already mentioned above, Climate Services show limitations in their effectiveness when it comes to deliver usable information for adaptation measures implementation; making climate information applicable may require tailoring, interpretation, or integration with other information [10].

The definition of Climate Services provided by the European Commission includes a broad number of applications obtained from "the transformation of climate-related data - together with other relevant information - into customized products such as projections, forecasts, trends, economic analysis, assessments, counselling on best practices development and evaluation of solutions and any other [...] that may be useful for the society at large". It introduces the possibility to integrate climate-related information with other relevant information from different sources. Kathleen, Swartling et al. broadly conceptualize the developments of Climate Services as ‘climate knowledge systems’ [10], stressing the importance of the three-phases transformation from data to usable information to knowledge.

For the purpose of this study it resulted extremely useful interpreting a definition provided by the CTCN (Climate Technology Centre and Network) that identifies climate technologies, in which the emerging idea of a new, innovative set of Climate Services generated by the synergy with Urban Facility Management services is well represented by the following adapted definition: any service, equipment, techniques, practical knowledge and skills that can be used to increase climate resilience of human system. This concept will be further explained in section 6 of this work, after having delineated what we intend with Urban Facility Management.

6.2 Urban Facility Management

UNI 11447:2012 defines Urban Facility Management as an integrated management service for the operation, the serviceability and the valorisation of urban facilities. [14] Urban facilities include: i) Services for the Territory: monitoring and maintenance of urban green, plants, road network; ii) Services for buildings, plants, infrastructures: monitoring and maintenance of water systems, sewers, infrastructure for public transport, security technology installations, telephone and data transmission networks, availability and emergency intervention; iii) Services for the environment and the community:

cleaning and environmental hygiene, waste collection and disposal, space management; iv) Government services: technical and inventory registers, implementation and management of information systems, operational centres.

Urban Facility Management is increasingly required not only to satisfy the primary requirement – guaranteeing an efficient and effective management of urban facilities through conditions monitoring and maintenance operations – but also to ensure a quick reaction and practical response in case of extreme natural events. In the light of raising hazard magnitude and frequency due to climate change, this aspect becomes of fundamental importance.

6.3 Potential synergies between Climate Services and Urban Facility Management

Optimizing Urban Facility Management by integrating it with climatic information through the use of current ICTs complies with the definitions of soft-resilience and low-regret strategy: this strategy relies on information management practices and gives back benefits (a better level of service and users comfort) whatever the climate conditions.

The table below provides some examples of adaptation strategies classified by the definitions introduced in section 4 of this paper, showing the overlaps between soft/hard regret strategies and low/high regret strategies.

Table 3. Matrix of adaptation strategies: examples and classification by definitions.

Strategies	Soft-approach adaptation strategies	Hard-approach adaptation strategies
Low-regret adaptation strategies	UFM integrated with CS: monitoring and maintenance practices for urban facilities	Green infrastructures; Improved building standards; Improved drainage systems
High-regret adaptation strategies	Soft-approach adaptation strategies are not high-regret strategies by definition	Flood protection walls; Improved irrigation systems; Improved urban infrastructures

The heterogeneity of services covering the urban scale requires the formulation of an overall framework in which each individual service is correctly identified through an accurate mapping of the package of goods and services and the relationships among them. This allows to identify and analyse services among which synergies are necessary or convenient.

This is the case of Urban Facility Management and Climate Services. The serviceability of existing urban facilities can be enhanced by linking the information provided in the form of climate models by scientific bodies, and elaborated by services providers to deliver Climate Services, with systems of Urban Facility Management. This allows to anticipate harmful events, raise the grade of preparedness, enable a quick response in case of emergency and, consequently, improve the resilience degree of human systems. Section 6 presents the outcome of this integration.

7. Innovative Urban Climate Services as an effective soft-approach and low-regret strategy to improve resilience of human systems

Despite Climate Services have been broadly investigated in the scientific literature, their grade of integration in human systems management is still insufficient. The lack of operative tools for their application is a main limiting factor of such operationalization [15].

The previous section explores potential synergies between Climate Services and Urban Facility Management systems: integrating the information provided in the form of Climate Services with operations and procedures typical of Urban Facility Management approaches gives rise to the implementation of a new model of urban services based on the effective information sharing to support systematic monitoring and interventions. Human systems needs and requirements for improving their resilience to the impacts of climate change are highly context specific: much meta-information is needed to transfer adaptation strategies [16]. Meteorological information as well as maps, risk and vulnerability analyses, impacts assessments (Climate Impacts Models), and long-term projections and scenarios (Climate Models) crossed with non-meteorological data (such as settlement in high-risk areas, road and

infrastructure maps, urban facilities conditions), may be combined depending on specific user needs [17].

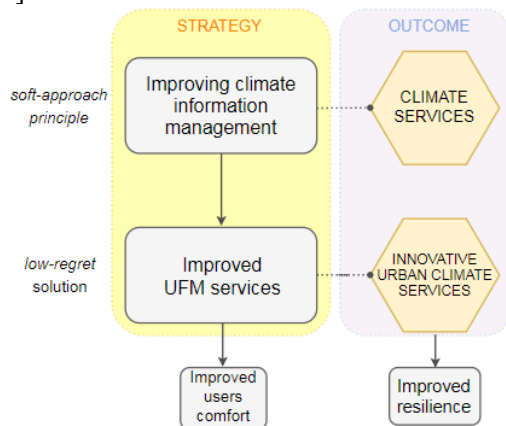


Figure 1. Synergies between Climate Services and Urban Facility Management.

The incorporation of a new operational entity responsible for the processing of multiple information should be envisaged: it will elaborate information making it usable and applicable for various purposes, tailoring it to specific users' categories needs.

The outcomes of this work will include improved conventional urban services that enhance the utility of existing urban facilities and a set of new urban services to cope with climate change trends and extreme events; these services will allow a constant monitoring of climate conditions and urban facilities conditions. The set of integrated Urban Facility Management systems may then be “fed” with geo-spatial and real-time status information extracted from the numerous ICTs systems incorporated in urban space: this would allow to take a step forward from the conventional management method that usually relies on manual maintenance following periodical inspection reports [15].

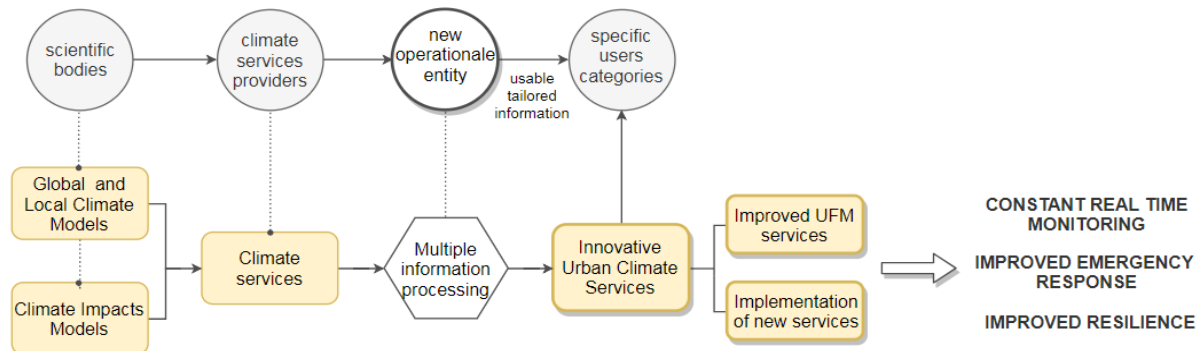


Figure 2. Innovative Urban Climate Services generated from the synergies between UFM and Climate Services.

This paper does not provide by choice a list of Innovative Urban Climate Services due to the fact that one-fit-all solutions would be in contrast with the logic of this research itself. The intrinsic complexity of human systems makes it necessary to consider the specificities of each context and tailor services on user's needs. We leave the presentation of a repertoire of case studies and applications for next publications.

8. Conclusions

This paper seeks to provide an original standpoint to address the issue of how to facilitate the investments in climate adaptation by stakeholders. It introduces the concepts of soft-approach adaptation measures and low-regret solutions and it applies them in the identification of effective short-medium term strategies to be included in the mix of strategies to improve resilience of built environment and human systems. It identifies Innovative Urban Climate Services, an integrated system of services

addressing both climate and urban issues simultaneously, as a strategy to overcome the barriers to adaptation action (uncertainty, wrong perception of unlikelihood of global warming consequences and intrinsic complexity of human systems) thanks to their flexibility, reversibility and cost-effectiveness. Maximizing the positive impacts of climate adaptation measures means promoting sustainable development. The forecasted side-benefits arising from the implementation of the solution presented are improved efficiency and effectiveness of urban facilities management, which may entail an improved urban facilities users' comfort level and a constant monitoring of climate conditions and urban facilities conditions; this may ensure an improved emergency response that will lead to improved resilience of human systems to climate change hazards. This study paves the way to the development of a set of Innovative Urban Climate Services allowing a flexible and customized support for human systems in adapting to climate change.

References

- [1] National Aeronautic and Space Administration – NASA (no-date) *Global Climate Change: Vital Signs of the Planet*. www.nasa.gov
- [2] Intergovernmental Panel on Climate Change – IPCC (2012) *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*.
- [3] United Nations – UN (1987) *Report of the World Commission on Environment and Development: Our Common Future*. Brundtland Report.
- [4] Intergovernmental Panel on Climate Change - IPCC (2014) *Summary for policymakers*. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability*.
- [5] United Nations – UN (2016) *Transforming our world: the 2030 Agenda for Sustainable Development*.
- [6] United Nations - United Nations Framework Convention on Climate Change – UNFCCC (2006) *Climate Change and Sustainable Development: an international workshop to strengthen research and understanding*. Keynote speech by Richard Kinley, Officer-in-Charge, UNFCCC, New Dehli, 7 April 2006.
- [7] European Commission – EC (2015) *A European Roadmap for Climate Services Roadmap*.
- [8] United Nations Environment Programme – UNEP (2013) *Sustainable Buildings and Climate Initiative*.
- [9] United Nations - United Nations Framework Convention on Climate Change - UNFCCC (2015) Adoption of the Paris agreement. In: *United Nations Framework Convention on Climate Change (UNFCCC)*. United Nations, Paris, France.
- [10] Kathleen, E., Swartling, M. et al. (2019) *Identifying climate service production constraints to adaptation decision-making in Sweden*. *Environmental Science and Policy*.
- [11] World Meteorological Organization – WMO (2016) *Climate Services for Supporting Climate Change Adaptation. Supplement to the Technical Guidelines for The National Adaptation Plan Process*.
- [12] Proag, V. (2014) *Assessing and Measuring Resilience*. *Procedia Economics and Finance*.
- [13] Sovacool, B. (2011) *Hard and soft paths for climate change adaptation*. *Climate policy*.
- [14] UNI11447:2012 (2012) *Urban Facility Management Services. Guidelines to set and program contracts*.
- [15] Lee, J., Jeong, Y. et al. (2013) *An integrated approach to intelligent urban facilities management for real-time emergency response*. *Automation in Construction*.
- [16] Cortekar, J., Bender, S. et al. (2016) *Why climate change adaptation in cities needs customised and flexible climate services*. *Climate Services*.
- [17] Global Framework for Climate Services – GFCS (no-date) www.wmo.int