Chapter 1

What does 'sustainable construction' mean? An overview

Sustainable construction is a relatively new subject with which many of those involved in planning and construction are not familiar. It has been covered in numerous technical papers, but few of them present specific measures for implementing sustainability in the building and construction industry. This publication aims to improve the information available to those working in the construction sector using examples and guidance on steel construction in particular. The background and basic principles of how to achieve sustainable construction are presented and dealt with in a clearly structured manner. This publication also aims to convey a comprehensive understanding of sustainability and identifies the opportunities and essentials that can result from sensible implementation of sustainable steel construction strategies. The latest developments in steel construction provide a means to measure the success of the building and construction industry.

1.1 INTRODUCTION

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The term 'sustainable' was first used in forestry to convey the idea that only as many trees could be felled in a given time period as were capable of growing again during the same period. A definition of the term 'sustainability' that is common today in the context of society can be found in the Brundtland report of the United Nations, which was published in 1987: 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs' [1]. These needs can be of an ecological, economic or social nature. A development or action is only sustainable if a minimum level of satisfaction is achieved in all areas and can be maintained in the future.

Sustainable Steel Buildings: A Practical Guide for Structures and Envelopes, First Edition.
Edited by Bernhard Hauke, Markus Kuhnhenne, Mark Lawson and Milan Veljkovic.

In 1992, the Earth Summit was held in Rio de Janeiro. It was an unprecedented event and attempted to establish sustainable development policies at a global scale. Among other documents, Agenda 21 was born during this conference [2]. It sought to move the interpretation of the sustainable development concept from just environmental protection to improvement of life quality and well-being, generation equity, ethics and healthy conditions [3].

Twenty years later, a new summit took place in Rio – Rio +20 Conference. The two main themes discussed were (1) a green economy in the context of sustainable development and poverty eradication; and (2) the institutional framework for sustainable development. Although still concerned with environmental and economic issues, this summit concluded that eradicating poverty is the greatest global challenge nowadays.

A shift in how sustainable development is seen is apparent. It started only as an environmental concern, and currently the social aspects of sustainability are highlighted. This shows the importance of going beyond environmental protection and considering also both the economic and social aspects. It implies that environmental protection is linked to maintaining and improving equity of the present and future generations, as follows: Sustainable development should be promoted by '*sustained, inclusive and equitable economic growth, creating greater opportunities for all, reducing inequalities, raising basic standards of living, fostering equitable social development and inclusion, and promoting integrated and sustainable management of natural resources and ecosystems that supports, inter alia, economic, social and human development while facilitating ecosystem conservation, regeneration and restoration and resilience in the face of new and emerging challenges*' [4].

Thus, the sustainability concept is based on the interrelation of three fields: environment, society and economy. A sustainable model should stimulate and pursue agreement and equality among the three (Figure 1.1).

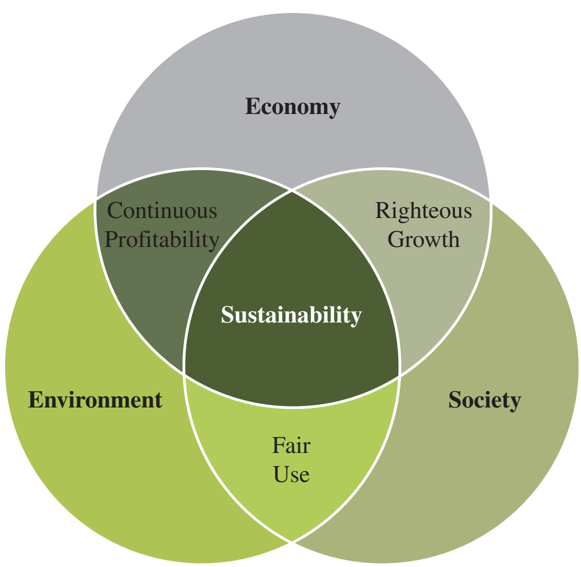

Figure 1.1 Three main overlapping fields defining sustainable development. © bauforumstahl.

1.1.1 The influence of the building sector

The building sector's influence on the above-mentioned problems is often underestimated. In 2013, €1162 billion was invested in construction in the countries of the European Union (EU-28). At the same time, the building sector was responsible for 8.8% of the EU-28 gross domestic product (GDP), providing 29% of the industrial employment and representing 6.4% of the total employment in Europe [5]. From the environmental side, the construction sector is responsible for 34.2% of the total waste produced in EU-28 in 2010 (851.6 million tonnes) [6]. In 2012, it was responsible for 11.7% of the greenhouse gases emission in EU-28 and accounts for approximately 47% of raw materials extraction. Besides economic and environmental impacts, the construction industry plays a major role in society. The employment of millions of world citizens depends directly and indirectly on construction. Buildings, roads, bridges and even water and energy infrastructures are all products from this industry. Buildings have a major influence on people's lives and well-being. In the past 60 years the world population has doubled, and most of our lives are spent inside buildings of all types.

Taking a closer look at buildings, their impact on people's lives is considerable. Data from the World Health Organization confirms that 90% of a person's lifetime is spent inside buildings [7]. With the current patterns, the expansion of the built environment will affect the natural habitats on more than 70% of earth's land by 2032 [8]. The economic influence of the property sector has also increased. Properties are now closely linked to the global finance markets via funds and credit guarantees. The last financial crisis showed the macroeconomic impacts that property can have. This clearly demonstrates that acting responsibly in the building sector can also result in an important contribution to preservation of the environment and conservation of resources as well as to economic efficiency.

This background data shows the influence of construction on the three pillars of sustainability. Charles Kibert defended this importance during the first international conference on sustainable construction in Tampa in 1994. He introduced the concept of 'sustainable construction' as being '*the creation and the responsible management of a healthy built environment based on resource efficient and ecological principles*' [9]. He highlighted the need for a life-cycle approach considering the impacts from the raw materials' extraction to the building's demolition [10]. With this holistic view, the following principles to achieve construction sustainability can be defined:

- efficiently use resources to avoid depletion of raw materials (energy, water and soil);
- protect ecosystems (waste, emissions, pollutants, land use);
- recycle materials in their end of life and use recyclable resources;
- eliminate hazardous products;
- minimize costs over the entire building's life-cycle;
- promote health, safety and well-being conditions for the inhabitants, neighbours and workers.

The growing shortage of resources and the high levels of emissions and waste production were the motivation for promoting sustainable construction more strongly. The building fabric plays a key role with regard to the primary energy consumption and global warming potential of buildings because it strongly affects the energy consumption that occurs during the building's life. Statutory requirements in the form of energy-saving ordinances and thermal efficiency of the building fabric and building services lead to lower energy use during the lifetime of a building. The choice of construction materials used is more important because they are increasingly also impacting the ecological quality of construction during its life cycle. Three questions particularly relevant here are: (1) *What environmental impacts occur during production?* As a matter of principle, materials and products with a small ecological footprint should be used as much as possible; specifically, construction materials should consume little energy and water during their production and should not contribute to emissions over their life and when dismantled at the end of their life (see below). (2) *How much 'construction' can be achieved using a unit of the product, in other words how efficiently can the product be used?* It is not sufficient to merely compare eco-relevant indicators in order to determine the ecological significance of a construction product.

It is also necessary to check how much functionality the use of a construction product offers, for example, how much useful area can be achieved using a kilogram of a construction material or what energy savings thermal insulation brings during the course of the life cycle. Here, comparisons are mostly only possible at building level; for example, lighter construction allows a certain method of construction and reduced foundation sizes. Environmental performance indicators can only be used to compare construction materials directly if the choice is between products of a similar type from different manufacturers. (3) *What happens to the construction material if the building is dismantled? Reuse, recycling or disposal site?* The question of whether a construction product can be reused or has to be disposed of after dismantling plays a decisive role in a sustainable – in other words, a future viable – approach. If products can be reused or recycled without any loss in quality they are available to be used by future generations. If they are disposed of as waste, they have to be replaced by primary resources. Reuse or recycling of materials and components also reduces the quantity of waste requiring disposal.

The building sector is therefore an important player in pursuing the sustainability goals. As one of the broad stakeholders, the building sector comprises the professionals involved in the building design, construction, maintenance and demolition (such as designers, engineers, urban planners, contractors, suppliers, manufacturers, etc.), decision makers (regulatory agencies at a local, national and international level, project developers and owners, etc.), and finally users and neighbours. In order to achieve the desired objectives, an integrated cooperation between all stakeholders is necessary. Only with having the will of all involved is it possible to change the way buildings are built and used to move towards a sustainable environment. The decisions made at building level are important but not sufficient, while the commitment of higher levels, such as regulatory agencies, is fundamental to achieving sustainability at building level. This imposes new challenges to each of the stakeholders, as presented in Table 1.1.

Table 1.1 Construction challenges for stakeholders to achieve sustainability in the built environment [11].

Stakeholder	Action
Authorities	Financial incentives
	Regulation and standards
	Effective labelling for consumers
	Research in improved construction practice
Clients, owners, developers and investors	Set appropriate and achievable environmental, social and economic targets
Users	Perform their own activities in a sustainable manner
	Operate the building and make environmentally friendly choices
Designers	Adopt an integrated design approach
	Make environmental improvements of the building fabric in the building design
	Adopt a 'life-cycle thinking'
Industry	Promote use of products with lower environmental impacts
	Promote recycling of materials and reuse, if possible
	Develop more efficient and less environmentally harmful products
Contractors and maintenance organizations	Reduce environmental impacts through better procedures
	Take environmental consciousness as a competitive factor
	Select partners based on their sustainable practices and standards

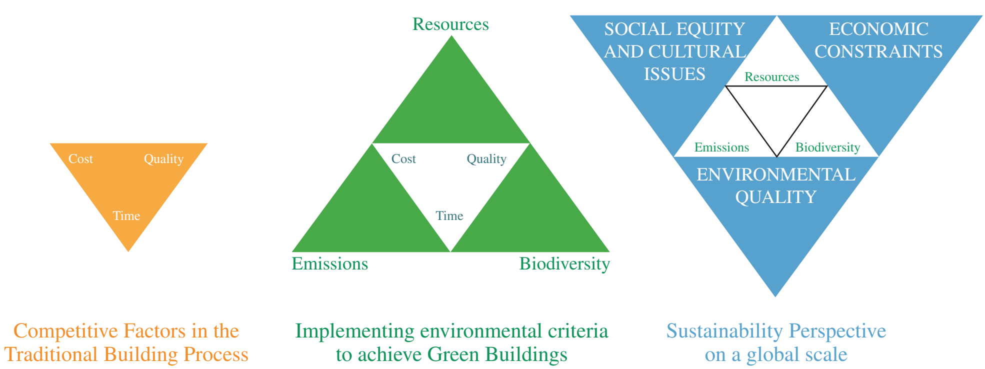

Figure 1.2 Evolution of the sustainable construction approach [14].

To reach this goal, a new approach to the way construction is thought of has recently been implemented (Figure 1.2). In the past, the planning of buildings concentrated primarily on construction costs and on the construction time as a measure of the return on investment. With greater environmental awareness, concerns about resources exploitation, pollution (emissions to air, soil and water) and the degradation of ecosystems biodiversity are increasingly considered in the construction approach. With a sustainability perspective, social and economic concerns on a global scale need to be added to the construction pyramid, as illustrated in Figure 1.2.

1.1.2 Can we afford sustainability?

When planned and designed well, projects can achieve a basic level of sustainability with little to no additional cost. However, society in general does not recognize the benefits of sustainable construction and does not understand the potential higher capital cost implications, thinking only of the initial cost.

A wider vision of the problem is required, as in construction there are two main types of costs: the initial cost required to build and the operational cost of the building. The life-cycle cost is the key parameter, together with labelling the resulting products as sustainable. Cost strategies, programme management and environmental strategies should be integrated into the design process right from the start.

Furthermore, a developer should keep in mind that sustainable construction may have positive economic effects by adding value to the building, as a sustainable image sells well. Furthermore, implementing criteria for sustainability at an early stage can result in short and medium term cost savings.

1.1.3 How can we achieve sustainability in the building sector?

In order to achieve a sustainable built environment, there is the need to work to achieve a balance between the three fundamental dimensions of sustainability – environment, society and economy. Unfortunately, there is no global formula to do that, in particular because societal concerns and economic status vary widely across the world. Having the same building under different conditions and trying to consider it as sustainable would not be sensible. Therefore, specific circumstances have to be considered when planning has to achieve sustainable design in the building sector, as good design is fundamental to sustainable construction. Decisions made at the initial design stage have the greatest effect on the overall sustainability impact of the construction project as well as over the lifetime of the building.

It is important to recognize that sustainability should be achieved in the context of existing buildings and cities, and it is hardly possible to build a sustainable city from zero. Nor would it make sense to demolish existing buildings, most of which are not considered sustainable, and build up a whole new set of sustainable buildings and localities. In this sense, rehabilitation of existent building stock is a cornerstone of achieving sustainability. Keeping existing buildings avoids unnecessary material use, saves on land use and preserves cultural identity and heritage. Rehabilitation projects should follow the principles of a sustainable design, as if a new building is being created. For instance, if structural components are in good condition and can be retained, this will reduce the building’s life-cycle environmental impact, as the use of new materials is avoided.

There are some basics that can help during the planning process of sustainable buildings, such as early determination of the basic goals, integral planning that includes the whole life cycle of a building, and good-quality management. What this means and how the theoretical foundations can be applied to steel construction will be explained in Chapter 4.

1.2 AIMS OF SUSTAINABLE CONSTRUCTION

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Sustainable construction is the process of creating buildings of high quality from ecological, economic and social points of view. Various measures are presented in Figure 1.3.

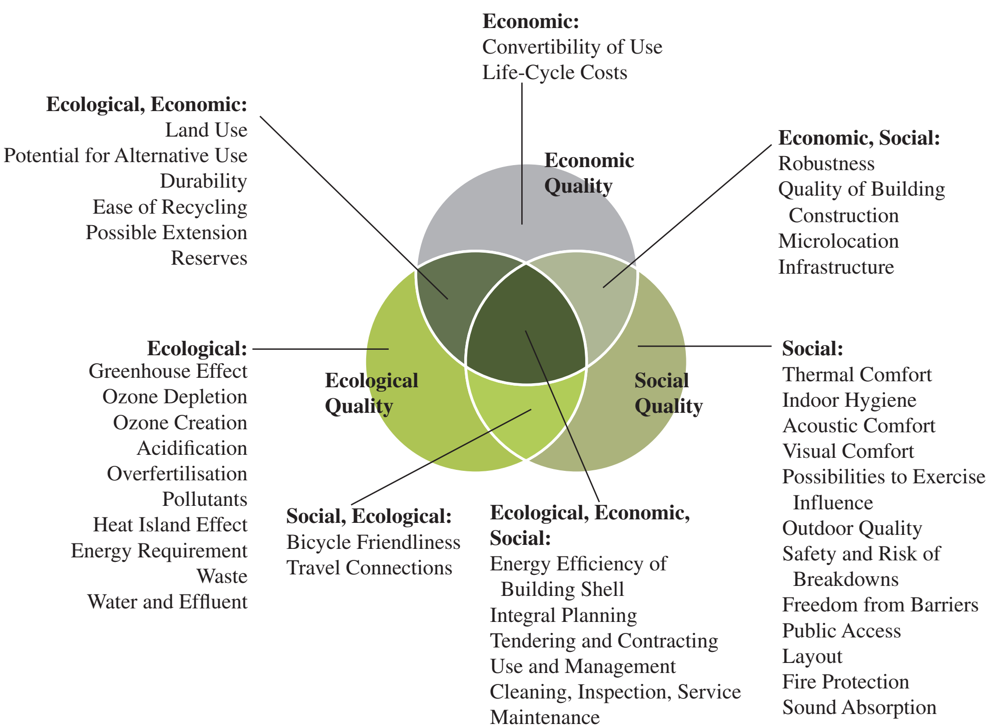

Figure 1.3 Illustration of sustainable buildings and their demands with respect to their ecological, social and economic quality. © bauforumstahl.

1.2.1 Ecological aims

1.2.1.1 Energy efficiency

Planning buildings that have high levels of moisture protection and thermal insulation has been standard practice in many European countries for years. Following the introduction of thermal insulation ordinances in the 1970s, planners' knowledge of building physics has improved and so has the quality of the thermal insulation used. However, given the improvements in products, higher energy prices and stricter statutory requirements, it is increasingly important to optimise the whole building

Docks Malraux

Location:	Strasbourg, France
Architect:	Heintz–Kehr Architectes
Building description:	Mixed-use development, culture, dwellings. Refurbishment/renovation of an old warehouse.
Steel details:	Replacement of the old tile roof by a three-storeys-high superstructure. A steel exo-skeleton of 800 t now shelters 67 prestige apartments.
Sustainability:	A high thermic performance was achieved – 20% lower than the 'BBC' standards (Batiment Basse Consommation) = 52 kWh/m²/y
Awards:	Docks Malraux is selected in the 100 buildings of the year 2014 in AMC-Magazin. The project is the winner of 2015 steel architecture Eiffel Trophy (Learning category).

Figure 1 On the northern facade, fire escapes are externalized, connecting the different uses with some structural acrobatics. © Heintz–Kehr Architectes.

Figure 2 The old Seegmuller warehouse, built in 1932, was refurbished and enlarged by a three-storey steel structure. © ConstruirAcier.

Example provided by ConstruirAcier.

concept. Practical experience has shown that use of intelligent concepts makes it possible to achieve energy savings of up to 60% compared with conventional buildings.

In addition to the energy requirement during the use of a building, consideration is also increasingly given to the 'grey' energy tied up in the construction materials – in other words, the energy that is used in the production of the materials themselves. From an energy point of view, a well-planned building is characterised by the fact that it fulfils the demands made with respect to economy, comfort and the health of the user with the lowest possible total energy requirement over the whole life cycle, which includes production, use, deconstruction and eventual disposal.

1.2.1.2 Resource efficiency

Using resources carefully also implies that consideration is given to use of recycled materials in manufacturing of construction products as well as to the recovery and handling of materials in the post-use phase of buildings. Reuse and recycling are important aspects of resource efficiency because they contribute to reducing the use of primary raw materials. Reusable and recyclable materials are also available for future generations. At the same time, they also contribute to reducing the amount of waste produced, avoiding inefficient burning and dumping of nonrecoverable materials. Sensible life-cycle management therefore makes a double contribution to reducing emissions: the volume of waste is reduced and the effort expended in the mining of new raw materials and making products again can be avoided.

1.2.1.3 Reduction of emissions

In addition to the efficient use of resources, noxious emissions have an important influence on the ecological quality of a construction. Here, too, it is a case of considering the whole life cycle of a particular construction, including the production and disposal of the materials used. The focus of politics is in particular on reducing environmentally damaging greenhouse gases, of which carbon dioxide accounts for the major share of about 75%. Other emissions such as sulphur dioxide, which causes acid rain, or fluorinated hydrocarbons (FCKW), which damage the ozone layer, should also be avoided.

1.2.2 Social aims

In the building sector, social quality covers very different aspects. According to EN 15643 [12], the social concerns applicable to sustainable buildings inter alia

- accessibility;
- adaptability;
- maintenance;
- health and comfort;
- impact on the neighbourhood;
- safety/security;
- stakeholder involvement.

Accessibility is the ability of a space to be entered with ease, including provisions to facilitate access to and use of its facilities such as building services particularly for the physically disabled, elderly and parents with small children.

Adaptability is the ability of the building or its parts to be changed or modified to make it suitable for a particular use. Together with adaptability is the *robustness* of the building's structure, which is the capacity to resist disproportionate or progressive collapse from a natural or manmade hazard. Robustness is somehow considered across codes and standards, but adaptability is not. Also, *space efficiency* is a key aspect of social impacts of buildings, concerning the utilization of floor space inside buildings and the suitability to the function it was designed for.

The way *maintenance* operations are managed and performed is also a topic for social concerns as part of sustainability. The consequences for users and *neighbourhood* should be accounted for, and their importance to maintain the building's technical performance has to be considered. It is an expression of the quality of the building design, its construction, the maintainability of its structure, surfaces and services, and the quality of the maintenance plan.

Health and comfort accounts for (1) acoustic comfort, (2) visual comfort, (3) indoor air quality, and (4) thermal comfort. A building should provide healthy and acoustically acceptable comfort conditions to its inhabitants. An acoustically comfortable environment improves productivity and well-being. *Visual comfort* regards the indoor lighting, which should provide the right amount of light in the right place. This allows building users to perform their tasks efficiently without strain or fatigue. Good indoor lighting enhances the appearance of a space and provides a pleasant working environment or attractive leisure area.

Indoor air quality (IAQ) is one of the most important factors in a building's performance influencing directly the health of the building users; otherwise the building would not satisfy its occupants. IAQ affects their comfort and the ability to conduct activities. There are many sources of indoor air pollution in a building, such as (1) microbial contaminants (mold, bacteria), (2) gases (including carbon monoxide, radon and volatile organic compounds), (3) particulates, or (4) any mass or energy stressor that can induce adverse health conditions. There are immediate effects that may occur after a single exposure or repeated exposures – such as irritation of the eyes, nose, and throat, headaches, dizziness, and fatigue, and long-term effects that may show up either years after exposure has occurred or only after long or repeated periods of exposure, such as respiratory diseases, heart disease or cancer [13]. Using ventilation to dilute contaminants, filtration and source control are the primary methods for improving indoor air quality in most buildings.

Thermal comfort aims to provide a comfortable thermal environment inside the building both in summer and winter conditions. A pleasant temperature inside buildings promotes productivity and well-being of occupants. As is well known each person has his or her own thermal sensations, and so it is the designer's role to provide average conditions for comfort within which occupants will adapt.

Safety and security concerns the capacity of a building to resist projected current and future loadings from, for example, rain, heavy wind, snow, flooding, fire, earthquake, explosion and landslides, as well as to provide security from external sources of disruption of utility supply. It is a measure of the building's ability to provide safe and secure shelter during exceptional events that have a potential impact on the safety of its users and occupants, and the building's ability to maintain its function and appearance and to minimise any disruption as a result of these exceptional events.

1.2.3 Economic aims

The integration of economics into a holistic approach to sustainability is an important aspect. Social and ecological goals should be achieved at as small of a cost as possible. To evaluate this, it is necessary to consider both the expenditure and the possible income due to improved sustainability. On the expenditure side, the total costs that a building incurs over its whole life cycle, in other words from the fabrication of the building through to its end of life with recovery or disposal, are taken into account. Income is usually more difficult to estimate. The basic prerequisite for future income is the market value of the building. In a way, the extent to which a building holds its value is an indication of the sustainability of an investment. This sustainability depends to some extent on both the building itself, such as the durability of the materials and facilities, and external changes, such as user demand and the unit cost of energy. Considering and assessing buildings over the whole life cycle provides a useful tool for risk management. The aim of a sustainable construction method is to minimise total cost and for as-built construction to hold its value and to meet social and ecological goals. A building with a high degree of flexibility and convertibility of use can be adapted to meet changing social demands. This leads to the property having a prolonged life cycle, which is beneficial economically and ecologically.

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