Adaptive Cycle Analysis of Urban Fragments

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Table of Contents

Index of Tables

Index of Figures

Summary

Urban development is a dynamic and complex process, consisting of different distinguishable phases. Based on the observation that urban quarters run through successive developmental stages, an approach is presented to describe and analyse urban development with an idea originating in ecology, the adaptive cycle concept (Gunderson and Holling). The introduction of the mosaic cycle concept (Remmerts) into the urban context and the four dimensions of sustainability allow a direct application. The social, cultural, economic and natural assets (sustainability dimensions) urban fragments possess are used as measures to analyse and assess the future a fragment will face. In this paper, the urban fragment is understood as the feature-based cluster under investigation, consisting of built urban units.

The adaptive cycle concept describes in four developmental phases the (re-)start of an ecosystem after a disturbance. Depending on its resilience, an ecosystem might resume a development cycle similar to the one prior to the disturbance or make a qualitative shift to another ecosystem. The urban developmental stages can be set into relation to the four phases of the adaptive cycle concept: alpha or α (reorganisation), r (exploitation of potential), K (build up and conserve new potential) and omega or Ω (destruction/release of potential). The development of a whole city can be interpreted as a mosaic of adaptive cycles of urban fragments. This work begins by demonstrating the general applicability of the adaptive cycle concept to the urban context via three broadly accepted urban developmental theories (Hoover/Vernon, van den Berg and Lichtenberger).

Moreover, the adaptive cycle of a single urban fragment can be divided into four virtual adaptive cycles if the four sustainability dimensions are considered individually. To make the sustainability of an urban fragment measurable, the four dimensions are treated as subordinate adaptive cycles. Being inevitably interlinked with each other and the built environment, their independence is incomplete and therefore they are termed “virtual”. Existing instruments to measure and model urban development are assigned to the adaptive cycle phases. They help to identify variables and parameters, to model the development of urban fragments and to analyse the drivers of adaptive cycle phase transitions. Additionally, a new tool to calculate the progress of the four sustainability dimensions of urban units (buildings, infrastructure and open space) is introduced.

For the analysis of the adaptive cycles of urban fragments, a new framework is developed, combining modified versions of the methods and instruments into a multilevel process. The framework leads from the historical analysis of an urban fragment to the development of the virtual sustainability adaptive cycles (indicators based assessment), and from the overall adaptive cycles of an urban fragment to future developments (scenario technique), providing predefined maintenance strategies for the individual units of urban fragments. The strategies vary in their economic, ecological, cultural and social impacts. The framework is applied to two case studies, one in Germany and one in France, which demonstrate the important impact the sustainability dimension ‘social resilience’ can exert on the future of a whole settlement.

Zusammenfassung

Stadtentwicklung ist ein dynamischer und komplexer Prozess, der aus unterschiedlichen Phasen besteht. Ausgehend von der Beobachtung, dass Stadtquartiere sukzessive Entwicklungsstadien durchlaufen, wird ein Vorgehen vorgeschlagen, das Stadtentwicklung mit einer Idee beschreibt und analysiert, welche aus der Ökologie stammt, das Konzept der adaptiven Zyklen (Gunderson und Holling). Eine direkte Anwendung erlaubt die Einbeziehung des Mosaikzyklenkonzepts (Remmerts) in den urbanen Kontext und der vier Nachhaltigkeitsdimensionen. Die sozialen, kulturellen, ökonomischen und ökologischen Kapitalien (Nachhaltigkeitsdimensionen), die Stadtfragmente besitzen, werden als Mass zur Analyse und Vorausberechnung der Vorsehung, welche ein Fragment begegnen wird, genutzt. In dieser Arbeit wird ein Stadtfragment verstanden als eine zu untersuchende merkmalsbasierte Gruppe, die aus gebauten Stadteinheiten besteht.

Das Konzept der adaptiven Zyklen beschreibt in vier Entwicklungsschritten den (Neu-)Start eines Ökosystems nach einer Störung. Abhängig von seiner Resilienz, kann ein Ökosystem eine ähnliche Entwicklung wie vor der Störung durchlaufen oder einen qualitativen Sprung in ein anders geartetes Ökosystem vollziehen. Stufen der Stadtentwicklung können mit den vier Phasen des adaptiven Zykluskonzepts in Bezug gesetzt werden: α (Reorganisation), r (Ausnutzung von Potential), K (Aufbau und Schutz von neuem Potential) und Ω (Zerstörung/Freisetzung von Potential). Die Entwicklung einer ganzen Stadt kann als eine Zusammensetzung von Mosaiken aus adaptiven Zyklen der Stadtfragmente gesehen werden. In einem ersten Schritt, wird die allgemeine Anwendbarkeit des adaptiven Zykluskonzepts auf den städtischen Kontexts anhand von drei weitgehend akzeptierten Stadtentwicklungstheorien (Hoover/Vernon, van den Berg und Lichtenberger) gezeigt.

Darüber hinaus, kann der adaptive Zyklus eines Stadtfragments in vier virtuelle adaptive Zyklen unterschieden werden, welche jeweils einer Nachhaltigkeitsdimension entsprechen. Um die Messbarkeit der Nachhaltigkeit eines Stadtfragments zu ermöglichen, werden die vier Dimensionen als untergeordnete adaptive Zyklen verstanden. Sie sind zwangsläufig untereinander und mit der gebauten Umwelt verbunden, weswegen ihre Existenz nur unvollständig als unabhängig gesehen werden kann und daher „virtuell“ bezeichnet wird. Bestehende Instrumente zur Messung und Modellierung der Stadtentwicklung werden zu Phasen der adaptiven Zyklen zugeordnet, in denen sie eingesetzt werden können. Sie helfen Variablen und Parameter zu identifizieren, die Entwicklung von Stadtfragmenten zu modellieren und die Einflussfaktoren der Phasenübergänge der adaptiven Zyklen zu analysieren. Zusätzlich wird ein neues Werkzeug zur Berechnung des Verlaufs der vier Nachhaltigkeitsdimensionen der urbanen Einheiten (Gebäude, Infrastruktur und Freiflächen) vorgestellt.

Für die Analyse der adaptiven Zyklen von Stadtfragmenten, wird ein Rahmenwerk entwickelt, das modifizierte Versionen der Methoden und Instrumente in einem Mehrebenenprozess

kombinieren. Das Rahmenwerk führt von der historischen Analyse eines Stadtfragments zur Entwicklung der virtuellen adaptiven Zyklen (Indikatorbasierte Beurteilung), und über die allgemeinen adaptiven Zyklen eines Stadtfragments zu zukünftigen Entwicklungen (Szenariotechnik), aus denen sich vordefinierte Bewirtschaftungsstrategien für einzelne Einheiten des urbanen Fragments ableiten lassen. Die Strategien variieren hinsichtlich ihrer ökonomischen, ökologischen, kulturellen und sozialen Auswirkungen. Das Rahmenwerk wird auf zwei Stadtfragmente in Deutschland und Frankreich angewandt, um die Bedeutung, welche die Dimension ‚soziale Belastbarkeit/Resilienz' auf die Vorsehung einer ganzen Siedlung ausüben kann, aufzuzeigen.

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Chapter I

I Applying the Adaptive Cycles Concept to the Sustainable Development of Urban Fragments

I1. Introduction

In this paper, the concept of adaptive cycle is proposed as a new approach to understanding urban development. It describes a new way to situate urban activities and resource depletion within a complex system, where both internal development as well as exterior impacts can result in system changes. The possibility that this can happen within as well as outside the considered part of a city and at different times, at present and in the future, entails the need for different tools and methods. Applying the adaptive cycle concept to urban fragments serves as a framework that combines city- and neighbourhood-related tools and methods.

Innovative Contribution

Research on urban development has resulted in a variety of approaches. On the theoretical level, the different views and concepts are often contradictory in their focus (e.g. social and economic). On the practical level, some of the implementations focus on data and calculation (e.g. models on urban metabolism and simulations), while others take also into account soft aspects (e.g. indicators). The number of existing approaches indicates how complex and complicated urban development is.

Nonetheless, research on urban development is still developing, producing advancements and refinements within new research fields. Such a field is the concept of built environment, initially discussed in social sciences and now taken up by transdisciplinary approaches[1].

Working Hypothesis

Approaches to understanding urban development, up to now, have been more problem oriented, but the multidimensionality of cities requires a framework that is flexible and supporting at the same time. A new approach that integrates methods can help to position problems that arise. The concept of adaptive cycles, which originated in biology, has been taken up in theories of complex systems. Depending on the context, the concept serves as a metaphor, analogy or model. By identifying urban systems as complex (social-ecological) systems, the idea of the adaptive cycle appears as a promising analogy for the basis of a new framework. It allows the incorporation of a number of other

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[1] [MOFFAT 08], [LUETZKENDO 07], [LORENZ 06], [BRADLEY 05], [KOHLER 03a], [HASSLER 01]

approaches and remains open for further extensions. The differentiated evolution of the built environment needs an approach that has flexible limits both in space and time, which is the aim behind the development of the adaptive cycle analysis of urban fragments. This analysis method might serve as model to help better understand the sustainable development of an urban fragment in its multiple dimensions.

Objectives of the thesis

1. To apply the adaptive cycle concept to urban development, specifically to urban fragments in a metaphorical or analogical way (Chapter I)
2. To integrate sustainability goals into the adaptive cycle concept and develop an adaptive cycle framework for analysing urban fragments (Chapter I)
3. To show that the topics that current approaches deal with can be positioned within and compose specific phases of the adaptive cycle for urban fragments (Chapter II) and
4. To create a model for adaptive cycle analysis for urban fragments that takes into account the evolution of the built environment, in particular the life cycle (the operation and maintenance) of individual buildings and building stocks (Chapter III).

Outline

Chapter I introduces the concept of the adaptive cycle and its potential for integrating and modelling complex urban developments. The adaptive cycle framework is developed by applying the adaptive cycle concept as an analogy to describe the dimensions of sustainable urban development.

Chapter II consists of a review of current tools and methods for analysing urban development and positioning them within the framework of adaptive cycles.

Chapter III sets out the steps for adaptive cycle analysis of urban fragments: urban fragment definition (identification), urban fragment phase and cycle description, and scenario and strategy development. Thereafter, adaptive cycle analysis is performed on two urban fragments. The chapter ends with conclusions and an outlook.

Chapter I introduces the adaptive cycle framework, Chapter II relates the topic to instruments and Chapter III uses some of the instruments within a new framework.

After Chapter I, the reader can continue to Chapter III omitting Chapter II if the instruments covered are known and the reader’s main interest is in the application of adaptive cycle analysis. For the exact positioning of the tools within the adaptive cycle framework, the reader may return to Chapter II later.

Figures and tables are own illustrations, if not indicated differently.

I2. Applying the Adaptive Cycles Concept to the Development of Urban Fragments

During cities' life cycles, they go through specific phases, which can be found in various Western and especially European cities. Several models illustrate these phases and their individual characteristics for city or neighbourhood development. All models have urban quarters as the basic unit in common. However, many features (characteristics) in the development of cities are not sufficiently dealt with by the models. A desirable aim is therefore to define a framework that illustrates the phases of urban development and the interdependencies of the features of the phases. This paper proposes such a framework based on two foundations: 1. a functional and dynamic definition for quarters and neighbourhoods that provides more realistic access to urban development; 2. the stages of urban development are interpreted as 'successive' phases and as generalised 'adaptive cycles', two concepts originally developed for ecological and socio-ecological systems.

The introduced approach defines the different sequences a system undergoes and places them in a specific order for a new, synthetic description of long-term urban dynamics. Based on this approach, the development of urban fragments can be described as adaptive cycles.

The chapter is in four parts. First, an introduction to the general concept of succession and its specific form of adaptive cycles are given (I2). Second, urban development sequences as adaptive cycles are illustrated (I3). A description of sustainability and its dimensions for cities constitute the third part (I4). Finally, the adaptive cycle concept and the dimensions of urban sustainability are connected (I5).

I2.1 Adaptation of Biological Models

Models from biology and ecology have been successfully adapted by other disciplines.[2] Below, the author introduces the concept of succession from ecology/botany and adapts it to the urban context.

Succession comes from the Latin word 'succedere'[3] and means, besides other translations, 'follow up' or 'succeed'. In ecology and botany, succession denotes sequences of system states of plant and animal communities that follow one another in a given regional and temporal continuity.[4]

Henry D. Thoreau[5] was one of the first authors to describe the natural phenomenon in '*The Succession of Forest Trees*' (1860) less than one year after the publication and lecture of Darwin's '*Origin of Species*'

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[2] Well-known examples are the concept of life cycles for products, ant algorithms copying ant behaviour to solve optimisation problems or technical adaptations of structures found in animals and plants (bionic).

[3] [LEWIS 79], succedo, II. B.

[4] [PICKETT 76]

[5] [THOREAU 60]

(1859)[6]. He observed succession patterns in pine and oak forests and aspired to link these with empirical, short-term seed dispersal.[7]
A quarter century later, in 1885, Hult[8] introduced the idea of a final stage of development for plant societies, called a climax, which was further developed in the following decades[9]. Clements defined his notion of climax "as a complex organism inseparably connected with its climate and often continental in extent".[10] Following his understanding, stabilisation is the ubiquitous tendency of all vegetation ruled by the existing climate.
At present, the idea of climax is accepted more in a metaphorical way: it is neither static nor predictable. Periodic small changes are necessary to keep a system in its running state. For woods, this means that an offspring of trees can only survive if it gets enough resources, such as sunlight, which is only possible if older trees die and leave open space. In that sense, most apparent climaxes might be only stationary, meta-stable states, which can also undergo further shifts.[11]
Due to its complexity, more than a century of observing patterns of succession has however not yet resulted in establishing the complete set of mechanisms that determine the documented changes for a specific species composition.[12] However, succession is still a matter of interest, for which Wali[13] identifies three reasons. First, it is universal and observable. Second, however, a high level of complexity is reached because each region comes with its own patterns of developmental changes in its attributes. Third, based on the two reasons above, succession provides a framework for searching for "common patterns in the operation of system variables and for deciphering principles that are plausible and widely applicable" [14].
The three reasons are also valid for applying the concept to urban development: Observable changes take place, which show a high degree of complexity making the individual development of an urban fragment hardly predictable. However, common overall patterns are identifiable.

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[6] [DARWIN 59]
[7] At that time, it was generally understood that plants can grow entirely without seeds or that their seeds remain in the ground for a long period before they start to germinate ([PIPKIN 01], p.536) Thoreau wanted to overcome this idea and based his thoughts on the premise of local homogeneity allowing the existence of relics, inliers and outliers. (ibidem, p.538)
[8] [HULT 85]
[9] [EGERTON09], p.54, 55
[10] [CLEMENTS 36], p.253 and originally in [CLEMENTS 16]
[11] [BLAKESLEY 10], p.2, 3: Due to the long timescale for trees, a stable wood must continuously renew itself. Otherwise, if the older trees start dying too frequently within an interval, the offspring may not be able to grow fast enough in adequate time and seedlings from other species will cover the vacated area.
[12] [GROSS 89], p.524
[13] [WALI 99]
[14] ibidem, p.197

I2.2 Succession

After Gunderson and Holling[15], development is seen as successive and does not have to have a defined starting point. Comprehensible initial points for the description of the succession of ecosystems are situations when an ecosystem has gone through a destructive or disturbed period. A phase of reorganisation starts when the disturbances have stopped but the area is not yet attractive for a broad collection of creatures.[16] After the destruction phase, the damaged areas will be populated usually by so-called r-strategists, which have a fast and high reproduction rate. They start to build up the rules and constraints for a new ecosystem. r-strategists are species that do not invest much energy in individual offspring. At this stage, diversity is low and the number of individuals from each species is high. Slowly long-term species, called K-strategists, start to inhabit the area. K-strategists are species with lower reproduction rates. Each individual has a higher probability to survive because K-strategists are better at fitting into a special environment (i.e. highly competitive).[17] Out of this combination and growing domination of K-strategists, a climax stadium can emerge (Figure 1).

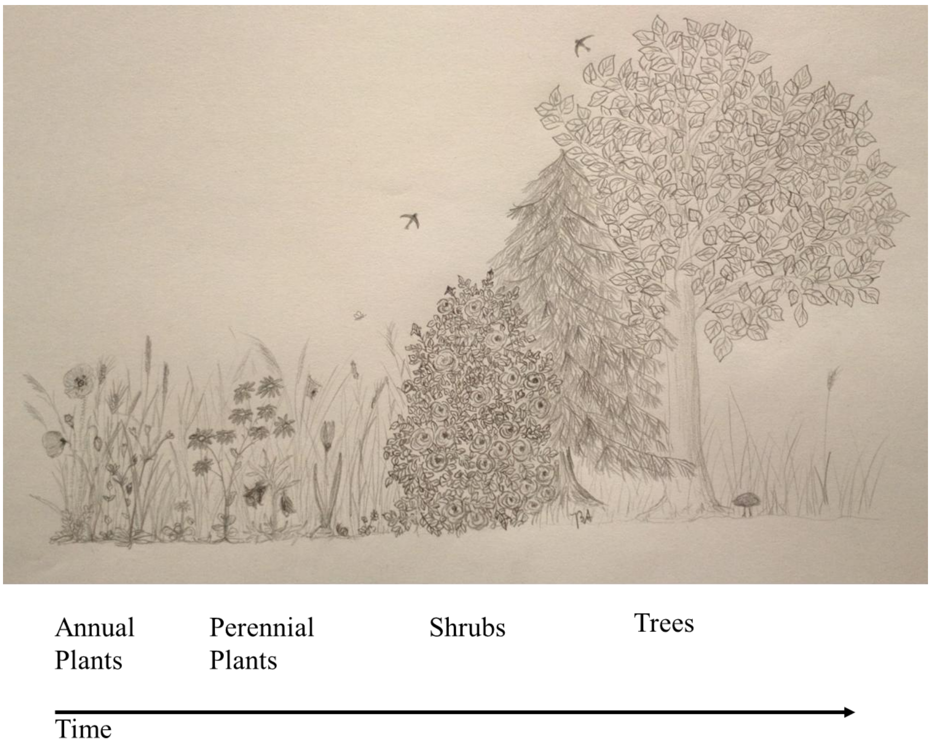

Figure 1 Succession of plants. Pioneering species comprise various annual plants. In the next stages, perennials and grasses, shrubs, softwood trees and finally hardwood trees follow.
Source: courtesy of Jasmin Barman-Aksözen adapted from [PIDWIRNY 06]

[15] [GUNDERSON 02], p.33, 34
[16] This is seen for example after a volcano eruption; the lava has to cool before the pioneer creatures can settle in the area.
[17] [GADGIL 72]

Because of permanent changes in the climate and other exogenous factors, there are seldom real, finite climaxes but rather meta-stable ecosystems. The extent of destruction affects the stability; usually small damage, e.g. the falling of a tree, allows individual changes within such an ecosystem but do not cause a shift to another ecosystem with different species combinations. Bigger disturbances or catastrophes (such as volcano eruptions) or long lasting changes (such as climate change or ozone depletion), which are difficult to reverse, can destroy or alter the characteristics of a whole ecosystem. A big disturbance results in new initial conditions, causing another ecosystem to start.

I2.3 Adaptive Cycles

Based on the described concept of succession, Gunderson and Holling developed the adaptive cycle theory[18], which is a generalisation of the succession concept and is applicable to other systems[19] (Figure 2). The main premise is that all systems go through phases, in which they emerge, ripen and, later, are modified and demolished, thus making space for new development. The sign ∞ illustrates the four steps. Every stage is indicated by a special sign: Ω stands for a phase of disturbance or destruction (release of biomass), α for the renewal (reorganisation), r for the incoming r-strategists (exploitation of biomass) and K for the subsequent K-strategists (creation and conservation of bigger amounts of biomass). After the four phases of one cycle (Ω, α, r, K), the system can stay within the same cycle (current: ∞_1 the cycle is closed) *or* transition to another adaptive cycle after a disturbance (Ω). Then the impact of Ω overstretches the adaptive capacity of the old system (∞_1) and a new α phase marks the beginning of a new adaptive cycle with different characteristics (∞_2 – indicated by the two arrows in Figure 3). Figure 3 shows these sequences for a catchment in time.

[18] [GUNDERSON 02], p.35, see also [HOLLING 01]
[19] Such approaches connect select ecological systems with their economic influence. In their examples they focus on ecological successions whereby natural resources depletion is considered to lead to disturbances (Ω phases) with a resulting new adaptive cycle, e.g. if the basis of the economy is fishery, then the economy cannot continue with diminished or depleted fish sources. Connecting ecology with its impact on the economy demonstrates the importance of the environment and the need for its stability, i.e. [WALKER 04]

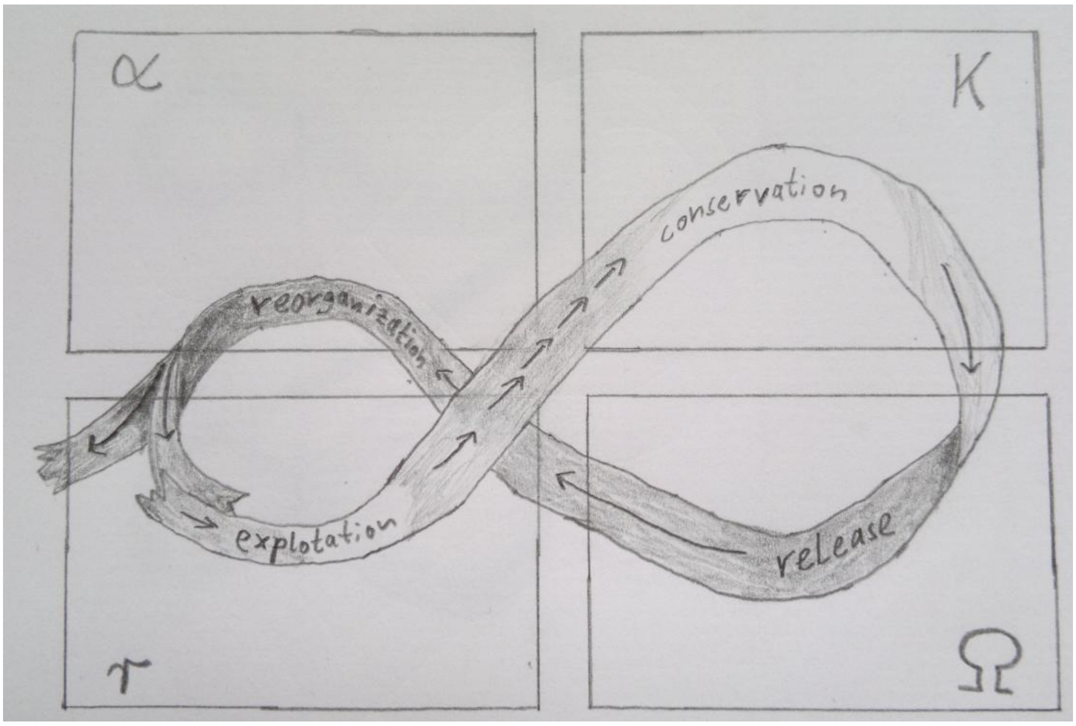

Figure 2 Representation of the four adaptive cycle phases (α, r, K, Ω).
The durations of the phases differ. Within the adaptive cycle the Ω phase represents the end of a cycle that is immediately followed by an α phase, the (re)start of a cycle. It quickly transitions to phase r and slowly phase K emerges, which proceeds then to a release Ω phase.
Source: own illustration adapted from [GUNDERSON 02], S.34).

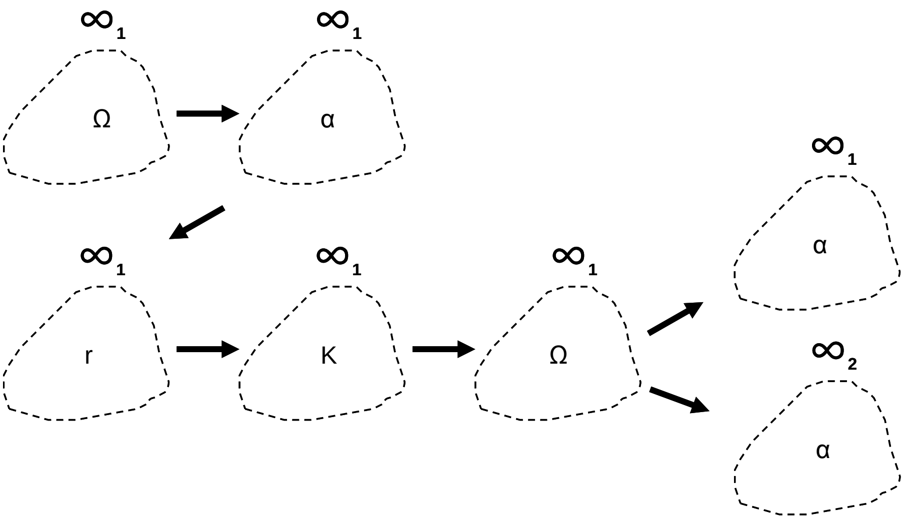

Figure 3 Representation of the four phases (α, r, K, Ω) for a cycle ∞_1 within a catchment.
The second Ω phase shows that thereafter the same cycle can restart or if the disturbance is too big another cycle ∞_2 can begin. The arrows represent the passing of time but are uneven in their actual duration.

I2.4 The Dimensions of Adaptive Cycles

After Gunderson and Holling, adaptive cycles possess three dimensions[20]: potential, connectedness and resilience (Figure 4).

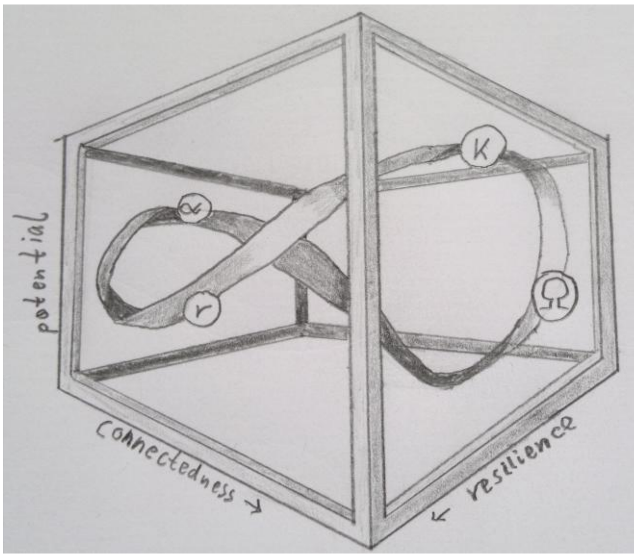

Figure 4 Adaptive Cycles have three dimensions: potential, connectedness and resilience
Source: own illustration adapted from [GUNDERSON 02], p.41

Potential comprises free space, biomass and diversity. In phase r, the remaining biomass and space of the previous adaptive cycle is used (potential decreases). In phase K, a system is established in so far that a growing amount of biomass and diversity is created, filling even the smallest niches and spaces (potential increases in total).

Connectedness is the level of linkages between species. In phase K, a high number of interlinkages accompanies the high number of niches.[21] The more complex a system becomes through the continuous filling of niches, the more it becomes vulnerable to new intruders. Such a system is highly sensitive and intruders may disturb the complexity, especially if keystone species[22] are endangered.

Resilience is the adaptive capacity, resistance or self-organisation of a cycle. Resilience is the cycle's ability to cope with disturbances. Higher resilience means less vulnerability. Within phases r and K, the resilience of a given system is high. In phase r, this is due to the amount of fast-growing species and their few requirements; even a big loss is balanced quickly by newly reproduced individuals. In phase K, the resilience is based on the stable establishment of r- and K-species so that they

[20] [GUNDERSON 02], see p.33-40 for potential and connectedness, p.40-47 for resilience
[21] [WILDAVSKY 88], p.4, assumes that connectedness is an axiom for all systems
[22] A single species may affect disproportionately the patterns (occurrence, distribution and density) of other species. [PAINE 69], p. 950

dominate the circumstances they have to handle. Variances as well as developments within these stages are stable within a certain frame. Disturbances that can be coped with to some degree do not lead to the transition to another adaptive cycle. Coexistence in phases r and K leads to increasing efficiency.
Due to the high complexity of K phases, their vulnerability to environment changes is higher compared to r phases. Such weakness can lead to continuous destruction within a system, which might result in a transition to an Ω phase where resilience is stressed and potential is extensively diminished or even destroyed. Big sudden impacts or slow but permanent disturbances do not have the same effect immediately on the existing connectedness. While resilience and potential decrease in an Ω phase, connectedness and dependence still exists for living creatures (Figure 5).
At the end of a chaotic period and with the transition into the renewal α phase, these linkages survive with their corresponding creatures and the nascent biomass becomes the potential for the next phase r in a new cycle. Alternatively, the following α phase can be within another adaptive cycle, missing some of the creatures and their linkages but providing potential due to the remaining biomass. Consequently, the less complex and newly commenced system has only a small amount of resilience.

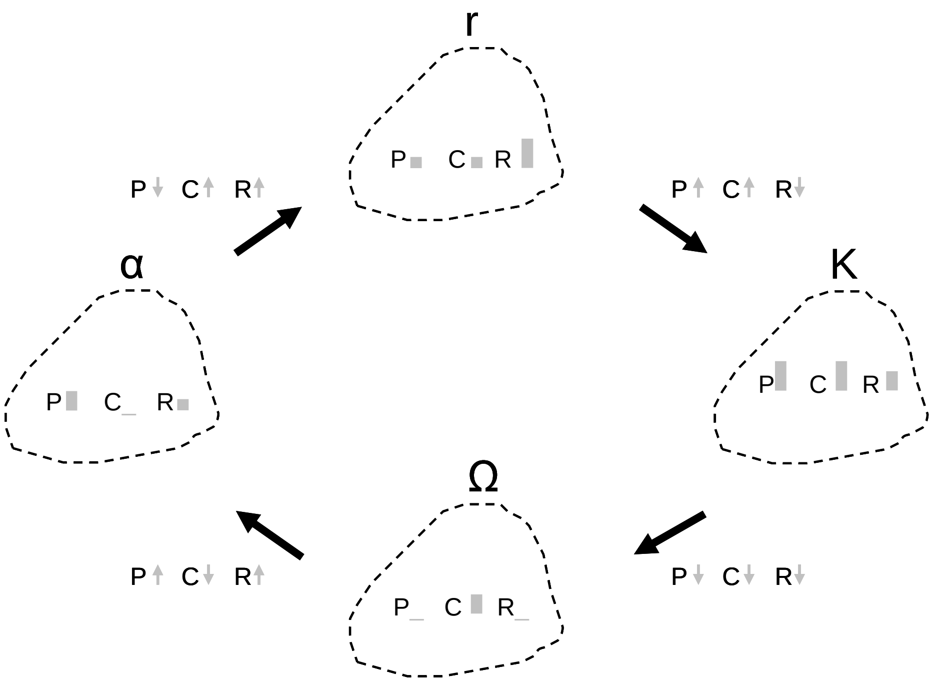

Figure 5 The fluctuations of the three dimensions of an adaptive cycle.
The degree of connectedness is low and growing within phases α and r. In phase K, the high connectedness between the elements of the cycle is dominated by inner relations and is not easily disturbed by outer influences. Potential is highest in phase K where many resources have been accumulated by the elements of the system. With disturbance in phase Ω, the potential changes in its quality, serves as a beginning in phase α and reduces in phase r. Resilience diminishes as the cycle progresses toward phase K when the adaptive cycle becomes more fragile. It expands increasingly when the system shifts rapidly back to phase α and phase r. Source: own illustration

I2.5 Mosaic Cycles

The mosaic cycle concept[23] arose in 1936 and was applied by Watt to grasslands[24]. It describes landscapes as mosaics with cyclical but asynchronous fluctuations of a set of phases. According to mosaic cycle theory, each part of a catchment follows the same adaptive cycle but may be in different phases.[25]

A new succession does not necessarily have to start from the beginning and not all phases have to be gone through in all details and at the same speed. Disturbances can happen at any time followed by a more or less quick progression of the different phases without a system shift. Instead of a homogenous climax, mosaic cycle theory proposes on the one hand a cyclic component where successions can be repeated (renewal) and on the other hand, the existence of irregular but not ubiquitous changes, which lead for example to a time lag or advancement toward the transition into the next succession phase (Figure 6).

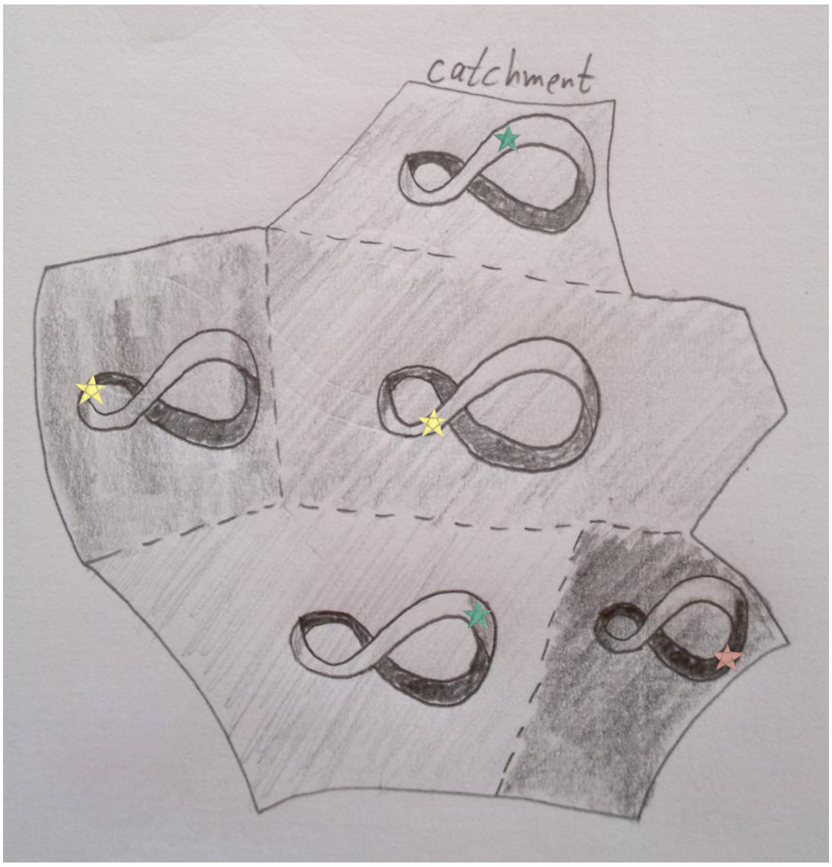

Figure 6 Mosaic of Adaptive Cycles in Different Phases
Within a catchment, adaptive cycles follow the same cycle but may be in different phases. Source: own illustration adapted from [GUNDERSON 02], p.137

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[23] [AUBREVILLE 36]
[24] [WATT 47]
[25] After four decades of little attention, with the exception of [WHITTAKER 77] and the addition of the concept of shifting mosaics by [BORMANN 79], since the 1980s starting with Remmert ([REMMERT 85]) many examples of mosaic cycles have been described, i.e. heathlands, wetlands, tall-grass-prairie, arid steppes and river ecosystems ([KLEYER 07], p.153). See for more in [HENDRY 95] and [REMMERT 91].)

Jedicke argues that mosaic cycles are needed for the rejuvenation and stability of an ecosystem[26]. In human-induced landscapes awareness or even the protection of processes is necessary to maintain an adaptive cycle (∞_1; Figure 7 top right). Without proper protection of the processes, the cycle can transit into a disturbance Ω phase with a large enough magnitude for another adaptive cycle (∞_2) to start within the catchment (Figure 7 bottom right; $\Omega_1 \rightarrow \alpha_2$).
In analogy, cities can be understood as combined catchments, wherein each catchment is within an adaptive cycle (contributing to the overall adaptive cycle) but not necessarily in the same phase of the overall cycle.

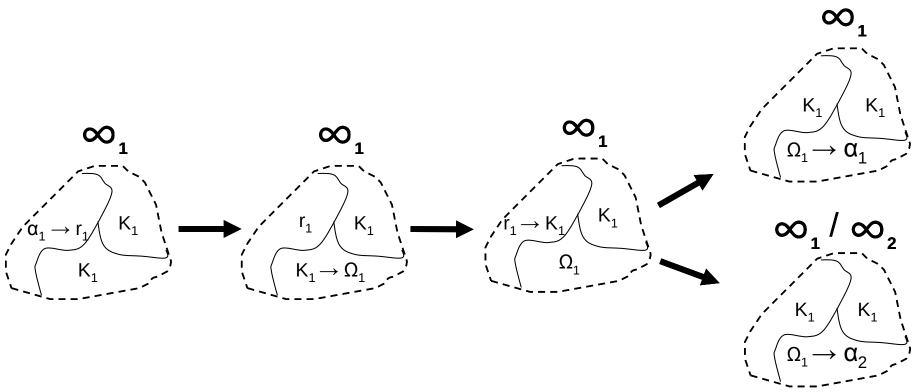

Figure 7 Representation of the four phases (α, r, K, Ω) for cycle ∞_1 with different progressions in the various parts of a catchment.
After the Ω phase in one part of the catchment, the same cycle can restart or if the disturbance is too big, another cycle (∞_2) can begin.
Source: own illustration

I2.6 Urban Fragment Definition

Historically grown cities as a whole are not homogenous, but comprise different more or less homogenous object combinations. Therefore, cities can be seen as a combination of urban fragments, naturally occurring or artificially put together into administrative units.
Urban fragments are the smallest and most comprehensible entities of a city and are the most suitable level for the analysis of urban development. Usually an urban fragment[27] (see also Table 1) consists of buildings, infrastructure and free space (urban units) and is an administrative entity (such as a postal district[28]), often with historically grown borders and structures (such as a neighbourhood[29]) but can also be chosen ad hoc[30].

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26 [JEDICKE 98], p.232
27 [KOHLER 07a]
28 [BRITANNICA 11]
29 a district or community within a town or city, [OXFORD 11]
30 [KOHLER 07a]

Scales of Urban Fragments	Spatial System Limits
Building	Parcel
Building stock	No limit/not connected
Group of buildings: neighbourhood	Ad hoc
Group of buildings: quarter	Administrative
Commune	Limit of commune

Table 1 Scales of urban fragments consisting of buildings
Source: [KOHLER 07a]

In this paper, urban fragments are defined in a way differing from [KOHLER 07a]. Urban fragments are seen as spatially and temporally defined constructs with a specific focus. This enables a researcher to define a fragment according to the feature under investigation[31] and solves some common problems connected with the scaling of an urban fragment.
Depending on the focus of the analysis, an urban fragment can be understood as a combination of socially, ecologically, culturally or economically related objects, which always have temporal dimensions but are not hierarchically ordered. As well, a religious community or administrative sub-body (school) can constitute an urban fragment combining buildings and stakeholders belonging to this special unit.
In ecosystems, mosaic cycles describe homogenous regions where different areas are in different successive phases of the same cycle.
In analogy, cities can be understood as combined mosaics of urban fragments[32], each in its own developmental stage.[33] Quarters developed for only one purpose, i.e. financial quarters are one anomaly: not all quarters have to have been a financial quarter during their development.

[31] Further examples for the homogeneity of the objects of focus would be schools within a city, buildings of an owner, organisation or retailers/resellers. A social example: the object of analysis can even be one building that is observed from a specific point of view, e.g. the socio-cultural or economic influence of a school. A focus on the ethnic diversity of the pupils of a school would spatially define the area of influence of the school and the number of pupils and their parents would be a non-spatial focus. In this example, there are temporal limits as each year one fourth of the pupils is replaced (in a four-year primary school).
[32] Comparable with the divisioning of a city into urban structure types (Stadtstrukturtypen) but more flexible in definition and use. See besides many others: [PAULEIT 99]
[33] An urban fragment can have various forms of a meta-stable state (climax), e.g. financial quarter, residential satellite, one family houses, village, an inner city core, multi-cultural student quarter, etc. There are many different types of urban fragments, each going through different phases.

I2.7 Adaptive Cycles Understood as Metaphors, Analogies or Models of Urban Fragments

The concept of adaptive cycles is broadly applicable to paradigms[34], institutions[35] as well as socio-ecological systems[36] but its application is not without critics[37]. Succession describes the development of a system through various differently enduring and steadily transforming or meta-stable phases that finally achieve a longer lasting climax state. In addition, climax stadiums can also be seen as meta-stable.[38] An urban fragment can also be described as going through different stages of succession:

- The α phase, which extant urban fragments have already undergone, but can start again after a transformation
- The r phase, a phase of consolidation
- The K phase, a slow transition into a meta-stable phase
- The Ω phase, in which the destruction or significant transformation of the qualities of a space (e.g. alterations to the number of individual buildings exceeding certain limits) may lead to a change of the adaptive cycle.

Pickett[39] introduced the idea that terms such as ecosystem or resilience have meanings that can be used metaphorically and/or for the development of models. The application of a concept in the contexts of other disciplines raises the question of how many common aspects exist. The similarities of the systems allow estimation if a new concept serves as a metaphor, analogy or model.

Metaphor[40]: In linguistics, a metaphor is the application of a term to a context outside its usual one. Two types of metaphor are translation and interaction metaphors. Translation metaphors allow direct substitutions of terms[41], e.g. ‘this man works like a machine’ may be translated as ‘this man works in a robust and methodical manner’. Interactive translations create a new meaning for a term, e.g. ‘man is a machine’. In this case, human beings are perceived as machines by suppressing some attributes and prioritising others.[42]

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34 [GUNDERSON 02], p.234
35 ibidem, p.250
36 ibidem, p.210-211
37 [BRAND 09]
38 [GUNDERSON 02], p.11-14
39 [PICKETT 04]
40 [LIVINGSTONE 81], p.95-96
41 [BLACK 62], p. 31-36
42 ibidem, p.40-41

Analogy: Analogies are used in different contexts. A simple analogy is "if abc changes to abd, what does iijjkkll change to?"[43]. Some analogies can be more complex, e.g. one drawn between the solar system and an atom. More challenging and interesting analogies are "active, evolving theoretical frameworks"[44] like the comparison of computation and cognition. Sereno characterises such complex generative and explanatory analogies in four steps: "1) decomposition of the source and target systems, 2) establishment of a map between two systems, 3) generation of predictions about the target, and 4) testing of the predictions."[45]

Model: Models represent systems and define spatial and temporal boundaries, system components and their interdependencies.[46] These system representations may consist of "equations, experiments, graphs, flow charts"[47].

The adaptive cycle concept as a model for describing the development of ecosystems is complex and therefore must be more than a translation metaphor. Based on the description earlier in this paper, adaptive cycles are at least interactive metaphors for urban fragments.
In the next chapter, the possibility of an analogy between adaptive cycles and urban fragments is demonstrated.

[43] [CHALMERS 91], p.22
[44] [SERENO 91], p.468
[45] ibidem, p.468
[46] [PICKETT 94]
[47] [PICKETT 04], p.370

I3. Interpretation of Urban Development Sequences as Adaptive Cycles

Due to scale invariance, the concept of adaptive cycles is applicable to small units comprising quarters but can also be applied to larger scales like whole cities. Thus, many of the currently accepted theories of urban development can be described as adaptive cycles and the qualities of the three dimensions (resilience, potential, connectedness) can be identified. Below, the author evaluates the applicability of the concept to the level of the city.

Urban development can be described using an urban sociological model for the change of residential areas (Hoover[48]). At the level of the city, it can take the form of several sequences (Van den Berg[49]) or one sequence (Lichtenberger[50]). The common characteristic of both approaches is the sequential development of quarters and neighbourhoods including the identification of special phases. Hoover and Lichtenberger propose a linear succession with a climax and point out that the further development is dependent on the handling of the quarters. Van den Berg's model focuses on the change of the attractiveness of urban areas depending on the size of population and the perspective of a bigger growing population. The different models and their relation to the adaptive cycle framework are presented in the following sections.

I3.1 Interpretation of Neighbourhood Development as an Adaptive Cycle

To apply the adaptive cycle by analogy to an urban fragment, the author introduces the work of Sabine Friedrich[51] on the development of two city quarters in Zurich (CH). The phases of an adaptive cycle are only qualitatively applied, to test whether the concept proves useful to understand the development of urban quarters in the sense of succession. Friedrich analyses the development of two quarters (Schwamendingen and Oerlikon) in Zurich, Switzerland. In the 19th century, Schwamendingen was a municipality encompassing Oerlikon.[52] While the former was mainly characterised by residential areas, the latter developed a dynamic industry as well as trade facilitated by rail connections to Zurich and southern Germany from 1855. The latter's economic strength resulted in separation from Schwamendingen

[48] [HOOVER 59]
[49] [VAN DEN BER 82]
[50] [LICHTENBER 90]
[51] [FRIEDRICH 03], p. 99-114
[52] [KURZ 03], p.39

in 1872, and thereby the establishment of residential and industrial buildings.[53]

The period of the study starts in 1934 with the incorporation of Schwamendingen[54] and Oerlikon[55] into the bigger municipality of Zurich (Table 2). The first decade concerned the administrative and juridical preparations, which can be interpreted as an α phase. Up to the beginning of the 1950s the residential building stock doubled in both areas[56], corresponding to an r phase. Until the 1970s, the building stock matured and still grew with adapting traffic plans and improving (green) area use (K-phase). In the 1970s, triggered by the end of the post-World War II boom and the simultaneous energy crisis, industry in Oerlikon collapsed (Ω phase). Accompanying the crisis, plans for big projects gave way to new redirection (α phase). Planning after the crisis concentrated more on the stabilisation of the existing building stock.[57] This was done through renovations as well as demolitions and new constructions resulting in re-densification in the 1980s (r phase). Whereas changes (good infrastructure, new service companies, good-quality open space, appealing architecture and the strengthening of the centre) in Oerlikon[58] led to an increase in value (K phase) in the 1990s. In contrast, the lack of an appropriate reaction to the energy crisis led to a stagnation of development in Schwamendingen. The effects of the crisis were not as strong as in Oerlikon and did not force development plans. Infrastructural connections remained low, a new national road dividing the quarter into two parts, noise from the nearby airport and a shopping mall diminished the importance of the quarter's centre and downgraded the value of the place for living.[59] Nevertheless, the quality of life is partially still high (thanks to many green areas). [60]

The high demand for more residential area in the whole city of Zurich[61] (Ω phase) led to the planning of residential settlements in both quarters at the end of the 1990s[62] (α phase).

[53] [BOLLINGER 59], [OERLIKON 10]
[54] [KURZ 03], p. 79
[55] ibidem, p. 45
[56] [FRIEDRICH 03], p. 101-103
[57] ibidem, p. 103
[58] [KURZ 03], p. 47; [FRIEDRICH 03], p. 106, 114
[59] [KURZ 03], p. 84
[60] [FRIEDRICH 03], p. 109
[61] ibidem, p. 111
[62] [KURZ 03], p. 48, 85

Time	Schwamendingen	Oerlikon	Phase
1930s	Incorporation into Zurich		alpha
1940s/1950s	Doubling of Building Stock		r
1960s/1970s	Adaptation and Improvement		K
1970s	Energy crisis and end of boom		Omega
1970s	Stagnation	Collapse of industry leads to new redirection and big projects	alpha
1980s	Infrastructure on low level, national road dividing the quarter, airport noise, shopping mall decreases importance of quarter centre	Stabilisation, redensification and good infrastructure	r
1990s		Strengthening of the centre and image improvement	K
End of 1990s	Need for Residential Areas		Omega
2000s	Still attractive with green areas and low density	New service companies, quality open space and appealing architecture	alpha

Table 2 Adaptive Cycles of Urban Fragments Schwamendingen and Oerlikon in Zurich
Both quarters were incorporated into the city of Zurich in 1934 and went through a similar development until the energy crisis and the end of the boom in the 1970s. Whereas Schwamendingen stagnated and went less attractive, Oerlikon's industry collapsed and decisive actions were needed which made the quarter attractive. The need for residential areas in the 1990s pushed both quarters to become more attractive, which succeded basing on different circumstances.

I3.2 Neighbourhood Level: Residential Area

Hoover and Vernon analysed the development of the metropolitan area of New York. The model going back to Hoover/Vernon identifies five stages of development of a neighbourhood: residential development, transition, downgrading, thinning out and renewal[63]. The authors suppose that not all stages have to be gone through by all neighbourhoods. Some phases can be omitted or phases can remain without developing into another stage.

In Hoover/Vernon's model the first stage, "residential development",[64] starts with rapid population growth at a low density. In the following "transition stage"[65], population growth is still substantial combined with new constructions leading to an increasing average population density. In the "downgrading stage"[66], population density continues to increase as existing building structures are transformed to fit long-term use. With this, onsets the "thinning-out"[67] stage whereby densities decrease, vacancies and demolitions increase with almost no residential construction anymore and the population declines. In the next stage, "renewal", further development depends much on public intervention (Table 3).

[63] [HOOVER 59], p.192-207
[64] ibidem, p.192-194
[65] ibidem, p.194-196
[66] ibidem, p.196-199
[67] ibidem, p.199-202

Hoover Stages	Description		PCR	Phases
Residential Development	Using Construction Area as Potential		P: diminishing; C, R: increasing	α to r
Transition Stage	Connections deepen		P, C: increasing; R: stable	r to K
Down-grading	Mature community, Ageing of Buildings		P, C: increasing; R: unstable	K
Thinning-out	Missing Renovation		P, R: decreasing; C: stable	K to Ω
Renewal	Renovation or Replacement?		?	α1 or α2

Table 3 Stages of Hoover/Vernon mapped to the Adaptive Cycle Phases
The stages of the Hoover/Vernon model are interpreted using the adaptive cycle dimensions potential (P), connectedness (C) and resilience (R) and corresponding adaptive cycle phases.

The Residential Development stage can be interpreted as the end of an α phase moving into an r phase, with increasing connectedness and resilience using the available construction area as potential for housing. The Transition stage can be seen as phase r to mid-phase K, where connections are deepened and resilience kept up. The Downgrading phase starts with the stabilising and increasing of potential due to the diversity of residents and possible uses as well as further establishing connectedness. With the danger of diminishing resilience due to the ageing of buildings, the downgrading stage represents a K phase's mid- to end-term. In the Thinning Out stage the neighbourhood's potential decreases as renovations are neglected, even if the remaining population is still connected with each other, and the whole becomes increasingly less resilient which leads to a change from phase K to phase Ω. The Renewal stage may be the start of the next succession[68] (transition from phase α to r) and could start with replacement of obsolete areas of housing by e.g. new multifamily housing (α_1) or interventions that rein in the population decline (α_2). The first option would lead to a qualitative and effective use of space, through which subsidised medium-income and low-income housing and luxury apartments could increase the neighbourhood's potential and connectedness to fulfil the requirements of a K phase, whereby the second option could provide conditions to stay in the same (adaptive) cycle (Table 3 and Figure 8).

[68] ibidem, p.202-204

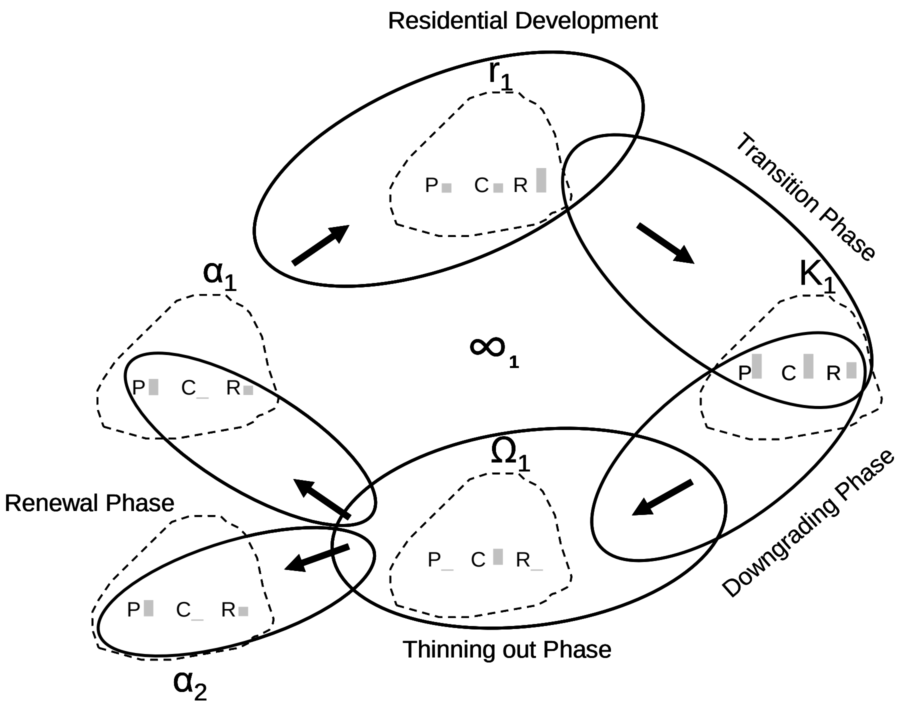

Figure 8 The stages of the neighbourhood development model of Hoover interpreted as an adaptive cycle with changing strength of the dimensions potential (P), connectedness (C) and Resilience (R) in the different phases

I3.3 City Level: One Sequence

Other models deal with the development of whole cities as entities. Here also, the adaptive cycle analogy provides a valid framework to understand these theories.

Lichtenberger analyses the development of the city of Vienna, Austria. She models four phases of city development comparable to a product life cycle, understanding a city as a product. The phases are innovation, take-off, high ("Hochphase") and late ("Spätphase"). Lichtenberger shows parallels between city renewal and product life cycles. Each urban renewal inherits an innovation, followed by a take-off phase if the innovation is accepted. Then a high phase is reached in which the most construction activities take place. Finally, a late phase with declining activities closes the product life cycle.[69]

According to Lichtenberger, in the innovation phase, first families slowly inhabit an area and start to organise themselves. The buildings and infrastructures are not yet finished. In the next phase, "take-off", inhabitants start to establish first relationships with their neighbours and efficient ways to work and enjoy leisure. In this phase, there is yet a high amount of openness between the new inhabitants. The urban fragment has many defaults still or inhabitants cannot get used to it. During the "high phase" the neighbourhood has developed a certain stability and also efficiency in coping with daily activities.[70] The city

[69] [LICHTENBER 90], p.18-20
[70] ibidem, p.18

has gone through several changes to fit to the needs of the stakeholders. The relationships between the neighbours have stabilised. Changes can still occur but do not alter the overall established character of the neighbourhood. More decisive changes, which may be small in the beginning, can lead to a post-mature phase called the "late phase"[71] in which relationships or buildings are partly in decline. This can start with demolitions, lack of renovation or inadequate renovations of a building or other activities that have immediate impacts on the whole urban fragment (Table 4).

Lichtenberger Stages	Description		PCR	Phases
Innovation Phase	New Construction Area		P: diminishing; C, R: increasing	α
Take off	Connections deepen, Building not ripe		P, C: increasing; R: high	r
High Phase	Mature community		P, C: high; R: stable	K
Late Phase	Demolitions, inadequate or Missing Renovations		P, R: decreasing; C: stable	Ω
Renewal	Renovation or Replacement?		?	α

Table 4 Phases of Lichtenberger's model interpreted as Adaptive Cycle Phases Lichtenberger's phases are interpreted using the adaptive cycle dimensions potential (P), connectedness (C) and resilience (R) and corresponding adaptive cycle phases.

Within urban development, the innovation phase, represented by a construction area that has been initiated totally anew or arises from an area after a demolition phase, corresponds to Adaptive Cycle phase α. The next phase "take-off" can be associated with an r phase. The "high phase" can be related to a K phase and the climax of the succession model. If the resilience of the urban fragment's system is overstretched beyond its capacity in the "late phase", the conservation of the known system (adaptive cycle) is not ensured anymore, e.g. if too much has changed. This can be seen as an Ω phase where a city is eventually driven into another adaptive cycle (Figure 9).

[71] ibidem, p.19

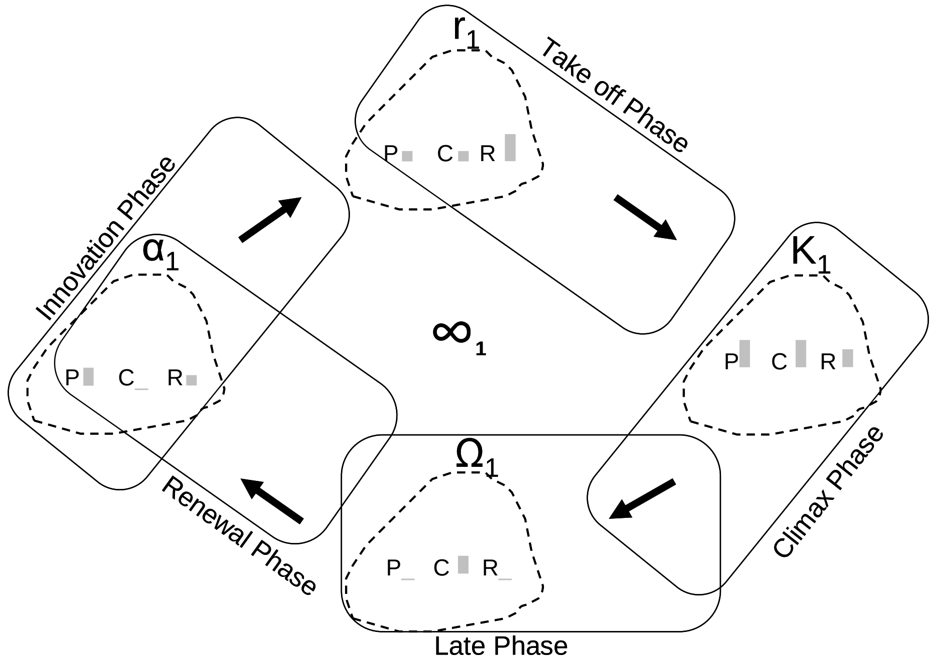

Figure 9 The urban development model of Lichtenberger interpreted as an adaptive cycle with changing strength of the dimensions potential (P), connectedness (C) and Resilience (R) in the different phases

I3.4 City Level: Sequences of Growth and Decline

In contrast to Lichtenberger, van den Berg sees city development as a sequence of phases. He identifies four sequential stages of development of a city[72]: 1. urbanisation, 2. suburbanisation, 3. desurbanisation and 4. a possible future reurbanisation. The model comprises the whole city and was developed while investigating European cities.

In addition, each stage functions as a system of its own, going through all the four phases of succession.

It starts with the **urbanisation**[73] process during which the core neighbourhoods of cities become the focus of development and start growing.[74] With improving means of transportation, more and more citizens become connected, which results in further urban area growth.[75] In the following period, new roads and rail infrastructure are built for new industrial and residential areas, which partly are for low-income populations. As a result, an increasingly connected area with rising potential in uses and residents emerges.[76] For further development, new areas are necessary which leads to changes in the existing connections.[77]

[72] [VAN DEN BER 82], p.25-45
[73] For empirical analysis, see ibidem, p.92-97
[74] ibidem, p.25
[75] ibidem, p.26
[76] ibidem, p.27
[77] ibidem, p.29

In the **suburbanisation**[78] process, first companies find it more feasible to use the potential of surrounding areas and move there. A change of functions between the new suburban areas and the first areas urbanised occurs. In the next phase the population grows, and innovators who earlier moved outwards are increasingly followed by imitators, accompanied by improvements in traffic infrastructure.[79] This leads to suburban areas with urban structures with comparable connections and potential but on a smaller scale. Van den Berg sees the concentration on the provision of services as a change of the system attributes,[80] which leads to a further extension of the used area. In the initial phase of the coming[81] **desurbanisation,** traffic infrastructure supports new uses of free land[82] to develop small and mid-sized periphery areas, which become better connected[83] but remain much more dependent on the suburban or urban areas. In a next developmental step, the volumes of services for the urban and suburban areas and of goods from the (sub)urban areas increase whereby dependencies grow.[84] Van den Berg sees two options for the further development[85]: town reconstruction and town renovation.[86]

van den Berg Stages	Description		Phases
Urbanisation	Core neighbourhoods Urbanized Core growth Growth pressure		α r K Ω
Suburbanisation	Companies move out of the core Urbanization of suburbs Change of functions Increase of services		α r K Ω
Desurbanisation	Peripherical growth Increasing connections High dependencies Pressure on the old core		α r K Ω
Reurbanisation	Reconstruction or Renovation?		α r K Ω
	Concentration or Diversity?		

Table 5 Stages of van den Berg's model mapped to Adaptive Cycle phases
The processes of van den Berg's model are interpreted using the adaptive cycle dimensions potential (P), connectedness (C) and resilience (R) and corresponding adaptive cycle phases.

[78] For empirical analysis, see ibidem, p.97, 98
[79] ibidem, p.30
[80] ibidem, p.33, 34
[81] For empirical analysis, see ibidem, p.98-101
[82] ibidem, p.34, 35
[83] ibidem, p.35
[84] ibidem, p.37
[85] ibidem, p.40-44
[86] ibidem, p.44, 45

Each process described by van den Berg is divisible into the adaptive cycle phases (Table 5 and Figure 10). The initial phase of the urbanisation process corresponds to the α phase. The expansion and improvement of transportation infrastructure and later the higher degree of diversity and connectivity can be interpreted as phases r and K. Growth makes the development of new areas necessary corresponding with the impact of an Ω phase.
The transition to a new adaptive cycle is based more on a change of perception than on one of the physical world. While the urban area is still active, companies first move into the suburban area and start an adaptive cycle for this area (α phase). With more people moving into the suburban area (r phase), a structure develops and ripens that is smaller but comparable with the urban area (K phase). When growth continues, the region around the urban area becomes more attractive due to the good infrastructure connections to the suburbs. Service companies can move outside more easily, which impacts the urban and suburban areas (Ω phase). The further development of infrastructure creates periphery areas (phases α and r) and in a more mature stage (K phase) the interdependencies between the three areas increase and the urban area may come under pressure (Ω phase) over its future use.

Two different adaptive cycles can begin now, reconstruction or renovation. Both imply different new succession phases: the first represents an accepted division of functions between urban and suburban areas (low external connectedness) with urban areas optimised for certain services (high internal connectedness, medium potential but little resilience due to high specialisation). This can be seen for example in financial quarters. Renovation represents a higher diversity of functions (high potential) that can also result in higher attractiveness for residents again (with higher connectedness and resilience likely).

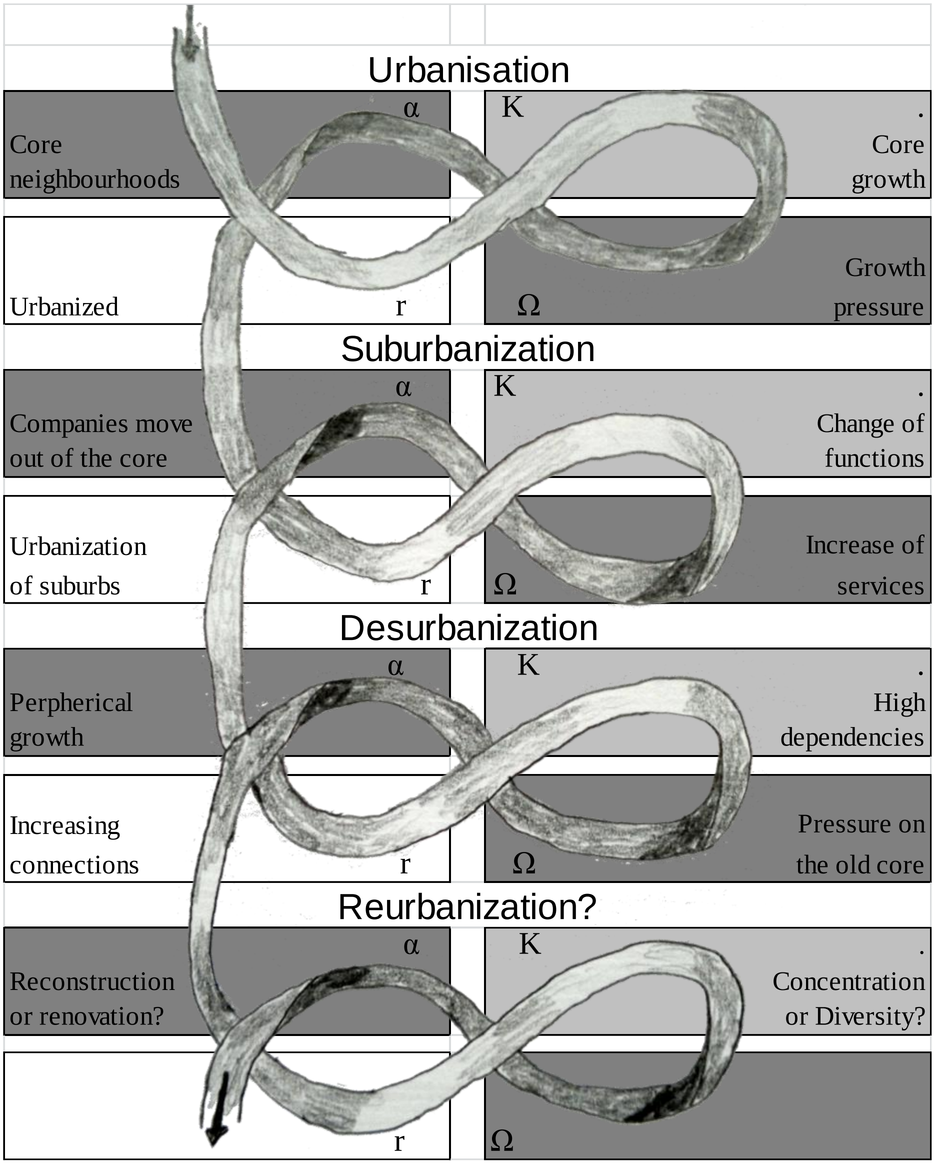

Figure 10 Temporal process of the urban development model from van den Berg represented by successive iterations of phases in several adaptive cycles
Source: own illustration, adaptive cycle band adapted from [GUNDERSON 02], p.316

Summary and Conclusion

Existing models of urban development can successfully correspond to the different phases of the adaptive cycle. The adaptive cycle concept predicts/identifies four phases of development, originally described in ecology. An α-phase, which is the start of every development de novo or after a disturbance, is followed by an r-phase. This transits slowly into a K phase characterised by a meta-stable climax. Finally, a destruction (an Ω-phase) is caused by internal or external factors leading to two possible outcomes. Depending on the system's resilience, the investigated entity finds a way back to its original cycle (restarting in phase α) or adapts into another development (restarts in a new phase α and therefore a new adaptive cycle). Every phase is described by the balance of three dimensions: resilience, connectedness and potential. In

analogy, city development can be described as an adaptive cycle. In Hoover and Lichtenberger's model, a linear succession with a climax and the transition into an Ω phase (with an undefined outcome for the neighbourhood) is proposed. Both expect that ageing buildings influence inhabitants. In contrast, van den Berg's model bases the shifting attractiveness of different quarters of a city on a growing and mobile population.
A common characteristic of all the theories described above is the focus on quarters as the basic unit of city development.[87] As Friedrich clearly shows, quarters cannot be seen as identical parts of the city always developing in the same overall direction. Like or similar life cycle phases of one urban fragment can be found in others as well. A mosaic cycle concept of cities, with each quarter seen as an independent and autonomous developing unit, is therefore more adequate to describe urban development. Independently interacting adaptive cycles are a better illustration of the interplay at the scale of a city.

The mapping of the phases of the urban development theories and the phases of the adaptive cycle framework for urban fragments show that the approach can be used at least as an analogy as well. The author demonstrates how the concept of the adaptive cycles can be used to develop a (conceptual) model for urban development in Chapter III.

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[87] Garry Peterson explicitly applies the adaptive cycle approach to buildings ([PETERSON 02], p.127-150). Yet, his application results in a rather linear interpretation of a building's development, not allowing the building to restart the ongoing cycle. According to Peterson, the design phase is based on experiences from the past and expectations for the future. This process needs the collection of information and its integration by assessment, and is referred to as an α-phase (ibidem, p.140-141). The construction phase establishes the building with the use of materials and energy. If this phase leaves the building unfinished in some aspects, it can be adapted later on by its occupants. The use of available resources exploits potential which is close to the understanding of phase r. In the operation and maintenance phase the building matures, and is adapted to "both the general human needs of its inhabitants and the specific needs of its current users, and that this tinkering gives rise to loved and admired buildings"(ibidem, p.143). This ripeness is similar to a K-phase. The allowance to ripen comes from the opportunities to adapt facilitated by the design and needs energy and materials. The Ω-phase is compared with the deconstruction of a building. Three design objectives are proposed: design for disassembly, design for reuse and design for decomposition. (ibidem, p.145)
According to this understanding, the use of the adaptive cycle is a more linear application. A restart of the cycle is not possible. But through adaptation opportunities facilitated by the design phase, the building adapts or is adapted within the K- or maintenance and operation phase. If the design objectives are applied then another adaptive cycle may begin for the materials used from the deconstructed building. But it will always be another new cycle. Of the three dimensions of adaptive cycles only resilience is considered.

I4. *The Sustainability of Urban Fragments*

Cities are the most important places for production, consumption and creativity,[88] but they are also the origins and sites of many environmental disturbances[89].

The ecological footprint of a city's consumption no longer correlates with its geographical size.[90] European cities contribute much to the global sustainability crisis, accounting for a significant proportion of waste and consumption.[91] This leads to an increased exploitation of distant rural areas and ecosystems.[92]

The evaluation of the sustainability of a system or a method of production depends on the definition used, i.e. weak or strong sustainability, and on the system limits considered, i.e. neighbourhoods, cities.

I4.1 The History of 'Sustainability' and its Application to Cities

In recent decades, interest in the concepts of 'sustainability' and 'sustainable development' has grown and influenced the way the impact of human activities are considered and assessed.

In the late 1960s, the assessment of impacts focused on environmental impacts of planned projects. Later propositions extended the requirements to the sustainable development agenda demanding to

[88] Sustainability definitions frequently base initially on human needs, and consider the safeguarding and improving of the quality of human life, rather than the evolution of the environment. These aspects are valued very differently by people. Some are not linked to the physical survival of the environment (e.g. "the aesthetic and cultural quality of surroundings, access to countryside and tranquillity") and some are not environmental at all (e.g. standards for material living, public health and safety; access to education, healthcare, fulfilling occupations, personal development opportunities as well as facilities for community, recreation, cultural and social life). All of them and many other factors contribute however to the quality of human life. [EC 96], p.57

[89] Due to their geographic size and concentration of activities within their regional ecosystems, cities can have substantial impacts on regional carrying capacity thresholds. Urban areas are or had been functioning ecosystems before urbanisation. In the past the demand for timber for buildings and fuel has led to deforestation in and around many cities. Urban development generally causes a reduction of biomass and biodiversity due to the volume used in construction and due to the forced displacement of animal and plant populations. On the other hand, new habitats and niches arise which can have the appropriate qualities if the type, structure and management of green spaces, the connections and interactions between them and surrounding buildings, and the levels of disturbance from noise and pollution (especially by the patterns of human behaviour, e.g. recreation) are actively supported. More generally, resource depletion is connected strongly to waste generation. In urban areas, whole environmental systems have been overwhelmed by the by-products and wastes of human consumption [PICKETT 85], p.6; [REBELE 94], p.177-179.

[90] [REES 96], p.235

[91] ibidem, p.237

[92] ibidem, p.236

integrate environmental impact assessments into sustainability procedures[93].

One of the early attempts to define sustainable development and to formulate the problem in a global manner was the World Conservation Strategy published by the International Union for Conservation of Nature and Natural Resources (IUCN) in 1980. One of the main sections of the report entitled ‘Towards Sustainable Development’ identified poverty, demographic pressure, social inequity and unfair terms of trade (which are against the interests of the poor or developing countries) as the main factors behind the destruction of natural habitats. Natural habitats are the basis of economic development. In 1987, the World Commission on Environment and Development lead by Gro Harlem Brundtland[94] agreed on the following general definition[95] of sustainable development:

> “Sustainable development is development that meets the needs of present generations without compromising the ability of future generations to meet their needs and aspirations.”

I4.2 Weak and Strong Sustainability

The goal to meet the needs of a generation is a question of how resources are consumed or transformed and how the relationship between different resources is defined. Sustainability can be classified as weak or strong according to the capital theory approach. The possibility of substitution between natural and non-natural capital is the distinguishing criterion.[96]

Within weak sustainability, the relevant capital stock is the total stock of natural capital. This means that theoretically, non-natural types of capital can replace and substitute all natural resources. Therefore, a reduction in natural capital results in an increase of non-natural (i.e. economic, cultural or human) capital. In contrast, strong sustainability requires a constant or at least a non-declining rate of natural capital.[97] Furthermore, there are intermediate positions that admit substitution in general but exclude it for certain assets of natural capital for which no equivalent substitutes can be found.[98] A look at various natural resources, such as oil reserves, clean air or aluminium deposits, shows

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[93] See also [DEVUYST 01]; [IAIA 02]; [SADLER 99]; [PARTIDARIO 03]; [GIBSON 01]; [VERHEEM 02]

[94] [WCED 87], p.43

[95] Among other definitions are: “Sustainable development means improving the quality of life while living within the carrying capacity of supporting ecosystems.” [WCU 91] in [EC 96], p.21

“Sustainable development is development that delivers basic environmental, social and economic services to all residents of a community without threatening the viability of the natural, built and social systems upon which the delivery of these services depends.” [ICLEI 94] in [EC 96], p.21

[96] See also [PEZZEY 01]; [STERN 95]

[97] [CONDALY 92], p.41, see also [PEARCE 94]

[98] [FAUCHEUX 95] in [STERN 95], p.11; [KNOEPFEL 05], [SCHELLER 01]

that there are difficulties to maintain a constant total asset of natural capital. Therefore, the maintenance of minimum assets for these resources seems more reasonable and appropriate.[99]

Moreover, the premise of weak sustainability violates the second law of thermodynamics, because a minimum amount of energy is always needed to transform matter into useful goods or services (from an economic point of view).[100] Every economic activity is directly or indirectly dependent on external short-term sources such as wind, sun, geothermal energy or long-term resources like oil, coal etc. In short, energy cannot be produced inside the economic system and needs resources from outside.

The concept of weak sustainability also violates the first law of thermodynamics on the grounds of mass balance.[101] Ecological principles considering the importance of diversity in system resilience indicate that a minimum of quantities for a large number of different capital stocks (e.g. species) are needed to maintain life-supporting services.[102] Strong sustainability incorporates these facts by assuming that there are higher thresholds on the assets of natural capital required to maintain economic activities in the long-term by supplying the economy with materials and energy. Manufacturing demonstrates that any industrial product requires energy and other natural capital. The end product and the used natural capital are complements, and in terms of the assimilative capacity of the environment, certain critical categories of natural capital cannot be replaced by forms of non-natural capital.[103]

The application of sustainability principles tends to avoid contradictions and conflicts between sustainability's different dimensions. The substitution between dimensions is generally very limited, even in the weak definition of sustainability. Therefore, sustainability is still inherently an open notion, difficult to measure due to its complexity.[104]

Some authors find it reasonable to consider sustainability a concept that is subjective and in itself contradictory. Something that is apparently unsustainable to an environmentalist does not have to be unsustainable to a conservation scientist or economist. What makes something sustainable or not may differ even according to the view of different experts/specialists[105].

Support for weak sustainability might arise when solar or renewable power for all energy regeneration is available and does not rely on the depletion of ecological resources. However, the requirements for the transformation of one resource into another must be more reliable to hinder limitless depletion.

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[99] [CONDALY 92], p.40
[100] [VICTOR 91], p.206-211; [PEZZEY 01], p.62-66; [HALL 86], p.577
[101] [PEZZEY 01], p.67-69; [PEZZEY 94]
[102] [COMMON 92], p.13
[103] [CONDALY 92]; p.41; [BERNDT 79], p.351, 352
[104] [WALKER 06], p.1-13
[105] [PHILLIS 01], p.438

I4.3 Initiatives for Sustainable Cities

The European Commission established an expert group on the urban environment, which in 1996 published “European Sustainable Cities” focusing on the systemic characteristics of cities.[106]

According to this report, the first international attempts to link urbanisation, environmental quality and poverty in the 1970s concentrated on the qualities of human settlements in the provision of adequate shelter, sanitation and local environmental quality. The so-called Brundtland Report initiated a new focus on cities. Based on the assumption that in the near future, the majority of the world’s population will be living in urbanised regions, the evolution of cities should be a central objective of sustainable development.[107] In 2010, cities accommodated more than 50% of the world population and almost 80% of European Union citizens.[108]

The growing awareness of the connection between economic, social and environmental concerns and the interpenetration of global and local issues make cities a key arena for the application of the concept of sustainable development. At the ‘United Nations Conference on Sustainable Development’[109] in Rio de Janeiro (1992) this focus was strengthened by the call for all local authorities in partnership with stakeholders and their communities to produce Local Agenda 21 plans. These agendas addressed sustainable development at the level of the municipality and initiated extensive actions all over the world[110]. Further initiatives such as the ‘Green Paper on the Urban Environment’ in 1990, the adoption in 1998 of ‘Sustainable Urban Development in the European Union: A Framework for Action’, and the ‘2004 Communication Towards a Thematic Strategy on the Urban Environment’ have strongly promoted the issue of urban sustainability within the European Union (EU).[111]

The Sustainability of Cities

Cities have to offer citizens opportunities for living in a sustainable way to combine a good quality of life with low environmental impacts. Concepts for sustainable living force the linkage between environmental impacts, the quality of life and the future success of cities. Especially cities have the potential to reconcile the numerous dimensions of sustainability, as stated in the ‘Green Paper on the Urban Environment’.[112] Population densities in cities allow an immense

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106 [EC 96]
107 [BUISQUIN 00] in [BENTIVEGNA 02], p.87
108 [UN 09], [BUISQUIN 00] in [BENTIVEGNA 02], p.84
109 [UNCED 92] in [BATT 92]
110 [SELMAN 98], p.533
111 [BULKELEY 05], p.44
112 [CEC 90] in [HASTAOGLOU 93], p.242

variety and choice of work, goods, services, recreation and society within easy reach. Moreover, this density can facilitate environment-friendly public transport, more efficient environmental services (e.g. reuse and recycling of wastes) and more energy efficient construction.[113]

People choose to live in cities if they offer a good quality of life and households 'vote with their feet' in response to changes in environmental quality[114]. Only cities providing a sustainable environment will be able to secure their own survival in the future. A situation of non-sustainability[115] can result in a structural deterioration of the economic base of a city over a long period ("reflected inter alia in population decline, environmental degradation, inefficient energy systems, loss of employment, ex-migration of industries and services, and unbalanced social-demographic composition"[116]). There are however two sides to the development of a city: its attractiveness via the provision of basic services and the realisation of a certain public luxury.[117] Current equilibriums are unstable. It is also a matter of time until cities tend towards overdevelopment or, on the contrary, dereliction. A shift towards more environment-oriented priorities is therefore required, and as a consequence, an adaptation to more sustainable lifestyles. A change of lifestyle is also a change of culture. Hawkes argues that "community wellbeing is built on a shared sense of purpose; values inform action; a healthy society depends, first and foremost, on open, lively and influential cultural activity amongst the communities within it; sustainability can only be achieved when it becomes an enthusiastically embraced part of our culture."[118]

Challenges for Sustainable Cities

The challenges arising from the objective of sustainable development are multi-fold. The major challenge lies certainly in the necessity to ensure economic, social, cultural and ecological sustainability targets that start now and in parallel consider the medium and the long term. The three factors - the physical, social and economic environments - seem to have reached critical thresholds[119]:

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[113] [EC 96], p. 65 and p.96; see also [NIJKAMP 94]

[114] See [BANZHAF 06] and [TIEBOUT 56] for general community migration as consumer-voting

[115] Depending on emission levels population decline in communities ([BANZHAF 06], p.19) and can be the starting of non-sustainable phases ([NIJKAMP 93], p.8)

[116] [NIJKAMP 93], p. 7

[117] The presence of what is called 'environmental gentrification' – environmentally motivated migration - differs systematically by income and minority status. It is important for analyses of equity as well as for the design of policies related to environmental issues to aim at supporting the less advantaged individuals of society. [BANZHAF 06], p.24

[118] [HAWKES01], p.25

[119] [EKINS 93] in [CURWELL 98], p.25

The determination of these thresholds is not easy. The precautionary principle is a way to face these challenges and thresholds.[120] Its application to environmental hazards has its origin in the study by German scientists into the possible causes of forest degradation or "forest death/Waldsterben"[121]. The principle is only possible when substantial weight is given in decision making to the prevention of potentially critical risks for the physical ecosystem (Maastricht Treaty)[122]. The general uncertainty on the best approach is accompanied by the difficulties of finding suitable methods and instruments to bring it into practice.[123]
However, the main challenge resides as often in the evaluation of soft factors and their lack of measurability. Every approach trying to understand and measure sustainability has to take a plethora of aspects into account. In contrast to global sustainability, an advantage in cities is that the impacts are local, close by and the change is seen in the near future. This makes it easier to find social consensus before a threshold is irreversibly crossed. However, to prevent a decline, stop or exit, strategies should be taken into account with caution.[124]

I4.4 The Dimensions of Sustainability

The basic idea of sustainability is a simple concept, easy to understand intuitively. At the same time, it is a head-scratcher on the practical level. A key issue arising from the Brundtland statement is that a consensus on principle guidelines can be achieved but their relative importance or interpretation is hardly self-evident. There is general agreement that sustainability comprises ecological, economic and social aspects, often referred to as dimensions of sustainability.[125] The common understanding is that the three dimensions reinforce each other. However, not everybody in the field accepts this understanding[126]. Additionally, the evaluation of the three dimensions is highly correlated with the cultural perception of the different aspects of environment. According to the preamble of Agenda 21, some authors suggest an

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[120] [EC 96], p.24
[121] [HARREMOES 01], p.13
[122] [MAASTRICHT 92], TITLE XVI, ENVIRONMENT, Article 130r, 2
[123] Works like [BULKELEY 05] (p.59) show the "multi- and transscalar nature of environmental conflicts" and their implications on sustainability and environmental politics.
[124] Applying the precautionary principle means that "human activities have to be carried out within limits imposed by the natural environment". This requires policy processes, which are designed to reduce or redirect necessary demands. Certain traditional demands will not be met but "the aspirations of human societies to develop, to progress and to improve wealth and living standards" must be reconciled with these restrictions ([EC 96], p.52-54). Further principles to achieve the mentioned reconciliation are: environmental efficiency ([ANASTASIADI 10], p.95; [BRUGMANN 92]; [ESCAT 94]; [LAUWERS 06]; [SELMAN 00], p.216,), welfare efficiency ([MILLER 04]), and equity ([WCED 87], p.43).
[125] In the general discussion, other objectives arose. Bentivegna proposes e.g. environment, equity, participation and futurity as objectives [BENTIVEGNA 02], p.85
[126] [LEVETT 98], p.295, 296

ethical dimension to sustainable management: ”Humanity stands at the defining moment in history. The world is confronted with worsening poverty, hunger, ill health, illiteracy and the continuing deterioration of ecosystems on which we depend for our well-being. The disparities between rich and poor continue.“[127]
Fewings brings up the issue that in dealing with sustainability different cultures may have a different ethical background resulting in different evaluations and judgements.[128] Bächtold would also add the ethical as a fourth dimension to the ecological, economic and social.[129]
Hawkes assumes two issues: “A sustainable society depends upon a sustainable culture. […] Cultural action is required in order to lay the groundwork for a sustainable future.”[130]
The consideration of culture forces us to admit that the relationship between the different dimensions of sustainability can be evaluated differently and to question the degree of substitutability of the values created and supplied by the dimensions of sustainability. There is not one correct definition of ‘culture’ in any language. Authors like Kluckhohn listed in the 1960s available definitions and meanings of ‘culture’ and found more than 100 different ones.[131] He added some himself: “Culture is to society what memory is to individuals”[132].
In this sense, every decision is subject to cultural values[133], which is one of the main determinants connecting rational economic decisions with social and natural environmental issues.
For the future, this may mean that changing lifestyles, e.g. towards more sustainable ones, will change our culture.[134] Based on this insight Yencken adds culture as the fourth pillar of sustainability: “Sustainability, as it has become formally adopted around the world, has not one but three pillars: ecological sustainability, social sustainability and economic sustainability. Some would argue that there should be four pillars and that cultural sustainability should always be included.”[135] Hawkes argues that without the incorporation of cultural

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[127] [UNCED 92]
[128] [FEWINGS 09], p.195
[129] [BAECHTOLD 98]
[130] [HAWKES01], p.12; In the sustainability debate, culture is mentioned as an issue that has to be protected in case of the “value of cultural diversity” but also changed to achieve sustainability if “profound cultural shift” is needed ([HAWKES01], p.25). In both cases it is interpreted as something that is more than just “finer and more refined artefacts of civilisation that one may appreciate after the food is gathered, the roof mended, the road sealed, the workers paid, the children vaccinated, the criminals apprehended and the water purified.” ([HAWKES01], p.25)
[131] [KROEBER 52]
[132] [KLUCKHOHN 54]
[133] [BLEISCH 11] give an example where the value of natural fishing grounds in Native American tribes are weighed against job opportunities for the total population. Cultural values strongly influence the result of the decision-making.
[134] The understanding, that Indigenous people in Australia have a differing relationship to land increased the awareness of the importance of their culture. [YENCKEN 00], p.4
[135] [YENCKEN 00], p.9

changes towards sustainability, the implementation of policies is difficult to communicate.[136] Hassler and Kohler stress the cultural as a fourth dimension of sustainability[137]. They integrate the two views (Figure 11) and conclude that "in any way sustainability is a multi-dimensional concept and privileging one aspect results in the diminution of other aspects".[138]

Figure 11 Different aspects of sustainable development
Source: own illustration of [KOHLER 03], p.6

Therefore, culture is considered a fourth dimension of sustainability in this paper as well. The term culture has many definitions. It is used in a very broad way by anthropologists and in rather restricted way when referring to heritage. In the context of urban fragments, culture is closely associated to cultural and architectural heritage.[139]

Kohler and Hassler explain the four dimensions as follows[140]: the ecological dimension is linked to resource conservation and carrying capacity, the economic dimension takes into account long-term

136 "Cultural vitality: wellbeing, creativity, diversity and innovation. Social equity: justice, engagement, cohesion, welfare. Environmental responsibility: ecological balance. Economic viability: material prosperity." [HAWKES01], p.25
137 [HASSLER 01]
138 [KOHLER 03], p.6
139 [HASSLER 02]
140 [HASSLER 01], p.5

conservation of natural and non-natural capital, the social dimension accounts for intergenerational equity, and the cultural dimension takes into account the conservation of cultural diversity.

I4.5 The Introduction of the Dimensions of Sustainability as Virtual Urban Fragments

Sustainability, understood as a paradigm with four dimensions, can be combined with the concept of adaptive cycles. In this work all four sustainability dimensions are defined as systems on their own, which go through different phases. The individual development stages are part of a bigger cycle. At the same time, the system is renewed and adapted (adaptive cycles), so that the changes do not alter the overall character of an urban fragment. Too many changes may result in a shift to another adaptive cycle, so that the overall character has changed.

The core problem of sustainability is the difficult way to handle and measure facts to make them evaluable, weighable and comparable. The content of the four dimensions of sustainability are quantifiably and qualitatively continuously changing:

- cultural heritage
- economic stability
- ecological intactness
- and social capital.

The sustainable dimensions of an urban fragment are interdependent as well as sensible. As the four dimensions all have an influence on the adaptive cycle of an urban fragment, they are considered virtual subdivisions of the whole adaptive cycle, each with a special focus. As with the phases of an adaptive cycle, the virtual adaptive cycle subdivisions can be analysed for potentiality, connectedness and resilience to provide further understanding of the fragment's state and the developmental direction the virtual adaptive cycle is going. A condensation of all four virtual adaptive cycle subdivisions composes the adaptive cycle of the urban fragment, but due to the prior factorisation a gain in special knowledge is achieved through analysis.

I5. Sustainability and Adaptive Cycles

I5.1 Dimensions of Urban Adaptive Cycles

Adaptive cycles are a possible way to deal with the difficulties in defining and measuring sustainability in the urban context.

Gunderson sets economic and ecological resilience into relation: economic resilience is about the optimisation within a rather stable ecological succession, which can lead to a time of growth and wealth. A crisis influencing economic resilience can affect ecological resilience.[141]

In the understanding of an adaptive cycle, we use an increasing amount of natural-ecological potential to build up less and less human/human-made/socio-cultural and thereby social/economic/cultural potential.[142] The current situation can be described by a build up of a high connectedness in social terms with a strong emphasis on economic values and that this endangers cultural and ecological values.

In our current urban world, understood as a mosaic of adaptive cycles, the subject of concern is the conservation or adaptation of the prevalent systems. The function of sustainability is the appropriate use of available types of capital, in a static as well as a dynamic sense, when considering the driving forces for change at sufficient levels to avoid the transgression of critical thresholds. Therefore, the three dimensions of the adaptive cycles are defined for urban fragments as below:

Potential: In phase α, potential is available in a form that is not used at this particular moment anymore, i.e. available resources that have not yet started to deplete. For example, the useable area within a neighbourhood can be seen as potential. Persons moving in use this. In urban fragments, this can be due to demolition or transformation. In phase K, potential is high because high efficiency is achieved within the system, so in a way, everything has its place and niche and on this basis there is a high flow of biomass. In phases α and K there is higher potential than in the other two phases.

Connectedness: Connectedness starts developing in phase r and grows continuously stronger. In phases K and Ω there is a high level of connectedness between the elements of the urban fragment; this means as mentioned above that there are established links between the different neighbours and the businesses within as well as outside the urban fragment.[143] This connectedness gives stability but makes a system also vulnerable against risks. Even if an impact occurs these linkages stay stable for a while allowing continuity within the current adaptive cycle.

141 [GUNDERSON 02], p.376
142 [DALY 11], p.254-255
143 [WILDAVSKY 88], p.4, even introduces the axiom of connectedness for systems meaning “that the good and the bad (safety and harm) are intertwined in the same acts and objects.”

Resilience: The resilience of a system means the flexibility to react when disturbances like catastrophes (Ω at any phase) occur, which are deep impacts into the structures of a system. Resilience-proving events in the urban context can be unwanted and wanted; unwanted impacts are natural or long-term human-made disasters, e.g. an earthquake or climate change; respectively, wanted ones are the demolition or conscious neglect of buildings. Urban fragments can be resistant especially against wanted impacts (e.g. a lack of new, better-off inhabitants in marginalised areas or juridical requirements (which can be based on aesthetic emotions) result in height limits for newly constructed buildings in a neighbourhood.[144]
Adaptive cycles tend to be resilient as long as they are not disturbed too heavily (e.g. massive out-migration of inhabitants due to economic reasons). By their size and importance, they are affected by short-term demand changes more heavily, whereby the improvement of one capital can result often in danger for another.

I5.2 Combined Evaluation of the Built Environment

The built environment contains the social, cultural, economic and ecological capital of an urban fragment (Figure 12). The valuation of this capital is dependent on factors of geography and time (e.g. development of resources, techniques, general zeitgeist and ageing). Four values can be defined: use value for the social dimension, monetary value for the economic dimension, heritage or cultural value for the cultural dimension and physical capital as ecological value. At the level of urban fragments, key goals will usually be to increase or at least to maintain these values by minimising the environmental impact, and to improve the costs/benefits ratio for the social, cultural as well as the economic dimensions over a specific life phase.[145]

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[144] Resistance can also disappear, e.g. a large movie theatre can endanger existing smaller ones. When residents change their visiting behaviour, the resilience of the habit was not strong enough.
[145] Specific benefits that may result from maintained or improved design include (adapted from [KOTAJI 03]): reduction of environmental impacts (ecologic capital), reduction of lifetime environmental risk (natural capital), reduction of lifecycle costs (economic capital), maintenance or improvement of the usability of the urban fragment (social capital), maintenance of the character of an urban fragment (cultural capital), and a better image for the urban fragment (social/cultural capital).

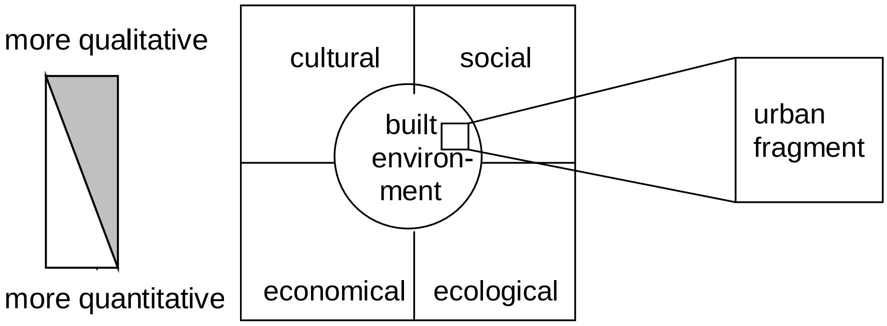

Figure 12 An urban fragment offers a unique view of the built environment. It is embedded into the ecological, cultural, social and economic capital of society. Cultural and social values are mostly qualitative. Ecological and economic values are mainly quantitative.

The proposed approach aims at understanding an urban fragment mainly by processing quantifiable data. The value of the qualitative aspects and data is an important component for the assessment of an urban fragment and improves the evaluation. The dimensions of sustainability all have qualitative and quantitative aspects. Ecology and economy are directly quantifiable whereas cultural and social aspects are more qualitative (Figure 12). This is only understood as a tendency because prices as well as emissions can also become an object of subjective valuation, resulting from the different preferences of users or the effect of human-made changes on ecosystems.

Definitions of the virtual adaptive cycles for the four sustainability dimensions

For a combined evaluation, a general adaptive cycle of an urban fragment is divided into four virtual adaptive cycles each representing one dimension of sustainability with its current level and tendency. Each sustainability dimension possesses the three characteristic features: Potential, Connectedness and Resilience (Table 6 and Figure 13).

The ecological virtual adaptive cycle: Ecological resilience means the ability to react to the changing circumstances of an ecosystem. Ecological connectedness defines the interdependencies of flora and fauna. Ecological potential is the amount and effect of the biomass.

The economic virtual adaptive cycle: Economic resilience is the ability of the economy to react to changing circumstances. Economic connectedness means the internal integration of the urban fragment and its connections to the rest of the city. Economic potential defines the economic activities within the urban fragment.

The social virtual adaptive cycle: Social resilience is the ability to react to changing social circumstances. Social connectedness means the strength of social networks and integration of the inhabitants and their buildings due to use. Social potential is the number of people and social supply.

The cultural virtual adaptive cycle: Cultural resilience means the ability to conserve cultural heritage. Cultural connectedness is how the inhabitants value the built environment as cultural heritage (in terms of belongingness and integration). Cultural potential defines the cultural heritage as a source for inspiration and memory for the people (i.e. history and meaning).

This divisioning helps to keep the overview on the different sustainability dimensions as well as on the general development, i.e. a big change in one virtual adaptive cycle may have an impact on the other dimensions as well and so on the general adaptive cycle, too.

		Resilience	Potential	Connectedness
Ecological	Level			
	Tendency			
Cultural	Level			
	Tendency			
Social	Level			
	Tendency			
Economical	Level			
	Tendency			

Table 6 Adaptive Cycles Description of Urban Fragments
In order to describe the adaptive cycles an urban fragment is in, information is needed on the potential, connectedness and resilience of the adaptive cycles for the four dimensions of sustainability. Further understanding is achieved by information on the state (level) and the direction of development (tendency) of an urban fragment.

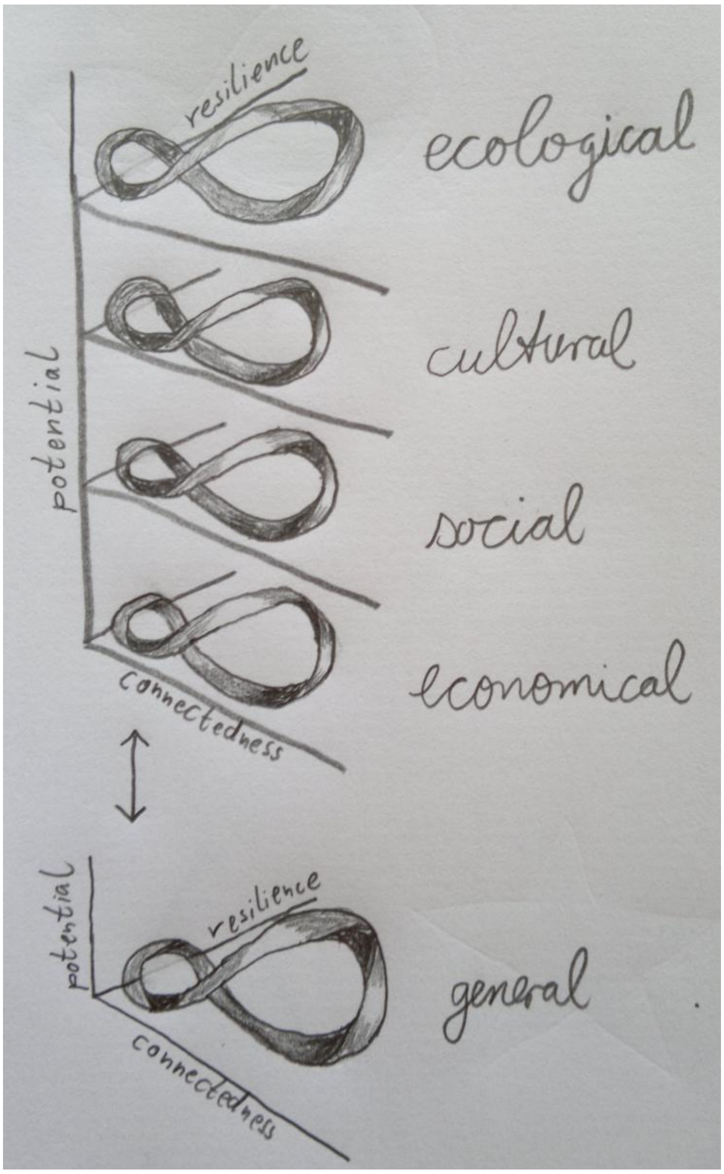

Figure 13 General adaptive cycle separated into virtual adaptive cycles with their individual three dimensions respresenting the four sustainability dimensions

Chapter II

II Concepts Related to Adaptive Cycles and Sustainability

II1. Introduction

This paper started with the description of the adaptive cycle approach, and its adaptation to cities. This approach considers cities as social-ecological systems and that the definition of the built environment cannot be simply opposed to the natural environment. The boundary between the built and the unbuilt environment is historically variable and part of the environment as such.[146] The concept of the adaptive cycle, which describes a succession model that is resilient, "growing out of a general understanding of large-scale ecosystem behavio[u]r"[147], appears to be apt analogy (Section I.3.) to describe also the social/cultural/economic/ecologic development of urban fragments. Discussions about sustainable development and in particular urban sustainable development have given rise to a number of new definitions and more significantly methods and instruments to 'measure' the social/cultural/economic/ecologic development of cities.[148] The different approaches reflect different objectives and contexts. Whitehead associates them with a tendency "to reduce the analysis of sustainable urban development to a technical matter of institutional restructuring, traffic management, architectural design and the development of green technologies" [149]. Political struggles around defining the sustainability of cities are neglected. According to Bulkeley, such a tendency results in analyses that take place in geographical isolation and do not consider the nested properties of political authorities. She suggests a multilevel governance perspective that can open up these geographical divisions "and provide insight into the opportunities and contradictions which emerge in the interpretation and implementation of urban sustainability across a range of scales and spheres of governance"[150]. Other integration efforts emphasise the importance of the evolution of the Earth to get an idea of the impact human living has and why it is not only ethically but also practically important to preserve the Earth system comprising its atmosphere, geosphere, biosphere, anthroposphere, hydrosphere, cryosphere, pedosphere and lithosphere[151]. Another approach toward integration is Baccini's and Oswald's "Netzstadt", an urban model based on a

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[146] [MOFFAT 08], p. 254
[147] [WALKER 02], p.2, see [GUNDERSON 95] for more detail
[148] [DEAKIN 07], p.8 and the other three volumes of Sustainable Urban Development, [CURWELL 07]
[149] [WHITEHEAD 03]
[150] [BULKELEY 05], p.3
[151] [LUETZKENDO 00], p.4-6

physical land use and flow model[152]. Kohler shows another way of integration. Similar methodological approaches using the same data can serve as the basis for Life Cycle Assessment (LCA) as well as for Life Cycle Costing (LCC) and for Material Flow Analysis (MFA) and allow the comparison of results[153]. Finally, there exist a number of methods based on long-term sustainable planning to address the current and future challenges and to discover to what extent a medium-term sustainability transition is possible at all.[154]

II1.1 Definition of Instruments, Methods and Frameworks

Various approaches have been proposed in recent decades to understand and assess the sustainable development of cities and urban areas. Approaches comprise sets of ideas on sustainable development that take into consideration the scope and objectives of a given situation. Starting from the global level Forester, Meadows and others[155] have formulated concepts that are more detailed, covering countries, regions, towns, and neighbourhoods. Concepts for sustainable development are approaches that have a specific perspective on sustainable development. They support the translation of the normative goal 'sustainability' into operational decision-finding in the form of 'action goals'. The perspective is a catalyst for knowledge generation. The objective of sustainable management is to propose heuristics to achieve close to optimal development. The concept of the adaptive cycle postulates that development occurs in cycles and that the pathway of sustainable development is one possibility within alternative cycles. The concept of system ecology posits that sustainable development has to be integrated within a higher order of ecosystems, which have to be understood and protected.[156] Life cycle approaches assert that sustainable development has to be based on a space-time flow model. The concept of total cost of ownership situates ownership costs within a larger system including externalities (positive and negative). The concept of intergenerational equity entails a long-term view that encompasses the possible needs and wishes of past and future generations. Together, these concepts have given rise to an increasing body of scientific literature, policy instruments and analytical methods (Figure 14).[157] Large projects have resulted in cross-national studies attempting to find comparable and common understandings for sustainability implementation.[158] Analytical

[152] [BACCINI 03]
[153] [KOHLER 07a], p.348-351
[154] [MOFFAT 03] in [REVI 05]
[155] [FORRESTER 61], [MEADOWS 74]
[156] [BAILEY 09], p.25, 26
[157] [CEC 98], [TAPPESER 99], [TAPPESER 98], [TAPPESER 97], [ENSURE 00], [CLEMENT 03]
[158] [RYDEVIK 04], p.27

methods constitute the implementation of the concepts with the emphasis on quantifiable aspects, which can result in tools, such as checklists or software. Policy instruments allow the evaluation of qualifiable and soft aspects by defining limits within frameworks, scenarios and labels. The basis for all the above is data, which may be available for attributes and values of a given situation, and have to be interpreted, estimated or at least described as necessary.[159]

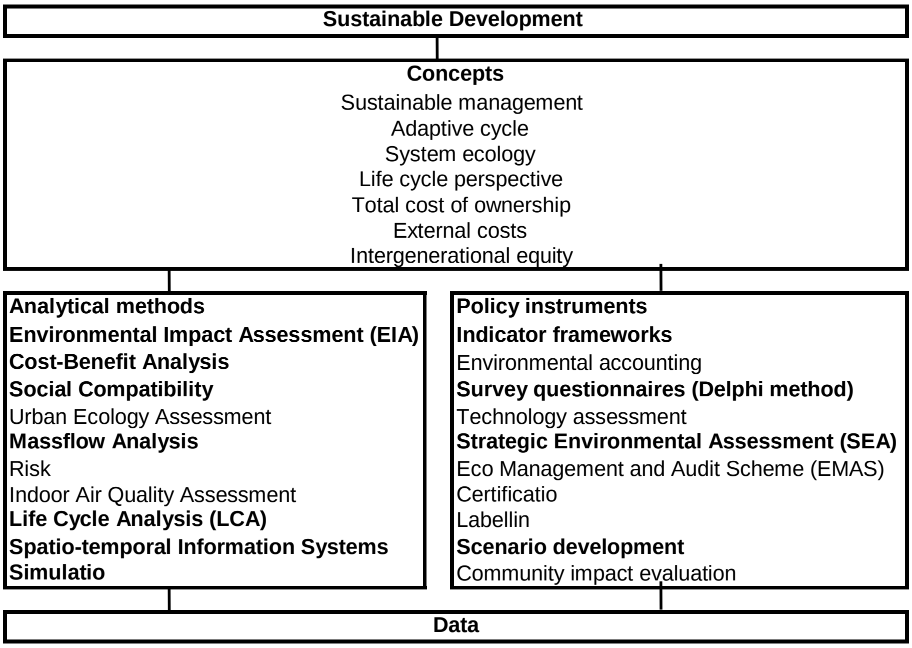

Figure 14 Sustainability concepts
Source: own illustration adapted from [SETAC 96], p.10 and [KAZMIERCZA 07], p.7

The overall goal is sustainable (urban) development. To determine the degree to which this goal is reached, both analytical methods and policy instruments need to:

- clarify the interdependencies of various factors,
- support the understanding of complex interrelations,
- integrate available knowledge and
- test decisions.

Analytical methods and policy instruments have qualitative and quantitative premises and hypotheses with common databases such as inventories and indicators and can contain benchmarks and tools for certification. For a deeper understanding of sustainable development these have to be discussed and taken into account when results are compared (Table 7).

[159] [SETAC 96], p.10

	Definitions
Approach	Application to a given situation through the objectives of sustainable development
Views	Macro-discourses on social-ecological systems
Concepts	Approach with a certain perspective on sustainable development
Framework	Purposeful combination of methods and instruments, which on their own do not fulfil broader goals
Method	Implementation of concepts and tools such as checklists, calculations, simulations and software
Instruments	Implementation of concepts considering soft aspects
Tools	Simulation: UrbanSIM, Life Cycle Assessment: LEGEP
Data	Attributes and values of a given situation

Table 7 Basic definitions for terms used

The definition of methods and instruments and their results may differ quite a lot depending on the knowledge of the author(s), user(s) and the audience. Depending on the knowledge level of the information receiver, according to Ryle, it is important to discriminate two types of knowledge: 'knowing-what' and 'knowing-how'.[160] 'Knowing what' concerns the transmission of information on a specific subject to a specific audience. It can take the form of articles on facts or ideas, e.g. reports or governmental declarations. When a deeper understanding is needed, more information is required. 'Knowing-how' needs become predominant and creative learning processes can be initiated. The effective use of a tool depends both on the performance and the design of the tool as well as on the skills of its user(s).

If knowledge is embedded within a process, a third level - 'knowing the context' - is necessary. This level is not often taken into consideration by many disciplines.[161] This is of importance concerning methods, especially (software) tools that are described using the term 'knowledge management'; the association is misleading. The tools referred to can handle information; they do not handle knowledge. Information is a process, which "changes the knowledge of an actor"; knowledge is therefore always the "knowledge of somebody", tacit knowledge.[162]

Cities as focal places for economic, social and cultural activities with large ecological impacts cannot be modelled fully by one method or instrument. Existing descriptions of activities are based on the specific intentions, hypotheses, restrictions and personal knowledge of the involved individuals. The integration of methods and instruments that take into account all activities with consideration to long-term

[160] [RYLE49], p.27-31

[161] Rydevik compares that differences between 'knowing what' and 'knowing how' to the dependence of a craft's quality on both the quality of the tool and the skills of the carpenter ([RYDEVIK 04], p.27-29). However, 'Knowing-the-context' goes one step further to include the question of whether the carpenter's approach is appropriate.

[162] [RITTEL 72]

objectives is still at its beginning due to the complexity of urban systems. Besides the uncertainty of forecasting, common approaches probably underestimate uncertainties within methods and instruments.[163] This limits the potential for forecasts of long-term (intergenerational) development, which is the condition for creating strategies of stewardship of urban fragments.

The generalisation of digital methods has given a new impetus to meta-studies, i.e. studies on the systemic characteristics of cities or propositions to establish conceptual ontologies relating the different methods and instruments. This already weakens the barriers to understanding that will lead to new insights.[164]

II1.2 Comparative Analysis

The aim of Chapter II is to show how the development of cities can be measured and how the different urban development analysis tools relate to each other when adaptive cycles of cities are examined. Particular tools help to analyse specific phases of adaptive cycles and their scopes overlap with each other.

Among the different indicator systems available, OECD-PCR, HQE2R and WinWin22 are chosen for examination. For each dimension of sustainability, analytical methods or policy instruments are evaluated below: Environmental Impact Assessments and Strategic Environmental Assessments for ecology, Cost Benefit Analysis for economy, Social Compatibility Assessment for social impact assessments and a group of cultural assessment concepts for cultural issues. As classical accounting methods, (Urban) Life Cycle approaches and Mass Flow Accounting are compared. For city related simulations UrbanSim and for neighbourhood related simulations SUNtool are investigated. For spatial analysis without contextual premises, temporal Geographic Information Systems (GIS) and spatio-temporal modelling are introduced. As general approaches, scenario technique and the frameworks BEQUEST and SUIT are reviewed.

It is one objective of this paper to situate the different methods and tools within the adaptive cycle concept. They will be evaluated from the point of view of their compatibility with the adaptive cycle concept.

The author first outlines the history of each tool and its general application. Second, the application of the tool to the urban context is discussed and variations are described. Third, the author reviews the tool with regard to its relevance for urban fragments and its applicability within the adaptive cycle concept.

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163 [WALKER 02], p.1

164 [METRAL09]

		Resilience	Potential	Connectedness
Ecological	Level		●	○
	Tendency			
Cultural	Level			
	Tendency			
Social	Level			
	Tendency			
Economical	Level			
	Tendency			

Table 8 Relevance of the combined dimensions of sustainability and adaptive cycles
(full relevance: ●, relevance with restrictions: ○ and no relevance: empty)
Based on Table 6

The examination of the tools aims to complete the adaptive cycle approach and create an integrated set of tools to analyse adaptive cycles. Therefore, the goal is to generate adequate knowledge on the relationship between the tools and the adaptive cycle concept, with the expectation that more knowledge will support more sustainable and adapted decisions, or at least open better opportunities to deal with the examined adaptive cycle. The effectiveness of tools lies therefore in a similar development and provision. In the development of future adaptive cycle tools maybe more attention will be paid to the fact that knowledge, discriminated from information, is gained mainly by application and learning processes.
Table 8 will be used to assess the suitability of the tools. The assessment is based on the three dimensions of the adaptive cycles (potential, connectedness and resilience) and the four dimensions of sustainability (the economic, ecological, social and cultural). The temporal characteristics are level (state at present) and tendency. The relations are threefold: no relevance for a dimension (empty), relevance with restrictions ○ and full relevance ●.
The examination of the tools will complete by demonstrating to which phases of an adaptive cycle they may be applied.

II2. Indicator Based Assessments

Introduction and General Approach

Humans using indicators, without calling them so, can be detected “since the dawn of history”[165]. Self-conscious applications of social indicators date back to the 1830s. Environmental indicators have a long history also[166].

Indicators are necessary for topics in which direct data is not available for evaluation. They are also useful when a system’s interdependencies are too complex to be modelled or cannot be examined in detail. Indicators can be qualitative as well as quantitative.[167] Indicators are pieces of information that have a wider significance than their immediate meaning[168] by assessing “conditions and trends”, providing “information for spatial comparisons”, providing “early warning information” and anticipating “future conditions and trends”.[169] The concept of indicators is used in many disciplines, like chemistry, economy, ecology[170] and urban research.

Application to the Urban Context

For urban fragments, indicators are used to determine the current state of development and to judge whether objectives have been reached. They can be used as a working tool to help consensus building about strategic actions among stakeholders. It is also important and necessary to work out the relationships between the different issues addressed by an indicator, e.g. the size of green areas may be an indicator for the quality of the urban ecology (environmental indicator) as well as for quality of life (social indicator).[171] The more important an indicator is for one or several aspects of sustainability the more it can be seen as highly connected and its integration within a community rises.[172] Compared to simple indicators, indicators for urban sustainability are

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165 [COBB 98], p.5

166 [MOLDAN 97] in [LAMBERTON 05], p.11

167 [GALLOPIN 97]

168 [BAKKES 94], p.3

169 [GALLOPIN 97]

170 An example of an environmental indicator is counting the number of wild salmon that return to spawn in a watershed. If the amount is adequate, then the local leaders conclude that the water quality is likely acceptable to the salmon and so for humans. Enough salmon running upstream means humans depending on fish and wildlife would have much of the required amount of food. Fishers and processors would secure their income and stay in business, staving off poverty. Moreover, good water quality in the watershed would mean an acceptable level of erosion from forest and land, both urban and rural. The usability of the water was also interpreted as enough rainfall. This example shows the importance of indicators to express complex relationships. [METER 99], p. 9-11

171 [VONALLMEN 05]

172 [METER 99], p.19

more integrated, forward looking and distributional, and might be developed from input from multiple stakeholders in the community.[173]

In the last 20 years many indicator systems for the urban context have been developed[174]. The aim of all the indicator systems was to establish quality control based on available numerical data for a given situation and to compare it to other similar situations. Below the author describes indicator sets of the Organisation for Economic Co-operation and Development (OECD) as an example of a general indicator system, the French HQE^{2}R as an example of a neighbourhood indicator system, the LEnSE approach focusing on buildings and the Swiss WinWin 22 as a project specific indicator set.

II2.1 OECD PSR indicators

The Organisation for Economic Co-operation and Development (OECD) created the Pressure-State-Response framework. Its basic premise is that human activities exert pressures on the environment. Such pressures can be socio-economic as well as environmental, e.g. population growth, poverty or consumption. These pressures result in changes in the state of the environment, e.g. ozone depletion, ground level water decreases or summer smog. These have further effects on humans, like diseases or drops in food production. It is essential to have an overview of the direct and indirect effects that cause a reaction in human society, e.g. easing or preventing negative environmental impacts or conserving natural resources. Indicators are used to identify such PSR-relationships (Figure 15).[175]

Stemming from the PSR framework is a large body of literature on indicator systems concerning economic, environmental and social aspects. Based on the PSR model, further frameworks have been developed. The European Environmental Agency and the European Statistical Office have modified the PSR (Figure 16) into the Driving forces-Pressure-State-Impact-Response (DPSIR) framework by adding ‘driving forces’ (e.g. the development of the economy or education) and ‘impacts’ (e.g. effects on health).[176] Another extended version is the more dynamic Driving forces-Pressure-State- Exposure-Effect-Action (DPSEEA) framework of the World Health Organisation (Figure 17).[177]

173 [LUNDIN 02], p.39
174 For a literature review see [BELL 08], Part I: The Bad Application of Good Science?
175 [OECD 91], [OECD 93]
176 [EUROSTAT 97]
177 [WAHEED 09], p.453

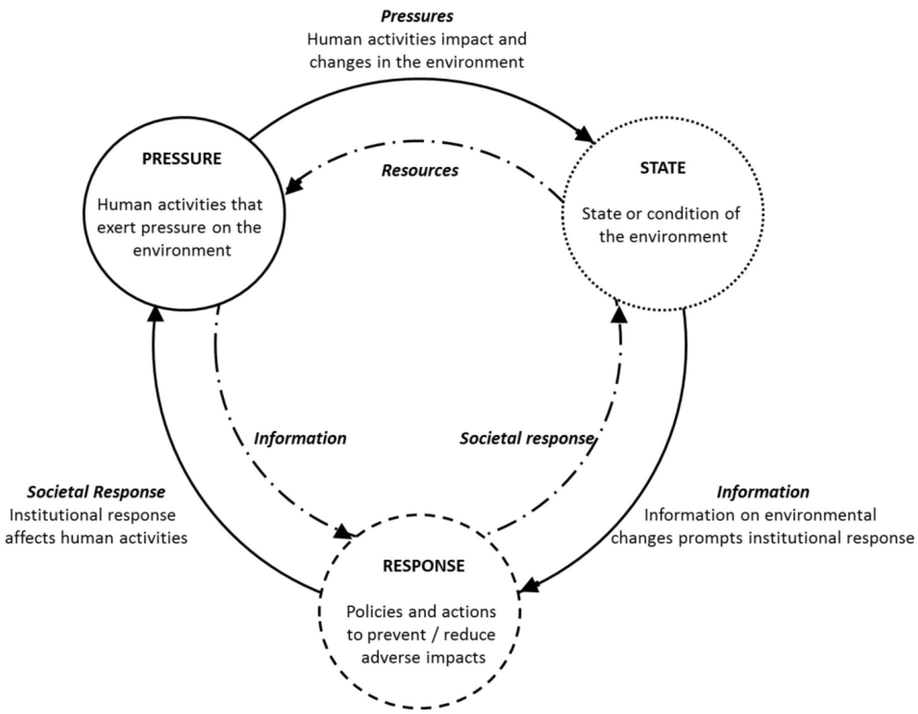

Figure 15 Pressure-State-Response (PSR) framework
Source: own illustration of ([WAHEED 09], p.452)

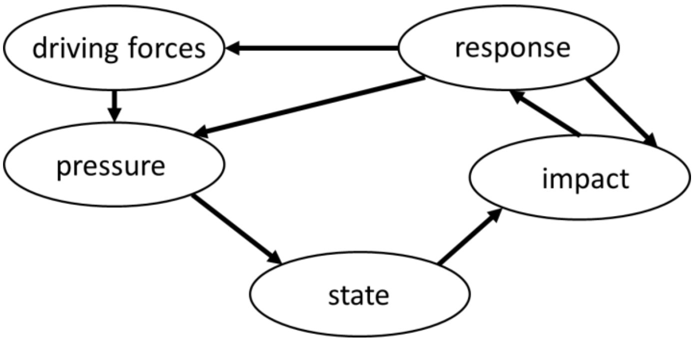

Figure 16 The Driving forces-Pressure-State-Impact-Response (DPSIR) framework
Source: own illustration of ([EUROSTAT 97])

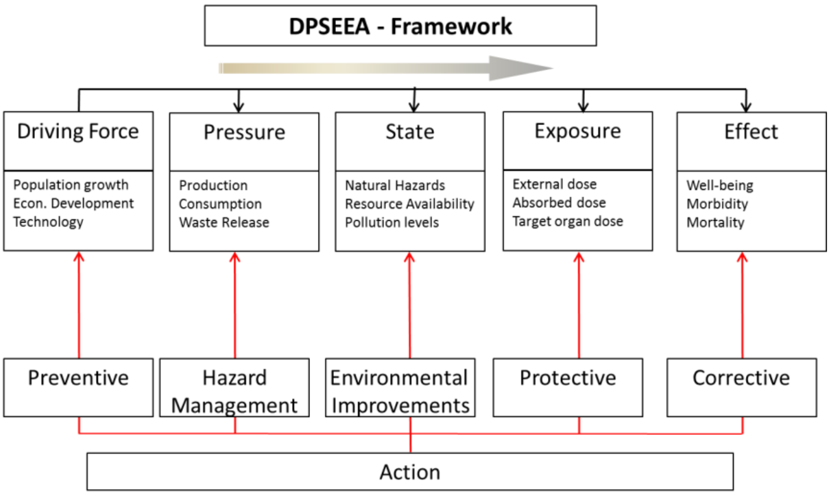

Figure 17 Driving forces-Pressure-State-Exposure-Effect-Action (DPSEEA) framework
Source: own illustration of [WAHEED 09], p.453

At the OECD Rome conference ‘Towards Sustainable Development” it was concluded that economic wealth is only achievable in a sustainable way when social and environmental objectives are taken into account and “placed in an inter-temporal framework”[178]. Discussions on the conference emphasise the appropriate understanding of linkages between the three sustainability dimensions as crucial for reducing possible conflicts.

In the report of the Joint Working Group on Statistics for Sustainable Development[179], based on a capital approach, a small set of sustainable development indicators have been proposed, and divided into two domains: economic and foundational well-being, with stock and flow indicators.[180] In conclusion, economic indicators are still considered insufficiently precise even if they are quantifiable[181] (Table 9). Physical indicators (environment/resources) should not be aggregated into monetary terms and need their own appropriate units of measure. For social capital measurements, the ability to work together and stable political, legal and cultural frameworks are significant. Future research on social indicators for bonding, linking and bridging are proposed (Table 10)[182].

[178] [OECD 00], p.19
[179] [OECD 08]
[180] ibidem, p.83
[181] ibidem, p.84
[182] ibidem, p.85

Indicator domain	Stock Indicators	Flow Indicators
Foundational well-being	Health-adjusted life expectancy	Changes in age-specific mortality and morbidity (place holder)
	Percentage of population with post-secondary education	Enrolment in post-secondary education
	Temperature deviations from normals	Greenhouse gas emissions
	Ground-level ozone and fine particulate concentrations	Smog-forming pollutant emissions
	Quality-adjusted water availability	Nutrient loadings to water bodies
	Fragmentation of natural habitats	Conversion of natural habitats to other uses
Economic well-being	Real per capita net foreign financial asset holdings	Real per capita investment in foreign financial assets
	Real per capita produced	Real per capita net investment in produced capital
	Real per capita human capital	Real per capita net investment in human capital
	Real per capita natural capital	Real per capita net depletion of natural capital
	Reserves of energy resources	Depletion of energy resources
	Reserves of mineral resources	Depletion of mineral resources
	Timber resource stocks	Depletion of timber resources
	Marine resource stocks	Depletion of marine resources

Table 9 A small set of sustainable development indicators
Source: own illustration of [OECD 08], p.79

Network type	Suggested indicators
Bonding	Resident population and sub-populations
	Number of people actively involved in clubs, organisations or associations
	Number of partnerships among government, academia and business involved in research and development
	Level of generalised trust
	Level of victimisation
	Level of social exclusion
Bridging	Level of unemployment
	Level of organised crime
Linking	Level of government effectiveness
	Level of institution trust
	Level of corruption
	Number of human rights violations

Table 10 Social indicators
Source: own illustration of [OECD 08], p.86

The OECD indicators can be used in principle for all dimensions of sustainability. It is often difficult to identify an indicator explicitly as pressure, state or response. Moreover, experience shows that the PSR-concept is not unproblematic in its use for economic, social and cultural aspects. The indicator frameworks often neglect the complex interlinkages within and between the different dimensions.[183] The latter approach of the Joint Working Group adds stocks and flow indicators to the rather static PSR-framework to enable the understanding of the system behind the developments. The social dimension is not yet treated in detail and the cultural dimension is taken for granted.

II2.2 HQE^{2}R (EU-Project)

HQE^{2}R, an EU Project under the 6th Framework Program, aimed to provide methods and tools for use by communities in urban renewal projects.[184] One of the tools is an indicator system established for neighbourhoods (ISDIS) and the related evaluation model (INDI). HQE^{2}R assists the evaluation of several dimensions that are considered as important for the development of a neighbourhood. The objectives of the indicators are grouped into heritage and resources, quality of the local environment, diversity, integration and social life. They include 21 targets (1. energy, 2. water, 3. land, 4. materials, 5. built and natural heritage, 6. urban design, 7. local environment, 8. living environment, 9. safety, 10. air, 11. noise, 12. waste, 13. diverse community, 14. diverse housing, 15. diverse functions and activities, 16. education and training, 17. access to the city, 18. integration with the city, 19. access and movement, 20. local governance, 21. increase social capital), 51 key issues (Table 11) and 61 indicators. After the application of ISDIS, INDI is used to assess change within each target for a given project or scenario (Figure 18). The indicators are understood, in the terms of PSR, as pressure and state at the same time and consider the project as a response.

[183] [LUNDIN 02], p.9
[184] [CHARLOT 03]

Objectives	Targets		Key Issues
Resources	1	Energy	Energy efficiency for heating & cooling
			Energy efficiency for electricity
			Use renewable energy sources
			Reduce greenhouse gas emissions
	2	Water	Drinking water consumption
			Use of rainwater
			Rainwater management
			Sewerage network
	3	Land	Optimisation of land consumption
			Use of brownfields & polluted sites
			Environmental concerns in planning
	4	Materials	Re-use of materials in construction
			Re-use of materials in public spaces
	5	Built & natural heritage	Enhancement of architectural quality
			Preservation and enhancement of the natural heritage
Local environment	6	Urban design	Visual quality of natural landscape
			Visual quality of urban landscape
	7	Housing	Building quality
			Housing quality
			Satisfaction of users and residents
	8	Living environment	Neighbourhood cleanliness
			Reducing sustandard dwellings
			Access to care and health
	9	Safety	Safety for people & goods
			Improvement of road safety
			Local management of technological risks
			Local management of natural risks
	10	Air	Quality of interior air
			Quality of outside air
	11	Noise	Neighbour nuisances
			Noise pollution due to traffic or other activity
			Noise pollution due to construction
	12	Waste	Household waste management
			Site building waste management
Diversity	13	Diverse community	Age distribution diversity
			Social and economic diversity
	14	Functions & activities	Economic vitality and jobs
			Shops
			Local amenity
	15	Housing	Diversity of housing
Integration	16	Education and training	Foster academic success
			Role of the school in neighbourhoods
	17	Access to the city	Improvement of the public transport system
	18	Integration with the city	City amenities within neighbourhoods
	19	Access and movement	Safe and convenient footpaths and cycleways
			Non-pollutant and efficient transport
Social life	20	Local governance	Engagement in the sustainable development process
			Effective participation in decisions & projects
	21	Increase social capital	Strengthening the local community
			Developing the social economy
			Cultural links across the globe

Table 11 Sustainable Development objectives, targets and key issues in HQE^{2}R Source: own illustration of [CHARLOT 03]

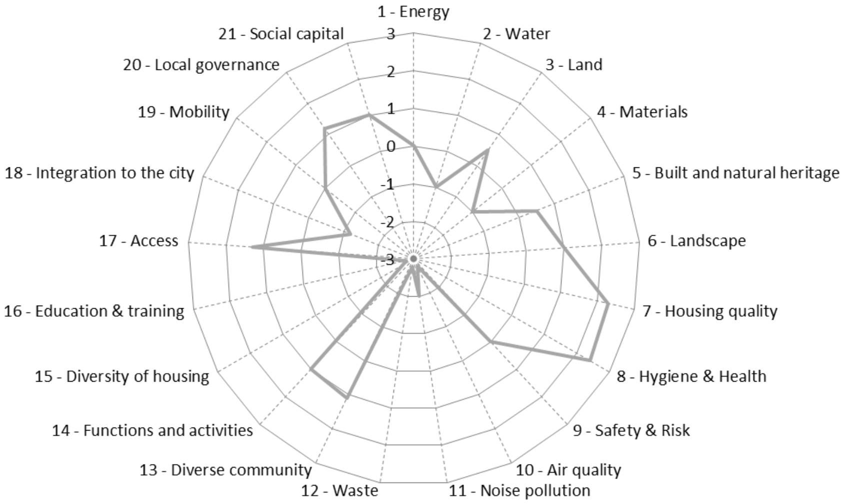

Figure 18 Evaluation of a neighbourhood based on the HQE^{2}R targets
Source: own illustration adapted from [CHARLOT 03]

The sustainability dimensions are considered as shown in Table 12. Most indicators are assigned to one dimension. Built and natural heritage is assigned to all dimensions due to its overall relevance. A diverse community is socially, culturally and economically important. Access and movement influence environmental, economic and social issues. Housing is relevant to the social and economic dimensions.

	Environmental	Economic	Social	Cultural
Energy	X			
Water	X			
Land	X			
Materials	X			
Built & natural heritage	X	X	X	X
Urban design				X
Housing				X
Living environment			X	
Safety			X	
Air	X			
Noise			X	
Waste	X			
Diverse community		X	X	X
Functions & activities		X	X	X
Housing		X	X	
Education & training			X	
Access to the city		X		
Integration with the city		X		
Access and movement	X		X	X
Local governance			X	
Increase social capital			X	

Table 12 Assignment of the HQE^{2}R indicators to the dimensions of sustainability
Source: Own illustration

II2.3 LEnSE (EU Project)

The 'Methodology Development towards a Label for Environmental, Social and Economic Buildings'[185] (LEnSE) is an EU Project under the 6th Framework Program and has the objective to develop a methodology to assess the sustainability of existing, new and renovated buildings. As a first step, a long list of issues for the three dimensions of sustainability was developed. As a second step, this list was critically reviewed to create a more concise list (Table 13) in accordance with two guiding principles:

> "1. That the scope of themes included is sufficiently wide to cover the relevant sustainability topics.
> 2. That each theme is practical in terms of developing content and completing an actual assessment"[186]

The evaluation difficulties of the short list (Table 13) were translated into sub-issues where potential indicators and their intent could be identified. Climate change, biodiversity, resource use and waste, environmental management and geophysical risk were labelled environmental; occupants' well-being, accessibility, security, social and cultural value as social; and whole life value, financing and management and externalities as economic. The measurability of these criteria allows the assessment of the sustainability performance of buildings (for example, within the category social and cultural value under the theme social, six sub issues - community impact consultation, social cost-benefit analysis, socially responsible and ethical procurement of goods/services, considerate builders and design quality - and 10 indicators were defined (Table 14)). There are no cultural categories, however some sub-issues could be included under the theme of culture: under resource use and waste (minimise primary energy consumption and limit raw material use and renewable/recycled/responsibly sourced materials), under occupants' well-being (improve visual comfort, improve thermal comfort, improve acoustic comfort and vibrations, improve indoor air quality, improve outdoor comfort), under social and cultural value (social and ethical responsibility, sensitivity to the local community, building aesthetics and context), under whole life value (preserve or improve the quality and asset value of the site, increase ease of building adaptability, improve ease of maintenance, contribute to image value and technical innovation).

[185] [DESSEL 07]
[186] [DESSEL 07], p.5

Category	Issue
Climate Change	- Reduce Greenhouse Gas Emissions and Acidification
Biodiversity	- Minimise Eutrophication - Mitigate Impact on Site Ecology - Enhance Site Ecology
Resource use and Waste	- Minimise Waste Production (solid, sewage, hazardous and radioactive) - Minimise Primary Energy Consumption (embodied, operational and renewability) - Limit Raw Material Use and Source renewable/recycled/ responsibly sourced materials - Minimise Water Consumption (reduce use and maximise reuse) - Minimise Land Consumption (reduce total use and maximise reuse of contaminated land/brownfield sites)
Environmental Management and Geophysical Risk	- Improve Environmental Management - Limit Climatological Risk (including flooding) - Limit Geological Risk (including subsidence and erosion)
Occupants' Well Being	- Improve Visual Comfort (internal and external lighting provision) - Improve Thermal Comfort - Improve Acoustic Comfort and Vibrations - Improve Indoor Air Quality (odours, ventilation and humidity) - Improve Water Quality - Improve Outdoor Comfort - Ensure Provision of Privacy - Reduce Exposure to Hazardous Materials/Substances (including radiation and electromagnetic fields) - Avoid Unsafe or Hazardous Features (including topography) - Avoid Accumulation of Intruding Hazards (radon, dust, pollen) - Provide Health Targets
Accessibility	- Improve Access to Public Services and Amenities - Public Transport Accesability - Improve Accessible Pedestrian Network - Improve Accessible Bicycling Network - Provision of Car Pooling
Security	- Improve Security of Buildings and Surroundings Against Crime
Social and Cultural Value	- Community / Stakeholder Consultation with Ongoing Participation - Social and Ethical Responsibility (including probity & transparency) - Sensitivity to the Local Community - Provide Affordable Housing - Building Aesthetics and Context
Whole Life Value	- Reduce Life Cycle Costs - Preserve or Improve the Quality and Asset Value of the Site - Increase Ease of Building Adaptability - Improve Ease of Maintenance - Contribute to Image Value and Technical Innovation
Financing and Management	- Improve Economic Feasibility - Reduce Construction and Financing Costs - Improve Construction and Management Standards
Externalities	- Optimise diverse and Long-term local Employment Opportunities, and Minimise Displacement. - Use and Purchase locally Produced Materials - Improve Building User Productivity

Table 13 Short list of LEnSE issues after a critical review of a longer list
Source: own illustration of [DESSEL 07], p.6

	Sub issue	Intent	Potential Indicators
Social and cultural value	Community impact consultation	Accounting for consultation with the community and appropriate stakeholders on the design/use of the building and its role within the local community.	Multi-criteria analysis and evaluation
	Social cost benefit analysis	Accounting for the local/regional social case for the building and its social benefits and costs.	Multi-criteria analysis e.g.: Degree of social housing, Health impact Job creation etc.
	Socially responsible and ethical procurement of goods/services	Accounting for the ethical procurement of goods and services associated with the development/use of the building.	Evidence of purchasing policies
	Considerate Constructors	Accounting for the consideration of the local environment/community during the construction phase.	Adoption of a code(s) of practice Third party audit and certification
	External 'neighbourhood' impacts	Accounting for the building's impacts that could cause a nuisance to surrounding buildings. For example: noise and light pollution, over-shadowing, lack of privacy.	Multi-criteria, e.g: Increase in background noise levels External lighting levels
	Design quality	Accounting for the design quality of the building during the development of the initial brief through to detailed design.	Multi-criteria analysis via third party assessment process. Adoption of relevant design codes.

Table 14 Definition and categorisation of LEnSE sub-issues under social and cultural value
Source: own illustration of [DESSEL 07], p.9

II2.4 WinWin 22

The aim of Winwin22[187] is to visualise the costs and benefits of a project based on the assumptions of the involved actors and taking into account the spatial (local/global), temporal (short-/long-term) and resource type (comprising 19 components within the stock of social, natural, human and human-made capital); Table 15. WinWin22 is not intended to enable complex decisions but rather to support communication during the management, planning and optimisation of a project in order to achieve a sustainability assessment that is based on indicators jointly agreed by the actors at the outset. Therefore, the tool offers a vast amount of indicators, presuming that no one set would fit all situations. The idea is that the appropriate indicator system for a specific situation can be assembled from the different indicator sets (Figure 19).

WinWin22 emphasises human capital by uncoupling it from social capital. Culture is not seen as a capital itself and is placed within social capital in the form of theatres and publications. Yet, there are components incorporated in human-made capital (material goods) and social capital (institutions) that could be regarded separately as cultural.

[187] [KNOEPFEL 06] and for a similar approach [KÖCKLER 05]

Capital	Component	Element
Natural capital	air, atmosphere	production of CO2, Nox
	biomass (nature, flora, fauna)	nature reserve, forest, space
	waste	non-recycable products, glassware, paper
	water	lakes, drinking water
	energy	renewable energy, fuel
	landscape	natural, cultivated, view
	soil	soil sealing, fertile
Man made capital	real assets	buildings, vehicles
	infrastructure	electricity, transportation
	financial resources	money, purchasing power
Human capital	mental well-being	satisfaction, stress
	knowledge and competence	experience, formation
	number of persons	participants, children
	physical health	illness, handicaps
Social capital	equal access to services	alimentation, hospitals
	culture	theaters, publications
	institutions	public participation, laws
	professional network	contacts, exchanges
	social network, reliance	societies, meeting places

Table 15 Components and elements of the WinWin22 evaluation tool
Source: own illustration of [KNOEPFEL 06], p.12

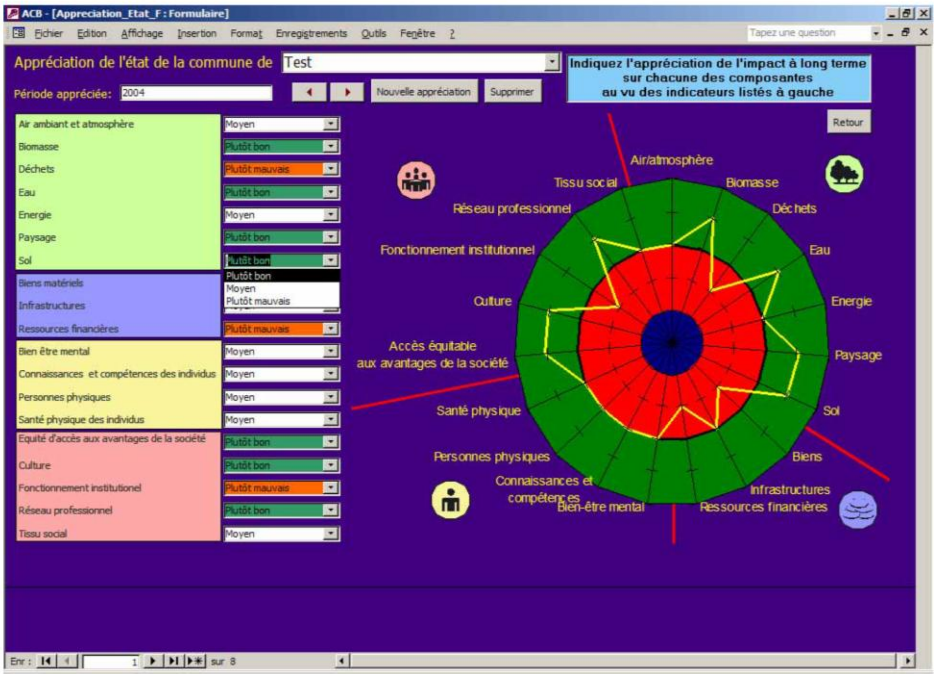

Figure 19 Illustration of the general state of a municipality using the 19 components of the WinWin22 tool
Source: Screenshot of WinWin22, [KNOEPFEL 06], p.34

II2.5 Review and Positioning within the Adaptive Cycle Framework

The snapshot character of indicators offers only a glimpse of an aspect of a bigger picture and therefore they lack knowledge of the broader context. Used at several times, they might measure change but they would miss the targeted objectives, e.g. speedometers can illustrate the

acceleration of a vehicle but not its direction. Another difficulty can arise through unclear definition and quantification.[188]. Differences in definitions might lead to very different qualitative assessment values and inconsistent decisions.
In final reports, different conventions can be misleading or make comparisons impossible.[189]. As long as there are no common guidelines on how to describe comparable environmental performance, each urban indicator system will give results comparable only to itself.
Due to this problem and to the fact that not all information is available for all neighbourhoods, indicator sets do not fit the specific circumstances. By using available sets, it is much easier to get a new set based on the available data. With this a rivalry between accuracy and comparability starts. Each time a new set is developed, it is no longer comparable with other ones. This problem is also not solved in WinWin22 but through the required mutual agreement of the involved stakeholders, the responsibility is explicitly transferred to the participants forcing them to compromise and look for solutions supported by all. In this way, a much more accurate result can be achieved by taking the knowledge of the participants more into account. However, indicator systems like HQE2R and LEnSE are much more comparable. Up to now, indicators have been mainly used to analyse a current situation, but in future they will probably be used for the calibration of systems variables. However, the abovementioned rivalry between accuracy and comparability will still be a key issue. Moreover, indicators also do not exactly locate and distinguish into sources and sinks.
Regardless of this rivalry, the aforementioned indicator sets usually cover all the dimensions of sustainability even if not labelled the same. Culture is not mentioned as a dimension itself in any of the sets. All the indicator sets allow discrete time comparisons between several situations and this can facilitate the creation of indicator sets (Figure 20) that evaluate in which phase an adaptive cycle ∞ is. All the indicator sets can provide good insight into the current level of the potential and, somewhat, the connectedness of an urban fragment (all the indicator sets have at least one or two indicators on participation). By comparing two points in time, tendencies can be taken into account. Only the

[188] Figge illustrates this with indicators for waste. The different definitions (in particular the allocation) of waste looking downstream or looking upstream might differ. The differentiation between by-product, co-product and waste is difficult. Even defined as waste, there is still the difficulty to assess type, e.g. wet waste vs dry waste. Compared only by their weight, dry waste will be considered as better. [FIGGE 06], p.69
[189] It makes a big difference if the potential contribution to global warming is described by an aggregation of all greenhouse gases into one figure of carbon footprint or by separated contributions of each greenhouse gases. While the first is easy to understand and might facilitate comparison, the second gives the opportunity to understand the greenhouse gas amount in detail and the potential for possible interventions for reduction. [BAKKES 94], p.13-17

OECD indicators emphasise tendencies explicitly with their flow indicators. In contrast, the resilience of an urban fragment needs a case-dependent definition to be measureable by indicators due to the very vast character and the complexity of the notion of resilience, i.e. in a transition phase the values for indicators may change quite rapidly (Table 16).

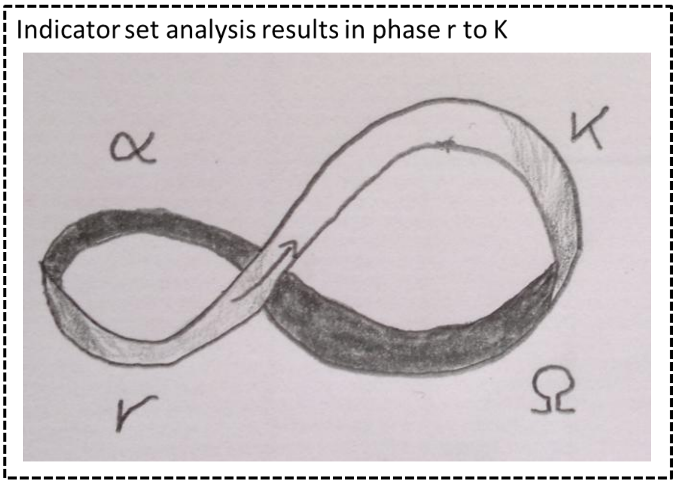

Figure 20 Indicators assess the current state of a system (∞) and estimate the probable current phase, e.g. transition from r to K.

		Resilience	Potential	Connectedness
Ecological	Level	○	●	●
	Tendency		○	○
Cultural	Level	○	○	○
	Tendency			
Social	Level	○	●	●
	Tendency		○	○
Economical	Level	○	●	●
	Tendency		○	○

Table 16 Dimensions of sustainability and adaptive cycles considered by the above indicator based assessments

II3. Special Assessment Methods

The planning, construction, operation and decommissioning of a project do not happen in isolation; they usually take place within a geographical and temporal context that includes existing plans, programmes, policies and other projects. The assessments methods described below aim at the evaluation, as far as possible, of cumulative impacts as opposed to single development projects.

Assessments help to evaluate a project's impact from a specific point of view. Assessments look at different scales (selected based on an analysis of benefits and disadvantages) and help to facilitate reasonably early input into the design process of a project. Below the author describes the different analytical tools developed for making policy decisions affecting the different dimensions of sustainability:

Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) for environmental analysis, Cost-Benefit Analysis (CBA) for economic assessment and Social Compatibility Analysis (SCA) for social assessment. Due to a lack of established cultural assessment methods, several approaches with cultural foci are discussed.

II3.1 Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA)

Environmental Impact Assessments and Strategic Environmental Assessments analyse the multiple short- and long-term direct and indirect impacts of a project and identify risks for possible system changes. EIA is a rather static approach whereas SEA includes a longer timeframe and broader topical frame.

II.3.1.1 Environmental Impact Assessment

Introduction and general approach

Environmental Impact Assessments have been carried out since 1970 and have become a powerful instrument for environmental protection and safety during planning processes all over the world. The experience of using EIAs and their quality have increased, but it is still difficult to evaluate their real effects on long-term decision-making processes.

The aim of an EIA is to ensure that the environmental impacts of a decision are identified and communicated if the result of the decision-making process has a significant impact on the environment.

In the EU, several directives form the legal basis for an EIA.[190]

[190] The preamble to Directive 85/337 mentions that “the effects of a project on the environment must be assessed in order to take account of concerns to protect human health, to contribute by means of a better environment to the quality of life, to ensure maintenance of the diversity of species and to maintain the reproductive capacity of the ecosystem as a basic resource for life” [EU EIA 85]

However, the main objective of an EIA is the protection of human and ecosystem health and not the protection of resources, at least not as an issue to be addressed in its own right[191].

The implementation steps for an EIA are[192]:

1. Screening: to see whether a project is subject to an EIA according to inclusion or exclusion lists (under the EIA directive) or on a case-by-case basis
2. Scoping: comprehensive assessment of the project and possible alternatives to study, and deciding which impacts to focus on. Scoping is regulated in accordance with an EIA amendment from 1997. This step aims at gaining a general overview of the project and focusing intent to a reasonable extent.
3. Writing the terms of reference for the procedure
4. Carrying out necessary environmental studies
5. Making a report on the findings (Environmental Impact Statement, EIS)
6. Publishing the EIS and collecting opinions of the public and the relevant authorities
7. Taking into account the EIS and received opinions before decisions on the project are made.

Application to the Urban Context

For the construction of ordinary buildings, an EIA is not needed. EIAs can be carried out in different urban contexts. No single detailed approach includes a ubiquitously applicable system of choice. The geographical area of study for a project is the most crucial decision in view of achieving an optimal assessment. Decisions taken at different levels can result in different effects. Different levels of EIA can be distinguished[193]: 1. Strategic EIA, 2. Project EIA, and 3. EIA of location choices or spatial organisation.

Strategic EIAs (SEIAs)

The foci of strategic EIAs are the goal or the related policy for reaching it.[194] SEIAs deal not with the realisation of a project but with the evaluation of (long-term) policies and associated decisions.

SEIAs are able to analyse the level and tendency of environmental potential, connectedness and potential due to their focus on the level of the system, but may need additional methods or instruments to do so successfully.

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[191] [TUKKER 00], p.440

[192] compare [COLOMBO 92], p.4; see also[KOHLER 02], p.2

[193] [EU EIA 85]

[194] For instance, the decision to construct a low-emission building or passive house will most probably involve questions on the types of material and energy sources. Obviously, such process alternatives have an influence on the environment. Constructing a passive house often means that fewer emissions are generated through its use. The possible alternatives have an influence at the system level: In the most comprehensive case, most environmental effects would change if a concurring alternative is selected.

Project EIAs

One concern of project EIAs is the production process behind end products or the fulfilment of certain needs.[195] Another concern is abatement alternatives that have no or little direct adverse effects on humans and nature in the direct surroundings of a construction.[196] Even when differences are small at the local scale, alternatives may have adverse overall impacts, especially when the whole system is considered. [197]

Project EIAs focus more on impacts at the level of a system, and less on its tendency. The assessment is mainly on the environmental potential, and less on resilience and connectedness.

EIAs of location choices or spatial organisation

The main concern of EIAs of location choices or spatial organisation is locating an activity. In general, alternatives have mainly local consequences, and are unlikely to influence other interdependencies within a system[198]. An exception would be if the location influences transport distances or overruns a spatially conditioned threshold and so tests the system's stability.[199]

EIAs of location choices help to better understand the level of impact, rather than tendency. The focus on location provides insights into environmental connectedness and based on this, the influence on resilience and potential may be partly assessed.

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195 An example of a project EIA is the search for the best mixture of prevention, reuse and final treatment of the demolition waste of construction. The reuse of materials might reduce the consumption of new raw materials, but could require a higher energy demand. Such secondary impacts can only be taken into account if additional approaches like Life Cycle Analysis are adopted and so a wider range of effects is considered. Some construction processes may have to use raw materials of better quality than others do. In such cases, these effects on the processes of other construction activities have to be considered for a reasonable comparison. Hence, a wider system-related approach seems to be necessary (see for more details [TUKKER 00], p.449.

196 Abatement measures deal with e.g. the reduction of volatile organic compounds emissions to prevent the formation of smog or the reduction of a certain emission (see for more details [TUKKER 00], p.449.

197 For instance, electricity from a nuclear power plant compared to electricity from a coal power plant may produce much more radioactive waste that needs further treatment with other (maybe not-yet-existing) technologies even if on the local level the emissions arising from the use of electricity are the same.

198 [TUKKER 00], p.450

199 For example, if a sports arena is built in a location that blocks winds from blowing fresh air into a city and the city thereby heats up (e.g. concerns regarding the SAP Arena in Mannheim, Germany) [BURST 10], p.51, 52, 105, 108.

II.3.1.2 Strategic Environmental Assessment

Introduction and General Approach

Despite considerable expectations in many countries EIA has until now proved neither to obtain and maintain environmental quality nor to support sustainable development. One of the reasons is the late starting point; the consideration of alternatives is too close to the specific site (strategic and project EIA) or location dependent for the same undertaking (EIA of location choices). Strategic Environmental Assessments aim to overcome such weaknesses[200].

In SEA, the scope of impacts is broader (e.g. cumulative, secondary or indirect effects) than in traditional EIAs. SEA starts before important decisions are taken; alternatives can be considered on policymaking or a project-wide level[201]. SEAs deliver assessments that consider a wider range, inclusive of constraints for decisions which are made in a cascade of incremental steps and which may otherwise be overlooked[202]. Some argue that SEAs can also incorporate less formal decisions and sustainability principles[203] whereas EIAs come quickly to their limits and need information and certainty, which are not available right from the beginning at the first levels of decision-making[204].

SEA is theoretically able to analyse possible environmental effects systematically and to reduce adverse influences. Because EIA is less well integrated into the planning level, it frequently serves as an "ex post facto rationalization for decisions"[205]. SEA on the contrary enables the taking into account of comprehensive and specific considerations of principles related to sustainability already in the planning process. In that way, policies and plans can be assessed in comparison with environmental objectives, targets, green plans and sustainability strategies[206]. Therefore, by further integration of SEA and urban planning, sustainability principles can guide decision-making[207]. Table 17 shows the stages of an SEA.

[200] For review and detailed description see [TAPPESER 99], [THERIVEL 92], [PARTIDARIO 96]
[201] [PARTIDARIO 00], p.651-2
[202] ibidem, p.649
[203] ibidem, p.655
[204] ibidem, p.649
[205] [SHEPHERD 96], p.323
[206] [SADLER 96]
[207] [SHEPHERD 96], p.323

KEY STAGES	NOTES
Plan or Programme Preparation	Draft plan or programme prepared by an authority at national, regional or local level.
Screening	The Member State makes the decision on whether an SEA of the plan or programme is required, the screening decision, including reasons for not requiring an environmental assessment, must be made available to the public (Article 3). Cultural heritage is specifically mentioned in Annex II. Criteria for determining the likely significance of effects referred to in Article 3(5). We need indicators here which will examine potential impacts on cultural heritage.
Preparation of assessment framework (scoping)	The authorities referred to in Article 6(3) shall be consulted when deciding the scope and level of detail of the information which must be included in the Environmental Report (Article 5(4)). In determining the scope of the assessment, the relevant policies, plans and programmes to the plan/programme to be assessed need to be identified (both international and national policies). The key issues and options which need to be resolved by the plan need to be identified, as do the cultural heritage indicators which will be used in the environmental/sustainability assessment process. The public should be involved in this stage and we need to devise appropriate consultation mechanisms.
Environmental Report	The information required is referred to in Annex I of the Directive and specifically includes cultural heritage (Annex I (f)). We could produce a model entry for such a report here to illustrate what should be covered. The Report will detail the results of applying the assessment framework to the plan/programme and will consider the significant effects of implementing it in its current form.
	Note that these two stages are likely to be repeated in a cyclical way. The Environmental Report should lead to changes in the Plan/Programme, requiring further assessment. This loop will be exited in practice once the assessment has improved the Plan/Programme to an acceptable level.
Consultation with Designated Authorities and the Public	Article 6 lays down the provisions for consultation with designated authorities (paragraph 3) and members of the public (paragraph 4). Opportunity to express opinion on both the draft plan or programme and the environmental report are required. Article 7 refers to consultations with other member states affected. Our role here is to indicate how best to carry out consultations related to cultural heritage.
Review of Adequacy of the Environmental Information	Article 12(2) of the Directive requires that Member States report back to the European Commission on measures taken to ensure the Environmental Reports are of sufficient quality. We therefore need to develop an Environmental Report review framework with respect to cultural heritage. This may be combined with the previous step?
Decision Making	The Environmental Report (Article 5), opinions expressed in consultations (Article 6) and the results of transboundary consultations (Article 7) shall all be taken into account during the preparation of the plan or programme and prior to its adoption or submission to the legislative process (Article 8)
Announcement of Decision	Article 9 of the Directive states that, Member States shall ensure that, when a plan or programme is adopted the authorities consulted under Article 6(3), the public and any Member States consulted under Article 7 are informed. The items to be made available are: the plan or programme as adopted; a statement summarising the rationale behind the decision including consultations, alternatives and environmental considerations; and the measures concerning monitoring.
Monitoring	Member States shall monitor the significant environmental effects of the implementation of plans and programmes in order, *inter alia*, to identify at an early stage unforeseen adverse effects, and to be able to undertake appropriate remedial action (Article 10 (1)). We need to be able to suggest monitoring frameworks which will allow effects on cultural heritage to be checked and referenced against the predictions made in the Environmental Report.
The highlighted steps must be followed in all Member States under Directive 2001/42/EC.	

Table 17 Key stages of a SEA
Source: [BOND 03], p.10-11

Application to the Urban Context

SEA enables the early stages of decision making to address the roots (e.g. the development of plans and policies) rather than the "symptoms of environmental deterioration"[208]. The term environment is considered in a very broad sense including social as well as biophysical aspects. SEA facilitates a more timely proactive steering towards sustainable development than the more reactive project-level EIA does. The variety of considered alternatives is greater, e.g. instead of creating an electric power plant an option could be to encourage energy conservation with the help of financial incentives.[209]

EIAs for individual projects do not necessarily recognise the impacts of development on wider spatial and temporal scales. SEAs allow the monitoring of cumulative impacts[210], which have been defined as the "result of additive and aggregative actions producing impacts that accumulate incrementally or synergistically over time and space"[211].

Monitoring links the short-term project goals and the long-term sustainability development goals of a city. SEAs help to configure monitoring programs in consideration of sustainability principles in three ways[212]:

1. Monitoring can control for whether mitigation measures were effectively implemented and can provide warning signals for unanticipated and critical threshold impacts. This helps to refine current mitigation measures, or to implement new mitigation measures prior to unacceptable impacts.
2. Actual effects can be compared to the predicted ones to adjust forecasting capabilities.
3. Monitoring helps to improve results of projects using adaptive environmental management; this copes with uncertainties via the continuous modification of management practices.

SEAs come in a great variety of forms, whereby the general aim and underlying principles are still the same. This wide range of forms comes from the different policy-making, policy-planning and policy needs at national and institutional levels.[213]

The goal of a unified SEA approach would need great imagination and flexibility[214] to achieve and is considered unpractical and unhelpful. Much more the opposite seems adequate. Due to the large mix of forces, different social values and uncertainty, great adaptiveness is demanded of SEA. Especially when considering that there are often many different

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[208] [SADLER 96] in [SHEPHERD 96], p.323-324
[209] [SHEPHERD 96], p.324
[210] ibidem, p.324
[211] [CONTANT 93], p.341 in [SHEPHERD 96], p.324
[212] [SHEPHERD 96], p.324, 325, see for more detail [CARPENTER 96] and [HOLLING 78]
[213] [PARTIDARIO 00], p.650
[214] [KORNOV 98]

ways to achieve the recognised objectives and various forms and contexts for decision-making. With the multiple forms of SEA, Partidario suggests referring to SEAs as a family of tools.[215]

Figure 21 maps the different forms of EIA and SEA. Expectations grow with the width of decision-making levels. In this sense, SEA can be a sensible instrument to interlink environmental assessment approaches.

After reviewing case studies from four countries, which "demonstrate the potential of SEA to contribute to sustainable urban development" [216], Shepherd concludes that SEA can integrate sustainability principles into urban planning. SEA is not seen as an end in itself but more "a facilitator"[217]. SEA helps to check systematically at each decision-making step what the causes and effects at subsequent stages of development are and to find ways to avoid negative impacts by following and keeping open different strategic options.

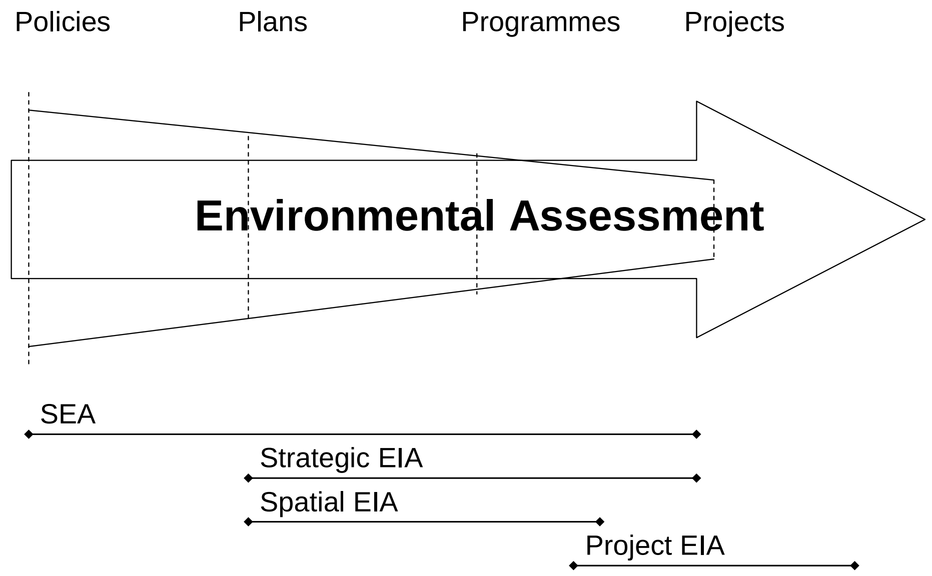

Figure 21: SEA and EIA in relation to sequential decision-making levels
Source: own illustration adapted from [PARTIDARIO 00], p.656

II3.2 Review and Positioning within the Adaptive Cycle Framework

EIA and SEA show that there are several phases that have to be considered individually. SEA is concerned with most of the decision-making stages whereas EIA deals more with their impacts. However, for the comparison of alternatives with long-running and continuous impact, further in-depth or complementary assessment tools, e.g. LCA, are needed for evaluation.

[215] [PARTIDARIO 00], p.655
[216] [SHEPHERD 96], p.333
[217] [PARTIDARIO 00], p. 658

Moreover, Morris suggests beside other tools[218]:

- Connection of the data with geographical information systems
- Use of more available information, databases, legislation documents (Internet etc.)
- Higher consideration of environmental enhancement and not only mitigation of negative impacts.

In relation to urban fragments, a project-EIA can help to understand the impact of smaller projects. The strategic EIA and SEA also account for effects external to the considered urban fragment. Applied to the adaptive cycle concept, EIA and SEA assist to assess impacts or bigger undertakings (Ω) in established systems. The spatial scope of EIA (apart from EIA for location choice) is rather limited to one project or a group of projects, from the local to the regional. The temporal aspects of EIA are aggregated into the overall impact and not on the development over a whole life or adaptive cycle (project and location choice EIA). EIA as well as SEA may be used in an r phase when the foundation for future development is considered. Usually, they are used in K phases, where the system change is often rather large considering all circumstances of a mature system.

Both the Strategic EIA and SEA evaluate ecological potential and connectedness. SEA can be used for the examination of whether ecological resilience is overstressed, whereas EIAs might overlook such thresholds. The SEA and Strategic EIA look at the long term and tendency considerations related to ecological potential more comprehensively than the other types of EIA. With the broader scope, a SEA seems to be more helpful to understand whether an impact brings a system into a new adaptive cycle with changed potential and connectedness or leaves it within the current running system. Due to its scope, the SEA also accounts for some social potential (Table 18).

Both the EIA and SEA may capable of more sophisticated assessment if combined with other methods and instruments.

		Resilience	Potential	Connectedness
Ecological	Level	○	●	●
	Tendency		○	
Cultural	Level			
	Tendency			
Social	Level		○	
	Tendency			
Economical	Level			
	Tendency			

Table 18 Dimensions of sustainability and adaptive cycles considered by Environmental Impact Assessment and Strategic Environmental Assessment

[218] [MORRIS 01], p.10

II3.3 Cultural Impact Assessment

Introduction and General Approach

The built environment constitutes an immense component of the image or representation of an urban area. Therefore any intervention is a sensitive issue. The image of an urban fragment can be manifold, for example perceptions of it may totally differ between one held by current inhabitants with the one held by former inhabitants who have not experienced change due to their absence. Cultural Value Assessment considers such possible perception shifts with regards to entire building stocks and their development, a topic which has been neglected since the beginning of the 20th century[219]. Changes in the built environment are twofold: besides material alterations, interpretations held by society may change[220]. These two ways of change are also interdependent; material change can result in cultural adaptation, i.e. result in changes in the patterns of behaviour of urban citizens.

Cultural value assessment is still not an established method. In this work, cultural value stands for the combination of attributes[221]: aesthetic, spiritual, historical, symbolic and authenticity value. Cultural value is a concept that considers culture a resource or capital. Bourdieu developed the notion of cultural capital within his educational research and it is based, according to Lareau, on two premises: knowledge of aesthetic culture and its separation from skills, ability and personal achievement.[222] Lareau proposes a definition of culture going beyond aesthetics comprising the different social milieus[223] and viewing the interaction of skills, abilities and achievements with "institutionalised standards of evaluation"[224] as part of cultural capital[225].

The multiple attributes of cultural capital complicates its evaluation. Without non-economic assessments, such impacts are dematerialised and are only characterised by their price.[226] A hypothetical example by eftec illustrates this difficulty for the evaluation of a monument.[227] A monument that nobody really likes would have an aesthetic and spiritual value of zero. Spending any effort on it seems useless. Nevertheless, some experts, who studied it, value its historical importance as

[219] [HASSLER 09], p.557
[220] ibidem, p.557
[221] [EFTEC 05]
[222] [LAREAU 03], p.568
[223] ibidem, p.579
[224] ibidem, p.597
[225] ibidem, p.582
[226] "The implementation of these networks also generated a social and cultural process of adaptation. Infrastructure development led to fundamental changes in behavioral patterns of urban residents […]. It favored the growth of resources use and caused a complete dematerialization of resources use, from which the only sensitive issue remaining is the price" [AGUDELO 11], p.2299; see for more detail [SCHOTT 04], p.522, 525
[227] [EFTEC 05]

extraordinarily high and recommend conserving it. The majority logic argues against conservation. Following the expert logic to conserve the monument favours the opinion of a few with knowledge. To make these two points of view come closer to each other, knowledge transfer is necessary if a few must not dictate their position. Insights provided by this example demonstrate reasons for continuous and future education on heritage but they do not solve the current practical problem of cultural evaluation.

For the assessment of culture, there is no general approach. Papers on cultural assessment very often deal with cross-cultural issues, especially in the health care sector or organisational management.[228] Below, this paper will briefly examine approaches or considerations that have linkages to cultural assessment: Heritage Impact Assessment, Contingent Valuation of Cultural Goods, Core Task Modelling, Bias by Culture and Ethical Decision-Making. All have rather different subjects (heritage, cultural goods in general, company evaluation culture, moral problems and scientific institutions) but aim to improve the objectives of their subjects.

Moffat, Hassler and Kohler propose a very different approach[229] to the incorporation of culture into available evaluation methodologies. They argue for the prolongation of the time horizon. With this extension, the importance of cultural capital becomes more evident and its evaluation more comparable considering necessarily historical interlinkages. For the immediate incorporation of the prolonged time horizon into economic practice, Hassler proposes “regulation of the prices for land use, an institutional relinquishment of high rates of return from real estate uses” and “corresponding incentive systems”[230].

Application to the Urban Context and Variations

Heritage Impact Assessment[231] is based on Environmental Impact Assessments. The first step is to create an inventory and the second, to assess impact severity via indicators.[232] The approach is applicable broadly to urban fragments but the evaluation remains fuzzy, as it does for EIAs, due to the difficulty to weigh the importance of the inventory and the indicators.

In contrast, the Contingent Valuation of Cultural Goods[233] consolidates cultural capital into one unit: money. It measures the nonmarket demand for cultural goods and services. The overall aim is to receive an

[228] Google Scholar Search: “cultural assessment” - 7400 results; “cultural assessment” & organisations – 4840 results; “cultural assessment” “management” – 3900 results; “cultural assessment” & "health care" – 2760 results; “cultural assessment” & “city planning” – 26 results; both “cultural assessment” & “urban development” and ”cultural assessment” ”built environment” – 71 results

[229] [MOFFAT 06], [KOHLER 03a], [KOHLER 02b]

[230] [HASSLER 09], p.562

[231] [GAIGHER 10], p.7

[232] ibidem, p.16-26

[233] [THROSBY 03]

economic value for cultural commodities when combined with valuations from market processes. Throsby shows that there are aspects of cultural goods that are considered only partially or not at all and so can provide an insufficient view. The application of this approach to urban fragments requires an atomisation of values of each urban entity, which is rather impractical but supports research on the complexity of urban fragments.

Core Task Modelling[234] analyses the culture of departments or companies. It investigates the organisation, its tasks, its goals and its prevailing values. An urban fragments, understood as a corporate department, represents and contains it own culture. Core Task Modelling facilitates the identification of the main characteristics of an urban fragment and setting them into relation with other forms of cultural capital.

The notion of ‘bias by culture’[235] assumes that bias in cultural assessments is unavoidable and that it is even predictable, especially when the assessors are part of their subject culture, itself a complex system. This approach is not an evaluation methodology, but it helps to relativise the possible bias by experts as well as by public opinion concerning the cultural capital of an urban fragment.

The Ethical Decision-Making[236] procedure developed by Bleisch helps to deal with morally relevant decisions. The procedure takes five steps: analysis of the as-is state, morally relevant questions, analysis of arguments, evaluation and decision, and implementation of solutions. Cultural evaluations of urban fragments are ethical decisions in the broad sense. This approach clarifies not only the effects of changes but also aims to identify the current cultural conceptions of an urban fragment prior to decision making.

II3.4 Review and Positioning within the Adaptive Cycle Approach

The above-presented approaches deal with the multiple attributes of cultural capital with different foci. Heritage Impact Assessment provides an overview of all cultural capital. Adaptations of it might help to consider cultural historical contexts of the building stock in detail as aimed for by deliberations for the World Heritage List[237]. Heritage Impact Assessment can help to understand the cultural potential of the built environment within an urban fragment. The approach does not seem developed enough to give estimations on cultural connectedness, resilience or tendency. Contingent Valuation of Cultural Goods and Core Task Modelling concentrate on the aggregation of value

[234] [OEDEWALD 03]
[235] [THOMPSON 97]
[236] [BLEISCH 11]
[237] [HASSLER 09], p.559

representants; the first by consolidating into one external value (money) and the latter by identifying a few internal value representants. The Contingent Valuation of Cultural Goods can help to monetise cultural goods (potential) and their attributes (potential and connectedness) within an urban fragment. It cannot consider resilience and tendencies in any cultural dimension. Core Task Modelling can help to discover the incorporated culture of an urban fragment. This could be used for the evaluation of cultural potential, connectedness and resilience at a certain time (level) as well as in the future (tendency). However, there is no known application to urban fragments yet. Overall, the presented cultural value assessment approaches consider all dimensions of adaptive cycles with regard to cultural capital. All start at the level of cultural potential, so this dimension is covered most deeply (Table 19).

		Resilience	Potential	Connectedness
Ecological	Level			
	Tendency			
Cultural	Level	○	●	○
	Tendency	○	○	○
Social	Level			
	Tendency			
Economical	Level			
	Tendency			

Table 19 Dimensions of sustainability and the adaptive cycle considered by Cultural Impact Assessments

Bias by culture is neither a real method nor an instrument but rather it reminds us that even scientific assessment is based on culture and so is biased by an individual's or group's background. It can be helpful to identify situations in which cultural opinions are embedded. The approach assumes that this bias is predictable. This insight would help to uncover possible biases within the development opportunities of an urban fragment and to avoid them. The Ethical Decision-Making procedure is more precise than the other approaches and aims at a comprehensive understanding of the context of a decision. It helps to concentrate fully on moral issues, which comprise ecological, cultural as well as social topics. This approach allows complete emphasis on non-economic issues within an urban fragment. It is dependent on the knowledge of its users but it can evaluate all dimensions, except the economic, without economic bias. Bias by culture and the Ethical Decision-Making procedure are not included in Table 19 due to the former's self-conception and the latter's possibly larger scope.

II3.5 Social Compatibility Analysis

Introduction and General Approach

The field of measuring social impacts is rather young. With the Rio conference in 1992, social impacts were 'officially' accepted as the third dimension of sustainability for the first time. There are studies that dealt with social impacts before[238], but they were controversial[239]. A large number of social impact measurement methods have been developed since then.

Social impacts usually do not have a market value and need to be incorporated into decisions by additional methods. So there are also several definitions and terms, which slightly do not mean the same, such as ‘impact’, ‘social impact’, ‘social value creation’, ‘social return’[240], ‘social compatibility’[241].

Current methods do not have a common sequence of actions and differ in the audience, reason, object and means of measurement.[242]

Application to the Urban Context

Maas proposes a preliminary list for social impact assessments[243]:

- Millennium Development Goal scan (MDG-scan)
- Poverty Social Impact Assessment (PSIA)
- Social Impact Assessment (SIA)
- Stakeholder Value Added (SVA)
- Social Return on Investment (SROI)
- Social Return on Assessment (SRA)
- Ongoing Assessment of Social Impacts (OASIS)
- Social Costs-Benefit Analysis (SCBA)
- Balanced Scorecard (BSc)
- Atkinson Compass Assessment for Investors (ACAFI)
- Local Economic Multiplier (LEM)
- Best Available Charitable Option (BACO)
- Triple Bottom-Line Accounting (TBL)
- Measuring Impact Framework (MIF)
- BoP Impact Assessment Framework
- Social Compatibility Analysis (SCA)[244]

Due to the differences between the methods, Maas proposes to categorise them according to six characteristics[245]:

1. User: profit or non-profit
2. Focus: ex-post or ex-ante
3. Orientation: input or output
4. Perspective: micro (individual/employee) or meso (company) or macro (society)
5. Approach: process methods or impact methods or monetisation
6. Purposes: screening or monitoring or reporting or evaluation.

The search for further methods and the development of a guideline for these characteristics is ongoing research.[246]

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[238] [RENN 85]
[239] [MEIER 88] and [LEITSTRITZ 86] in [JOOS 99], p.423
[240] [MAAS 08], p.75
[241] [JOOS 99], p.423
[242] [MAAS 08], p.76
[243] ibidem, p.76
[244] [JOOS 99], p.424 and [WINISTÖRFER 99]
[245] [MAAS 08], p.77
[246] ibidem, p.78

The social impact assessment tool 'Social Compatibility Analysis'[247] is comparable to the Environmental Impact Assessment and is based on a set of 16 objective criteria[248]:

1. Participation
2. Information and Communication, Transparency
3. Restriction of decision parameters
4. Compliance with social laws
5. Occupation
6. Education and training
7. Income distribution
8. Living/working conditions in developing regions
9. Discrimination
10. Protection of minorities
11. Law and order/crime
12. Health hazards
13. Nuisance
14. Encroachment into living space
15. Risks for the population
16. Winner-loser symmetry

When applied to a project, the relevant criteria are separated into three classes: A. highly relevant social problems, B. medium relevance, C. low relevance. The choice of the classes A and B for a criterion is explained.[249] A one-off use of this evaluation tool stays rather subjective but with more involvement from stakeholders, it can illustrate a consensus. Still the assignment of a criterion to class A, B or C is dependent on the user(s) of the tool. Applied to a project at several points in time when the similarities and differences are clearly defined, a certain level of comparability can be achieved. This might be possible also for comparing different projects but this requires enough similarities and good project descriptions.[250]

II3.6 Review and Positioning within the Adaptive Cycle Framework

Social impact assessments have resulted in multifold methods. These methods are not compatible and need a multifaceted categorisation scheme, suggesting that the sources of controversy in the 1980s are not overcome (yet).

Social Compatibility Analysis, as one example, is assigned to cover all topics of the social dimension but is strongly dependent on the user's knowledge and interest. Especially if used for urban fragments, detailed knowledge is of importance to understand the complex social relationships within and outside the fragment.

[247] [JOOS 99], p.424
[248] [WINISTÖRFER 99], p.3
[249] ibidem, p.4, 5
[250] ibidem, p.5, 6

SCA concentrates on the potential for the social dimension (Table 20) and partly asks for information that is relevant to social connectedness (e.g. participation, discrimination) and resilience (e.g. health hazards, risks for the population). Within the textual description for each evaluation, with a large amount of effort, all successive dimensions have to be considered; here lays also a possibility to incorporate temporal aspects (tendencies).

		Resilience	Potential	Connectedness
Ecological	Level			
	Tendency			
Cultural	Level			
	Tendency			
Social	Level	○	●	○
	Tendency			
Economical	Level			
	Tendency			

Table 20 Dimensions of sustainability and adaptive cycles considered by Social Compatibility Analysis

II3.7 Cost-Benefit Analysis

Introduction and General Approach

The earliest uses of Cost-Benefit Analysis (CBA) were made in 1808 by Albert Gallatin, who recommended comparing the costs and benefits of water-related projects[251], and in 1844 by Jules Dupuit, who wanted to analyse the cost and benefits of a bridge construction.[252]. Until the 1950s the main focus remained on water resource management and the interdependencies of river systems. In the 1960s, other public goods came into interest, e.g. wildlife, human health and aesthetics. For the measurement of intangible benefits, additional techniques arose, e.g. travel cost method, contingent valuation, hedonics. In the 1970s and 1980s, the consideration of non-use values started.[253] Today, there is a vast literature on CBA applications for a multitude of issues. They differ from each other in many aspects, so in the following the main stages[254] are introduced:

1. Definition of Project
   A project definition comprises the proposed new allocation of resources and the consideration of the beneficiaries and losers in the population. The first part of the definition aims to clarify the limits of analysis and the second is necessary when a project affects different levels, e.g. regional as well as supranational.

[251] [HANLEY 93], p.4
[252] [DUPUIT 44] in[JOHANSSON 93], p.1
[253] [HANLEY 93], p.6; see also [PEARCE 06b], p.52-62
[254] These stages are a summary of [HANLEY 93], p.8-20

2. Identification of Project Impacts
   A list of project impacts encompasses needed resources, changes in employment, traffic and prices, and non-priced alterations. Further, the impacts are to be examined for their net benefit (additionality), i.e. parallel - but not project-related - changes must not be taken into account. Another concept to consider is displacement; this can happen if a project makes another enterprise or institution partly or totally obsolete.

3. Which Impacts are Economically Relevant?
   A project's impacts are assessed by their utility and so divided into benefits (positive utility) and costs (negative utility). Utility must only be recordable but does not have to be priced or need a market. Impacts without prices are called externalities[255]. They can be positive or negative.

4. Physical Quantification of Relevant Impacts
   In this step, the physical amounts of flows and their temporal occurrences are calculated. Often estimations will serve as a basis for bringing in probability and uncertainty into the quantification. For environmental or social impacts, additional analyses (e.g. Environmental Impact Analysis or Social Compatibility Analysis) play an important role.

5. Monetary Valuation of Relevant Effects
   For the comparison of the positive and negative effects, a common valuation unit is needed, which is almost always money. If prices are not available or biased, they have to be predicted (i.e. future prices), corrected or estimated. For the comparison of real monetary values, discounting considering price indices and inflation is needed to adjust the nominal figures. The correction or estimation of prices is necessary if there is imperfect competition, government intervention or no market. Techniques have been developed to find missing prices, like contingent valuation, travel cost method, hedonic pricing and others. Such techniques have helped to price, for example, the benefits of preservation which before had been "confined to sentiments and emotions existing only in the woolly heads of environmentalists."[256]

6. Discounting of Cost and Benefit Flows
   In this step, the monetary amounts are converted into present-day values. This concept illustrates or embeds the preference to value a benefit higher the earlier it can be achieved. This is done using interest rates and discounting.

[255] Externalities have already been a topic in the works of [SIDGWICK 83]; [MARSHALL 90]; [PIGOU 20], see [PEARCE 06b] for more, p.31
[256] [RANDALL 86], p. 193 in [HANLEY 93], p.15

7. Applying the Net Present Value Test[257]
   In this step, discounted benefits and losses are summed. Calculation methods used are the net present value, the benefit-cost ratio and internal rate of return. In the first, the difference of subtracting the calculated losses from the calculated benefits must be bigger than zero. In the second, the quotient of calculated benefits divided by calculated losses must be bigger than unity. In the third, the discount rate is calculated if the net present value would be zero and then compared with the interest rate available on the market. The last calculation is rarely practiced due to its narrowness, e.g. it does not account for timeframes or absolute monetary amounts. As an option, the calculated benefits and costs may be weighted if one outcome is valued differently by the various affected groups. This variation is interesting for CBAs if income redistribution is considered and so undertaken by governments often.

8. Sensitivity Analysis
   Uncertainty in the basic data influences the reliability of outcomes. Changes of the basic parameter assumptions (discount rate, physical quantities and qualities of inputs, outputs, prices and lifespans) may have great impact on the calculated results. A sensitivity analysis helps to find the parameters that influence outcomes most radically.

Application to the Urban Context
The application of CBA to urban contexts began in the 1960s and has been controversial.[258] The identifying, enumerating and monetising of intangibles in urban areas, where many social, cultural and environmental impacts are affected, are problematic due to the incompatibility of monetary and non-monetary units. In recent decades, a vast amount of literature has been generated. There are repeated applications of the well-delineated version of CBA described above but also other procedures and approaches exist, which do not follow the same steps and still may be understood as legitimate CBAs.[259] For the comparison of alternative town plans a variety of CBA-based techniques have been created. Lichfield developed the ‘planning balance sheet’, a variation of CBA, acknowledging the problems while attempting to monetize intangible effects. In this approach, transactions between producers and consumers of impacts are listed allowing the reader to consider the distributional impacts of the alternatives[260]. Further developments resulted in the ‘community impact evaluation’ also integrating EIA.[261]

257 [HANLEY 92], p.39, 48, 49
258 [MORISUGI 94], p.462
259 [SEN 00], p.933
260 [LICHFIELD 65], p.131
261 [LICHFIELD 96]

Another example is the benefit incidence matrix approach from Morisugi that defines a set of assumptions about the real world and so enables the calculation of intangibles.[262] One assumption is that the society aims toward long-run equilibrium. This assumption shows that the results can differ quite a lot considering real-life application when short-term interests overweigh. In that sense, the result can be interpreted as one solution/evaluation of the benefits but not the only right one.

Both approaches adapt the CBA to the current aim of their study by formulating assumptions. From a practical point of view, this is necessary but from the theoretical point of view, there is also an ongoing interest to establish a general valid monetary valuation technique for intangibles. For the better discrimination of intangibles, a classification of values helps[263]:

[262] [MORISUGI 94]
[263] [NIJKAMP 02] in [DEAKIN 07], p.146-147

Use values

Direct use value: consumption good or production factor

Indirect use value: affecting consumption goods or affecting production factors positively by a good's existence

Non-use values[264]

Option values: possible use in the future

Quasi-option value: possible importance of a good in the future

Existence value[265]: philanthropic value (current) or bequest value (future)

To assess these values there are several approaches[266]:

Valuation approaches (behavioural)[267]

Surrogate markets:

Hedonic techniques

Travel cost method

Household production functions

Hypothetical markets

Contingent valuation

Conjoint analysis

Short-cut approaches (non-behavioural)

Damage costs

Costs of illness

Prevention costs: hypothetical defensive, abatement or repair programmes

Actual defensive abatement or repair programmes

II3.8 Review and Positioning within the Adaptive Cycle Framework

The tools introduced help to value goods that are not traded in the market. They also have specific limitations[268]: 1. uncertainty of information due to information not being generally known[269]; 2. uncertainty of information due to individual or institutional lack of

[264] The irreversibility of projects makes it necessary to value not yet known aspects of an area or a system [HANLEY 92], p.50, 51

[265] Often the origin of this value is related to Krutilla: "There are many persons who obtain satisfaction from mere knowledge that part of wilderness North America remains even though they would be appalled by the prospect of being exposed to it." [KRUTILLA 67], p.781 in [ROSENTHAL 92], p.1 (see also for methods and problems of this approach)

Rosenthal argues for the abolition of existence values in CBA due to the danger that existence value claims could arise and just become a "reflection of personal values and preferences" and CBA could lose its objective economic determination. Something economists have aimed to exclude for a long time. [ROSENTHAL 92], p.121

[266] [HANLEY 92], p.34-36 or [VERHOEF 96] in [DEAKIN 07], p.147

[267] The behavioural approaches are also referred to as Willingness-To-Pay or Willingness-To-Accept a decrease.

[268] For an overview see [DEAKIN 07], p. 147-148

[269] E.g. cumulative effects producing an increase in ecological instability are difficult to integrate into CBA and so the costs are underestimated. [PEARCE 76]

information gathering[270]; 3. partiality of valuation methods due to concentration on single aspects[271]; 4. method inaccuracy (methods applied to the same case result in different valuations, e.g. Willingness-To-Pay - WTP - for the saving of a situation differs from the Willingness-To-Accept a decrease)[272]; 5. CBA is indifferent to intergenerational (e.g. income distributions) and inter-temporal equity[273].

Even if reducible to one assessment criterion, the question of marginal utility still remains (i.e. that one monetary unit has different values for poor and rich people). Moreover, distributional effects are ignored and only the overall change in the welfare of a society is estimated. Furthermore, the well-established discounting method forces a fast erosion of future costs and benefits. The discounting rate has a significant influence on the assessment of capital for coming generations. [274]

		Resilience	Potential	Connectedness
Ecological	Level		○	
	Tendency		○	
Cultural	Level			
	Tendency			
Social	Level		○	
	Tendency		○	
Economical	Level	○	●	
	Tendency		○	

Table 21 Dimensions of sustainability and adaptive cycles considered by Cost-Benefit Analysis

CBA can take into account the costs and monetised benefits of economic, social and ecological potential in a rather static view. It is dependent on methods for the evaluation of ecological (e.g. EIA) and social aspects but also on methods to monetise the evaluated potentials (Table 21). The timeframe can be set broad so future costs and benefits may be taken into account, with option- and quasi-option values and also ecological and social issues considered. Nevertheless, difficulties with discounting and not considering cumulative effects have not yet been solved. There are also approaches to value cultural aspects but it is still ongoing research.[275] There are no evaluation techniques to measure connectedness in itself. The question can be raised and then incorporated by other techniques (e.g. WTP) but is not yet part of the

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270 [HANLEY 92], p.52, 53
271 [ACKERMAN 02], p.1576-1578 and [HANLEY 92], p.51-52
272 [ACKERMAN 02], p.1563-1570 and [HANLEY 92], p.37
273 [ACKERMAN 02], p.1573-1576 and [HANLEY 92], p.44
274 ”the use of discounting improperly trivializes future harms and the irreversibility of some environmental problems“[ACKERMAN 02], p.1570, 1571
275 [THROSBY 01]

known literature. This is a similar situation with resilience, where in cases of risk reduction and mitigation measures, financial data may be available and so easier to handle. Approaches like the benefit incidence matrix try also to incorporate resilience aspects aiming at long-run equilibriums but mainly for the economic perspective.[276]
The spatial setting of a CBA is of importance, i.e. in order to take into account beneficiaries and losers further away. Even if it is desirable that all CBAs have a global perspective[277], Vreeker doubts its viability in practice[278]. Due to the spatially flexible definition of urban fragments, such a global perspective seems to be nevertheless necessary.

II3.9 Positioning Assessment Methods within the Adaptive Cycle Framework

Many assessment methods do consider location as part of an urban unit's attributes but do not differentiate the variety of uses. As an example, demolition/new construction with the same use would be judged as parts of an urban fragment's life cycles for keeping up stability and continuance of one use and would not be seen as a change. From a social point of view, this might be perhaps partly valid, if the same persons as before can stay in the buildings. From the cultural point of view, a demolition can only be assessed as a cultural loss.

The analysis above shows that many approaches are aware of such shortcomings and try to integrate methods and instruments from other disciplines, e.g. EIAs with LCA or CBA with SEAs. Whereas the methods for ecological and economic assessments have a long history and are well established, social impact analyses are still emerging. Various approaches remain barely hierarchical to each other. The term 'cultural assessment' may subsume several approaches, but it is not yet an established practice. The combination of assessment methods of one to refine the results of another helps to obtain new insights. Integrated Assessments[279] go one-step further and start with a more deep system analysis to gain a more holistic view. The complexity of urban fragments makes such an approach necessary. The different development stages assessment types are in currently, represents also the budding situation of integrated assessments.
The assessments of sustainability dimensions, integrated or not, within the adaptive cycle concept helps usually to analyse a situation in which a bigger impact is expected. Such assessments are often in a K phase and question on each dimension of sustainability whether the undertaking (Ω phase) will result in another adaptive cycle or restart the

[276] See [ELLINGHAM 06] for a long-term application of CBA
[277] [NIJKAMP 02]
[278] [DEAKIN 07], p.149
[279] [ROTMANS 99]

current cycle. The parallel use of the assessment methods supports influences by interlinkages between the sustainability dimensions. The result of the assessments also provides information on the character of possibly new adaptive cycles. Assessments may be possible in r phases but seem not to be very feasible due to the higher complexity of the situation owing to the large amount of opportunities.

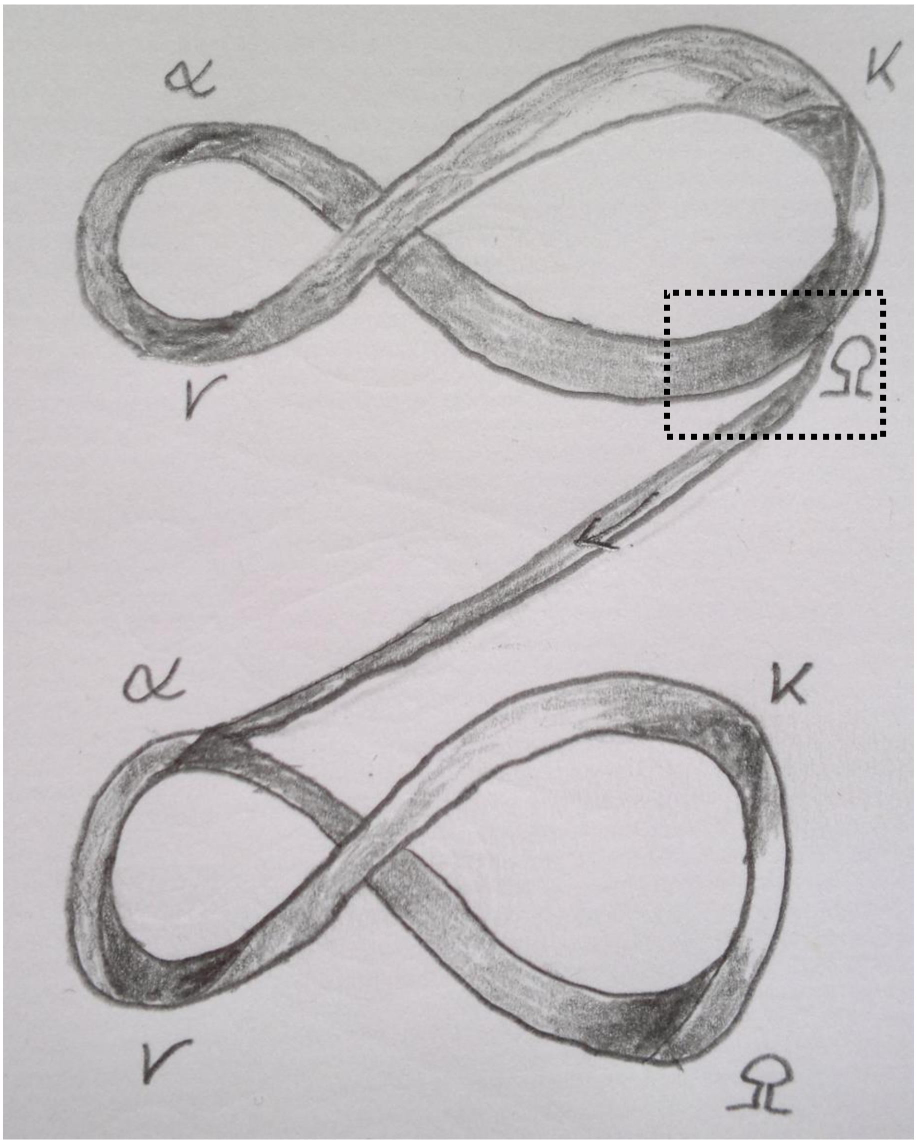

Figure 22 Positioning of Assessment Methods within the Adaptive Cycle Framework
Assessments like Environmental Impact Assessment, Strategic Environmental Assessment, Cost-Benefit Analysis, Social Compatibility Analysis and cultural impact assessments are able to estimate, from their respective points of view, whether an assessed project will cause a system to shift (to another adaptive cycle) or to stay in the basic cycle (dotted box).

II4. Methods for Urban Metabolism Analysis

Introduction

Within the last 100 years, the human population has increased fourfold, while the amount of material and energy use is ten times bigger. These challenges are dealt with by reducing the resource use within industrial metabolism, which can be at the level of the national economy or a product.[280]

To understand the metabolism of a socio-economic system requires the input of several disciplines. The use of theories and methodologies from social and natural sciences results in an interdisciplinary approach that addresses the existence of different concepts for similar issues and of uncertainties and missing knowledge at its beginning. Fischer distinguishes the following phases in the development of the paradigm of socio-economic metabolism[281]:

- First phase: in the late 1860s, mostly connected with a 'positivist' evolutionary worldview. At this time, also a high level of integration of natural sciences, physics, ecology, biology and economy was targeted[282].
- Second phase: still based on the first phase, some critical overtones arise in the interval between the First World War and the mid-1950s; especially the use of the term metabolism for ecosystems was and is still questioned regarding its legitimacy.[283] Besides researchers like F. E. Clements and A. Lotka[284], there were also landscape architects like Leberecht Migge, who planned settlements of social housing for workers[285]. His work is a formulation and implementation of the principles of urban metabolism.
- Third phase: in the late 1960s, long-term, resource-oriented models start to question seriously the one sided optimistic technical worldview, and environmental concerns become dominant. At this time, system theory is developed based on ecological modelling[286] like Odum's work on ecological development[287].

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280 [WEISZ 10], p.1

281 [FISCHER 03], p.36-37; for energy flows during the agrarian-industrial transition in UK, 1800-2000, see [MUSEL 09]

282 [MOFFAT 08], p.251

283 [FISCHER 03], p.37

284 [CLEMENTS 16], [LOTKA 25]

285 [MOFFAT 08], p.252; His calculations comprised garden sizes sufficient for inhabitants for the cultivation of food but also for "complete recycling of materials through the composting of organic waste and the production of biosolid fertilizer from sewage – a balanced socio-ecological metabolism for organics"; see also [HANEY 05]

286 [MOFFAT 08], p.252

287 [ODUM 69]

- Then came a phase of stagnation over two decades, in which a holistic view of size and growth of "industrial metabolism receded behind the predominance of pollution and toxicity"[288].
- Subsequently in the 1990s, research on industrial metabolism, relating the functioning of society and its economy to its consequences for the environment, expanded. With more than half of the world population living in urban areas as of 2008, urban metabolism will continue to attract the attention of researchers, international organisations and governments.[289]

Application to the Urban Context and Variations

Urban metabolism[290], similar to industrial metabolism, can be considered as the total flow of materials, energy and information into and out of an urban system aiming at the generation of goods and services (physical output) as well as the increase in human well-being (non-material or social output). Analysis of urban metabolism captures inputs, outputs and material recycling within an urban area. The translation of various physical quantities into units of energy facilitates a consistent comparison between cities. Urban metabolism can also be regarded more explicitly in terms of sustainability.[291] For Mitchell, the definition for urban metabolism comprises processes "social as well as biophysical by which cities acquire or lose the capacity for sustainability in the face of diverse and competing problems"[292]. Such a consideration of urban metabolism fits to the 'ecological footprint'[293] concept. It offers a common unit for the assessment of consumption patterns, and therefore may be seen as a complement to energy-based analyses of urban metabolism. Regarding a city or region, the highest quantity of biologically productive areas can be found outside the system. This is reflected by the common exploitation of an opportunity for wealthy nations to externalize the effects of higher levels of consumption by "both importing resources and exporting wastes, often over tremendous distance"[294]. The result of many studies calculating municipal and national ecological footprints and setting these in relation with the national productive land area is that consumption exceeds the globally available materials and energy producing an ecological debt[295]. Regarding the general patterns of cities, Decker argues that the "macroscopic patterns of human settlements may be far more constrained by fundamental ecological principles than more fine-scale

[288] [FISCHER 03], p.37
[289] [WEISZ 10], p.185, see also for global comparison [MILLS 07], p.1857
[290] [WOLMAN 65], the first article on urban metabolism considering a hypothetical US city's overall inputs and outputs
[291] [RUTH 07], p.328
[292] [MITCHELL 98] in [RUTH 07], p.328-329
[293] [WACKERNAGEL 99], [REES 96]
[294] [RUTH 07], p.329
[295] [GOEMINNE 09]

socioeconomic factors."[296] Weisz analyses the aspects of urban form, characteristics of the building stock and urban consumption patterns[297] and concludes that "cities can significantly lower material and energy flows through efficient urban form and built environment"[298] and that not urbanisation itself but the accompanying high-income lifestyles matter more.[299]. These two apparently opposite outcomes suggest that urban patterns have a natural development and may provide opportunities to lower energy and material use but that socio-economic issues do not influence these patterns but rather other energy and material flows.

To calculate energy and material use one has to cope with several challenges: lack of data, no common definition of a city or urban area, openness of cities, dematerialisation versus securing access depending on the country and the impact of urban scale[300].

Interesting approaches are the Australian Stocks and Flows Framework that assesses the longevity of the Australian economy[301] and the material flow studies examining the entire cities of Lisbon[302] and Paris[303]. Kennedy shows more studies in a chronological overview (Table 22).[304]

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296 [DECKER 07]
297 [WEISZ 10], p. 186
298 ibidem, p. 190
299 ibidem, p. 188, 189; for data and the approach see [STEINBERGER 10]
300 ibidem, p. 186
301 [TURNER 11]
302 [NIZA 09]
303 [BARLES 09]
304 [KENNEDY 11], p.1966

Author (year)	City or region of study	Notes/contribution
Wolman (1965)	Hypothetical US city of 1 million people	Seminal study
Zucchetto (1975)	Miami	Emergy approach
Stanhill (1977); Odum (1983)	1850s Paris	Emergy approach
Hanya and Ambe (1976)	Toyko	
Duvigneaud and Denayeyer-De Smet (1977)	Brussels	Includes natural energy balance
Newcombe et al. (1978); Boyden et al. (1981)	Hong Kong	Particularly comprehensive metabolism study
Girardet (1992)		Recognized link to sustainable development of cities
Bohle (1994)		Critiqued metabolism perspective for studying food in developing cities
European Environment Agency (1995)	Prague (comprehensive metabolism study)	Energy use data for Barcelona and seven other European cities given in the report
Nilson (1995)	Gävle, Sweden	Phosphorus budget
Baccini (1997)	Swiss Lowlands	
Huang (1998)	Taipei	Emergy approach
Newman (1999); Newman et al. (1996)	Sydney	Adds liveability measures
Stimson et al. (1999)	Brisbane & Southeast Queensland	Framework relating urban metabolism to quality of life
Hermanowicz and Asano (1999)		Water
Hendriks et al. (2000)	Vienna & Swiss Lowlands	
Warren-Rhodes and Koenig (2001)	Hong Kong	
Baker et al. (2001)	Phoenix & Central Arizona	Nitrogen balance
Sörme et al. (2001)	Stockholm	Heavy metals
Svidén and Jonsson (2001)	Stockholm	Mercury
Obernosterer and Brunner (2001)	Vienna	Lead
Færge et al. (2001)	Bangkok	Nitrogen & Phosphorus
Chartered Institute of Wastes Management (2002)	London	
Gasson (2002)	Cape Town	
Barrett et al. (2002)	York, UK	Materials
Obernosterer (2002)		Metals
Sahely et al. (2003)	Toronto	
Emmenegger et al. (2003)	Geneva	
Burstrom et al. (2003)	Stockholm	Nitrogen & Phosphorus
Gandy (2004)		Water
Lennox and Turner (2004)		State of the Environment report
Hammer and Giljum (2006)	Hamburg, Vienna and Leipzig	Materials
Kennedy et al. (2007)		Review of changing metabolism
Schulz (2007)	Singapore	Materials
Barles (2007a)	Paris	Historical study of nitrogen in food metabolism
Forkes (2007)	Toronto	Nitrogen in food metabolism
Zhang and Yang (2007)	Shenzhen, China	Develops eco-efficiency measure
Ngo and Pataki (2008)		Los Angeles
Chrysoulakis (2008)		New project under EU 7th framework
Schremmer and Stead (2009)		New project under EU 7th framework
Barles (2009, 2007b)	Paris	Analysis of central city, suburbs and region.
Zhang et al. (2009)	Beijing	Emergy approach
Niza et al. (2009)	Lisbon	Materials
Deilmann (2009)		Studies relationship between metabolism and city surface
Baker et al. (2001)		Water
Thériault and Laroche (2009)	Greater Moncton, New Brunswick	Water
Browne et al. (2009)	Limerick, Ireland	Develops measure of metabolic efficiency

Table 22 Chronological overview of urban metabolism studies.
Source: own illustration of [KENNEDY 11], p.1966

Different assessment methods and tools underlie decisions on urban metabolism analysis. At the micro-level for example Life Cycle Assessment (LCA) and Material Input Per unit of Service (MIPS) can be used[305]:

- Life Cycle Assessment (LCA) evaluates the effects of a product, process or service during its lifespan. The system limits are the spatial limit to nature and lifespan of the product. The effects can be midpoint[306] or endpoint (damage to persons or ecosystems)[307].

305 See [KLEIJN 01], p.1 for both and [KYTZIA 04] for LCA
306 [GUINEE 02]
307 [HEIJUNGS 03], p.14

- Material Input Per unit of Service (MIPS) evaluates the basic environmental impact of a product, process or service through the overall material input (including so-called material “rucksacks”) at all scales (product, company, national economy, region). The method does not differentiate materials. [308]

At the macro-level, in the case of countries, cities, sectors of industry, Environmental Input-Output Analysis and Material Flow Accounting can be used[309]:

- Environmental Input-Output Analysis (IOA) is an advancement of the traditional Leontief input-output model. The environmental extension includes data on emissions and resource use and supplementing conditions that enforce consistency within industrial production, pollution generation and pollution abatement activities. The power of the tool relies on the availability of average data on resource use and environmental emissions from the involved sectors.[310]
- Material Flow Accounting (MFA) quantifies the material flows in a defined geographic area (country, city etc.). Usually all material flows are considered in total.

On the micro-level this paper will focus on LCA and on the macro-level on MFA.

II4.1 Life Cycle Assessment (LCA)

Introduction and General Approach

Life Cycle Assessments are often understood as the definition of the development process a product goes through. The development process is divided into several life cycle phases, which are characterised by different attributes. A temporal classification in the development process enables decision makers’ analyses and prognoses. The origins of life cycle analysis lie in evolutionary biology. Biological life cycle analyses have been applied to economic issues for about 50 years. Within this time, several different economic constructs such as companies, sectors or buildings were observed as objects[311]. Especially since the mid-1980s, the development of LCA accelerated and the number of scientific publications increased.[312] An advantage of LCA is it avoids problem-shifting, i.e. shifting from one area to another, from one stage to another or from one environmental impact to another.[313]

[308] [ALANNE 08], p.1747
[309] See [KYTZIA 04] and [KLEIJN 01], p.1 for both
[310] [FINNVEDEN 09],p. 7
[311] [KERTH 05], p.9
[312] [FINNVEDEN 09], p.2, 9
[313] ibidem, p.1

With regard to buildings and constructions, the following issues are characterised as being especially eminent for LCA, mainly based on Kotaji.[314]

As a first step, the **goal and the scope** of the product or service under examination are defined. Here information is collected, including:[315]

- the variety of the different actors who use LCA in different applications,
- the functional unit, from the perspective of the construction performance concept, and
- the description of the construction.

In the second step (**inventory analysis**) the already embedded products and services are analysed in terms of:

- the construction life cycle and the system limits (i.e. the service life, dynamic or static view of a construction's physical performance, etc.),
- the system boundaries[316] of the building material and component combinations (BMCC),
- the allocation of long-living products, with consideration to potential re-use or recycling in the future, and
- the collection of end-of-life information that is connected to the BMCC.

The different processes occurring during the life cycle of a construction can be aggregated in various numbers of life cycle stages, depending on the goal. Some distinctions delineate three stages: 1. the original production of building material and component combinations, 2. use phase of the building, and 3. the final waste treatment. Others divide the life cycle into five stages: 1. production, 2. construction, 3. use and maintenance, 4. demolition, and 5. waste treatment. All stage sequences result in the same total life cycle. Kotaji summarises a review of the results from some studies on the modelling of life cycles[317]:

- Results do not clarify whether the approaches indeed included all components including their production.
- The input for equipment and personnel transportation is seldom included.
- The construction phase is often included inaccurately, if at all.

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314 [KOTAJI 03], for a general description of and literature see [FINNVEDEN 09], p.2

315 [KOTAJI 03], p.7

316 According to [GUINEE 02] system boundaries can be determined by the distinction between the technical system and the environment, between significant and insignificant processes or between the technological system under study and other technological systems. The distinction between time and space is seen as a special case [FINNVEDEN 09], p.5. Nevertheless, spatial differentiation is needed to gauge correctly the exposure of the impacts: the emitted quantity of substance, the properties of the substance, the characteristics of the emitting source and the receiving environment [FINNVEDEN 09], p.10.

317 [KOTAJI 03] p.19, 20

- Several tools include water consumption in addition to energy use. Energy use dominates during the use phase in comparison to the energy-related environmental effects caused by the building materials and products. The ratios vary between 9:1 (conventional) and 6:4 (low-energy consumption buildings).
- There are differences in the level of detail in the examination of maintenance and replacements.
- Often, but not always the demolition stage is calculated based on the functional unit, the material output or, if available, material input.
- The transportation of waste to the treatment site is usually included. Aspects of interventions, operating effects and material-related waste treatment are seldom considered.

The third step of LCA (impact assessment, earlier classification) calculates the effect caused by the embedded products and services:

- Influences of chemical substances on the indoor climate
- Deterioration of eco-systems or general land use (especially important due to the large amounts of minerals used in the construction industry).

This step evaluates the quantified results of the inventory analysis and aggregates them into environmental loads. LCAs mainly focus on external regional and global environmental effects omitting consideration of to what extent these effects are dispersed in space and time. Still, there exist important local environmental issues interlinked with constructions, e.g. the emissions of dangerous substances into the indoor climate affecting human health. In addition, the impacts of land use and disturbance to ecosystems can occur locally, close to the assessed construction[318].

The fourth step considers the **evaluation and interpretation of the impact results** for instruments of presentation and communication[319]. Therefore that the interpretation and evaluation step is not only specific for constructions. The following recommendations aim to restrict to construction-specific issues[320]:

- For comparisons, constructions and/or building materials and component combinations have to be functionally equivalent.
- The basis for the performance characteristics of the building is the functional unit.
- Life expectancies of the construction and its components.
- Importance of the relation between the durability of components and their environmental performances.

[318] ibidem, p.33-37
[319] ibidem, p.7
[320] ibidem, p.39

- Scenarios for the whole life cycle of a construction and also for only parts of it.
- Consideration of end-of-life scenarios.

Application to the Urban Context and Variations

Finnveden sees two types of LCA: attributional and consequential. The first deals with the "environmentally relevant physical flows to and from a life cycle and its subsystems."[321] The second focuses on change of flows due to different decisions.[322] The attributional LCA is favoured due to its higher applicability, especially in situations where the difference in results from those of a consequential LCA is likely to be small, the uncertainty grows inadequately with the latter one or no decision is to be made.[323] Consequential LCA allows the setting of system boundaries that include environmentally relevant activities that contribute "to the consequences of a change, regardless of whether these are within or outside"[324] the directly impacted system of an analysed product.

There are also hybrid techniques, such as Input-Output LCA[325] or combinations with Environmental Impact Assessments[326], Strategic Environmental Assessments or Cost-Benefit Analysis[327].

The overall aim of LCA is to protect the area's "human health, natural environment, natural resources and […] man-made environment"[328]. To achieve this aim two different schools of thought have established[329]: the midpoint and the endpoint school. The first one stops the modelling somewhere before the endpoint and assesses the impact on the areas of protection by other means. The second one requires the modelling of the whole environmental mechanism (Figure 23). Both have their uncertainties: midpoint modelling relies on the accuracy of additional assessments whereas the endpoint approach may include unfeasible or uncertain modelling.[330]

In addition to Life Cycle Assessment (LCA), there exist other analysis methods that are related to the life cycle of a product: Life Cycle Costing (LCC)[331] and Social LCA[332].

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321 [FINNVEDEN 09], p.3
322 [FINNVEDEN 09], p.3, [CURRAN 05]
323 [FINNVEDEN 09], p.3; for other distinctions see [GUINEE 02]
324 [FINNVEDEN 09], p.6
325 [HORVATH 04], p.188; [FINNVEDEN 09], p.8
326 [TUKKER 00]
327 [FINNVEDEN 09], p.16
328 [FINNVEDEN 09], p.7
329 See ibidem, p.10 for more on the two schools and harmonisation processes
330 See ibidem, p.14 for more on uncertainties in LCA and p.15 for more on the as-yet-unsolved limitations of LCA.
331 [HUNKELER 08]
332 [JØRGENSEN 08]

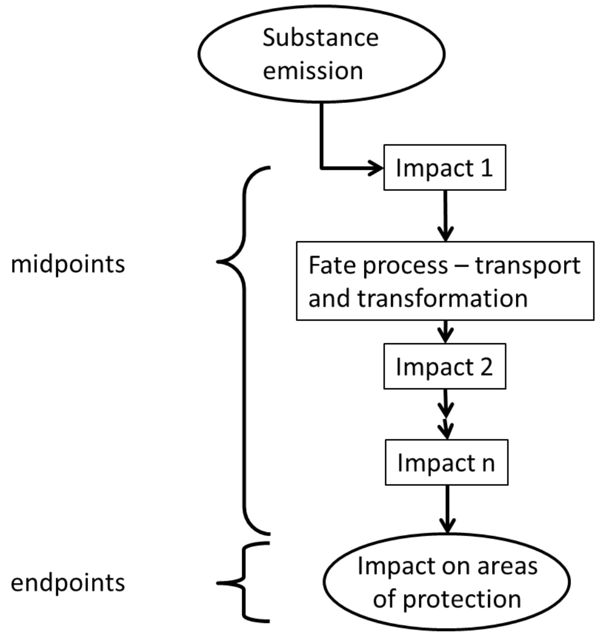

Figure 23 Schematic representation of an environmental mechanism underlying the modelling of impacts and damages in Life Cycle Impact Assessment ([FINNVEDEN 09], own illustration adapted from [HAUSCHILD 05]

The purpose of an LCC calculation is to sum up the capital and operating costs for a construction and its components, so that the figures can be presented as relative values that are easier to interpret and to compare with alternative results or solutions. Common aspects for both LCC and LCA are the use of data on:

- "amounts of used materials,
- service lifetime the materials are planned for or able to be used within,
- maintenance and operational effects from using the products, and
- end-of-life relations regarding recycling (and respective sale value) and disposal." [333]

There are also differences between LCC and LCA. Most LCC methods do not take into account production processes. Their main concern lies in the market cost, whereas LCA considers production. Life cycle costs usually are discounted over time and that is not possible for environmental impacts[334].

To overcome calculation differences and to combine LCC and LCA, several tools have been realised, including the Swiss OGIP LCA (www.ogip.ch) and the German LEGEP (www.legep.de).[335] These tools base mainly on the works of Niklaus Kohler.[336]

[333] [KOTAJI 03], p.45, see also [ELLINGHAM 06] for more detail
[334] [KOTAJI 03], p.45
[335] See [FINNVEDEN 09], p.16 for further tools
[336] [KOHLER 03b] or [KOHLER 97]

Social LCA (SCLA)
Social LCA has a short history and has similarities in its development to those of Cost-Benefit Analysis and Social Impact Assessment. SLCA supports the assessment of impacts, e.g. from those direct effects on workers up to the consequences for a whole society. In contrast to environmental LCA, there is no direct link between an activity and its social impact but impacts still serve as the basis of the assessment.[337] The system boundaries in Social LCA are much narrower and are reduced in accordance with the social impacts that can be influenced by different activities. Most of the models work with midpoint impacts (or better indicators due to their indirect link).[338] There are arguments to expand the areas of protection from the environmental LCA to include human dignity and well-being.[339] Adequate data collection during inventory analysis seems to be rather difficult, e.g. the same result may have significantly different social impact and so needs site-specific data capture. A common database is difficult to establish but is proposed in the form of literature and internet reviews to reduce the amount of required site-specific data. There is still no commonly agreed approach for classification and characterisation with the exception of a minimum list of stakeholders. Overall, SLCA is still in a development stage prior to consensus and harmonisation.[340]
LCA, LCC and SLCA share similar functions and goals and there are attempts to integrate them.[341] They all attempt to assess impacts with consideration to the whole life of a construction and aim for the presentation of the acquired information appropriate to decision-making processes. Comparisons of LCAs cover important aspects but other serious issues are not considered, e.g. results are often presented in total and not on a yearly basis. Time is an often a neglected challenge in many evaluations, e.g. the lifespan of a product is longer than the timeframe of an analysis or the time needed by nature to produce a resource such as oil or trees. Here the turnover rate of resources is a helpful measure[342]. The incorporation of time is also approached by energy accounting procedures.[343]

[337] [JØRGENSEN 08], p.97
[338] ibidem, p.98
[339] ibidem, p.100
[340] ibidem, p.101, 102
[341] See [FINNVEDEN 09], p.2 for projects
[342] [ULGIATI 10], p.177
[343] [ODUM 88] within energy accounting, all types of energy are converted into equivalents of one type of energy, e.g. solar energy.

II4.2 Review and Positioning within the Adaptive Cycle Framework

Life cycle approaches for urban fragments open a broad spectrum for analysis. Endpoint evaluation would enable the overview of possible developments during the whole lifetime of an urban unit/fragment and without spatial limits. Concentration is not on local benefits or disadvantages but more on a general view, which would allow an analysis that achieves efficient results. Firstly, urban fragments would have to be divided into individual urban units, such as buildings, infrastructure, etc. Secondly, a possible life cycle of the whole urban fragment would be assembled. This would allow discovery of efficient strategies to maintain the urban units (see section II4.3). In contrast to LCA and LCC, Social LCA is limited to the considered urban fragment.

		Resilience	Potential	Connectedness
Ecological	Level		●	
	Tendency		●	
Cultural	Level			
	Tendency			
Social	Level		●	
	Tendency		●	
Economical	Level		●	
	Tendency		●	

Table 23 Dimensions of sustainability and adaptive cycles considered by life cycle evaluating approaches

A method combining LCA, LCC and Social LCA is able to assess the economic, ecological and social potential of an urban fragment (Table 23) at present (level) as well as in the future (tendency). An evaluation with LCA and LCC captures a big part of the total potential. From an ecological perspective, concentration is more on resource consumption or waste; there are no considerations of biodiversity or the immediate impact on the surroundings as there are in an EIA. Similarly for LCC, the costs are not evaluated on an individual level, so the overall most efficient analysis does not consider the feasibility for each individual stakeholder. Whereas Social LCA is more concerned with individual stakeholders.

Combining the three life cycle approaches could facilitate the retrieval of information on the connectedness and resilience of the ecological, economic and social dimensions. This has yet to be applied.

Life cycle evaluation approaches can be used for an urban fragment and result in different development paths. While some individual constructions within an urban fragment may not have changes in their life cycle, the overall life cycle of an urban fragment may be in another adaptive cycle. Life cycle evaluations of an urban fragment can provide a basis for understanding possible adaptive cycles but due to the missing information on connectedness and resilience, they cannot holistically explain the characteristic of the considered adaptive cycle. The results of life cycle evaluations indicate the size of impacts: if an LCA of an urban fragment shows a high resource flow (Ω_1 phase), this may result in a transition into another adaptive cycle (α_2 phase). Alternatively, if an LCC reveals a lack of investment into an urban fragment's buildings, this may signal deterioration and the later demolition of constructions. In addition, if an SLCA of an urban fragment shows long-term tenant relationships, this may suggest a stable phase (K phase). Nevertheless, current life cycle evaluations could contain several transitions of adaptive cycles without being realised by the user.

Future combined or even integrated applications may come up with benchmarks for the indicators that could represent the phases of adaptive cycles.

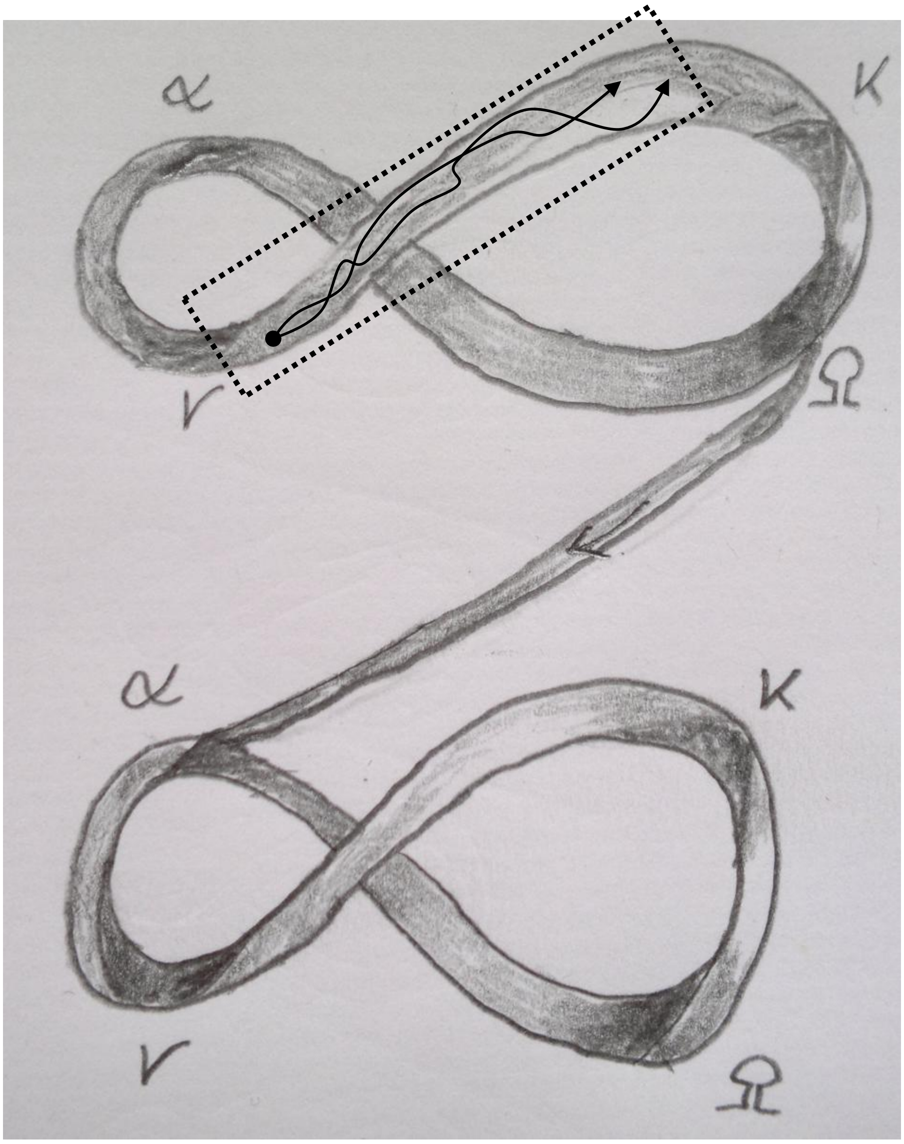

Figure 24 Life Cycle evaluations illustrate alternative development paths of an urban unit starting from a specific point in time (arrows in dotted box) depending on the maintenance and renovation activities.
Their results can act as indicators to facilitate the recognition of an adaptive cycle's phase. The analyses do not however identify system changes within the life cycle of an urban unit and needs to be modelled separately.

II4.3 Urban Life Cycle Analysis

Introduction

The Methodology to Evaluate the sustainable Development of cities (MED), created at the Institute for Industrial Building Production (ifib) in cooperation with the European Institute for Energy Research (EIfER) (both Karlsruhe, Germany), is a tool for the life cycle analysis of cities.[344] The MED-tool divides cities into urban units: buildings, infrastructure and open spaces[345]. Each urban unit is further described by its construction year, use, shape, technical equipment and qualitative completion[346]. The units go through different stages and have an environmental effect. The specific effects and the ageing of the urban unit depend on the maintenance strategy chosen. The tool generates simulations based on the strategies, the development of the stages and their effects at the level of urban units.

Application to the Urban Context

The application concentrates on the calculation of the impacts of the four stages of the life cycle of urban units.: construction, operation, renovation and deconstruction/demolition.

Construction:

During construction, the attributes for use, gross floor area, form, technical equipment and qualitative equipment are set. For this, economic (money and work power) and environmental (materials, energy) input is required. Based on the inputs, the environmental output is calculated (emissions).

Operation:

During operation, the attributes do not usually change, but materials, energy and money is required. The necessary amount of materials can differ a lot compared to that embedded in the urban unit and is dependent on activities: maintenance, cleaning and heating. The operation of buildings, infrastructure and open space requires also energy for, on the one hand, the production of auxiliary materials (cleaning materials, construction elements) and on the other hand, heating, hot water and services (by energy source). The use of energy creates emissions dependent on the energy source and the transformation process. Costs are generated by materials required for the daily operation, construction elements and energy carrier.

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[344] The project had its starting point within der project [SUIT 03]

[345] See for more detail [SUIT 03], p.31 and Annex A.1.

[346] See annex A.2 for more detail.

Renovation/maintenance:
The term maintenance is not properly defined in the different European countries. According to DIN 31051 for example, maintenance is a sum of inspection, attendance, repair/restoration and improvement[347]. Due to this ambiguity, there is also a lack of datasets that differentiate the cost factors. For renovation/maintenance, environmental (materials and energy) and economic inputs (money and work power) are required. During renovation, the attributes for use, gross floor area, form, technical equipment and qualitative equipment can change.

Demolition
Demolition destroys the economic value and grey energy of an urban unit. Often also, its environmental impact is reduced to zero. Nevertheless, the handling of the decomposition can be environmentally dangerous, e.g. hazardous components, and the diminished environmental impact has to be set in relation to an optional new construction's impact.

Calculating the Effects of the Stages
Existing tools can calculate the amount of materials, energy and financial means used to build an urban unit including taking into account regular maintenance. One hundred fifty four buildings were analysed in order to understand the effects of constructions phases and develop the general strategy underlying the existing life cycle analysis tool (LEGEP). Data on costs for the construction, operation, maintenance and renovation were analysed for the use class "housing"[348], divided into five age classes (0-1870, 1871-1918, 1919-1949, 1950-1976 and 1977-2000) and three size classes (0-1300, 1301-5000, 5001-99999 square metres), see Table 24.

Age class (year)	min	max
1	0	1870
2	1871	1918
3	1919	1949
4	1950	1976
5	1977	2000

Size class (m^2)	min	max
1	0	1300
2	1301	5000
3	5001	99999

Table 24: Age and size classes for the use class housing

The results of the costs and the environmental effects have been standardised in two steps[349]:
1. the absolute yearly costs for each size class are set in relation to the construction costs and

[347] See for more detail [KLINGENBER 07], p.19
[348] See Annex A.3 for other use classes and the data collection
[349] See Annex A.3, p.273

2. yearly values above 20% are kept as they do not set themselves apart from the background significantly. These values have been smoothened by dispersal to the surrounding years. The same approach has been used for environmental effects.

On average, 25 years after construction buildings are partially renovated (21-33% of the construction costs), after 40 years there is a full renovation (39-83% of the construction costs), after 50 years there is again a partially renovation (30-50% of the construction costs) and after 75 years another with 22-32% of the construction costs. After 80 years, it is assumed that an investment comparable with the costs after 40 years has to be made if the building is not demolished.
For costs that stay below 20% of the construction costs, it is assumed that they are related to operations and daily maintenance and are incorporated into these costs. The values are dispersed in the interval between renovations so that constant annual costs for the further calculations can be assumed. This dispersion results in an average value of 3 to 5 %.

Definition of the Ageing Curves
The cost development is used to define an ageing curve under the assumption of just-in-time maintenance of all components.[350]
The aim of this tool was to present and calculate the ageing process in an abstract and generally applicable way. Building elements can be roughly divided into two groups, each of which has a cycle of 25 and 40 years respectively. The two ageing functions constitute the ageing function of the whole building (Figure 25). Weighting factors of approximately 0.7 for the 40-year cycle and approximately 0.3 for the 25-year cycle result in the following development of the building condition/use value (Figure 26).

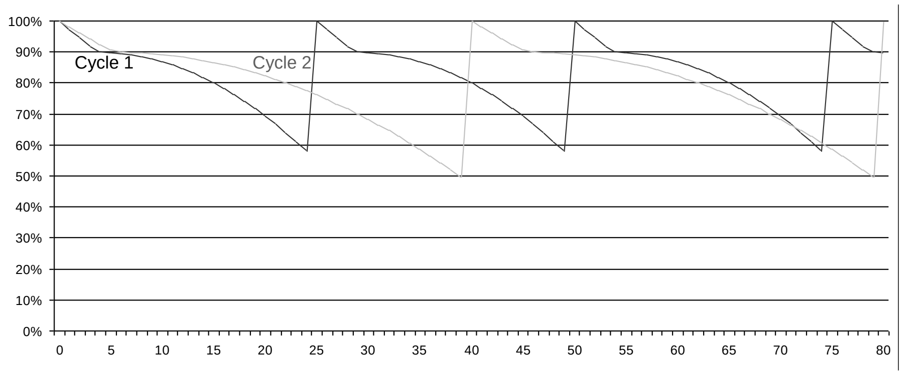

Figure 25 Two cycles of renovations for housing, 25 and 40 years

[350] See Annex A.4 for state calculation

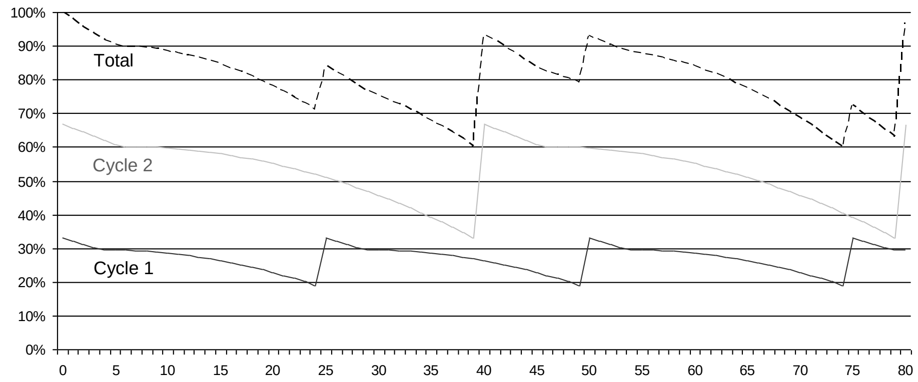

Figure 26: Ageing curve for housing, Cycle 1 with a weighting factor of 0.3 and Cycle 2 with a weighting factor of 0.7

After 25 years, it is possible to postpone renovation until Cycle 1 costs reach 20% (i.e. the state of the components comes close to obsoletion). At about the same time, total state costs reach 50%. The comparison of these strategies after 30 years shows that the standard strategy results in an integral of the total state value of about 2174% (average state per year 72.5%) and the alternative strategy a total state value of 2000% (average condition per year 66%).

To secure an average state of the building at about 65% or to avoid too much volatility, renovation in Cycle 2 can be brought forward. Overall, this constitutes a 35-year renovation cycle for keeping up the performance of the building (Figure 27 and Figure 28).

How **maintenance** of the building’s condition is defined plays an important role. Maintenance can mean that the condition of the building stays above a certain value for a certain period. In this case, the definition can be based on the standard strategy. The area below the curve indicates the reference value. With a significant excess of value, an improvement/augmentation of the building can be characterised and vice versa for a significant downgrading or loss of value. Within this interval, additional strategies can be described similar to the one above, which maintain a constant value independently of the costs.

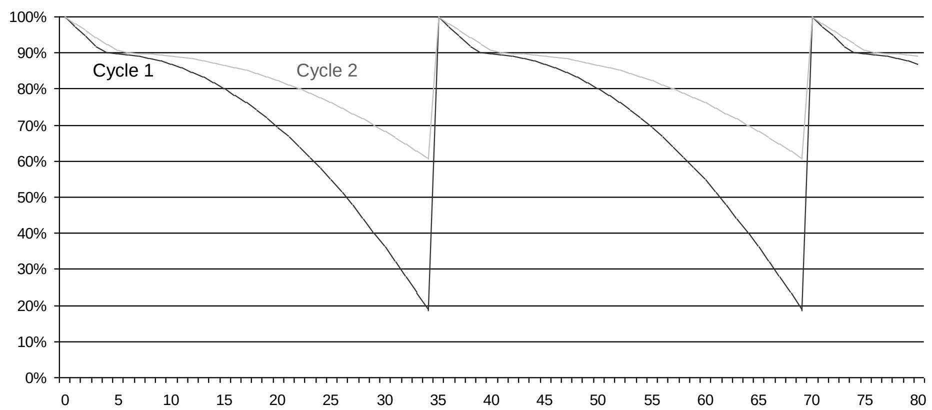

Figure 27 Two cycles of renovation for housing, postponed until Cycle 1 reaches 20% of the total state

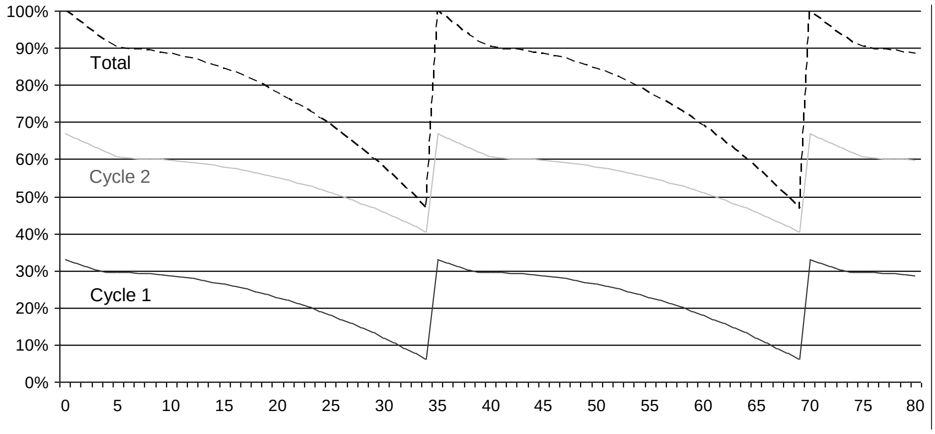

Figure 28: Alternative strategy: 25-year cycle requirements are fulfilled first after 35 years and combined with early renovations in Cycle 2 to maintain an average state above 65%

Strategies

The impact of each phase depends on the strategy chosen for a construction. The different strategies[351] influence the properties of the urban units. Internal attributes and ageing can be influenced by strategies. The strategies are based on data on ageing and on the effects of the urban units. In this context, it is relevant to identify what kinds of strategies exist and if they are appropriately useful for the description of the development of urban units.

Current real estate strategies concentrate primarily on the interest of financially involved stakeholders, that is, mainly the owner/investor who has the authority on decisions. For constructions with an illiquid market and that are rented, or given over for similar use, the users often are involved in the decision-making. More peripheral stakeholders are considered secondary stakeholders or not at all, even if activities may also affect them. Based on these factors, the strategies of maintenance, technical and/or qualitative improvement, waiting and dereliction arise[352]. Their details depend on the demands of the financially involved stakeholders.

[351] [WITTMANN 05]
[352] See Annex A.5 for a detailed description

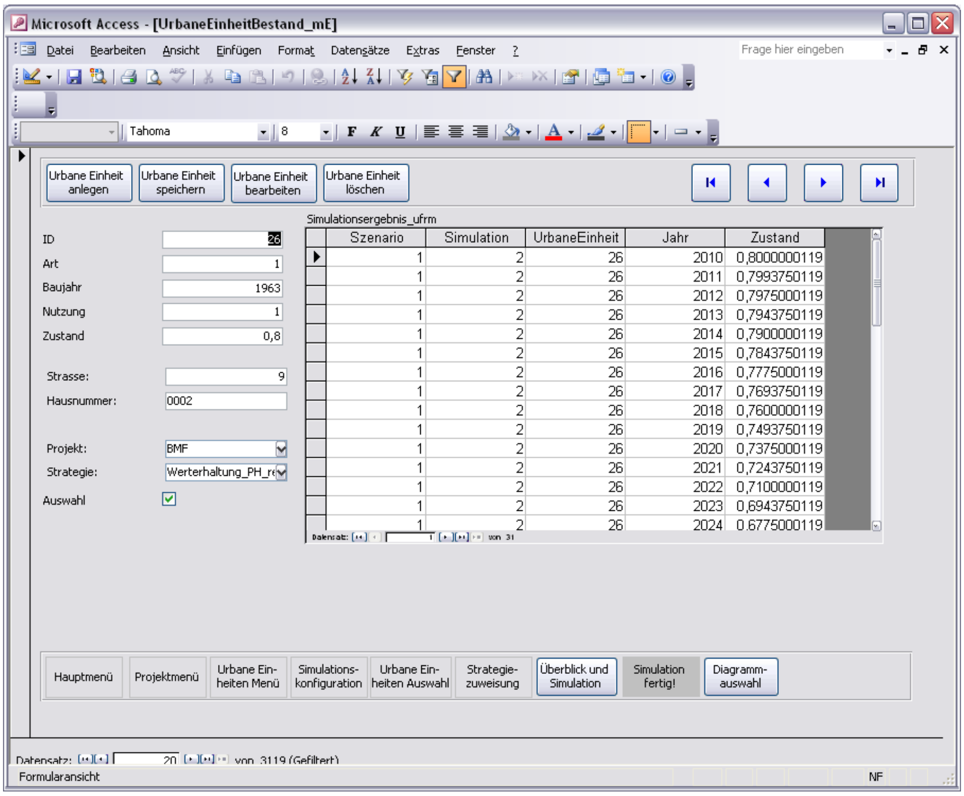

Figure 29 Form for strategy definition in MED
Source: Own illustration

Based on the approach described a computer model[353] has been developed which can be used to simulate the process of the development of a city over a period of time. It is designed to calculate the effects of different strategies and to compare the results of different scenarios (Figure 29).

II4.4 Review and Positioning within the Adaptive Cycle Framework

The described approach was developed during the Methodology for the Evaluation of sustainable Development of cities (MED) project and is still in the refinement phase. The 'tool' might be useful for planners, public administrations, political authorities, project developers, stakeholders (users, inhabitants) and environmentally oriented organisations.

Its general view and broad spatial, temporal and value-based perspective might provide a new kind of discussion space for a multitude of stakeholders. With a policymaker as initiator of a partial urban successive analysis, contribution to overall goals such as the minimisation of impacts from national building stocks, promotion of environmental urban fragments, or investigation of the impacts of

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[353] See Annex A.6 for a detailed description

subsidies, taxes and regulation on environmental performance, etc. could be discussed.[354]

Uncertainty constraints and data limitations are a common issue in empirical studies. The difficulties in this type of study arise especially from the long time horizon and the integration of multiple data sources[355]. In the following, problems in the handling of endogeneity and data constraints arising from the long time horizon are briefly discussed.

For urban unit optimisation, the urban fragment perspective can be omitted if it is clear that the urban fragment (structure or performance) is not influenced by the performance of the newly developed or optimised buildings.[356]

For the environmental and economic impact of urban units, cradle-to-gate data can be quantitatively measured.

To undertake a meaningful adaptive cycle analysis (comprising the cultural, social, ecological and economic dimensions), all life cycle phases of the urban fragment, from the past until the present, should be taken into account. The above-introduced model helps to understand ecological impacts and economic as well as cultural maintenance to some extent. The analyst should quantify the retrospective adaptive cycles and phases (e.g. construction to current use or cradle-to-gate) and make qualitative, semi-quantitative or quantitative assumptions about the prospective (future) phases (e.g. possible phases with the impact of demolitions or gate-to-grave) as appropriate. Therefore, it is possible to combine this approach with the adaptive cycle concept.

It is necessary to define the aim of the scenario and describe the meaning of optimisation (i.e. the sustainability dimension) within the scenarios for adaptive cycle modelling. Optimisation can accompany several adaptive cycles resulting in one that has incorporated the targeted optimisation. The scenario would implicitly explain which successions have to be undergone to achieve the defined aim and support the identification of how the virtual adaptive cycles of the other dimensions might develop. Then, strategies are chosen to achieve this aim considering urban units individually. Indicators assess the results of the simulation looking at the four sustainability dimensions and the adaptive cycle dimensions. This allows the identification of which adaptive cycle phase (α, r, K, and Ω) the urban fragment is in. The best results of the approach are achieved in phases K and the transition from

[354] compare with [KOTAJI 03], p.11

[355] Within this paper's methodology, the issues and assumptions mentioned in [KOTAJI 03], p.19 must be considered to achieve general usability. If the life cycle of an urban fragment is divided into urban unit stages, the total of the stages should reflect the entire life cycle. In this tool, the Life Cycle Assessment (LCA) of an urban unit is based on a specific (commercial) database of materials, component combinations, energy related data.

[356] similar to LCA [KOTAJI 03], p.13

phases K to Ω. Within the succession model, the standard strategy appears the most appropriate for stable situations, a wait-and-see strategy for situations close to phase Ω, and a demolish/new construction strategy for reinforcing Ω situations.

The MED-tool mainly concentrates on ecological and economic potential, with most calculations made for the first but may be supplemented by cultural valuation on if more construction data is available.

		Resilience	Potential	Connectedness
Ecological	Level		●	
	Tendency		●	
Cultural	Level			
	Tendency			
Social	Level			
	Tendency			
Economical	Level		○	
	Tendency		○	

Table 25 Dimensions of sustainability and adaptive cycles considered by MED

II4.5 Mass Flow Accounting

Introduction and General Approach

Behind flow analysis lies the principle of systems analysis, like that used for socio-economic, societal or industrial metabolism[357]. Flow studies have been carried out in many disciplines, with widely varying scopes, scales and timeframes.

There are several terms for the different applications of the same principle of Mass Flow Accounting, including Substance Flow Analysis (SFA) and Material Flow Analysis (MFA).[358] Usually, SFA is the most detailed version that looks at different substances. In other contexts, MFA is used when a flow is an aggregation of more substances. MFA describes the flow of more complex materials and industrial products.

The concepts behind MFA were introduced in the 1970s[359], and in the 1990s the first MFAs with nationwide application increased scientific interest in the approach, which resulted also in international working groups harmonising country-specific accounts.[360] Generally, MFA aims to assess the ecological disturbance by the withdrawal or diversion by human activities of materials from their initial pathways in an ecosystem. The calculated material amounts of the individual inputs are summed for several environmental aspects and linked with the output of the system as a measure of its cumulative environmental burden from the aspect of the individual (also referred to as ‘ecological rucksack’).[361]

MFA essentially comprises the following steps[362]. In the first, the goals and questions of the study are defined. In the second (system description), the system to be investigated is defined by spatial and temporal boundaries. System relevant substances, goods and related processes are defined and linked. Trying to articulate real life relations in a simplified manner constitutes one of the most critical and demanding steps within this type of analysis, whereby the selection of the goods and substances depends on the aim of the study.

In the third step, data is acquired and the state of the system is analysed. Here the flows and stocks of the concerned system are determined by measurements, best estimates, expert judgement, interviews, market research as well as ‘hands on’ experience[363].

In the fourth step, the flows are balanced and modelled allowing scenario building. For processes without data, balances are calculated on the principle of mass conservation (mass in = mass out). If needed, the understanding of the system can be used for the generation of

[357] [BACCINI 03], see [KOVANDA 11] for more
[358] [LASSEN 00]
[359] [KNEESE 70]
[360] See [GILJUM 11], p.301 for further harmonisation approaches
[361] [ULGIATI 05], p.435
[362] The detailed methodological steps of material flow analysis are described in [BRUNNER 04], [BACCINI 96], [BACCINI 03], [BACCINI 91], [BRUNNER 90]
[363] [ARNOLD 98], p.188f.

dynamic models. Based on the models, scenarios can be built up allowing the assessment of the impact of different measures on regional stocks and flows of chosen substances with regard to environmental loads or resource depletion.
The fifth and final step is the interpretation of the results, looking at quantities and the significance of stocks, checking back with environmental standards, sustainability standards or further assessment methods[364] with the aim to develop appropriate concepts, plans and selection means[365].
Key characteristics of MFA are: 1. MFA is based on a systems perspective, 2. flows are considered from their source to their sink, 3. calculations are balanced with regard to the law of conservation of masses[366] and that input is equivalent to the output, 4. MFA focus on yearly flows, and 5. the system has geographical system boundaries.

Excursion
A small example shall illustrate the MFA approach for a system with two processes (three input variables, two output variables and internal flows. Input **a**, **b** and **c** go into processes. The outputs are **d** and **e**. Process I has input **a** and output **d**, process II has inputs **b** and **c** and output **e,** and internal flow x goes from process II to process I. The output of process II can be used for process I or can leave the system as well.

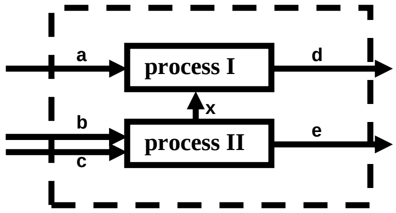

Figure 30: Scheme for MFA - example

	I	II	Output d	Output e
I	0	0	d_i	0
II	x_i	0	0	e_i
Input a	a_i	0	0	0
Input b	0	b_i		
Input c	0	c_i	0	0

Table 26 Input-output matrix

Following two equations are valid:

$a_i + x_i = d_i$

$b_i + c_i = x_i + e_i$

The input-output-balance is a + b + c = d + e. There is no inventory in this example.

$k_{id} = 1$

$k_{ie} + k_{ix} = 1$

With help of transfer coefficients and the input flows, the inner flow x and the outputs d and e can be calculated, with N_{In} for the number of inner flows, N_{Ip} for the number of inputs, N_{Op} for the number of output flows and N for the number of equations.

$N = 2, N_{In} = 1, N_{Ip} = 3, N_{Op} = 2$

So $F = N_{In} + N_{Ip} + N_{Op} = 6$ flows are defined, if additionally to the two equations four further relationships are known ($N_{In} + N_{Ip} + N_{Op} - N$). The three transfer coefficients and the three input flows provide these relationships, which define all output flows.

364 [HENDRIKS 00]
365 [ARNOLD 98], p.187
366 [LAVOISIER 65]

Application to the Urban Context and Variations

Mass Flow Analysis (MFA) is a method which helps to understand the metabolism of an area, i.e. region, city, etc. It facilitates the systematic linkage of processes and activities, such as construction, transportation, consumption and waste treatment, together with input and output flows. More detailed MFA allows the examination of material flows into the system of interest (private household, company, region, city, etc.), the stocks and flows within such a system and the final outputs from the system into outer systems. In this way, MFA is also able to study the relationship between a region or a city and its corresponding backcountry. MFAs have been realised for many countries and cities in the last two decades. Decker analysed the data and models of the 25 largest cities in 2000.[367] The variety of models has been wide. In projects where the interest is on understanding regional or urban metabolism, indicator materials such as carbon and nitrogen (essential for the biosphere) and the elements lead, iron, aluminium and zinc (some of the most important metals of the anthroposphere) are typically selected. In more specific applied investigations, where the interest may be on special environmental issues, problem-oriented materials have to be selected (e.g. forestry management issues may focus on timber, or eutrophication issues may focus on nitrogen and phosphorus as indicator materials). Despite its possibilities, MFA does not treat urban centres and connections between cities explicitly or at all.[368] Besides the flow analysis of national economies, many applications work on the level of biogeochemical cycles down to the local level of agricultural fields. Even if the objects of interest may vary widely, and so also the conclusions and implications for policies, the basic methodology stays quite the same for most examinations.[369] They aim to balance the mass flows.[370] Newer models cope also with the flows of construction materials in cities. Simplified models have been realised by Lichtensteiger.[371] A more recent review concentrates on the change of material flows in cities and processes that endanger sustainable development (Figure 31)[372]. Such approaches model the material and energy use of complete national economies: Kovanda for Czechoslovakia in 1855-2007[373]; and Brattebo and Bergsdal introduce a highly developed application of MFA in the urban context, analysing the historical flows of dwelling stocks starting from 1900[374] and calculating the material and energy demands until 2100[375].

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[367] [DECKER 00]
[368] ibidem, p.712
[369] [KLEIJN 01], p.2
[370] first recognised by [LAVOISIER 65]
[371] [LICHTENSTEI 07]
[372] See [KENNEDY 08] for an overview
[373] [KOVANDA 11]
[374] [SANDBERG 11]
[375] [SARTORI 08], [BERGSDAL 07]

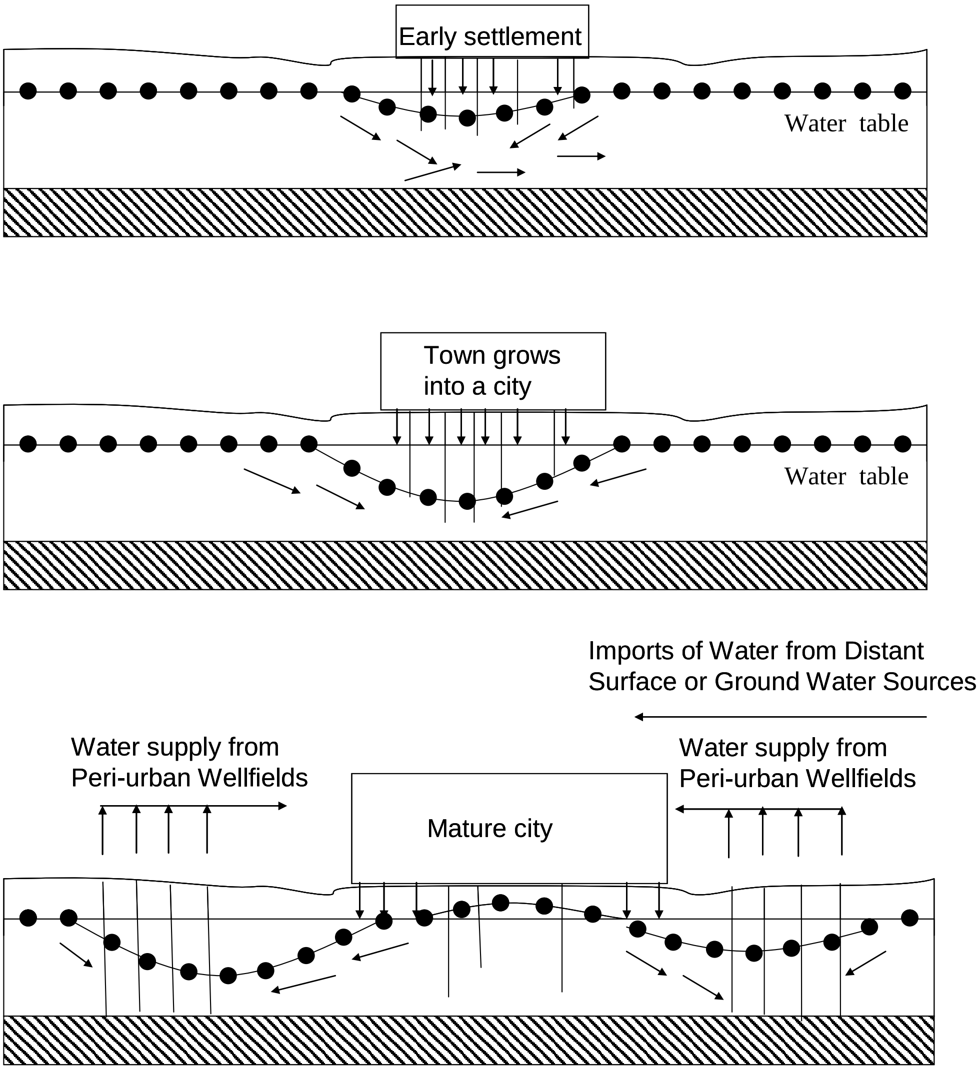

Figure 31 Evolution of water supply and wastewater disposal for a typical city underlain by a shallow aquifer. The arrows indicate water flows: the line with dots indicates the water table.
Source: own illustration of [KENNEDY 08], p.50

II4.6 Review and Positioning within the Adaptive Cycle Framework

There is ongoing research to model material flows over longer time periods aiming to answer such questions as: "how has industrial metabolism developed over the past, say, 200 years, and what preceded it?"[376], or how do technological changes influence material end energy flows and vice versa[377]. The absolute change of the flows is dependent on changes of resource use of activities and on changes in the practice of the activities. These questions are also valid for urban fragments and result in similar limitations to those of material flow analysis. MFA used for urban fragments provides information on the input and output

[376] [FISCHER 03]
[377] [HABERL02]

of the whole fragment on an annual basis without explicitly showing which constructions are the source. Localisations are made for processes in the form of “into the system”, “out of the system” and “within the system”[378]. The combinations of variables and parameters make up a stable and rather stationary model. During such periods, the parameters remain nearly constant or do not constitute a cycle transition. In the adaptive cycle, MFA is useful within a K phase. If it is possible to model a stable development before a K phase and within a K phase with one system description then also the material flow of an r phase could modelled (Figure 32). As long as the urban fragment stays within one adaptive cycle the model would work. Changes within the system might occur, but are not the subject of the calculations. The emphasis is more on resource use calculations. Therefore, MFA is a system description mainly focusing on the change of resources but not on the system’s soft requirements and implicit premises. This means in the case of a transition into another adaptive cycle, the material flow settings (parameters, variables and relations) have to be fitted to the circumstances of the new system[379]. In this sense, MFA is helpful to understand the level of a stable system in ecological resource consumption terms (potential) and possible system preserving adjustments, but in its spatial extent, it makes sense only if used within a system that has internal interdependencies (connectedness). Then it can cope with the total area of interest. MFA examines not the individual elements but rather the processes (activities and resource consumption) behind groups of elements. Therefore, the processes cannot be related to the specific location of elements[380]. Further comparability might be incorporated if resource consumption could be assigned to the dimensions, e.g. the influence of physical changes on prices or demand.
Tendencies are incorporated by assessing the gradient of the flows, and examining misbalances within the system or with the outside. Due to the approach’s aim to make complex systems comprehensible, discovered interdependencies can be modelled and provide an understanding on connectedness for resource consumption. Nevertheless, the analysis of tendencies is limited and only possible inasmuch as stability of the system is needed. Other sustainability dimensions and resilience are not considered at all (Table 27).

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[378] [KOHLER 07], p.352
[379] See for examples [BERGSDAL 07][SARTORI 08]
[380] [KOHLER 07], p.352

		Resilience	Potential	Connectedness
Ecological	Level		●	●
	Tendency		○	○
Cultural	Level			
	Tendency			
Social	Level			
	Tendency			
Economical	Level			
	Tendency			

Table 27 Dimensions of sustainability and adaptive cycles considered by Mass Flow Accounting

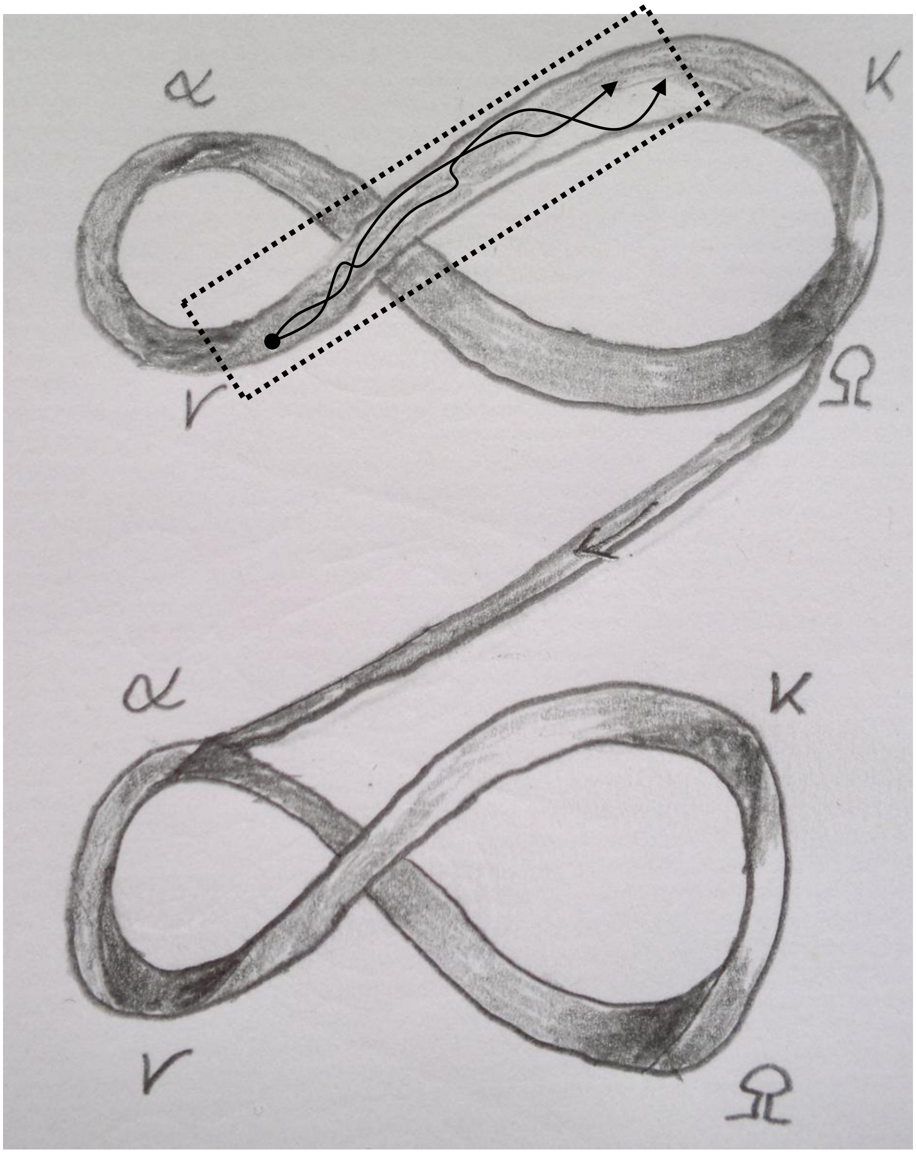

Figure 32 Mass Flow Accounting is able to calculate flows under stable circumstances
(i.e. ∞_1 constant or predictable changing parameters, but not the change of the parameters itself, which may lead to ∞_2 or ∞_3).

II5. Simulations

Introduction and General Approach

According to the "New Shorter Oxford English Dictionary", 'to simulate' is "to imitate the appearance or character of", "pretend to have or feel (an emotion)", "produce a computer model of"[381]. The first published work on simulation modelling was more than 50 years ago.[382] Taylor divides simulations into three types: historical reviews, methodological reviews and application reviews, and makes a study of three important journals to find the real-world benefit[383] of simulation modelling in different areas[384], including: biology, computing, control, defence, education, environment, general, healthcare, manufacturing and logistics, networks and communication, social systems and transportation (Table 28). The real-world benefit of the published papers is between 5% and 16%.[385] Even if compared to area-specific journals, where real-world papers are also low, Taylor concludes that the academic world becomes more irrelevant for the real world and the real world (industrial practitioners) knows less on advancements in science.[386] Simulation modelling has application in the real world but does often not have academic relevance in operations research. Nevertheless, it seems to be necessary for engagement from both sides such as in the workshops organised by the working group simulation (ASIM) of the Gesellschaft für Informatik (Organisation for Computer Science)[387] to find links between the different disciplines[388].

Simulations need assumptions to conceptualise the real world, and one of the most important assumptions is on behaviour. It is expected that human actors make decisions to achieve a desired outcome. Their actions may be referred to as rational choice. Actions relying on ignorance, instincts, emotions or altruism undermine this rationality. Partial adherents to rational choice accept these limitations and work on incorporating 'irrational' choices into their models or argue that their models help to discover the impact of such 'irrationalities'.[389] Velupillai puts it like this: "In every field to which he contributed, economics, psychology, computer science, philosophy of science and management science, *simulation by digital machines* played a fundamental *epistemological role* – in discovering laws, in implementing retroduction, in making induction scientifically respectable."[390]

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381 [OXFORD 11], "imitate the conditions of (a process), especially for the purpose of training; spec. produce a computer model of (a process)" in [PFAFFENBICH 03] p.12
382 [TOCHER 60]
383 [TAYLOR 09], p.S69
384 ibidem, p.S72
385 ibidem, p.S78
386 ibidem, p.S80
387 [ASIM 11], ASIM workshops connect practitioners and theorists in small groups.
388 [ORMEROD 10], p.1773
389 ibidem, p.1762
390 [VELUPILLAI 10], p.49

Area	Notes
Biology (Bio)	
Computing (Comp)	Including computer architecture, management, performance, high performance computing, logic, ubiquitous computing and distributed systems
Control (Cont)	Including electrical, hydro-electric, mechanical and real-time systems
Defence (Def)	
Education (EDu)	Including distance learning and technological support issues
Environmental (Env)	Including physical, water, energy, chemical and mining issues
General (Gen)	Including methodologies, tools and techniques such as those relating to discrete-event simulation modelling, system dynamics, Monte Carlo simulation modelling, mathematical modelling, languages, DEVS, component-based simulation modelling, agent-based simulation modelling, parallel and distributed simulation modelling, standards, Grid computing, visualization and statistics
Health Care (HC)	
Manufacturing and Logistics (ML)	
Networks and Communication (NC)	
Social Systems (SS)	
Transportation (Trans)	Including air, road, maritime and related issues
Other	Categories having one entry for all journals over review period (see results for specific areas)

Table 28 Areas of simulation modelling
Source: own illustration of [TAYLOR 09], p.572

Application to the Urban Context and Variations

Understanding cities or urban areas as systems dates back to the 1960s. In the urban context, urban land use models have been established. Some are for individual case studies and others are for different regions. They differ in structure, in the way they conceptualise decisions and in methodological implementation.[391] The first approaches focussed on the dynamics of physical infrastructure[392] and the concept of urban metabolism[393] (see Section II.4.), and aimed at a holistic view of urban planning. Further elaborations included the exploration of interdependencies between resource flows, processes of urban transformation, streams of waste and quality of life.[394]

In international literature, there is an ongoing debate on the theoretical basis of (simulation) models and their capabilities, now and in the future.[395] Urban land use models may be based on frameworks such as DPSIR (see Section II.2.1) but "the main drawback of using these analytical frameworks is the assumption of one-directional processes between driving factors and impacts"[396] Driving forces are differentiated into the socioeconomic, political, technological, natural and cultural with three levels and intrinsic as well as extrinsic characterisation.[397] Timmermans criticises linear functional chains and proposes to integrate and interlink: households, residential and job choices, vehicle ownership, scheduling of activities, competition and agglomeration of land uses and actors, co-evolutionary development of demographics, employment sectors, land use and activity profiles and, especially, differing time horizons as well as anticipatory and reactive behaviour[398]. Hunt proposes 11 axioms for urban land use modelling[399]

[391] [HAASE 09], p.5
[392] [FORRESTER 69]
[393] [WOLMAN 65]
[394] [NEWTON 97] and [ROTMANS 99]
[395] [TIMMERMANS 03], [GROSSKURTH 07]
[396] [VERBURG 06], p.1173
[397] [BÜRGI 04]
[398] [TIMMERMANS 03], see also [MILLERE 04] for other propositions

that are also relevant for the simulation of urben development in general:

1. "In referring to the urban system, the focus is on those elements that influence and/or interact with the transportation system. Notwithstanding, the model should be extensible as appropriate
2. Urban system consists of physical elements, actors and processes. The modelling representation of this urban system must contain all three of these
3. Transportation system is inherently multimodal and involves the flows of both people and goods
4. Markets represent the basic organizing principle for most interactions of interest within the urban area, providing price and time signals to producers (suppliers) and consumers (demanders) of housing, transportation services, etc.
5. Flows of people, goods, information and money through time and space arise as a derived demand from market interactions that are distributed in time and space
6. Urban areas are open, dissipative systems subject to external forces. As such, they never achieve a state of equilibrium
7. Future is path dependent. To generate a forecast year end state, the model must explicitly evolve the system state over time
8. Model must address both short- (activity/travel) and long-run (land development, transportation infrastructure, etc.) processes. There must be feedback/interaction between both processes
9. Some factors and processes are clearly exogenous to the urban system per se. Others may be treated as exogenous as a modelling strategy
10. Some activities within the urban area are 'basic' in the sense that they arise in response to external demand
11. Ideal model should be conceptualized at a very fine level of representation (i.e. analytical units) so as to maximize 'behavioural fidelity' in the representation of actors and processes, recognizing that any practical implementation probably will occur at higher levels of aggregation"

Verburg stresses the goal to integrate "feedbacks between driving factors and effects of land use change […], the feedback between local and regional processes, and the feedback between agents and spatial units"[400]. Haase, focusing on such feedbacks, reviews 19 models with one of the following main purposes: Spatial Economics/Econometric Models, System Dynamics, Cellular Automata and Agent-Based Models.[401] She concludes, "[e]ach author or working group has its own view and focuses on other parts of the urban system and the relationships within that system. Thus, the landscape aspect is of minor importance. […] We see the reason for this in the gap between social science methods and findings, and computational models […]. To bring both approaches together and to better incorporate qualitative, social

[399] [HUNT 05], p.369
[400] [VERBURG 06] in [HAASE 09], p.7
[401] [HAASE 09], p.11-13

science data into quantitative models is still one of the major challenges of urban land use and landscape modelling.”[402]

This challenge is obvious when models deal with urban sustainability. The implicit normative character of urban sustainability increases the systemic complexity, especially when the evolution of individual and social preferences is considered. Grosskurth lists models that deal with the management, control and manipulation of complex systems but they seem to be only stepping-stones on the way to a comprehensive system approach. [403] The theoretical objectives and the practical achievements of such models differ, often considerably. [404] Van der Sluijs describes the theoretical objectives of such an approach with “model[ling] the complete so-called causal chain, including all the feedbacks within this chain. The causal chain starts with socio-economic drivers leading to economic activity and other practices, leading to emissions and other pressure on the environment[,] leading to environmental changes, leading to physical impacts on societies and ecosystems, leading to socio-economic impacts, eventually returning to cause changes in the socio-economic drivers.”[405] Another objective is “the transparency of models; their capability to explore uncertainties, trend breaks and discontinuities; their potential to foster deliberation and their relevance to decision makers”[406] These objectives are not met yet.[407]

Integrated assessment models are not ready to address complex sustainability problems, neither vertically nor horizontally. Horizontal integration means the incorporation of the different dimensions of sustainability.[408] Vertical integration refers to the interlinkages of causes and effects adapted from DPSIR (see above). Especially, the cultural dimension is not part of simulations at all.

The sufficient complexity of a simulation system remains a crucial point. A too-straightforward, easy-to-use model with a large group of different stakeholders and multiple decision parameters will likely lead to incorrect forecasts because essential feedbacks are not modelled and further effects (secondary or tertiary) of activities and processes are not taken into account. On the other hand, too much complexity would hinder practical application because of the large amount of necessary data and the high level of user skill required. This is a common experience of land use models.[409]

To demonstrate the scope of urban simulations, two tools with different scales (neighbourhood and city) are introduced: the Sustainable Urban Neighbourhood Modelling tool (SUNtool) and UrbanSim.

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402 [HAASE 09], p.19, see also [GROSSKURTH 07], p.3, [LEITMAN 99]
403 Beside others [EHRENFELD 05], [ROTMANS 98], [FORRESTER 69]
404 [GROSSKURTH 07], p.3
405 [VAN DER SLUI 97]
406 [GROSSKURTH 07], p.3
407 [TOTH 03] and [GREEUW 00]
408 [GROSSKURTH 07], p.3
409 [LEE 73] and [LEE 94]

II5.1 SUNtool (Sustainable Urban Neighbourhood Modelling tool)

The Sustainable Urban Neighbourhood Modelling tool (SUNtool) has two components: modelling and educating. The first component integrates architectural design and environmental simulation[410]. Moreover, SUNtool supports users' ability to optimise the sustainability of designs. The user of the SUNtool draws the form of a neighbourhood and sets the descriptions of building use and age as well as default values for attributes of the buildings' construction and operation.[411] The scale can range from several buildings to a whole quarter (50-500 buildings). Additionally it simulates climate information (the microclimate) surrounding the buildings. An important concern is the influence of occupant behaviour on the consumption of resources, which constitutes one of the greatest uncertainties in building simulation.[412] Whereas classic simulation programs concentrate on buildings' heat balance and electricity use, newer approaches tend to incorporate water use as well as household waste production based on stochastic methods. SUNtool's objective is to develop a first approximation for a method capable in "predictions of casual heat gains and any associated electrical power load, water (differentiating between hot and cold) and waste (human/refuse) production which if aggregated produce reasonable means and variances (compared to say a repeated casual gain profile)."[413]

The goal of the educational component is to give insight into design problematics and to present guidelines, benchmarks and examples of successful neighbourhoods.

With its holistic approach, the tool aims at reducing uncertainties in the design and planning process and at supporting the choice of sustainable technologies.[414]

Issues like transportation, consumption of materials related to "short (food, clothing), medium (furniture, automobiles) and long time (constructional) scales" are not considered. There is also no alternative design comparison.[415]

In recent years, development of the tool has been targeted at understanding and incorporating the "evolutionary dynamics of urban metabolism".[416] The objective is a current description, representation and calibration of resource flows by their production source. The simulation model for sustainability will include interdependencies and

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410 [SUNTOOL 06]
411 [ROBINSON 07b], p.1197-1201
412 ibidem, p.1201-1204
413 [ROBINSON 03], p.1118
414 See for more in [SUNTOOL 06]
415 [ROBINSON 07], p.218
416 ibidem, p.221

crucial key processes in a city. The authors hope that "computational optimisation methods could be used to identify promising strategies which lead a city to evolve along a sustainable pathway"[417]. The basic process starters in the simulation are urban agents with interlinkages with each other and explicit spatial dependency. Such microscopic simulations (microsimulations) allow understanding of the competition for the local urban space between the different agents and the respective resource demand. This understanding helps to analyse strategies on a very local level and to enable actions that facilitate transportation, reduce and combine resource consumption and improve the quality of life in a city. The modelling of complex systems based on actions and interactions of agents without considering external forces is an interesting approach to find ways to realise higher overall sustainability and satisfy the basic demands of actors.[418] CITYSIM is the successor of SUNtool and aims to incorporate transport and to achieve a "comprehensive micro-simulation of resource flows for sustainable urban planning".[419]

Review and Positioning within the Adaptive Cycle Framework

SUNtool is able to simulate the environmental impact of buildings within an urban fragment. It implicitly expects a stable level of use of buildings and only partly incorporates possibilities of change, e.g. different behaviours among occupants. The environment is considered in terms of waste and energy/water consumption. No system relevant information is collected. CitySim shall be more powerful but it has yet to be released; journal articles and conference papers are the only source for information.

SUNtool concentrates on the ecological dimension. The level of ecological potential is examined. The tendency of the ecological potential is partially considered by the aim to find improvement opportunities. Simulations of the effects of microclimate on urban form could assess, in part, ecological connectedness, but it is not clear what the tool can produce exactly. If an urban fragment is a group of constructions that are dispersed, then climate simulation will not work. The tendency of ecological connectedness is not considered. Neither the level nor the tendency of ecological resilience is assessed (Table 29).

[417] ibidem, p.221
[418] ibidem, p.221
[419] [ROBINSON 09], p.1

		Resilience	Potential	Connectedness
Ecological	Level		●	○
	Tendency		○	
Cultural	Level			
	Tendency			
Social	Level			
	Tendency			
Economical	Level			
	Tendency			

Table 29 Dimensions of sustainability and adaptive cycles considered by SUNtool

II5.2 UrbanSim

UrbanSim is a well-known open source software that "allows any interested user to apply, modify and redistribute the source code without costs"[420]. UrbanSim differs greatly in its layout from other current modelling approaches. Synthesised households are stochastically assigned to parcels with a cell breadth and width of 150 meters.

UrbanSim simulates, among others, "the creation or loss of households and jobs by type (based on demographic and economic transitions), the movement of households or jobs within the simulated region (based on a household and employment mobility model), location choice of households and jobs from the available vacant real estate (based on a household and employment location model), the location, type and quantity of new constructions and redevelopments by developers (based on a development model) and the price of land at each location (based on a land price model)"[421].

The development of land use is the result of market-driven decisions of various actors interacting with each other. Due to the fact that the behaviour of individual actors is a subject of the simulation, UrbanSim can be considered a microsimulation, even if the resolution is not (yet) at the level of an individual person[422]. Usually, the data on land use and induced traffic, socio-demographics and development scenarios can be retrieved from a central database. For the calculations, the software accesses the database sequentially for the variables and updates it with the results, e.g. the new location of households or new land prices. These calculations are repeated for each simulated year.[423] The central function of the database is to collect information on the recent past, so that rules and patterns for the future can be derived. The important point about the data is that its existence does not necessarily mean its availability. Usually the question of availability depends on costs and access. Unexpectedly, it is less difficult to handle the frequent fact that

[420] [WADDELL 02]
[421] [PFAFFENBICH 03], p.43
[422] [LOECHL 07], p.3
[423] [LOECHL 07], p.4 and see for more detail [BATTY 01]

the desired data does not always exists; it is common practice to look for and use estimates or data from other similar regions or similar contexts. This is often unavoidable; as such data sets commonly have inconsistencies and gaps, which have to be coped with.

Review and Positioning within the Adaptive Cycle Framework

The application of UrbanSim to urban fragments is rather impractical. Already the data collected from different institutions with dissimilar methods and varying backgrounds can require considerable effort to make compatible. This is the case for data on building volumes and floor areas, where the source, i.e. insurance data, is not complete or has systematic bias. The year of construction indicated in the record might actually be the year of the first insurance contract, not the true year. The differing years (construction, contract or change) are often aggregated into one number by approximation or average.[424] Besides issues with data, the modelling concept of UrbanSim does not fit to the definition of urban fragments: if an urban fragment is dispersed then the land use approach of UrbanSim is too detailed to be applicable. The area of an urban fragment is usually too small and has many more links to the outside than interlinkages within. UrbanSim concentrates on land use, household and job types. It takes the built environment for granted. UrbanSim is basically economically driven and the results are concerned with the dynamics of the behaviour of people and less with their influence on the environment and cultural impacts. The simulation model and the results can be interpreted for the current economic and, partly, for social potential and connectedness (level). Under stable circumstances, tendencies are also part of the calculation results. The model behind the simulation can also allow illustration of the economic reaction capacity (resilience level and tendency) of well-conceptualised impacts. Social resilience is more difficult and would entail incomplete, indirect and questionable interpretation of the results (Table 30).

		Resilience	Potential	Connectedness
Ecological	Level			
	Tendency			
Cultural	Level			
	Tendency			
Social	Level		●	●
	Tendency		○	○
Economical	Level	○	●	●
	Tendency	○	○	○

Table 30 Dimensions of sustainability and adaptive cycles considered by UrbanSim

[424] See also [LOECHL 07], p.5

II5.3 Positioning within the Adaptive Cycle Framework

The two types of simulations have to be handled differently.
SUNtool simulations demonstrate more sensitivity at smaller scales and refer to individual buildings. They also require stable circumstances (r to K phase), i.e. the buildings have a constant existence. This persistence is the basis for the construction activity and microclimate calculations. Other phases of adaptive cycles cannot be modelled due to their highly dynamic parameter changes.
UrbanSim needs an urban context that is in a K phase (Figure 33) where the parameters must be stable but relationships may be complex. Other phases are too dynamic in their settings to be stable. City simulations, such as UrbanSim, are based on aggregated cells and do not take into account single constructions. Small changes[425], e.g. the change of the type of a cell into another or an exchange of cell types, are not realised within the larger framework as changes within the adaptive cycle.
However, at the local level such a change can have great significance or severe impact on the urban fragment and the daily life of inhabitants, e.g. if a department store closes. Situations in the past can be well simulated (ex ante) but the assumptions about future developments can only be based on experience and simulation results.

Overall the simulation tools cover many points of sustainability dimensions but they differ from each other spatially and temporally. Therefore, their results are apparently not comparable as long as they do not base on the same system definition.
UrbanSim is usually used for a period a decade or two in length. SUNtool could span several decades. UrbanSim can model a whole city considering internal interlinkages, whereby SUNtool concentrates on a neighbourhood and regards internal connections less. There is also a big difference between how the two tools consider microclimates within their urban simulations: complex physical laws steer UrbanSim, while the driving factors in SUNtool are much more complex due to its higher dynamism. Embedding the simulations within the adaptive cycle would help them to understand the dynamics surrounding the simulated object, e.g. the same policies for similar cities can result in divergent outcomes when the adaptive cycles they are in differ.
The research focus is to validate the development over a certain duration. For simulation to function during this period, no big conceptual changes can occur and parameters must remain nearly constant (Figure 33). Conceptual changes require a reset of the parameters to refit the reality and cope with a transition into another adaptive cycle. The aim to discover more about the system dynamics is futile; the system is always running behind due to the complex dynamism of reality.

[425] i.e. loss of cultural values

The scale of urban fragments does not allow a system limit that facilitates modelling where interactions within the urban fragment are considered in depth. Obviously, there are interdependencies such as owner strategies to delay action, which influences the decisions of other owners, or the increase of land prices due to new projects or constructions. The modelling of these types of scenarios would need detailed information on the specific real estate market. [426]

[426] The historic analysis of the development of building stocks shows that punctually there can be important short-term changes but that as a whole the stock changes slowly. This is due both to the political institutions, the economic conditions and last but not least: the solidity of the traditional buildings. So the conclusion is that fast changes are not impossible but that on the whole they are not probable. Looking at the micro level however there can be a multitude of changes which are not fast and dramatic but which are incremental, slow and not visible in the beginning. Over longer periods they result in loss of all type (building fabric, cultural information, social capital). The scenarios and modelisation can take into account this type of slow/internal changes only to a certain degree. From the losses of cultural capital the results can be dramatic. [HASSLER 09]

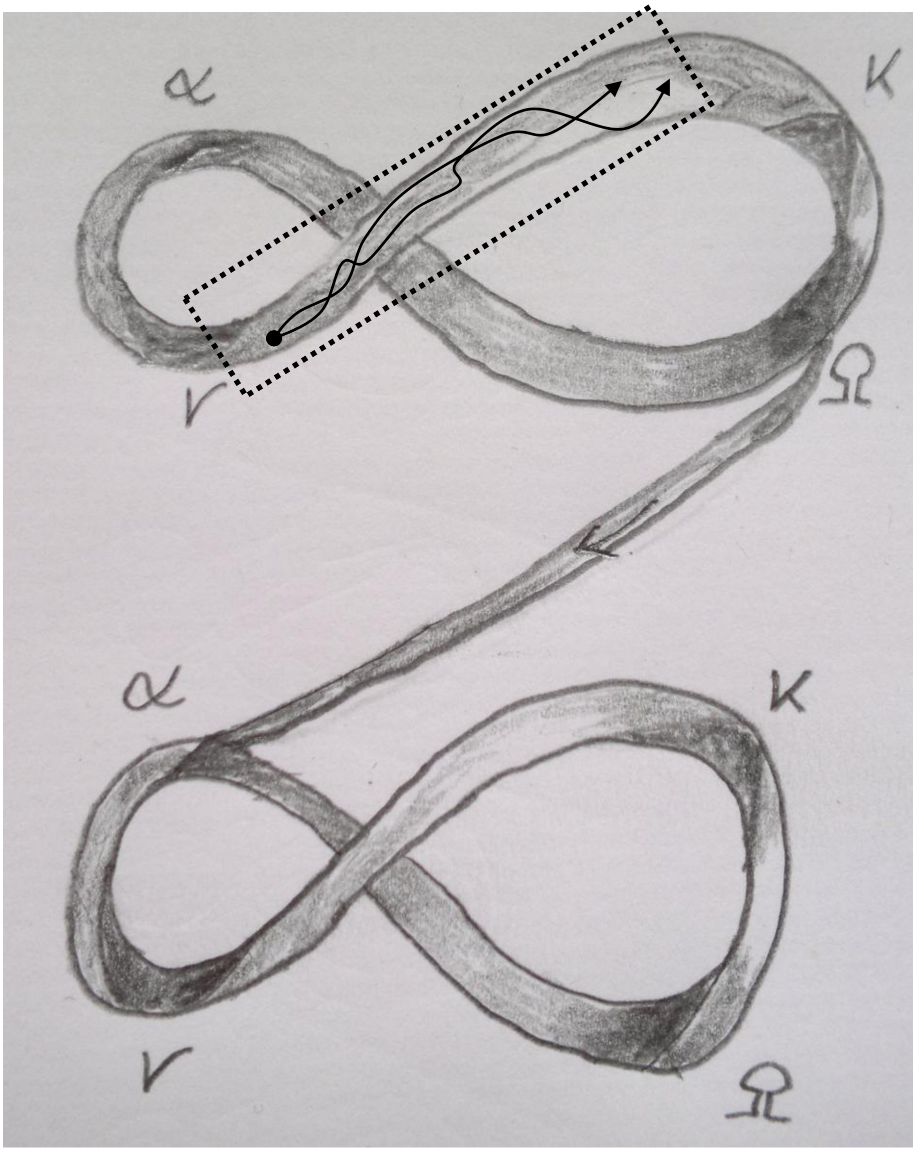

Figure 33 Stable circumstances are mainly found in phase r and phase K. Whereas in phase r there is higher dynamism, in phase K the system is much more complex.
Urban simulations are able to produce results for a certain duration with stable circumstances (i.e. constant or predictably changing parameters). System changes are difficult to simulate due to uncertainty about the parameters.

II6. The potential of spatial-temporal simulation

Introduction

Due to its importance, spatio-temporal analysis is examined here in more detail. It generally uses Geographic Information System (GIS) support and contributes to understanding the geographical situation of an urban fragment. Due to the predominance of temporary aspects in succession, it is important to take into consideration ways to represent time and space. Considering mosaic cycle theory (see Section I2.5, p. 11), it seems crucial to understand the interdependencies in space and time as well as the technical facilities to work them out.

The vast field of theory regarding multidimensional representation in relation to GIS has its origins in antiquity[427] and is still an important and ongoing research area, as demonstrated by the 2008 Noble Prize for Economics. The key idea within the concept of geographical phenomena is identification. The identification of phenomena occurs by the interaction of "socially driven cognitive acts with the heterogeneous structure of the world"[428].

The following considerations on spatio-temporal GIS are based on a presentation (in cooperation with Prof. Dr. Niklaus Kohler and Martin Behnisch) at the 2006 EMUE conference in Paris.[429]

Widespread methods for visualisation are tables and charts. The first show too much data in one view and the latter aggregate data so that important information may be biased[430]. Users need a combination of several media such as text, graphics, sound, animation and video, or powerful visualisation techniques[431] such as virtual reality, to represent and convey information. Visualisation has been increasingly important for strategic analysis in the last 150 years. An often-mentioned study of 1854 is Dr. John Snow's discovery on the outbreaks of cholera by mapping the relation between cholera and water supplies.[432] The explicit aims of many early experiments with automation in cartography[433] were the improvement in the efficiency and scope of mapping through digital methods[434]. Already the antecedents of GIS, like automated address matching, became more and more attractive with increasing processing speeds[435]. This continued and made it a significant tool for the exploration of locations, using graphical display as a visualisation means. There has been a rapidly growing interest in

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427 [RAPER 01], p.85
428 [RAPER 01], p. 122
429 [AKSOEZEN 06]
430 [HAO 07], p.1
431 [HAO 07], p.1
432 [SNOW 55]
433 [TOBLER 59]
434 [COPPOCK 91]
435 [COPPOCK 91], p.26

new visualisation methods for cartographic data in recent years by the GIS community, including in the visualisation of alterations in maps to facilitate spatio-temporal analysis, process modelling and animated maps. An important area of visualisation in GIS is 3D visualisation technology connected with new techniques in multimedia, 3D modelling and virtual reality.
The advancement of geographical information systems based on the development of Geographic Information Science (GISc) as a field of study, which emerged in the early 1990s[436] and had its 20th anniversary in 2010[437]. The term GISc was first used in the title of a paper by Goodchild[438] and is described in the following way: "Information science generally can be defined as the systematic study according to scientific principles of the nature and properties of information. […] GISc [is] the subset of information science that is about geographic information."[439] Raper summarises that "GISc today is a dynamic and multidisciplinary framework rich in new opportunities for research."[440] Other researchers prefer the term 'geocomputation' to describe the connection of computation with space and time, especially in the formulation of models.[441] Openshaw described geocomputation as "the application of a computational science paradigm to study a wide range of problems in geographical and earth systems … contexts".[442] The term geocomputation refers to an array of activities involving the use of new computational tools and methods to depict geographical variations of phenomena across scales.[443]

A temporal Geographic Information System (tGIS corresponds to the expression "4D GIS") supports the administration and analysis of the temporal changes of spatial objects. Typical functions are the collection, management, analysis and visualisation of data in consideration of both temporal and spatial modelling. There are many reasons why a fully operational tGIS does not exist at present. The shortcomings of the current GIS lie in its highly abstract view of the world and how it deals with the complex ways in which phenomena change over space and time.[444]
Harvey proposed "a general theory in geography that examined the interaction between temporal process and spatial form"[445]. Theories on time supply a variety of approaches to conceptualise events and change.[446] Frank argues that models of time can be classified by types

436 [RAPER 01], p.4
437 [GOODCHILD 10]
438 [GOODCHILD 92]
439 [GOODCHILD 98], p.7
440 [RAPER 01]
441 [COUCLELIS 98]
442 [OPENSHAW 00], p.3
443 [LONGLEY 98]
444 [GOODCHILD 00]; [HORNSBY 00]; [WANG 01]
445 [HARVEY 69], p.484
446 [POIDEVIN 98]

of temporal representation primitives (points or intervals), the distinction between linear and cyclic times, the contrast between ordinal and continuous times, and the viewpoint employed.[447]
Research on modelling temporal GIS dates back to the mid-1980s.[448] Its aim is to work with, organise and analyse spatio-temporal data. As with other information systems, its capabilities are strongly dependent on the design of its data model, which constitutes the conceptual core of an information system.[449] Data models define data objects, types, relationships, operations and rules to preserve database integrity.[450] A stringent data model must be able to cope with spatio-temporal queries and analytical methods that may be applied in a temporal GIS. The definition of data objects in data models must be capable of storing and retrieving information on temporal constructs for analysis in a GIS. Without a good data model, a temporal GIS will support temporal queries and analysis inefficiently.[451] Non-temporal GIS data models are based on static representations of reality.
A set of single-theme layers as regular (raster) or irregular (vector) tessellation models represents the geographic information for the area of interest.[452] Transitions, motions and other dynamic information are not mappable with these layers. Raster cells encode the values of attributes for each location without consideration of temporal characteristics.[453] In contrast geometrically indexed vector objects ”force a segmentation of the entities being represented into separate layers whenever they interact in time or space: adopting this representational method forces compromises on most environmental modelling”.[454] To cope with geographic complexity, scale differences, generalisation and accuracy,[455] GIS requires a stringent and consistent framework[456].

Adaptation to the Urban Context and Variations

Current GIS software presents numerous deficiencies in visualisation methods for events where time and location are of equal importance, such as inventorying spatio-temporal data and the interpolation of functions for the management of a continuous period.[457] In the last two decades, many research efforts concentrated on the development of temporal databases and temporal query languages.[458] The proposed methods for the incorporation of temporal information into a relational

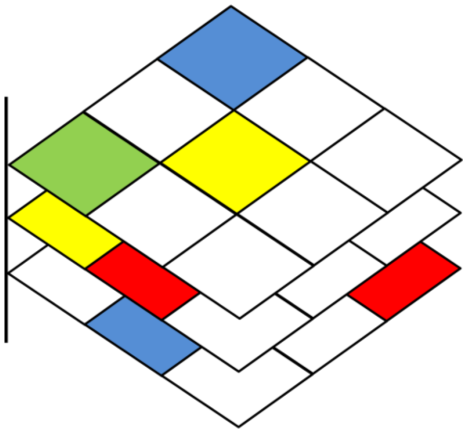
447 [FRANK 98], p.45
448 [YUAN 96], p.10
449 ibidem, p.1
450 [DATE 95]
451 [YUAN 96], p.1
452 [FRANK 91]
453 [YUAN 96], p.1
454 [RAPER 95], p.359
455 [BURROUGH 95]
456 [GOODCHILD 92]
457 [LONGLEY 96]; [HORNSBY 00]
458 [TANSEL 93]

database comprise time-stamping a relation (a table[459]), individual tuples (ungrouped relations[460]) or individual cells (grouped relations[461]). Two concepts help to describe the passing of time in GIS: continuous and discrete time instants.[462] There are also other differentiations such as flow oriented (similar to continuous) and event oriented (similar to discrete).[463]

II6.1 Continuous time instants and intervals

The continuous approach is viewed as being isomorphic to real numbers, with each real number corresponding to a "point" in time. Continuous instants are just points on the line of all anchored time specifications. They are entirely ordered by the relation "later than" [464]. Langran, in examining the exploration of spatio-temporal knowledge representations in GIS, employs the concept of 'dimensional dominance' to describe how spatio-temporal information is usually dominated in display and query terms by either the space or the time dimension.[465] The length of the time sequence is the time state, and specific events occur during the time sequence. [466] Langran provides a comprehensive synthesis of temporal GIS research.[467]According to the three relational database approaches, GIS spatial data models can work with temporal information by time-stamping layers (the snapshot models[468]), attributes (space-time composites[469]) and spatial objects (spatio-temporal objects[470]). The snapshot model comprises temporally homogeneous units of one theme in one layer (Figure 34, left). This model illustrates "the states of a geographic distribution at different times without revealing the explicit temporal relations among layers."[471] The time intervals between layer pairings can vary and there is no information on the occurrence of changes between two layers. Another implementation of the snapshot idea is Beller's Temporal Map Sets model (Figure 34, right). It enables the modelling of geographical events that are either valid or not for a cell, creating binary Temporal Map Sets.[472]

[459] [GADIA 85]
[460] [SNODGRASS 85]
[461] [GADIA 88]
[462] [PEUQUET 02] and [BOGAERT 01]
[463] [RABE 08], p.585
[464] [SNODGRASS 92], p.3
[465] [LANGRAN 92] and [LANGRAN 88]
[466] [SNODGRASS 92], p.3
[467] [LANGRAN 93]
[468] [ARMSTRONG 88]
[469] [LANGRAN 88]
[470] [WORBOYS 92]
[471] [YUAN 96], p.1
[472] [BELLER 91]



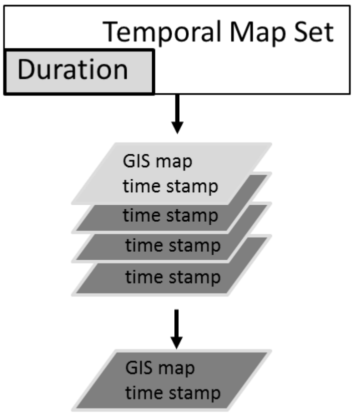


Figure 34 An example of the snapshot model (left) and of a Temporal Map Set (right)
Source: [ARMSTRONG 88] (left) and [BELLER 91] (right)

Obviously, these approaches frequently create data duplications with the same properties in space and time. Langran illustrates that the creation of temporally distinguishable layers at relation, record or attribute level results in a barely acceptable additional data volume (data redundancy) and violations of integrity in the tables (data inconsistency).[473] The Space-Time-Composite (STComposite) data model improves the snapshot spatial data model by combining separate GIS layers representing different time points into a single STComposite GIS layer of all changes that have occurred over all periods (Figure 35).[474]
Discrete points in time serve to record attribute changes, whereby "its temporal resolution is not necessarily accurate"[475]. The STC model facilitates the recording of attributes within the largest common units of space and time (i.e. alteration in situ), but when it comes to capturing attribute changes in space (i.e. movements) it does not succeed. This means some updates to the database of STC require a reconstruction of the STC units, so the relationships (geometrical and topological) between STC units alter and the "whole database, both spatial objects and attribute tables, need to be re-organized"[476].

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[473] [LANGRAN 88] and [YUAN 96], p.1
[474] [LANGRAN 88] and [LANGRAN 92]
[475] [YUAN 96], p.2
[476] [YUAN 96], p.2

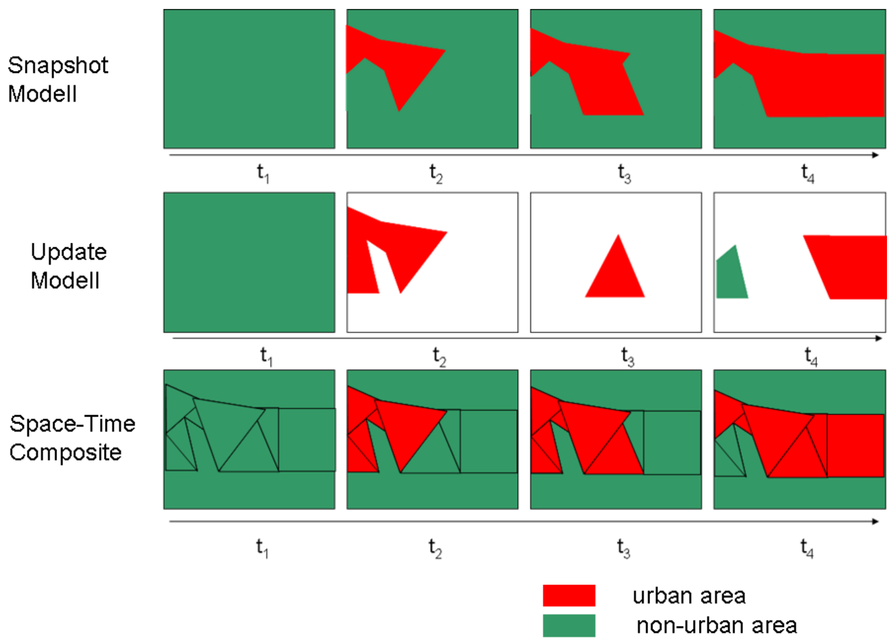

Figure 35 Space-Time-Composite model
Source: [LANGRAN 92] and [LANGRAN 88]

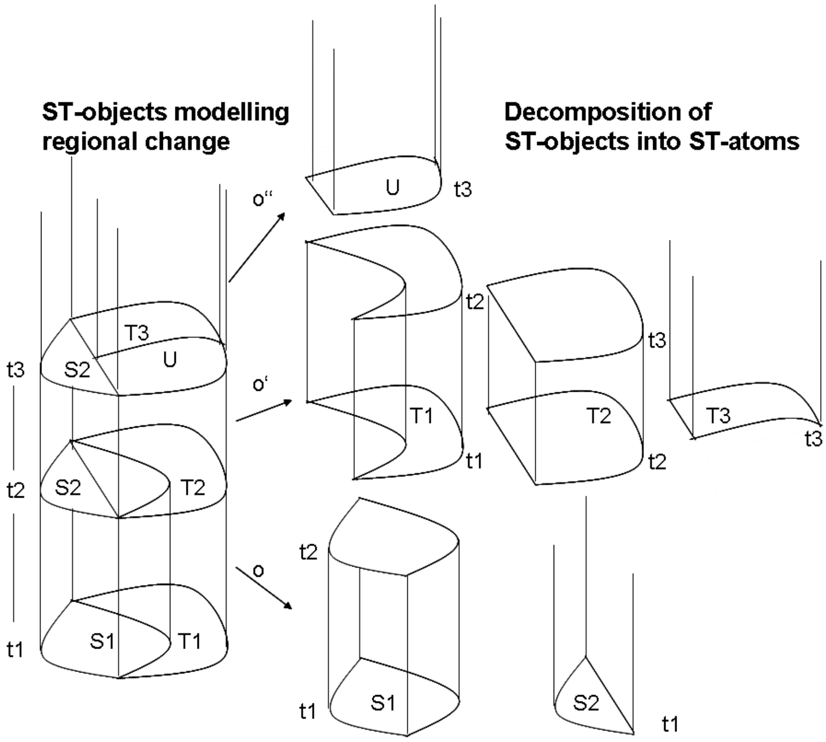

Figure 36 Spatio-temporal Objects and Atoms
Source: own illustration of [WORBOYS 92]

Worboys proposes an object-oriented spatio-temporal data model, in which objects are two-dimensional spatial objects along a third dimension for the event time linked with each object[477] (Figure 36).

The organisation of data is along a temporal dimension (i.e. event lists) and a spatial dimension (i.e. the smallest geographic units).[478] The basic

477 [WORBOYS 94] and [WORBOYS 92] and [XIN 02]

elements in the data model are spatio-temporal atoms that have homogeneous properties in both space and time. The spatio-temporal atoms (ST-atoms) form spatio-temporal objects (ST-objects) that represent the changes of real-world entities. The data model maintains persistent object identification numbers for both ST-atoms and ST-objects in order to monitor individually their links and their changing history.[479] Worboys later developed this approach further into a spatio-bitemporal model adding a second time axis to record the existence of an object also in database system.[480] The snapshot, STC and ST-object models can represent states through time. The latter two are also capable of dealing with changes of locations. None is able cope with transition, process or motion.[481] Further developments in temporal data models are based on the concept of time sequences (temporal sequence collection[482]) and time objects.[483] They are comparable with Peuquet's schemata in which attribute, spatial and temporal reference (what, where, when) define an object and allow formation of a history model: "Spatial-temporal data is the records of spatial data changes in a period of time. It was process complex phenomena at the interaction between time and space."[484] Peuquet proposed an event-based approach to temporal change called the Event-based Spatio-Temporal Data Model (ESTDM). An event component illustrates alterations to "a pre-defined location (a raster cell) at a particular point in time"[485] (Figure 37). A component memorises the new value of all grid cells that underwent alterations of a specific attribute from t_{i-1} to t_i and the spatial information of grid cells that received the new value. Each grid cell equals the "smallest spatial feature stored in the space-time composite model that permits the storage of its change history. The ESTDM also includes a header with a time stamp of t_0 pointing to the base raster layer of the initial state of the entire study area. This design allows the ESTDM to record only amendments with respect to the initial and previous states." [486] ESTDM seems capable to support spatial as well as temporal queries efficiently. Originally developed for raster-based GIS, the adoption of the ESTDM model to a vector-based system makes the substantial redesign of event components necessary. Changes of spatial objects or their topology would fragment historical or transitional information of an entity or a process. This requires mechanisms that allow event components to maintain their pre-defined entities and locations.[487]

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478 [WORBOYS 92] and [XIN 02] and [SHAW 02]
479 [WORBOYS 94]
480 [WORBOYS 98]
481 [YUAN 96], p.2
482 [SEGEV 93]
483 [WUU 92]
484 [PEUQUET 94]
485 [YUAN 96], p.3
486 [SHAW 02]
487 [YUAN 96], p.3

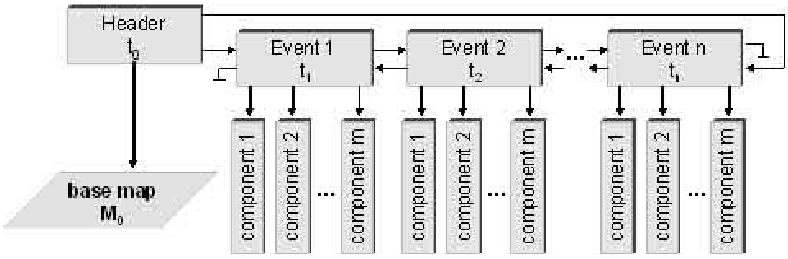

Figure 37 Example of the primary elements, pointer structure of an ESTDM Source: own illustration of [PEUQUET 95], p.15 in [AKSOEZEN 06] and [WITTMANN 06]

In contrast to ESTDM, where changes are stored for a single-theme at a pre-defined location, OOgeomorphs' design aims to "incorporate geomorphological processes and theories with classes in an object-oriented representation"[488]. Objects have references in attribute classes to information on 3D location and the time dimension. In contrast to Worboys' space-time object model[489], OOgeomorph stresses the importance of a physical system and processes within the system. It can handle point-based location information well, but it has "difficulty in manipulating area data and topological relationships".[490] Temporal GIS modelling presents challenges in cases when identities of spatial objects require persistence along the evolution of the geometrical properties and topological relationships.[491] Attribute changes are caused by phenomena, environmental settings, behaviours of an event or mechanisms of a process. Yuan defines six major types of spatial and/or temporal changes in geographic information[492] (Table 31). Current temporal GIS data models have difficulties in completely mapping Type III to Type IV changes.[493] Temporal GIS addresses these kinds of change and seems to be a promising method to reveal characteristics on a temporal scale with the originally available spatial scale. Langran states that "[p]recisely articulated information about what and where changes occurred within a geographic area is at the heart of a TGIS"[494]. The incorporation of time as a component of a geographical object greatly increases the feasibility of temporal analyses and tracking the history of objects.[495] The current approaches show some comprehensive research results for the integration of spatial data models into spatio-temporal data models but there is no commercial GIS software.

	Description of different types of changes

488 [RAPER 95]
489 [WORBOYS 98]
490 [YUAN 96], p.4
491 ibidem, p.5
492 [YUAN 95]
493 ibidem, p.10
494 [LANGRAN 92], p.419
495 [LESLIE 01]

I	For a given site where occurrences and duration of events or attributes may change from time to time, analysis is done by fixing location, controlling attribute, and measuring time.
II	For a given point in time where a certain phenomenon may change its characteristics from site to site, analysis is done by fixing time, controlling attribute, and measuring location.
III	For a given period of time where attributes may change from site to site, analysis is done by fixing time, controlling locations, and measuring attributes.
IV	For a given event where its characteristics or processes may change at sites through time, analysis is done by fixing attributes, controlling locations, and measuring time.
V	For a given area where attributes may change site to site and from time to time, analysis is done by fixing location, controlling time, and measuring attributes.
VI	For a given event where its location may change from time to time, analysis is done by fixing attributes, controlling time, and measuring locations.

Table 31 Major types of spatial and/or temporal changes
Source: own illustration of [YUAN 95]

II6.2 Discrete time instants and intervals

The discrete time approach is viewed as isomorphic to natural numbers. Snodgrass uses a discrete model and proposes that time is modelled by a closed interval on the real number line.[496] Time has both an origin and an endpoint. The timeline can be subdivided into a finite number of contiguous, pair-wise disjointed sub-intervals. Each sub-interval is called a chronon.[497] A chronon is the smallest duration of time. A different model of time, where the chronons are partially ordered, is called branching time. As one can count the chronons, the size of each chronon is usually fixed by the granularity of the interpretation (e.g. second, day or year).[498] The notion of discrete time is based on the time geography of Hägerstrand, who came up with the concept of a space-time path to represent how an individual navigates his/her way through the spatial-temporal environment.[499] The physical environment around a person is reduced to a two-dimensional layer. There his or her location and destination are illustrated as zero-dimensional points. The vertical axis represents time. The three dimensions together create an 'aquarium' showing a specific partition of space-time (Figure 38). Miller illustrates how space-time prisms could be applied to modern transportation GIS systems.[500] Spatial-temporal positions linked together make up a space-time path, which an observer can follow[501]. Four characteristic elements describe a space-time path[502]: 1. states characterise an entity at a defined point of trajectory; 2. events represent the points of time that are responsible for changes and in a chronology they document an existing process; 3. episodes describe the duration of a state, the duration of a change of state or the duration of an event; 4. verifications or reasons are an expression of the existence of entities and states or the beginning of events[503].

[496] [SNODGRASS 92]
[497] ibidem, p.3
[498] ibidem, p.7
[499] [HÄGERSTRA 70]
[500] [MILLER 91]
[501] [WACHOWICZ 99], p.17, 18; see [KWAN 00] for space time aquariums
[502] [KRAAK 94], p.4 and [LANGRAN 92]
[503] [WACHOWICZ 99], p.20; [KRAAK 94], p.5

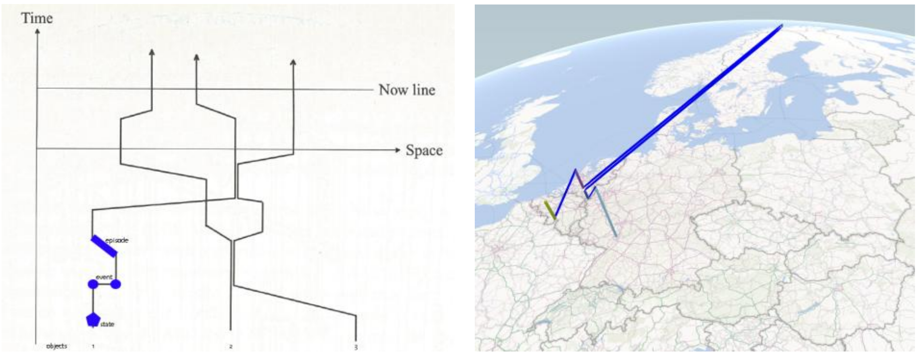

Figure 38 Examples of a space-time path
Source: Own illustration of [WACHOWICZ 99], p.17 (left), own illustration of a path similar to a space time aquarium created with Microsoft GeoFlow Preview for Excel 2013 (right)

In recent years, there have been several related projects: CHOROCHRONOS by the European Union[504], ‘Time Center’ by cooperative research groups of scientists from Europe and the USA[505] and ‘Spatial and Temporal Object Databases’ at Keele University in the UK.[506] A temporal and spatial topology model for building information systems was a research topic at the University of Karlsruhe.[507] Moreover, representation and “reasoning about space and time is a major field of interest in many areas of theoretical and applied Artificial Intelligence, especially in the theory and application of temporal and spatial models in planning, high-level navigation of autonomous mobile robots, natural language understanding, temporal databases, and concurrent and distributed programming”[508].

II6.3 Review and Positioning within the Adaptive Cycle Framework

Spatio-temporal simulation helps to represent dynamics but interpretation is left to the user. An examination of location is necessary to obtain deeper insights into the geographical context. Spatio-temporal simulation can support this aim in two ways: 1. it facilitates the visualisation of the temporal development of an area, touching on the technical question ‘how can continuous developments be illustrated?’ 2. it supports the analysis of different points in time.

The first use is more related to specific levels in time. When data is not available and a development must be assessed, a set of indicators, valid and available for the completely examined period, can be generated and GIS analyses can be made based on them. For each time point of

504 [CHOROCHRO 02]
505 [FARIA 98]
506 [MASON 02]
507 [BRADLEY 06]
508 [FLAIRS 07]; see also [FLAIRS 11]

interest, it gives an IS-analysis of that specific situation. Development between the snapshots has to be interpreted independently, which gives some insights into the tendency of the system but does not offer clarity on development.

The second type of application of spatio-temporal simulation concerns different snapshots. The second use is possible when data is available or the time between events can be estimated with little uncertainty. In this case, the continuous visualisation of development can be undertaken and enables easier identification of the precise time when a change has taken place, of the parallel development processes that have contributed to the change and of their interdependencies.

Hornsby presents one the first commercially used techniques incorporating the time dimension into GIS, the snapshot (time-slicing) model that saves data as discrete slices over time. Problems arise due to the semantics (dynamics) of time and the way time is captured as slices of reality. Necessarily, various attempts at integration have emerged from different perspectives. Still there is no agreement on one particular temporal data model.[509]

Spatial data analysis can provide valuable insights into the processes of urban fragments and specific urban units. For the built environment, the usefulness of navigation through virtual areas is not only spatial but also related to design and morphology. GIS-based analysis in general is not specified for a special topic and so has no particular approach that deals with precise factors of socioeconomic and other household issues. Additionally, spatial information on such issues varies significantly within small areas and is not easy to obtain practically. Information on wealth and education levels, on accessibility to administrative services (e.g. governments, banks) as well as on household sizes are examples of variables that can be critical in determining the choices and constraints of citizens and other actors. Nevertheless, the combination of information on the design and attributes of constructions especially constitute an important source for constructional as well as cultural considerations. Important aspects of (heritage) value assessment have to be connected with the location of a building and its real-world context.[510] Laing suggests widening the possibilities of conservation theory by using emerging computer-based modelling for education and research. Established methods to value heritage and approaches assessing those evaluations will need to be incorporated in geographical information systems themselves. This can be understood in the way that there is a demand for models that facilitate the "interrogation of any cultural data embedded within"[511].

Activities within an urban fragment can have long intervals between each other and sometimes they can follow each other very quickly.

[509] [HORNSBY 00]
[510] [CARTER 02], p.187, 197
[511] [LAING 07], p.839

Continuous instants modelling seems more appropriate for such situations.
Regarding the adaptive cycle concept, spatio-temporal simulation enables the location of economic, ecological, cultural as well as social potential at different points in time in an urban fragment (Table 32). With spatio-temporal simulation, analyses of tendencies will be increasingly improved. With more and more available data and newer analytical approaches, it will facilitate the understanding of geographical influences on the adaptive cycles of urban fragments in detail. Future tools may allow visualising external impacts on internal sources. In recent years, geographic information systems have been getting more and more powerful by connecting simulation and evaluation methodologies.[512]

		Resilience	Potential	Connectedness
Ecological	Level		●	
	Tendency		○	
Cultural	Level		●	
	Tendency		○	
Social	Level		●	
	Tendency		○	
Economical	Level		●	
	Tendency		○	

Table 32 Dimensions of sustainability and adaptive cycles considered by spatio-temporal simulation

The visualisation of connectedness and resilience is dependent on the available knowledge on the urban fragment, which is more difficult to obtain than status data, and needs new visualisation techniques incorporating complex interpretations of real life.
It is possible to use spatio-temporal simulation for the analysis of all adaptive cycle phases. However, current limitations mean that spatio-temporal simulation is best used for analyses of stable phases with potential reduction and potential build-up (r and K phases). Nevertheless, within the highly dynamic phases of adaptive cycles (α and Ω phases), the more snapshots available the more visual assistance there is in interpreting the changes, barriers and interlinkages (Figure 39).

[512] [BEHNISCH 07]

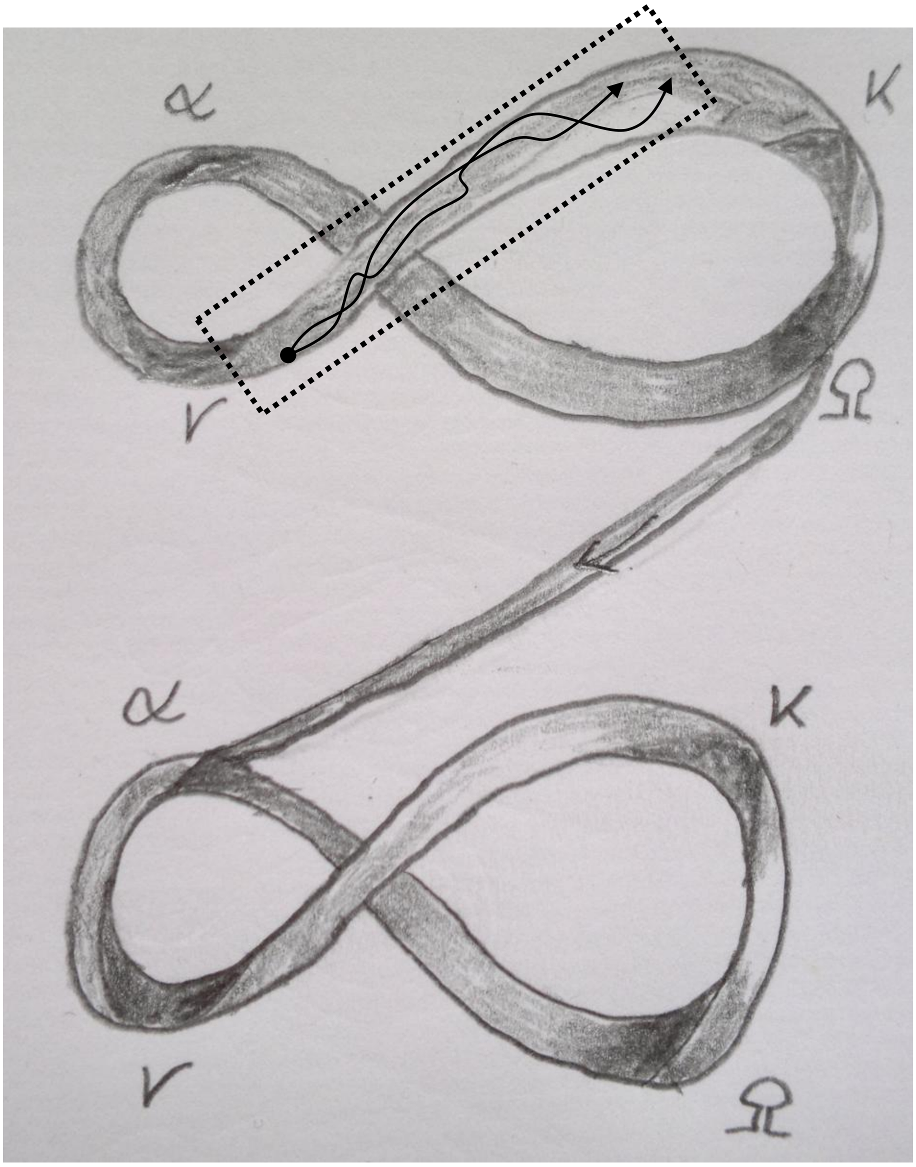

Figure 39 Spatio-temporal information systems and adaptive cycles
Spatio-temporal information systems are able to illustrate the simple spatio-temporal interlinkages of development (stable alternative development paths and changes of the adaptive cycles). In the future, more complex interdependencies (i.e. spatially and/or temporally distinct processes) may be illustratable.

II7. Scenario technique

Introduction and General Description

Scenario technique is one approach to undertake studies on the future. Scenarios describe a logical and plausible follow-up of hypothetical and therefore not unconditioned probable events[513]. Scenario building bases on driving forces that are uncertain like the final outcome of causal action chains or uncontrollable like decision points; the driving forces make up the alternatives for the scenarios[514]. In practice, scenarios can have a descriptive or normative character, can be combined from forecasting or backcasting assumptions, can be based on knowledge and/or opinions and can result in policy settings or what-if trees. Scenario planning results in several "alternative, self-consistent stories about the future" (usually less than 10).[515]

There is a variety of scenario typologies, which Börjeson classifies as predictive, explorative/normative, and which are presented below. [516]

Predictive scenarios answer the question 'What will happen?' and comprise forecasts and what-if assessments. A forecast is the most likely scenario (business-as-usual[517]) and can be paired with a second, less likely scenario. If there are several driving decision or event points, connecting them allows the development of what-if scenarios that are interlinked.[518]

The question 'What can happen?' is answered by explorative scenarios which can be either external or strategic. External scenarios describe possible external developments, which help to position internal actions. Strategic scenarios allow the comparison of the results of strategic decisions under different probable circumstances.[519]

Normative scenarios respond to the question 'How can a specific target be reached?' whereby the targets can be of a preserving or transforming nature.[520] Preservation scenarios aim for a specific target and investigate the needed actions for achieving it. A transformation scenario is a backcasting[521] approach that investigates the necessary changes to reach a target that under business-as-usual development would not emerge.

According to Börjeson, scenario development consists of three steps: the generation of scenarios, the integration or connection to history, and the check on consistency considering interlinkages. The generation of scenarios usually involves several persons. These can be the public (e.g. through surveys), experts or researchers (e.g. for Delphi methods) or

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513[MOFFAT 06], p.48
514 [PETERSON 03], see for scenario building, i.e. [SCHWARTZ 96]
515 [LEMPERT 03], p.30
516 [BOERJESON 06]
517 [MOFFAT 06], p.167
518 [BOERJESON 06], p.726
519 ibidem, p.727
520 ibidem, p.728
521 [MOFFAT 06], p.167

mixed groups (e.g. in workshops). The resulting scenarios need to be integrated or connected to current developments (e.g. through time series analyses, or explanatory and optimising modelling such as simulations). Techniques for checking consistency include cross impact analyses and morphological field analyses.[522]
The time horizon lengthens from predictive forecast scenarios to transforming normative scenarios.[523] The first focus on a short time period (up to 5 years) wherein the understanding of many driving forces is possible. The period of the latter can go up to 100 years.[524]
Figure 40 shows a set of six scenarios from the Global Scenarios Group (GSG) that look at possible interrelated population and economic developments for the 21st century.[525] The 'Reference' scenario represents business as usual, whilst the 'Policy Reform' scenario shows the results of improvement on currently existing values and institutions. The scenario pair of the 'Great Transition' model decentralised and local solutions (Eco-Communalism) and a globally accepted solution (New Sustainability Paradigm). The scenario pair under 'Barbarization' presents situations wherein there is a loss of many of the currently available institutions and values. In the 'Breakdown' scenario, collapse results in a disaggregation of societies into rivalling tribes. In contrast, the 'Fortress World' allows small oases of wealth under internal authoritarian protection and a great number of impoverished outside.[526]

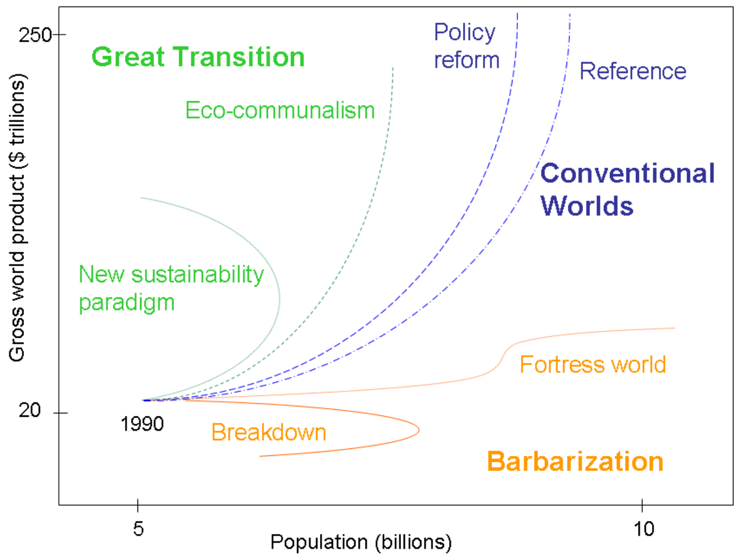

Figure 40 Global Scenario Group results for possible global developments in the 21st century: the Conventional Worlds scenarios with the fewest changes, Barbarization scenarios with the loss of current institutions and the Great Transition scenarios with new institutions facilitating a more sustainable world. Source: own illustration of [LEMPERT 03], p.34

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522 [BOERJESON 06], p.735
523 [MOFFAT 06], p.59, 60
524 [LEMPERT 03], [MOFFAT 06], p.81-100
525 [LEMPERT 03], p.34, see for original figures in [GALLOPIN 97a], p. 14 and for further descriptions of the scenarios [RASKIN 02]
526 [LEMPERT 03], p.33

Application to the Urban Context and Variations

The complexity of urban development makes the scenario technique a tempting approach for planning. Scenarios allow inclusion of environmental, social, economic and cultural aims[527]. The possibility or even need to engage several persons facilitates the incorporation of various disciplines and views. Differences in interpretation can easily become important distinguishing characteristics between scenarios. At a minimum, forecasting can lead to two scenarios allowing the rivalry between a majority and minority, a discipline-related separation or two similarly probable but clearly distinguishable developments. The same reasoning is also applicable to the other scenarios types. The use of further tools and methodologies for scenario planning is obviously conceivable and practised.[528]

Review and Positioning within the Adaptive Cycle Approach

The scenario technique is especially of interest when development is obviously uncertain and outcomes range so widely that possibilities need to be grouped into scenarios (Figure 41). Forecasts and what-if scenarios, which need some basic information on the future development, are applicable in the short term for stable adaptive cycle phases such as r and K. External and strategic scenarios help to deal with longer time periods with more uncertainty. Transformation scenarios make transitions (phases Ω and α) to other adaptive cycles comprehensible. Preservation scenarios help to develop strategies and actions to stay within the same adaptive cycle after a phase Ω. Scenarios support the understanding of adaptive cycles in all phases.

[527] [BOERJESON 06], p.728
[528] [MOFFAT 06], p.79

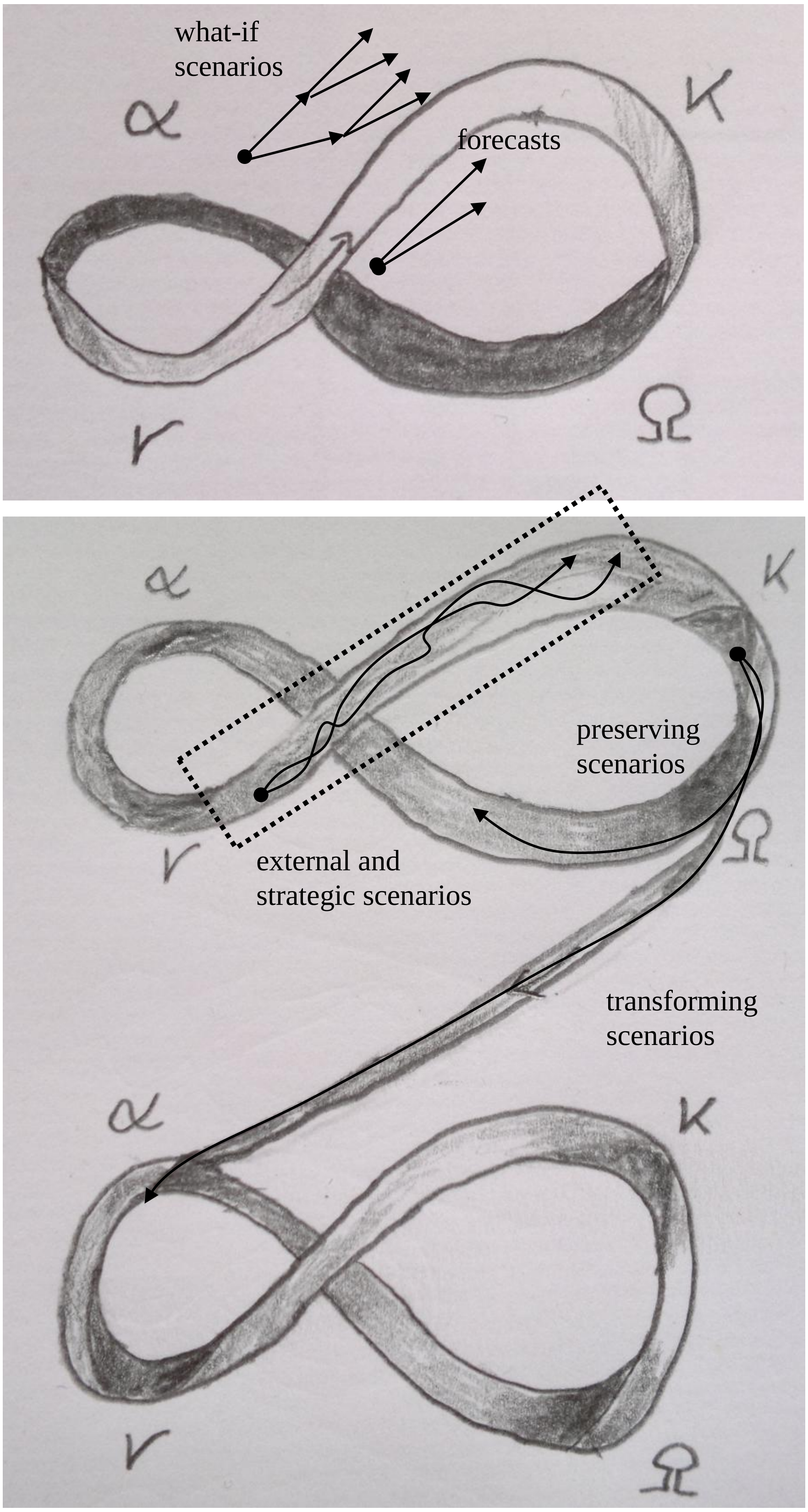

Figure 41 Positioning scenario types within adaptive cycles
Predictive and explorative scenarios can illustrate development under stable circumstances in r and K phases and preservation and transformation scenarios can represent changes after Ω phases (continuation within the same cycle or transition into another adaptive cycle).
Scenario techniques are able to illustrate the development of stable circumstances as well as changes from one adaptive cycle to another one.
The results are more descriptive regarding the circumstances of the cycles.

Applied sensibly, scenarios can qualitatively include all dimensions of both sustainability and adaptive cycles (Table 33), but need the quantitative and qualitative results of other methods as starting points. Their descriptive character and reliance on other tools make them flexible but also more difficult to handle. For the use of quantitative methods, the characteristics of the agreed circumstances have to be transformed into reliable parameters. The scenario developers need to understand the tools and interlinkages on several levels.

		Resilience	Potential	Connectedness
Ecological	Level	o	o	o
	Tendency	o	o	o
Cultural	Level	o	o	o
	Tendency	o	o	o
Social	Level	o	o	o
	Tendency	o	o	o
Economical	Level	o	o	o
	Tendency	o	o	o

Table 33 Scenarios are able to account for all sustainability and adaptive cycle dimensions.
The complexity of their application requires good knowledge of the tools, but their interlinkages limit their quick and immediate use.

II8. Frameworks for City Evaluation

Introduction

There is a discrepancy today between the different goal systems, targets and benchmarks on the one hand and the number of isolated tools that cover the different aspects but are not compatible and do not really share the description of the object (i.e. the urban fragment). The so-called frameworks for city evaluation tend to create a common conceptual basis, establish links between data and results of the tools, and try to relate and visualise the results. These frameworks generally have their own set of values and often propose weighted schemes to aggregate partial results. The existing frameworks have generally the character of prototypes and not of operational tools. Traditional rating methods for individual buildings (LEED, BREEAM, HQE2R), in fact weighted checklists, have been extended in application to neighbourhoods and communities. They constitute a low-level solution, which is very easy to use and to communicate. Until the frameworks include more complex simulation and scenario techniques and efficient stakeholder considerations, these extended rating systems might create illusions of off-the-shelf sustainability evaluations for communities.

II8.1 SUIT

Within project SUIT[529], a framework has been developed that combines the objectives of "long-term active conservation strategies"[530] with assessment methods of a "proposed plan, programme or project"[531] in the form of an EIA and SEA. The EU-funded project structures 19 theses under four themes in order to embed the life cycle of urban fragments into a sustainable urban development framework and specifically to introduce aspects of long-term resource conservation within the urban fabric[532]. The following is a summary of these theses.
In the sixth Position Paper of SUIT.[533], cities are seen as complex urban systems having significant parallels to ecosystems.[534] This analogy helps to understand the challenges of urban sustainability and to find appropriate solutions. Furthermore it is assumed that "techniques from empirical system ecology can be applied to modelling cities"[535] from an urban metabolism perspective. Construction materials, energy, waste, water, biomass and other resources are regarded as flows that are

529 [SUIT 04]
530 ibidem, p.8
531 ibidem, p.14
532 ibidem, p.117-120
533 ibidem, p.2
534 ibidem, p.2
535 ibidem, p.2

triggered by processes (maintenance, restoration and closed cycles) which in turn follow sustainable development objectives. The framework facilitates a theoretic understanding of how urban process actions cause specific environmental impacts. System limits are crucial and only a highly structured ‘cradle-to-grave’ evaluation can allow the comparison of results from a number of specific assessment methods such as Mass Flow Accounting (MFA), Life Cycle Assessment (LCA), Life Cycle Costing (LCC), cultural and social impact assessments, etc. This is also a basis for economic assessments that take into account internalities as well as externalities in the mid- and long-term. The SUIT project assumes that a number of existing assessment methods such as Risk Assessment, SEA, Cost-Benefit Analysis, LCA and LCC would altogether constitute a holistic methodology by sharing their individual data. The improvement of processes and products may support sustainability but in the long term not only efficiency but also sufficiency and resource conservation are necessary.[536] An important question is raised by the SUIT project concerning the systematic description of the built environment, the related use and the construction process. A new framework, extending and combining the mentioned assessment methods, approaches the aim of bringing these together. This combination might integrate the sustainability objectives for current and future situations. A crucial point is that most standardised assessment methods have specific temporal and spatial system limits and they describe the built environment in different ways.[537]

The definition of identical time and spatial limits, using geographical information systems, was supposed to facilitate the appropriate description of the built environment. A further requirement was seen in the inclusion of the “history of the building site and the general building production conditions” to bridge to “engineering (technical) and economic history as well as to the conditions of use of buildings and the social and managerial aspects”.[538]

Especially for European towns it appears that the incorporation of social and historical information on the built environment can help to provide significant insights into the possibilities of a development based on resource value conservation. The analysis of the social and cultural values that are embedded in the built environment (at a certain period) can explain the varying speeds of development of specific parts of a town.[539] The influence of the refurbishment processes on the built environment is highlighted as a determining factor for the volume and type of building activity in the long run.[540]

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[536] ibidem, p.2
[537] ibidem, p.3
[538] ibidem, p.4
[539] ibidem, p.4
[540] ibidem, p.5

The above demonstrates more consideration for the built environment as a whole than for individual buildings.[541] This distinction has to be made. Whereas the individual building obtains its value mainly by its uniqueness, the European built environment is a mosaic of varying "regional and local cultural techniques and building traditions"[542]. Each local urban fabric has to be handled differently due to its specific historical evolution (influenced by destruction, scale and scope). This is also true for the evolution of "natural" systems, which are in actuality all social-ecological systems.[543]

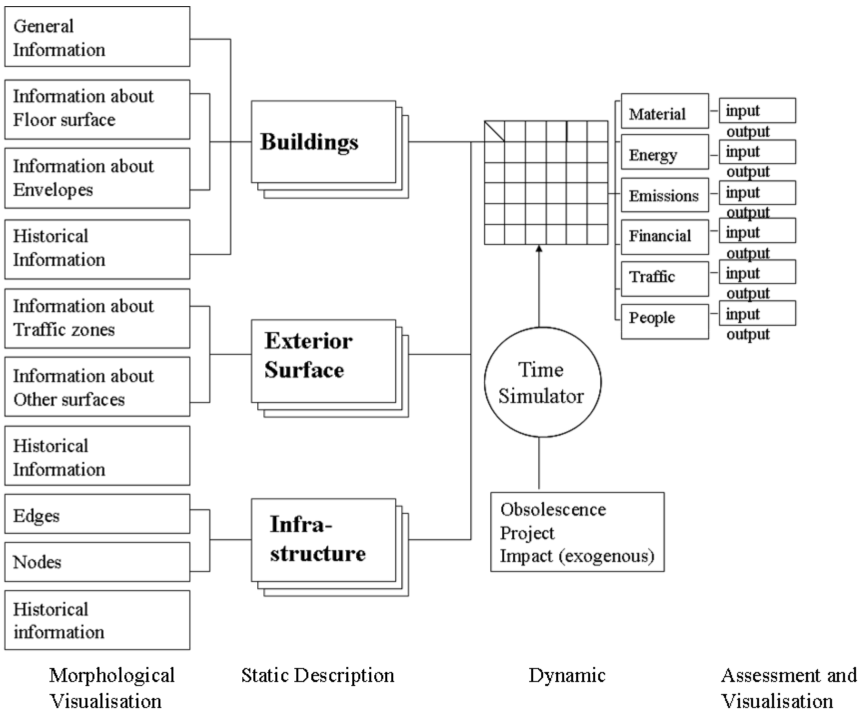

Figure 42 Framework proposition for a simulation model
Source: own illustration of [DEAKIN 07], p.364

Both very high and slow urban transformation rates are seen as a danger for differing urban fabrics, each with its unique physical and non-physical characteristics.[544] The urban fabric is (part of) a spatial-temporal continuum that is seen as a resource itself and requires protection. This means a type of protection that ensures "sustainability through the continuity of development and the embedded social and physical [and the author would add cultural] understanding and values for the members of the urban society."[545] A development can be seen as endangering in terms of the interlinkages between destruction of the physical with its impacts on the social and cultural, "even if the concerned objects are not outstanding monuments."[546] Conscious of the difficulties of a unique theoretical model, a framework has been

[541] ibidem, p.5
[542] ibidem, p.5
[543] ibidem, p.6
[544] [DEAKIN 07], p.366
[545] [SUIT 04], p.6
[546] ibidem, p.6

developed which could support scientific research work, public participation as well as architectural and cultural planning and procedures. This framework describes the built environment as the sum of buildings, infrastructures and exterior surfaces. Each component can be linked with qualitative and quantitative attributes. Within a matrix, the dynamic current condition of the built environment is described by its use, use intensity and construction phases.[547] Based on assumptions on future developments considering internal projects, external impacts and the obsolescence of constructions, changes in the matrix are assigned to changes resulting in calculations on resource flows. Finally, these are assessed with the help of indicators and visualised[548] (Figure 42).

II8.2 Review and Positioning within the Adaptive Cycle Approach

The SUIT framework aims to deal with all the dimensions of sustainability by incorporating all available information on attributes of urban units (potential and level). Emphasis is given to ecological aspects. Historical information helps to understand the development of the urban fragment and derive assumptions for scenarios (tendency). Checks on the speed of transformation (cultural, economic and social) test the level and tendency of resilience of an urban fragment. Ecological resilience is not tested. There are no indicators for the assessment of connectedness but it would be possible to incorporate some.

		Resilience	Potential	Connectedness
Ecological	Level		●	
	Tendency		●	
Cultural	Level	o	o	
	Tendency	o	o	
Social	Level	o	o	
	Tendency	o	o	
Economical	Level	o	o	
	Tendency	o	o	

Table 34 Dimensions of sustainability and adaptive cycles considered by SUIT

547 [DEAKIN 07], p.365
548 ibidem, p.366

II8.3 Building Environmental Quality Evaluation for Sustainability (BEQUEST)

The Building Environmental Quality Evaluation for Sustainability (BEQUEST) network has its roots in an EU network that ended with an international conference on ‘The Environmental Impact of Buildings and Cities’ held in Florence in 1995. BEQUEST started from four principles (futurity, environment, public participation and equity) and a review of the wide range of sustainable development concepts from government, non-governmental organisations (NGOs), industry and research. The project aimed at developing a common language and an approach to Sustainable Urban Development (SUD). Another goal was to produce a framework for mapping sustainability assessment (Table 35), a list of assessment methods (Table 36) and a set of procurement protocols for such purposes. Altogether, this framework is targeted at building environmental capacity, and qualifying and evaluating the sustainability of urban development[549].

The BEQUEST framework covers different development activities at different spatial levels and different timescales.

A key motivator for the project was to reduce the barriers produced by the lack of common understanding of the term “sustainability” by all the parties engaged in the planning, design, construction and use of the built environment. A process of interaction between the wide range of interests involved in urban development (i.e. the planning, provision, use and maintenance of the built environment as a form of human settlement) was provided in a structured way by the adopted research method. The main issues are the development of urban futures, the cities of tomorrow and their cultural heritage; and questioning how to build the capacity needed to not only conserve resources and protect the environment, but also qualify and evaluate whether such action is equitable and dealt with in a manner that fosters public participation.

[549][DEAKIN 02], p.102

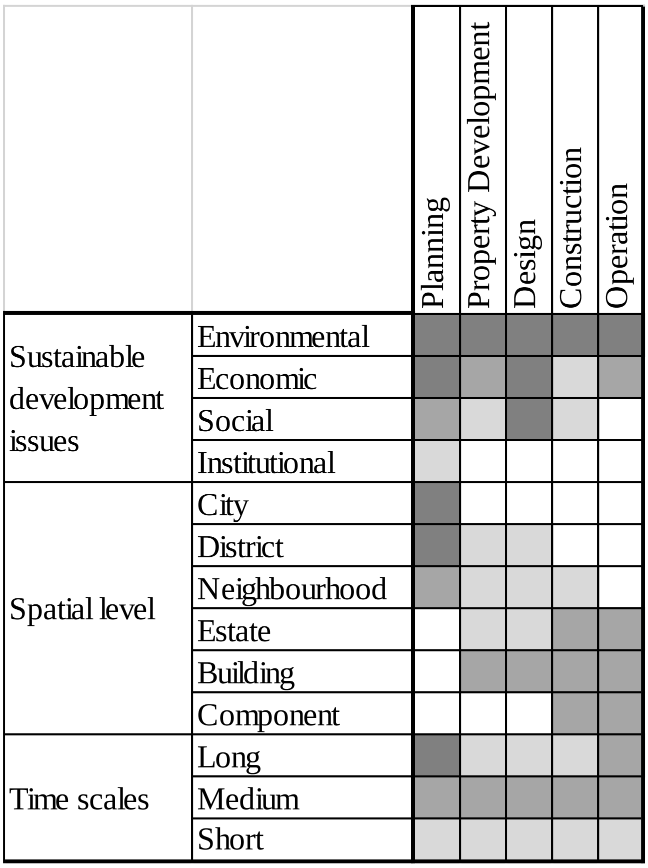

Table 35 Mapping the frequency of assessments methods in sustainable urban development issues, for spatial levels and for time scales in BEQUEST (dark grey: >75%, grey: 50-75%, light grey: 25-50%, white: <25%)
Source: own illustration of [DEAKIN 02], p.101

Environmental valuations	**Environmental, economic and social assessments**	
	Simple	**Complex and advanced**
Contingent valuation	Compatibility matrix	Project
Cost benefit analysis	Eco-profiling	Strategic - economic - social
Hedonic analysis	Ecological footprint	Community evaluation
Multi-criteria analysis	Environmental auditing	BEES
Travel cost theory	Flag method	BREEAM
	Spider analysis	Eco-points
		Green Building Code
		ASSIPAC
		MASTER Framework
		Meta-analysis (Pentagon method)
		NAR model
		Quantitative City model
		Regime analysis
		SPARTACUS
		Sustainable City model
		Sustainable communities
		Sustainable regions
		Transit-oriented settlement

Table 36 Assessment methods in BEQUEST
Source: own illustration of [DEAKIN 02], p.100

II8.4 Review and Positioning within the Adaptive Cycle Framework

The toolkit developed within the BEQUEST project was one of the first to structure a sustainability framework in a formal way, bridging different scales of action from planning to design and providing access to a classified list of sustainability assessment methods[550]. BEQUEST can be seen more as a set of guidelines for a sustainable urban development approach. It does not manage content but rather assists in determining certain types of information or results and the appropriate assessment tools. BEQUEST can help to understand in which domain changes are necessary to improve but it is not a description of a system.

Due to its stronger framework character, BEQUEST is highly dependent on its user and the focus made. Generally, the available tools allow the assessment of the potential of all the sustainability dimensions (level and tendency). Some of the assessment methods may also focus partly on connectedness and resilience but the individual methods available for BEQUEST were not analysed in detail for this paper and so assume that these two adaptive cycle dimensions are not considered explicitly.

		Resilience	Potential	Connectedness
Ecological	Level		o	
	Tendency		o	
Cultural	Level		o	
	Tendency		o	
Social	Level		o	
	Tendency		o	
Economical	Level		o	
	Tendency		o	

Table 37 Dimensions of sustainability and adaptive cycles considered by BEQUEST

II9. Conclusion

Adaptive cycles consider various dimensions, which are only partly analysed by the individual tools described above. The dimensions, which they take into account, as well as their overlaps, must be clearly distinguished and set in relation to the phases of the adaptive cycle approach. The different methods and tools do not exclude each other; they can be seen rather as complementary under the condition that they are related in an explicit way.

While the above observations on the content and operation of evaluation methods for urban developments show that there are a number of

[550] [HUOVILA 01], p.11

unresolved or unintegrated issues, it remains essential to ensure that an evaluation methodology fits the characteristics and requirements of the individual territory under analysis. Most of these models can only produce good results when used in the original context of their development. Otherwise, large restrictions must be made due to limitations imposed by time, finances and other resources, data acquisition and accountability.

The demand for a universally applicable, comprehensive evaluation methodology can be compared to the medieval quest for the philosopher's stone, as an interesting and ambitious vision, but with little chance to become the basis of a long-term oriented approach.

Connecting different approaches with each other can provide interesting results. The integration of the varying approaches can lead to validations. For example, if a Life Cycle Analysis proposed for an aspect of a project is consistent with existing evaluations within a scenario, the LCA can be shortened by simply referring to the evaluated aspect, instead of retesting the analyses in the scenario. Nevertheless, this cooperation of tools also brings the danger of subverting LCAs. A project (with minor impacts) may be substituted by an alternative project (with major impacts) that was not anticipated in the scenario. The scenario could 'hide' the LCA of the alternative project, so that significant impacts might be overlooked. Therefore, it is crucial to understand how much efficiency and support is gained, and to what extent dangers to the sustainability dimensions can be overlooked, by combining tools.

This chapter results in the view that common approaches (in this paper: Indicators, Material Flow Accounting, Life Cycle Assessment, Urban Simulations, Environmental Impact Assessments/Strategic Environmental Assessments, Social Compatibility Analysis, Cost-Benefit Analysis and Geographical Information Systems) are necessary to cope with the complexity of cities, but that – even when brought together – they are still far from comprehensively covering reality. The links between the approaches need a higher degree of definition to understand them and to ease the translation and comparison of their results. Nonetheless, there will remain unexplained areas between the approaches.

Chapter III

III Adaptive Cycle Analysis Framework and Case Studies

III1. Framework Proposition for Adaptive Cycle Analysis of Urban Fragments

Introduction

After demonstrating that the concept of succession fits to theories of urban development and can incorporate existing tools used for the analysis of urban development, in this chapter, a framework is proposed, which uses some of the described tools. The framework enlarges the analogy shown in Chapter 2 into an analysis. The proposed framework takes the form of a step-by-step procedure focussed on urban units such as buildings, open spaces and infrastructure. The framework will be applied in the analysis of two case studies in sections III.2 and III.3.

Steps	Description
Urban fragment definition	Determining the urban fragment's parameters: feature based or project oriented
Current state description (adaptive cycle phase)	Identifying and measuring indicators for the four dimensions of sustainability
Historic state descriptions: Phase at t-1, …, t-n	
Adaptive cycle evolution description	Combining the virtual sustainability adaptive cycles
Scenarios for future development	Creating and testing scenarios for urban adaptive cycles
Strategy design	Creating strategies and calculations

Table 38 Steps for Applying the Adaptive Cycle Analysis Framework

The approach can be described generally in five steps (Table 38). In the first step, the urban fragment of interest is defined in its spatio-temporal dimension. The second step is divided into two sub-steps: first, the current state and present phase of the urban fragment is described using indicators and second, the indicator set is used to evaluate different time points in the past in order to comprehend moments in the current and past adaptive cycles. This evaluation helps to construct the adaptive cycles that an urban fragment has gone through in the third step and clarifies the influence of the virtual sustainability adaptive cycles on the general adaptive cycle. In the fourth step, scenarios for possible future developments of the adaptive cycle are textually described. The strategies, which best represent the goal of the scenarios, describe the activities related to the urban units as the fifth step. The user can configure strategies to influence the development of the urban units in respect to the four sustainability dimensions. Elements of the development of the urban units that can be modelled are quantified and illustrated. A comparison between the results of the modelling and the intended scenarios support the feasibility of the scenarios and the appropriateness of the strategies.

III1.1 Step One: Define Urban Fragment

In the first step, the urban fragment to be of interest is chosen (Table 39). To enable a deeper analysis, it is important that the urban fragment under investigation be characterised by certain homogeneity to ensure certain comparability. This can be a homogeneous space, e.g. neighbourhood, administrative district, any cohesive catchment area. A characterisation by homogeneous use is also possible, e.g. churches, green areas or the network of a certain infrastructure type, and additionally their area of influence.[551] The difference between the definition of an urban fragment and another unit like the quarter of a city, resides in the fact that the fragment does not exist as such before the appearance of a project transforming the urban scene at a certain point. The fragment is the area affected by the impacts of this project during the time the project has an influence (i.e. is active). The limits of fragments can coincide with other limits (a quarter, a block etc.) but the coincidence is not constitutive of the fragment.

Steps	Description
Urban fragment definition	Determining the urban fragment's parameters: feature based or project oriented
Current state description (adaptive cycle phase)	Identifying and measuring indicators for the four dimensions of sustainability
Historic state descriptions: Phase at t-1, …, t-n	Identifying and measuring indicators for the four dimensions of sustainability
Adaptive cycle evolution description	Combining the virtual sustainability adaptive cycles
Scenarios for future development	Creating and testing scenarios for urban adaptive cycles
Strategy design	Creating strategies and calculations

Table 39 Step 1 of the adaptive cycle analysis framework: urban fragment definition

[551] An urban fragment can be a single building on one parcel of land, unconnected building stock without clear limits, a group of buildings such as a neighbourhood with ad hoc limits or a quarter with administrative boundaries or, if homogenous enough, a commune with administrative limits.

The definition of an urban fragment in its spatio-temporal context is crucial due to the missing scale invariance. Urban fragments, similarly to dynamic living organisms, evolve through interdependencies between different activities, which sometimes change the whole character of an area within less than one generation.[552] Depending on the point of view, activities are to be evaluated differently, e.g. the demolition of a building and construction of a new building at the same location has an overall energetic impact, but at the same time it has local socio-cultural meaning. A change in one aspect often has an influence on other aspects and contradicts ‘ceteris paribus’ assumptions. [553]

Therefore, the contextualised definition of the urban fragment is at the same time the basis for the system designation and adaptive cycle analysis.

After the designation of the urban fragment, its state is described. The aim is to understand the current state of the fragment’s adaptive cycle by comparing its qualitative and quantitative variables. This investigation of data (e.g. uses, sizes, locations, populations etc.) as well as specific information facilitates the description of the urban fragment, and determination of current correlations and dependencies.

III.1.1.1 General System Limits

As in other modelling frameworks, the system descriptions for urban fragments are a key concept that stem from the original ecological systems theory developed in the 1920s through the modelling of ecosystems.[554] Later on, Odum developed an energy system theory[555] and Von Bertalanffy formalised a general system theory[556]. In the 1960s, Forrester provided a fundamental, rigorous mathematical formalism for representing dynamic systems[557], which was applied to the long-term modelling of resource use.[558]

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552 [SUIT 04], p.14

553 The following example shows that keeping only one variable open and the others fixed does not provide an acceptable result. It could be assumed that demolition and new construction within a certain area does not change the character of the urban fragment, if the use and the users stay the same. This has to be considered carefully, because dwellings can undergo social changes, which means that when after the new construction the same persons continue living there, one could be tempted to say that the character has remained. In this sense, a change of the age class ratio of the buildings ceteris paribus can be fulfilled without changing the character. This perspective implies that the constructions’ structure and age do not have value, which amounts to a total rejection of the cultural and social importance of buildings and of other urban units. This is a perspective that has been argued, but is not realistic. The assumption of ‘ceteris paribus’ is not valid; it stands more for the missing consideration of changes in other aspects. For a comprehensive state description, information on variables from all aspects that make up the character of the urban fragment has to be collected. Therefore, the data to be looked for comprises social, cultural, ecological, economic and geographical information.

554 [LINDEMAN 42], [VOLTERRA 27]

555 [ODUM 83], p.

556 [BERTALANFF 68]

557 [FORRESTER 61], [FORRESTER 69]

558 [MEADOWS 74]

System theory distinguishes between system structure (the inner constitution of a system, e.g. a building) and system behaviour (its outer manifestation, e.g. emissions from energy consumption). Viewed as a black box, the external behaviour of a system is the relationship between its input time record and its output time record. The system's input/output behaviour consists of data records gathered from a real system or model.

The internal structure of a system includes its states and state transition mechanism (dictating how inputs transform current states into successor states) as well as the mapping from state to output. Knowing the system structure allows the analysis of its behaviour.

System structures can be further characterised by the following attributes:

- Open or Closed:[559] Interactions with the outside are allowed or not
- Dynamic or Static: [560] Change of variables e.g. economy models where changes in reality have to be incorporated or automatic teller machines where no changes are needed or allowed
- Continuous[561] or Discrete[562]: Definition of the minimal time steps
- Determined or Stochastic:[563] Same situation results in the same effect (otherwise there is a necessity for Monte Carlo Simulation)
- Stable or Unstable:[564] Stability of the model and impacts from parameter or variable changes.

The approach sets limits on geography as well as on time. Many of the flows, converted materials and energy[565] for an urban fragment, have a supplementary direct link to outside areas (spill-over effects)[566]. The development of the urban fragment can only be described as a part of its surrounding city (i.e. an open system). Moreover, owing to the importance of retarded environmental human impacts such as climate change and the lastingness of urban structures, time has to be considered at various scales, that is months as well as years (i.e. a continuous and dynamic system). The complexities coming from the interdependencies making up the inner structure of an urban fragment and its dependency on its surroundings do not allow a determined system description (i.e. a stochastic system). In this paper, more difficulties arise due to the aim to consider cultural and social aspects as well. Therefore, the geographical frame and the timeframe need further consideration because many changes in the outer world influence each urban fragment (i.e. an unstable system).

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559 [ZEIGLER 00], p.151, 152
560 ibidem, p.235-240
561 ibidem, p.49
562 ibidem, p.37
563 ibidem, p.233-235; 332-334
564 ibidem, p.54, 55
565 [BALOCCO 03], p.232
566 [FREY 97], part 1

III.1.1.2 Spatial limits

The spatial limits comprise the area that is of interest for the project. Minimally, it contains the urban fragment, which is influenced directly by the actions and effects of the considered project.
The limits can be administrative or follow topographic features but more likely they will be set considering the extent of impact of the project. Depending on the scope of the studied neighbourhood the approach might change, i.e. for a bigger neighbourhood less data might be available, whereas for a smaller area more information can be collected.
In most approaches, attributes are defined in the beginning and are evaluated as static; in reality, the influences may change over time. Going into more detail, it is also important to consider the urban structure in which the building is embedded, e.g. a perimeter block development, in order to understand the influence of the surrounding area and its capability to affect change. Additionally, the location of the urban structure within the urban fragment is of importance. Moreover, urban fragments have an influence that goes beyond their direct and immediate environment. A fragment in its whole can be a crucial element of a city and its stability.

Limits of Urban Unit Definition

A premise of the MED-Tool (see Section II.4.3 – Urban Life Cycle Analysis) is integrated into the framework presented here. A composite of the three types of urban units – buildings, infrastructure and open spaces including urban furniture – describes any urban fragment as defined in this paper. The differences between the urban units make it necessary to work with such a differentiation, i.e. the various uses of infrastructure comprise very separate materials and technical levels[567].
Additionally, temporal limitations on the spatial and spatial-temporal conditions of the system exist which also should be taken into consideration.

III.1.1.3 Temporal limits

The framework includes description of how and when an urban fragment (neighbourhood) has been constructed, used, maintained and demolished.
Therefore, time is a key dimension for the analysis, not only when looking at a whole cycle but also for a view to future development. The past, even if more or less exactly known, is necessary to understand the present state, which can be influenced, and to deliberate or simulate the future adequately.

[567] see Annex A1 and A2 for more information

Time needs to be considered in four external and one internal aspects (**Figure 43**):

- changing zeitgeist
- changing environment (geography)
- developing opportunities (technology and resource related)
- the form of physical ageing (internal).

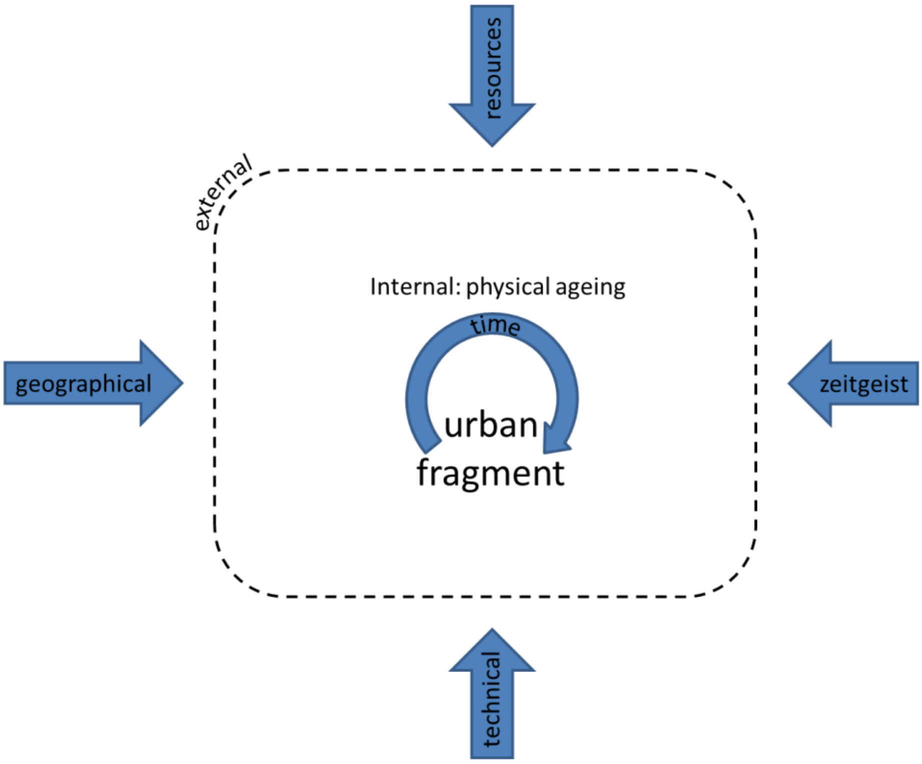


Figure 43 Internal and external temporal aspects of an urban fragment influence the four dimensions of sustainability

To model time, two calculations are needed: generally, a global time for the urban fragment as a whole (external) and a local time for the buildings considering their individual life cycles (internal).[568] Local time and global time are linked. Similar constructions, built in different years, have different states in the same global year but probably more similar states with regards to their local time that began with construction.

Circumstances, such as zeitgeist and technology/resource changes, comprise changes within or outside the urban area as well as changes in value with time or technological development. These changes are however difficult to model due to their high complexity. When looking to the future, the precision of forecasts diminishes and the analysis becomes 'prospective' in the context of urban fragments. A modeller of urban fragments should be aware that data is needed from the past, from the 'now' and from the future[569], and is left to his/her expertise and estimation.

[568] [ZEIGLER 00], p.34-35, for local and global time
[569] similar to [KOTAJI 03], p.11

III.1.1.4 Spatio-temporal Conditions

Buildings go through different life cycles, construction, transformations and demolitions. Twumasi describes the concept of change as follows: "if an object O changed, then it cannot be considered as the object O".[570] Therefore, if a building is altered, then it has at least no longer the same condition and in more extreme cases one cannot talk about the same object anymore. "Modelling time therefore means modelling change."[571]

Time in spatial databases is modelled with the alteration of one or more attributes of an object:[572] geometrical (e.g. relocation); topological (e.g. changed spatial relationships between objects); attributable (e.g. updated condition). Such alterations are not mutually exclusive and may happen contemporaneously (e.g. "merging existing objects to create a new object involves changes in the geometry, attributes and topology of the original objects").[573] There are eight possible changes a spatial-temporal object may undergo (Figure 44).

For application within this framework, a few minor modifications are needed. Topological changes can occur within an urban fragment (internal) but also in the surroundings (geographical context). Changes in attributes and geometry happen predominantly within an urban fragment (internal). An urban fragment can change its character by inner changes in one of the four sustainability dimensions or by regional transformations. Inner changes are e.g. constructional changes (office tower within a residential area), social or economic impacts (gentrification) and modifications to the location/neighbourhood (traffic connections). Besides these changes, there are contextual pressures on urban fragments. Regional transformations include formation of new neighbourhoods in unoccupied areas and economic/social marginalisation of regions in which the urban fragment is situated (e.g. East Germany). Therefore, even if urban fragments do not change at all, their valuation would alter e.g. due to changes in zeitgeist, resource availability and technological development (Figure 45).

570 [RAZA 01] cited in [TWUMASI 02], p.48
571 [TWUMASI 02], p.48
572 [ABRAHAM 99]
573 [TWUMASI 02], p.49

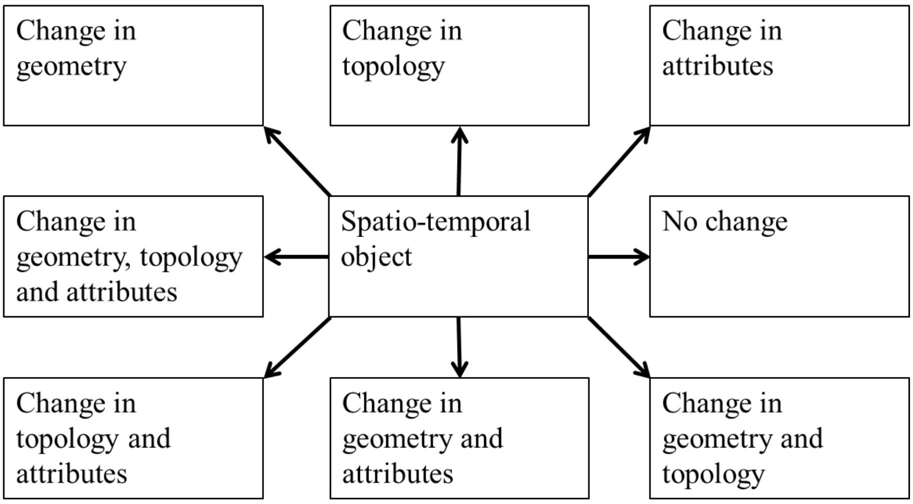


Figure 44 Eight possible changes to a spatio-temporal object
Source: own illustration of [ABRAHAM 99]

All transformations have in common a change in the evaluation of quality (here quality of space or product): e.g. the maintenance of public and private space is re-evaluated by a transformation (such as gentrification, cultural influences, modes, economic situation of the users). If the space is altered by constructional measures then objective changes occur and are influenced by other aspects as well.

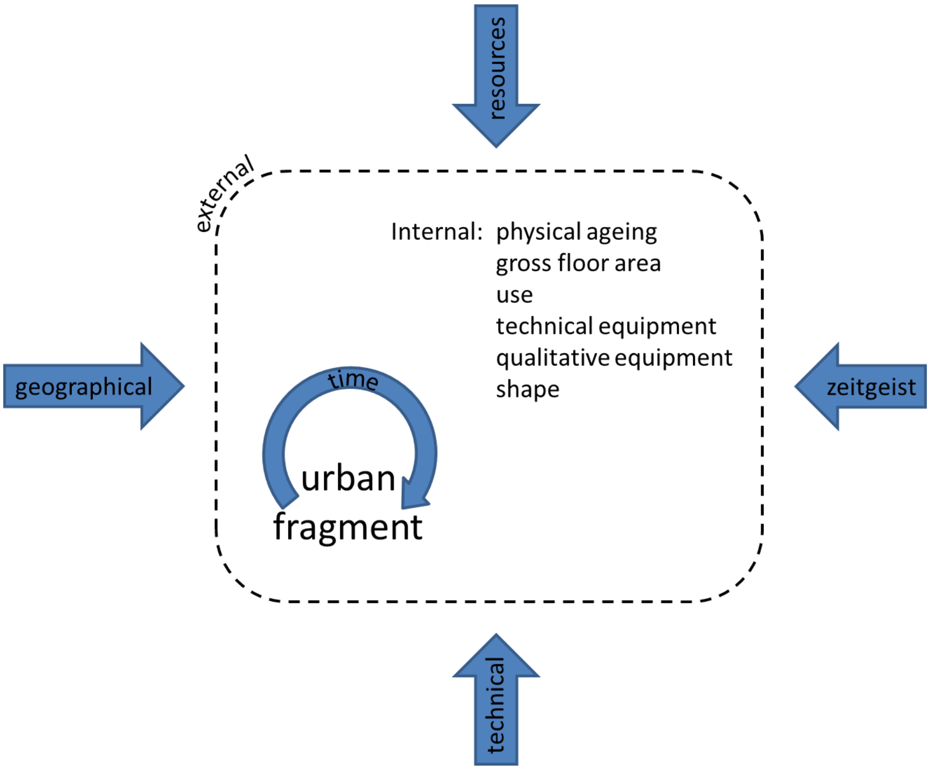


Figure 45 Internal and external aspects that influence the evaluation of the four sustainability dimensions within an urban fragment

Both geographic location and temporal circumstances are important issues for cultural, social, economic and ecological evaluation. Both influences are in general very difficult to estimate; this means the assessment of one region cannot be transposed simply onto others without being revised in detail. The general as well as the geographic circumstances also rely very much on the development of the surroundings; this means that the built and natural environments have different impacts when many people influence them. For a differentiated observation of the influence, it might be of importance to analyse them in the beginning one by one. If the geographical facts are fixed, no greater influencing changes occur within the region. If circumstances, e.g. energy prices, are fixed as well, then the influence of construction activities (new construction, maintenance, renovation and demolition) on the four dimensions can be assessed. For an understanding of the construction activities, the attributes of a building (construction year, gross floor area, use, shape, qualitative and technical equipment) have to be considered (Figure 45).

III1.2 Step Two: Determine and Describe Current Adaptive Cycle Phase

In step two of applying the framework, the current state of the urban fragment is investigated to discover in which adaptive cycle phase it is: in other words, whether it is part of a stable, unstable or metastable environment (Table 40). In analogy to the succession states in biology, urban fragments[574] evolve through four phases (α, r, K and Ω).

Steps	Description
Urban fragment definition	Determining the urban fragment's parameters: feature based or project oriented
Current state description (adaptive cycle phase)	Identifying and measuring indicators for the four dimensions of sustainability
Historic state descriptions: Phase at t-1, …, t-n	
Adaptive cycle evolution description	Combining the virtual sustainability adaptive cycles
Scenarios for future development	Creating and testing scenarios for urban adaptive cycles
Strategy design	Creating strategies and calculations

Table 40 Step 2 of the adaptive cycle analysis framework: phases of the virtual adaptive cycles

[574] Many European cities have reached a built state that compels either new areas for construction around the cities or the transformation of built-up areas with high potential and connectedness to meet new needs. This means the stability of urban fragments that proved their resilience sometimes for centuries ([SUIT 03], p.19, 20) and offer a viable mixture of uses (phase K) is tested now. However, the complexity of the reached stability is not understood. Therefore, changes need careful preparation and can reveal, but also destroy, important interrelationships and endanger existing values.

For the assessment of the virtual ecological, cultural, social and economic adaptive cycles, through which an urban fragment goes, indicators are defined[575]. These indicators inform on the resilience, connectedness and potential. Primarily they are developed for residential areas and can be extended to other types of areas as well. For ecological aspects, they are separated into those with internal and external importance. Urban fragments are very individual, so only very general indicators for the analysis of the state and development can be used. Measured values can only work in a descriptive sense; e.g. the causes of an increase in sale prices within an urban fragment depend on several factors and their interdependencies.
The aim is to determine in which phase the virtual ecological, cultural, social and economic adaptive cycles of the urban fragment are.

Ecological Virtual Adaptive Cycle
The ecological virtual adaptive cycle has thirteen indicators (Table 34).
The ecological impacts of an urban fragment have effects inside and outside of the urban fragment. Therefore, ecological assessment is divided into internal and external indicators.
Ecological resilience is assessed internally by the amount of noise, air quality and the cleanliness and care of green areas, and externally by the fragment's ecological footprint and emissions.
Internal and external ecological connectedness is assessed by the internal and external continuity of green areas and their biocoenosis.
Internal ecological potential is assessed by the quality and size of green areas, and the number and amount of species. External ecological potential is assessed by resource consumption/efficiency (i.e. energy), the maintenance of grey energy and the use of renewable resources.

Cultural Virtual Adaptive Cycle
To assess the cultural virtual adaptive cycle eight indicators are identified (Table 34).
Cultural resilience is assessed by the possibility of use change, the frequency of renovation and the morphology of the buildings.
Cultural connectedness is assessed by the location of the urban fragment and the cultural importance of the urban units.
Cultural potential is assessed by the types of construction, the importance of use and architectonic quality.

Social Virtual Adaptive Cycle
The social virtual adaptive cycle is evaluated through eleven indicators (Table 34). Social resilience is assessed by the number of vacancies, the cleanliness and care of buildings, the happiness of users and inhabitants, the security level, and risks of ghettoisation and gentrification.

[575] See Section I4.5 for the definition of virtual adaptive cycles.

Social connectedness is assessed by local organisations and events, participation opportunities for the public and inhabitants, access to social and health services, and the frequency of user change.
Social potential is assessed by education levels, the age structure and the availability of substandard dwellings.

Economic Virtual Adaptive Cycle
The economic virtual adaptive cycle can be determined and defined through fourteen indicators, given in Table 34.
Economic resilience is assessed by the diversity of uses, the possibility for change in the urban units' use(s), the number of vacancies and the preparedness for natural and technological risks.
Economic connectedness is assessed by the accessibility and availability of infrastructure, the owner status of the urban units, the consumption behaviour of the inhabitants in the urban fragment and the frequency of tenant change.
Economic potential is assessed by rent levels, the number of existing companies and number of jobs, the supply of retailers, the product of the urban units (size of available use area, equipment), the income structure and the location of the urban fragment.

The indicators can have a positive value (+/green), a neutral value (ø/yellow), a negative value (-/red) or can be irrelevant (grey).

Ecological	Indicators	State
Resilience (Resistance)	Noise (internal)	+ ø -
	Air quality (internal)	+ ø -
	Cleanliness and care of green areas (internal)	+ ø -
	Ecological footprint (external)	+ ø -
	Emissions (external)	+ ø -
Connectedness (Relations)	Continuous green areas with biocoenosis (internal)	+ ø -
	Continuous green areas with biocoenosis (external)	+ ø -
Potential (Quantity)	Quality and size of green areas (internal)	+ ø -
	Number and amount of species (internal)	+ ø -
	Resource, i.e. energy, consumption and efficiency (external)	+ ø -
	Retention of grey energy, i.e. recycling, renovation (external)	+ ø -
	Use of renewable resources (external)	+ ø -

Cultural	Indicators	State
Resilience (Resistance)	Possibility to change use	+ ø -
	Frequency of renovation	+ ø -
	Morphology of buildings	+ ø -
Connectedness (Relations)	Location of the urban fragment	+ ø -
	Cultural importance	+ ø -
Potential (Quantity)	Types of construction	+ ø -
	Importance of use	+ ø -
	Architectonic quality	+ ø -

Social	Indicators	State
Resilience (Resistance)	Vacancies	+ ø -
	Cleanliness and care of buildings	+ ø -
	Happiness of users and inhabitants	+ ø -
	Security level	+ ø -
	Ghettoisation/gentrification	+ ø -
Connectedness (Relations)	Organisations and events	+ ø -
	(Public) Participation	+ ø -
	Access to social and health services	+ ø -
	Frequency of user change	
Potential (Quantity)	Education levels	+ ø -
	Age structure	+ ø -
	Availability of substandard dwellings	+ ø -

Economic	Indicators	State
Resilience (Resistance)	Diversity of uses	+ ø -
	Possibility for change of use	+ ø -
	Vacancies	+ ø -
	Preparedness for natural and technological risks	+ ø -
Connectedness (Relations)	Infrastructure/accessibility	+ ø -
	Owner status	+ ø -
	Clients of local companies	+ ø -
	Frequency of tenant change	+ ø -
Potential (Quantity)	Rent levels	+ ø -
	Existing companies and number of jobs	+ ø -
	Supply of retailers	+ ø -
	Product of urban units (size of available use area, equipment)	+ ø -
	Income structure	+ ø -
	Location of the urban fragment	+ ø -

Table 41 Indicators for the Virtual Adaptive Cycles

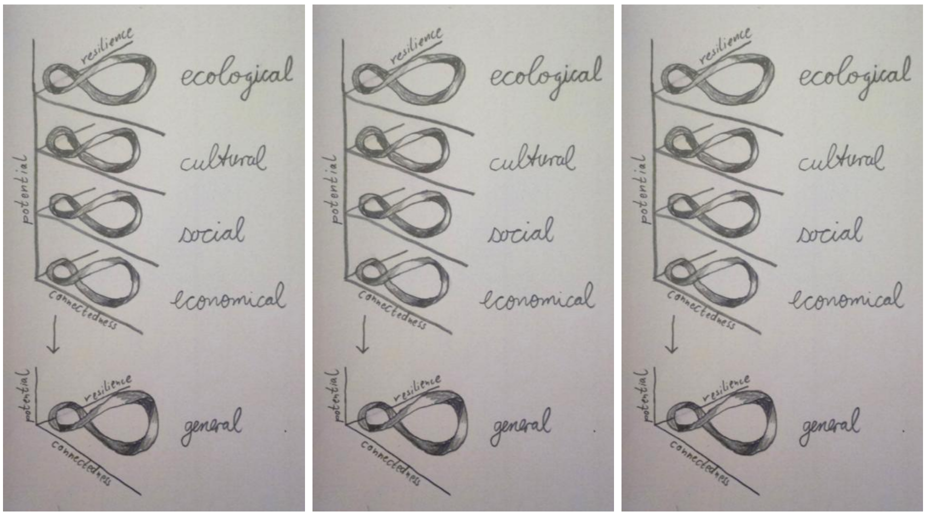
III1.3 Step Three: Adaptive Cycle Evolution Description

$(\infty_1 \longrightarrow \infty_2)$

In step three of applying the framework for adaptive cycle analysis of urban fragments (Table 42), knowledge on the current phase (t=0) is supplemented with indicator assessments of past points in time (t=-1, t=-2 …; see also Figure 46). The additional assessments help to reconstruct the development of the current adaptive cycle. With more assessed time points, past adaptive cycles might be identifiable. With the assessment of the historical and tendential development at each time point, the time between two sequential assessed time points is interpreted. The comparison between the historical, current and tendential assessments provides information on whether an urban fragment is in a transformation phase. The assessed time points and the interpreted intervals in between are lined up and result in sequential adaptive cycle descriptions.

Steps	**Description**
Urban fragment definition	Determining the urban fragment's parameters: feature based or project oriented
Current state description (adaptive cycle phase)	Identifying and measuring indicators for the four dimensions of sustainability
Historic state descriptions: Phase at t-1, …, t-n	
Adaptive cycle evolution description	Combining the virtual sustainability adaptive cycles
Scenarios for future development	Creating and testing scenarios for urban adaptive cycles
Strategy design	Creating strategies and calculations

Table 42 Step 3 of the adaptive cycle analysis framework



t = 0 t = -1 t = -2

Figure 46 Adaptive cycle analysis of three different time points (t=0, t=-1, t=-2)

Excursion

Urban fragments are not deterministic systems; the crucial point is to model the transition between states. Many models and simulations are limited to a certain time span, in which the simulation parameters are constant or changing in a determinable way.[576] This means, such periods with stable circumstances can exist and be modelled. The system characterisation is basically ex post. Beyond these conditions, the modelling becomes difficult because not all influences can be modelled or quantitative attributes are difficult to identify.[577] One challenging aspect are slow changes that can result in a vulnerable meta-stable state of a system with a tipping point, which stands for a point of no return that can be crossed without real-time perception.[578] The overstepping of ecological resilience can result in a shift of the ecological system leading to a totally new situation for e.g. economics.[579] Although current simulation models take into account the impacts of such effects, they do not model when or how they are created.[580]

Due to the assumption that the land use area of most Western - especially European - cities is mainly covered, new construction often makes the demolition of existing construction necessary. This opens the way for several opportunities: either buildings are refitted to the new circumstances maintaining the adaptive cycle the urban fragment is in, or new constructions transform the adaptive cycle, which makes a more detailed assessment of the impact necessary. Adequate renovation can improve continuously the quality of an urban fragment without changing the current adaptive cycle. Larger impacts, due to necessary construction or other causes, may change the character of an urban fragment in such a way that the result is a new system. The most obvious change is a new use of buildings, which usually also brings new users with other social and economic behaviours, e.g. gentrification. Both the new activities and the new users generally alter the established flow patterns (monetary, energy, biomass and information).

An analysis of a city’s past would show many such system changes; depending on their attributes they can be endogenous as well as exogenous. Each system change has a resultant succession, whereby the succession states do not have to start from the beginning of an adaptive cycle. According to the environment in which an event occurs, it can result in different effects.

Only comprehensive system analysis avoids the drawbacks of discipline-driven approaches. Such an analysis can show, if and which concepts and interests were at the root of certain urban structures and if these are still relevant or should be kept in memory (heritage, collective memory). Historically evolved social structures have resulted in multiple interconnections, which can be vital in emergencies. They may be part of the system’s resilience when recovering from catastrophes. Urban structures can contain and even inherit the knowledge necessary for continuous long-term development.

A historical and more evolutionary long-term analysis can lead to different perspectives. Even descriptions of the system from the alternative points of view of different disciplines can change. The interpretation of available information on the system components can also vary considerably. [581]

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[576] [FOLKE 06], p.257

[577] Similar differences exist between the present economic and financial crises due to the securisation of subprimes ([ACHARYA 09]) and other crises such as Tulip Mania in Europe in the 16th century ([POSTHUMUS 29]). In both cases, development up to the beginning of the crisis can be simulated with a limited number of parameters but the development of the crisis is chaotic and a number of different, unpredictable developments can take place.

[578] See for more on tipping points, [GLADWELL 00]

[579] See for examples [ROSENZWEIG 11]

[580] In an urban context, the decisions leading to the construction of a shopping mall can be simulated, but obviously the influences and consequences, especially ecological effects are not usually modelled. [SUIT 04], p. 51-57

[581] Vulnerability by System Choice: [HASSLER 09], p.563; see for drivers for demolition [FORSYTHE 11]

III1.4 Step Four: Scenarios for Future Development

In step four of applying the framework for adaptive cycle analysis of urban fragments, scenarios are constructed to test developments within their current and future cycles (Table 43).

Each scenario is defined in terms of adaptive cycles and considers cycle changes. Within a scenario, one adaptive cycle can be enough, for example renovation as protection against ageing but without extensive external changes. Nevertheless, changes can occur, e.g. demolition/new construction/transformation, ageing with late or no renovation, or extensive external changes.

Steps	Description
Urban fragment definition	Determining the urban fragment's parameters: feature based or project oriented
Current state description (adaptive cycle phase)	Identifying and measuring indicators for the four dimensions of sustainability
Historic state descriptions: Phase at t-1, …, t-n	
Adaptive cycle evolution description	Combining the virtual sustainability adaptive cycles
Scenarios for future development	Creating and testing scenarios for urban adaptive cycles
Strategy design	Creating strategies and calculations

Table 43 Step 4 of the adaptive cycle analysis framework: scenarios

The urban fragment interacts with the outer world and impacts on the cultural, social, economic and ecological virtual adaptive cycles must be identified. Especially ‘spill-over effects’, which comprise effects beyond the system limits with internal origin, can be estimated within the scenarios; these can be social benefits, cultural conservation or ecological protection. External effects/drivers and impacts are incorporated into the scenarios by the users/stakeholders.

Whereas the spatial frame appears to be somehow controllable, if immediate political changes are ruled out, the timeframe might hide many more risks due to the growing uncertainty[582] the deeper one looks into the future, e.g. energy prices, inflation, resource scarcity/availability, changes in zeitgeist. The scenarios model zeitgeist, technological development, resource availability and geographical changes. To incorporate such uncertainty, scenarios consider different

[582] Further impacts like the possibility of other big catastrophes are not incorporated due to their topical distance, e.g. earthquakes, terrorism. They also endanger the future but cannot be influenced on a local level. The problems that are globally independent and locally solvable, e.g. environmental problems, can occur everywhere but can be minimised locally.

possible speeds for changes in technological development, e.g. continuous innovations.

These scenarios should not be misinterpreted as forecasts of the virtual adaptive cycles. It is not possible to predict reliably what the urban framework conditions – determined largely by national and EU policy – will look like in 20, 30 or 50 years. Moreover, dramatic changes in world markets and technologies are possible and hard to predict.

It is important that the scenarios are made in a way that they are comprehensible; therefore, scenarios have to be discussed and agreed on in advance.

How the scenarios are defined also influences the resultant internal and external attributes and the sustainable value of an urban unit. The scenarios describe external attributes, zeitgeist, technological and resource development and geographical changes, and their effects on buildings.

The Values of Buildings

For buildings, the original values are constituted by the following internal attributes: construction year, use, form, size, technical equipment and quality of completion. These values change over time. Changes in the values are triggered and biased by external time-dependent developments (technological and resources-related changes), geography, ageing and construction activities (attribute maintenance or improvement) (Figure 47).

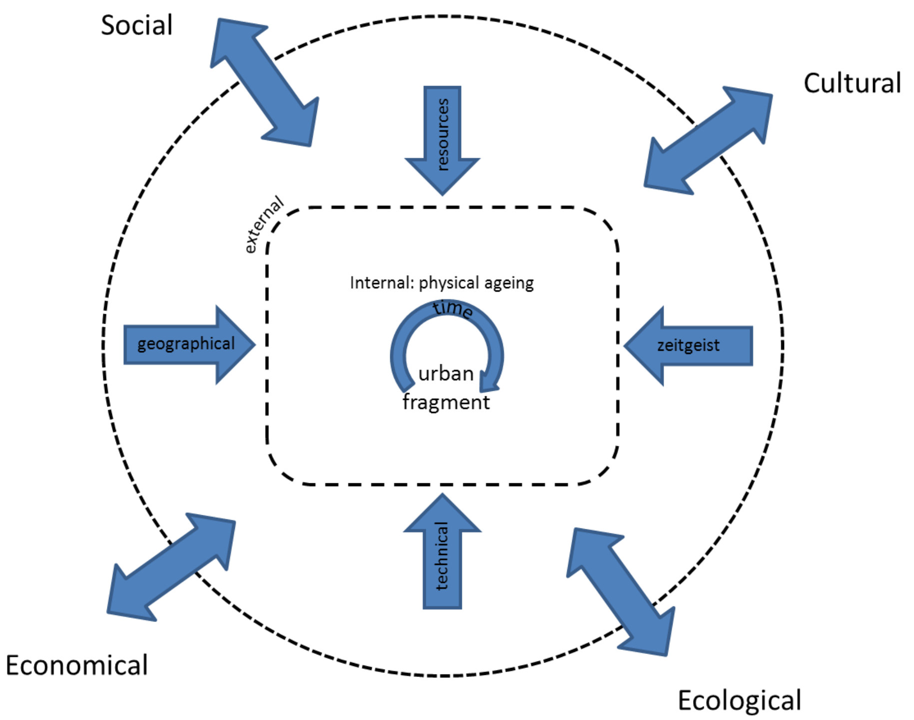

Figure 47 Internal and external aspects that influence the evaluation of the four sustainability dimensions of an urban fragment

Economic value

The economic value of an urban unit or fragment is largely based on the monetary valuation of its use(s)[583]. Original use value is derived from the following attributes: form, size, technical equipment[584] and quality of completion. Changes in economic value result from ageing (time), zeitgeist, technological and resource requirements, localisation and construction phases (use changes). New construction and technological alternatives may make existing structures appear less cost-efficient and so obsolete. There is an ongoing discussion on the necessity to incorporate sustainability related factors during the valuation process.[585] Approaches, e.g. Cost-Benefit Analysis (Section II.3.3), exist which include values for the other sustainability dimensions. Besides the evaluation of the benefits of past construction activities, their costs may also be evaluated for comparison reasons in terms of:

1. construction costs using current technologies and prices, if substitution construction is the objective (Figure 48)
2. costs for historic labour and material consumption in current prices (Figure 49)
3. costs by converting historic (i.e. original) prices into current rates (Figure 50).

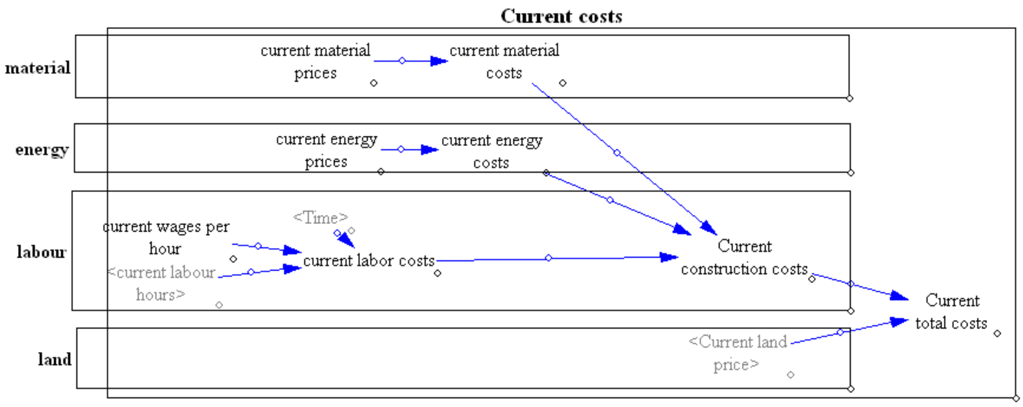

Figure 48: Calculation of current material, energy, labour and land costs

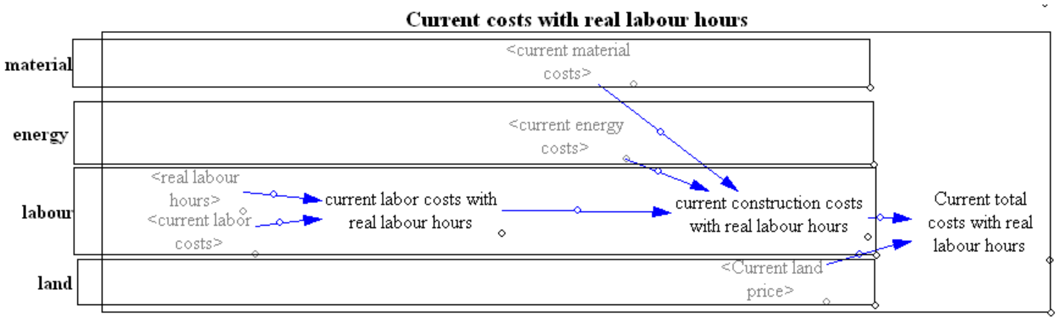

Figure 49 Calculation of current material, energy and land costs with real labour hours and current labour costs

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583 This corresponds with the concept of 'use value' found in Alois Riegl's (1858-1905) approach to urban units in 'Der moderne Denkmalkultus. Sein Wesen und seine Entstehung'. [RIEGL 03]

584 [KLINGENBER 07]

585 See [LORENZ 11], p.648-650 for an overview on the discussion and a systematisation of approaches

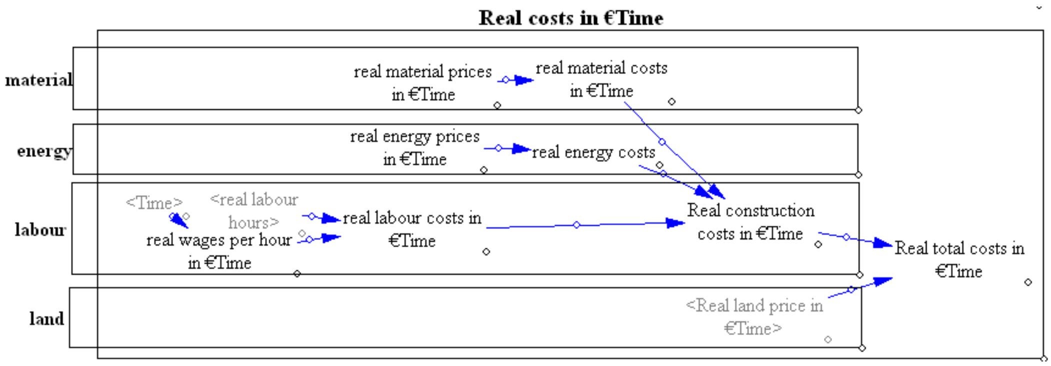

Figure 50 Calculation of real (former) material, energy, labour and land costs in €Time (converted into the basis of the time variable)

Ecological value

The ecological value of a construction is measured negatively. Emissions, energy consumption and related impacts damage/destroy natural capital. The ecological value of a building is the inverse of the sum of all its impacts per year. The fewer resources consumed per square metre per year, the greater its ecological value.

This value develops in stages with construction phases as well as continuously with everyday consumption. Internal attributes are the main contributors to ecological value. Among possible external attributes, new technologies may create opportunities to improve the ecological value by altering internal attributes but this has to be considered thoroughly in order to avoid harmful construction impacts and to diminish the direct impact of the activities themselves, i.e. energy demand or emissions.[586] If the ageing of an urban unit starts to limit functionality, ecological value may decrease, e.g. damaged sealing. However, new knowledge may let the ecological value appear decreasing, i.e. the impact of nuclear waste, or increasing, i.e. the low energy consumption of older buildings (before 1920) which makes insulation less necessary[587]. Even if ecological value is quantitatively measurable, zeitgeist plays a qualitative role in the evaluation.

Social value

The social value of an urban unit or fragment is defined by the possibilities of the population to benefit from its use.[588] The influence of zeitgeist, resource development and geography can increase or decrease the social value. Technical developments' influence on the social value

586 [PELZETER 06], p.70

587 [MICHELSEN 10], p.454

588 The social value of buildings is currently not generally defined in literature. For some authors this value is not yet realised and needs further research to "reduce the distance between buildings and users." ([MASUDA 11], p.263). Other authors leave the evaluation of social value to stakeholders, i.e. residents, general consumers, architects, environmental experts, social and human affairs experts ([LEE 12], p. 28). Finally, some try to create a value by a comparison of market prices and optional social values of greenspace as a basis to achieve Pareto efficiency ([TURNBULL 03], p.6)

may be both positive if they facilitate the use and negative if they make the use of a construction obsolete due to limits in adaptability.

Participation can be limited, for example the possibility to enter a building. A higher degree of participation means providing more opportunity to achieve well-being and fair treatment. A very high degree means to open up decisions to all the people affected or the whole public. Social value can be determined by variations in the social capital of the fragment. Social capital equals trust, relations, public space etc.

Cultural value

The significant portion of an urban unit's cultural value[589] stems from the originality of the internal attributes of the construction. Changes in cultural value result from ageing (time), zeitgeist, localisation and construction phases (use changes).[590] The influence of ageing, under ceteris paribus conditions for other attributes, increases the cultural value (as long as the construction is not near collapse). The cultural value is very dependent on the zeitgeist and the stakeholders, from the scientific as well as public point of view, i.e. a construction can gain greater or lesser cultural value. Inappropriate impacts by construction activities risk decreasing cultural value.

Resource development, like scarcity, may increase the interest into construction types and influence the cultural value as well. Changes in the geographical context have little influence on the cultural value. Technical developments do not influence the cultural value of constructions absolutely but give it a possibility for relative comparison. Nevertheless, depending on the age, some cultural consequences of construction activities are irreversible:

1. Some materials used in the past are no longer available and so it is not possible to build the same construction.
2. Some construction types are not feasible anymore due to the high rise of wages in the past century.

Cultural value recognises that there are different construction methods and that all have their own value; even if some stakeholders may see contemporary approaches as more efficient than older ones. With their time dependency, buildings are witnesses to construction possibilities and objects at the same time.[591]

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589 Cultural value as conceptualised in this paper encompasses Alois Riegl's 'historical value', 'artistic value', 'age value' and the newness value in his approach to cultural heritage [RIEGL 03].

590 Besides material ageing, there is also a form of immaterial ageing, which means a reduction in the value of an urban unit due to the market side supply of newly developed technological, economic and ecological urban unit products as well as due to increased requirements from juridical-driven renewals or user expectations. This kind of value reduction diminishes through modernisation.

591 Morphology can be considered in the scenarios, but requires an experienced evaluator due to its complexity. Still it is seen as essential and key to understanding

Conclusion

The effects of use and the physical ageing of an urban unit influence its state and reduce the value if no action is taken. Actions to slow down these processes are maintenance, refurbishment or possibly demolition. They vary in the extent of their direct influence on the different values. A construction phase of renovation for example aims to maintain economic value as well as a certain social value. From an economic point of view, the aim is to invest a specific amount of resources that ensures an improved level of cash flow from the construction. As long as repair and maintenance do not endanger the original construction (e.g. damage, inappropriate replacement), cultural value is unlikely to reduce. Finally, from the ecological point of view, such actions might aim to have as small a negative effect as possible on the ecological capital.

In construction activities such as demolition and new construction, materials are set free. Demolition is a rather energy intensive process that generates emissions and therefore has a high ecological cost. Furthermore, it can be accompanied by a cultural loss and, if not appropriately analysed and managed, by social losses. These costs have to be weighed against the possible monetary gains expected (at least in the short term).

Scenario descriptions cannot be assessed with the assessment methods because scenarios already incorporate within themselves evaluations of possible future developments. To achieve more detailed scenario descriptions, strategies are developed in the next step. The strategies illustrate the quantitative (economic and ecological) and qualitative (social and cultural) development of urban units.

solutions in very similar projects where the differences lie more in the structure of the urban fragment than in the variety in uses of the urban units. See for more [HILLIER 07]

III1.5 Step Five: Strategy Design

In step five of applying the framework, the state of the adaptive cycles is determined by the strategies chosen, with the objective to represent the influence of a scenario on an urban unit as closely as possible. External factors – zeitgeist, resource development, technological development and geography – are treated ceteris paribus by the strategies. The main contributor to the development of the values is ageing.

Usually a strategy has a special aim: e.g. an economic goal (gaining money), a social goal (facilitating education) or a cultural goal (protecting heritage). The result of the strategy will have an effect on the other dimensions of sustainability as well. Construction activities oriented to maintaining current conditions have a different design depending on the scenario, i.e. such activities mean something different in a scenario with a more ecological focus than in an economic improvement scenario. Therefore, several maintenance strategies are needed to handle associated activities and their influences on the phases, on the attributes of the elements of an urban unit and on the wider impacts. Maintenance strategies have different focuses and therefore they can have unintended consequences on other dimensions of sustainability.

The aim is to define strategies that are pursued independently of financial and other obligations and that presuppose a scope of action for participants. An economically driven strategy aims to make financial gains, a socially driven one to improve the use opportunities of a construction. An ecological evaluation of an urban unit is inversed, so high ecological value means few impacts. Whereas economic, social and ecological value can be increased through measures, cultural value is a combination of already achieved properties. The professional maintenance of a construction retains its value, but any impact endangers its cultural value (Figure 51).

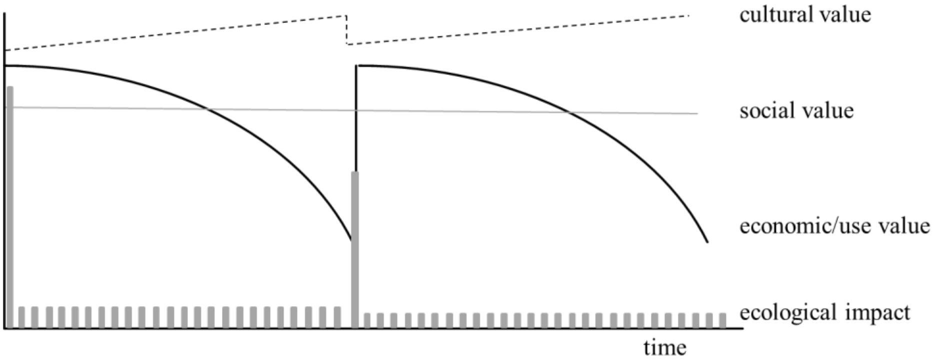

Figure 51: Ageing with phases of construction with ecological impact may help to maintain the social and use/economic value but the cultural may be in danger (dashed)

To calculate strategy outcomes, the focus here is set on the definition of possible strategies for buildings. The adaptation of the results is also possible for other types of urban units (infrastructure and open spaces). Necessary requirements for urban units regarding the four sustainability dimensions are presented below.

From an economic point of view, the fulfilment of following demands is expected: capital investment, such as returns and security; production factor, e.g. usability and efficiency; construction, such as construction materials and building sites; technical equipment, e.g. reliability and potential for improvement; services, e.g. post and security.

Requirements for buildings from an ecological perspective are: lower energy consumption, e.g. less hot water and electricity use; low resource consumption, e.g. less building materials and transformation; low emissions, such as energy carriers; low immissions; e.g. noxious air pollution from (contaminated) materials; lowest possible negative effects of supply and disposal on the surrounding ecology, such as heat, disruption of habitats and air corridors, endangering animals.

From a social perspective the following requirements for buildings are set: satisfaction among users, i.e. tenants, customers and service providers; satisfaction in the neighbourhood, e.g. among residents and users of neighbouring houses; general satisfaction, such as of pedestrians and other non-users; general security, such as of persons and transportation; occupational safety, e.g. from chemicals and through technology; participation of non-owners, e.g. tenants and residents; flexibility, i.e. current and future usability by new or other citizens.

Possible cultural expectations are: use and operation within the meaning of architects, builders, and principals; value assurance; importance for the location; design aesthetics and useful construction details; spatial effects, both inside and outside; flexibility and diversity.

In response to the above-mentioned requirements, strategies in terms of ‘advocacy’ are developed. Such strategies tend to emphasise one sustainability dimension, in terms of both the scope of work on the building as well as the timeframe (short, medium and long term - 10, 30, 50 years). The strategies set out the life stages of a building, such as construction, operation, renovation, alteration, transformation or demolition. During construction, renovation, alteration and transformation, the properties of a building are determined. During operation, a change in their assessment can befall these properties, through either degradation or change of quality expectations. Depending on the advantages claimed, there is an influence on the timing and extent of construction activity, and on the resultant operations. A renovation can include all internal attributes of a building. Changes in values are in the details of elaboration.

The goal, at the level of urban fragments, will usually be to improve the value of the urban fragment, to minimise the environmental impact, and to both lessen the costs and increase the benefits for the social, cultural as well as the economic capital over a specific life phase for a project or a scenario.

Depending on the focus of a strategy, the state of an urban unit and the values of the four sustainability dimensions are determined.

III.1.5.1 Definition and Quantification of Specific Strategies

In the last step, one or more strategies are assigned to the urban units of an urban fragment (Table 44). They help to define scenarios in more detail. Strategies consist of quantitative and qualitative virtual parts. The quantitative parts (economic and ecological) are derived from the results of the MED-Tool introduced in Section II4.3 (Urban Life Cycle Analysis and Annex A3). The qualitative ones (cultural and social) get an evaluation according to the use and the maintenance of the buildings.

Steps	Description
Urban fragment definition	Determining the urban fragment's parameters: feature based or project oriented
Current state description (adaptive cycle phase)	Identifying and measuring indicators for the four dimensions of sustainability
Historic state descriptions: Phase at t-1, …, t-n	
Adaptive cycle evolution description	Combining the virtual sustainability adaptive cycles
Scenarios for future development	Creating and testing scenarios for urban adaptive cycles
Strategy design	Creating strategies and calculations

Table 44 Step 5 of the adaptive cycle analysis framework: strategy design

Decisions on the four virtual strategies define the whole of a strategy. These decisions influence five aspects:

- economical aim: the value starts with 1 and decreases with the ageing, possibly down to 0; it develops similar to the state in chapter (compare Figure 27 in II4.3) but shows the construction's economic value over time
- economical costs: the number starts with 100% for the construction costs; operation (5% of the construction costs) and renovation costs (at the end of cycle 1 30% and at the end of cycle 2 40%; compare p.98/99 in II4.3) are represented in relation to the construction costs.
- Natural/ecological costs: the value starts with 100% for the environmental impact of the construction; operation and renovation impacts stay in relation to the construction impacts similar to the economical costs.
- cultural sensibility: the value starts with 0 points (remarkable constructions can start with a higher value). This number is a very rough measure of culture that increases yearly as long as an urban unit ages and keeps its properties. In case of deterioration and in dependency of the other strategy choices' impacts the value may decrease.
- social considerations: this value is chosen considering the circumstances (in the following it starts with 10 points) and usually stays at the same level; changes may occur in dependency of the other strategy choices' impact

Virtual Strategies with an Economic Focus

Four main economic strategies can be discriminated (without consideration for the cultural, social and environmental):

- asset exploitation – 0 [592]
- value increase – 1 [593]
- value maintenance – 2 [594]
- necessary maintenance – 3 [595].

Within a strategy of **deterioration** (***asset exploitation***), there is no renovation within the first 40 years of an urban unit's life (Figure 52). Economically, this means initial construction costs and then stable operation costs (5% of the construction costes). This means a rising cultural value for approximately 35 years (1 point each year) and then a rather fast decrease due to deterioration (2 points each year, when economic value is below 0.2). Socially, this strategy results in a loss of social connectedness and participation opportunities (starting from 10 in t=0, down to 6 at t=25 and to 2 in t=40). The environmental costs behave similarly to the economic costs: a high initial investment and then stable operational environmental effects (5% of the construction effects).

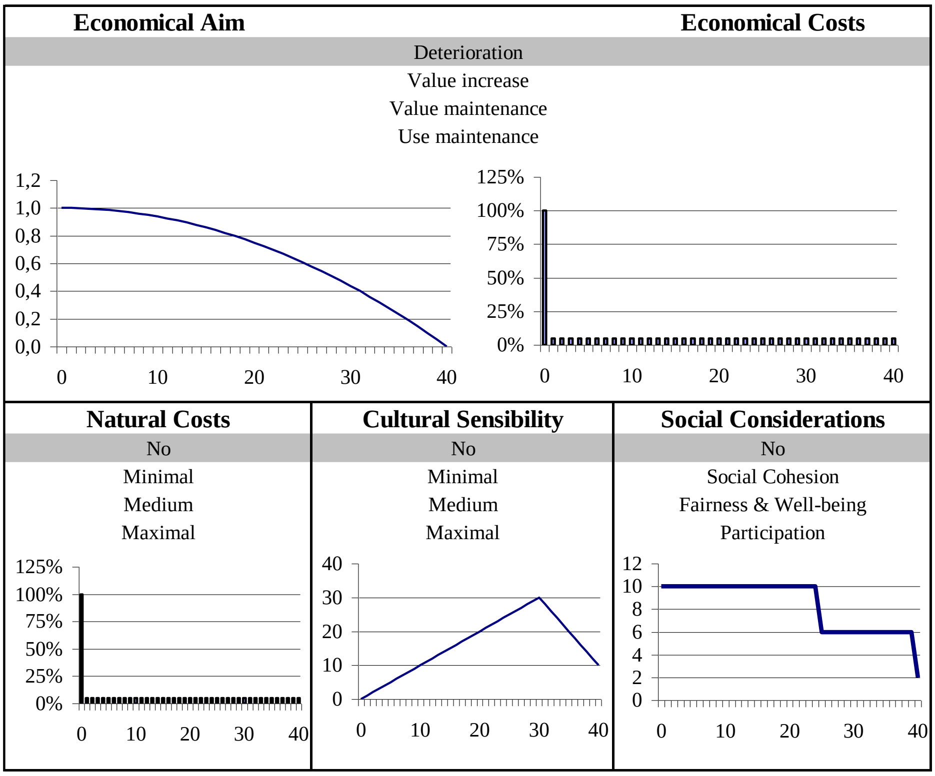

Figure 52 Strategy of Deterioration

[592] comparable with a in between strategy of the strategies 'dereliction' and 'waiting' in Annex A5
[593] comparable with a in between strategy of the strategies 'maintenance' and 'technical and qualitative improvement' in Annex A5
[594] similar to the 'maintenance' strategy in Annex A5
[595] similar to the 'waiting' strategy in Annex A5

With a **value increase** strategy, there is renovation after 25 years, when the economic value of the urban units drops below 65% of the original value (Figure 53). Following renovation, the economic value then increases to 1.2 times the original value. Economically, initial construction costs are followed by stable operation costs (5%) until the renovation of Cycle 1 (40%) and then again between cycles 1 and 2 (compare Figure 27 in II4.3). The renovation costs of Cycle 2 (50%) are higher than those of Cycle 1. This means a rising cultural value (1 point per year) until the renovations. The renovations decrease cultural value (no cultural sensibility) due to their high impact, necessary for the modifications. The social value decreases (from 10 to 8 points) due to diminishing affordability of the building after the renovation (no social considerations). The environmental costs behave similarly to the economic costs, i.e. peaks of impact in construction and renovations phases (40%) with stable operational environmental effects (5%) in between.

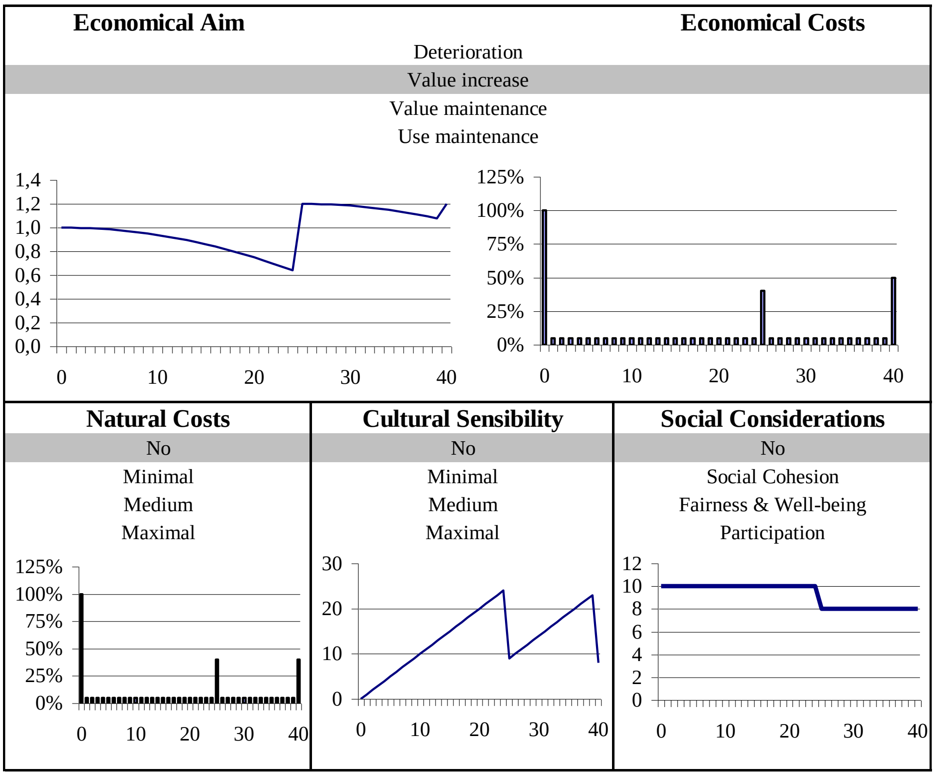

Figure 53 Strategy of Value Increase

With a strategy of **value maintenance**, there is a renovation after 25 years, when the economic value of the urban units drops below 65% (Figure 54). The value increases to 100% after the renovation. The economic (cycle 1: 40% and cycle 2: 30%) and environmental (30%) costs are lower than in a value increase strategy but peak and stabilise at the same points. This strategy results in a rising cultural value (1 point per year) until the renovations with a decrease in value from the impact of the renovation (no cultural sensibility), but not to the same extent as in the value increase strategy. The social value might slightly rise if greater affordability of a better standard is achieved.

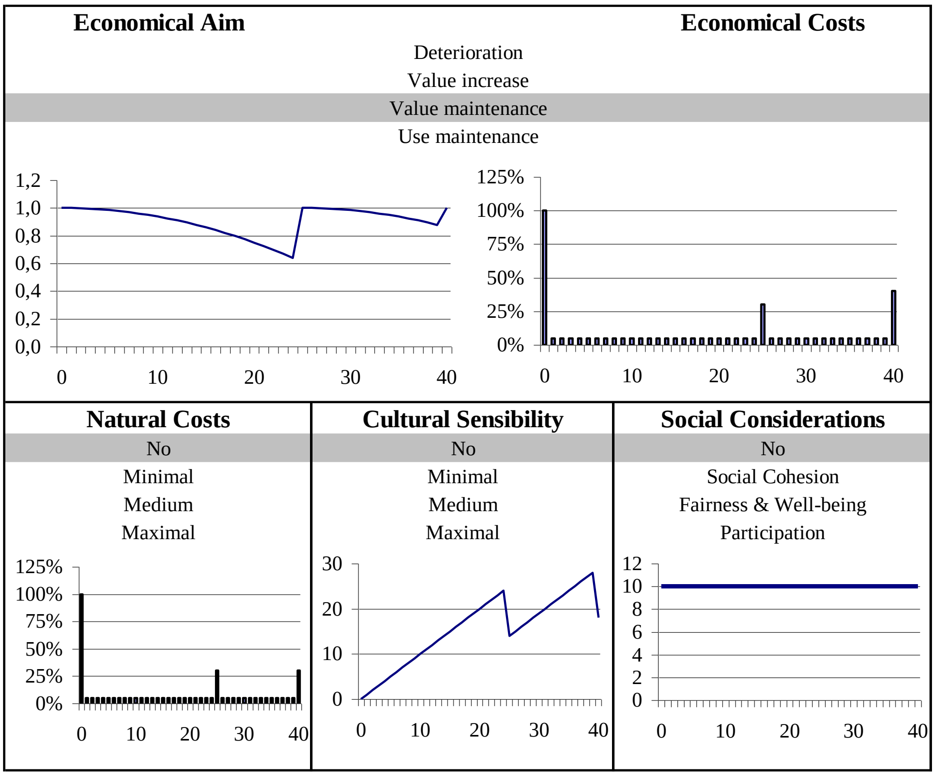

Figure 54 Strategy of Value Maintenance

With a strategy of **necessary maintenance (use maintenance)**, there is renovation after 25 years, when the economic value of the urban units drops below 65% (Figure 55). The economic value increases to 80% the original value after the renovation. The economic (cycle 1: 20% and cycle 2: 30%) and environmental (20%) costs are lower than in the strategy of value maintenance but the peaks and stabilisation happen at the same points. Rising cultural value (1 point per year) until the renovations is followed by a decrease due to the impact of maintaining the use without considering cultural aspects and is accompanied by some of the hazards of effects similar to those in a depreciation strategy (no cultural sensibility). The decrease in cultural value is therefore greater than that in a value increase strategy. Because this strategy is connected with lower equipment requirements than current standards, a stable social value is expected (no social considerations).

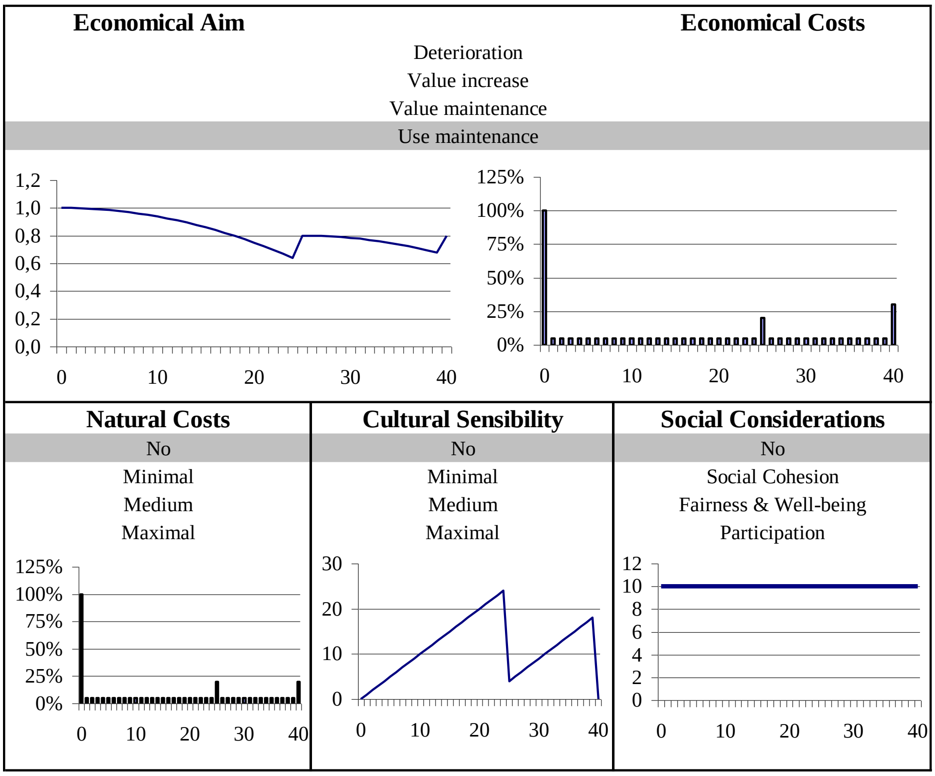

Figure 55 Strategy of Use Maintenance

Virtual Strategies with an Ecological Focus

For the different age and size classes of urban units, the evolution of the state of elements, material flows, energy consumption and emissions have been calculated [596] These calculations have had no focus on environmental improvement but are adapted here for defining virtual environmental improvement strategies. There is no social or cultural focus. The economic focus is set out in the second strategy illustrated below to provide better comprehension of the interdependencies between the strategies:

0. no environmental improvement
1. minimal environmental improvement
2. medium environmental improvement
3. maximal environmental improvement

The latter three environmental strategies are differentiated by increasing economic and environmental investment costs (10%, 20% and 30% more) and the decreasing economic and environmental operation costs (10%, 20% and 30% less). A minimal improvement strategy (Figure 56) can be achieved with little means. However, the more sophisticated the improvements are, the more expensive (environmentally as well as

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[596] see for more detail section II4.3 and Annex A3. Due to the differences of each urban unit, the materials used vary quite a lot. Averaged data is used to calculate the used materials for each urban unit.

economically) they are (Figure 57 and Figure 58). With rising environmental impact (environmental friendly renovation), the cultural value is diminished more (no cultural sensibility). The social value is not influenced greatly (10 points).

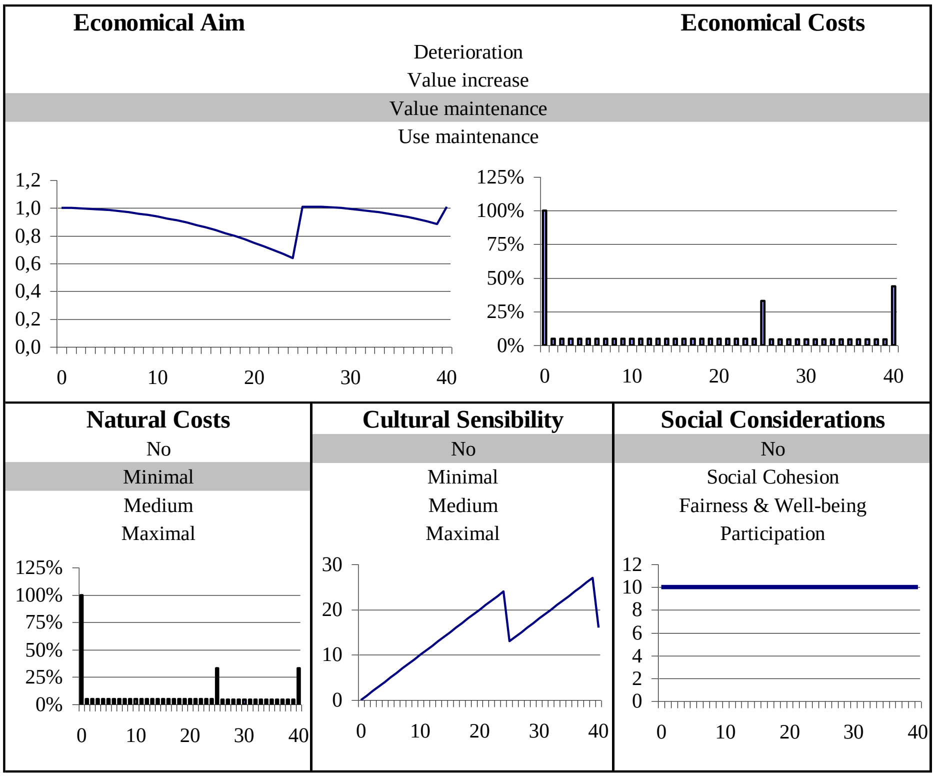

Figure 56 Strategy of minimal environmental improvement

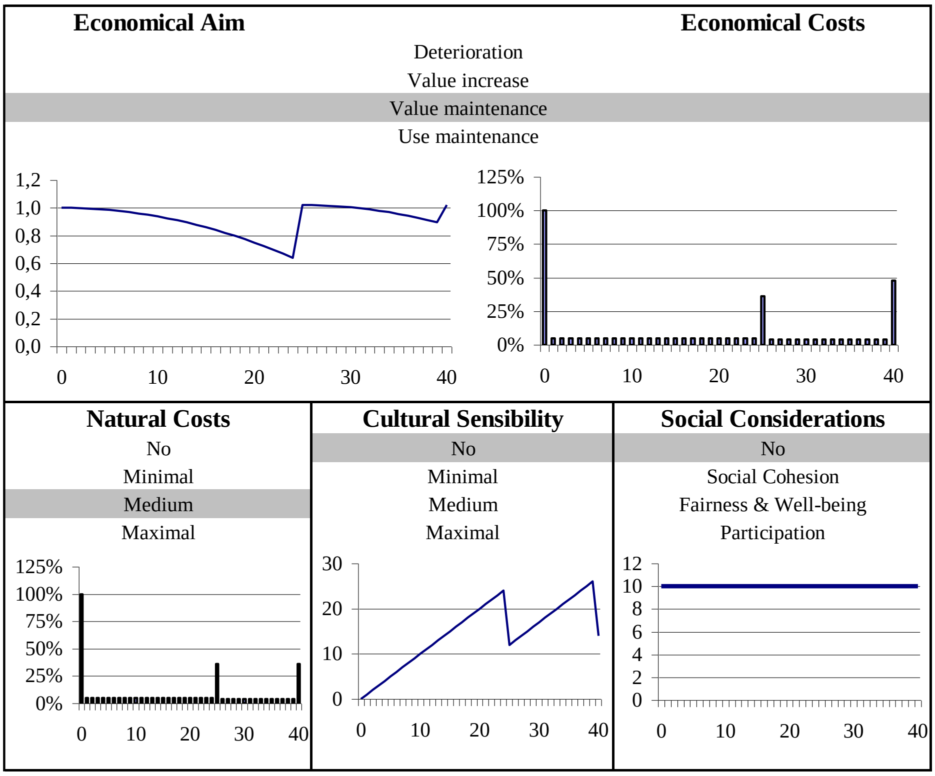

Figure 57 Strategy of medium environmental improvement

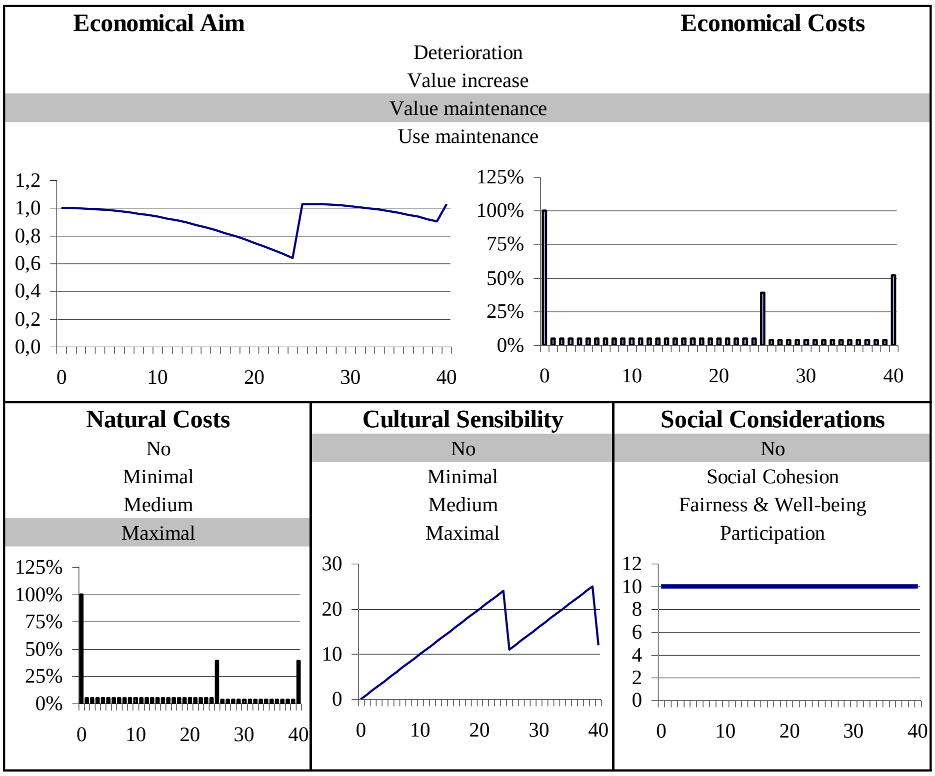

Figure 58 Strategy of maximal environmental improvement

Virtual Strategies with a Cultural Focus

The influence of ageing, with all other attributes ceteris paribus, increases cultural value as long as the construction is not near collapse. Strategies of increasing cultural sensibility assume a continuously growing cultural value if handled adequately:

0. no cultural sensibility
1. minimal cultural sensibility
2. medium cultural sensibility
3. maximal cultural sensibility

Cultural sensibility leads to adequate renovation. The higher the cultural sensibility, the more cultural value increases (1.1; 1.2; 1.3 points per year). The economic difference between the three latter cultural strategies lies in the increasing investment costs (10%, 20% and 30%).
A strategy of minimal sensibility (Figure 59) can be achieved with little economic means (0%, 10% and 20% more operation costs). The higher the sensibility is, the costlier it is (Figure 60), but at the same time economic value decreases more slowly due to better quality. The environmental costs of the three strategies stay at the same level. Social value is first influenced by a strategy with high sensibility, if the higher cultural awareness influences social considerations (from 10 to 12; Figure 61).

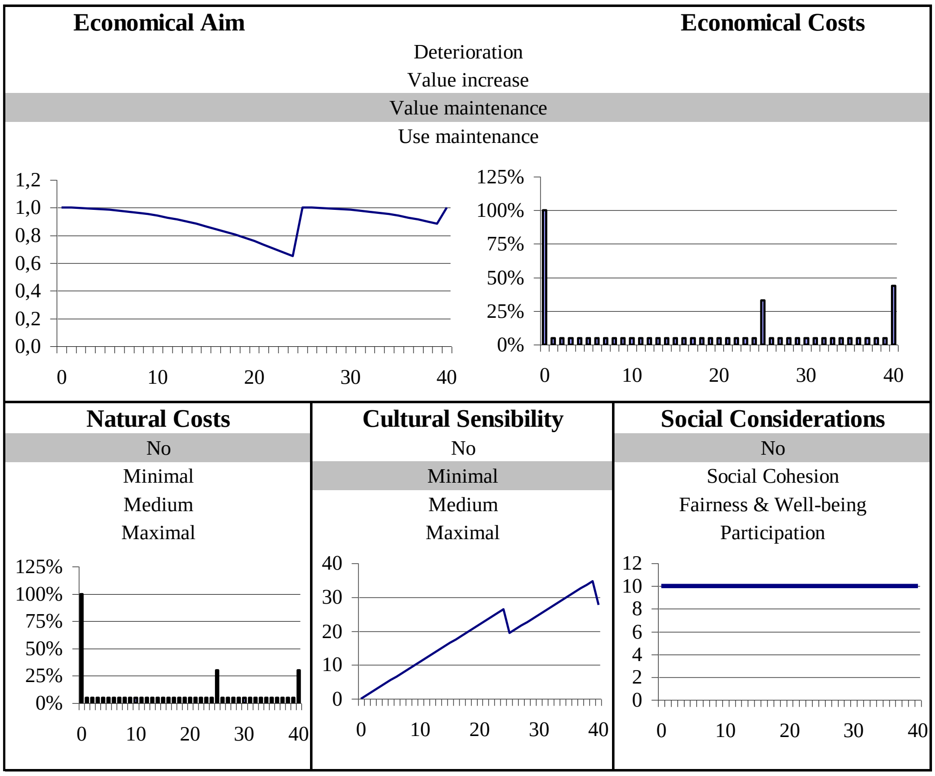

Figure 59 Strategy of minimal cultural sensibility

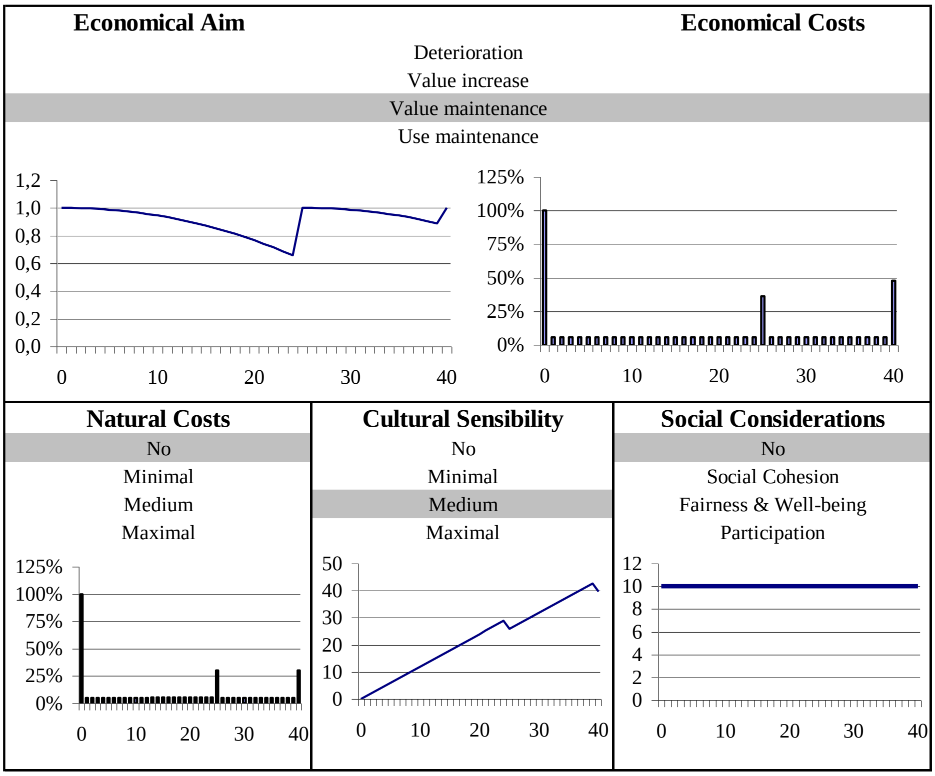

Figure 60 Strategy of medium cultural sensibility

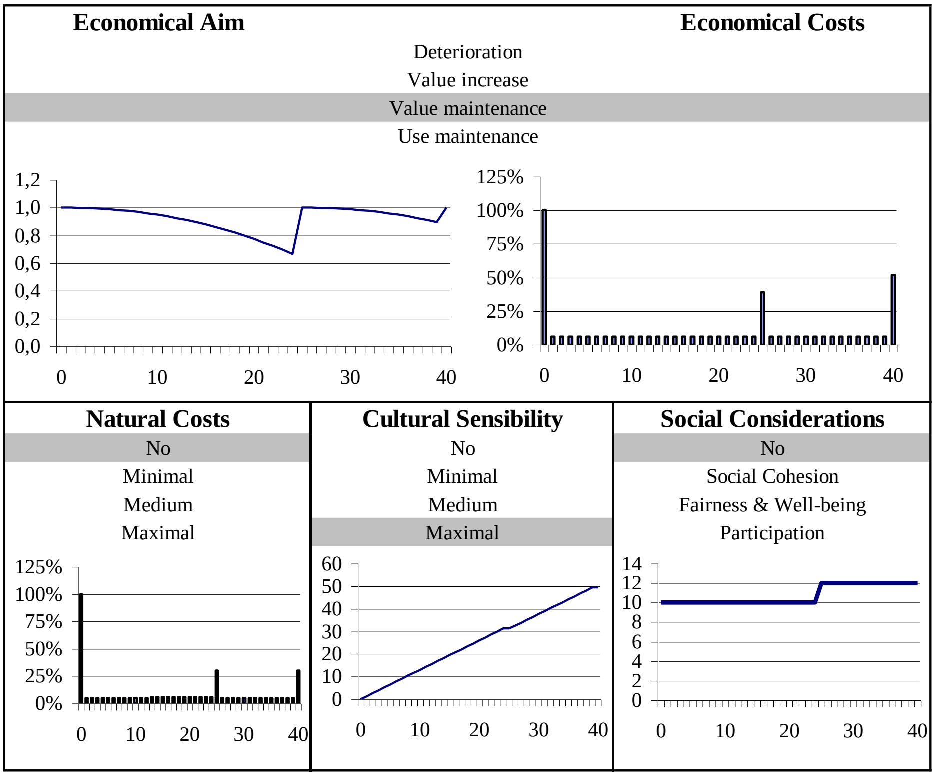

Figure 61 Strategy of maximal cultural sensibility

Virtual Strategies with a Social Focus

The basic underlying assumption for strategies with a social focus is that no changes mean a stable value:

0. no social consideration
1. strengthening of social cohesion
2. regard of social fairness and well-being
3. upgrade by boosting social participation opportunities for the inhabitants and/or the public

A strategy emphasising **social cohesion** (social considerations: 12 points) diminishes the economic value slightly faster. The strategy increases economic costs (5.5%) but results in no change in environmental costs. Cultural value rises faster.
A strategy emphasising social **well-being and fairness** requires higher economic costs (6%) but the environmental costs and the economic value do not change. Cultural value increases (1.05 points per year). Social value is higher than in a strategy of social cohesion (14 points).
A strategy of **participation** slows down the decrease in economic value slightly, increases the economic value to 1.05 after the renovation and requires the highest economic costs of the virtual strategies focussing on social value (6.5%). Environmental costs stay on the same level, while cultural value rises faster (1.15 points per year). Social value is higher than in the strategy of well-being and fairness (15 points).

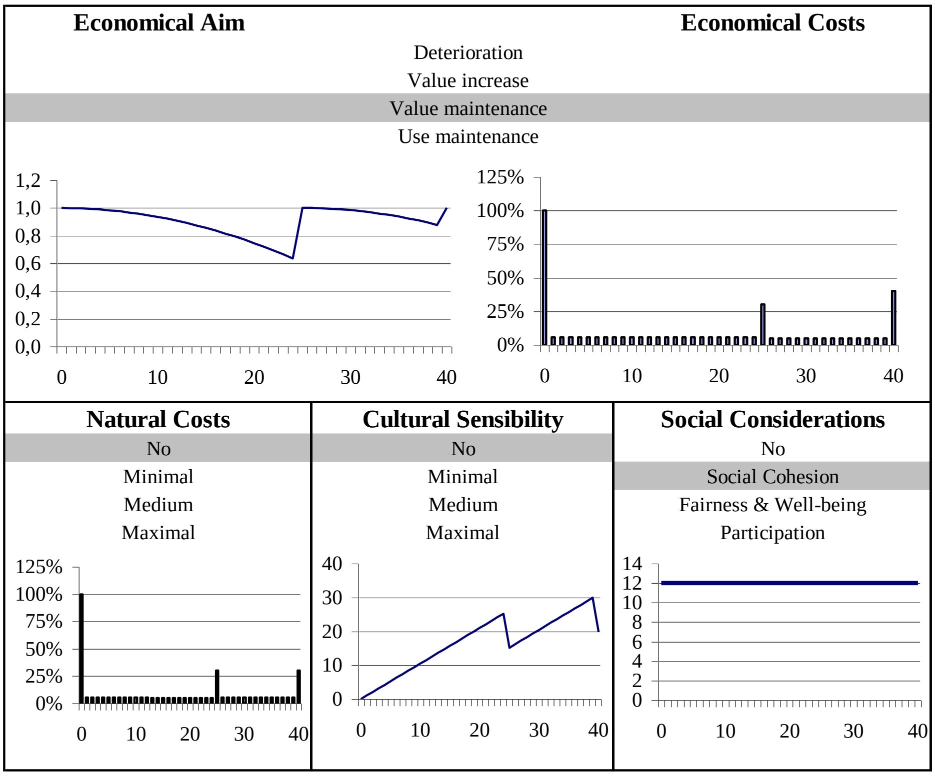

Figure 62 Strategy of social cohesion

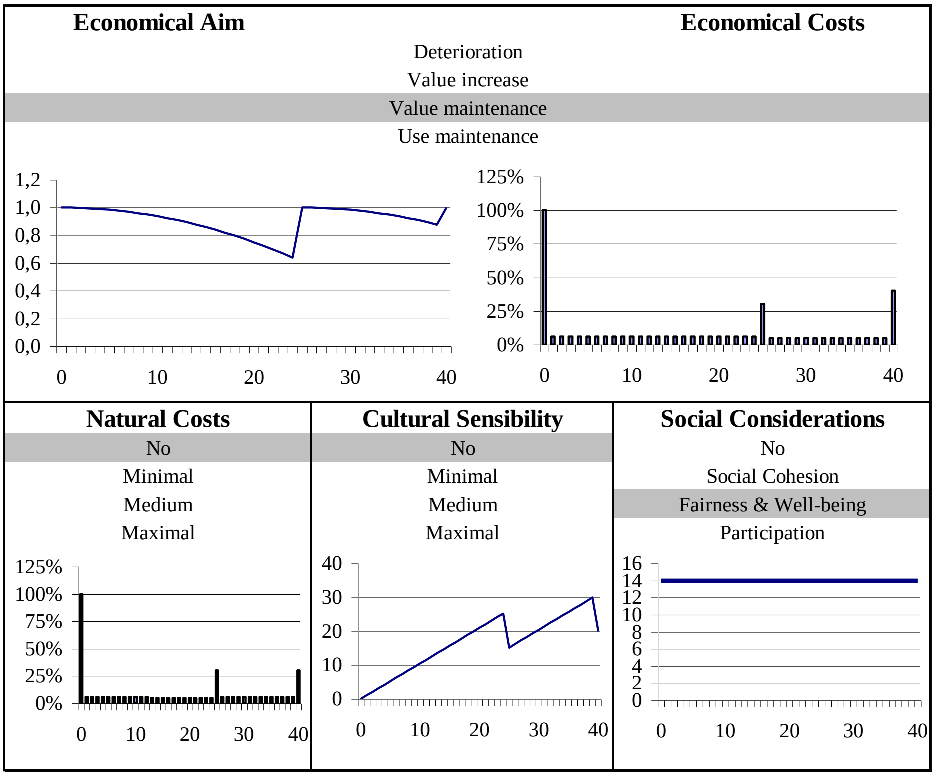

Figure 63 Strategy of social fairness and well-being

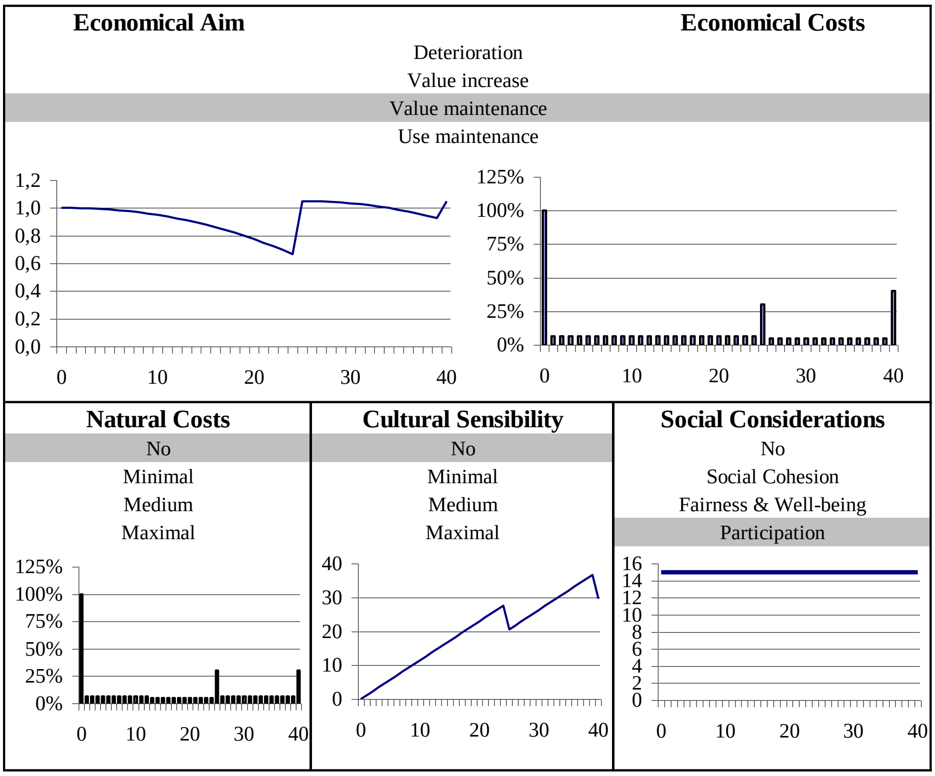

Figure 64 Strategy of social participation

In order to develop a tool, the interdependencies of all virtual strategies have been modelled: from combinations 0000 to 3333. For the standard strategy in II4.3 (Figure 25), the strategy combination 3300 (Figure 65) fits best: use maintenance with the highest cultural sensibility due to the exchange of components with the same type. With strategy combination 3300, the cultural sensibility increases by 1.3 points per year, economic costs are at 6% per year (operation), 26% and 39% for the renovations after cycle 1 respectively cycle 2.

Strategy combination 0000 (Figure 52) shares partially the same path as the alternative strategy (Figure 27); strategy combination 0000 illustrates the effect when renovations are not undertaken after 35 years. Due to the close similarity between the standard and alternative strategies from the overall perspective of sustainability, the latter is not modelled separately.

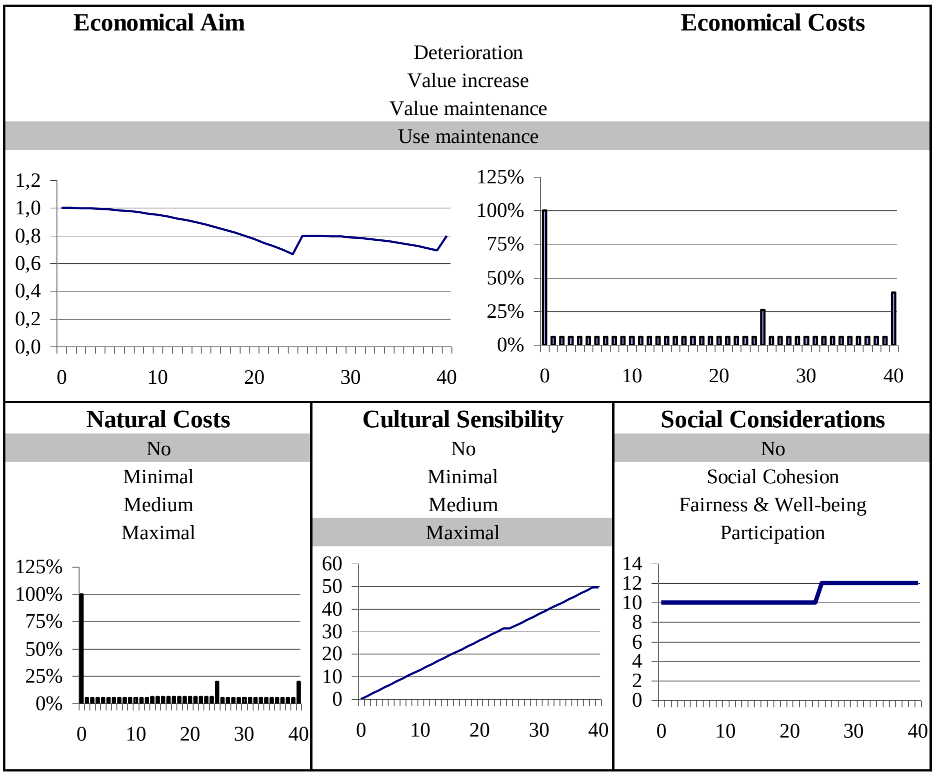

Figure 65 Strategy combining use maintenance and maximal cultural sensibility

III.1.5.2 Discussion and Conclusion

The **intradimensional** strategy combinations can be mutually exclusive due to different time horizons. Short-term asset exploitation leads to a reduction in long-term options. A short-term strategy of energy consumption reduction through measures with a larger extent may in the long-term result in greater overall energy consumption and emissions output if compared with a strategy that is planned for the long-term and takes into account future technological possibilities.

In the short term, strategy objectives may contradict **interdimensionally**. Economic objectives can be pursued regardless of environmental, social and cultural disadvantages. Environmental objectives, which are associated with costs and major intervention, may counteract economic and cultural goals. Cultural aims may obstruct social goals (e.g. necessary transformation is made impossible), ecological goals (e.g. energy consumption remains high) and economic goals (e.g. professional and temporally necessary renovation is too expensive). In terms of resources, conservation of cultural values can also be ecologically meaningful if resources are not destroyed to be rebuilt. A similar beneficial link between cultural preservation and social appreciation can be quite possible, for example if the cultural significance of a building serves cohesion of the public. Social goals often seem expensive in the short term, but ecologically they are rather irrelevant and so they can be combined rather well. As aforementioned, social goals can conflict with the preservation of cultural values. In

aligning goals, sensible planning can be thoroughly helpful to avoid loss in any virtual sustainability dimension and prevent conflicts.
By focusing on one dimension of sustainability, in the short term many building components may lose their other values, e.g. photovoltaic panels on the roof increases the ecological value, but destroys the cultural value, or the foundation of a cooperative increases the social value of residential buildings but prevents a higher economic return. In the long term, strategies come somewhat closer to each other. If a building is to be maintained in the long run, economic, ecological, social and cultural objectives can be combined appropriately. Careful management of the building can maintain assets in the cultural and ecological senses, and parallel it can contribute to the social value by supporting longevity between generations and classes. The long-term perspective helps to identify common objectives, which would get no preference in short- and medium-term perspectives.

Virtual strategies for the economic, ecological, social and cultural help to comprehend in more detail the influence of the adaptive cycle, described by the scenario developed in step four, on the urban units (here buildings) of an urban fragment. Even if applied and represented here in a simple way. This approach can be further developed to discriminate age, size and use classes, which is partly applicable for the economical and ecological aspects already (see Annex A.3).
In following sections, the adaptive cycle analysis framework is applied to two case studies.

III2. Case Study: Ludwig-Frank Estate, Neckarstadt, Mannheim, Germany

The application of the framework for adaptive cycle analysis of urban fragments (presented in Section III.1) is demonstrated through two case studies, one in Neckarstadt, Mannheim, Germany and the other in Bourtzwiller, Mulhouse, France (Figure 66).

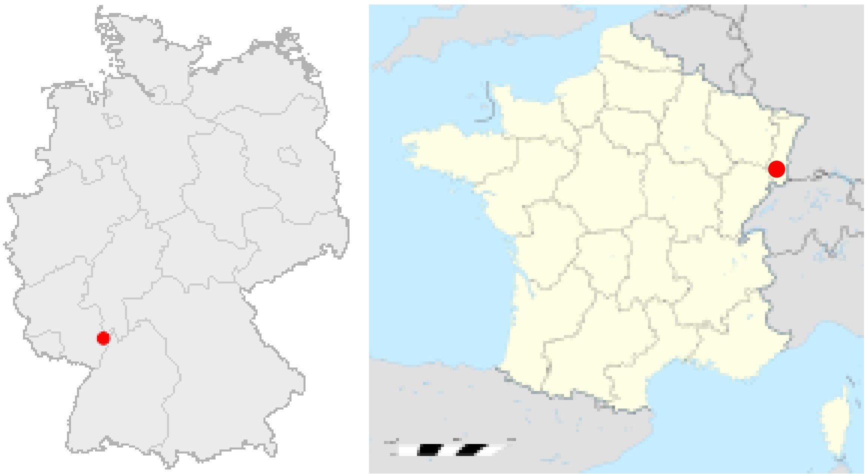

Figure 66 Location of the cities Mannheim (Germany) and Mulhouse (France) Source: [KLEMPERT 05] (left); [GABA 08] (right)

III2.1 History of the Urban Fragment

The urban fragment (Ludwig-Frank-Estate) is situated in Neckarstadt. One of the old town districts of Mannheim that still possesses an initial core represented by several old buildings. Neckarstadt has gone through a long construction period over the last 100 years. It borders downtown Mannheim.[597]

The Ludwig-Frank Estate is located close to the borders of areas already built-up in 1890, putting it in proximity to the inner city (a major factor of attractiveness). Well-known architects from the region (Wilhelm Schmucker, Emil Serini und Ferdinand Mündel) designed the buildings. Ludwig Frank was a representative of the Social Democratic Party of Germany (SPD), a member of the 'Reichstag' (German parliament) and Landtag (state parliament of Baden-Württemberg) for Mannheim, who advocated decent accommodation for workers before the war.[598]

Prior to the German monetary union in 1949, it was obvious that although material and labour were available, neither developers nor public authorities could raise the needed funds for the construction of affordable housing. In 1949, the local council decided to establish a housing fund that was advertised under the slogan 'Mannheim baut Wohnungen - Jeder hilft mit' ('Mannheim constructs homes - Everyone is helping')[599] (Figure 67).

[597] [SOZIALE 03]
[598] [MOERSCH 08], p.278
[599] [MOERSCH 08], p.277

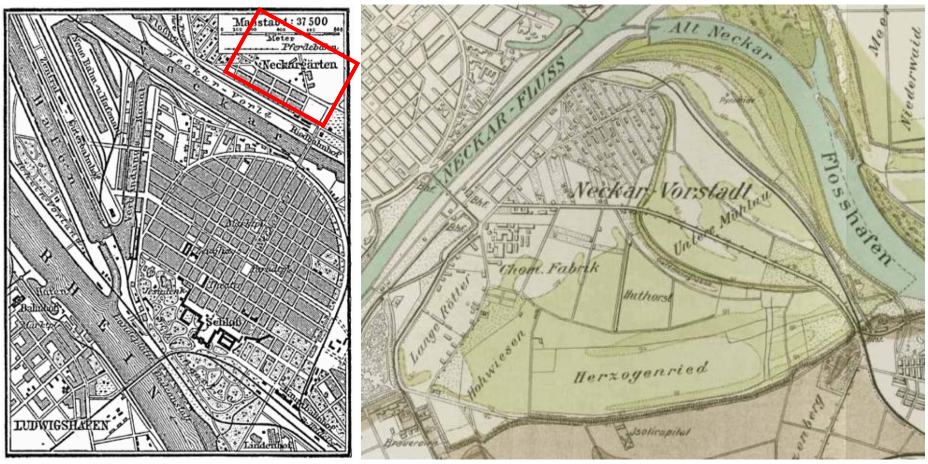

Figure 67 Mannheim Neckarstadt in 1888 (red box) north of the inner city and Mannheim-Neckarstadt in 1890 in more detail
Source: [MEYER 88] (left); [SCHOTT 07] (right)

This development on the local level later triggered one on the federal level.[600] The first major housing project in Mannheim after the war, which was supported by development funds, started in the spring of 1949 in the working-class district Neckarstadt. Using crushed stones from debris, the apartment blocks were built with simple construction methods by the Gemeinnützige Baugesellschaft (GBG - Municipal Housing Cooperation).[601] Two hundred eighty apartment units were constructed and became occupiable in 1951. The Ludwig-Frank Estate was considered for years a sought-after address. Many prominent citizens made it their first post-war residence.

Figure 68 Poster advertising the new blocks in 1949 and Mannheim Neckarstadt in 2012 (Ludwig-Frank Estate in red box)
Source: courtesy of the Vermietungsgenossenschaft Ludwig-Frank eG, [RUDOLPH 13], p.62, see also [SCHENK 99], p.23 and [PAHL 02] (left); created with Microsoft GeoFlow Preview for Excel 2013 (right)

Being initially very popular and while the floor plans, materials and interiors were of high standard considering the circumstances of post-war Mannheim, they proved to be unsatisfactory in the long run.[602] Parallel to the rise of economic prosperity, the population’s demands linked to housing grew. Larger dwellings with better facilities were

600 ibidem, p.276
601 [SCHENK 99], p.25
602 [PAHL 92], p.3

preferred and the initial tenants of the estate mostly moved to flats that met their demands or to newly constructed houses. In the 1970s, the city of Mannheim and social services began to make homes in the estate available for the unemployed, socially disadvantaged, refugees and migrant families, which changed significantly the composition of residents in this area.[603]

The proportion of residents with immigration backgrounds grew to 65% (1988) and represented 15 different nations. Because of communication difficulties and different cultural backgrounds, daily life was characterised by tensions and short lease terms. [604]

At the end of the 1980s, the buildings needed renovation and modernisation, which had not been conducted for 20 years. The one-sided assignment practices of the housing office finally led to a loss of attractiveness for the estate. Rapid deterioration of the building fabric and increasing vandalism and pollution soon turned the settlement into a social focal point. For reasons not exactly reconstructable, the buildings were under consideration for replacement. Possible explanations are that the land was regarded as too valuable for the mostly underprivileged groups, principally social assistance receivers, the unemployed, foreigners, etc. and the view of GBG that new constructions are cheaper than renovation. The GBG as owners of apartments decided in agreement with the city of Mannheim as the owner of the site to demolish the houses and replace them with new ones. Any further investment in renovation was stopped. The total cost of modernisation was estimated at about €43,000 per dwelling, which would have resulted in big increase to rent levels. The neglect resulted in 100 dwellings becoming empty, although at the end of the 1980s there was a housing shortage in Mannheim.[605]

In 1988, tenants in the Ludwig-Frank housing complex received demolition notices from the GBG. For the residents, however, the demolition and new construction were seen as a big threat, since the new flats would not have been affordable for most of them. Comparable dwellings in the area would have been hard to find; the Ludwig-Frank housing estate is well situated both in relation to the central city as well as to various recreational areas such as parks and swimming pools. Buses and trains as well as the central station are also favourably reachable. Schools and kindergartens are available in a sufficient quantity. With the announcement of the plans of the construction company, some tenants founded a tenants' advisory action committee. To prevent the demolition of the apartments, they requested the GBG invest again in renovations and turned to the population with a petition. According to a survey, 95% of the residents were in favour of preserving the residential estate. In the meantime, members of the City

[603] [PAHL 92], p.4
[604] [SOZIALE 03]
[605] [PAHL 92], p.4

Council were taken on tours of the housing stock, which apparently had become too bad for human habitation. Initially the renovation plan was rejected by the City Council. After the commitment of the action committee's Mr. Walter Pahl, who as a member of different International Cooperative Alliance committees had the necessary knowledge and experience of campaigning for social issues, it was supported finally also by the City Council. In order to prevent demolition, the City Council approved the creation of a cooperative to take over the modernisation of the apartments. Each of the initial 53 cooperative members committed themselves to buying shares of approximately €500 each. Members who wanted to rent an apartment had to buy one additional share for each room. In the end, 99% of the tenants were won over to the cooperative.[606] In November 1990, the city transferred the housing complex to the newly established cooperative free of charge. The period of ground rent and the obligation to maintain and care for the housing stock was set at 99 years. A proposal by the cooperative to shorten this period to the normal lifetime of the building (as the buildings would then be 140 years old) was rejected.[607]

Within the Ludwig-Frank Estate, 280 dwellings constructed from 1949 to 1951 were renovated between 1990 and 1991. After circa 40 years without refurbishment and only occasional maintenance, the buildings had to be renovated thoroughly. Less complicated interventions and clean up were accomplished by the tenants themselves (Figure 69). For major works, companies were commissioned. At first, the empty flats were renovated and modernised. After the retrofitting, the residents could move from their old homes into the newly refurbished apartments. Finally, these now empty apartments were modernised. One company and one housing manager were recruited to manage business affairs.[608]

In order to discuss emerging problems during the renovation, a tenant meeting was set up in a beverage market, which could also be used for socialising one night a week. However, the tenants alone were not capable of solving the problems with which they were suddenly confronted. The people were not only gathered from 15 different nations, but also had different backgrounds (religious communities, large families, low incomes, unemployment, the aged etc.). Many people were necessarily focussed on achieving self-sufficiency and therefore not really ready or equipped with the necessary social skills to deal with the problems of others. As a result, it was decided to set up a meeting with a social worker, who should address the concerns of the residents and pave the way for understanding. The cooperative has the motto: 'Working together to maintain peace'. Works were completed towards the end of 1993, five years earlier than planned.[609]

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606 [SOZIALE 03]

607 [PAHL 92], p.16

608 [PAHL 92], p.28

609 [PAHL 92], p.30

Figure 69 Tenants of the cooperative Ludwig-Frank in Mannheim-Neckarstadt Source: photo taken by Ludwig Friedrich, courtesy of the Vermietungsgenossenschaft Ludwig-Frank eG, [PAHL 92], p.16

A day-care centre and a cultural centre were established in the Ludwig-Frank housing estate. The cultural centre provided a social meeting place. Caretaker roles and other volunteer activities were coordinated, and self-organised socialising programmes, such as German language courses for women and homework assistance for migrant children, were offered. The Ludwig-Frank housing complex now has a ratio of 75% migrant households from 19 countries to 25% German households.[610] The budget amounted to €11,000,000, for mainly cleaning and restoration, and €150,000 for social work. Of the budget, 49% was provided by the cooperative, 26% by the L-Bank and 23% by the city of Mannheim. Since the project gathered national and international interest, 1% of the budget came from the EU and 0.2% from the Lion's Club Mannheim in cooperation with a German-American women's group, other organisations and donations from the public. [611] Even though there was financial assistance from the city and the European Union, financial self-help played an important role in the project. A reserve of about €250,000 was created despite the €7,000,000 cost to renovate the dwellings. The cooperative has also mobilised private capital for housing purposes. Besides the residents, there are now approximately 120 individuals or companies who support the cooperative without having a dwelling unit. Even though rent levels have increased since the modernisation, the rise has been moderate in comparison to the levels that would have been reached if the dwellings had been demolished and rebuilt. In 1993, rents were €2.25 per m^2 per

[610] [SOZIALE 03]
[611] [PAHL 92], p.19

month, much lower than the €4 per m^2 per month for new social housing available elsewhere in Mannheim and the citywide average of €3 per m^2 per month for all social housing. Besides others means, the cooperative was able to keep the costs of the modernisation low by requesting tenants pay for internal decoration on their own. Residents managed the work either individually or with the aid of neighbours.[612]

The foundation of the cooperative was notable in particular by the fact that it could contribute to the integration of foreign residents and received various awards, e.g. in 1993 the United Nations' 'World Habitat Award' (WHA), the first given to Germany, was received on behalf of the cooperative by the initiator Walter Pahl. On the website of the WHA, the reasoning behind the decision is explained, inter alia, with the following introduction: "The Housing Cooperative Ludwig-Frank is an outstanding and innovative example of how a dilapidated residential area, housing a multi-cultural population from 15 different countries, can be transformed into an attractive and habitable district through cooperative self-help and solidarity. The project demonstrates that genuine renewal of an area can not be achieved simply through technical improvements, but that social and cultural development is a key aspect of inner city renewal."[613] In Istanbul at Habitat II in 1996, Minister Prof. Dr. Klaus Töpfer presented the project. By 2002, the cooperative already had 543 members and 99% of the estate's residents were cooperative members.

III2.2 Step One: Define Urban Fragment

The urban fragment of interest consists of seven buildings of the Ludwig-Frank Estate in Mannheim-Neckarstadt, Germany from its construction in 1949-51 until today (Table 45).

Steps	Description
Urban fragment definition	Location: seven buildings of the Ludwig-Frank Estate in Mannheim-Neckarstadt, Germany Time period from construction in 1949-51 until today
Current state description (adaptive cycle phase)	Identifying and measuring indicators for the four dimensions of sustainability
Historic state descriptions: Phase at t-1, …, t-n	
Adaptive cycle evolution description	Combining the virtual sustainability adaptive cycles
Scenarios for future development	Creating and testing scenarios for urban adaptive cycles
Strategy design	Creating strategies and calculations

Table 45 Step 1 of Adaptive Cycle Analysis for the Ludwig-Frank Estate

612 [PAHL 03], p.3
613 [WHA 93]

III2.3 Step Two: Determine and Describe the Current Adaptive Cycle Phase

The current phase of the urban fragment is analysed using the abovementioned indicators, which divide the urban fragment into the four virtual sustainability adaptive cycles. Indicators evaluate the time periods after renovation (1995 to 2010), prior to renovation (end of 1980s) and almost two decades after construction at the end of the 1960s.

Ecological Virtual Adaptive Cycle Analysis

There are no large sources of noise close to the settlement and air quality is fine. The cooperation cares for the cleanliness and maintenance of green areas. Improvements carried out on the dwellings included better energy efficiency, replacement of single glazing with double glazing, provision of roller shutters and new interior and exterior window sills, full heat insulation and cladding. Furthermore, sanitary facilities comprising supply and disposal systems were replaced and the central heating system was linked into municipal district heating. The CO_2 equivalent emissions exposed by the renovation were paid back by operational savings within the first five years.

The quality and size of the green areas are good and could be used more efficiently. With insulation, the efficiency of the heating is up to date. The renovation facilitated the retention of a high degree of grey energy. (Table 46)

Cultural Virtual Adaptive Cycle Analysis

There is no great opportunity to change the use of the buildings. The morphology of the buildings is not sophisticated but the road dividing the settlement makes it accessible and crossable. The frequency of maintenance will be tested in the next years.

Neither the type of construction nor the architectonic quality adds significantly to the cultural potential, but there are small differences (e.g. the entrances) that make each building identifiable and somewhat individual. The possibility to continue the cooperation for a further 70 years adds to the importance of the estate’s use. (Table 46)

Social Virtual Adaptive Cycle Analysis

The door entry systems, renewed staircases, balconies and the replacement of letterboxes helped to provide a strongly improved quality of life for the residents. There are almost no vacancies, a secure environment and ethnic and cultural diversity (no ghettoisation). Working together and the outcomes improved both the social climate amongst tenants and the satisfaction with the new housing conditions in the estate. The new look of the buildings and the consequent effect on the neighbourhood and the whole district helped to diminish the ghetto character and increase acceptance within the district. The trust, which was set up by the residents as the new co-owners of the community property, was not disappointed. The residents pay great attention to cleanliness and maintenance. While in the 1990s, many works (care of green areas and cleaning of the stairways) were accomplished by the tenants, nowadays the cooperation has taken over many tasks. The education levels, types of students and workers and the age structure of the tenants are diverse and substandard dwellings are still available. The frequency of user changes is rather low. The cooperative's main objective to reduce or avoid tensions between the different nationalities and establish friendships among the residents has succeeded. Ethnic and religious differences remain, but are tolerated. The improved economic, cultural, social and political conditions of the cooperative have awakened understanding and tolerance in the neighbourhood. The tenants are accepted by the inhabitants of the surrounding quarter. The 'Treffpunkt' organises events that are open to the public, highly appreciated and regularly frequented. (Table 46)

Economic Virtual Adaptive Cycle Analysis

There have been no big changes since the renovations finished in 1995. The cooperative managed to rehabilitate the dwellings at a cost of €17,500 per flat. It would have cost approximately more than four times this amount if the houses would have been demolished and rebuilt, with apparent consequences for the rent levels. The city authorities' subsidy was about €6,250 per dwelling. The costs for a new construction have been estimated at about €40,000-50,000 per dwelling.

With the kindergarten and the different courses (languages, activities for young and old) in the 'Treffpunkt' ('meeting centre'), and two stores the diversity of uses is high. The amount of vacancies is low, with many families and singles who want to move into the settlement. The purpose of the dwellings is difficult to change to another use. The infrastructure and accessibility are good due to the proximity to the city centre. With the cooperation, the owner status of the tenants has a positive influence on the maintenance of the buildings. The frequency of the tenant turnover is low; people are even on waiting lists to get a flat (up to 18 months according to a member of the supervisory board). In comparison to the absolute rent levels in Mannheim and in relation to the quality and location of the estate, the rent levels are very attractive. Tenant incomes are low to middle, with many singles, young families and old families. The location of the urban fragment is still highly attractive, with a nearby park and other facilities necessary for daily life. The buildings seem to be coming close to a renovation period (as of 2012). The cooperative is conscious on this and started cooperations with universities to developed ideas for the coming decades[614] (Table 46).

[614] [RUDOLPH 13]

Ecological	Indicators	State in 2010
Resilience (Resistance)	Noise (internal)	
	Air quality (internal)	
	Cleanliness and care of green areas (internal)	+
	Ecological footprint (external)	
	Emissions (external)	+
Connectedness (Relations)	Continuous green areas with biocoenosis (internal)	
	Continuous green areas with biocoenosis (external)	
Potential (Quantity)	Quality and size of green areas (internal)	ø
	Number and amount of species (internal)	
	Resource, i.e. energy, consumption and efficiency (external)	+
	Retention of grey energy, i.e. recycling, renovation (external)	+
	Use of renewable resources (external)	

Cultural	Indicators	State in 2010
Resilience (Resistance)	Possibility to change use	-
	Frequency of renovation	ø
	Morphology of buildings	ø
Connectedness (Relations)	Location of the urban fragment	
	Cultural importance	+
Potential (Quantity)	Types of construction	-
	Importance of use	+
	Architectonic quality	ø

Social	Indicators	State in 2010
Resilience (Resistance)	Vacancies	+
	Cleanliness and care of buildings	+
	Happiness of users and inhabitants	+
	Security level	+
	Ghettoisation/gentrification	+
Connectedness (Relations)	Organisations and events	+
	(Public) Participation	+
	Access to social and health services	
	Frequency of user change	+
Potential (Quantity)	Education levels	ø
	Age structure	+
	Availability of substandard dwellings	+

Economic	Indicators	State in 2010
Resilience (Resistance)	Diversity of uses	+
	Possibility for change of use	-
	Vacancies	+
	Preparedness for natural and technological risks	
Connectedness (Relations)	Infrastructure/accessibility	+
	Owner status	+
	Clients of local companies	
	Frequency of tenant change	+
Potential (Quantity)	Rent levels	+
	Existing companies and number of jobs	
	Supply of retailers	
	Product of urban units (size of available use area, equipment)	ø
	Income structure	+
	Location of the urban fragment	+

Table 46 Virtual Adaptive Cycle Analysis of the Ludwig-Frank Estate, Mannheim in 2010

Determining the Virtual Adaptive Cycle Phases

With the insulation, the emissions of the urban fragment and its pressure on the inner and outer ecological resilience are low. The green areas have only a little relevance for outer ecological connectedness and internally their biocoenosis is of limited importance. Overall, ecological potential is good. The indicators are a good sign that the ecological virtual adaptive cycle is in a K phase (Table 47).

The importance of the settlement after the war supports its cultural internal connectedness and connectedness with the surrounding quarter. The main contributor to its cultural potential is its prospective use for several decades. The estate's cultural resilience mainly depends on the upcoming renovation works. Overall, the cultural potential and especially the cultural resilience are not high, which might be a sign of an Ω phase, while cultural connectedness is not affected yet (Table 47).

Overall, social potential, connectedness and resilience are high, which is a good sign of a K phase (Table 47).

Overall, the urban fragment is economically resilient, with high economic connectedness internally as well as with its surroundings and good economic potential. The indicators are a good sign that the economic virtual adaptive cycle is in a mature K phase, in which in the coming years decisions have to be made to avoid an upcoming Ω phase (Table 47).

Steps	Description
Urban fragment definition	Location: seven buildings of the Ludwig-Frank Estate in Mannheim-Neckarstadt, Germany Time period from construction in 1949-51 until today
Current state description (adaptive cycle phase)	2010
	ecological virtual adaptive cycle in a K phase
	cultural virtual adaptive cycle between a K phase and a Ω phase
	social virtual adaptive cycle in a K phase
	economic virtual adaptive cycle in a K phase
Historic state descriptions: Phase at t-1, …, t-n	
Adaptive cycle evolution description	
Scenarios for future development	
Strategy design	

Table 47 Step 2: The phases of the virtual adaptive cycles the Ludwig-Frank Estate, Mannheim is in for the year 2010

General Adaptive Cycle in the 2010s

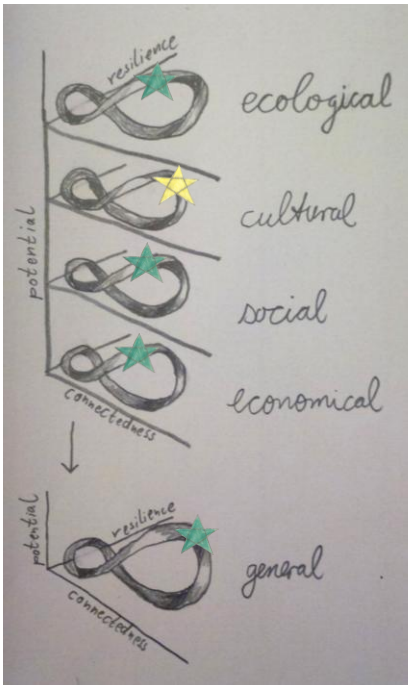
The current general adaptive cycle has its beginnings at the end of the 1980s. Plans to replace the settlement with buildings of a higher standard would have resulted in higher rents and new tenants forcing the old ones to move into the suburbs.

The strong will of the inhabitants and the political support and help of experts from tenants associations showed that a high degree of resilience and the desire to cooperate (connectedness) existed. The prospect of establishing a cooperative increased the connectedness among residents. The difficulties that the inhabitants had to face were typical for such a phase. This reorganisation phase needed the cooperation of different individuals within a highly heterogeneous population, as well as intensive public relations work and initial support from the city council.

The constitution of a cooperative was a new experience for the majority of the tenants and it provided a formal framework for common interests. Socio-economic barriers required a broad range of information, which helped to prepare the tenants adequately for the new venture.

The foundation of the cooperative, initially with 'only' 53 members, can be considered as the beginning of an adaptive cycle phase r, during which the people living there had the opportunity to move to other, renovated apartments. The time after the completion of the renovation and restoration measures can be seen as a transition into a K phase (mid-1990s).

The long-term commitment of the cooperative also made possible the increase in social potential, especially with the cultural centre that served as a place of integration and contributed to the stabilisation of the settlement. In this period, the potential of the buildings increased greatly and the potential of the location began to climb so that the urban fragment became appreciated in its immediate vicinity as well as in the larger neighbourhood. With the commitment to low financial and low environmental costs, the use value and monetary value increased. The rescue of the urban fragment raised its cultural value and preserved an interesting piece of post-war architecture.



t = 2010

Figure 70 State of the General Adaptive Cycle of the Ludwig-Frank Estate in the 2000s

Plans to Demolish (End of the 1980s)

Ecological Virtual Adaptive Cycle Analysis

Noise and air quality were not of importance. The estate was not cared for and the buildings were technologically out of date. The green areas of the settlement had no relevance, internally or externally.

The quality of the green areas was ecologically low but their size was rather big. The buildings' energy consumption was not efficient due to the out-of-date technical equipment. (Table 48)

Cultural Virtual Adaptive Cycle Analysis

Due to the poor condition of the whole urban fragment, there was no possibility to change the use, renovations were omitted and the morphology was inflexible. The settlement had a little cultural importance stemming from its initial meaningfulness. There were no sophisticated types of construction, no important use and no architectural quality of note. (Table 48)

Social Virtual Adaptive Cycle Analysis

The tenants were happy with the urban fragment in general, which in turn drove the willingness of the tenants to maintain their homes. Nonetheless, there were vacancies, a lack of building care, a feeling of insecurity partially within and almost completely in the surrounding quarter, resulting in the perception that the settlement was a ghetto. There were no activities bringing the tenants together. The tenants moved out when they found other apartments, often much further away. Education levels were not high but there were a few educated families and a significant portion of young families remained. The availability of substandard dwellings was important for all. (Table 48)

Economic Virtual Adaptive Cycle Analysis

The situation was completely different in 1985 prior to the plans to demolish the estate. Besides the dwellings, there were stores (a small supermarket, tailor, 'beverage store', etc.) but they were not especially important for the quarter. The possibility for changes in use was limited and there were many vacancies. The infrastructure and accessibility were two of the few positive factors. The estate's owner did not support the linkages between the settlement and the quarter, but rather the opposite: new tenants were more and more socially underprivileged and this propelled former tenants to move out. For the owner, rent levels were not very profitable, as opposed to their affordability for the tenants. The location was attractive, independent from infrastructure. The quality of the buildings' shell construction was in such good shape that it had lasted 40 years without major renovations. Nevertheless, external building components were partly out of order or missing. Overall, tenant incomes were low, with the exception of the few remaining middle-income young families or retired couples. (Table 48)

Ecological	Indicators	State at the end of the 1980s
Resilience (Resistance)	Noise (internal)	
	Air quality (internal)	
	Cleanliness and care of green areas (internal)	-
	Ecological footprint (external)	
	Emissions (external)	-
Connectedness (Relations)	Continuous green areas with biocoenosis (internal)	
	Continuous green areas with biocoenosis (external)	
Potential (Quantity)	Quality and size of green areas (internal)	ø
	Number and amount of species (internal)	
	Resource, i.e. energy, consumption and efficiency (external)	-
	Retention of grey energy, i.e. recycling, renovation (external)	
	Use of renewable resources (external)	

Cultural	Indicators	State at the end of the 1980s
Resilience (Resistance)	Possibility to change use	-
	Frequency of renovation	-
	Morphology of buildings	-
Connectedness (Relations)	Location of the urban fragment	
	Cultural importance	ø
Potential (Quantity)	Types of construction	-
	Importance of use	-
	Architectonic quality	-

Social	Indicators	State at the end of the 1980s
Resilience (Resistance)	Vacancies	-
	Cleanliness and care of buildings	-
	Happiness of users and inhabitants	+
	Security level	-
	Ghettoisation/gentrification	-
Connectedness (Relations)	Organisations and events	-
	(Public) Participation	+
	Access to social and health services	
	Frequency of user change	-
Potential (Quantity)	Education levels	-
	Age structure	+
	Availability of substandard dwellings	+

Economic	Indicators	State at the end of the 1980s
Resilience (Resistance)	Diversity of uses	ø
	Possibility for change of use	-
	Vacancies	-
	Preparedness for natural and technological risks	
Connectedness (Relations)	Infrastructure/accessibility	+
	Owner status	-
	Clients of local companies	
	Frequency of tenant change	-
Potential (Quantity)	Rent levels	-
	Existing companies and number of jobs	
	Supply of retailers	
	Product of urban units (size of available use area, equipment)	ø
	Income structure	ø

Table 48 Virtual Adaptive Cycle Analysis of the Ludwig-Frank Estate, Mannheim at the end of the 1980s when the owner planned to demolish the settlement

Determining the Virtual Adaptive Cycle Phases

The buildings and their green areas did not support any ecological resilience and had no connectedness internally or with outer areas. The only positive aspect was that there were green areas within the estate. The ecological adaptive cycle can be interpreted as being in an α phase, characterised by ecological potential that may be used but remains stable until then. (Table 49)

Overall, cultural resilience and potential were low, and only the urban fragment's small cultural importance supported cultural connectedness.
The cultural adaptive cycle can be seen as being in an Ω phase, where in a next step the neighbourhood could serve as potential for as yet unforeseeable cultural development. (Table 49)

Social resilience was based mainly on the tenants' happiness with the urban fragment in general. The willingness of the tenants to maintain their homes represented the main driver behind participation and therefore social connectedness. Social potential was fed by the availability of substandard dwellings and an age structure where young and dynamic, mainly foreign, families lived with older, experienced German couples.
The social adaptive cycle can be interpreted as being in a late K phase with connectedness and potential but lowered resilience. (Table 49)

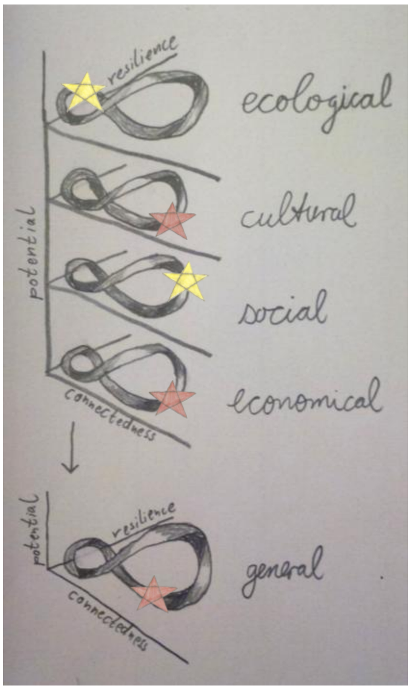
With the existing but small diversity of uses, the limited possibility for change and the high vacancy rate, there was little economic resilience. Only the available infrastructure supported the economic connectedness of the neighbourhood. The economic potential of the estate was based on the location and the quality of construction, even though the buildings had been neglected and not renovated. The low but not too low incomes of the tenants can also be seen as a positive. Overall, the economic adaptive cycle can be interpreted as being in an Ω phase, that is soon to be followed by an α phase supported by the economic potential of the location. (Table 49)

Steps	Description
Urban fragment definition	Location: seven buildings of the Ludwig-Frank Estate in Mannheim-Neckarstadt, Germany Time period from construction in 1949-51 until today
Current state description (adaptive cycle phase)	
Historic state descriptions: Phase at t-1, …, t-n	End of 1980s ecological virtual adaptive cycle in phase α cultural virtual adaptive cycle in a phase Ω social virtual adaptive cycle between a K phase and a Ω phase economic virtual adaptive cycle in a phase Ω
Adaptive cycle evolution description	
Scenarios for future development	
Strategy design	

Table 49 Step 2: The phases of the virtual adaptive cycles the Ludwig-Frank Estate, Mannheim is in at the end of the 1980s

General Adaptive Cycle in the 1980s

The start of the general adaptive cycle analysed at the end of the 1980s began in the 1970s with a change in the tenant mix. This change can be seen as reorganisation and exploitation in the sense of a general α and r phase. The general adaptive cycle stabilised in a new K phase at the end of 1970s. The suspension of maintenance and renovations in the 1980s that led to a deterioration of the buildings' conditions and hence to a worsening environmental balance at the end of the decade can be interpreted as an α phase of the ecological virtual adaptive cycle. With a rise in vacancies and ghettoisation, the social value (a social virtual adaptive cycle between phases K and Ω) as well as monetary value (an economic virtual adaptive cycle in phase Ω) diminished continuously so that this urban fragment no longer fit into its surroundings. No significant cultural meaning was assigned to the buildings (a cultural virtual adaptive cycle in phase Ω). Thus, at the end of the 1980s the general adaptive cycle seems to be at the start an Ω phase, leading toward a completely different cycle that is based on the demolition of the buildings and the realisation of higher rents in new constructions.



t = 1980s

Figure 71 General Adaptive Cycle in the 1980s

Post-War Period

Ecological Virtual Adaptive Cycle Analysis
The cleanliness and care of the green areas were good. Emissions were not considered but did not have a higher impact than other buildings at that time. The quality and size of the green areas were also good. Energy consumption and resource use were also not considered. By recycling the remainings of older buildings, grey energy was used in the new construction. (Table 50)

Cultural Virtual Adaptive Cycle Analysis
There was no possibility to and no need for change. The buildings came slowly toward a renovation period. The morphology of the buildings was average. The buildings' cultural importance was based on their uniqueness after the Second World War. The types of construction and the architectonical quality were negligible. The importance of the use could rise with time. (Table 50)

Social Virtual Adaptive Cycle Analysis
There were no vacancies and the buildings were clean and cared for. Old and new tenants were happy and there were no problems internally or with the surrounding neighbourhood. No information was found on special organisations or participation opportunities. The frequency of user change increased slowly with the general increase in the number of surrounding buildings; new tenants started to become less socially privileged. With this, social participation, which was high immediately after construction, decreased. Education levels were good, but as socially underprivileged tenants began moving in, the average started to fall. The age structure was a good mix of old and young families. The buildings started to become substandard. Social potential was good due to the balanced mix of ages, educational backgrounds and dwelling standards. (Table 50)

Economic Virtual Adaptive Cycle Analysis
At the end of the 1960s, the situation was as follows. The dwellings and also the stores were new but their importance for the quarter decreased as the estate's surroundings developed. There were no vacancies and the possibility for use change was not considered.
The infrastructure and accessibility added mainly to the economic connectedness of the estate. The status of the owner was a guarantee for the maintenance of buildings. The tenant turnover was low but the initial families moved out to dwellings with higher standards.
The rent levels and location were very attractive. All the buildings were in good shape. The income structure was rather mixed, around a middle-income level. (Table 50)

Ecological	Indicators	State at the end of the 1960s
Resilience (Resistance)	Noise (internal)	
	Air quality (internal)	
	Cleanliness and care of green areas (internal)	+
	Ecological footprint (external)	
	Emissions (external)	
Connectedness (Relations)	Continuous green areas with biocoenosis (internal)	
	Continuous green areas with biocoenosis (external)	
Potential (Quantity)	Quality and size of green areas (internal)	+
	Number and amount of species (internal)	
	Resource, i.e. energy, consumption and efficiency (external)	
	Retention of grey energy, i.e. recycling, renovation (external)	+
	Use of renewable resources (external)	

Cultural	Indicators	State at the end of the 1960s
Resilience (Resistance)	Possibility to change use	
	Frequency of renovation	ø
	Morphology of buildings	ø
Connectedness (Relations)	Location of the urban fragment	
	Cultural importance	ø
Potential (Quantity)	Types of construction	-
	Importance of use	ø
	Architectonic quality	-

Social	Indicators	State at the end of the 1960s
Resilience (Resistance)	Vacancies	+
	Cleanliness and care of buildings	+
	Happiness of users and inhabitants	+
	Security level	
	Ghettoisation/gentrification	
Connectedness (Relations)	Organisations and events	
	(Public) Participation	ø
	Access to social and health services	
	Frequency of user change	ø
Potential (Quantity)	Education levels	+
	Age structure	+
	Availability of substandard dwellings	ø

Economic	Indicators	State at the end of the 1960s
Resilience (Resistance)	Diversity of uses	ø
	Possibility for change of use	
	Vacancies	+
	Preparedness for natural and technological risks	
Connectedness (Relations)	Infrastructure/accessibility	+
	Owner status	+
	Clients of local companies	
	Frequency of tenant change	ø
Potential (Quantity)	Rent levels	+
	Existing companies and number of jobs	
	Supply of retailers	
	Product of urban units (size of available use area, equipment)	+
	Income structure	+
	Location of the urban fragment	+

Table 50 Virtual Adaptive Cycle Analysis of the Ludwig-Frank Estate, Mannheim at the end of the 1960s

Determining the Virtual Adaptive Cycle Phases

Ecological resilience can be interpreted as medium to high. Most factors were not considered, and only one is regarded as positive. Ecological connectedness was not considered. Ecological potential is interpreted as medium to high thanks to a few positive aspects.
The ecological adaptive cycle is interpreted as being in a K phase. (Table 51)

Overall, cultural resilience was intermediate. Cultural connectedness was low to intermediate. There was very low cultural potential.
The cultural adaptive cycle can be interpreted as being in an r phase wherein only one aspect could seem to bring potential for the transition into a K phase. (Table 51)

Social resilience can be seen as being high. Overall, social connectedness became intermediate due to the increase in change of users. Social potential was high due to the balanced mix of ages, educational backgrounds and dwelling standards.
The social adaptive cycle can be interpreted as being in a K phase, wherein the decrease of connectedness endangers the stability of the phase. (Table 51)

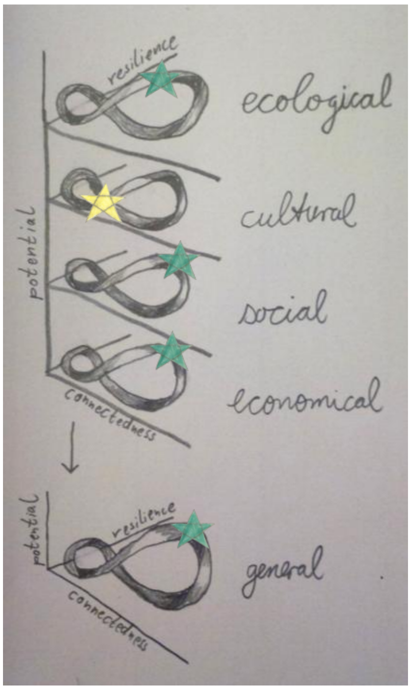
The low number of vacancies but barriers to use change can be interpreted as medium economic resilience. Accessibility and the support from the owner contributed to a medium to high economic connectedness. The economic potential of the buildings was medium to high for both the owner and the tenants.
Overall, the economic adaptive cycle can be seen as being in a K phase with slowly declining economic resilience. (Table 51)

Steps	Description
Urban fragment definition	Location: seven buildings of the Ludwig-Frank Estate in Mannheim-Neckarstadt, Germany Time period from construction in 1949-51 until today
Current state description (adaptive cycle phase)	
Historic state descriptions: Phase at t-1, …, t-n	End of 1960s
	ecological virtual adaptive cycle in a phase K
	cultural virtual adaptive cycle in a phase r
	social virtual adaptive cycle in a phase K
	economic virtual adaptive cycle in a phase K
Adaptive cycle evolution description	
Scenarios for future development	
Strategy design	

Table 51 Step 2: The phases of the virtual adaptive cycles the Ludwig-Frank Estate, Mannheim is in at the end of the 1960s

General Adaptive Cycle in the 1960s

The general adaptive cycle of the Ludwig-Frank housing estate at the end of the 1960s had its start with the construction of the buildings at the end of the 1940s. The beginning of the 1950s comprises the phases α (reorganisation) and r (exploitation) of the general adaptive cycle. From the mid-1950s to the end of the 1960s a phase of stability (phase K) develops. Even if the economic, ecological and social virtual adaptive cycles are in a K phase, broader technological developments and growing demand for functionality result in a relative loss in the economic value of the buildings and initiate a slow decrease in rent levels. The cultural virtual adaptive cycle is in an r phase, slowly building up a minimum of cultural importance.



t = 1960s

Figure 72 General Adaptive Cycle in the 1960s

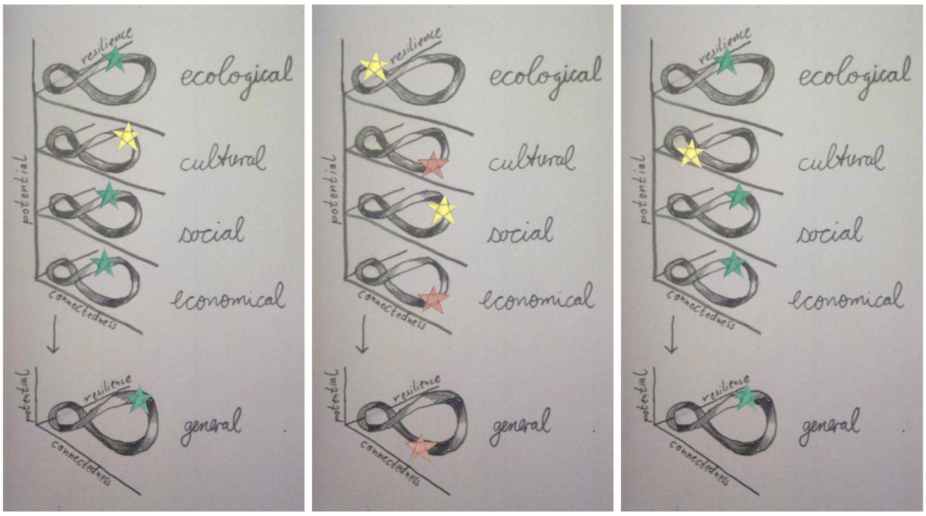
III2.4 Step Three: Adaptive Cycle Evolution Description

Steps	Description
Urban fragment definition	Location: seven buildings of the Ludwig-Frank Estate in Mannheim-Neckarstadt, Germany Time period: from construction in 1949-51 until today
Current state description (adaptive cycle phase)	Adaptive cycles for 1960s, 1980s and 2000s
Historic state descriptions: Phase at t-1, …, t-n	
Adaptive cycle evolution description	Combined adaptives cycle for the urban fragment since 1949
Scenarios for future development	
Strategy design	

Table 52 Step 3: Constructing the combined adaptive cycle for the urban fragment in Mannheim

The α phase of the combined economic, ecological, social and cultural virtual adaptive cycles of the Ludwig-Frank Estate starts with its construction after the Second World War. The adaptive cycle progressed quickly into a stable situation (a K phase). Broader technological developments and growing demand for functionality resulted in a relative loss in the economic value of the buildings, leading to lower rents from the end of the 1960s (an Ω phase). The reorganisation (phases α to r) led to a new system with a different tenant mix, which resulted in a new K phase (end of 1970s). The suspension of maintenance and renovations led to a deterioration of the buildings' condition and hence to an ever-worsening environmental balance. With increasing vacancies and ghettoisation, the social as well as monetary value diminished continuously so that this urban fragment no longer fit into its surroundings. Thus, an Ω phase seems to be initiated at the end of the 1980s that would have lead to a completely different cycle, through demolition of the buildings and higher rents in new constructions.

The will of the tenants and the support of experts from tenants associations revealed that a high degree of resilience and connectedness existed and was further increased by the prospect of establishing a cooperative. The foundation of the cooperative can be considered as the beginning of an adaptive cycle phase r. At that time, the tenants had the opportunity to move to other, renovated apartments. The period after the renovation and restoration can be seen as a transition into a K phase (mid-1990s). Then, the potential of the buildings increased immensely and the potential of the location began to increase so that the immediate and larger neighbourhood appreciated the urban fragment. With the commitment to low financial and environmental costs, the use value and monetary value raised. The rescue of the urban fragment increased its cultural value and preserved one early piece of post-war architecture.



t = 2010 t = 1980s t = 1960s

Figure 73 Combined Adaptive Cycle for the Urban Fragment in Mannheim

III2.5 Step Four: Scenarios for Future Development

Scenarios

Today, a set of services has been established and the diversity of the uses is accepted within and outside the cooperation. The buildings are over 60 years old. The lease of the buildings to the cooperation is guaranteed for more than five decades. The age, income and education structures are very mixed. Demand is continuously high. There is a sound basis for a continuous stable K phase in the current adaptive cycle. Further development of the cycle depends however on the maintenance of the buildings and stable infrastructure, which will in turn rely on situational changes.

Two scenarios seem possible: 1. the estate either maintains its attractiveness or 2. loses it.

Steps	Description
Urban fragment definition	Location: seven buildings of the Ludwig-Frank Estate in Mannheim-Neckarstadt, Germany Time period: from construction in 1949-51 until today
Current state description (adaptive cycle phase)	Adaptive cycles for 1960s, 1980s and 2000s
Historic state descriptions: Phase at t-1, …, t-n	
Adaptive cycle evolution description	Combined adaptive cycles for the urban fragment since 1949
Scenarios for future development	Business As Usual or Attractiveness LosT
Strategy design	

Table 53 Step 4: Scenarios for the Ludwig-Frank Estate

Business as Usual (BAU)

In this scenario, a population increase and/or a decrease in wealth in the next three decades makes the cooperative less affordable for low-income families. Increasingly, new tenants are medium-income families who contribute to an improving financial basis for the cooperative. The acceptance of the ‘Treffpunkt’ and the stores supports their continued functioning. The economic virtual adaptive cycle stays in a stable K phase.

The new renters change the tenant mix. The cooperative introduces a minimum quota for low-income families and subsidises their dwellings when necessary. The social virtual adaptive cycle changes slowly in its character. The introduction of the quota (marking a Ω phase) stops this continuous transformation and leads to a consolidation of the tenant mix in a K phase.

The care of the buildings and green areas remains good. The buildings undergo extensive renovation (Ω phase) with big reductions in the environmental impact and results in a K phase in the ecological virtual adaptive cycle.

The stable long-term management adds to the cultural sensibility of the buildings, which represent some of the developments and successes of recent post-war German history (‘wirtschaftswunder’, immigration and integration). The cultural virtual adaptive cycle stabilises within a K phase.

The general adaptive cycle stays in a K phase with changing virtual adaptive cycles contributing to the stability.

Attractiveness LosT (ALT)

In this scenario, the estate undergoes renovation in the next few years, reducing the environmental impact, but it loses its attractiveness due to population shrinkage and/or a wealth increase within the next three decades. As a result of both factors, dwellings of better standard become more affordable and people avoid investing in cooperative shares to get low-priced dwellings. The cooperative loses its financial basis. This leads to an Ω phase in the economic virtual adaptive cycle.

The care of the settlement continuously decreases with the lowered financial basis. Reduced demand and less investment by the cooperative for renovation of the dwellings lead to a lower energy standard that is not aligned with national energy laws. The environmental virtual adaptive cycle transitions into an Ω phase.

The loss of tenants has a negative impact on social cohesion within the estate. The ‘Treffpunkt’ with its range of services is still attractive and becomes more important within the cooperative. The social virtual adaptive cycle goes through an Ω phase and transitions into a new social virtual adaptive cycle with a broader range of services provided by the ‘Treffpunkt’.

With the dwellings’ lost of attractiveness, the estate’s cultural

importance is valued low and does not allow a stable K phase, resulting in a permanent α phase where the settlement presents low cultural potential for future cultural importance.
The general adaptive cycle transitions from a K phase into an Ω phase in which the public increasingly questions the settlement's economic and ecological significance. The buildings are eventually demolished allowing new constructions and hence starting economic, ecological and cultural virtual adaptive cycles using the potential of the construction area. Only the social virtual adaptive cycle of the 'Treffpunkt' is likely to continue in the new constructions.

III2.6 Step Five: Strategy Design

Strategies for the Business-As-Usual (BAU) Scenario

The description of the scenarios allows the choice of one or several strategies that are designed in the last step of applying the adaptive cycle framework (Table 54) and support the aim of the scenarios.

Steps	Description
Urban fragment definition	Location: seven buildings of the Ludwig-Frank Estate in Mannheim-Neckarstadt, Germany Time period: from construction in 1949-51 until today
Current state description (adaptive cycle phase)	Adaptive cycles for 1960s, 1980s and 2000s
Historic state descriptions: Phase at t-1, …, t-n	
Adaptive cycle evolution description	Combined adaptive cycles for the urban fragment since 1949
Scenarios for future development	Scenarios: Business As Usual or Attractiveness LosT
Strategy design	Value Increasing Renovation with Social Considerations or Asset Exploitation

Table 54 Step 5: Strategy design for the Ludwig-Frank Estate

The Business-As-Usual scenario implies adequate renovations, improving the economic value of the buildings (E=1) with medium or even great reduction in environmental impact (N=2 or 3). The tenancy quota for socially underprivileged families can be interpreted as social fairness (S=2) or at least as strengthening social cohesion (S=1). Cultural sensibility emerges slowly (C=1).
Two strategies for the BAU scenario are illustrated below with the objective to be as different as possible to represent the breadth of possible strategies: Strategy combination A (1; 1; 1; 2) and Strategy combination B (1; 1; 2; 3).

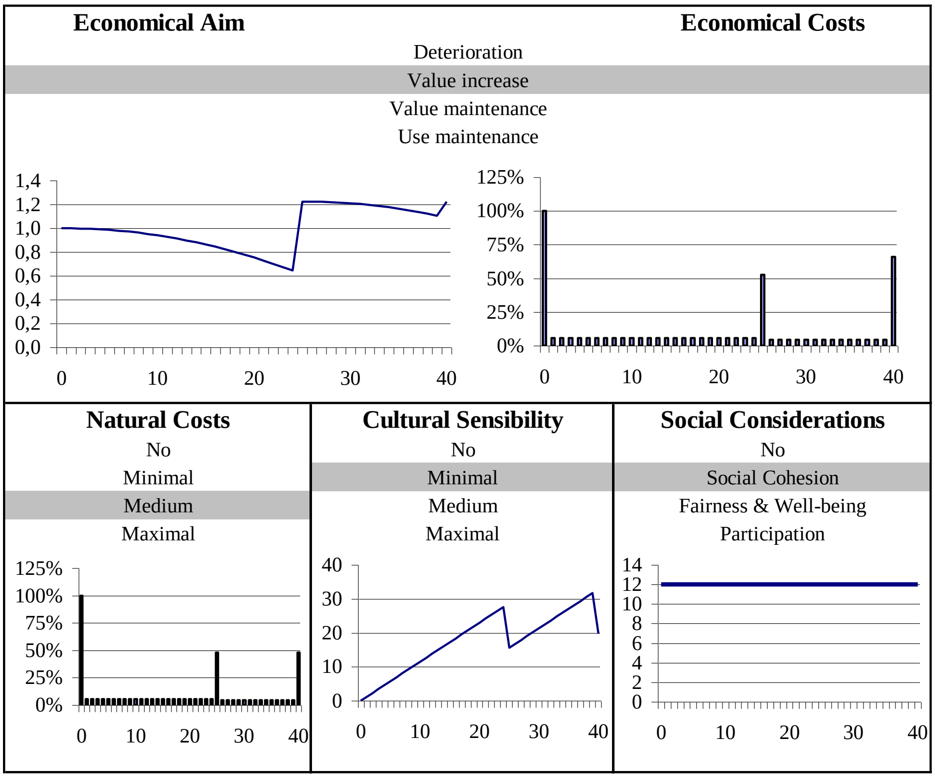


Figure 74 Strategy combination A for Scenario BAU in Mannheim

Strategy combination A (Figure 74) results in economic operation costs of 5.5% down to 4.4 % after the renovation that costs 52.8% (after cycle 1; 66% after cycle 2), in environmental operational costs of 5% down to 4% after the renovation that costs 48%. The value for cultural sensibility increases with 1.15 points per year. The social points are at 12 points.

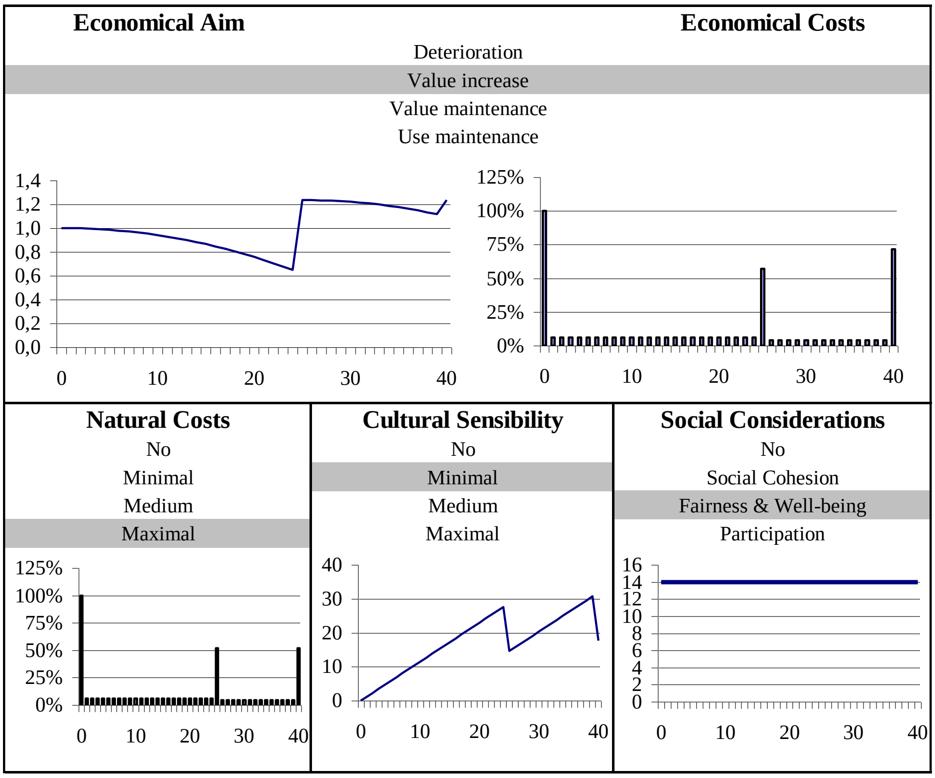


Figure 75 Strategy combination B for Scenario BAU in Mannheim

Strategy combination B (Figure 75) results in economic operation costs of 6% down to 4.2 % after the renovation that costs 57.2% (after cycle 1; 71.5% after cycle 2), in environmental operational costs of 5% down to 3.5% after the renovation that costs 52%. The value for cultural sensibility increases with 1.15 points per year. The social points are at 14 points.

Both strategies seem to fit to the scenario. If the funds are available, the cooperative would benefit more from strategy combination B for little more investment costs.

Strategies for the Attractiveness-LosT (ALT) Scenario

The Attractiveness-LosT scenario implies adequate renovations, maintaining the value of the buildings (E=1) with a low to medium reduction in environmental impact (N=1). Social considerations will be few with only the ‘Treffpunkt’ as a cohesion point, but independent from the constructions (S=0). Cultural sensibility cannot emerge (C=0).

With the assumptions of change in the economic/social circumstances, two sequential strategies may result: Strategy combination C (3; 0; 0; 1) and Strategy combination D (0; 0; 0; 0).

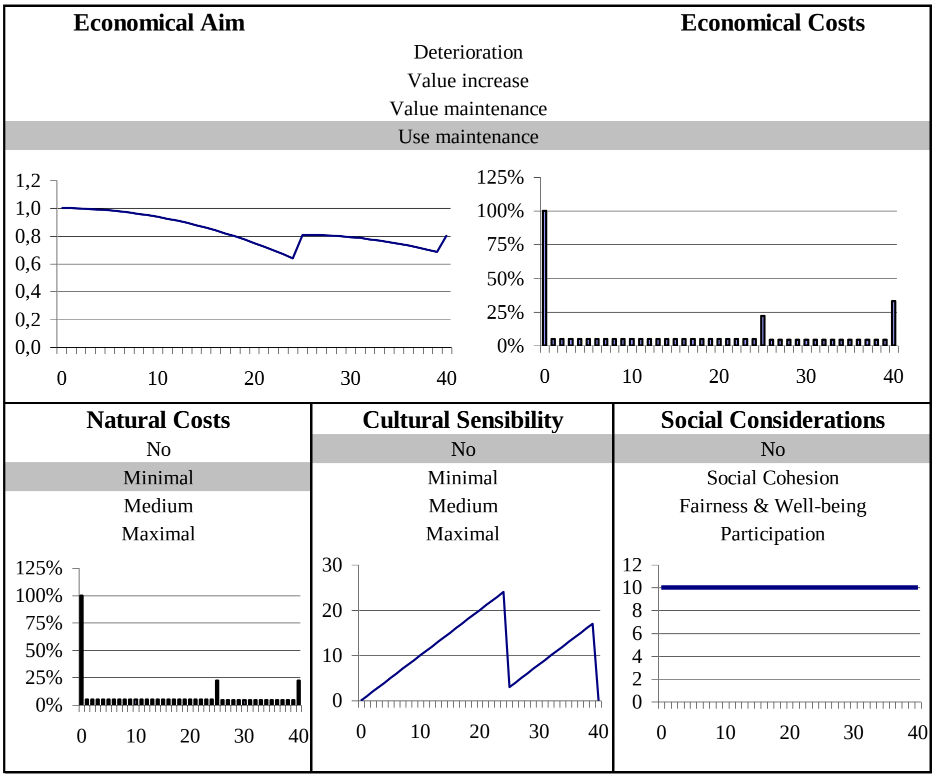


Figure 76 Strategy combination C for Scenario ALT in Mannheim

Strategy combination C (Figure 76) results in economic operation costs of 5% down to 4.5 % after the renovation that costs 22% (after cycle 1; 33% after cycle 2), in environmental operational costs of 5% down to 4.5% after the renovation that costs 22%. The value for cultural sensibility increases with 1 point per year. The social points stays at 10 points. Strategy combination D (Figure 52) could follow and result in a deteriorated state of the buildings at about the time when the cooperative’s obligation to take care of the stock would end.

III3. *Brossolette Estate, Bourtzwiller, Mulhouse, France*

III3.1 History of the Urban Fragment

Until 1947, Bourtzwiller was a simple provincial town, a northern suburb, connected to the city of Mulhouse (Figure 66) via the Pont de Bourtzwiller bridging the River Doller. The neighbourhood was characterised by its village centre with a public square, church and shops. After destruction by bombing in the Second World War, the municipality of 3,900 inhabitants voted in a referendum to join Mulhouse in 1947. Since the 1950s, Bourtzwiller has been somewhat known for its architecture, especially the social housing that constitutes the Brossolette Estate.

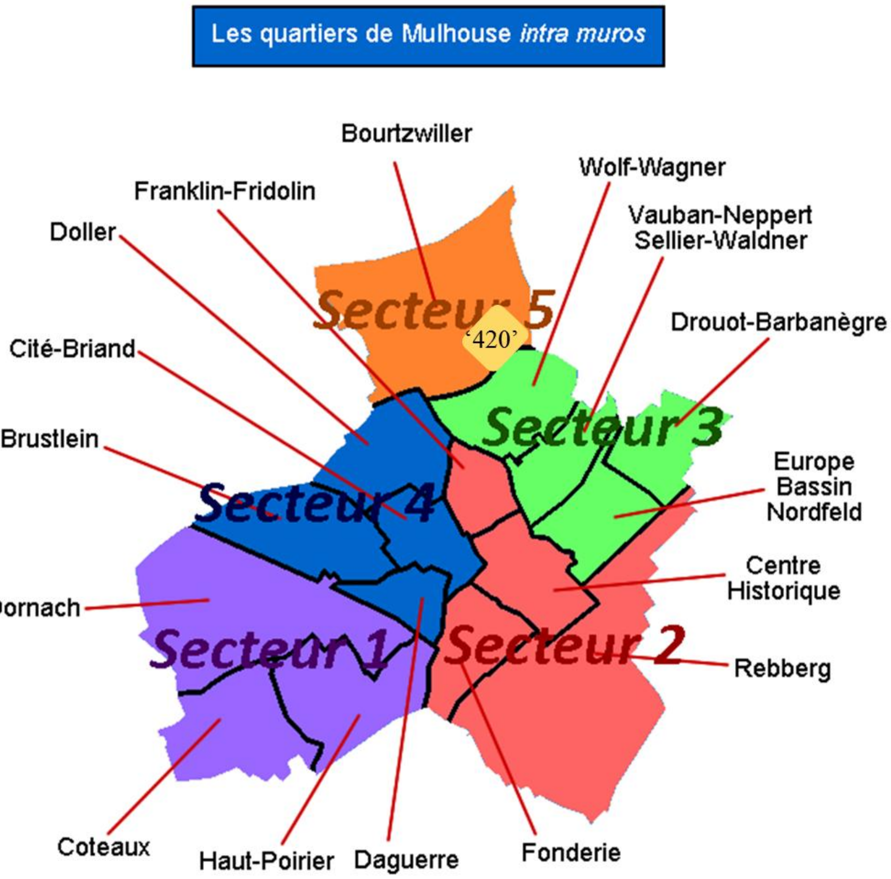


Figure 77 Location of Cité Brossolette ('420' - orange polygon)
Source: Adapted from [FOU 09]

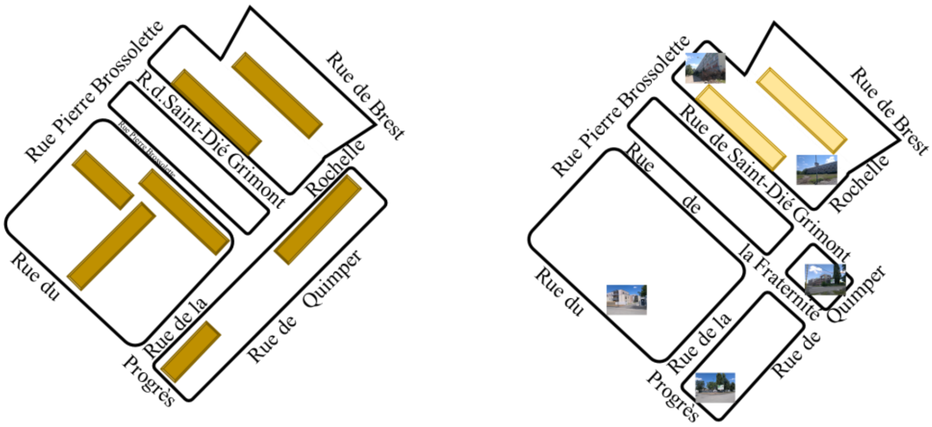


Figure 78 Location of the seven buildings of Cité Brossolette (left) and two still standing but vacant buildings in July 2012 (right)
Source: own illustration of [LINDER 04], p.1 (left) and own illustration (courses of the roads base on the front cover in [CCPM 09]; right)

This estate is known today as the ‘420’ with the same amount of dwellings in seven buildings constructed between 1962 and 1965 for the French who had to be housed after leaving Algeria following its war of independence.[615] Later workers (mainly from the Maghreb) at the nearby Peugeot factory found their homes here. Between 1954 and 1968, the number of inhabitants rose from 4,300 to 14,000. Up to 1,800 persons have been placed in the Cité Brossolette.[616] In 1974 the Florival freeway and in 1976 a highway and shopping centre were added. These actions did not improve the area; on the contrary, with the River Doller they turned the estate into a figurative cul-de-sac. It became one of the most populated neighbourhoods of Mulhouse. In this part, one can find Bourtzwiller’s tallest buildings (four storeys). The urban morphology has a loose structure without a centre or main axis (Figure 78). These buildings are not really connected to the rest of the neighbourhood. In 1989, the dwellings underwent rehabilitation. Today, there are people representing approximately 23 nationalities living here.
In 2005, the buildings were in poor shape, which contributed to the bad image of the estate and connections to adjacent neighbourhoods were weak. Security concerns, highlighted by an attack on a bus driver, further deteriorated the image of the inhabitants, even if they were the first victims of the violence. Discussions about the possible demolition of the buildings arose in 2002. At that time, the buildings were in very bad condition. Rehabilitation was thought to lead to increased rents and therefore more vacancies. In addition, the common desire of the inhabitants to obtain an individual house with its own entry and garden was taken up as policy by the city. A further argument for demolition was for a ‘change of social structure’; the contemporary social mix was

[615] [BRANCHET 04]
[616] [MULHOUSE 11]

considered bad, i.e. containing a too high percentage of state-supported flats. [617] Following a survey of the 'Mulhouse Habitat', only one third of the inhabitants wanted to stay in the estate, the others preferred to be relocated in the neighbourhood or to leave it for another area of town.[618] Nonetheless, the study described the situation as not being too urgent and the Cité Brossolette was not analysed in more depth. Between 2001 and 2006, only three public information meetings took place.

Residents learned about the demolition plans from the newspapers and felt it as the destruction of their social networks and solidarity links established in many cases over the last 30 years. There were some reactions to express the point of view of the inhabitants including a music video, a movie and a working group. Some younger inhabitants produced a song about their rage called '420 year zero!' and mixed interviews with inhabitants into the video. Even though the residents understood that the buildings are not tourist attractions, they felt like they were being expelled from the city. The video was at least one way for the inhabitants to conserve the memory of the place. The movie was made to reveal the positions of the different actors by interviewing operators, historians, social workers and especially the inhabitants who were confronted with the loss of their dwellings and through this an essential link to the neighbourhood, their collective memory and their social life. On the announcement of demolitions, a group of women did not want to accept the decision passively, decided to show that they were active members of their community and defended their social life. The working group was the result of the critical attitude of women living in this multicultural neighbourhood. First they were five persons, later 20, and at present the group counts about 40 members, the initiators being still present. Without any professional support, they started to work together to find common themes of action and to inform the neighbourhood. The group was named 'Smile to life in the 420'. The group continued to work even though the early demolitions could not be stopped. By continuing to live in the neighbourhood, they believed that the new constructions would not solve the problems and the demolitions had mainly discredited the neighbourhood and its residents.[619]

Demolition was considered inevitable, as was the desired change in social structure that would result. A programme realised in cooperation with the French federal agency for city renewal (Agence Nationale pour la Rénovation Urbaine - ANRU[620]) to renovate the neighbourhood through demolition of the social housing and the consecutive reconstruction with a different social mix led to a deep transformation.

[617] [LINDER 04], p.22
[618] [PUCA 07], p.10, 11
[619] [BRANCHET 04]
[620] [ANRU 11]

The demolitions started in 2007 and were not understood by the inhabitants who criticised them for their poor handling, especially by the management. In July 2012, five of the seven buildings had been demolished. The other two were vacant (Figure 79).
The former tenants were situated for

- 35% within the neighbourhood Bourtzwiller, outside the Cité
- 45% in other neighbourhoods of Mulhouse
- 20% outside of Mulhouse. [621]

Sparked by a new tram connection, which was extended by 1.8 km in 2006 and linked Bourtzwiller directly to the city centre, the neighbourhood was chosen for a pilot “sustainable neighbourhood” project in cooperation with European Institute for Energy Research (EIFER) in Karlsruhe, Germany.[622] The project is under implementation (2006-2012) in coordination with inhabitants and associations within the neighbourhood. Besides the new residential constructions at the same location of the former “420” block (Figure 80 and Figure 81), 250 new dwellings on a former industrial site (Bel-Air) have been planned on the basis of a contract between the City of Mulhouse and the ANRU.[623]
The overall objectives of the project are the reduction of energy consumption and CO_2 emissions, the creation of local jobs and local economic development. Other aims are to achieve a higher social diversity and to turn some public spaces into private spaces. In addition, trees were planted, cycling paths created and pedestrian paths renewed to improve the appearance of the neighbourhood.[624]

Figure 79 Two still standing and vacant buildings in rue Pierre Brossolette of the former ‘420’ in July 2012

[621] [ANRU 11], p.56
[622] [MULHOUSE 12]
[623] [LINDER 04], p.17
[624] [MULHOUSE 12], [LINDER 04], 15

Figure 80 New constructions at rue du Progrès and rue de Quimper on the site of the former '420' in July 2012

Figure 81 New constructions at rue du Fraternité on the site of the former '420' in July 2012

III3.2 Step One: Define Urban Fragment

The urban fragment of interest consists of seven buildings of the Brossolette Estate in Mulhouse, France, from their construction in 1962-65 until today (Table 55).

Steps	**Description**
Urban fragment definition	Location: seven buildings of the Brossolette Estate in Mulhouse, France Time period from construction in 1962-65 until today
Current state description (adaptive cycle phase)	Identifying and measuring indicators for the four dimensions of sustainability
Historic state descriptions: Phase at t-1, …, t-n	
Adaptive cycle evolution description	Combining the virtual sustainability adaptive cycles
Scenarios for future development	Creating and testing scenarios for urban adaptive cycles
Strategy design	Creating strategies and calculations

Table 55 Step 1 for of the Adaptive Cycle Analysis of the Brossolette Estate in Mulhouse, France

III3.3 Step Two: Determine and Describe the Current Adaptive Cycle Phase

The transformation of the Brossolette Estate and its surroundings is ongoing and will be finished in 2012.[625] The abovementioned indicators will be used to analyse the four virtual sustainability adaptive cycles of the urban fragment over a period spanning between the decision to demolish and implement new construction activities in 2005 and the completion of renovations at the end of the 1980s.

Before Current Construction Activities

Ecological Virtual Adaptive Cycle Analysis
Ecologically, the owner made no efforts to improve the buildings and the vacancies made energy consumption even more inefficient. The isolation of the buildings by the A36 express highway and another highway allowed no continuous green areas. (Table 56)

Cultural Virtual Adaptive Cycle Analysis
There are no aspects of the estate that are of cultural value. (Table 56)

Social Virtual Adaptive Cycle Analysis
The vacancies and neglected buildings had led to ghettoisation of the urban fragment's tenants. Many former tenants had left the buildings due to the planned demolition. The area seemed insecure (e.g. an attack on a bus driver). The municipality allowed only a very late public participation meeting, which mainly served to inform the public of the plans. Mainly, the tenants who stayed could not afford other dwellings. Nevertheless, these tenants had lived there for several decades and were still happy with their houses and some started to organise meetings to stop the demolition. (Table 56)

Economic Virtual Adaptive Cycle Analysis
In 2005, the neighbourhood had many vacancies and the quality of the buildings was low. The owner (the municipality of Mulhouse) had acted on both and rent levels were nonetheless still attractive for the remaining inhabitants. The possibility to get subsidies from the state for a development plan that included demolition motivated the owner to consider pulling the buildings down. Most of the economic indicators are negative. (Table 56)

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[625] [ANRU 11]

Ecological	Indicators	State in mid 2000s
Resilience (Resistance)	Noise (internal)	
	Air quality (internal)	
	Cleanliness and care of green areas (internal)	-
	Ecological footprint (external)	
	Emissions (external)	-
Connectedness (Relations)	Continuous green areas with biocoenosis (internal)	
	Continuous green areas with biocoenosis (external)	-
Potential (Quantity)	Quality and size of green areas (internal)	-
	Number and amount of species (internal)	
	Resource, i.e. energy, consumption and efficiency (external)	-
	Retention of grey energy, i.e. recycling, renovation (external)	-
	Use of renewable resources (external)	

Cultural	Indicators	State in mid 2000s
Resilience (Resistance)	Possibility to change use	-
	Frequency of renovation	-
	Morphology of buildings	-
Connectedness (Relations)	Location of the urban fragment	-
	Cultural importance	-
Potential (Quantity)	Types of construction	-
	Importance of use	-
	Architectonic quality	-

Social	Indicators	State in mid 2000s
Resilience (Resistance)	Vacancies	-
	Cleanliness and care of buildings	-
	Happiness of users and inhabitants	+
	Security level	-
	Ghettoisation/gentrification	-
Connectedness (Relations)	Organisations and events	ø
	(Public) Participation	-
	Access to social and health services	
	Frequency of user change	
Potential (Quantity)	Education levels	-
	Age structure	-
	Availability of substandard dwellings	ø

Economic	Indicators	State in mid 2000s
Resilience (Resistance)	Diversity of uses	-
	Possibility for change of use	-
	Vacancies	-
	Preparedness for natural and technological risks	
Connectedness (Relations)	Infrastructure/accessibility	-
	Owner status	-
	Clients of local companies	
	Frequency of tenant change	
Potential (Quantity)	Rent levels	ø
	Existing companies and number of jobs	
	Supply of retailers	
	Product of urban units (size of available use area, equipment)	-
	Income structure	-
	Location of the urban fragment	-

Table 56 Virtual Adaptive Cycle Analysis of the Brossolette Estate, Mulhouse is in around 2005

Determining the Virtual Adaptive Cycle Phases
With only negative ecological indicators, the ecological virtual adaptive cycle appears to be in an Ω phase.

All indicators for cultural resilience, connectedness and potential are negative or non-existent. The cultural virtual adaptive cycle is interpreted as being in an Ω phase.

Most of the social indicators are negative. Even if some social resilience, connectedness and potential could have been boosted, the social virtual adaptive cycle appears to be in an Ω phase.

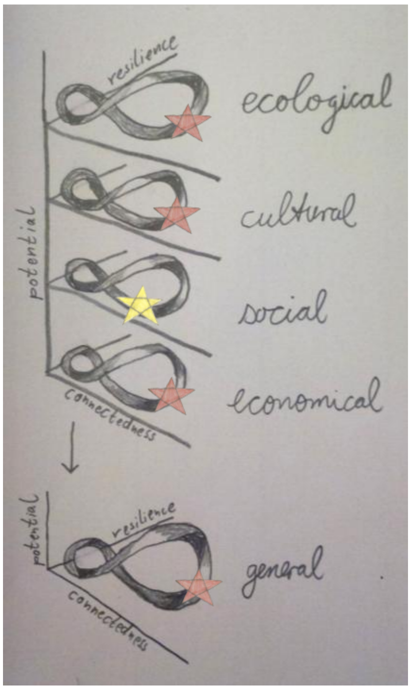
Economic resilience, connectedness and potential are low and the economic virtual adaptive cycle is interpreted as being in an Ω phase. (Table 57)

Steps	**Description**
Urban fragment definition	Location: seven buildings of the Brossolette Estate in Mulhouse, France Time period from construction in 1962-65 until today
Current state description (adaptive cycle phase)	Mid 2000s ecological virtual adaptive cycle in phase Ω cultural virtual adaptive cycle in phase Ω social virtual adaptive cycle in phase Ω to α economic virtual adaptive cycle in phase Ω
Historic state descriptions: Phase at t-1, …, t-n	
Adaptive cycle evolution description	
Scenarios for future development	
Strategy design	

Table 57 Step 2: The phases of the virtual adaptive cycles the Brossolette Estate, Mulhouse is in around 2005

General Adaptive Cycle in the mid-2000s

The general adaptive cycle of the mid-2000s starts after the renovation (Ω phase) at the end of the 1980s which helped to adapt the urban fragment to the needs and expectations of both the remaining and the new inhabitants (α and r phases). This situation did not transition into a stable K phase with increased resilience and connectivity due to a lack of development. Therefore, in the mid-2000s all virtual adaptive cycles were in an Ω phase. The owner had no interest in the buildings anymore. Therefore, the signs of social resilience against the plans to demolish do not seem to have been strong enough. The general adaptive cycle is interpreted as being in a transition from an Ω phase to α phase facilitating the initiation of greater changes with new buildings and constructions and still remaining two abandond buildings from the former settlement.



t = 2000s

Figure 82 General Adaptive Cycle in the 2000s

Time to Renovate

Ecological Virtual Adaptive Cycle Analysis
With renovations at the end of the 1980s, grey (embodied) energy was saved but the renovation had no emphasis on energy saving or reduce emissions. Green areas were disconnected from the surrounding neighbourhoods by high- and expressways. Further aspects are unknown. (Table 58)

Cultural Virtual Adaptive Cycle Analysis
The timely renovation and the importance of the use for the city of Mulhouse can be interpreted as minimum support for potential future cultural importance of the estate. The other indicators contribute little. (Table 58)

Social Virtual Adaptive Cycle Analysis
High demand for substandard dwellings resulted in few vacancies. Owing to the continuous turnover of tenants and the relative happiness of the tenants with different working and social backgrounds ('pieds noirs', workers of Peugeot), there was no far developed ghettoisation. Nevertheless, low education levels and the absence of organisations and public participation contributed to the establishment of a ghetto-like area. (Table 58)

Economic Virtual Adaptive Cycle Analysis
In the 1980s, after more than two decades of use the buildings needed renovation. Despite a low diversity of uses, little possibility for change, a less-than-advantageous location, insufficient infrastructure/accessibility and poor quality of the buildings, the settlement helped to meet the demand for dwellings (it had few vacancies) so the owner decided to renovate. For low-income tenants, mainly working for Peugeot, the rent levels were attractive. Nevertheless, those who could afford to leave the estate did. (Table 58)

Ecological	Indicators	State at the end of the 1980s
Resilience (Resistance)	Noise (internal)	
	Air quality (internal)	
	Cleanliness and care of green areas (internal)	
	Ecological footprint (external)	
	Emissions (external)	-
Connectedness (Relations)	Continuous green areas with biocoenosis (internal)	
	Continuous green areas with biocoenosis (external)	-
Potential (Quantity)	Quality and size of green areas (internal)	
	Number and amount of species (internal)	
	Resource, i.e. energy, consumption and efficiency (external)	-
	Retention of grey energy, i.e. recycling, renovation (external)	+
	Use of renewable resources (external)	

Cultural	Indicators	State at the end of the 1980s
Resilience (Resistance)	Possibility to change use	-
	Frequency of renovation	ø
	Morphology of buildings	-
Connectedness (Relations)	Location of the urban fragment	-
	Cultural importance	-
Potential (Quantity)	Types of construction	-
	Importance of use	ø
	Architectonic quality	-

Social	Indicators	State at the end of the 1980s
Resilience (Resistance)	Vacancies	+
	Cleanliness and care of buildings	
	Happiness of users and inhabitants	+
	Security level	
	Ghettoisation/gentrification	ø
Connectedness (Relations)	Organisations and events	-
	(Public) Participation	-
	Access to social and health services	
	Frequency of user change	ø
Potential (Quantity)	Education levels	-
	Age structure	
	Availability of substandard dwellings	ø

Economic	Indicators	State at the end of the 1980s
Resilience (Resistance)	Diversity of uses	-
	Possibility for change of use	-
	Vacancies	+
	Preparedness for natural and technological risks	
Connectedness (Relations)	Infrastructure/accessibility	-
	Owner status	+
	Clients of local companies	
	Frequency of tenant change	ø
Potential (Quantity)	Rent levels	+
	Existing companies and number of jobs	ø
	Supply of retailers	
	Product of urban units (size of available use area, equipment)	-
	Income structure	-
	Location of the urban fragment	-

Table 58 The phases of the virtual adaptive cycles the Brossolette Estate, Mulhouse is in at the end of the 1980s

Determining the Virtual Adaptive Cycle Phases
Available information indicates that ecologic resilience and connectedness were little and only limited ecological potential can be seen. The ecological virtual adaptive cycle phase is interpreted as being in an α phase (Table 59).

With mainly negative indicators and only two not negative indicators for both cultural resilience and potential, the cultural virtual adaptive cycle appears to be transitioning from an α to an r phase with little possibility for future cultural importance.

Only social resilience has positive values. The slight dominance of negative indicators for social connectedness and potential suggest the social virtual adaptive cycle was in an r phase but with an unclear developmental direction.

Economic resilience, connectedness and potential seem very ambivalent, slightly dominated by negative (red) indicators. The situation appears to be at the end of a K phase.

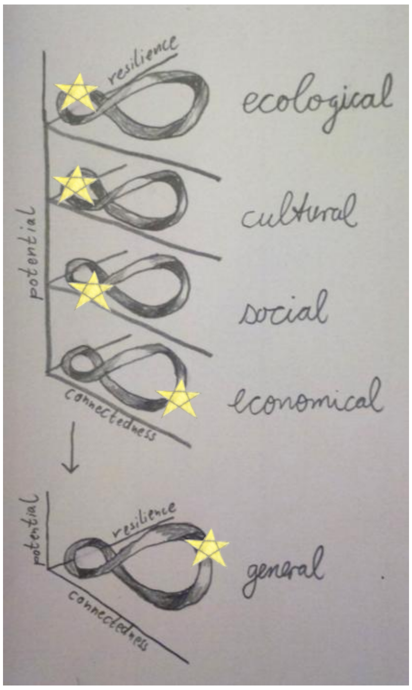
Steps	**Description**
Urban fragment definition	Location: seven buildings of the Brossolette Estate in Mulhouse, France Time period from construction in 1962-65 until today
Current state description (adaptive cycle phase)	
Historic state descriptions: Phase at t-1, …, t-n	End of 1980s
	ecological virtual adaptive cycle in phase α
	cultural virtual adaptive cycle between an α phase and an r phase
	social virtual adaptive cycle in phase r
	economic virtual adaptive cycle at the end of a K phase
Adaptive cycle evolution description	
Scenarios for future development	
Strategy design	

Table 59 Step 2: The phases of the virtual adaptive cycles the Brossolette Estate, Mulhouse is in at the end of the 1980s

General adaptive cycle in the 1980s

The general adaptive cycle of the Brossolette Estate starts in the early 1960s with its construction. Constructed for the 'pieds noirs' from Algeria (α to r phase), it later served as dwellings for the workers of Peugeot. Required during the energy and industrial crises in the 1970s and so used steadily for two decades (K phase), the renovation of the estate in 1989 (Ω and α phases) helped to adapt it to the needs and expectations of the remaining as well as the new inhabitants (r phase) staying in the same general adaptive cycle.

At the end of the 1980s, the ecological (low level), the social (critical but with potential to develop) and cultural (low level) virtual adaptive cycles were situated between the phases α and r. The driving virtual adaptive cycles were the social (possibility to develop a stable society) and economic ones, the latter appearing to be in an unstable (low level) K phase. The general adaptive cycle was situated in an ambivalent K phase, whose direction seems uncertain.



t = 1980s

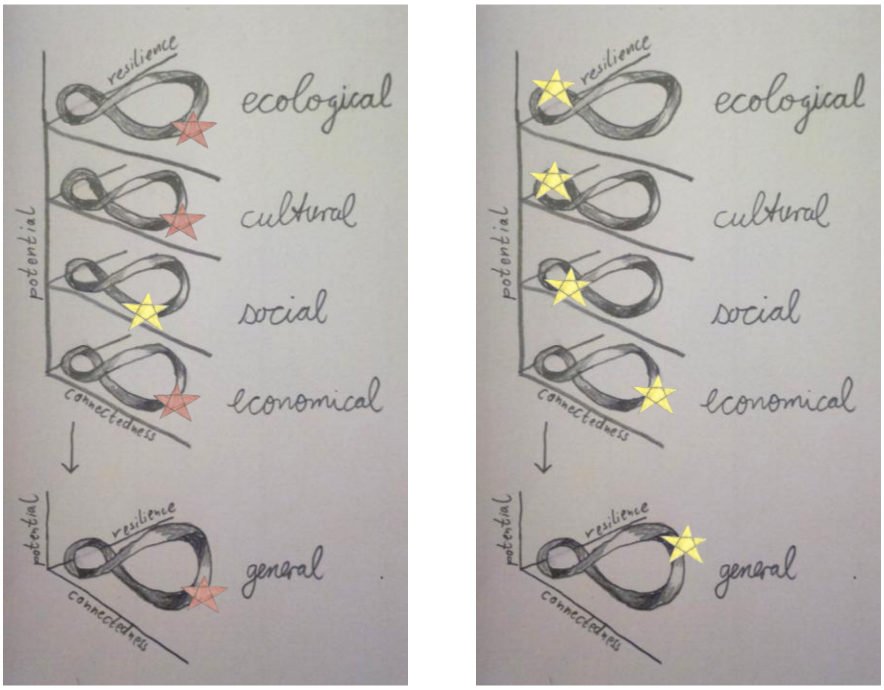
Figure 83 General Adaptive Cycle in the 1980s

III3.4 Step Three: Adaptive Cycle Evolution Description

Steps	Description
Urban fragment definition	Location: seven buildings of the Brossolette Estate in Mulhouse, France Time period from construction in 1962-65 until today
Current state description (adaptive cycle phase)	Adaptive cycles for the end of 1980s and mid 2000s
Historic state descriptions: Phase at t-1, …, t-n	
Adaptive cycle evolution description	Combined adaptive cycles for the urban fragment since 1962
Scenarios for future development	
Strategy design	

Table 60 Step 3: Constructing the combined adaptive cycle for the urban fragment in Mulhouse

The first general adaptive cycle starts with the construction of the settlement in 1962 using the potential of the site. In a period when many "pieds noirs" came from Algeria, they quickly needed dwellings (α and r phases). The potential of the site was used to establish a fast-growing neighbourhood. Apparently used steadily for the next two decades (K phase), the estate still had potential for new inhabitants maintaining some of its resilience and connectedness in the neighbourhood. In this sense the renovation of the buildings in 1989 using their potential (Ω and α phases) helped to adapt it to the needs and expectations of the remaining as well as the new inhabitants (r phase). This situation did not transition into a stable K phase with increased resilience and connectivity due to a lack of development. The isolated position of the neighbourhood (with little infrastructure and a shortage of entrances/roads) within the developing city worsened the situation of the location. Additionally with the deterioration of the building fabric, the settlement lost more of its potential. Fragmented activities of resilience (the women's working group) and connectedness (a music video by youths) could not succeed against the City of Mulhouse's fixed plan (Ω phase) to not only demolish but also build fewer dwellings afterwards. Nonetheless, the project profited from the integration into an overall development plan promising economic, ecological and social development (Figure 84). Additionally, the federal agency for city renewal (Agence Nationale pour la Rénovation Urbaine) subsidised the project with up to 50% of the costs at different stages. Without even looking for alternative solutions a "tabula rasa" policy was implemented resulting in a totally new cycle whose success or failure will be seen in the coming decade after the completion of the project in 2012. From a social and cultural point of view, the loss of social memory and cultural witness is considerable. No alternative solutions were sought, the implications for the inhabitants are not decisive and the mid- to long-term prospects are probably not very good.



t = mid 2005s t = 1980s

Figure 84 Combined Adaptive Cycle for the urban fragment in Mulhouse

III3.5 Step Four: Scenarios for Future Development

Scenarios

Currently, five of the seven buildings are demolished and the rest is vacant and may be renovated for the first time since 1989. The oldest buildings have been constructed 50 years ago and have aged normally. A tramline has been extended to improve the connection of the Brossolette Estate to the quarter. Further development of the settlement depends however on the integration of the estate with the new constructions and within the quarter.

Two scenarios seem possible: either the estate becomes integrated with stable social diversity or the integration does not work (Table 61).

Steps	Description
Urban fragment definition	Location: seven buildings of the Brossolette Estate in Mulhouse, France Time period from construction in 1962-65 until today
Current state description (adaptive cycle phase)	Adaptive cycles for the end of 1980s and mid 2000s
Historic state descriptions: Phase at t-1, …, t-n	
Adaptive cycle evolution description	Combined adaptive cycles for the urban fragment since 1962
Scenarios for future development	Scenarios:Long-term or Short-term Renovation
Strategy design	

Table 61 Step 4: Scenarios for the Brossolette Estate

Scenario Long-term Renovation with Social Diversity

In this scenario, the buildings are renovated completely to current standards including energy savings, resulting in an ecological virtual adaptive cycle in a stable K phase.

Economically, the old buildings with their substandard dwellings and the new constructions provide appropriately for the current use diversity of the neighbourhood. With the extended tramline, the substandard dwellings become more attractive. The economic virtual adaptive cycle becomes stable and transitions into a K phase.

The program for Bourtzwiller works well. The Brossolette Estate is integrated within the new construction areas and profits from the better infrastructure and other services. Social diversity results in good social cohesion and a social virtual adaptive cycle in a K phase.

The buildings have no cultural importance and the cultural virtual adaptive cycle can be seen as being in a non-directional α phase.

Scenario Short-term Renovation and Isolation

In this scenario, the old buildings undergo minor renovations with plans to demolish them in near future. With the tram coming closer, only the new buildings become more attractive, not the parcels of substandard dwellings.

Ecologically, the renovations do not improve the estate's environmental friendliness. The ecological virtual adaptive cycle can be interpreted as being in an α phase, in which something needs to happen to achieve the increasing environmental requirements.

The higher attractiveness of the quarter increases the attractiveness of the area of the estate and brings about different uses or at least the construction of new buildings. This pressure does not allow the development of a stable K phase and will sooner or later result in an Ω phase for the economic virtual adaptive cycle.

The limited level of renovation attracts only very underprivileged tenants constraining greater social diversity. The integration of the estate with the new constructions and the quarter does not occur. The social virtual adaptive cycle can be interpreted as being in a non-directional α phase.

A similar α phase is valid for the cultural virtual adaptive cycle due to the cultural insignificance of the buildings.

III3.6 Step Five: Strategy Design

Strategies for the Long-term Renovation with Social Diversity (LRSD) Scenario

The construction of the scenarios facilitates the choice of one or several strategies in the last step of applying the adaptive cycle framework (Table 62).

Steps	Description
Urban fragment definition	Location: seven buildings of the Brossolette Estate in Mulhouse, France Time period from construction in 1962-65 until today
Current state description (adaptive cycle phase)	Adaptive cycles for the end of 1980s and mid 2000s
Historic state descriptions: Phase at t-1, …, t-n	
Adaptive cycle evolution description	Combined adaptive cycles for the urban fragment since 1962
Scenarios for future development	Scenarios:Long-term or Short-term Renovation
Strategy design	Renovation maintaining social and economic value or only use value

Table 62 Step 5: Strategy Design for the Brossolette Estate

The LRSD scenario implies a high level of renovation for the old and new buildings resulting in an economic value increase (E=1) and medium ecological improvement (N=2). Good integration is interpreted as good social cohesion (S=1). The mediocre cultural impact is represented by C=0. This choice results in Strategy combination E (1; 0; 1; 2).

Strategy combination E (Figure 85) results in economic operation costs of 5.5% down to 4.4 % after the renovation that costs 48% (after cycle 1; 60% after cycle 2), in environmental operational costs of 5% down to 4% after the renovation that costs 48%. The value for cultural sensibility increases with 1.05 points per year. The social points are at 12 points.

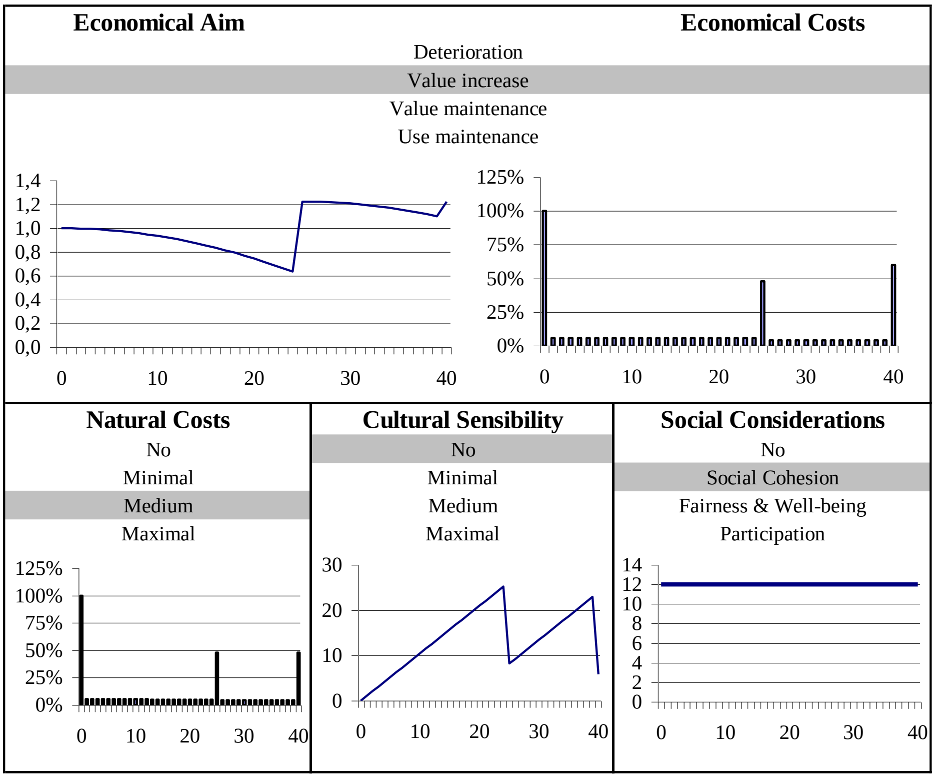


Figure 85 Strategy for the old and new buildings in Scenario LRSD in Mulhouse

Strategies for the Scenario Short-term Renovation and Isolation (SRI)

The SRI scenario implies a low level of renovation resulting only in use maintenance (E=3) with no ecological improvement (N=0). The absence of integration facilitates no social cohesion or any other social benefits (S=0). The mediocre cultural impact is represented by C=0. This choice results in Strategy combination F (3; 0; 0; 0) for old buildings (Figure 55). The strategy for the new constructions is the same as in the LRSD scenario but without social cohesion (S=0); so Strategy G (1; 0; 0; 2). Strategy combination G (Figure 86) results in economic operation costs of 5% down to 4% after the renovation that costs 48% (after cycle 1; 60% after cycle 2), in environmental operational costs of 5% down to 4% after the renovation that costs 48%. The value for cultural sensibility increases with 1 points per year until the cultural value decreasing renovation after 25 years. The social points are at 10 and go down to 8, when the new constructions undergo an economic value improving renovation without social consideration.

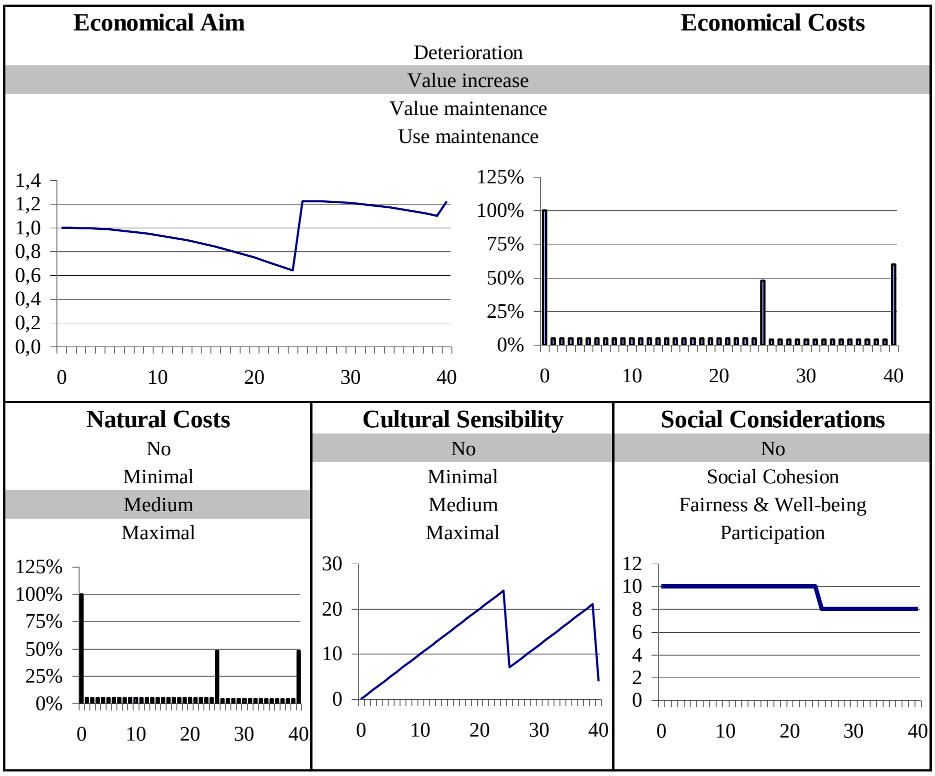


Figure 86 Strategy for new constructions in Scenario SRI in Mulhouse

The two scenarios show a similar handling of the new buildings (strategy combination E and G). More questions arise on how to take care for the old constructions (strategy combination E or F). The strategy applied on them may be crucial for the coalescence of the whole Brossolette Estate.

III4. Conclusion on the adaptive cycle analysis framework

The application of the adaptive cycle analysis on the urban fragments in Mannheim and in Mulhouse shows that step for step the current situation, the recent past and the history of an urban fragment can be analysed. The application studies dealt with small residential areas and a period of several decades. No contradictionary developments came up, so the virtual adaptive cycles pass through comparable phases. The possibility to analyse the interdependancies between the virtual adaptive cycles has not been tested. The framework is conceptualised to allow a continuous overview on the development of an urban fragment. If there is enough data and information, the analysis can be done more in detail and helps to keep up a comparible level of detail for the virtual adaptive cycles and the general adaptive cycle, i.e. if several additional instruments or methods are used. In cases of less information and more uncertainty, the framework can help to derive insights on interdependencies by the results of the created scenarios and possibly concretise them with the help of the strategies.

IV Conclusions

Summary

The concept of adaptive cycles is a description of the resilience and succession patterns seen in ecosystem development; it furthermore serves as an analogy for a variety of social and economic phenomena, and is applicable, as shown in this work, to the development of urban fragments. Adaptive cycles consist of four temporally distinguishable phases, specified by three dimensions that represent the driving forces for change (resilience, connectedness and potential). Existing phase-based urban development models exhibit a successful correlation to the different phases of the adaptive cycle concept.

Typically, an adaptive cycle goes through four phases of development (alpha, r, K, omega), as originally described in ecology. The α phase, which is the new start of every development or the reorganisation after a disturbance, is followed by an r phase of fast development. The r phase transitions into the K phase, which is characterised by a slower developmental rate and results in a meta-stable climax. The fourth phase (the Ω phase) starts when internal or external factors cause disturbances or destructions. The Ω phase can lead to two possible outcomes, depending on the system's degree of resilience (i.e. its ability to resist disturbance): the investigated entity finds a way back to its original cycle (restarting in phase α) or transitions into another developmental state which means a restart in a new phase α of a different adaptive cycle. In addition to resilience, connectedness and potential are used to describe the state of a phase.

In analogy, the phases of the adaptive cycle concept match models describing urban development. Hoover's or Lichtenberger's models, for example, propose a linear succession with a climax (a quasi-final point within a development) and the possibility for transition into an Ω phase (with an undefined outcome for the neighbourhood). Both expect that the ageing of buildings also influences the characteristics and behaviour of the buildings' inhabitants. In contrast, Van den Berg's model is based on the shifting attractiveness of city quarters depending on the growth and mobility of a population and comprises several adaptive cycles.

Although notionally all the models described are theories for cities, a common characteristic is the focus on quarters as the basic unit of urban development. As Friedrich clearly shows, quarters are not identical parts of a city that develop through the same phases and in the same overall direction. Nevertheless, there are life phases that urban fragments share, including similar cyclic development. A mosaic cycle concept of the city, within which each quarter is seen as an independent developing unit, therefore facilitates a more adequate description of urban development and illustration of the complex interplay on the citywide level.

To deal with the complexity of urban development, new divisions of the adaptive cycles based on the sustainability dimensions are employed: in general, three dimensions are differentiated (the social, economic and ecological) and additionally, a fourth less often used but nevertheless necessary dimension of sustainability in the urban context is the cultural. In this approach, the four dimensions are represented by four independent "virtual" adaptive cycles – which together compose the complete (real) adaptive cycle. Furthermore, examining the level of a phase and its direction with regard to the adaptive cycle dimensions refine the assessment of the virtual adaptive cycles. The result is a matrix of sustainability and adaptive cycle dimensions that provides a framework for the analysis of the development of an urban fragment.

Existing methods and instruments supplement this adaptive cycle framework. The selected, rather diverse approaches are necessary to cope with the complexity of cities and originate from several disciplines with different aims. These approaches range from those well established within their disciplines to newly introduced ones that are pioneering in their field. Approaches employed in this work include: Indicators, Material Flow Accounting, Life Cycle Assessment, Urban Simulations, Environmental Impact Assessments/Strategic Environmental Assessments, Social Compatibility Analysis, Cost-Benefit Analysis and Geographical Information Systems.

The integration of the different approaches clarifies the adaptive cycle framework and facilitates the understanding of their relations to each other, but even with integration there are still limitations in covering the entire breadth of real urban development.

For the application of the adaptive cycle framework to urban fragments, the different approaches are combined to cover a broad focus and condensed to a five-step adaptive cycle analysis. The analysis addresses the development of urban fragments, first by defining the urban fragment and clarifying the scope of investigation. The second step consists of the assessment of extant conditions through indicators, which helps to interpret the present virtual adaptive cycles and facilitates the definition of the current real adaptive cycle and its history (step three). Possible future adaptive cycles or phases are considered through scenario techniques (step four) and refined by strategies (step five), which are developed for the maintenance of buildings. The strategies, based on the scenarios as starting points, help to simulate the aim of the scenarios as closely as possible in regard to their intended effects (culturally, socially, ecologically and economically) on the building stocks. The strategies examine the age class, size class and use class combinations of the buildings for basic evaluation. The performance of future calculations is in relation to this evaluation.

Two case studies (in Mannheim, Germany and in Bourtzwiller, France) on building stocks demonstrate the applicability of adaptive cycle analysis. Both of the building stocks, constructed in periods of necessity (after the Second World War and after the Algerian War, respectively), had over time lost much of their attractiveness. However, plans to demolish the urban fragments by the municipalities concerned were stopped (in Mannheim) or limited in implementation (in Bourtzwiller). Adaptive cycle analysis reveals that there has been strong social and economic resilience and connectivity to and within the urban fragment in Germany. The inhabitants used and even strengthened the social and economic potential of their living space. In the French case, social resilience limited the extent of demolitions, and, in contrast to the German case, the municipality supported the economic and social potential of the urban fragment by improving traffic connections.

Discussion

The introduced adaptive cycle framework for analysing urban fragments serves as an analogy to the adaptive cycle concept in ecology. The framework itself is neither a model nor a method, it rather constitutes a matrix for considering the three adaptive cycle dimensions (resilience, connectedness, potential) and the four dimensions of sustainability (the social, cultural, economic and ecological). For each dimension, applicable approaches are given. However, the complexity of real-life situations makes complete coverage by assessment tools an ambitious goal, beyond the scope of the provided framework. In particular, tools that assess social and cultural aspects focus rather on individual aspects without overlapping and without thorough investigation. There are tools that have differing levels of institutionalisation and width of use within the social and cultural disciplines. Usually, economic and ecological approaches possess a higher degree of connectivity. The different approaches do not exclude each other; they are rather complementary under the condition that they can relate mutually in an explicit way. Nevertheless, the bases of many approaches differ too much to allow direct comparisons or immediate transference/translation. The differences in breadth and depth between the tools leave gaps in the coverage of all dimensions. Nevertheless, there is also mutual overlapping among the tools. This overlapping could help to validate and to understand the interdependencies of the approaches.

The division of virtual adaptive cycles along the dimensions of sustainability helps make clear the possible shortcoming that there is clearly no single definable step in the direction of greater sustainability that exists for all dimensions. It is very likely that an assessment will result in the support of a medium-term economic agenda that undermines long-term environmental aims. To prevent such mutual foiling, proponents of the ecological viewpoint on sustainability aim at a broader understanding of economic limits [626] and to formulate the

[626] See also [SCRASE 03] in [POPE 04], p.597, on the risk that an assessment could support the current economic agenda and so undermine the achievements in environmental policies of recent decades.

objectives of the different sustainability dimensions in such a way that Pareto efficiency can be aimed.

While the above observations on the content and operation of methods to evaluate urban development show that there are a number of unresolved or unintegrated issues, it remains essential to ensure that an evaluation methodology fits not only the characteristics but also the requirements of its individual discipline. A large amount of literature exists that pretends to be comprehensive (e.g. cost-benefit analysis) and to facilitate objective evaluation of decision-making. However, most of these evaluation methodologies can only produce good results when used in the original context of their discipline.

Limitations of time, finances and other resources, data acquisition and accountability often result in large restrictions on outputs. The demand for one universally applicable comprehensive evaluation methodology resembles the medieval attempt to invent the philosopher's stone; an interesting and ambitious vision, but with little chance to become the basis of one long-term oriented approach.

The adaptive cycle analysis framework introduced and applied in this paper mainly concentrates on evaluation methodologies that come with width and depth (indicators, scenarios, urban life cycle analysis); it does not however use all the above-mentioned evaluation methodologies. For a more detailed designation of current and former adaptive cycles, some of the introduced evaluation methodologies can be useful for future studies. The construction of long-term scenarios and their refinement by maintenance strategies derived from urban life cycle analysis can allow detailed insight into future possibilities. This version of adaptive cycle analysis may be too discrete for application to more complicated urban fragments.

Nevertheless, the application of adaptive cycle analysis to the case studies in France and Germany demonstrates that it is able to provide structured information on the urban fragments and to set the information within the mutual relations of the sustainability and adaptive cycle dimensions, creating or validating insights into the dynamics of the urban fragment. Neglecting necessary continuous repair and modernisation does not save money; rather the costs of repairs rise disproportionately if there is retardation of maintenance activities. The cooperative in Germany even shows the possibility that greatly delayed repair and modernisation may sometimes be preferred over demolition and rebuilding, unless of course decay has gone too far.

Outlook

The adaptive cycle framework presented in this paper needs distinct improvement and more sophisticated evaluation methodologies to cover all the phases and dimensions of adaptive cycles and the dimensions of sustainability. The implementation of these tools will provide a better understanding of the interrelations and the interdependencies between the four dimensions (i.e. the ecological, economic, social and cultural). Combining different approaches with each other can further result in higher efficiency. If an evaluation methodology, such as Life Cycle Analysis, of a project in one scenario is consistent with existing evaluations within another scenario of an adaptive cycle analysis, a second project LCA can be shortened by simply referring to the evaluated one.[627] For the analysis of the current situation of an urban fragment new methods are developed, i.e. Leadership in Energy and Environmental Design (LEED) for neighbourhood development[628]. The checklist for LEED for neighbourhood development is broad in the analysed topics but interdependancies, the various available levels of knowledge and the different time horizons between the topics of the rating system seem not to be considered.

To understand in detail the interdependencies of the limits of the evaluation methodologies and to ease communication of the results between each other, the limits need improved description. This will help to validate the individual results or will reveal as yet unrealised or unexplained gaps between the approaches and the analysed issues. These insights are necessary for the implementation and application of the adaptive cycle framework in analyses that are able to flexibly incorporate future evaluation methodologies and help to understand in a systemic way the development of an urban fragment.

In addition to the results of adaptive cycle analysis, the strategies can be structured in a more complex manner and elaborated in order to serve more adequate applications in the scenarios.

If accomplished in a thorough manner, scenarios and strategies can result in adaptive cycles that have limits in each of the four sustainability dimensions. These limits could be illustrated as interdependent curves (connecting the feasibility of the cultural, social, economic and ecological dimensions) as they exist already for three-dimensional sustainability optimisation. These curves facilitate an understanding of the limits of each sustainability dimension in relation to the others, like the marginal rate of substitution in economics. Such curves would help to find transitions and substitutes between the dimensions that are more efficient and would show the opportunities and risks for the sustainability dimensions by moving along the curve. The curves would not mean that there are always smooth transitions between the values in the sense of weak sustainability but that they help to identify inefficiently used resources, which can be used to improve the value of at least one dimension (Pareto improvement). The limits of the curves would be representative for one adaptive cycle.

[627] This combination of tools also presents the danger of subverting assessments, here LCAs. The scenario may 'hide' an alternative assessment of a project, so that significant impacts in a second scenario might be overlooked. Therefore, it is crucial to understand how much such shortcuts improve efficiency and how much they hide risks for, and so endanger, sustainability issues.

[628] [LEEDND 13]

Transgression of the limits would result in a transition into another adaptive cycle and so another constitution of the four-dimensional substitution curves.

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Annex

A.1 Urban units

A premise is that the combination of three types of urban units describes any kind of city: buildings, infrastructure and open spaces including urban furniture. The differences between the urban units make it necessary to work with such a differentiation, i.e. the various uses of infrastructure comprise very separate materials and technical levels. True functional equivalence for built environment functions can be assessed only at the level of the whole structure over its entire life cycle, defined according to predefined urban unit performance characteristics.

A.1.1 Buildings

Within the German jurisdiction, there are several definitions for the term ‘building’. The following definitions are not complete, only valid in Germany and serve as examples. Within the German ‘Landesbauordnung’ (§ 2 Abs. 2) of Baden-Württemberg the word building is defined as autonomous usable, covered construction, which can be entered by human beings and is appropriate to give shelter for human beings, animals or goods.[629] According to the ‘Einkommenssteuerrichtlinien (EStR)’, a guideline which organises the taxation of income, buildings are constructions on own or foreign property, giving protection to living creatures as well as things by spatial enclosure against exterior influences, allowing the presence of living creatures, directly fixed with the property, are of some durability and stable.[630] A judgement of the ‘Bundesfinanzhof’ (Federal Finance Court) gives another definition: a real estate comprises the parcel of land, on which a construction is situated.[631]

Both the quality and the long-term durability of a building depend upon the selection of appropriate products and the manner in which they are assembled on site. Without going to the level of building products and the difficulties of specifying them in terms of building cost and operation time, we assume that there is knowledge about the “building as built”[632] and composed of a multitude of assembled products.

A.1.2 Infrastructure

There are several types of civil urban infrastructure systems, all contributing to create and keep up certain flows (i.e. water, cars, electrons etc.). Designing these systems for a particular service life and

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[629] “selbstständig benutzbare, überdeckte bauliche Anlagen, die von Menschen betreten werden können und geeignet sind, dem Schutz von Menschen, Tieren oder Sachen zu dienen“ [IMIG 07]
[630] [ESTR 08]
[631] [ZEITNER 06], p.29, 31
[632] [EMMITT01], p.4

maintaining them in operation has been recognized as a critical issue worldwide. Derelict infrastructure like the electricity network problems in the USA or the collapse of a bridge over the Mississippi in Minneapolis draw the attention to the fact that insufficiently maintained infrastructures can become a problem also in highly developed countries.[633] A lot of structures constructed in the 1960s are reaching the end of their predicted life time or show first serious signs of deterioration or damage. Therefore the preservation respectively renewal becomes continuously important. According to Booz Allen Hamilton between 2007 and 2032 around 40 trillion US dollars must be invested to maintain or improve the urban infrastructure at a level that allows them to function normally.[634] Restrictions of public budgets hinder the accomplishment of necessary measures of maintenance. The erected structures have been designed with high margins of safety, so the safety of the users is not endangered. Moreover, "these kinds of structures often have the capability to redistribute loads from the damaged area to intact areas".[635] The design of infrastructure cannot be concentrate only on solving the mechanical challenges. It needs also to consider the interaction between upcoming processes throughout the life of an infrastructure unit as well as its direct and indirect impact on the built environment. In summary, the development of infrastructure has to be designed and built on integrating all four sustainability dimensions.

A.1.3 Open Spaces

Open spaces are all kind of spaces (or surface) which have a specific purpose or function but can not be categorized as buildings and infrastructure.

If the general utility of open spaces is obvious, the direct benefit is more diffuse, i.e. sewage water systems have a direct benefit and protection, i.e. against disease. There are of course formal and informal economy related activities like pavement vendors using public spaces, whereby the linkages between the two are an on-going research topic.[636].

The overall benefit of open-spaces is often uncertain because the positive externalities associated with proximity such as a view or nearby recreation facility might be outweighed by negative externalities, for example, traffic congestion and noise. Open spaces may have an influence on the market value of buildings situated close to open spaces. Results show that proximity to an open-space and open-space type can have a statistically significant effect on the market value of buildings. These estimates provide an important argument in quantifying the overall benefit from preserving open spaces in an urban environment.[637]

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633 [ROETZER 07]
634 [DOSHI 07], p.67
635 [HOSSER 06], p.271
636 [CHEN 07]
637 [BOLITZER 00], p.192, 193

A.2 Urban Unit Attributes

A.2.1 Construction Year and Uses

For each type of urban units, different years of construction mean different construction techniques and therefore partilally changing attributes. Differing construction years represent also general historic conditions i.e. energy consumption or workforce necessary for a construction.

Following urban unit classes have been successfully applied; for buildings[638]

- Housing: comprises one family houses, multiple family houses, skyscrapers etc.
- Office and administrative uses
- Education (schools, universities)
- Shops
- Commerce, Department stores and shopping malls
- Schools
- Hotels/Hospitals: are put together in one category due to their similar use and concentration on rooms with beds and gastronomic facilities
- Restaurant
- Storages buildings
- Production buildings (workshops, factories);

for infrastructure[639]

- Telecommunication
- Roads
- Electricity
- Gas
- Water distribution
- Sewage water systems
- District Heating
- Railway
- Trams;

for open spaces and urban furniture[640]

- Open spaces for office buildings, banks, schools, nursing homes
- Courtyard greening
- Design of living environments
- Urban places and village squares
- Playgrounds
- Residential gardens
- Public Parcs and city gardens
- Outdoor sport facilities
- Leisure facilities
- Renaturation activities
- Natural areas

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[638] [KOHLER 99], p.

[639] [SUIT 03], p.33

[640] The collection of open spaces bases on [BKI 04]

A.2.2 Shapes and dimensions

Needed data on the urban units are lengths, areas or volumes. Required data can be found based on square metres or metres etc. Buildings may be discriminated by gross floor areas and shapes. Common building shapes are L, T, E, F, H, U-form.[641] Specific shapes for roofs, facades and open space can be added. Infrastructure may be discriminated by the length and width of longitudinale elements and by the area and the number of connections to longitudinale elements of knots. Open spaces may be discriminated by their shape and the urban furniture placed on.

A.2.3 Technical and Qualitative Equipment

The construction date consolidates the technical abilities and qualitative strengths of an urban unit's equipment. At least partly, urban units, undergone maintenance and renovation, may have newer equipment with different properties. The equipment is different for the three different urban unit types, and inside each type, the use requirements differ. Nevertheless, the knowledge on the equipment of an urban unit is necessary to value it considering the sustainability dimensions. Besides technical characteristics also the qualitative characteristics are of importance and sometimes as functional as the technical ones.

There exist several understandings of the term quality. Traditionally the term comprises a level of excellence or goodness of a product and compliance to requirements on the level of processes. For urban units eight aspects are applicable.

- Performance: fulfilling main functions for and needs of users[642]
- Reliability: probability an urban unit will not fail within a predefined period (comprising Quality of Components, Design/Detailing and Installation/workmanship)[643]
- Conformance: degree of the fulfilment of pre-established standards[644]
- Durability: service life of an urban unit until no repair options are available and it is necessary to replace[645]
- Serviceability: speed, competence and provenience of reparations[646]
- User acceptance and satisfaction: subjective perception of the urban unit quality[647]
- Aesthetics: sound and look of an urban unit as well as the feeling it generates[648]
- Cultural Value[649]

[641] see for more detail [STEADMAN 06], [BRADLEY 05], [STEADMAN 00], p.80
[642] [GARVIN 84], [McGEORGE 97]
[643] Factors A, B and C of ISO 15686
[644] [GARVIN 84], [McGEORGE 97]
[645] [GARVIN 84], [McGEORGE 97]
[646] [GARVIN 84], [McGEORGE 97]
[647] [KLINGENBER 07]
[648] [GARVIN 84], [McGEORGE 97]

Considering sustainability of urban fragments, the research on the relation between life-cycle costs and quality is an important aspect. Studies see the biggest barriers in the lack of accurate historical cost data and comparibility.[650] It seems reasonable that the quality of design, materials used and craftmenship will affect the operation and renovation costs and totally, the life-cycle cost of any kind of construction. The quality of an urban unit has an influence during its whole service life, but is mainly determined during the design phase.[651] Current decisions regarding the design and construction imply the potential to influence coming costs significantly. Obviously higher construction costs due to quality reasons will logically result in savings during the operation and maintenance phases. The question is if cost effectiveness can be reached in the long term? There exist several studies which found that repair costs for urban units constructed in the 1980s and 1990s amount to higher sums than those constructed before 1980:[652] reasons were less durable construction and inappropriate design and faulty work.

Even if the quality was measured, i.e. in the construction phase, later inspections and condition assessment programmes do not show the whole picture. When there are no good cost data, it is not possible to connect quality with money savings.[653]

The choices on the adequate kind and time of a renovation of constructions aim to minimize costs and maximize value with scarce operation and renovation funding allocations at the same time. Regarding limited areas the balance between the requirements to maintain older stocks with the need for new construction has to be kept.

Opening a possibility to quantify the impact of quality on the life-cycle costs and to develop an easy equation, which utilizes the building design, construction and operating/maintenance quality score to foresee operation and renovation costs, would be a valuable step for the evaluation of construction activities.

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649 [KLINGENBER 07]
650 See for more detail [NEWTON 99], [PULAKKA 99], [ARDITI 98]
651 [BURATI 92]
652 [MARSHALL 99]
653 [NEWTON 06]

A.3 Data collection

Environmental Effects of Phases

Existing tools can calculate the amount of materials, energy and financial means used to build an urban unit basing on its regular maintenance. Assuming a just in time maintenance of all components, the aim is to construct an ageing curve and derive the development of the sustainability values. For the understanding of the construction phases, 154 buildings have been analysed with the aim to make up the general strategy underlying in an existing life cycle analysis tool (Table 63, buildings individual list Table 64). Five buildings had missing values.

construction type	number	average construction year	average gross floor area in sqm	average volume in cbm
Commerce	8	1964	7157	46689
Education	10	1957	4121	16604
Hospital	5	1946	9969	33425
Housing	66	1954	2454	6689
Office	21	1916	8551	33880
Other	18	1884	3994	125115
Production buildings	13	1947	4614	48305
Storage	8	1924	2975	12731

Table 63 Building uses, number of buildings, average construction year, average gross floor area in square metre and average volume in cubic metre
Source: own illustration

Use Type	Construction Year	Storeys	Gross floor area in sqm	Volume in cbm	City
Einfamilienhaus	1976	3	278	763	Aachen
Mehrfamilienhaus	1978	4	2324	6157	Aachen
Wohnen	1900	2	298	808	Alsfeld
Krankenhaus	1907	5.5	4006	14414	Altena
Reihenhaus	1994	2	3611	8498	Altötting
Handwerkerhaus	1521	4	393	781	Augsburg
Mehrfamilienhaus	1977	8	5684	15765	Bad Dürrheim
Wohnen u. Lager	1612	3.5	780	1664	Bad Salzuflen
Wohnanlage	1988	4	2552	6024	Bad Tölz
Landwirtschaftl.Gebäude	1954	2	346	1941	Baden
Kaserne	1881	4.5	15649	59239	Berlin
Museum	1886	4.5	37597	197854	Berlin
Mehrfamilienhaus	1905	5.5	1554	5390	Berlin
Reihenhaus	1934	3.5	156	462	Berlin
Fahrradschuppen	1934	1	216	643	Berlin
Mehrfamilienhaus	1956	9	11229	31132	Berlin
Wohnhochhaus	1970	19	13094	38013	Berlin
Mehrfamilienhaus	1990	7	6497	19838	Berlin
Krankenhaus Anbau	1995	nicht bekannt	4442	15905	Berlin
Werkstattgebäude	1930	1	1474	9649	Berlin Britz
Kaufhaus	1977	4	1761	5630	Böblingen
Industrie	1877	5	1362	6535	Bochum
Reihenhaus	1956	3	752	1454	Bonn
Werkstattgebäude	1930	6	6526	26234	Braunschweig
Landmaschinenhalle	1992	1	1040	6865	Braunschweig
Getreidesilo	1844	3	1887	22563	Bremen
Residenz	1725	4.5	10926	51839	Brühl
Reihenhaus	1951	3	715	1643	Crailsheim

Use Type	Construction Year	Storeys	Gross floor area in sqm	Volume in cbm	City
Fabrikgeb.+Förderturm	1924	2	1239	5784	Dortmund
MFH Wohnen, 9 WE	1930	4	752	2255	Dresden
Mehrfamilienhaus	1945	7	2007	5697	Dresden
Schwimmbad	1909	3	4286	1924166	Duisburg
Stall/Tenne	1812	2.5	409	1606	Dürr Ellenbach
Einfamilienhaus	1955	3	290	707	Düsseldorf
Schule	1935	3.5	907	2900	Elenz, Baden
Mehrfamilienhaus	1983	4	6947	21389	Erding
Verwaltungsgeb.Flughafen	1990	4	5617	19447	Erding
Wohnhochhaus	1955	12	3514	9508	Esslingen
Einfamilienhaus	1975	3	317	858	Esslingen
Mehrfamilienhaus	1977	3	1208	3129	Esslingen
Industriebau	1977	2	1236	4106	Esslingen
Lager+Produktion+Büro	1977	1	613	2186	Esslingen
Einfamilienhaus	1982	3	595	1611	Esslingen
Einfamilienhaus	1987	3	255	758	Esslingen
Mehrfamilienhaus+Bank	1992	4	1982	5632	Esslingen
Mehrfamilienhaus	1956	4	1508	3964	Fellbach
Landw. u. Wohnen	1800	2.5	74	168	Finkenbach
Einfamilienhaus	1989	3	323	588	Frankenthal
Reihenhaus	1929	3	178	478	Frankfurt
Verwaltung IG Farben	1930	9	53227	232256	Frankfurt
Bürogebäude	1951	13	19164	60471	Frankfurt
Berufsschule	1979	3	8015	32843	Frankfurt a. M
Mehrfamilienhaus+Laden	1976	4	1814	5306	Freiburg
Mehrfamilienhaus	1977	5	5227	14219	Freiburg
Wohnen	1914	2	283	644	Friedrichshafen
Mehrfamilienhaus	1952	5	4048	9579	Friedrichshafn
Hammerwerk	1600	nicht bekannt	0	0	Frohnau
Mehrfamilienhaus	1978	4	719	1899	Goeppingen
Schule	1991	1	1016	3369	Hassberge
Schulgebäude	1909	4.5	553	1694	Heidelbach
Mehrfamilienhaus	1976	4	751	1875	Heidenheim
Mehrfamilienhaus	1976	4	1959	5267	Heidenheim
Werkhalle	1976	7	1396	8094	Heidenheim
Einfamilienhaus	1979	3	414	1042	Heidenheim
Landwirtschl.Geb.	1961	1	489	2491	Heistardburg
Krankenhaus	1930	4.5	7517	25313	Hilden
Verwaltung	1600	6.5	2334	7446	Hildesheim
Mehrfamilienhaus	1978	4	1145	3008	Hohenlohe
KFZ-Zulassungstelle	1989	3	1472	5477	Ingolstadt
Mehrfamilienhaus	1992	4	2187	6025	Ingolstadt
MFH Wohnen, 4WE	1929	2.5	793		Kaiserslautern
Industriebau	1977	2	8813	52900	Karlsruhe
Wohnen/Landwirtschaft	1910	1.5	336	880	Kassel
Gericht und Verwaltung	1883	4.5	23327	107294	Köln
Wohnen	1895	3	1615	6444	Köln
Warenlagergebäude	1927	5	17064	71885	Köln
Handelsgebäude+Großmarkth.	1941	2	18932	219773	Köln
Sparkasse	1952	nicht bekannt	0	0	Köln
Mehrfamilienhaus	1977	4	435	1155	Konstanz
Reihenhaus	1977	3	3164	8455	Konstanz
Werkhalle	1980	1	1992	6157	Konstanz
Mehrfamilienhaus	1970	12	3871	6103	Leipzig
Kaufhaus	1958	4	9741	42612	Leverkusen
Autobahnpolizei	1994	3	1213	4151	Lörrach
Verwaltungsgebäude	1977	5	7008	24708	Ludwigsburg
Mehrfamilienhaus	1981	nicht bekannt	1594	4580	Ludwigsburg
Lagerhalle	1984	2	1151	3129	Ludwigsburg
Bürogebäude	1988	4	1632	1578	Ludwigsburg
Wohn/Geschäftshaus	1908	3.5	1638	5022	Lüneburg
Rathaus, Schirn	1525	5.5	1920	9001	Marburg
Krankenhaus	1956	8	9590	32032	Memmingen

Use Type	Construction Year	Storeys	Gross floor area in sqm	Volume in cbm	City
Warenhaus	1908	6.5	6100	24966	München
Kirche	1932	1	927	4969	München
Verwaltung	1938	5	3693	11393	München
Mehrfamilienhaus	1955	3	2151	5647	München
Wohngebäude	1955	13	11273	30777	München
Wohnhochhaus	1955	19	7157	19856	München
Einfamilienhaus	1957	2	225	545	München
Vertriebs-u. Bürogeb	1977	3	6685	30417	München
Bunker	1933	3	1598	6104	Neufert
Industriebau	1912	7	14916	68363	Niederzwönitz
Getränkelager	1990	1	1216	9276	Nürnberg
Fabrik+Werkstg.Gasom	1927	2	7178	347000	Oberhausen
Landw. und Wohnen	1780	3	731	1296	Odenwald
Mehrfamilienhaus	1984	5	3699	9706	Offenburg
Mehrfamilienhaus	1977	7	4441	12242	Ostalb
Schule	1989	1	1186	4598	Ostallgäu
Mehrfamilienhaus	1952	5	5692	14705	Pforzheim
Mehrfamilienhaus	1983	6	1391	3953	Pforzheim
Wohnhaus	1885	3.5	1089	3768	Prenzlau
Mehrfamilienhaus	1975	12	10973	29764	Ravensburg
Berufsschule	1973	3.5	7570	27956	Regen
Kaufhaus	1976	2	12375	45921	Rems-Murr-Kreis
Reihenhaus	1977	3	713	2132	Rems-Murr-Kreis
Kaufhaus	1978	3	3671	15014	Rems-Murr-Kreis
Einfamilienhaus	1978	3	324	872	Rems-Murr-Kreis
Industriebau	1906	nicht bekannt	0	0	Rheine
Landwirtsch.gebäude	1951	2	446	2034	Sallenbusch
Bauernhof	1860	2.5	1783	6272	Schleswig- Holstein
Verbrauchermarkt	1982	1	2836	15059	Schwäb.Hall
Geschäftshaus	1993	5	1840	4539	Schwäb.Hall
Verwaltungsgeb	1979	4	1783	6120	Schwarzwald-Baar
Kirche	1853	2	407	4541	Seelscheid
Reihenhaus	1978	2	1182	3447	Sigmaringen
Wohngebäude	1955	nicht bekannt	0	0	Starnberg
Wohngebäude	1955	3.5	1023	2876	Starnberg
VerwaltGeb-Landratsamt	1987	4	15408	59969	Starnberg
Scheune	1750	2	316	868	Steinfurt
Krankenhaus	1940	5	24291	79460	Stralsund
Büro.u.Lagergeb.	1958	6	4830	13309	Stutt.Vaihingen
Schulgebäude	1906	5	7942	36935	Stuttgart
MFH Wohnen, 18 WE	1928	4	1889	5383	Stuttgart
Sportgebäude	1932	2	3331	8457	Stuttgart
Einfamilienhaus	1935	2	275	1039	Stuttgart
Mehrfamilienhaus	1974	5	1048	2872	Stuttgart
Produkt. Büro-u.Lager	1976	2	1718	6202	Stuttgart
Mehrfamilienhaus	1977	4	654	1833	Stuttgart
Mehrfamilienhaus	1977	9	4470	11803	Stuttgart
Reihenhaus	1977	4	1020	2436	Stuttgart
Einfamilienhaus	1979	3	523	1284	Stuttgart
Reihenhaus	1987	4	5265	13387	Stuttgart
Inst.f.Bildschirmtech.	1991	3	5280	20177	Stuttgart
Landratsamt	1984	6	8611	30470	südl. Weinstraße
Druckereibetrieb	1992	4	5792	35499	Südthüringen
Schule	1959	2	1332	6358	Theesen
DH Wohnen	1933	1.5	240	657	Treuchtlingen
Produktionshalle	1984	2	3401	18465	Ulm
Einfamilienhaus	1986	3	378	1304	Ulm
Landwirtschaft	1894	1	957	5511	Usedom
Schule	1977	3	8718	34905	Weilheim
Einfamilienhaus	1986	3	339	1022	Weilheim
Fabrik-u.Werkstattgeb.	1925	1.5	4662	39181	Weiz(A)
Landw. u. Wohnen	1871	2	394	1273	Westfalen
Schulgebäude	1952	4	3973	14484	Würzburg

Table 64 Buildings with use type, construction year, number of storeys, gross floor area in square metre, volume in cubic metre and city of location
Source: own illustration

The buildings, selected from all over Germany, form the basis of the data sample. Each building was described with the Life Cycle Assessment tool LEGEP ('Lebenszyklus Gebäude Planung') means 'life cycle building planning' and is the result of several research projects at the Institut für Industrielle Bauproduktion, University of Karlsruhe (TH)[654]. The now commercial software consists of several modules. Based on a cost-element structure, it is stepwise possible to describe a building at different levels of detail. Missing informations can be covered by default data of average buildings contained in an external database. The program calculates costs, material use, energy use as well as a number of environmental impacts for each life cycle phase and at the desired level of detail (from whole building to individual building specifications. The connection to a professional cost and specification data base (SIRADOS) containing several thousand elements which are updated each year simplifies the description of a building in LEGEP.

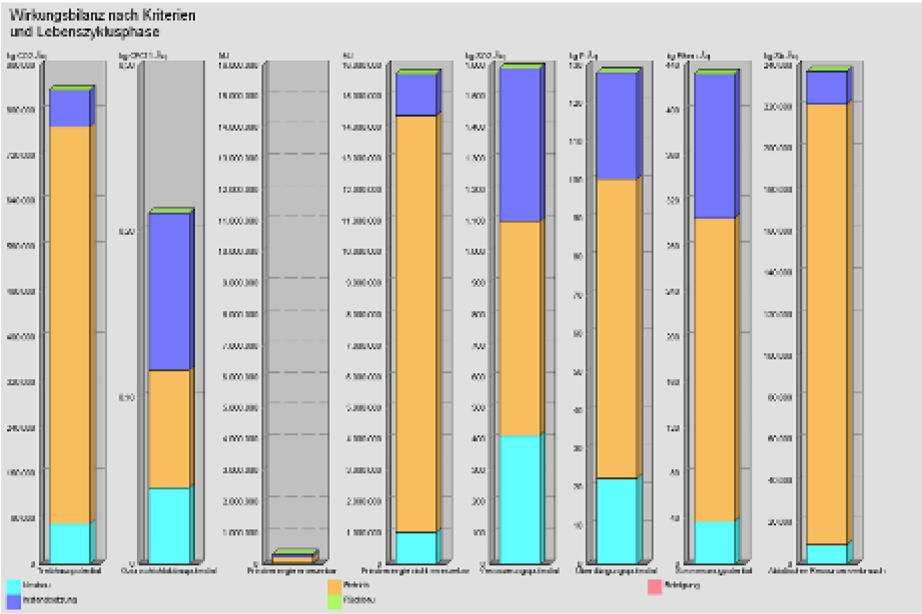

Figure 87 Environmental related effects of the phases
Source: Illustration made with LEGEP

Using LEGEP each building was entered according to the available data on the buildings (Table 64)[655]. Based on these data for each building a life cycle analysis was performed. As an example Figure 87 shows the effects of a one family house with 323 m^2 of gross floor area in Frankenthal (Rhineland-Palatinate) divided into its construction, renovation and operation phase in total and Figure 88 shows the results for the evolution of the global warming potential (GWP). The operation is considered constant during the life cycle. Regarding the renovation, the picture is more complex. Each of the building's components is used

[654] [KOHLER 96], [KOBEK 99]
[655] This was carried out by Regina Walder and students at the Institut für Industrielle Bauproduktion (ifib), University of Karlsruhe (TH).

during an assumed time span. At the end of this span the component is substituted by a new one, i.e. a window sill has a life span of 40 years and after that period it is replaced by a new one, which has beside other effects a global warming potential of about 2.144 kg CO_2-equiv. Due to the different life times of the various building components peaks due to clustered replacement appear (see year 2060 in the example).

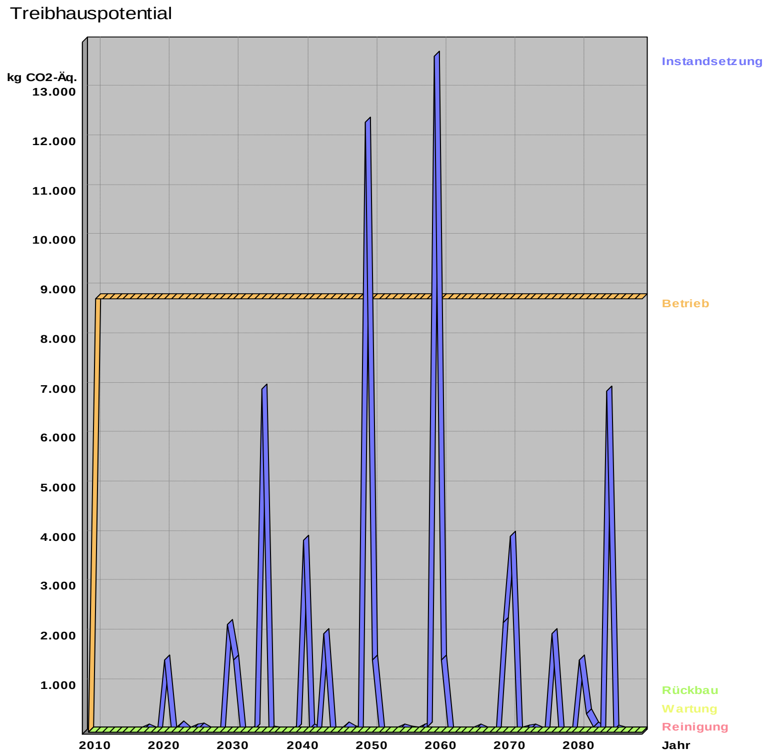

Figure 88: Global warming potential for Renovation (Instandsetzung) and Operation (Betrieb) in kg CO_2-equiv.
Source: Illustration made with LEGEP

Besides the environmental impact of CO_2-equiv. the acidification potential, the ozone depletation potential, the amount of waste materials, eutrophication potential and abiotic resource consumption are calculated based on the needed material amounts for the building's components for each building and for the total of the buildings (Figure 89 to Figure 92). In LEGEP the following life cycle phases exist: construction ('Neubau'), cleaning ('Reinigung'), operation ('Betrieb'), repair ('Instandsetzung') and deconstruction ('Rückbau').

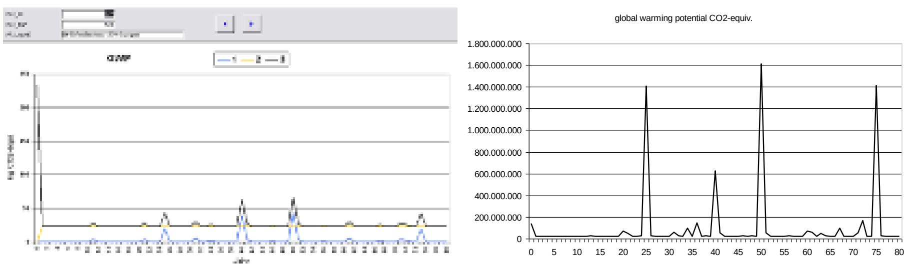

Figure 89: Example for global warming potential for a 1-familiy house in Stuttgart, Germany
with 1: Renovation related, 2: Operation related and 3: total CO_2-equiv. emissions (left); total global warming potential of all examined buildings (right)
Source: own calculations

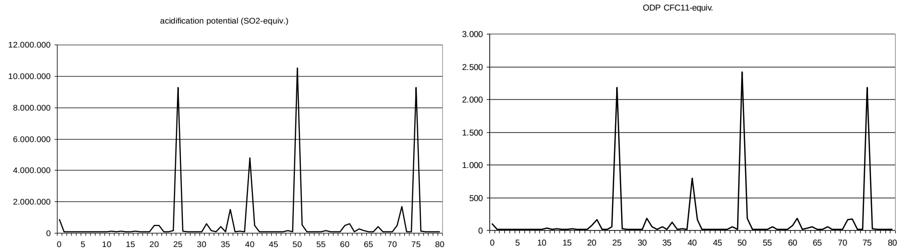

Figure 90: Example for total acidification potential of all examined buildings (left) and ozone depletion potential of all examined buildings (right)
Source: own calculations

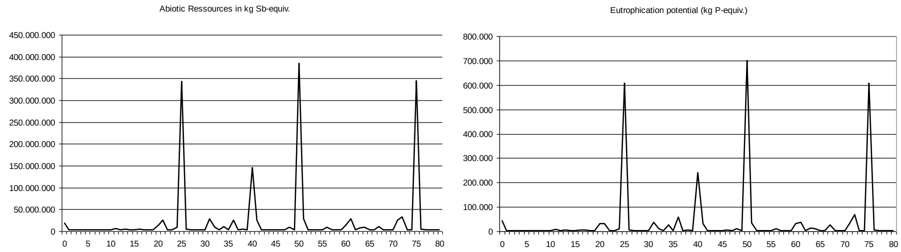

Figure 91: Example for total abiotic resources consumption (left) and total eutrophication potential (right)
Source: own calculations

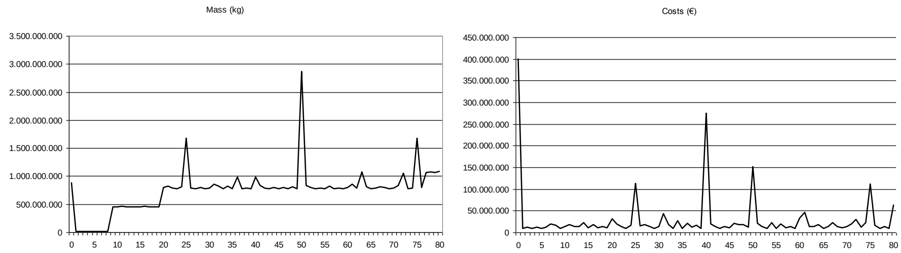

Figure 92: Example for total mass flows of all examined buildings (left) and total costs of all examined buildings (right)
Source: own calculations

In a next step, the buildings were first classified regarding their age, size and use. In the second step for each age/size/use class averages were calculated on the basis of the gross floor surface (‘Bruttogeschossfläche’ - BGF) for the phases. Not for all classes buildings have been analyzed. For the use class “housing”, the following classes have been built for the ages and sizes of the buildings (Table 65):

Age class (year)	min	max
1	0	1870
2	1871	1918
3	1919	1949
4	1950	1976
5	1977	2000

Size class (m^2)	min	max
1	0	1300
2	1301	5000
3	5001	99999

Table 65 Age and size classes for the use class housing
Source: own illustration

Based on these classes, Table 66 shows the number of buildings in each age and size class and the total sum of its gross floor area for the use "housing".

age class	size class		
	1	2	3
1	2		
2	3	2	
3	5	2	
4	9	6	6
5	16	10	5

age class	size class		
	1	2	3
1	467		
2	1670	3169	
3	1601	3896	
4	5399	17051	59418
5	10227	29433	29620

Table 66 Number of buildings (left) and sum of gross floor area (right) of 'housing' for the defined age and size classes
Source: own illustration

The standardisation is realised in two steps: 1. the absolute yearly costs for each size class (Figure 93 to Figure 95) are set into relation to the original construction costs (Figure 96 to Figure 98) and 2. yearly values above 20% are kept and the ones below are smoothened by dispersing on the surrounding years (Figure 99 to Figure 101).

1. Step: Yearly costs as percentage of the construction costs

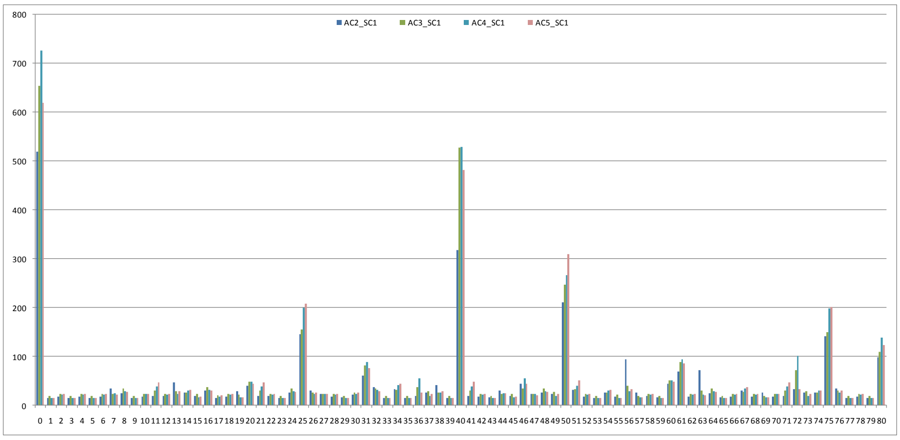

Figure 93 Absolute yearly costs per square meter for size class 1
Source: own calculations

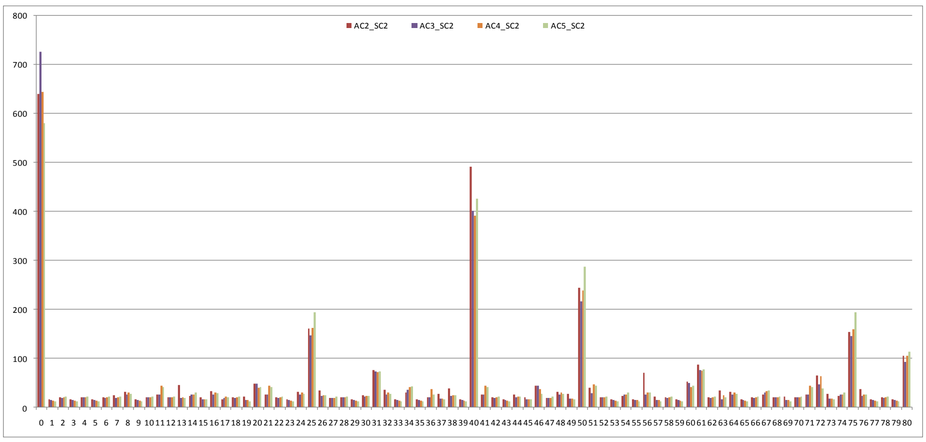

Figure 94 Absolute yearly costs per square meter for size class 2
Source: own calculations

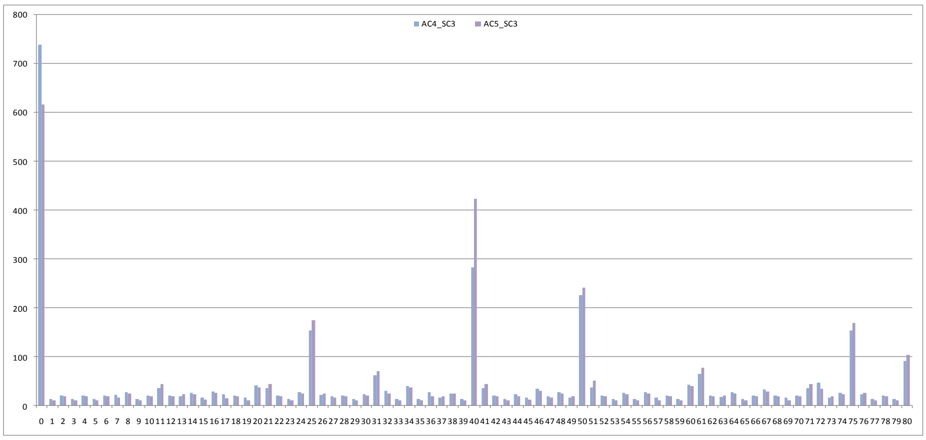

Figure 95 Absolute yearly costs per square meter for size class 3
Source: own calculations

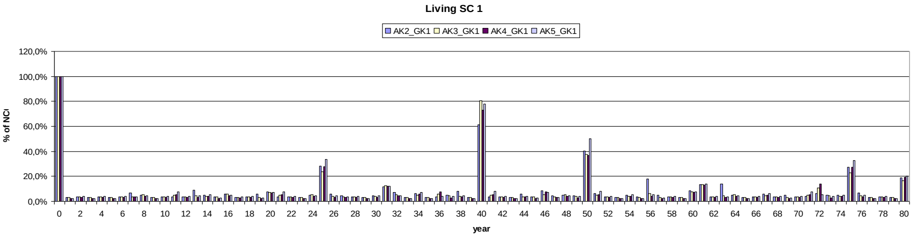

Figure 96 Yearly costs as proportion of the construction costs for Housing of size class 1
Source: own calculations

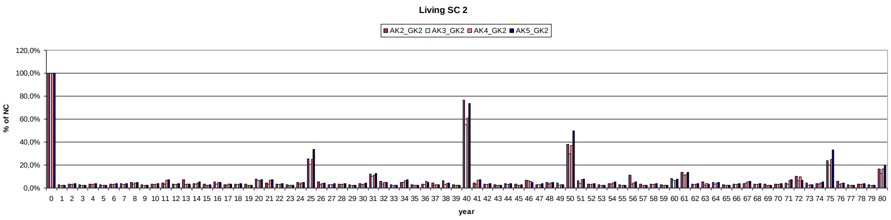

Figure 97 Yearly costs as proportion of the construction costs for Housing of size class 2
Source: own calculations

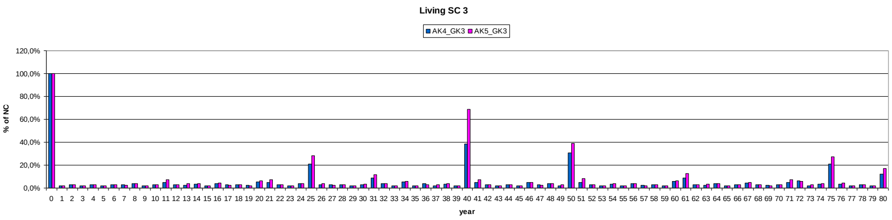

Figure 98 Yearly costs as proportion of the construction costs for Housing of size class 3
Source: own calculations

2. Step: Smoothened order by size

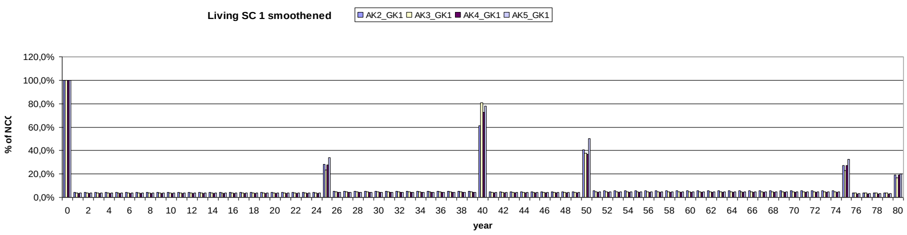

Figure 99 Housing smoothened for size class 1
Source: own calculations

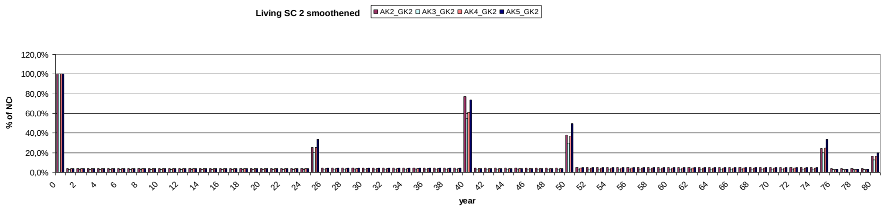

Figure 100 Housing smoothened for size class 2
Source: own calculations

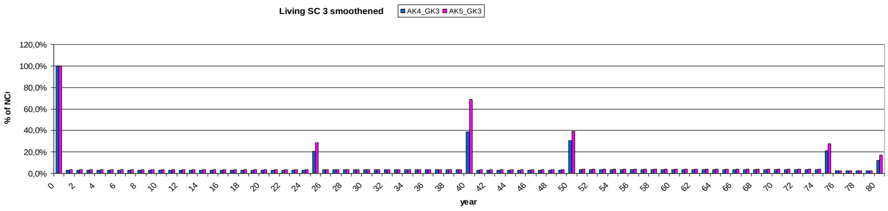

Figure 101 Housing smoothened for size class 3
Source: own calculations

Definition and Calculation of Standardised Effects

Environmental standardisation

Based on the standardisation of the costs, the material flows (Figure 102), the energy consumption (Figure 103) and the emissions (Figure 104) have been calculated for age class 2 (1871-1918) and size class 1 (0-1300 square meter). The figures show the effects for each phase (construction, cleaning, renovation, operation, maintenance and demolition). The same calculation has been made for all the reference buildings allowing to determine the average values for all age-, use-, size-classes.

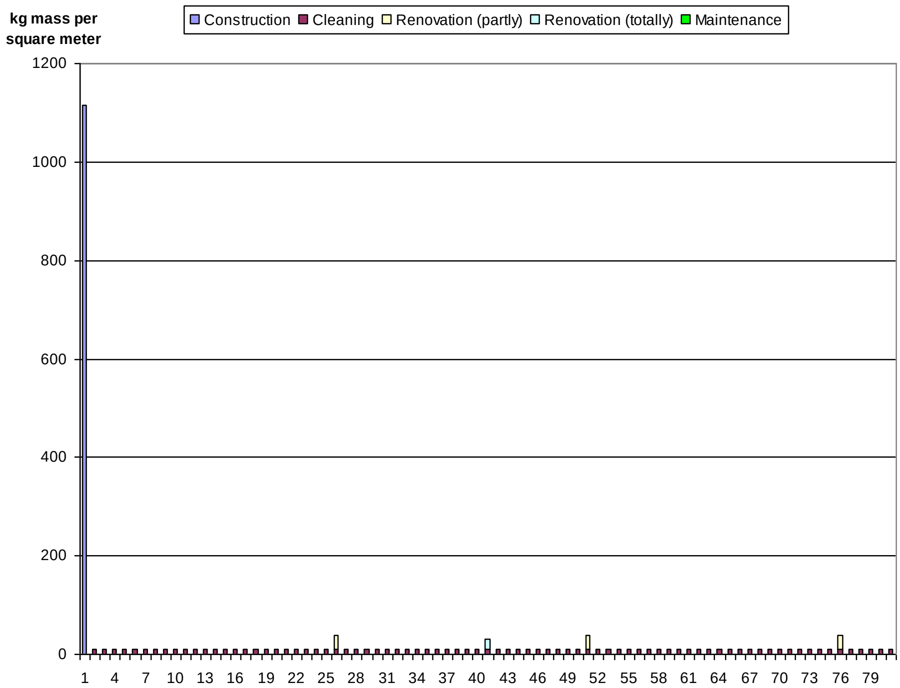

Figure 102 Standardised material flows of age class 2 and size class 1
Source: own calculations

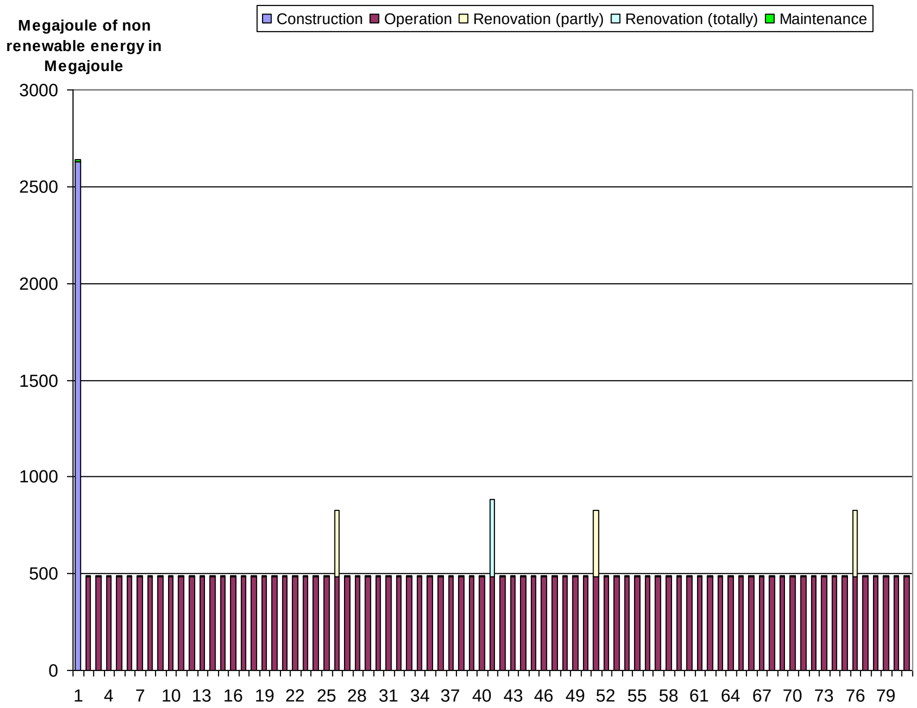

Figure 103 Standardised energy consumption in Megajoule of age class 2 and size class 1
Source: own calculations

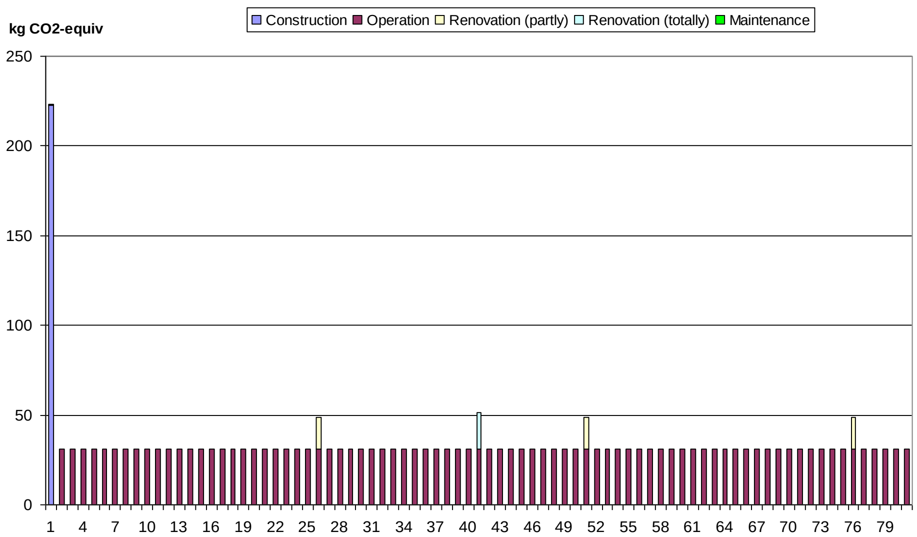

Figure 104 Standardised emissions of age class 2 and size class 1, here CO_2–equivalent in kg per square meter
Source: own calculations

A.4 State calculation

Urban units are materially ageing by physical, chemical and biological processes. Examples for such processes are wear and corrosion. This evolution of the state and the value regarding the sustainability dimensions is influenced by the planned service life of the urban units. State is standing for the condition of the urban unit. The identification of the state of the urban units can result from an inspection, a means to assess and to determine the current state of a subject unit (functionality and usefulness). Usually this is done with the determination of the causes of the deterioration and the deduction of necessary consequences for the future use[656]. They help to anticipate failure or problems and to plan future activities. Inspections comprise quantitative and qualitative information when inspected (Table 67). Whereas the quantitative information describes the constructive and technical features, the qualitative information comprises an assessment of the use state.[657]

						Wertung								Anteil	
		Kein Eintrag =normal				intakt		schadhaft						Anteil	
Bauteile	Beschreibung	Nutzwert	Belastung	Widerstand	Bewertungsjahr (Bauteil)	neu 1.0	gebraucht 0.9	leicht 0.8	0.7	mittel 0.5	stark 0.2	irreparabel 0	im Auswertungsjahr	Vorgabe	effektiv
Rohbau	Massiv				2002		○						0.90	35	36
Steildach	Ziegel				2002		○						0.88	4	4
Flachdach	kein				0								-	4	0
Fassade	Beton gestrichen				2002		○						0.88	8	4
Fenster	Holz-Metall, IV, Rolladen				2002			○					0.60	8	8
Wärmeerzeugung	Oelbrenner				2002		○						0.72	1	2
Wärmeverteilung	Radiatoren				2002				○				0.53	2	3
Sanitär	KW, WW, AW				2003			○					0.86	6	8
Elektro	Kraft, Licht				2002		○						0.56	6	4
übrige Technik	Personenlift, Warenlift				2002			○					0.58	3	4
Innenausbau	Gesamt				2002			○					0.67	27	28
Innenausbau	kein				0								-	0	0
Disponibel					0								-	0	0

Table 67 Inspection form to estimate the state of a building
Source: own illustration of [GRA 11], p.12

From Components to Urban Units

There are different approaches how the state is measured. Generally, a continous function starting at 100% (1) and go down to 0% (0) is used. There are also numbers used for ordinal scales, so that only a hierarchical comparison is possible and not a relative one. This is valid also for scales along the alphabet, i.e. A-E. Due to calculation reasons, we will use the quantitative scale function from 100% down to 0%, whereby ordinal orders can also be mapped to this scale.

The process of depreciation is according to DIN 31051 (06.03) described as the disposal of available depreciation stock. This stock is

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[656] i.e. [DIN 03], Ziffer 4.1.3.
[657] [COX 00], p.2; [KLINGENBER 07], p.25

created with the construction of a component and facilitates the fulfilment of the usage under certain conditions, in other words the fulfilment of the component's requirements for a specific use type and intensity. The number for the condition lies within the interval 0 to 1, whereas 1 stays for a newly built respectively a newly renovated urban unit. The higher depreciation with passing time considers state decrease due to emerging damages by different building components.

Here the state lies between 100% and 0% and is divided ordinally into a, b, c and d.[658]
Condition a: Good to very good condition of the urban unit (approximately 85-100% of the depreciation stock)
Condition b: Light material depreciation, the functionality of the urban unit is not restricted at all (approximately 60-85% of the depreciation stock)
Condition c: Heavy material depreciation, the functionality of the urban unit is only possible with restrictions (approximately 20-60% of depreciation stock)
Condition d: The depreciation stock threshold is passed, the urban unit, can, should or must not be used anymore (approximately 0-20% of the depreciation stock). With the excess of the threshold, the technical lifetime of the urban unit is reached. Below 0.2 only some or none of the requirements can be fulfilled.

The reduction of the depreciation stock of a component can be drawn as a curve in dependency on time. The parabolic curve[659] is asymptotic to the x-axis. When the curve reaches a predetermined minimum value, the threshold of the depreciation, the breakdown by definition of the component has occurred. Depending on the use intensity, an interval of the material ageing and the technical lifetime can be made up. [660] Theoretically, the depreciation of a stock can follow several curve types depending on exterior factors (degressive, progressive and others). Mexis distinguishes three kinds of curves.[661]

Type 1: can be described by a little reduction of the depreciation stock at the two third of the life time followed by a faster reduction (4/5) in the last part of the life time (Figure 105, left).
Type 2: can have a low reduction in the beginning and in the end. In the middle of the life time there might be a higher reduction (Figure 105, middle).
Type 3: can be more balanced with a lower reduction until the middle of the life time and increasing reduction speed later on (Figure 105, right).

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[658] [SUIT 03], p.16
[659] See for more detail [MEYER 94]
[660] See ibidem for more detail on the principles of material ageing behaviour of urban units and their components.
[661] [MEXIS 90], cited in [KLINGENBER 07]

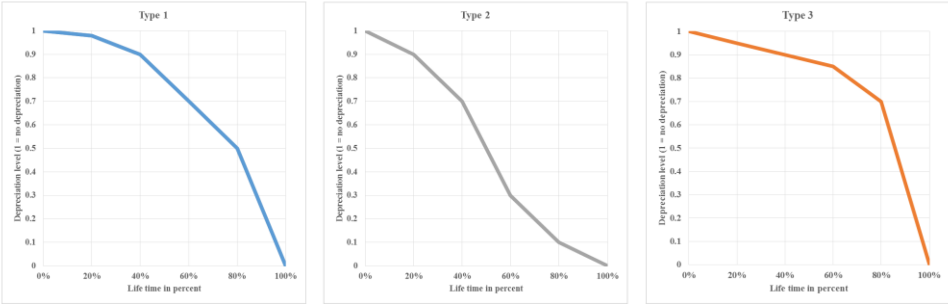

Figure 105 Depreciation development
for building shells, facades, interior work (type 1); for roofs, windows (type 2); for heating, ventilation and air conditioning (type 3)
Source: own illustration of [MEYER 94], p.28

In reality, the two-sided delimitation of each depreciation condition should be carefully checked depending on the ageing principle. In the case of type 3 the condition "a" can last for a longer period, whereby the conditions b, c and d can be reached very quickly. Therefore, an early renovation already in condition b can make sense (Figure 105, right).

The ageing of urban units has not been sufficiently analysed up to now. The concept of the reduction of the depreciation stock for urban units can be derived from components ageing behaviour. Due to renovation activities on individual construction components and the emerging urban unit attributes, usually urban units do not have such simple functions (Figure 106). Moreover, the condition of the urban unit requires a calculation in dependency on the life time (internal ageing) and the time (external impacts).

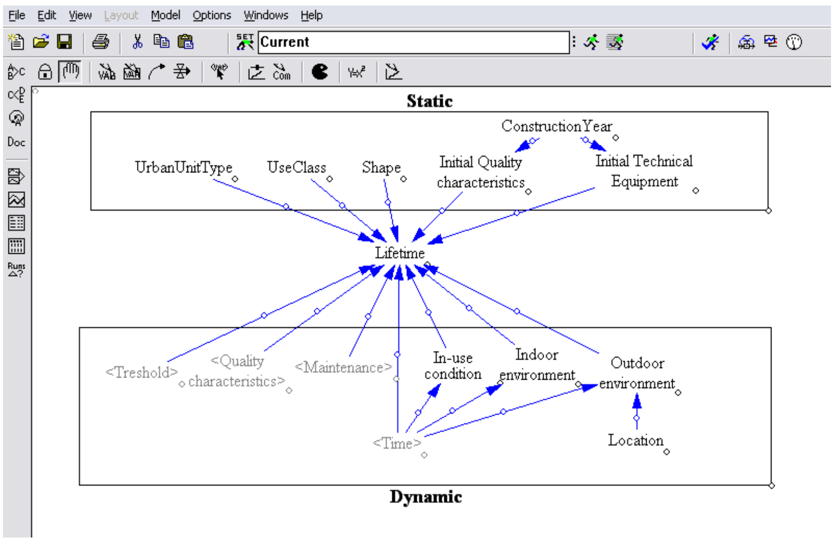

Figure 106 Static (based on the construction characteristics) and dynamic (based on the maintenance strategies) variables to calculate the theoretical lifetime of an urban unit
Source: own illustration

In this work, an ageing function is defined with a linear ageing part until 90% followed by a parabolic curve (Figure 107). This ageing curve has been tested in combination with service life time references for urban unit components[662] (Table 68) and with ISO 15686. The ISO scale starts with the average life times for the different types of urban unit components. Further refinement is done with the use, location and the quality of the equipment (0.8 – 1.2). Depending on this additional information the lifetime can increase or decrease, i.e. good (1.2) quality of equipment can prolong the lifetime of an urban unit or a bad (0.8) location can require an earlier renovation and so reduce the life time.

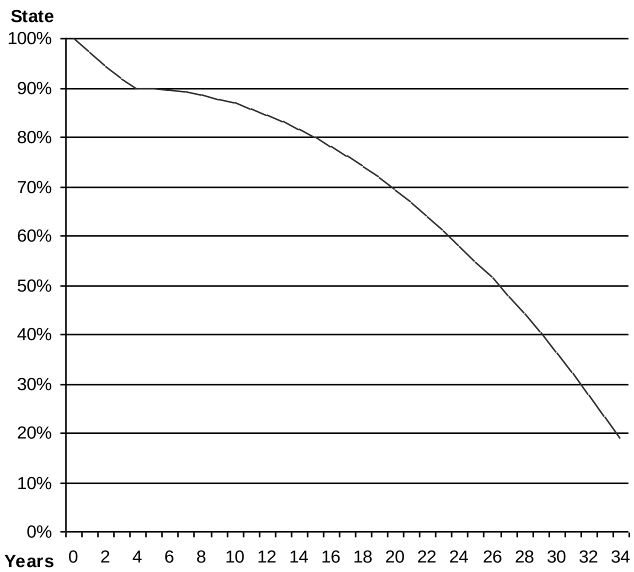

Figure 107 State development
Source: own illustration

	Bauteil/Bauteilschicht	Lebenserwartung von - bis [Jahre]	mittlere Lebenserwartung [Jahre]
Tragkonstruktion	Fundament Beton	80 - 150	100
	Aussenwände/-stützen Beton, bewehrt, bewittert	60 - 80	70
	Naturstein, bewittert	60 - 250	80
	Ziegel, Klinker, bewittert	80 - 150	90
	Beton, Betonstein, Ziegel, Kalksandstein, bekleidet	100 - 150	120
	Leichtbeton, bekleidet	80 - 120	100
	Verfugung, Sichtmauerwerk	30 - 40	35
	Stahl	60 - 100	80
	Weichholz, bewittert	40 - 50	45
	Weichholz, bekleidet Harthol, bewittert	60 - 80	70
	Hartholz, bekleidet	80 - 120	100

Table 68 Service life time references for urban unit components
Source: own illustration of [BBR 01], p.6.11

[662] [BBR 01], p.6.11

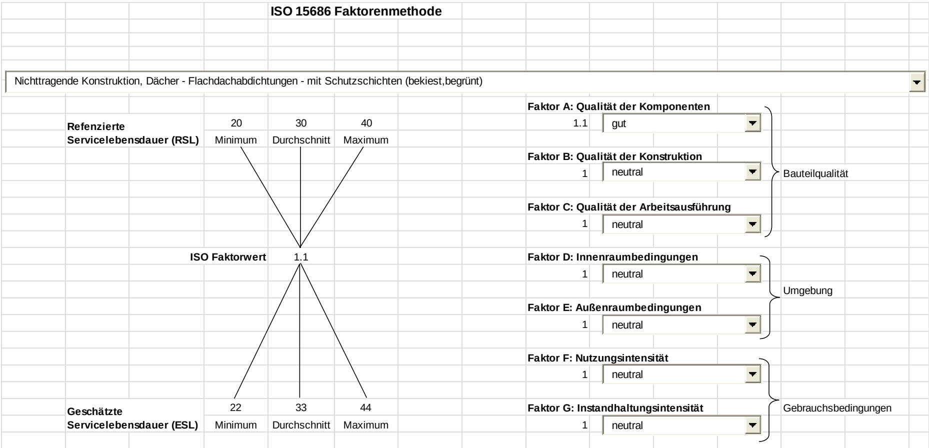

Figure 108 Combinated calculation of estimated life times basing on ISO 15686 and service life time references from [BBR 01]
Source: own illustration

Depending on the choice for use, location and the quality of the equipment of ISO 15686, the values are multiplied with each other, and finally with the referenced average life time and the result is the estimated life time. The estimated life time is the basis for the calculation of the condition of an urban unit (**Figure 108**).
Out of this, it is possible to calculate the development of urban units, here buildings (**Figure 109**) with individual weighting for the construction components (**Table 69**) which make up the development of the whole building (**Figure 110**).
The evaluation is done by associating a value to each component and to add the weighted evaluations to obtain an overall state for the building.[663] The thresholds can be seen as part of the strategy definition for renovations (frequency of maintenance) and can symbolise the nature of the maintenance (replacements requirements)[664]. After a renovation, the new service life is calculated again considering attribute changes, and then the next operation phase starts.

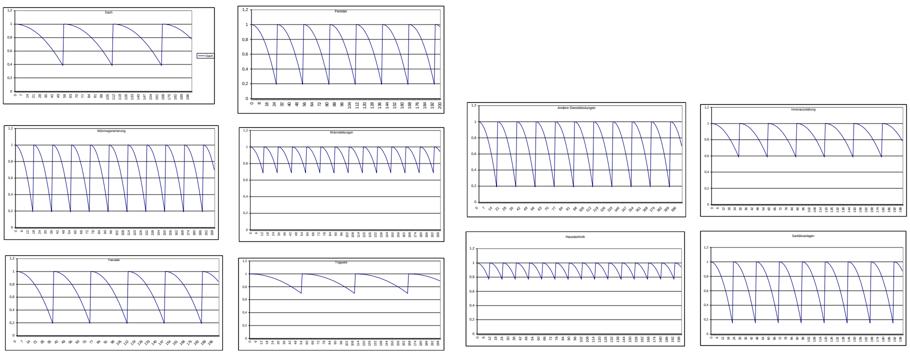

Figure 109 Example for ageing functions of different components of an urban unit with various life times
Source: own illustration

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[663] The depreciation of a building or of a stock can also be expressed through four different states, see for more detail [RUST 95], p.22. Whereas for components state c means restrictive useability, the same state for buildings may mean that the buildings are partly unuseable. There are difficulties and disadvantages, i.e. lower rent level, consecutive damage and others.
[664] See also [KOHLER 07a], p.357.

		Dach	Fenster	Innenausbau	Sanitär	Elektro	übrige Techni	Wärmeverteil	Wärmeerzeug	Fassade	Rohbau
max 0,8	Grenzwert für Ersatz	0,4	0,2	0,6	0,2	0,8	0,2	0,7	0,2	0,2	0,7
0 bis 1	Verbesserungsfaktor	0	0	0	0	0	0	0	0	0	0
	Lebensdauer	70	30	45	25	25	20	25	20	40	100
	Nutzwertgewichtung	4	8	27	6	4	3	3	4	6	35
	Kostengewichtung	11	5	4	4	4	1	1	1	10	8
	KEA Gewichtung	9	8	20	5	4	2	1	1	20	30

Table 69 Setting of the weighting of components considering user interest, costs and environmental impact
Source: own illustration

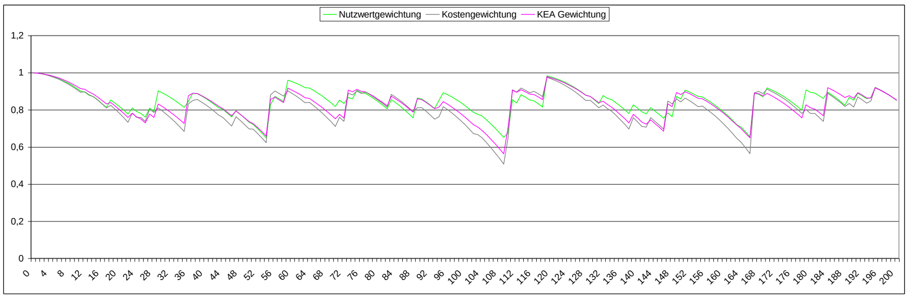

Figure 110 Sum of the weighted ageing functions of different components of an urban unit
Source: own illustration

For infrastructure, there is a similar approach with time-variant measures of structural quality. The deterioration of the material properties clearly affects the performance of the structural system and, consequently, the quality is time-dependent[665]. According to Berger[666], there exist five state classes: immediate need for action, short-term need for action, mid-term need for action, long-term need for action, no need for action.

The difficulty of the approach was to find a common method and data form for all kinds of urban units. On the mathematical level, ageing curves are useable for urban units.

A.5 Strategies for Urban Units

For each scenario the urban units get their strategies leading to the construction processes as there are construction, operation, maintenance/refurbishment and demolition followed by a new construction and reason the flows between buildings and nature.

Technical and Qualitative Improvement

This strategy comprises several possibilities for the improvement of the original equipment by improving the technical and/or qualitative attributes by i.e. renewal of installations to improve the energetic balance (resources-saving techniques) or through aesthetic improvements (increase of the quality of life). Renovations take place at the earliest stage, so that a good to very good state value is maintained. Within this strategy the improvement increases the use and economical value of a building. The ecological value is only increased if the improvements comprise resource saving aspects. Qualitative and technical changes as well as use alterations are possible.

665 [BIONDINI 07], p.9, see also [SANTANDER 06]
666 [BERGER 01], p.6

Maintenance
The strategy maintenance is defined as a combination of technical and administrative measures during the life cycle of an urban unit of interest. Maintenance[667] guarantees the functioning or the repair of the urban unit. For this strategy, the building is between a medium to good condition. At the threshold below a medium condition a refurbishment with the objective to re-establish the original state is accomplished, which is usually 20-25 years after the new construction. The result is a condition that fulfils the contemporary demands and usually allows to keep or increase the rent.

Waiting
The use value of an individual building (building-complex) is not only defined by the building, it depends also on the environment (neighbourhood, city fragment). Renovation and/or depreciation decisions have a direct and indirect influence on the value of the neighbouring buildings and they influence the urban activity pattern. The waiting strategy is generally chosen when the situation is uncertain and a fair to medium condition is acceptable. This is often the case, if the demand is high enough to maintain stabile rents with low costs.

Dereliction
The dereliction of a building becomes a target, if in the medium term the aim is to demolish. During this strategy, the building condition gets worse or is only preserved at a minimal fair condition (20-30% of the original use value) by necessary repairs. Within this strategy, the following renovation events go never beyond the value of the previous total renovation.
The final demolition comprises the destruction of the physical fabric of the building with the loss of its economical and ecological value. A new construction comprises a new composition of material giving it a economical and ecological value and starting a possibility for the participation in the cultural development.

Newer studies try to incorporate ecological, social and cultural values by hedonistic price models.[668] Yet, this approach shows a high time dependent variance of the monetary valuation of each sustainability dimension. It is also an illustration of the valuation of the demand of financial stakeholders. The ecological, social and cultural interests of other stakeholders are not part of the valuation.
In the introduced form, strategies deal with economical and ecological aspects, less with the qualitative cultural and social ones. Nevertheless, the development has continuously an influence on all sustainability dimensions (Figure 111 and Figure 112).

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[667] See for more definitions and details [KLINGENBER 07], p.19, [DIN 01], [DIN 03]
[668] See for example [LORENZ 07]

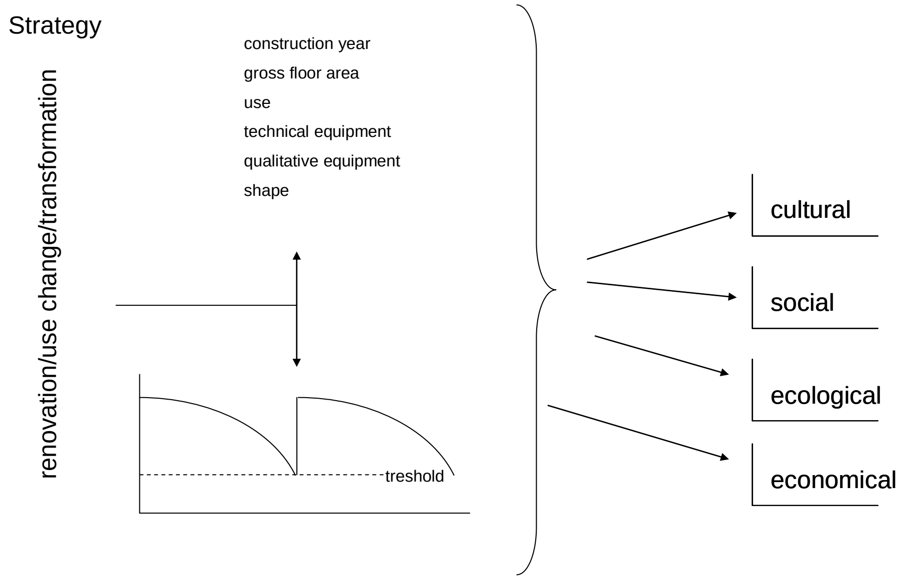

Figure 111 Strategies and their influence on building's attributes and cultural, social, ecological and economical values (ordinate) over time (abscissa)
Source: own illustration

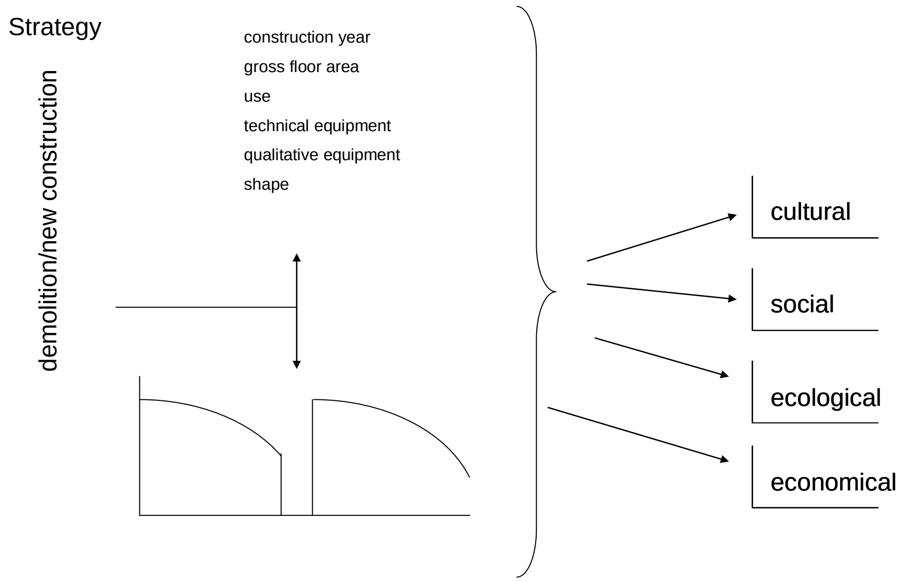

Figure 112 Influence of demolition on building's attributes and cultural, social, ecological and economical values (ordinate) over time (abscissa)
Source: own illustration

A.6 Tool

The first form helps to get an overview on the urban fragment one is interested in. On the upper left part one can define a new project and on the left part one can enter shapefiles (if available) of the urban fragment. It is possible to use simple GIS functions on the upper right part (identify and zoom) and to overlay several shapes on one another. The middle box informs on the identified building, street name, use, size, owner type and the geographical position and the right box shows its geographical position (Figure 113).

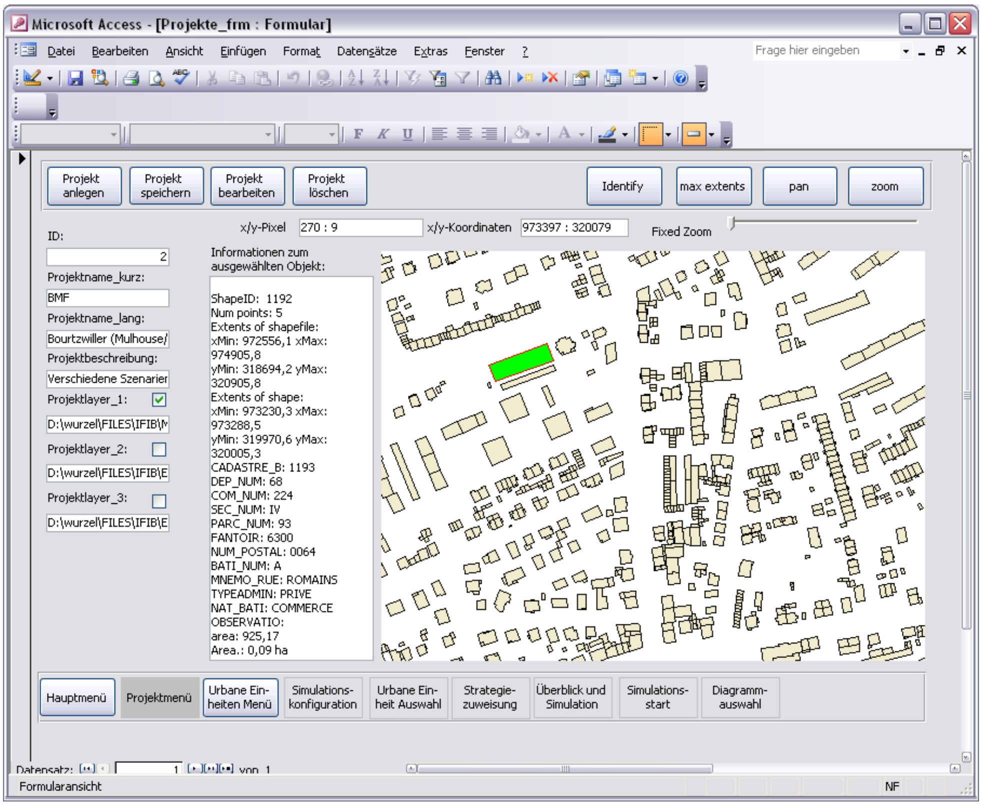

Figure 113 Project definition
Source: own illustration

In the form 'Urbane Einheiten Menü' one can type in the data of the urban units (type of urban unit, construction year, use, initial state, address) and relate maintenance strategy and project to it (Figure 114).
In the form 'Simulationskonfiguration' one defines a simulation for the chosen project by giving a name and by adding the time interval for the simulation (Figure 115).
In the form 'Urbane Einheit Auswahl' one chooses the urban units of interest for the simulation. This can be done in different ways. One can choose them by type of the urban units (left upper part), by their construction year (left lower part) or by addresses (lower middle part). For detailed simulation it is also possible to choose individual urban units (three right boxes). The decision is finalized by the button on the left upper part (Figure 116).

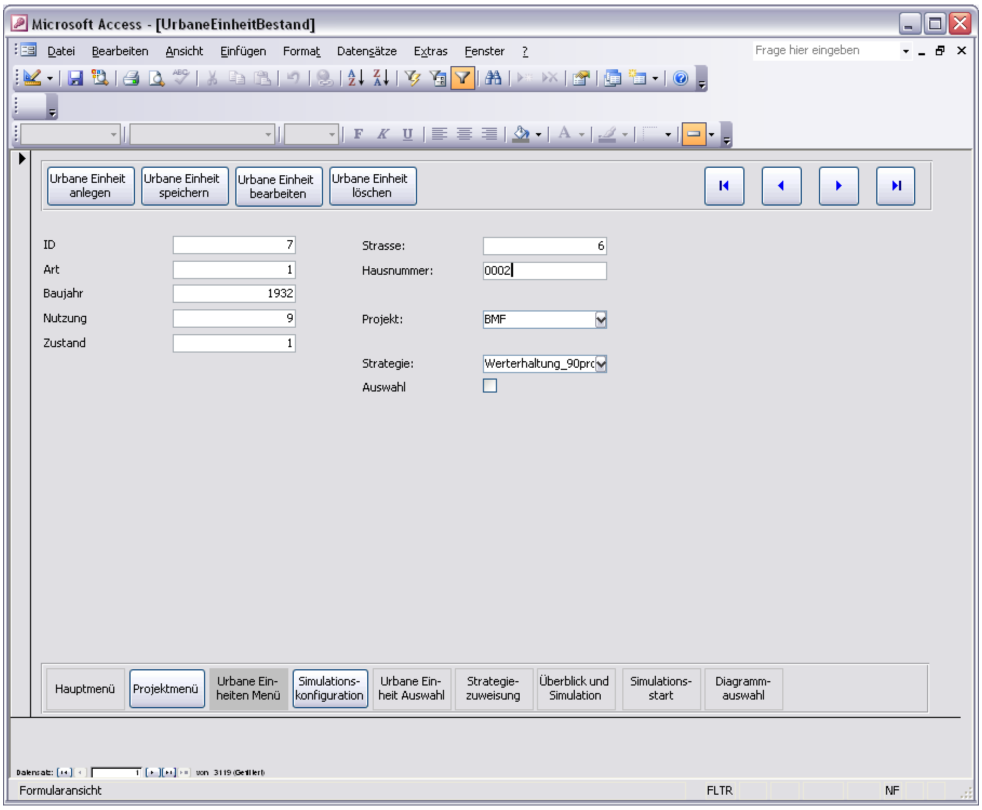

Figure 114 Urban unit input
Source: own illustration

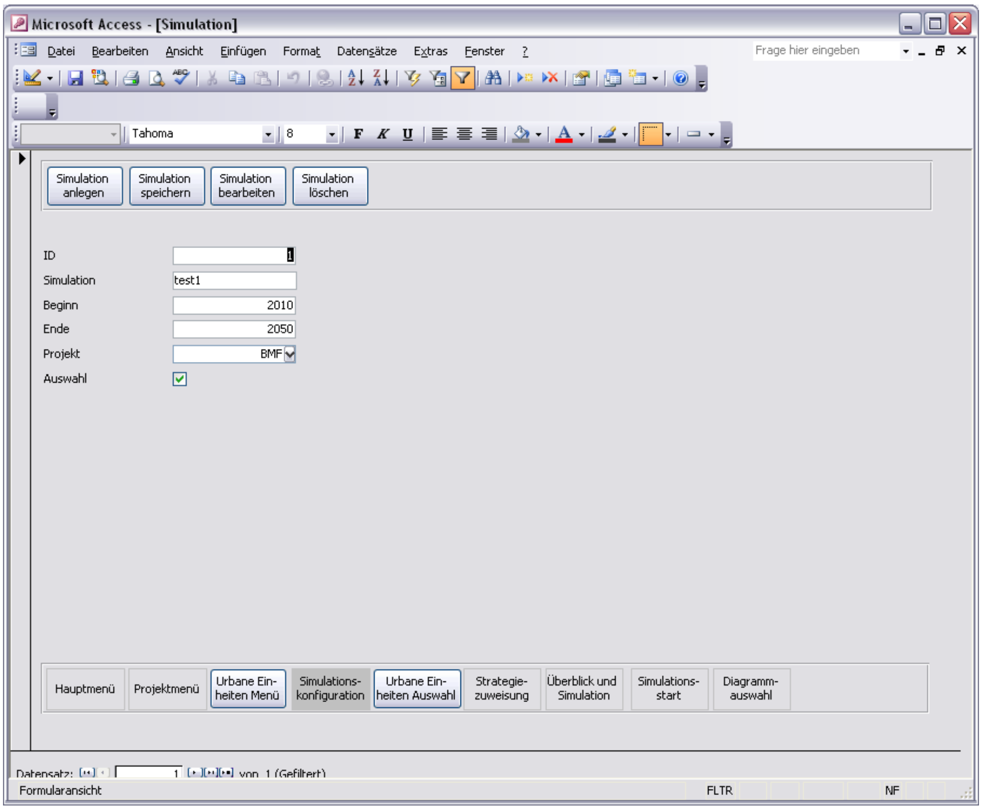

Figure 115 Simulation definition
Source: own illustration

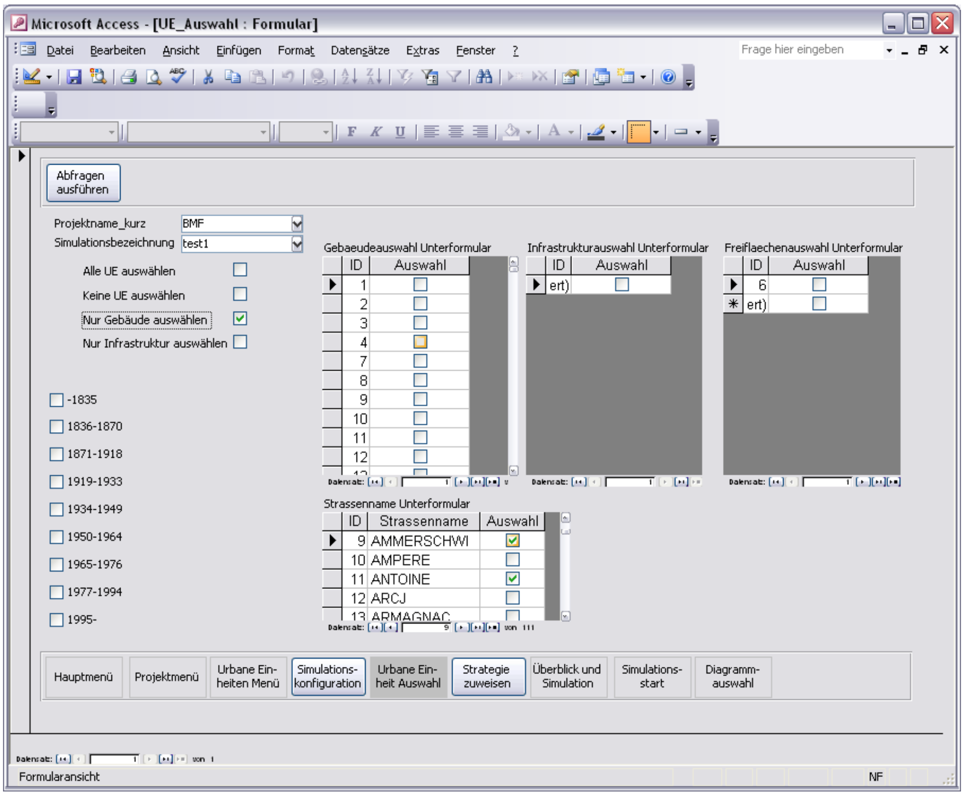

Figure 116 Urban unit choice
Source: own illustration

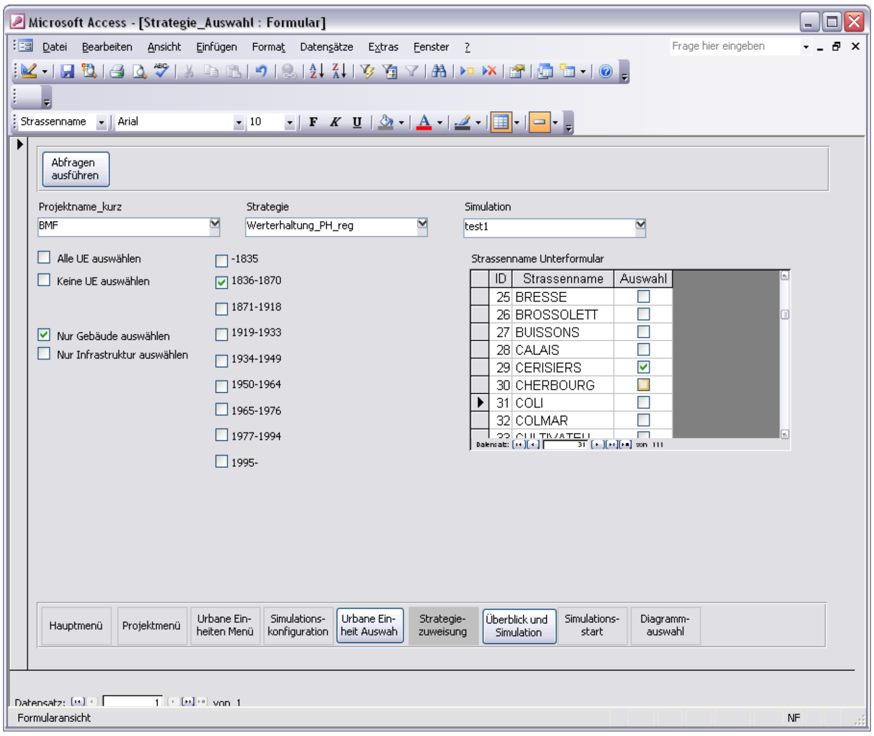

Figure 117 Strategy assignment
Source: own illustration

In the form 'Strategiezuweisung' the urban units are linked with strategies (middle upper part) if this has not been done before individually (Figure 117) by their type (left), their construction year (middle part) or by their address (right part). Each urban unit can get one strategy for each simulation configuration. The decision is finalized by the button on the left upper part (Figure 117).

In the form ‘Überblick und Simulation’ one gets an overview on the urban units and the related strategies. The lowest number shows the amount of urban units chosen for the simulation. With button on the right lower part, one starts the simulation (‘Simulationsstart’ in Figure 118).

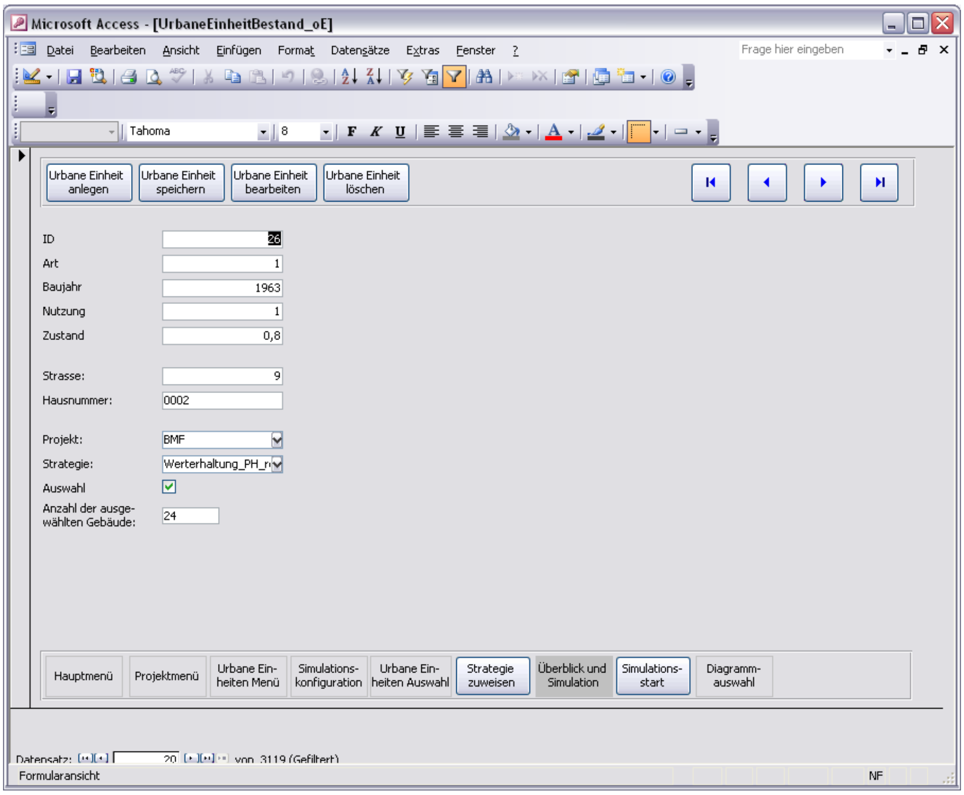

Figure 118 Simulation overview
Source: own illustration

After the input of attribute combination (urban unit type, age class, use class, technical equipment, size and state)[669], it is mapped to the basic ageing function, the economical costs and the environmental impact from the data out of LEGEP. The focus of the strategies allows adjusting the values considering economic and environmental aspects (output data).

A particular problem which had to be solved is on how to maintain the history of objects in the database and how to visualize the data.

Relational databases are based on the relational model, which organises the data into relations or tables. A relational scheme is a set of attribute names and mappings from each attribute name to a domain. The relational scheme contains the structure of the relation but does not include the data. A relation is a finite set of tuples associated with a relational scheme according to the number of attribute names in the schema.[670]

[669] In this version the technical development is only considered in form of environmental protection measures but not from a general quality point of view. The influence of shape and location is not incorporated.
[670] See for more detail [HEUER 00], besides many other literature one data bases.

Entities in the spatio-temporal database are represented as objects with attributes, relationships and behaviour. To understand and model the environment, large volumes of different data are required that vary in both space and time. These data must be efficiently stored and managed so that relationships between datasets can be explored. Building stocks as time dependant and data intensive objects can be described with their properties and development within a spatio-temporal database. Figure 119 shows the ER (Entity Relationship) model of a few compo-nents of the spatial-temporal database for the site of the building stock.

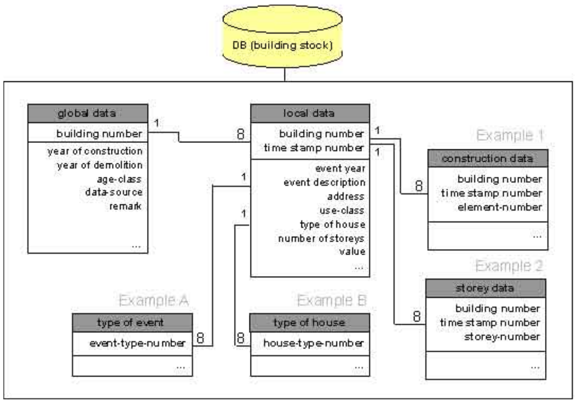

Figure 119: ER-model of spatial-temporal database of different building stocks
Source: own illustration as in [AKSOEZEN 06] and [WITTMANN 06]

The concept for this ER scheme bases on the already mentioned temporal-spatial considerations of ESTDM (Section II.6 and Figure 37) which seems basically useful in the design and implementation of a spatial-temporal data model for buildings. The ESTDM represents events without duration and there are gaps between the events. Regarding building stocks however, events have a start and an end time therefore the expression “phase” is preferred to “event”. Moreover, buildings have a dependency between the phases and there are no gaps in between. There are attempts to adapt ESTDM for other contexts, i.e. historic sites[671], but they do not cover all mentioned requirements.
This scheme is a modification of the current ESTDM model (Figure 120). Each affected urban unit attribute (element) of a phase is realised as spatiotemporal data and has its own description (state of elements) to indicate which changes occur in the phase. Therefore, when a phase starts, each element is represented in its individual mode so that changes and their type can clearly be represented. The modified ESTDM is realized with an MS-Access data base which is divided into a global and a local table.[672] The global table contains the standard information that is not changing but important for the description. The local table is developed for all changing data. A primary key that allows describing one building during its lifecycle links both tables. In this case a new

[671] [CHIU 05]
[672] The data base is an enhancement of the data base used in [BRADLEY 03] and bases on the experience in that project.

timestamp will be defined when something is changing and the data will be stored for every new situation and timestamps can only be allocated to one existing building-number. A set of entries is needed to describe a building and to avoid inconsistencies of the database by using classified entries which are stored in special tables. These tables with classified information are linked to the local table by a primary key.

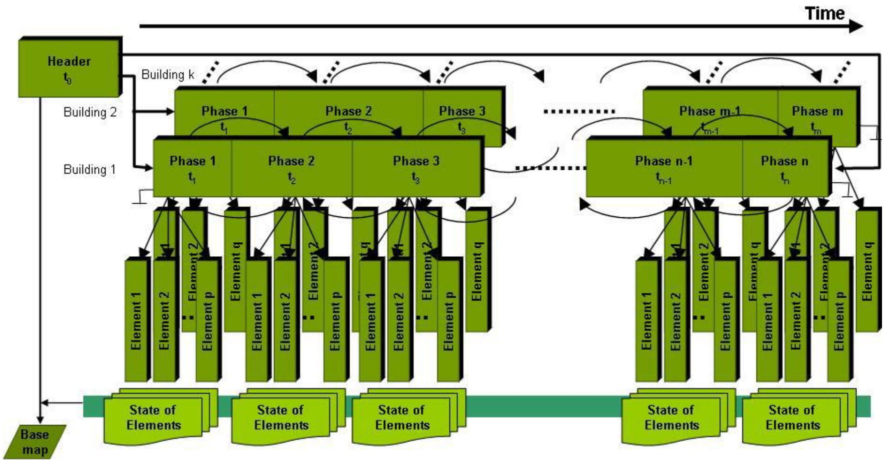

Figure 120: Modified ESTDM
Source: [AKSOEZEN 06] and [WITTMANN 06]

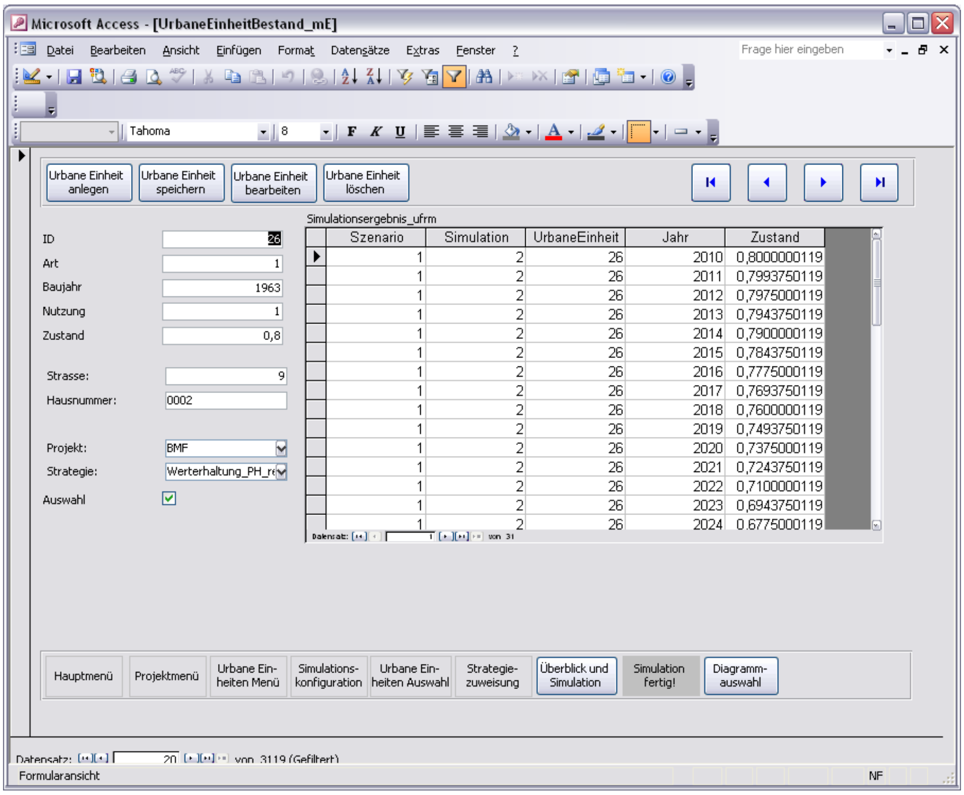

Figure 121 Simulation results – individual urban unit
Source: own illustration

When the simulation is finished the button is named 'Simulation fertig' and the form shows the results (the development of the state for each year) for each urban unit (Figure 121).

The form 'Diagrammauswahl' shows the summed up condition development of the urban units of the project, if the button 'Nutzwertdiagramme'(Figure 122) is pressed, whereby individual use types can be chosen individually or together. By clicking on 'Wirkungsdiagramme' summed up yearly flows of a chosen environment related impact for the urban units are shown (Figure 123).

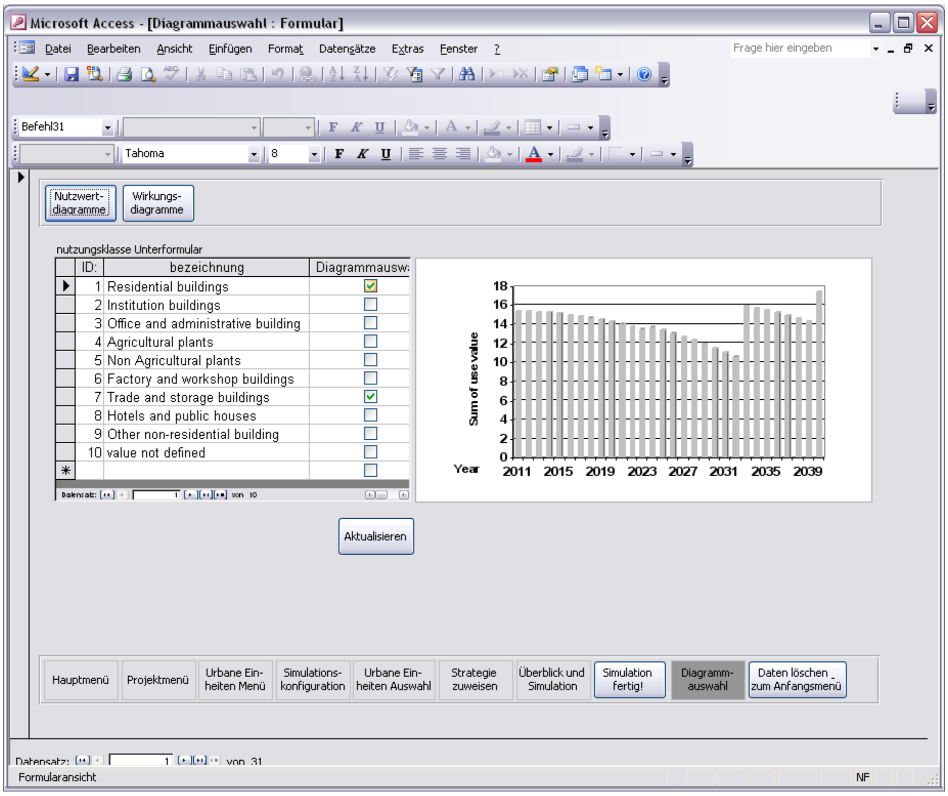

Figure 122 Simulation results – sum of the state development of the urban units
Source: own illustration

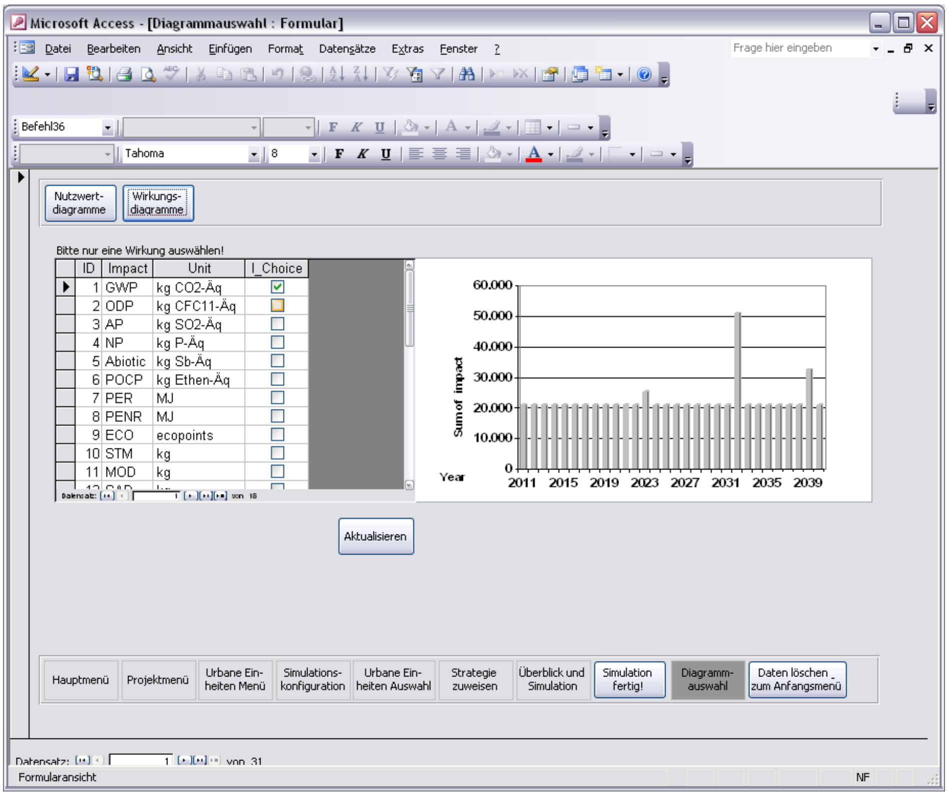

Figure 123 Simulation results – sum of the environmental flows of the urban units
Source: own illustration