Paper from: *The Sustainable City II*, CA Brebbia, JF Martin-Duque & LC Wadhwa (Editors).
ISBN 1-85312-917-8

Sustainability in three dimensions - the importance of improving the use of space and life span beside technological efficiency

A.A.J.F. van den Dobbelsteen[1], Th.S. de Wilde[1,2] & M.J.P. Arets[1]
[1]*Department of Building Technology, Faculty of Civil Engineering and Geosciences, Delft University of Technology, The Netherlands.*
[2]*Holland Railconsult, The Netherlands.*

Abstract

The performance of the built environment is behind schedule on the way to a factor 20 environmental improvement by 2040. A substantial improvement can be achieved by an approach on the urban scale, focussing on all three dimensions of sustainability: technology, space and time. Beside solutions for technological efficiency, in which combining facilities on an urban scale offers better opportunities, a focus on efficient use of space and prolonging the life span of the built environment are important measures with which the environmental performance can be improved.

Space efficiency can be improved by multiple and intensive use of space. Stacking and combining of functions avoid claims on rural areas and diminish the amount of building materials and energy needed. Indicators like the floor space index (f.s.i.) and environmental indices on floor and ground surface use of reference projects sharpen awareness of the impact on the environment.

The life span of urban areas can be prolonged by a sustainable urban fabric that has possibilities of adaptability to unforeseen future changes within it. This functional adaptability is enabled by technical flexibility on an urban scale. Another important life span factor of urban areas is functional diversity. The combination of functions within an urban project ensures a better useful life span. The useful life factor (ULF) is an indicator for the efficient use of an urban plan and its buildings.

Paper from: *The Sustainable City II*, CA Brebbia, JF Martin-Duque & LC Wadhwa (Editors).
ISBN 1-85312-917-8

1 Introduction

1.1 The required factor 20 improvement

The concept of sustainability was introduced with the report of the 'Brundtland Commission' [1], which made a connection between environmental and social goals in the world. In the year 1990 Ehrlich & Ehrlich [2] and Speth [3] re-introduced a formula, which made this connection quantifiable:

$$EP = P \times W \times E$$

In this formula EP stands for environmental pressure, which in 1990 was said to be too high and had to be halved in 50 years from then. P stands for the world population, which is predicted to double within 50 years. W stands for the average welfare rate of a world citizen. The Brundtland Commission declared that for developing countries it is necessary to catch up with the prosperous part of the world, meaning an improvement of factor 5 in 50 years. Therefore E, environmental impact by welfare per citizen, equals:

$$\tfrac{1}{2} = 2 \times 5 \times \underline{1/20}$$

The calculation shows that by the year 2040 a diminishment of ecological damage by 95% has to be achieved: i.e. an improvement of the environmental quality with a factor 20. This factor 20 target is apt as a benchmark and it can be used as a guiding line for environmental performance of the built environment.

1.2 Determining the environmental performance

The year 1990 can be seen as a general starting point for the environmental performance, since many countries implemented a structural approach of the concept 'sustainable building' then.

In order to determine the environmental performance the environmental load of the studied object(s) can be calculated in relation to a well-defined reference environmental load in 1990. This results in an environmental index or an improvement factor (see Figure 1).

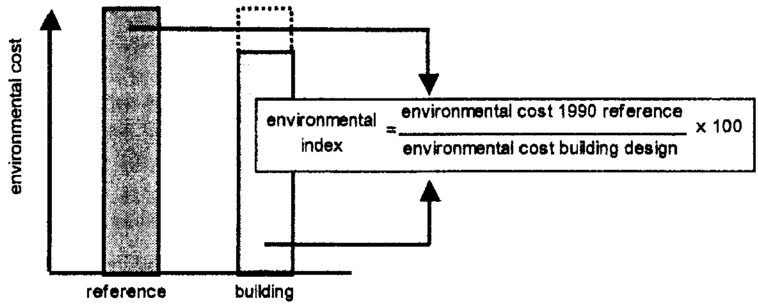

Figure 1: Determination of the environmental index.

Paper from: *The Sustainable City II*, CA Brebbia, JF Martin-Duque & LC Wadhwa (Editors).
ISBN 1-85312-917-8

There are many environmental calculation models that apply for these basic calculations, of which most are focussed on buildings. However, estimation of the performance of urban areas is possible as well.

1.3 We're behind schedule

In order to see whether sustainable building policy is effective or needs to be changed the performance has to be related to a target, preferably the factor 20. Taking 1990 as the reference year (with environmental index 100) in the year 2040 an environmental index of 2000 is necessary. If the performance was to develop linearly an environmental index of 480 (factor 4.8) would have been necessary in the year 2000. This in-between target is of course open to discussion.

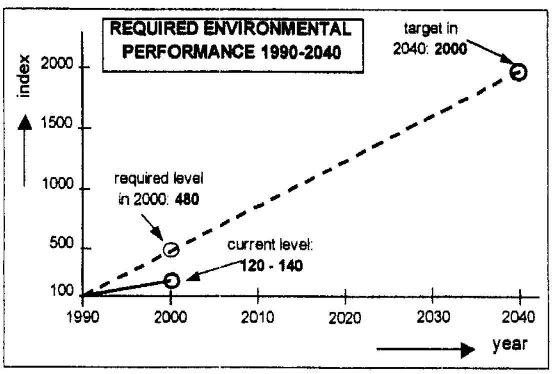

Figure 2: The factor 20 target line and recent performance of buildings.

With recently built, relatively sustainable buildings an index of 140 to 250 is achieved [4]. Buildings with no particular focus on sustainability achieve an estimated index of 120-140. This is only a factor 1.2 or 1.4 improvement with respect to 1990 (see Figure 2). This performance would be well behind the factor 20 target, even if the target line was progressive. This means acceleration is needed in the next few years, as well as a focus on effective solutions.

2 A new focus on sustainable solutions

2.1 Causes of the arrears

There are various causes for the environmental arrears of individual buildings. Technically, an environmental index of 800 is already possible, but the combination of measures necessary is expensive and complex. Sustainable building as a policy is focussed on small adaptations on traditional solutions.

Another reason for not meeting requirements, even in well-intentioned projects, might be caused by the approach on the building scale and by disregarding urban solutions. A wider urban approach of sustainable building can reap greater environmental profits than the improvement of an individual

Paper from: *The Sustainable City II*, CA Brebbia, JF Martin-Duque & LC Wadhwa (Editors).
ISBN 1-85312-917-8

building. This has two reasons. First, some sustainable measures can be not feasible on a building scale but are cheaper or more efficient taken up in town planning (e.g. energy and waste facilities). Second, some aspects can simply only be tackled on the urban scale. An example of this is multiple and intensive use of ground surface.

The mentioned causes of insufficient environmental performance are of a technological kind, since solutions tend to be automatically sought in that direction. Solutions for a sustainable city might be found in a more functional direction.

2.2 Three dimensions of sustainability

The limited progress of environmental performance shows that a focus only on technological efficiency is not enough for the factor 20. Nevertheless, sustainability has more than one dimension. We often forget the factors space and time, which are largely independent from technology but important for the eventual environmental load.

The improvement of the use of building space and the prolonging the life span of objects, buildings and urban areas have played a minor role in sustainable building can be additional factors to technological efficiency, which together might enable factor 20 improvement of the whole built environment (the whole volume in Figure 3).

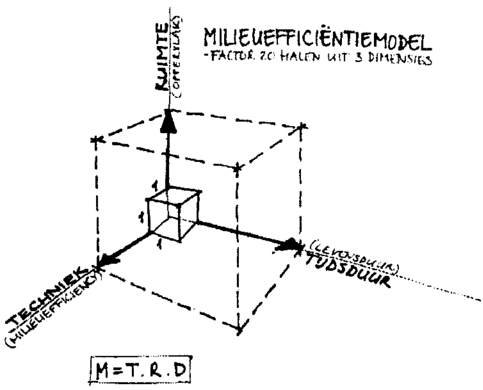

Figure 3: Achieving factor 20 improvement by three dimensions of sustainability (in Dutch): technology (efficiency), space (surface) and time (life span).

3 The factor space: intensive use of space

3.1 The usual sustainable planning

Sustainable urban planning is often associated with green town enlargements with small-scale building, a lot of water and a friendly urban environment. It can most easily be practised in open areas with enough space for environmental

Paper from: *The Sustainable City II*, CA Brebbia, JF Martin-Duque & LC Wadhwa (Editors).
ISBN 1-85312-917-8

measures, but the consequence of too many of these projects is that towns just keep enlarging and 'consuming' their surroundings. These projects also lead to a substantial growth of commuter traffic, mostly by car.

Therefore, a different approach is finding new building areas within the borders of existing towns. Inner-city reconstruction diminishes deterioration of natural and cultural surroundings. Both are specifically suited for multiple and intensive use of space.

3.2 Multiple and intensive use of space

Multiple and intensive use of space can be put in to optimise the use of new inner city building areas. Multiple use of space is used to combine different functions on a limited building area and intensive use of space is used to maximise the amount of floor area that is realised on the building site [5].

Multiple use of space appears in three different forms with combinations being possible (see: figure 4). The first form is multiple use of space in the second dimension, the plain surface. Different functions are put next to each other, which is defined as *mixed use of space*. The second form is a differentiated form of mixed use of space, in which the different functions are put on top of each other: *multiple use of land*. The third form is *multiple use in time*, in which a set amount of floor area is used for different functions on after the other.

Intensive use of space can be measured by density, like the amount of floor area that is realised per hectare of building surface. Projects of intensive use of space do not include multiple use of space by definition. Intensive use of space is furthermore partly defined by culture. For an inhabitant of Tokyo, the space in European city centres is not used intensive, while Europeans experience these cities as intensively used space. The intensity of the use of space in projects is best measured by comparing them to their direct surroundings.

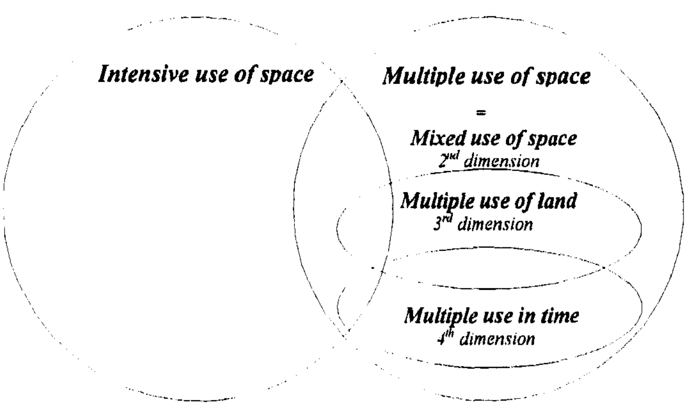

Figure 4: Different types of intensive space use

Paper from: *The Sustainable City II*, CA Brebbia, JF Martin-Duque & LC Wadhwa (Editors).
ISBN 1-85312-917-8

3.3 The difficulty of measuring environmental impact of space use

Avoidance of buildings or built mass through intensive use of space easily shows impact on the environmental performance, because less materials and less energy are needed and thus the environmental load is smaller. More difficult is the estimation of environmental improvement by a diminished use of ground surface. The only way to do so is by determining the avoided deteriorated or changed area, dependent on the potentially occupied surface. The weight of this surface depends on the ecological value (in case of an environmental comparison) or the economical value (in case of a financial comparison). There are a few methods for this assessment, but no broadly accepted one.

Until the moment of acceptance of one of these methods we can only calculate some characteristics of the use of space, like the floor space index or environmental indices for the use of space factor.

3.4 The floor space index

The floor space index (f.s.i.) can be used to measure the density of an urban project. It measures the intensity of the use of space. The floor space index is calculated by dividing the amount of floor area realised by the surface of the building area on which it is realised. The floor space index of four projects of multiple use of space near railway stations are calculated in Table 1.

Table 1: Examples of FSIs of different urban projects [6, 7, 8, 9].

Project	Floor area (m^2)	Surface area (m^2)	f.s.i.
Liverpool Street Station, London	360,000	100,000	3,60
Seine Rive Gauche, Paris	1,920,000	1,300,000	1,47
Zuidas, Amsterdam	2,252,000	1,720,000	1,31
Euralille, Lille	274,000	700,000	0,39

The floor space indices show huge differences. The redevelopment of Liverpool Street Station realises ten times more floor area per square meter of building site than Euralille. Euralille makes less intensive use of space, maybe even extensive use of space, compared to the other projects. The projects show how the limited building sites that are left in contemporary city centres can be re-used in a more optimal way.

3.5 Environmental indices for floor and ground use

Another indicator for the efficiency in the use of space can be obtained by comparing the floor and ground use of an urban plan with a reference project. This reference project should be based on the amount of people for which the area is designed.

A project in which this method was used was the environmental assessment of 14 government offices [10]. In this project ground and floor use of the offices was compared to those of reference offices, leading to environmental indices.

Paper from: *The Sustainable City II*, CA Brebbia, JF Martin-Duque & LC Wadhwa (Editors).
ISBN 1-85312-917-8

Table 2: Results of indices for space and ground use [6].

project	ground use index	floor use index
Food Inspection Department, Zutphen	111	173
Mixed office, Arnhem	85	92
Tax office, Gorinchem	99	122
Ministry of Social Affairs, The Hague	206	88
Ministry of Spatial Planning, The Hague	375	178
Public Works office (monument), The Hague	72	66
Goods Traffic Department, The Hague	194	84

The results in Table 2 give an impression of the efficiency with which ground and floor surface is used, compared with a reference office (which has an index of 100) for as much people as the studied office.

3.6 Opportunities for sustainability in dense areas

Efficient, innovating floor concepts (especially in offices), multi-functional use of buildings and multiple use of space in the third dimension reduce the urban space needed, and thus consumption of materials and energy. Furthermore, deterioration of nature through building extension outside the urban environment is prevented.
Progress in the sustainability of technical services like energy, water and IT-supply can be made through concentration and collection of these functions, because of scale and efficiency advantages. On the field of energy one can think of cold and heat storage in the ground and a central heat pump, solar or power service. In a dense area wireless information and telecommunication makes application of cables until in every corner of the buildings unnecessary.

4 The factor life span: urban adaptability

4.1 Change

A part of the environmental load develops during the life span of a building or urban area (e.g. by energy and water consumption or travel); another part is mainly initial, imposed at the beginning of the life span of the building or urban area (e.g. use of building materials) or at the end of it (e.g. demolition waste). Because of the initial environmental load, in case of a short life span the environmental load per unit of time is bigger than with a long life span, taking a long lifetime as a reference.
Therefore, prolonging the life span of buildings and urban areas as a whole is an important means to diminish the environmental load. Because most buildings are brought into a demolition phase when they lose their function and we cannot usually predict changes in use, adaptability is a primal necessity.

Paper from: *The Sustainable City II*, CA Brebbia, JF Martin-Duque & LC Wadhwa (Editors).
ISBN 1-85312-917-8

4.2 Flexibility types for adaptability

The success and size of young companies is so fluctuating that they do not dare tie themselves to long-term contracts [11]. This is also a tendency with bigger companies. For accommodation this means that the conditions might change completely within a few years. In that case it is dangerous to bet on a function that is boosting at the moment of decision. It is wiser to strive after multi-functionality, or functional flexibility.

In order to achieve functional flexibility technical flexibility forms the basis. Sustainable urban structures, structures that offer enough possibilities to undergo changes through times, are a solution for this. An example is the central canal area of Amsterdam, where a strong basic structure (the ring of canals with several main axis's) is combined with adaptability on a smaller scale (connected buildings and internal garden yards).

An overview of urban flexibility forms, the drive behind them and possible solutions can be seen in the table underneath.

Table 3: Types of urban flexibility.

FLEXIBILITY TYPE	POSSIBLE SOLUTION
Financial flexibility	
Financial unboundness Organisations are not tied to long financial obligations	• functional flexibility (see below) • short-term (hiring)contracts • buildings not tuned to current trends → sustainable quality
Functional flexibility	
Multi-functionality an urban area is adaptable to changing circumstances; an area can locate different functions	• technical flexibility (see below) • reckon with growth • elaboration to the highest quality
technical flexibility	
oversizing/ overdimensioning the urban structure has sufficient measurement for a living and growing city	• spacious urban plan, in which additions are possible • heavily dimensioned bearing structure for multi-layered developments or additions
re-arrangeability the urban structure offers opportunities to vary public space; buildings can extend	• reservation of urban space for later additions or adaptations • light urban design: removable, dismantleable buildings and urban furniture, in a setting of arranged light infrastructure • collection of technical functions, infrastructure and parking space

4.3 Extendibility within the urban space

In dense areas extensions of buildings and urban enlargements can be found within the existing structure of a town or city. One could think about building over infrastructure or redevelopment of inner city areas. On a smaller scale extension in the existing structure can be achieved by adaptability within urban building blocks. An example is one of the plans applying for the Zuidas in Amsterdam [12]. In this plan building blocks are proposed with sufficient space for additions, new building volumes and semi-public functions.

Paper from: *The Sustainable City II*, CA Brebbia, JF Martin-Duque & LC Wadhwa (Editors).
ISBN 1-85312-917-8

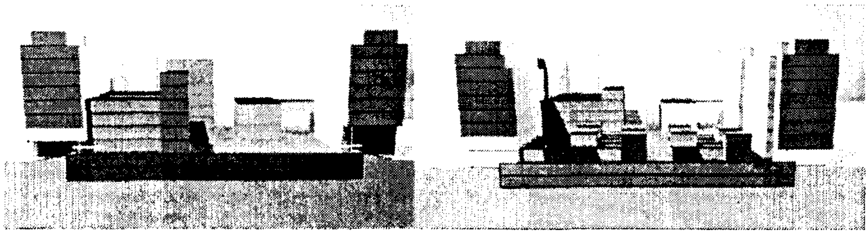

Figure 5: Cross-section with different fill-in of building blocks in one of the proposed plans for the Zuidas in Amsterdam [12].

4.4 Diversity

Many town enlargements take place for either dwellings or shops or businesses, thus often mono-functional. The long-term sustainability of these new areas can be doubted. For if economy, functions and life in general change, these mono-functional places can easily lose their usability. In sustainable building more focus is necessary on a long functional life span of locations and subsequently of buildings. The fundament of the necessity of adaptability lays in the future possibility to use space, buildings and especially urban areas differently, for other functions than originally counted for.

4.5 The useful life span

Bringing space efficiency and life span together, the potential and current use efficiency of the built environment can be estimated with the useful life factor. It is calculated as follows (Figure 6).

ULF	**=**	**Le / Lt**	**x**	**Du / Dt**	**x**	**Occ**
	=	25 / 75		(5x12) / (7x24)		50%
	=	**6,0%**				

Figure 6: The useful life factor (**ULF**); **Le**: expected life span (years); **Lt**: technical life span of essential components (years); **Du**: duration of use in a week (hours); **Dt**: total duration of a week (hours); **Occ**: occupancy rate.

In this particular example we see that an average office building with a life expectancy of 75 years (the building structure) normally does not last longer than 25 years. The doors are open for work approximately 12 hours a day, 5 days a week and the occupancy rate is no more than 50%. This means that within the potential of the building the useful life factor is only 6%. Houses achieve between 20 and 24%, almost a factor 4 better. A useful life factor of 100% is unrealistic, but better than 6% should be possible. Adaptability of the building, combinations of functions in the building or surroundings, evening and weekend activities and innovative office concepts can support that.

Paper from: *The Sustainable City II*, CA Brebbia, JF Martin-Duque & LC Wadhwa (Editors).
ISBN 1-85312-917-8

The essence of the useful life factor is that if one area can achieve a factor 2 better ULF than another, twice as less surface and building materials plus probably less energy are necessary, connected to a certain period and amount of people using the area.

5 Conclusion and discussion

Sustainable urban planning should focus more on the intensification of space use and a longer useful life span of built areas, rather than improving technological efficiency. This paper gives an overview of conceptual solutions with which these factors space and time can add to a better environmental performance.

A remark can be put here. Good buildings have no future in bad areas; a good urban plan however tolerates bad buildings. We can see it in many old inner cities: the quality and the use is not seriously deteriorated by a few disturbing buildings. Therefore, it is important to have a good urban fabric as the foundation of sustainable building.

Intensive space use and life prolonging measures will be stimulated if some environmental assessment tools are developed, with which the environmental impact of them can be determined. Together with existing life cycle assessment tools these new instruments can facilitate a better and integral decision in urban planning.

References

[1] World Commission on Environment and Development, *Our common future*, Oxford University Press: Oxford/New York, 1987
[2] Ehrlich, P. & Ehrlich A., *The Population Explosion*, Hutchinson: London, 1990
[3] Speth, J.G., Can the world be saved? *Ecological economics*, vol. 1, pp. 289-302, 1990
[4] Croes, H., Dewever, L.M. & Haas, E.M., *One number says it all* (poster), Government Building Agency: The Hague, 2001
[5] Wilde, Th.S. de, Meervoudig ruimtegebruik en binnenstedelijke verdichting rond treinstations. *Cement*, no. 2, pp 33-36, 2002
[6] Rosehaugh Stanhope Developments plc., *Broadgate*, Penhurst Press: England, 1988
[7] http//www.parisrivegauche.com (February 2002)
[8] Physical Development Department of Amsterdam, *Perspective on the Zuidas* (in Dutch), Amsterdam, 2001
[9] Spit, T. & Bertolini, L., *Cities on Rails*, E & FN Spon: London, 1998
[10] van den Dobbelsteen, A.A.J.F. & Arets, M.J.P., *Milieubelasting van rijkskantoorgebouwen – hoofdrapport*, TU Delft: Delft, 2002
[11] van Eldonk, A. et al., *Het Nationale Kantorenmarktonderzoek 2001*, Twynstra Gudde: Amersfoort, 2001
[12] Johan Matser Projectontwikkeling et al., *Due South - Wonen aan de Zuidas*, Amsterdam, 1999