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Unsatisfying Transfer of Climate Research to Urban Planning: The Regulatory Trap in the Triple Helix

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Abstract

Making urban areas more sustainable by transferring scientific results into the building, shaping, and governance of cities is a complicated process which involves – amongst other dimensions – science, local governance, and regulatory processes. There are non-linear interactions within each of these three dimensions which are influenced and enhanced by interactions between the three dimensions. After a short analysis of different sustainability concepts, this conceptual paper considers each of the three dimensions and finally tries to find some suggestions as to how these dimensions could interact more smoothly also considering Triple Helix theory. One basic suggestion is that without updating laws, norms, and standards, urban administrations will often not be able to integrate new scientific findings into procedures for more sustainable cities. That is, all three dimensions need to be aligned in the process of building sustainable cities.

Keywords

climate sciences – regulation – sustainable cities – urban governance

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1 Introduction

Urban agglomerations are complex entities which are difficult to govern not only due to their internal structure and organization but also due to their embedding in larger regional, national, and global structures. Efficient governance is nevertheless indispensable, because more than half of mankind is presently living in urban areas and this share is ever increasing. Simultaneously, urban areas account for 60–80 percent of energy consumption and 75 percent of carbon emissions (UN, 2021a). Following the UN Sustainable Development Goal SDG 11 for sustainable cities and communities (UN, 2021b), the New Urban Agenda (Habitat3, 2021), the Paris Agreement on Climate Change (UNFCC, 2021), and the latest urgent IPCC Assessment Report (AR6, see IPCC, 2021) the shaping of existing and planning of new cities towards sustainability involves major endeavors.

Many different partners and dimensions have to work together in making cities more sustainable by bringing in innovations in greenhouse gas mitigation, climate adaptation, built environment and new building standards. Such innovations always have both positive and negative effects, bringing with them a persisting and unresolved controversy over the balance between reward and risk (Zhou and Etzkowitz, 2021). We will concentrate here on three major intertwined dimensions (Figure 1): scientific research and knowledge as, e.g., summarized in AR6 on the one side, urban societies which have to decide on the future of their cities on the other side, and larger regulatory structures which impact on urban governance from the outside. Each of the three dimensions involves complex internal interactions which requires simultaneous internal action and mutual interaction of all three dimensions. As the impact of regulatory structures in this context has not found much attention so far, this paper wants to point to the necessity to consider this impact. Standardization procedures, that are one part of regulatory structures, will be looked at as one example.

Fallmannn and Emeis (2020) have recently addressed the scientific part of this complex interaction: the unsatisfying nexus of climate sciences with urban planning and architecture. One of the conclusions of this analysis was that there seems to be consensus in several studies from the last two decades that nearly none of scientific studies, neither climate studies nor sustainability studies, have had a considerable influence on actual city planning and/or building design so far (Eliasson, 2000; Mills et al., 2010: Parsaee et al., 2019). According to Eliasson (2000) the low impact is said to be a result of (1) conceptual and knowledge-based variables, (2) technical variables, (3) policies and politics, (4) organizational variables, and (5) market variables. While

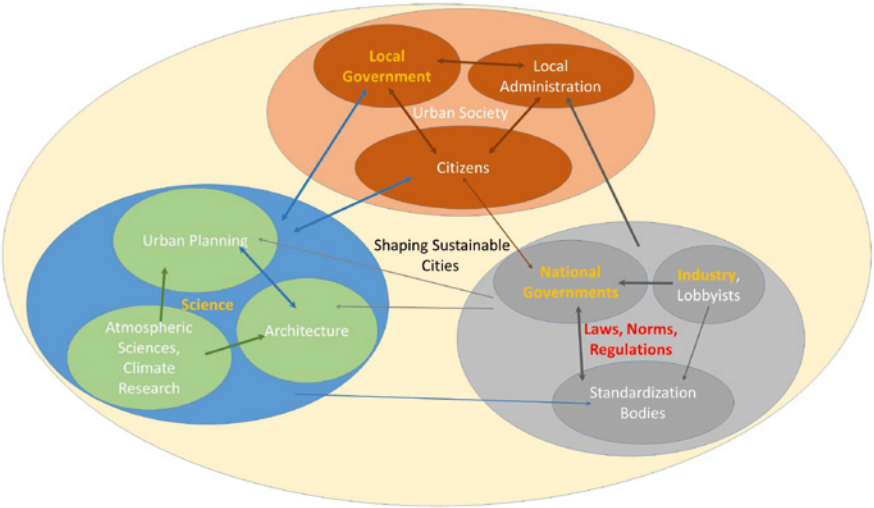

FIGURE 1 Schematic of three major dimensions shaping sustainable cities. Blue and green: the scientific dimension, light and dark brown: the local urban societal dimension, grey: the regulatory dimension. Arrows illustrate selected impacts (one-way arrows) and interactions (two-way arrows). Actors written in orange are the classical Triple Helix actors. Red text indicates the actor introduced in this article

a substantial body of knowledge on the science of urban climates has been developed over the past fifty years, there is little evidence that this knowledge is incorporated into urban planning and design practice (Mills et al., 2010). For example, urban heat island mitigation strategies (a very recent review of these is given in Goodess et al. 2021) have had negligible contributions to urban development policies and action plans as they necessarily have to involve the dynamic nature of the urban landscape with regard to social and economic aspects (Parsaee et al., 2019). Heidrich et al. (2016) summarize this failure more generally (not only for the scientific dimension) by stating that there is a poor understanding of the relationship between city strategies on climate change mitigation and adaptation and the relevant policies at national and European levels.

Also, so-called smart and innovative cities often do not live up to environmental and social sustainability. Cugurullo (2016) gives the example that the city of Masdar in the UAE failed in this respect, because it has been mainly planned around economic and political targets. In this, sustainability has been understood as reflections of broader policy priorities, not focused on the environment and Climate Change. Amado et al. (2016) even more generally state that current urban planning is not a process that ensures energy efficient cities and then demand both reducing energy consumption and supporting the integration of solar energy systems and smart grid technologies in urban context should be part of urban planning. Martos et al. (2016) analysed more specifically that the impact on the environment and the elevated energy consumption generated by the dominant use of private motor vehicles in cities is one of the most pressing demands on making urban policies more sustainable. Notwithstanding the high interdependences between the urban issues and sustainability strategies, cities have not been analyzed comprehensively from a life cycle perspective so far due to their complexity (Petit-Boix et al., 2017).

The abovementioned lack of influence of climate research on city planning, the poor understanding of the mechanisms between large-scale environmental policies and local strategies, and the shortcomings due to a narrowed view on sustainability and missing life cycle perspectives demand further analysis. Empirical evidence shows that, although radical institutional change seems to be necessary, only incremental change is possible unless outer factors such as the oil crisis in the 1970s help to make greater progress (Van Bueren and ten Heuvelhof, 2005). Presently, the ever increasing number and extension of heat waves, droughts, wild fires, and floodings definitely exert such outer pressure on society. But even the clear wording of the latest IPCC report does obviously not suffice to drive the necessary change (IPCC, 2021). According to this report, any reasonable doubts on the reality of Climate Change have now disappeared. Statement C.2.6 in the Summary for Policymakers of this report warns the stakeholders of severe heat waves and increased heavy precipitation in cities and of the risks which the rising sea level will mean to coastal urban areas.

This notion of missing or the failing impact of scientific results and innovations on shaping sustainable cities also arises, because many scientific or engineering analyses of urban sustainability ignore or do not sufficiently understand the ways in which economic, social and political processes across different levels and systems of governance interact in cities (Bulkeley and Betsill, 2005). Traditional distinctions between local, national, and global environmental politics, which have been fostered to take place in isolation by a broader tendency within the literature of environmental policies, must be challenged and must lead to a multilevel governance (Bulkeley and Betsill, 2005). In such governance arrangements, multiple actors interact to shape the 'rules' and processes needed to manage and transform cities. Governance could be defined as 'the sum of the many ways individuals and institutions, public and private, manage their common affairs' framed by a normative vision for the future (Baud et al., 2021). According to Sato (2017), communication has to happen in the framework of a global knowledge economy, where dedicated transfer programs between global and local players as well as public and private stakeholders can be implemented with less complexity.

The DISCUS project (Developing Institutional and Social Capacities for Urban Sustainability, the results of this project are compiled in Evans et al., 2004) found that most actors still believe in the assumption that good local governance is a necessary precondition for the achievement of sustainable development, and that the mobilization of local communities is an essential part of this process. These assumptions, which have guided the policies and programs of over 6,000 local authorities around the world in starting Local Agenda 21 or similar processes, have never been seriously tested (Evans et al., 2004). About 15 years later, governance techniques that could lead to sustainable cities are still under debate, because often the focus is still too narrow on science and technology (Gebhardt, 2019). Different forms of participation of the relevant societal groups are necessary. Van der Jagt et al. (2021), e.g., suggest the technique of 'reflexive governance' meaning an iterative procedure of system analysis, goal formulation, and strategy implementation in order to proceed towards sustainable and just cities.

The abovementioned analyses of shortcomings (especially those of Heidrich et al., 2016 and Bulkeley and Betsill, 2005) are a sign of unknown or insufficiently understood linkages between the different dimensions depicted in Fig. 1. One of these linkages is the usually retarding impact of regulation on the actions of cities. Any new measure or action taken in cities in order to transform them towards more sustainability has to fit into the existing body of laws, rules, and standards. This barrier has already been listed amongst many other barriers in Ekstrom and Moser (2014) and has been named as one reason for urban sprawl (Turner 2017). Non-compliance with pre-existing standards has also been identified by da Trindade et al. (2020) as an obstacle to sustainability. The necessity to remove such barriers has been recognized in principle (EU 2014; CEN-CENELEC 2016) but action is starting only very slowly (e.g., Kind et al. 2021), also because a taxonomy of these barriers is nearly nonexistent (Cristino et al., 2021).

Thus, it makes sense to take a closer look at how these unknown or insufficiently understood linkages can be identified and addressed. The Triple Helix (TH) model has been suggested as one method to identify fields of technological development that at one and the same time deliver both objectives, innovation and sustainability (Zhou and Etzkowitz 2021). In its basic shape – by linking the three actors university, industry and government – the method was constructed to resolve the dilemma of creative destruction in the renewal of the New England region in the 1920–1940s (Etzkowitz 1983). Almost as soon as it was proposed, observers were tempted to add additional helices to address additional issues beyond innovation (Zhou and Etzkowitz 2021). For example, the Quadruple Helix (QH) concept as an extension of the TH concept had been proposed by Carayannis and Campbell (2009) who suggested the civil society together with the media as a fourth dimension of the Helix. In purely extending this concept by including the regulatory dimension, the inclusion of the regulatory dimension would be a fifth dimension in the Helix concept leading to a Quintuple Helix QiH). Galvao et al. (2019) provide a literature review of different variations of the triple helix approach, concluding that holistic strategies towards sustainable development has yet to include another fifth dimension – the natural environment (see also Figure 2 in Cai (2022) for the hierarchy of TH, QH and QiH). In the view of Galvao et al. (2019), decision making towards sustainable solutions also includes socio-ecological interactions in the framework. We will here consider the natural environment as an outer condition and not as an active player in this paper.

Recent reviews (Zhou and Etzkowitz, 2021; Cai, 2022) try to adapt the method to current issues in innovation and sustainability. Zhou and Etzkowitz (2021) suggest a "Triple Helix twins" approach while Cai (2022) proposes a "Neo-Triple Helix" model. The purpose of this paper is not to decide between these recent approaches but to point to the importance to consider the role of regulation in one way or the other in such models which should serve to bring innovation and sustainability together.

This article will, after a short methodical Section 2, present some existing key concepts in urban sustainability research including linkages between the 'smart city' concept and the 'Triple Helix' concept in Section 3. This Section also shortly compares existing Triple Helix concepts with the three dimensions chosen in the concept for this paper. The first of these three dimensions, the scientific dimension, will be introduced in Section 4 followed by the urban dimension and the regulatory dimension in Sections 5 and 6. These three sections will concentrate on the choice of the main actors in each dimension and on the links between the three dimensions. Section 7 will suggest some enhancement to the Triple Helix theory and practice which could help to better represent the impact of the regulatory dimension. The final Sections 8 and 9 present Discussions and Conclusions.

2 Method

This is a conceptual article. In terms of Jaakkola (2020) the focal phenomenon addressed in this paper is the unsatisfying transfer of findings from climate research into urban planning. The factor which is to be identified to hinder this transfer is the regulatory domain. The focal theory is the TH method. The regulatory domain has not been a visible part of present TH methods so far.

The assessment of the focal phenomenon is mainly coined by the scientific expertise of the authors who have both experienced conflicting views in climate science and in administrations in recent years. The assessment of the interaction of scientific knowledge with local and larger-scale governance and regulatory structures will be partly made from personal experiences of the authors as climate scientist, city councilor, and as a member of a standardization committee (first author), and as climate scientist, scientific advisor in a scientific outreach institution, and now as a member of a city administration (second author). Besides the authors' own experiences over many years, the study is purely based on a literature research approach. No specific field or simulation data have been collected for this paper. The overall roadmap to the article is Figure 1. This Figure displays relations which could be integrated into the focal theory addressed in this paper in order to find a possible way to heal the focal phenomenon identified in this article. The way how this could be done is left to the expertise of TH specialists.

3 Sustainability Concepts for Cities and Involved Dimensions

Sustainability covers a wide field of social, environmental, and economic aspects and has many definitions. A sustainable city is, e.g., according to Guimarães (2012), one that is designed to (or is willing to) reduce its ecological footprint by minimizing its required inputs of energy, water, food and its output of heat, waste, air and water pollution while improving the citizens' quality of life (health, housing, transportation and space). Social, environmental and economic aspects of sustainable cities have been summarized by Alvarez-Risco et al. (2020). These concepts detail the well-known more general definition given by Brundtland (1987) that sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs.

There has been frequent use of the term 'smart city' in recent years (Yigitcanlar and Kamruzzaman, 2018). It usually implies that data-based information and communication infrastructure and enhanced IT applications lead to better governance. In this, the meaning of 'smart' is somewhat different from 'sustainable'. Often social sustainability dominates over environmental and economic sustainability in smart cities (Ahvenniemi et al., 2017). Bibri and Krogstie (2017) give a literature review on the designations 'smart' and 'sustainable' (and all possible combinations thereof) for cities. A recent review (Angelidou et al., 2018) showed that the links between smart applications and sustainable cities are fragmented and that there are at least six fields of action which need further research. These are: (1) green mobility, (2) waste management, (3) air pollution, (4) energy consumption, (5) urban biodiversity, and (6) water management. Having these six fields in mind, we want to look into the shaping of 'sustainable' cities, not of 'smart' cities. A recent summary of 'smart city' concepts is given by James et al. (2021) also linking Triple Helix (TH, academia, government, industry as actors, see, e.g., Leydesdorff and Etzkowitz, 1998; Deakin and Leydesdorff, 2013) and Quadruple Helix (QaH, adding citizens as fourth actor) ideas for creating innovation to the 'smart city' concept.

Another frequently used term in recent years is 'artificial intelligence (AI)' (Laplante et al. 2020). This can be seen as part of the 'smart city' concept (Kirwan and Fu 2020). Or it goes even further in that digital infrastructure is not only used to widen platforms for information and communication, but also to prepare and may be even eventually to take and substitute decisions on shaping future cities (e.g., the optimization of energy consumption, Chui et al. 2018). A review of recent developments on how AI can impact city planning through reshaping the urban planning and design of the built environment can be found in Abd El-Hameed (2020). But it is not yet understood whether AI could herald a utopian future where humanity co-exists harmoniously with machines, or portend a dystopian world filled with conflict, poverty and suffering (Goralski and Tan 2020). According to Goralski and Tan (2020) it is also unclear whether AI would accelerate our progress on the United Nations Sustainable Development Goals (UN, 2021b) or bring us further down the path toward greater economic uncertainty, environmental collapse, and social upheaval. Thus we will merely consider AI as one of the many possible methods for shaping future cities.

The concept of this paper will be limited to a discussion on the interaction between three dimensions (Figure 1), i.e., between science (= academia in the original TH concept), urban society, and regulations. For this purpose, citizens will be seen here as part of the urban society, and not as an independent actor as in Carayannis and Campbell (2009). The second TH actor, Government, will show up in both the urban society and the regulation, and also the third classical TH actor, industry, will contribute to the urban society as well as to regulation. This re-shuffling has been made in order to better isolate the role of regulation in this context. The three dimensions chosen here will be addressed in the three subsequent Sections. Please note that Figure 1 although looking very similar to Figure 3 in Cai (2022) has been drawn independently from the ideas conveyed in Cai (2022). Thus Fig. 1 is neither to be seen as a confirmation nor as a decline of the "Neo-Triple Helix" approach.

There are also other outer conditions and forces acting in Fig. 1 which have not been depicted in the graphic. Amongst these are the physical, biological, and chemical facts which govern nature and ecosystems on this planet. These facts directly impact on the results of scientific studies. And even more important, these facts as such cannot and must not be subject to discussions in the other two dimensions. Only the way how to apply them may be debatable. Another outer force in the framework of Figure 1 are global environmental and ethical goals reached in consensual meetings and treaties prepared by the United Nations or their respective sub-organizations. They directly impact all actors and acting bodies in all three dimensions shown in Figure 1, but more specifically they have to be integrated into the laws and guidelines produced in the regulatory dimension. In contrast to the physical, biological, and chemical facts, they are at least in principle debatable, because they emerged from extensive, partly ethical discussions and not from first principles.

4 The Scientific Dimension

The first of the three dimensions chosen in the concept for this paper is the scientific dimension. This dimension as such is characterized by a clear pre-assessment of the measures and their expected outcome/benefit and also by being able to provide quantitative evaluation in preparation of the intended measure. Climate sciences, atmospheric sciences, architecture, and the engineering discipline of city planning are seen here as core parts of the scientific dimension of re-shaping our cities towards sustainability (Figure 1). This scientific dimension has been analyzed in more detail in Fallmann and Emeis (2020). There are more involved disciplines (see, e.g., the definition of a sustainable city by Guimarães (2012) given above) but on the road to more sustainable communities in climate change those disciplines depicted here play a major role and can thus serve as actors whose interplay needs some assessment. Limiting the number of considered disciplines also helps to keep some simplicity in order to make the major aspects visible. This selection does not contradict to the fact that key findings and innovations in science usually have their origin in specific disciplines while the transfer of findings and innovations into societal application very often requires interdisciplinary and even transdisciplinary cooperation.

Facts, findings and results from the scientific dimension impact citizens and local governments in the urban dimension (Figure 1). This impact can be quite different. While citizens often unintentionally digest output from the scientific domain by consuming media (social networks, television, internet, etc.) and mainly relate this information to their personal situation, members of local governments (councilors, secretaries, mayors, etc.) note especially information which relates to their tasks. This can lead to quite different ways of reception of one and the same fact.

The scientific dimension also impacts on the law-making and standardization bodies in the regulatory dimension by providing the basic facts and guiding first principles. On the other hand, laws and rules issued in the regulatory dimension influences and partly even guide city planning and architecture, because they set the outer boundary conditions for the work in these disciplines (Ramirez Lopez and Grijalba Castro, 2021). Even climate research is somehow influenced by the regulatory dimension, because much applied research is funded (and thus partly steered) by the national governments (e.g., Lord Adrian, 1992).

5 The Urban (Local) Dimension

The second dimension chosen for the concept of this paper is the local urban dimension. This dimension is represented here by citizens, local governments (mayors and councilors), and local administration (Figure 1). Once again, as in the scientific domain, there are definitely more players around in the urban dimension which have been discarded for the sake of simplicity. This urban dimension involves many partners which have to find a consensus. Mediation has to be made between the political will and the societal consensus of the citizens, the factual needs of the city (this also includes the wishes, needs, and offers of local industry and traders), and the ability of the administration to run the city in accordance with very detailed laws, rules, and guidelines mainly imposed from the outside onto the city. Scientific findings and results have to be made available to the various partners before this mediation process starts.

Usually, there is only small space for local legislation to change the impact of these outer rules and guidelines. This inflexibility is partly by intention, because national governments want to maintain equal living conditions all over the country. The urban administration has then to execute their tasks in accordance with the outer laws, rules, and guidelines and the local legislation. The urban dimension is not free to set new local rules which are in contradiction to national laws, rules, and guidelines, even if they were based on good new scientific arguments. This is, because there is another player not mentioned so far: jurisdiction. Everybody who feels to be negatively affected by local changes to given national laws is free to appeal to court and to ask for the unchanged execution of given national regulation. Thus, the left room for local action following new scientific insights is small. In the concept of this paper, jurisdiction will be regarded as an outer force.

Bulkeley and Castán Broto (2013) show that numerous cities, while having adopted greenhouse gas reduction targets, have failed to pursue a systematic and structured approach and, instead, prefer to implement no-regret measures on a case-by-case basis. According to Bulkeley and Castán Broto (2013) this is because municipal authorities sought to engage with an issue that lay outside their core competencies. Thus they turned to an enabling mode of governance that depended on discrete pots of financial assistance and on re-framing climate change as an issue related to existing core agendas (concerning financial savings, congestion, air pollution, urban planning and so on), which resulted in the mentioned fragmented, case-by-case approach to the development of initiatives and measures. A way out could be experiments, governance experimentation, socio-technical experimentation, and strategic experimentation as possible means to change urban governance of climate change (Bulkeley and Castán Broto, 2013). But Baud et al. (2021) mention that also participatory experiments which try to include people and new knowledge from various sources remain limited because existing regulatory frameworks keep these more inclusive processes outside mainstream administrative processes.

This shows that scientific information may reach the urban society by the ways mentioned in Section 4, but the usage of this information is very much limited by constraints imposed on the urban society from larger scales, e.g., by the regulatory dimension described in the subsequent section.

6 The Larger Regulatory Dimension

The third and new dimension in the concept for this paper is the regulatory dimension. This third, large-scale regulatory dimension is detailed into three players as well: national governments, lobbying organizations and standardization bodies. Once again, like in the other two dimensions described in Sections 4 and 5, there are other actors as well in the regulatory domain. We will concentrate on the three mentioned ones in order to keep the simplicity of arguments.

Global environmental goals such as they are defined in the United Nations Sustainable Development Goals (UN, 2021b), the New Urban Agenda (Habitat3, 2021), and the Paris Agreement (UNFCCC, 2021) and as they are demanded by IPCC reports (IPCC, 2021) as well as own national goals are usually converted by the national governments into national laws and regulations which are equally valid for all communities of a country. By standardized legislative processes these goals are incorporated into a large pre-existing body of laws, rules, and guidelines which had developed over decades. During this integration process considerable influence by political parties, industry, and lobbying organizations can be felt (Figure 1). These actors have contact to the scientific world although their receptions of scientific facts and results is limited and very selective. This reception is very much dominated by internal discussions within these actors and can only weakly be influenced from the outside.

A non-political, more technical part of this regulatory process is performed by national and international standardization committees. Scientists may have direct influence here on the setting of guidelines and standards. The European standardization organization CEN has released a guideline how to change standards with respect to Climate Change in 2016 (CEN-CENELEC, 2016) following Mandate 526 of the European Commission from March 2014 (EU 2014). But a recent German study assessing the situation in Germany and briefly also in the UK, Sweden, and the Netherlands shows that there is yet a long process ahead of us (Kind et al. 2021). The outcome of Kind et al. (2021) is summarized in seven theses. Amongst these are thesis 2: "Standards should reflect recognised rules of technology. Therefore, standardization is only conditionally suitable as a lever for promoting adaptation to climate change as long as many adaptation measures are not considered state of the art" and thesis 4: "Climate science knowledge is often not sufficiently represented in standardization committees".

Using recycled concrete for the construction of buildings in Germany may serve as one example. According to a guideline published by the Baden-Württemberg ministry of the Environment, Climate and Energy in 2017 (BWMECE, 2017), the German standards of DIN EN 12620, DIN 4226-101, and DIN 4226-102 have to be obeyed. These standards restrict the use of recycled concrete to given lower and upper bounds. Nevertheless, the outlook of this guideline informs the reader that the before mentioned standards were based on research in the 1990s (about 20 years ago!) and that several projects have already proven that higher amounts of recycled concrete can be used. But in 2022 the valid version of DIN EN 12620 is still from 2008, and the two standards DIN 4226-101 and 4227-102 are still from 2017. Thus, a sustainable use of recycled concrete is still limited more than necessary by the regulatory dimension.

Recycling of phosphate directly from waste water treatment slurry can be listed as another example. Germany has made the recycling of phosphate from this slurry mandatory from 2029 onwards. But according to the existing regulations, production of new phosphate for fertilizers has to be made from ashes, i.e., the slurry has to be burned first in order to remove other pollutants from this product. Processing via pyrolytic processes is limited by existing fertilizer regulation to the usage of slurry with very low content of other pollutants. Here more flexibility is needed (Roskosch and Heidecke, 2022). This fertilizer regulation is older than the new requirement to recycle phosphate.

Kind et al. (2021) state another retarding aspect of regulation which is of a more cultural type: Regulation is done with a strong focus towards the past, because it sets standards from what has proven to be good. Climate adaptation and mitigation in order to shape sustainable cities on the other hand has to look towards the future. There is no proof from the past what could be appropriate for the future. Only analogies can be used stipulating that the governing physical and mathematical rules and laws are unchanged. This contrast has to be acknowledged as well and then has to be overcome.

The main conclusion from Kind et al. (2021) is that comprehensive incentives for contributions to climate change adaptation can only be developed in the field of standardization by revising central existing standards that have a broad circle of users. The development of new standards in the circle of a community that already has a strong affinity with climate change cannot replace this. But this necessary revision takes time. The subsequent subsection describes the typical work process and its time constants of these committees in some more detail.

6.1 *Standardization Committees*

Standardization committees such as ISO for world-wide distribution, CEN in Europe, ANSI in North America, or DIN and VDI in Germany (just to name a few examples) are among the bodies in the larger regulatory dimension which are closest to scientific experience and knowledge. These committees ideally bring scientists, companies (producers as well as applicants), and authorities together in order to specify the current state of the art of a method or a device. Usually, it takes months to years to apply for the foundation of a working group for a selected method or device. Then, after taking care that relevant stakeholders are involved in a working group, regular meetings start to design and write a guideline or standard on the selected task. After two to three years, a draft is prepared upon which all members of the committee have agreed and which is then put on trial to a larger audience. Finally, after about at least five years, a guideline or standard is ready for publication. Having in mind that the working group only included knowledge that had already proven some relevance and reliability to the task described in the intended guideline or standard, a newly published standard or guideline usually comprises knowledge and techniques that are at least ten years old. Once a standard is finalized and approved by all relevant committees of a standardization body it holds for at least five years before it will become subject to checks whether the content is still fully valid.

These time scales related to creating standards and guidelines are a well-designed mechanism for shielding off half-baked ideas and techniques which are too new to have been tested sufficiently. On the other hand, innovations which are urgently needed to progress in shaping sustainable cities need their time to be filtered through such a standardization process before they can find wide-spread acceptance and use. Nevertheless, standardization has proven to be a successful tool in governance which should not be by-passed (Krechmer, 2004) and which are one of the important tools for national economic growth and for unconventional strategies of businesses (Shin et al., 2015).

The accepted standards and guidelines have to find their way into urban policies. Albeit often not being compulsory by law, regulatory processes and norms can help to steer climate adaption processes in local administrative action. In 2014 CEN and CENELEC (Comité Européen de Normalisation) founded the coordination group for the adaption to climate change (ACC-CG). After various iterations, in summer 2019 the Standardization Organisation (ISO) accordingly published the first international norm on climate adaptation ISO 14090 – "Adaptation to climate change: fundamentals, requirements, and guidelines". It targets to support organisations assessing climate change impacts, putting in place effective adaptation plans and hence helps to identify and manage risks as well as potentially benefit from chances. The technical committee ISO/TC 207, which developed that norm, works on the two additional guidelines ISO 14091 – "Assessment of climate risks" and ISO 14092 "Adaptation on local level" (Kind et al. 2021). As an example, ISO 14090 critically points out the need for action with respect to climate sensitive building design, which in turn protects people and material during for instance extreme heat events. That claim can act as a framework for setting up master plans, whereas in actual implementation there are still large margins on how these measures are being put in place. A key requirement for norms acting as force to adaptation is the proper integration (called mainstreaming) into the planning process, which necessarily involves classical Triple Helix actors according to Figure 1 (Kind et al., 2021).

Another example for a regulation in the process of climate adaptation dedicated to the pre-planning phase is the German guideline VDI 3787 – Environmental meteorology – Climate and air pollution maps for cities and regions (VDI 2015). This guideline helps to justify so-called climate functionality maps as planning criteria for the urban planning process.

7 Possible Enhancements of the Triple Helix Theory and Practice

In the three sections above, the regulatory dimension has been identified as an impactor in the process of shaping sustainable cities. The regulatory dimension usually causes delays and cannot be simply circumvented. Therefore, concepts and plans which aim at forming more sustainable cities have to take into account this regulatory dimension. This section now just shortly resumes considerations in section 3 about the dimensions which constitute Triple Helix concepts.

TH theory and its derivatives (e.g., Zhou and Etzkowitz, 2021; Cai, 2022) are theories that describe ways to operationalize innovation and policy implementation. It has been applied to the development of sustainable cities as well (e.g., Deakin and Leydesdorff, 2013). The set-backs in forming sustainable cities mentioned in the Introduction and in Section 3 indicate that present TH theories do not fully cope with all necessary interrelations between the different relevant actors or even do not involve all relevant actors. The regulatory dimension has been identified as one of the actors not sufficiently accounted for in science (Cristino et al., 2021) and thus most probably also not in TH. Therefore, the regulatory dimension should be either included as a further actor in the TH concept or at least considered as an outer framework with a given long time scale. Following the Introduction and Section 3 it does not matter whether this obviously important dimension is included in a TH twins concept (Zhou and Etzkowitz, 2021) or in a Neo-TH concept (Cai, 2022).

8 Discussion

Due to the dominant role of cities in the global climate system as stated at the beginning of the Introduction, mitigation of climate change is a major aim in shaping sustainable cities. This mitigation means amongst other tasks a drastic reduction of the usage of fossil fuels, drastic reduction of land use changes (cutting tropical forests etc.), strong changes in agriculture (less meat, less fertilizing etc.), and strong changes in building techniques (less cement, more wood, green roofs and façades etc). This complex task cannot be fulfilled within a few years. As the impacts of climate change become increasingly more visible (flooding, heat waves, wild fires, polar ice melting, …) the actions for mitigation of climate change in cities and elsewhere have to begin immediately. The analysis in the Introduction has shown that the present process of (re-)shaping cities towards sustainability is a slow one; most probably too slow. The regulatory dimension has been identified as one actor which is causing delay. The retarding impact of this dimension has become more visible in recent times. This dimension had always been active in the last decades, but the general speed of change towards sustainable cities was so small that the rather long time constant of five to ten years of the regulatory dimension was not the major retarding force in the interplay of the different dimensions. There are indications that this now changes with accelerating climate change.

The analysis in the previous Sections has made visible that actors in the urban dimension are caught between the scientific dimension and the regulatory dimension. Urban governance structures have to deal with the hopefully merged output of the scientific dimension on the one hand and with the specifications and orders from the regulatory dimension on the other hand. Usually, the input from the scientific domain is not merged but fragmented and not unanimous, and the actors in the urban dimension are not able to decide between various contradicting information. The input from the regulatory dimension is not much better. This regulatory input is stratified in many layers and sometimes misses the necessary flexibility which would be desirable when accounting with non-standard tasks. It has to be noted that, e.g., the German standardization body DIN alone has issued roughly 33,000 norms so far (Kind et al., 2021). The international body ISO has issued about 24,000 norms (ISO, 2021).

The major statement from the analysis in this article is that regulation is partly delaying the shaping of sustainable cities, because laws, rules, and guidelines do not include the latest scientific results for an efficient mitigation of climate change. On the other hand, updating of these laws, rules, and guidelines takes much more time than obviously seems to be available for this re-shaping of cities.

9 Conclusions

Following the discussion above, cities often cannot efficiently start innovations, because these would not fully comply to the existing regulation. And the regulatory dimension cannot effectively start to be the driver of re-shaping cities towards sustainability, because the laws, rules, and guidelines have not yet been updated in an appropriate way. Therefore, both problems have to be attacked simultaneously, a classical task for TH methods. The role of science in this respect is to provide consistent collections of findings on climate change that is transferable to the urban and to the regulatory dimension and to the global bodies, which decide on modified strategies to cope with climate change. For instance, the three above mentioned international policy-making bodies which are relevant for urban development, the UN Sustainable Development Goals (UN, 2021b), the New Urban Agenda (Habitat3, 2021), and the IPCC (e.g., IPCC, 2021) are largely influenced by science. In all three examples, however, science is not the only actor but is always confronted with political and economic interests. Transferring scientific knowledge to actual urban applications and governance needs to follow a multi-dimensional approach, where the urban dimension must be willing to digest the findings from the science dimension. The discussion cannot be "if", but can only be "how" scientific findings are incorporated into urban governance of climate change. The regulatory dimension must try to incorporate findings from the scientific dimension together with the global consensus on future strategies (SDGs, New Urban Agenda, Paris Agreement) as fast as possible. Given the description of the work mode of standardization bodies in this paper, this will not be an easy task. Speed-up may come from a faster appointment of new standardization committees for specific tasks but not so much from a change of their principal work mode.

Therefore, future strategies to shape more sustainable cities must address all three dimensions in Figure 1 simultaneously. Without updating laws, rules, and guidelines in the regulatory dimensions, the actors in the urban administrations are not able to change their minds and decisions, even if a departing consensus between the citizens and the urban governments had been found. The internal structure and organization of the regulatory dimension has guaranteed so far in most cases and countries the stability of governance procedures. The price paid for this stability has been a rather long time constant of the regulatory dimension which made rapid changes difficult. It could be that the rapidly progressing climate change will put some more force on this dimension to accelerate their updated procedures.

If TH theory is used to organize the introduction of innovation in the development of sustainable cities, this theory should be updated to a version, e.g., by making a different choice of the main three dimensions which have to interact or by an extension to more complex forms of this theory (QaH, QiH, TH twins, neo-TH) which considers the regulatory dimension as an important actor. Leastwise it should take the rather long time scales and the non-market and non-democratic character of the regulatory dimension into account as an outer condition constraining the actions of all other actors. This conceptual paper hence can be understood as input for dedicated triple helix specialists to adjust TH concepts according to the local circumstances and needs.

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Conflict of Interest

The authors declare they have no conflict of interest.

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