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Long-term management of building stocks

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Abstract

The built environment is composed of buildings, infrastructures and cultural landscapes (stocks). These man-made artefacts constitute a complex capital (natural, man-made, human, social and cultural) and its evolution is a crucial parameter in sustainable development. Their composition and dynamics can be modelled as flows or as capitals or combinations of the two. Examples of the modelling of the long-term behaviour of different types of stock are given and their behaviour is analysed and discussed. A resource economic framework is presented and strategies for two different types of stocks, old/stationary and new/expanding, are compared. The importance of institutional regimes for the long-term management of stocks and the relation to demographic and retirement finance are discussed. The long-term institutional aspects have to be taken into account to avoid dramatic losses of economic, social and cultural capitals in the coming decades.

L'environnement construit est composé de bâtiments, d'infrastructures et de paysages aménagés (parcs et jardins). Ces artéfacts fabriqués par l'homme constituent un capital est un paramètre crucial du développement durable. Leur composition et leur dynamique peuvent être modélisées sous la forme de flux ou de capitaux ou d'une combinaison des deux. L'article donne des exemples de la modélisation du comportement à long terme de différents types de stocks de bâtiments puis analyse et examine leur comportement. Il présente un cadre d'analyse d'économie de ressource et compare des stratégies pour de deux types différents de stocks de bâtiments, à savoir un stock ancien/statique et un stock nouveau/en extension. L'article examine ensuite l'importance des régimes institutionnels pour la gestion à long terme de stocks de bâtiments ainsi que leurs rapports avec l'évolution démographique et les plans de financement de la retraite. Les aspects institutionnels dans le long terme doivent être pris en compte pour éviter les pertes dramatiques de capitaux économiques, sociaux et culturels dans les décennies à venir.

Mots clés: gestion des actifs, stocks de bâtiments, remise en état, rénovation, économie de ressources, développement durable

Keywords:

asset management | building stock | refurbishment | renovation | resource economy | sustainable development

Importance of the building and infrastructure stocks for sustainable development

The built environment, i.e. the production, operation, maintenance and disposal of buildings, infrastructures and, to a certain degree, cultural landscapes, is the largest part of the physical and economic, man-made capital. It is, however, also an important part of the social and cultural capital of a society. This gives it, by definition, a central position in all attempts to achieve sustainable development, both in industrialized and emerging countries. The complex composition, the multiple interactions above all with natural capital, and the relative inertia due to high time constants, make that individual efforts have little effect (good or bad), but that systemic errors can practically not be corrected in the long-term and can severely restrict the development of a society. The during time. Significant work has been done related to the energy and morphological aspects (Steadman et al., 1991) and mortality functions which were introduced by Johnstone (1994). A more recent interest in building stock (Kohler and Hassler, 2002) has been closely linked to the sustainable development debate in the last few years. Following the Brundtland definition and consecutive operation-oriented frameworks like Agenda 21, a whole series of assessment methods and tools have been developed and are used today by local authorities, planners, contractors and manufacturers. These methods and tools lead in general to more appropriate environmental solutions than the business-as-usual approach, they relate, however, mainly to individual buildings or sectoral problem fields (e.g. transport, green spaces). Their basic shortcoming is the lack of a clear conceptual framework and common physical basis.

The relation of the built environment as man-made capital to natural capital has two aspects: extracting resources from nature and reintroducing emissions into nature. All enlargement of the built environment is by definition a reduction of nature within common planetary system limits. All building activity is reducing natural capital in one way or another. This flow-based approach is therefore generally related to 'strong' definitions of sustainability, tending to postulate priority of constant natural capital (Daly, 1992). Theoretically, no substitution of natural capital through other forms of capital is admitted in this definition. Extending the definition of sustainability to other aspects, i.e. to other forms of capital (economic, social, human, cultural), has lead to the formulation of a 'general constant capital rule': a sustainable society would improve its global wealth (available for the future generations) and in this process substitutions of different forms of capital are necessary and possible. (Pearce and Warford, 1993). For example, there is no principal objection to the substitution of economic capital through human capital (investment in education and research). The main discussion is in how far natural capital can be substituted by other forms of capital, and whether at the limit, a society without nature is possible. This 'weak' definition of sustainability, which is very probably not acceptable in the unlimited extent of substitution of natural capital, has however a considerable conceptual interest when dealing with the conservation of the built environment as a complex capital. The objective of this paper is to show how both approaches (flow- and capital-based) can be applied to the evolution of the built environment and give complementary insights for a sustainable development in general.

Flow-based approaches

Environmental impact of buildings and infrastructures

The impact of the man-made environment on nature has been considered in the studies made after the first energy crisis of 1973 as nearly exclusively energy related (both as non-renewable resource consumptions and as emissions into nature). The material aspect in the form of embodied energy and waste came up next, through complete mass flow analysis (MFA) (Bartelmus et al., 2001) and life cycle analysis (LCA) (ISO, 1997), related to macroeconomic data (Input–Output Analysis) (Kohler et al., 1999). Even at present the dominant view of politics, administration and practice is that the environmental problem can be solved through standards and new ('innovative') technologies developed for new construction. In the industrialized European countries with large and old building and infrastructure stocks, the research interest shifted already ten years ago to the understanding of the composition and the dynamic behaviour of the stocks, i.e. to operation, maintenance, refurbishment and disposal problems. The flow-oriented approaches, based on system-ecological and thermodynamic models proved to be very efficient, above all through the superposition of mass flows, energy flows, financial flows and information flows in integrated Life Cycle Analysis (Kohler and Lützkendorf, 2002). Using life cycle product modelling techniques, it was possible to make these approaches scaleable from particular objects to urban fragments and national stocks and link them to Life Cycle inventory data.

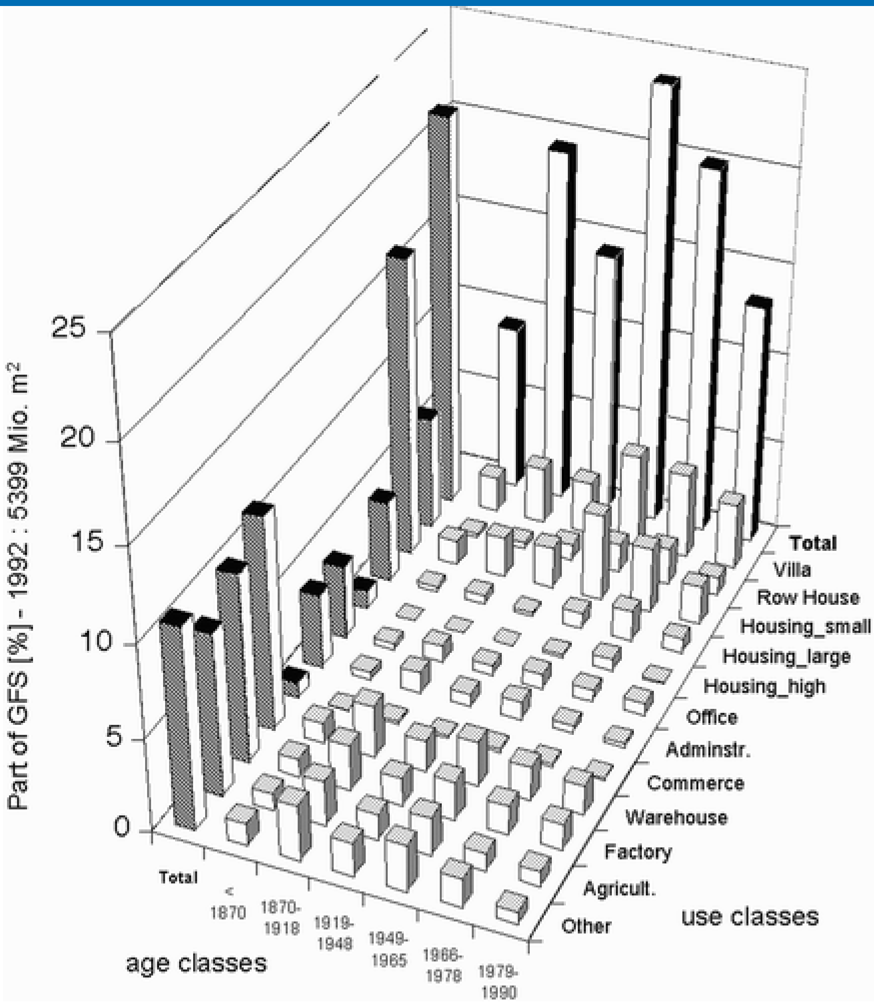
Integrated modelling (mass, energy, costs) of the German building stock

The evolution of the building demand in Germany has generally been estimated on the narrow basis of trend analysis of construction activity (building permits for new construction and for refurbishment). Only in specific situations like the description of the buildings in the eastern part of Germany after reunification has the state of physical degradation been used to estimate the refurbishment needs. Research on sustainable development has considerably enlarged system limits by including the complete energy and mass flows (up- and downstream) and taking into account the lifetime behaviour of constructions. For the first time the perspective of the national built stocks was taken into consideration for a period of 40 years. The Committee for the Protection of Man and Environment of the German Parliament commissioned a combined study about the mass, energy and monetary flows in the building sector in 1996. The objective was to changes up to 2030 and identify areas for more detailed research. The study (Kohler et al., 1999) employed a three-pronged approach:

- Estimation of the present flows (inventory) through a top-down and a bottom-up approach. The top-down approach uses general macro economic data (input–output tables) and sometimes more detailed industry production data. The bottom-up approach is based on the division of the building stock into buildings, elements, materials, etc. that are linked to detailed (up- and downstream) process analysis. An upper limit of the flows is given by the top-down approach, a lower limit by the bottom-up approach which contains indications where and when the flows appeared.
- Estimation of the future development of these flows that is based on a dynamic model of the ageing and the management of the building stock. This task is complicated due to the longevity of buildings and parts of buildings. Estimates of current input and output cannot be used to predict the future inputs and outputs.
- Systematic mapping of raw materials (process chains), building elements and auxiliary materials, enables the tracking of materials and the understanding of detailed (end-point) environmental impacts. The toxicological effect of particular emissions and the dissipation of problematic materials through deposit, recycling and reuse can be analysed.

This study encompassed all buildings (housing and non-housing) existing in Germany, which proved to be very difficult to establish. Before the study there were no estimations on how many buildings existed in Germany and how large the total gross surface of the stock was (Figure 1). This was particularly problematic for the non-housing stock where better data have been established only recently (Hassler and Kohler, 2004).

Figure 1 Model of the German building stock (Kohler et al., 1999). Half of the stock existed prior to 1949. Housing occupies approximately 50% of the gross floor surface



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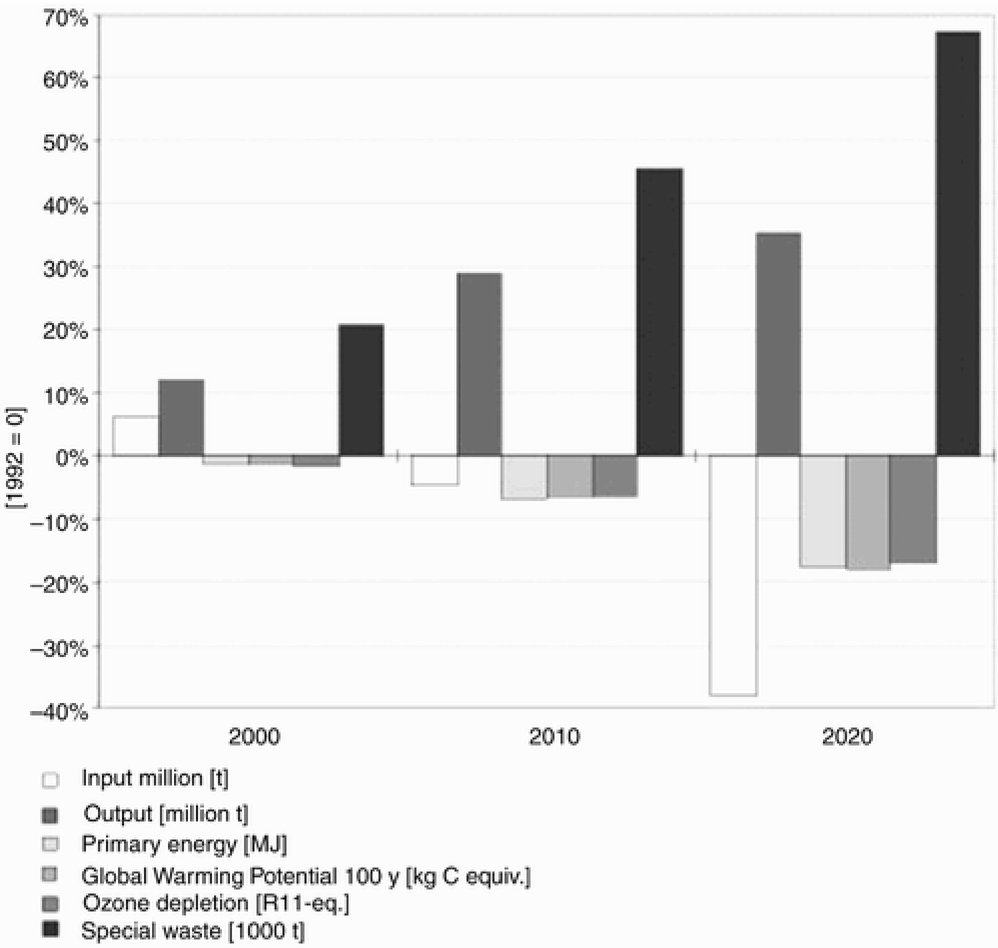
To establish mass flows buildings are divided along a cost breakdown structure into six element groups and about 50 elements. For each element there are new construction, operation, maintenance, refurbishment and disposal elements with their specifications. All material and process specifications are mapped to approximately 300 Life Cycle Inventories. For each age-use class the interval between refurbishments (average value) and the standard deviation has been estimated. The model assumed that if a building was not refurbished after a certain time, it becomes vacant (vacancy distribution) and if it stayed vacant a certain time, it was demolished (demolition distribution). This detailed calculation was done in order to be able to simulate the probable flows (input/output) for each material at a given future moment, which allows simulating different recycling strategies. The geometric and material related information of the cost elements is sufficient for a heating energy need calculation along the CEN standards. Electrical energy demands were estimated on a building level.

The trend scenario until 2020 reflects the reduction of new construction, the continuous improved standards. Most impacts and flows in 2020 are below the level of 1992; only waste, and in particular special waste, increases (Figure 2). The study of the mass flows of auxiliary materials shows a tendency of spreading problematic materials throughout the stock; if no measures are taken, this undesired effect could be amplified through recycling.

Figure 2 Evolution of the mass flows and impacts of the German building stock – the trend scenario. Change with respect to the level of 1992 (Kohler et al., 1999)



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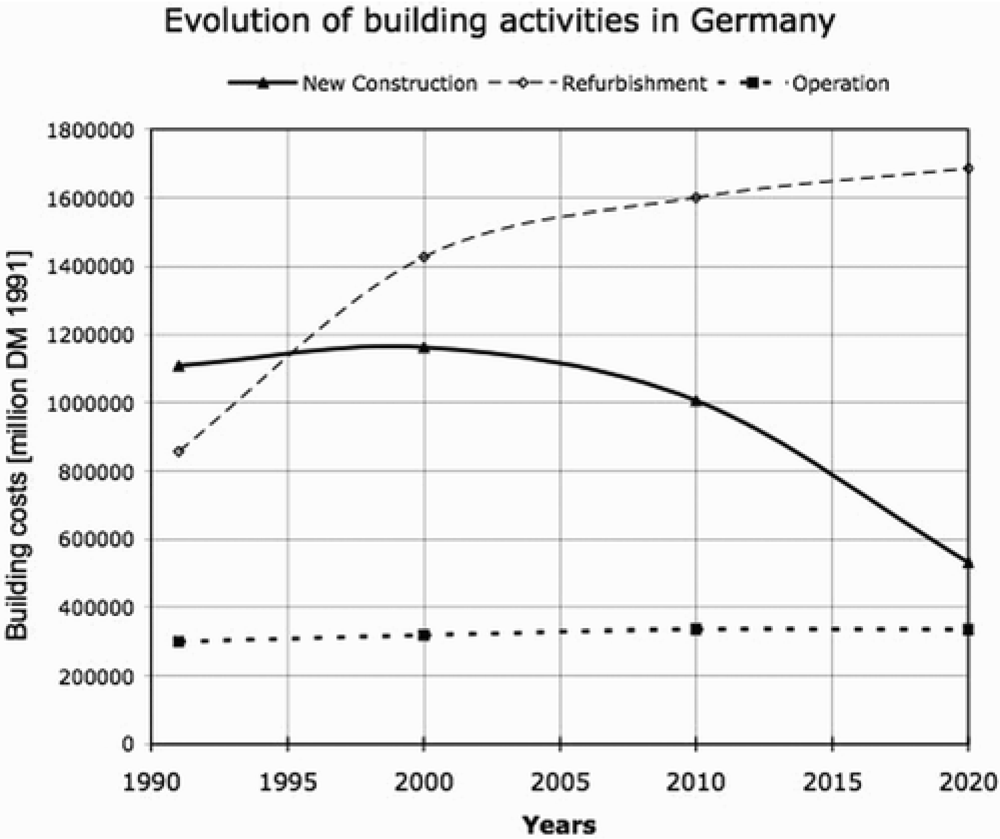
The trend scenario showed the growing importance of refurbishment (Figure 3) and the change in material input and output (Figure 2). The study in itself attracted the interest of politicians and professionals to the importance of the evolution of the stock. The scenarios established in 1995 have been confirmed by the domination of the refurbishment fraction over new construction. Even if the results are not new and have not been criticized in Germany, there have been (as far as the authors know) no similar studies in other European countries. This is problematic because there is an urgent

Figure 3 Simulation of the evolution of building activities in Germany from 1990 to 2020 (Kohler et al., 1999). The refurbishment activities gradually dominate new construction



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Capital-based approaches

Resource economic approaches

Industrial sectors are generally described in flow-type approaches comparing output and capital and labour input, capital and labour productivity and the probable evolution of the demand. Environmental economists (Bromley, 1991; Pearce and Warford, 1993; Pearce, 2003, 1993; Pearce, 2006) have developed a capital based approach (also called ‘resource’ or ‘asset’ based), which is based on the long-term evolution of different capitals, their interrelation and the possibility for substitution of one capital by another. As the building and infrastructure stocks constitute the most important part of produced (man made) wealth of industrialized societies, this approach is a priori relevant (Figure 4).

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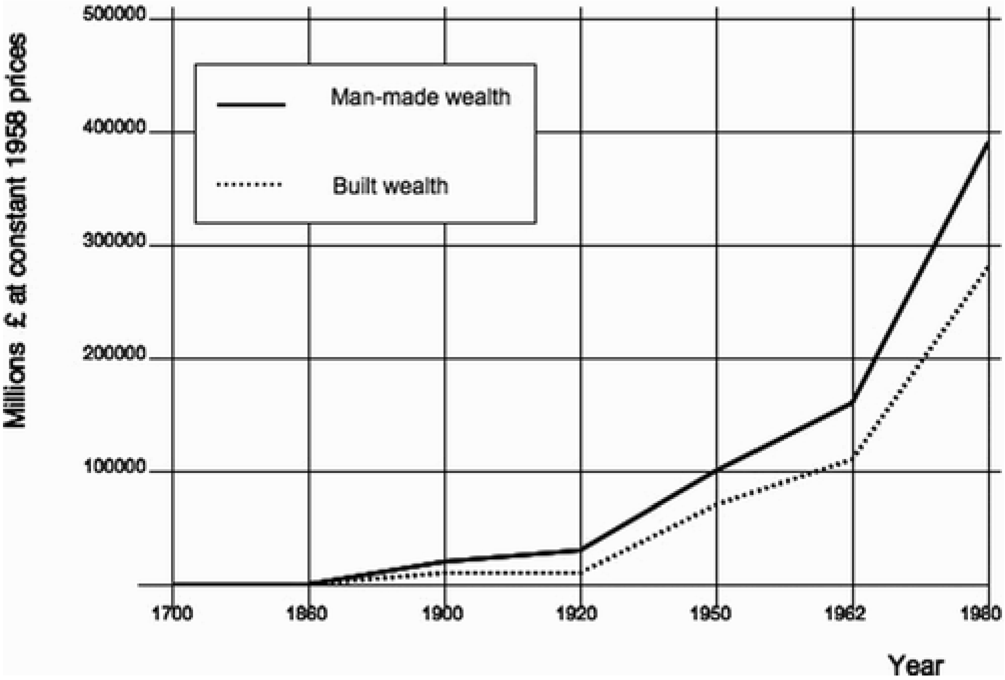
Figure 4 Built environment and man-made wealth (£ millions at constant 1958 prices) (Pearce, 2003). The part of built wealth in produced capital (man-made wealth) is predominant



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An international comparison shows that the intangible capital (i.e. social, human, cultural capital) has the highest share in all countries (Table 1). The proportion of natural capital is higher in low-income countries even if in absolute value it is much lower than in high-income countries.

Table 1 Composition of the wealth of different types of countries in US$ per capita and percentage share. Oil states are excluded

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This approach has considerable advantages compared to the flow oriented approaches where a system is basically described by its inputs and outputs. Of course, the two approaches are complementary, they use the same data, but they do not have the same focus. Different systems (from a local community to an industrial sector or to a national economy) can be considered as capital stocks of different types (natural, man-made, human and social, sometimes also cultural). The same notions are also used in

Constant capital rule

The constant capital rule, which has been formulated for sustainable development in general can be applied in the case of the built environment. The built environment is a dominating part of the man-made, physical capital but it is also part of the social capital in the sense that it constitutes the place for social relations. In this sense, there is a clear relation between the quality of the environment and the quality of social relations. If the physical state of housing estates is decreasing, a number of the tenants leave the place and the social problems in the remaining population increase. In a similar way the built environment through his complex historical composition can only be maintained through well-trained professionals, i.e. through the existence of human capital. Finally, the building and infrastructure stock constitute a cultural capital that allows the society to develop an identity, that in turn is a form of social capital. The same arguments can be developed through the analogy of natural diversity, social diversity and cultural diversity as factors that will contribute to the resilience of systems. A sustainable development would therefore assure the increase (or at least the stability) of the different forms of capital and this can only be realized by substitution process. The amount and speed of transformation / substitution can in itself become criteria for sustainable development (Kohler, 2006a; Gunderson and Holling, 2002).

Institutional regimes

The mentioned capitals can be regarded as resources which produce goods and services which are allocated to different users/actors through so called institutional regimes (Knoepfel and Nahrath, 2005), i.e. combinations of use or property rights (Bromley, 1991) and public policies. These rights can take a multitude of forms. As long as there is no scarcity and no damage, resources can be used freely. This is, of course, time and place dependent. Institutional regimes as such can be considered as part of the social capital. The main advantage of this approach is that relations between different types of capitals and substitutions of capitals (investment of financial capital into education and training will raise human capital, investment in research will raise human and social capital, etc.) can be described and compared. The growing importance of social and cultural capital, their simultaneous existence as economic and normative common goods and the specific new forms of use and property rights, in particular the growing commodification of access to social and cultural goods and

This multifaceted capital approach to sustainable development imposes a permanent obligation on society to consider all forms of capital (and resources) and to avoid developing one capital when it creates a disadvantage for another. It allows Pareto optimum solutions or at least, constraint-satisfaction-type evaluations. An additional interesting property is that under-use as well as over-use of a resource can be a threat to the resource. This is also verified when considering urban fragments (neighbourhoods or smaller urban areas) as resources: high speeds of transformation, which can be associated with an over-use, and too low speeds of transformation, which can lead to dereliction, are both threats to a resource (Kohler, 2006b). The fact that in the construction sector there is less a scarcity of (natural) resources than a scarcity of (natural) sinks is another interesting conclusion from a capital (or resource) based approach.

Long-term dynamic of building and infrastructure stocks

Both in the flow-based approach and in the capital-based approach the consideration of long time periods is crucial. It is not a question of predicting the future (which is impossible) it is important to be able to imagine long-term scenarios that are based on long-term evidence (i.e. evidence from looking back). The assumptions on how long buildings and stocks last and why some have lasted and last longer than others is of course not only a physical question, the answers depend also on the context. However, the longer the period of time taken into consideration, the more the purely physical and statistically describable behaviour of stocks will become dominant.

Lifetime of buildings: service lifetime

The definition of service life according to ISO 15686 is: “Period of time after installation during which a building or its part meet or exceed performance requirements” (ISO, 15686–1, 2000). If the structural framework is solid, buildings can be made last well over hundred years with appropriate maintenance and periodic refurbishment. Therefore, service life can be the end of the physical life of a building, but it can also be just the indication of what a client expects of a building in his time horizon. On the other hand, economic lifetime is an assumed period of time over which costs and benefits of buildings are assessed. The economic life is sometimes established by tax regulations, legal requirements or accounting standards and is not necessarily related

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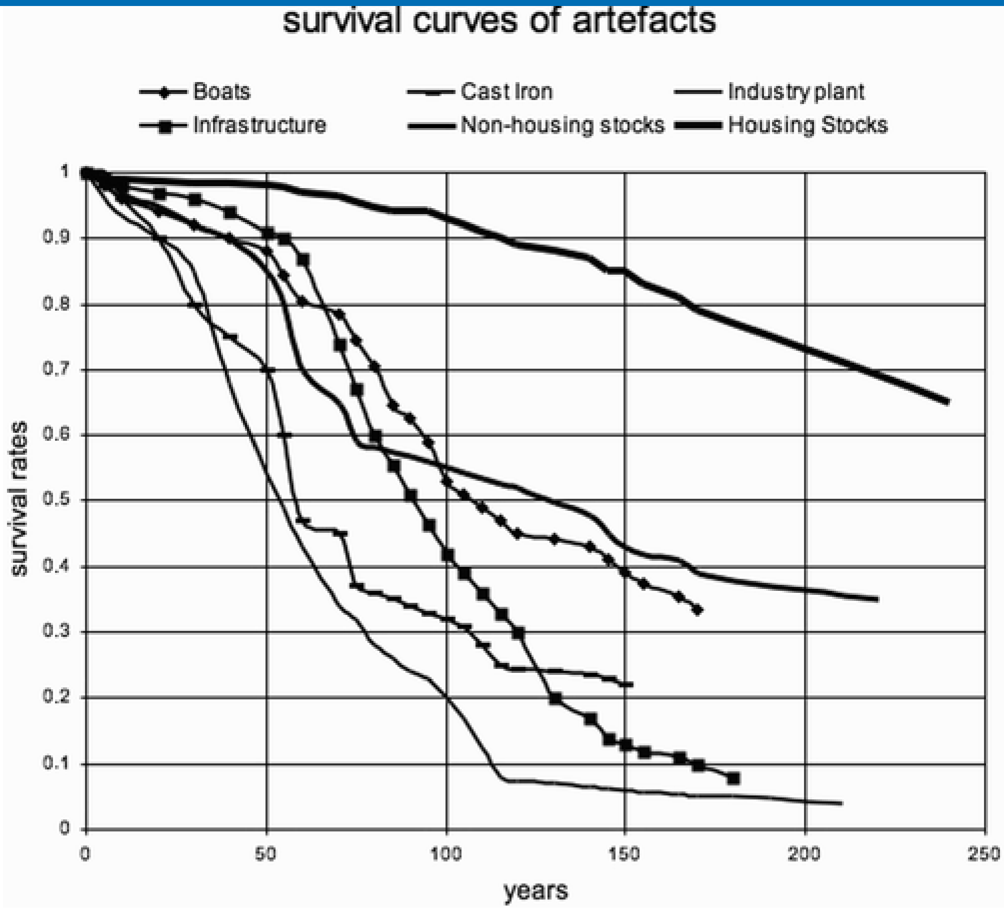
to the likely service lifetime or physical lifetime. These notions generally concern individual buildings. In the case of larger assets, comprising building stocks, perpetual inventory methods (Meinem et al., 1998) allow to construct estimates of capital stock and consumption of fixed capital from time series of gross fixed capital formation. This also concerns service life.

Physical lifetime

In survival analysis of building stocks (Bradley and Kohler, 2007) one looks at building/infrastructure stocks backwards in time in order to find out how many objects have been built and how many have disappeared. These effective, physical, lifetimes seem to be much higher in central Europe than the usual assumptions of service life and economic life – at least for the older parts of the stocks. Similar conclusions can be derived from historical data obtained for residential and non-residential (Hassler and Kohler, 2004) buildings. A central issue is the mortality of buildings. Life tables of classical population dynamics (Klein and Moeschberger, 1999) can be used for estimating the mortality of a sample of building and infrastructure (Herz, 1998; Schiller, 2007) stocks. Special attention has to be paid to methods of data collection that seem to be a crucial point for the analysis building stocks in general. Test of fits of standard survival curves can also be performed for censored data. It is also interesting to compare building and infrastructure survival functions to survival functions of transport and production equipment (Figure 5).

Figure 5 Probability of survival and half-lifetimes for a German housing stock (A), German non-housing stock (B), German sewage infrastructures (C), an industrial sugar plant (D), American cast-iron buildings (F), and ships on Lake Geneva (G) (Kohler, 2004)



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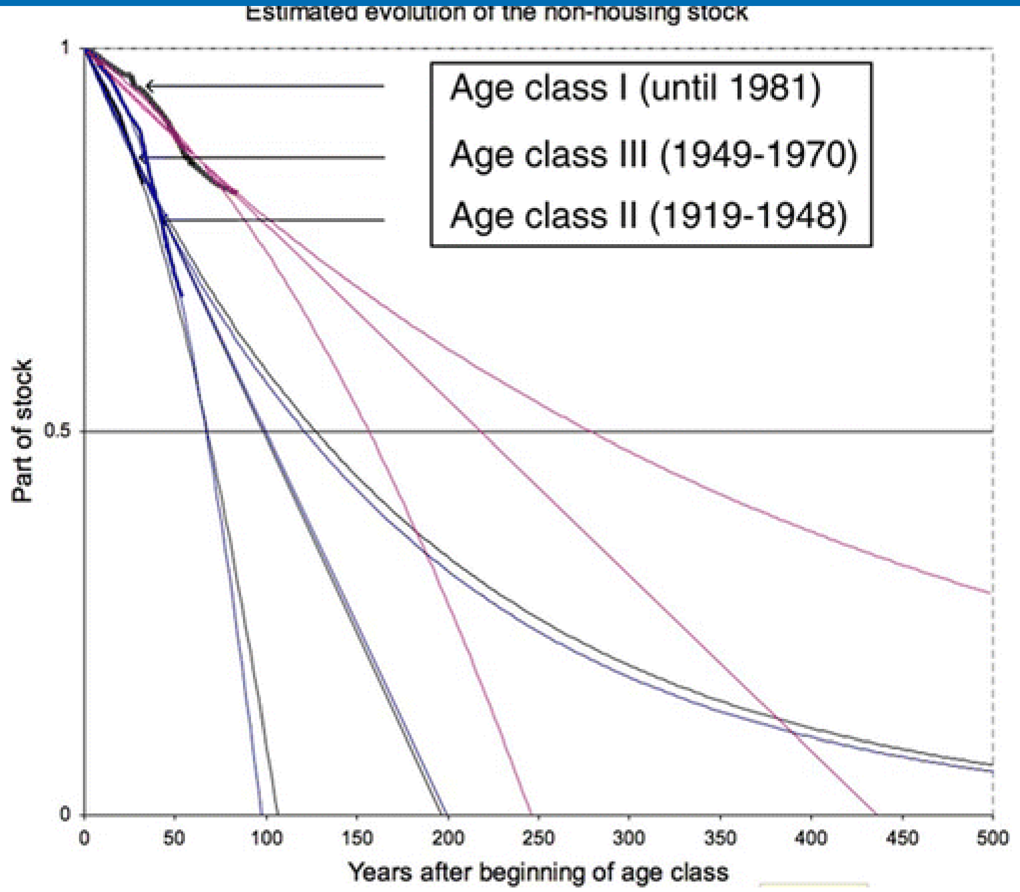
In order to be able to make predictions on the building stock in the future, parametric survival function can be estimated. It appears that a log-log plot of the cumulative hazard function H(t)= − log S(t) could be linear, indicating that it is not unreasonable to assume a Weibull distribution for the survival function S(t). An effected Weibull fit yields that there should not be much change in the existing building stock in the next century (Bradley and Kohler, 2007) (Figure 6).

Figure 6 Survival functions and extrapolation of different ages classes of the German non-housing stock. The younger classes (left) disappear faster than the older classes (Hassler and Kohler, 2004)



The detailed analysis of particular (German) buildings stocks by establishing historical loss functions shows astonishingly high half-lifetimes of stocks (Hassler and Kohler, 2004; Kohler, 2004). Of course, the buildings have been refurbished and transformed many times during this period, but the volume, the bearing structure, the form and basic function remain. From the analysis of the survival functions of other stocks it appears that the older age classes have much higher survival probabilities, and that the newer age classes will disappear before the older ones.

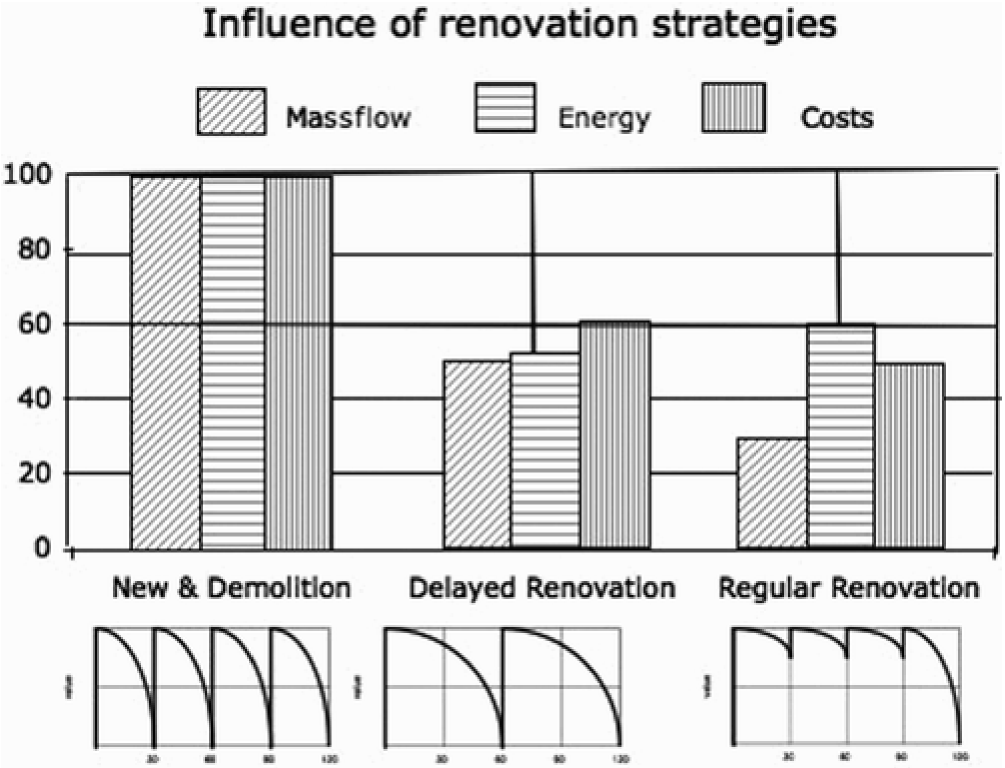
Demolition versus conservation strategies

Why are buildings demolished? The answer seems quite mundane: because they are obsolete or in other terms because they are not considered to have value anymore. The definition of value is, however, not simple. Market value does not take into account externalities, is often based on incomplete information, neglects transaction costs etc. In general, there are several obsolescence factors: functional obsolescence, technical obsolesce, formal obsolescence, regulatory obsolescence, etc. These questions have already been raised by Cowan (1963). The exact mechanisms vary in time and place environmental impacts showing that identical results can be obtained either by reducing resource inputs and impacts or by raising the lifetime of the functional unit (spreading the inputs/impacts over a longer period). This is however only considering the conservation of the physical and economical capital, when we take into account the human, social and cultural capital values, long lasting solutions are largely preferable (Hassler and Kohler, 2001; Kohler and Hassler, 2002).

The link between the different types of service life (as a performance level to be obtained and guaranteed) and the effective lifetime of buildings resides in the difference between a reasonable (individual) planning decision and a (societal) interest to use the complex resource of the building stock in a sustainable way. This means that for the planning decision service life can be considered as the time for which a certain probability of survival (in the sense of the effective lifetime point of view) can be guaranteed. Thus, for many buildings, service life would be followed by a post-service lifetime. The parts of buildings that can technically last longer than the assumed service lives (foundations, structure, parts of envelopes and surfaces) should be easily maintainable. The subsystems that will eventually have to be replaced should be controllable and replaceable. Furthermore, certain reserves of space (e.g. floor heights), redundancy of distribution systems and lean (passive) technologies could be provided in the perspective of a possible ‘second service life’. These demands could take the form of societal, intergenerational demands, e.g. in the form of specific standards and recommendations. For a more detailed discussion, see Bradley and Kohler (2007).

In the architectural discussion, conditioned by the modern movement, the lifetime of buildings was supposed to decrease rapidly allowing unlimited progress through new materials and better understanding of design and industrial production. The results were rather disenchanting: buildings from the 19th century were less subject to obsolescence than ‘modern’ buildings and from an economic point of view, it was not possible to demolish entire sections of towns. There is a general agreement among managers of building stocks, that regular refurbishment, based on periodic diagnosis is the most economical strategy. There are, however, limits to renovation when the renovation costs pass a certain share of new construction costs or when a building has clear performance shortcomings (energy consumption, acoustic isolation, too small rooms, etc.). Schematic simulations of different renovation strategies over longer periods show that from a mass-flow, embodied energy and global cost point of view regular renovation strategies are preferable (Figure 7). Short lifetime (less than 30 operation energy performance; from a resource and economic point of view they are not interesting. The land ownership and land price issue is not taken into account in this comparison.

Figure 7 Scenarios for renovations over 120 years taking into account the reduction of operation energy (for all scenarios) and the additional renovation and maintenance costs for delayed renovation. Relative values, the new and demolition strategy = 100%



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Long-term strategies for large stocks

Optimization problems

Flow-based approaches, prioritizing the conservation of natural capital, in the sense of strong sustainability (Daly, 1992), and resource economic approaches considering different capitals and possible substitutions (Pearce and Warford, 1993) (weak sustainability) can be combined in a specific strategy. A resulting strategic framework would rely on a strictly physical flow model, establishing balances of natural capital. Based on this physical framework other forms of capital can be quantified and rules for the limitation of substitution can be defined, i.e. in the research of Pareto optima. In establish a single general optimization (target) function. Constraint satisfaction approaches are therefore more promising because they can handle both quantitative and qualitative constraints when defining an n-dimensional solution space. This is particularly important when dealing with institutional problems (Kohler, 2006a).

Crucial parameters of stocks

The behaviour of a stock can be modelled in variable depth and granularity. For strategic decisions a limited number of parameters have to be known. Second, derived parameters and indicators can later on be mapped to the basic parameters. Three types of parameters can characterize the existing part of the stock:

- State parameters: size and composition (possibly normalized to population), the average (or median) age of the buildings and infrastructures, and the state of degradation (the quality), which can be indicated by the difference between the present state of the stock (present value) and the state at the beginning (new value).
- Dynamic parameters: the rate of new construction, the rate of demolition (or the average physical life expectations), the rate of refurbishment (or the average interval between refurbishments). The new construction rate depends on social needs and on policy decisions, the demolition rate can be the result of many reasons, the important point is that both economic and physical capital is destroyed (waste production). The refurbishment rate is the real refurbishment rate. It must be compared to the normative (necessary) refurbishment rate to express a possible loss of quality in case of non-refurbishment or delayed refurbishment.
- Performance parameters: total resource consumption taking into account all up stream flows, total waste flows, total energy inputs including operation energy and embodied energy, environmental impacts, impacts on human health. An alternative to the mid-point impact assessment (effects) can be an end-point assessment (real damage to ecosystem and human life) (LCIA, 2003).

To these basic parameters, generally expressed per m^2 gross floor space or km length of infrastructure network, a large number of physical, economic and social attributes can be linked and secondary indicators calculated. At the same time certain ratios can allow one to characterize stocks and compare them. Such ratios are: the relation between input and output flows (throughput), the relation between operation energy buildings, and the relation between half-lifetimes of the different parts of the stock. The described simple model can be applied to very different stocks. Two types of stocks with distinct properties will be discussed briefly.

Old, stationary building stocks of industrialized countries

These stocks have developed from the industrialization in the 19th century and have been doubled in the middle of the 19th century and once again in the mid-20th century (from 1950 to 1980). Since then, they are more or less well maintained by a combination of a low rate of new construction and high refurbishment rates. The refurbishment part is higher than the new building part and this tendency will continue for the coming 30 years. The key questions for the construction industry are according to Meikle and Connaughton (1994, p. 320):

(1) how to maintain the existing stock of housing in habitable condition and

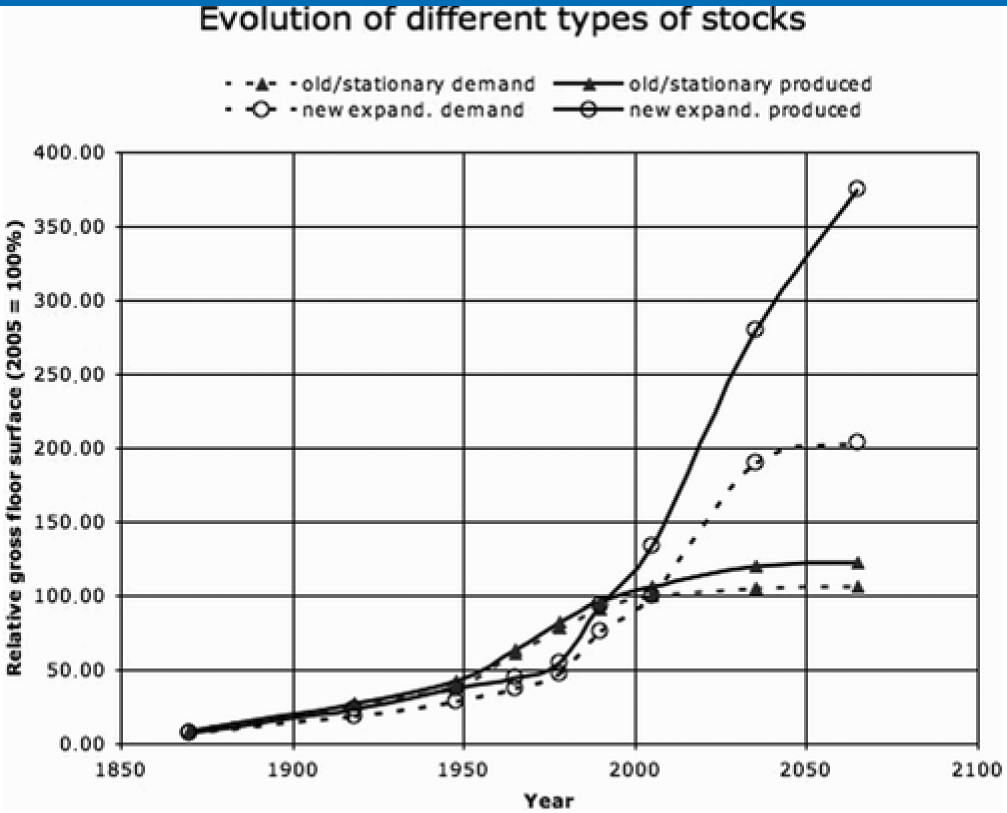
(2) how to design and deliver adaptable and maintainable new housing.

The crucial indicator is the state of degradation of the different components of the stock. If the older cohorts are in bad state, it means that a high average lifetime is a disadvantage. If, on the contrary, the older cohorts not only survived longer, but are also in better shape (because better built), a high average age of the stock is an asset. There is a large debate at present on the consequences of regressive demography (and fast ageing population) in many European countries. In some regions the building and infrastructure stocks are already now too large and the influence of shrinking phenomena are not well known (Schiller, 2007).

Fast-growing stocks in emerging countries

In these societies the rapid industrialization and population migration of the last 30 years, has led to fast growing urbanization, doubling the building and partially the infrastructure stocks in very short periods (20–30 years) and this maybe more than once a century (Yang, 2006; Yang and Kohler, forthcoming). The rate of change is very high and it is not always known, how well these stocks are constructed. If they have physical lifetimes that are close to the doubling periods, the resource needs (and the resulting impacts) will continually grow even if the planned level of the stocks has been reached. It is doubtful that a large-scale development of new construction and directly following demolition (without refurbishment to prolong the service life) is possible from significant after the rapid accumulation phases. If there is not enough refurbishment, the global quality of the stock (physical, economic, social, cultural) will fast decrease. The resources that have been created by an enormous social effort and at a high environmental impact cost, will be destroyed before they can produce goods and services (harvest) over a longer period. Figure 8 compares the schematic evolution of two different stocks. For each stock the lower curve indicates the real available volume (or the demand), the upper curve indicates the necessary production to reach and maintain the demand volume. The difference is equal to the demolition volume resulting from the average lifetime of the buildings. The closer the doubling rate and the life span are the larger this difference. It can be seen that even if an emerging stock becomes stationary (assumed in 2050) the need for new construction will continue to grow if the life span of the buildings is of the same magnitude as the doubling rate. If this should happen in a very large country like China, there would be a dramatic shortage of available building materials and at the same a continuously high level of resulting environmental impacts. Of course, this model is very schematic and the conclusions should be verified through much more detailed models needing a large amount of validated input data. These data do not exist in most countries (industrialized or emerging); a need for international research collaboration is certainly apparent.

Figure 8 Comparison of the relative evolution of the gross floor surface of two stocks that will become stationary around 2050. The cumulated evolution is normalized to 100% in 2005 for the demand function. The demolition rate of the old stock is 0.5%; the demolition rate of the new stock 3%. The difference between demand and production represents the loss due to demolition



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Strategies

The long-term evolution of the building and infrastructure stock is one of the key aspects of sustainable development in all countries, even if the dynamics of the stock and the priorities are not the same. There is a growing awareness that this evolution cannot be controlled by simple market mechanisms, investment incentives or standards. The briefly described institutional approach is more promising when dealing with long-term and complex societal issues like the evolution of the building and infrastructure stocks in a sustainable perspective. In a capital-based, resource economics approach, natural as well as man-made resources provide goods and services that can be used directly, indirectly or can give rise to immaterial uses. For these uses, there are different groups of beneficiaries (owners, users, etc.) whose relations are ruled not only by economic mechanisms (like markets), but also by a number of property and use rights. This is particularly important in the case of capital substitution. Institutional regimes are the basis for the long-term implementation of public sustainability policies through combinations of use and property rights. The preservation of different forms of capital can be evaluated by combining monetarization (taking into account externalities) and by setting limits to substitution e.g. by the observation of all legal norms setting minimal requirements for stock preservation. This standards and economic viability (Knoepfel and Nahrath, 2005). A brief example for the importance of institutional regimes in very different situations can be given for the long-term capital conservation of housing estates. In the case of rapidly expanding stocks, simulations show that the construction quality of the load-bearing structure has a strong influence. In a similar way the refurbishment rate and quality is a crucial parameter in old, stationary stocks. Assuming in both cases a public policy of sustainable development, the forms of property in housing are determining for the long-term outcome. State-owned housing with insufficient investment or insufficient quality claims can and do lead to dereliction within one generation. Mass privatization of public housing can lead to situations, where the individual ownership makes the necessary refurbishment necessary for the long-term conservation of urban capital (physical, economic, social and cultural), difficult. Individual owners do not have the same abilities to finance the refurbishment work and to obtain professional high quality work, as corporate or public owners of large numbers of flats (Meikle and Connaughton, 1994). In the same way individual owners do not have the necessary information and ability to judge the long-term quality of the construction. It appears that only public policies combined with differentiated forms of use and property rights and access to qualified information can assure a long-term capital conservation.

It is striking to see that in many countries (industrialized and emerging) there is an attempt to solve the problem of subsistence of the retired population through private ownership of housing. The pension funds also invest in housing projects expecting high rates of return to guarantee the pensions. These measures are supposed also to solve the problem of reduced demography (voluntary or not) and the resulting ageing of the population. There is a considerable risk that the present institutional regimes developed to link retirement and private ownership of housing will not be able to solve these problems, in particular if the building stocks are not of good quality and not well maintained – but also the involvement of pension funds may lead to overproduction of housing, which then becomes redundant as the overall population shrinks. This strategy for supporting the ageing population may be incompatible with the most obvious demographic consequence of the ageing population.

They might, on the contrary, amplify the problems in 20–30 years. There is a considerable need to develop research on scenarios of the evolution of the stocks related to different institutional regimes.

Conclusions

The building and infrastructure stock is the largest physical, economic, social and cultural capital of most societies. Its evolution is a crucial parameter in sustainable development. The composition of stocks and their long-term behaviour are not well known. The establishment of long-term scenarios faces severe problems of data collection on the past behaviour of stocks. The uncertainty issue in all long-term scenarios is only very partially considered. A bundling of international research efforts is necessary to advance rapidly in this highly sensitive knowledge field. A possible combination of flow- and capital-based approaches taking into account institutional regimes could be a promising basis for necessary long-term scenarios. The long-term institutional aspects have to be taken into account to avoid dramatic losses of economic, social and cultural capitals in the coming decades.

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Integrated life-cycle analysis

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Studies in the morphology of the English building stock

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The Mortality of New Zealand Housing Stock

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