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Cognitive Sustainability

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Abstract

Sustainability is a crucial dimension of our life at the beginning of the third millennium. Our society transforms and changes even faster and more continuously than earlier. Our work aims to define a new concept: the cognitive sustainability domain. Several fields of science were explored to recognise how the interdisciplinary approach of cognitive sustainability is valid. The former joint use of cognitivity and sustainability was reviewed in the literature. Results showed that digital development lets us extend our experiential cognition in most fields of our lives. Limits of the available resources and the development of cognitive functionalities are the enablers of connecting and addressing sustainability. The main dimensions and parameters of cognitive sustainability were identified, and several key research areas were defined. The structured handling of cognitive tools within sustainability results in a broader interpretation framework for analysing, understanding and developing processes in sustainability.

Keywords

Cognitive Sustainability, Mobility, Architecture, Economics, Interdisciplinarity

1. Introduction

Sustainability is a day-to-day issue of 21st-century life in technical and technological processes such as mobility (Zöldy, 2021), which use resources directly, even irreversibly, and in economics and the humanities. In addition to the growth-driven mindset of recent decades, there is an increasing drive to maintain the current state and its qualitative dimensions. The cognitive perception spreading in our world opens new dimensions in understanding sustainability.

The term 'sustainable' started to become famous after Lester R. Brown (1981) first published the terminology of sustainability from a social aspect (sustainable society) and the work of the Brundtland Commission (1987), although examples of practical implementation remained few and far between, as shown by the events at the United Nations as the UN Conference on Environment and Development (Rio Earth Summit) in Rio de Janeiro (1992), World Summit on Sustainable Development in Johannesburg (2002) and the UN Conference on Sustainable Development (Rio+20) in 2012. This can be explained by the slow transition from philosophy to practice, conflicts of interest and the difficulties in interpreting the integrative nature of sustainability. Most of the international sustainability-related conferences provided a unique opportunity to reveal and rethink political commitments considering the three dimensions of sustainable development acknowledged today. The UN SDGs

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(Agenda 2030) are in scope both from policy and scientific perspectives. The concept of sustainable development is strongly tied to environmental protection. Environmental impacts and research results have drawn attention to the importance of environmental protection and the need for international cooperation in this area.

Parallel to the emergence of sustainability, different interpretations have also been developed. One-dimensional models mainly focused on ecological limits and environmental considerations. Two-dimensional models were the next step, adding socio-economic aspects to the focus and differentiating between welfare and well-being. The three-dimensional model is the most recent and the most popular one, according to which the three dimensions are the biosphere, the economy and the society, which are interdependent and have complex interactions. Further dimensions have also emerged in literature, such as the institutional dimension, which is related to establishing the background necessary for measuring and monitoring progress towards sustainability (data acquisition and analysis). Cultural aspects have also been emphasised as a direct result of putting man at the centre of sustainability. The multi-dimensional model of sustainability includes technological, time and space dimensions in addition to the original three. In summary, the magnificence and complexity of the concept of sustainability come from the fact that it can be applied to all levels and dimensions. The field of cognition-related knowledge can deliver a broader and more holistic perspective in the further development of sustainability science.

Our goal was a deep understanding of cognitive sustainability across disciplines in this research. Sustainability can be interpreted in almost all fields of science, but in many cases, with entirely different content. However, increasing cognition allows for better understanding and is the key to better understanding, thereby increasing sustainability. In the scientific literature, several studies have drawn attention to different approaches to defining sustainability depending on the characteristics of the possible sustainable development pathways (Munasinghe, 1993; Luke, 2005; Liu, 2009; Hussen, 2013; Ramsey, 2015; Sauvé, 2016; Whyte-Lamberton, 2020; Ruggerio, 2021). The structure of sustainability in terms of cognition and motivation has previously been examined by van Dam and van Trijp (van Dam, 2011) from consumers' perspectives. Users of sustainable products have been empirically compared with the Brundtland definition (WCED 1987) and the Triple-P-Baseline definition (Hammod, 2006) of sustainability. Their results show that research into consumers' cognitive understanding of sustainable development aligns with consumer motivations and thus helps them buy sustainable products.

In his summary, Bruni (2010) links the implications of the expansion of digital culture for sustainability, in particular the economic crisis of 2007/2008. The work puts the impact of the expansion of digital culture on the relationship between sustainability and information technology in context. This path outlines the eco-ethical dimensions of development and the expansion of comprehensive digital-interactive-immersive representation technologies. Three aspects are examined: Batesone's sustainability (Bateson, 1972), recent developments in the technosphere and Yuri Lotman's concept of the semiosphere (Lotman, J. (2005/1984). As a result of his work, some eco-ethical dimensions are outlined.

The merger of cognitive capabilities for humans and the developing artificial cognition of machines open space to measure, understand and predict sustainability more deeply. The current models are not well equipped to deal with the challenges we face, so a new approach is needed, which also concerns the cognitive sphere. A new way of thinking is necessary, for example, in engineering, economics, urban development and finance. This new attitude is the approach of „cognitive sustainability", which is based on interdisciplinarity, as several areas of life are interconnected in their links to the issue of sustainability.

Climate change is one of the most critical economic and social challenges of the 21st century, and its environmental unsustainability is confirmed by a number of documents (Stern et al., 1996; Stern, 2006; WWF, 2011; IPCC, 2019; IPCC, 2021). The climate challenge is too big for anyone disciple to solve alone. All spheres must work together in a coordinated and aligned manner. Their work must be complementary, as their functions and toolkits are different. It is necessary to exchange knowledge and share best practices in an emerging and uncharted territory of work for many.

This paper aims to provide a possible framework in which human and machine capabilities are part of a holistic, sustainable system.

2. Definition

Cognitive Sustainability (CogSust) investigates the links between sustainability and cognitive sciences research areas. Sustainability can be interpreted as an environmental discipline issue to a first-order approach. Alternatively, as an engineering challenge in a broader range of interpretations, but can be interpreted in many more disciplines.

The key aim of CogSust is to provide a holistic view of how sustainability in a broader sense can be understood, described (modelled) and optimised for human value creation by the application of the tools of cognitive sciences. It results in a deeper merger of artificial and biological cognitive systems with engineering applications.

The sustainability requirement is intended to mean that the objectives cannot be chosen freely in one dimension or sector but must respect certain constraints due to complex systemic contexts (Fleischer, 2014).

Three essential characteristics of cognitive sustainability should be defined: the substance, the equity and the implication of sustainability. Figure 1 introduces the frame of reference considering the main characteristics of the CogSust concept.

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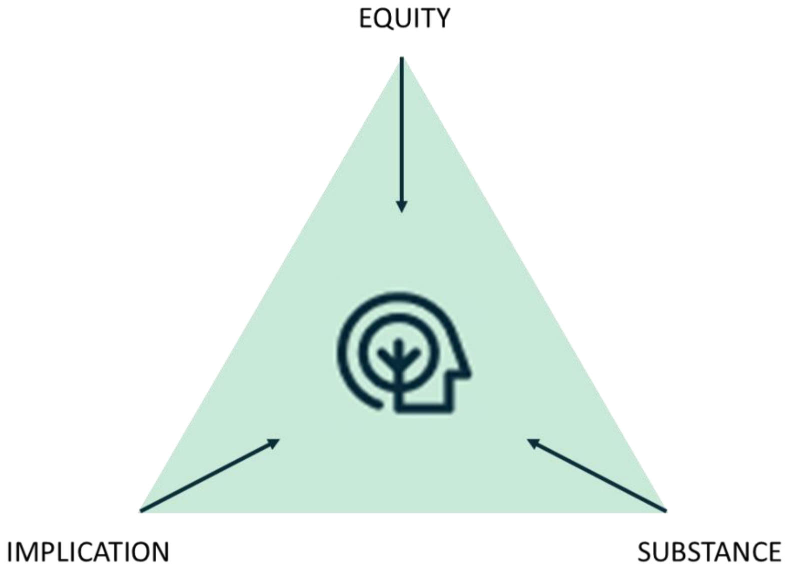

Figure 1. The main characteristics of the cognitive sustainability concept

Substance of Sustainability

Physical sustainability – sustainability can be interpreted at the level of substances.

Non-physical sustainability – sustainability can not be interpreted at the level of substances (i.e. social sustainability or emotional sustainability)

Equity of sustainability

Inter-cognitive sustainability – the actor/decision-maker and its affected zone are different cognitivity levels.

Intra-cognitive sustainability – the actor and the area are at the same cognitivity level.

Implication of sustainability

Extended sustainability – when the decision-maker makes his decision not only by himself but also by managing the set of aspects and dimensions affected by the action.

Island-like sustainability – when the decision-maker puts the sustainability of only the narrowest circle in the focus of his decision.

3. Discussion - Historical view

The cognitive sustainability research area will be examined from a historical and cognitive informatics perspective in the discussion section.

During the industrialisation in the second half of the nineteenth century and the twentieth century, humanity realised by the turn of the 1960s and 1970s that the processes going on for a long time could no longer continue. The unprecedented results, including the pace of urbanisation and the improvement of industrial and agricultural productivity, are based on the use of resources that adversely affect spatially and or temporally distant societies due to their finiteness. An emblematic event in this process was the 1972 Stockholm Conference, or the same year's report of the Club of Rome (Meadows et al., 1972).

The 1980s drew attention to the fact that not only do we consume environmental goods, but we also pollute our environment with emissions. Deforestation caused by acid rain or increased ultraviolet radiation associated with the depletion of the ozone layer was also perceptible environmental damage due to pollutant emissions. Around the turn of the millennium, the issue of climate change put the issue of sustainability at the centre: the environment is now perceived as a sensitive, functioning system with a finite absorption capacity. Human activity can overload the environment in such quantities that it can change the established processes of nature, and consequently, the environment we have adapted to over the centuries is also modified.

Cognitive methodologies have been incorporated into science in parallel with an increasingly broader interpretation and deeper understanding of sustainability. In addition to advances in engineering, the increase in data in other fields, such as finance or sociology, has allowed for a more detailed understanding of sustainability through data and analysis (Fleischer, 2014).

Most authors vigorously defend the ecological dimension of sustainability because it discusses non-human nature and promotes the idea that the more nature changes, the less environmentally sustainable it is. The less human intervention in nature, the more sustainable it will be. For example, environmental data collection has evolved exponentially with the proliferation of meteorological sensors and the expansion of their detection, allowing for a deeper understanding, modelling, and prediction of the environmental impacts of actions (Börcsök et al., 2020).

The cultural dimension focuses on modernisation models and integrated rural production systems, emphasising changing the core of cultural continuity and incorporating the normative concept of ecological development into a range of individual solutions that reflect the specific characteristics of each ecosystem, culture, and site.

The economic dimension revolves around treating the planet's resources and efficiently using natural resources in a competitive environment. With the globalisation of the financial world the almost total online tracking of market processes, a considerable amount of data is available to understand the processes better and create more effective interventions. The strengthening of sustainability in the economy is linked to the development of behavioural economics.

One of the cornerstones of sustainability is the social dimension. The protection of the environment and the conservation of natural resources only make sense and are relevant if products are made from renewable raw materials that different societies can use. Our social processes, primarily through the tremendous digital development of recent decades, are better and more widely documented and analysed than ever before in history. Increasing analytical capacity expands the assessment of past social events and sometimes raises the need for reassessment (Szenthe, 2021).

The spatial dimension encompasses space organisation, follows the occupation criteria and is intertwined with a permanent natural network that seeks to restore quality of life, biodiversity, and human-size in every fragment of the system and every neighbourhood. The proliferation of sensors and the combination of traditional architectural principles prioritise sustainable architecture to minimise environmental impacts.

Sustainability focuses on several strategies and policy documents on the global, regional, and local levels. In the political dimension, sustainability is built by social actors active in their socio-economic and cultural environment, whom the government gives several opportunities to control the resources needed for policy decisions.

Finally, the psychological dimension involves a sense of well-being that transcends the social aspect, as it includes emotions as a quality that is part of the individual's subconscious.

It can be considered that the different dimensions and levels of sustainability may be related to cognitivity. The aim of CogSust is primarily a holistic approach to sustainability, connecting its areas with the tools used by info-communication. It connects certain elements of the system, such as ecology, economy, sociology, or politics, and offers a common space for optimisation with the help of IT tools, which they consider to be part of a cognitive system.

4. Examples

In this chapter, some examples are provided which clearly show the combination of cognitive levels, sustainability modes, and sustainability types.

4.1. Sustainable vehicle energy and emission management

The sustainability question of mobility increases in several fields in the value chain: design, production, use and waste management. The emission of vehicles goes hand-in-hand with their energy management. In the early decades of the vehicle industry, the diesel oil and gasoline used were the by-products of public lightning petroleum refining. The oil crisis in the 1970s and the lead use supported increasing octane demand in the eighties led to energy and fuel quality consciousness. Hybridisation in the first decades of the third millennium opened management opportunities. Today, alternative fuels (Valeika et al., 2021) plug-in-hybrid technology enables the most significant optimisation space for managing the vehicle's energy demand and environmental load (Zsombok 2019). On-board energy management importance is confirmed, especially for self-driving vehicles (Cao and Zöldy. 2019). On-board sensors collect data about the vehicle (mass, C_v, tire pressure, available fuel/energy etc.) and mobility (speed, fuel consumption, etc.). The data acquisition of sensors is not limited to the vehicle itself; the traffic information and geography of the chosen route and weather information are also gathered. It must be extended with refuelling/recharging information such as time-to-wait, expected charge/refuel time, price etc. Combining these provides a complex decision matrix (Zöldy et al. 2018), where sustainability has to be one of the main deciding factors.

The cognitive approach, supported by the large amount of data coming from the vehicle and its surroundings, helps make vehicle-level mobility decisions based on sustainability criteria.

4.2. Sustainable traffic and emission management

Nowadays, the environmental aspect of mobility can be improved by energy and fuel management and applying so-called soft tools, like traffic management or marketing, to change travel behaviour and attitude towards new modes of transport. *Sustainable mobility* is a complex term here. As mentioned above, the emission of vehicles goes hand-in-hand with their energy management. However, what would happen if there were no emissions? Should we stop transporting, or can we change to less

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environmentally polluting modes of transport? The answer, according to modern economists, is pricing. However, who determines the prices? Are all used resources counted when forming a price? Does one make a conscious decision, perceiving all circumstances? Data acquisition in this field is minimal. We have a massive amount of rapidly changing information around us. Moreover, although information has significant monetary value, it is changing rapidly. In contrast, sustainability should be the main deciding factor.

4.3. Sustainable, intelligent urban development and cognitivity

Nowadays, urbanisation processes go hand in hand with the dynamic development of information and communication technology (ICT). However, the growth of cities – due to environmental degradation and pollution, intensive energy use, ineffective urban planning, traffic congestion, increasing social vulnerability and decreasing living conditions, and so on – can threaten the sustainability of cities (Bibri 2019). Meanwhile, ICT has become pivotal in decreasing the recent and possible impacts and risks of urbanisation to meet the requirements of sustainability innovatively. Digital transformation can paint a picture of utopian cities where futuristic solutions make people live better than ever. In terms of sustainability, the potential of digitalisation is still untapped, and the consequences are not precisely predictable. The different subsystems of a city can play a pivotal role in the multi-dimensional resilience of the city due to technical, socio-economic, nature-based and cognitive solutions. Nowadays, the role of local people as intelligent agents of a city has become more crucial in the practical implementation of innovative, sustainable city goals enhancing the main aim of the Sustainable Development Goal 11 (SDG 11). The potential risks of ICT solutions to sustainability can also be grasped from the stakeholders' perspective related to social sustainability in terms of equity, fairness, participation, inclusion, privacy, security, polarisation, social vulnerability etc. (Bibri 2019).

From a management perspective, according to sustainability and cognitive aspects, the stakeholder-oriented approach may provide an overview and highlight the interrelations between the examined terms in different urban subsystems (Szalmáné Csete 2021). As intelligent agents of the urban environment, local citizens or residents also need to have special cognitive skills. Effective urban policies should deliver feasible solutions that can foster the practical implementation of sustainable urban development in the era of climate change and digitalisation, which may be crucial, especially in the 21st century. The question is whether digitalisation is a solution that can support the transition towards the practical implementation of sustainability (Szalmáné, 2021). There is a lack of cognitive aspects in urban policy development and planning, which can hide future cities' hidden potential.

4.4. Cognitivity in sustainable management

Sustainable management can be applied in all the fields of our life to foster the necessary steps towards a practical implementation towards sustainable transition. Sustainable management methods, tools, and solutions can be related to a wide range of business operations, entrepreneurship, innovation, education, environment, healthcare, agriculture, transport, tourism, industry, society, etc., and in our activities.

Sustainable management processes depend on the decisions of different stakeholders on diverse levels in distinct fields of activity. These processes can be based on top-down or bottom-up approaches, can be ex-ante or ex-post, community-based or individual-oriented, supply or demand side-related, etc. There is one common aspect of the sustainable management issues independent from the space and time range, the stakeholder perspective, or the area of the planned intervention, and that is the significant role of decision. The future of sustainable management issues should consider not only the capability to successfully preserve or further develop the quality of life in general, but it should be a result of a series of conscious decisions taking into account all the positive synergies of cognitive developments.

4.5. Sustainable cognitivity in economics

Economics is the science of efficiency: the core question is how resources could be allocated efficiently and effectively. According to mainstream economics, thinking is rather technical because it is value-neutral – but can that be the case when we face a macro-critical challenge (IMF 2021), such as climate change? The shocks induced are already impacting the social sphere, economic activity, financial stability, and inflation. The scale of the impact is already significant and growing further. While environmental risks are non-linear, complex, and subject to radical uncertainty and 'green swan' event (Bolton et al. 2020)s, the extent to which they materialise partly depends on the action we take today. For that reason, it is more and more urgent to integrate the future in our thinking and economic models. In the field of sustainability, economics, by definition, must consider the technological possibilities (Söderholm 2020). However, knowledge can come only from engineering or architecture, respectively – this is one example of the interdisciplinarity mentioned above. How can an environmentally sustainable project be financially sustainable? Where does funding fit in with the environmental sustainability of the financed activity? Can an economist, in his or her own right, make appropriate economic decisions or is it necessary to have a broader approach to economic problems if we are talking about sustainability? We badly need „long-term sustainable economics" (Virág, 2019), but what are its most essential features and pillars?

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4.6. Cognitivity in sustainable architecture

Sustainability in architecture is a series of interconnected ideas that can be interpreted on several levels or layers. The benefits of technology, sociology, and regionality must be addressed in parallel, all so that the minimum lifespan of buildings is fifty years.

Advances in technology and building management systems in conjunction with alternative energy sources cannot deliver satisfactory results. Installing an infinite number of intelligent systems and sensors is an advantage, but in many cases, it can be avoided if engineering design properly balances regional environmental impacts and building materials with the potential of technology. According to the theoretical architect Lebbeus Woods (Manaugh 2007), fundamental revolutionary changes in the architecture of the future cannot take place until humanity changes its current sociological model. Of course, this change must have regional diversity to be sustainable.

The future architecture must reduce the carbon footprint of construction and operation while creating flexibility that is expected to accommodate the functional needs arising from changing social and sociological influences over the lifetime of the building.

5. Conclusions

Sustainability is one of the most exciting challenges of the 21st century. The compulsion of continuous growth in recent decades has guided our thinking and actions, but it is now clear that this leads to the destruction of the planet and humanity. Cognitive sustainability is the result of a belief that fundamental change is required. We need to move beyond the usual framework, and the disciplines must work together to find a solution. The new framework, which also sets out what needs to be done at the level of ordinary people, needs to be created scientifically. A deeper understanding of the world, supported by a better understanding of sensors, the growing amount of data, and artificial and natural thinking, is an essential help in designing the new system.

This recognition is the basis for this article to describe the cognitive sustainability framework. Its most important characteristics are presented and defined: the substance, the equity and the type of sustainability. Cognitive mobility, sustainability, urban planning and architecture, and economics are considered examples.

The presented topics illustrate the interdisciplinary existence of the cognitive sustainability approach. It is necessary and enriching to research sustainability issues beyond the disciplines and by thinking together. These are brought together in a system by cognitive sustainability.

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