**10. Adaptability**

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# INTRODUCTION

Real estate is a product with a high economic value, a long technical life cycle and a large spatial-physical impact. That is why it is of great societal importance to use real estate as efficient as possible. To enable a high-quality use and a high occupancy rate, a building must be able to move along with qualitative and quantitative changes in demands. In recent decades the interest in flexible building, also called adaptive building, has grown substantially. In many countries this interest is mainly caused by the structural vacancy of real estate, in particular office buildings, the economic crisis, the congestion of the housing market and the increased awareness of and interest in sustainability ([Arge and Blakstad, 2010](#_ENREF_3); [Cairns, 2010](#_ENREF_8); [Horgen, 2010](#_ENREF_22); [Hansen and Olsson, 2011](#_ENREF_20); [Van Meel, 2015](#_ENREF_27)). A direct connection can be made between adaptive building and sustainability ([Wilkinson et al., 2009](#_ENREF_29); [Wilkinson and Remøy, 2011](#_ENREF_30)). Market developments show increased demands for flexibility and sustainability by users and owners as well as a growing understanding of the importance of a circular economy ([Eichholtz et al., 2008](#_ENREF_11)).

Different actors may have different interests and needs regarding adaptability:

* Users; an accommodation that is adaptable to a changing primary process;
* Owners; a building with the highest possible profitability during ownership and adaptability to organisational changes such as growth or shrinkage and market change; sometimes the user is the owner as well;
* Society; real estate that contributes to an attractive and sustainable living and working environment.

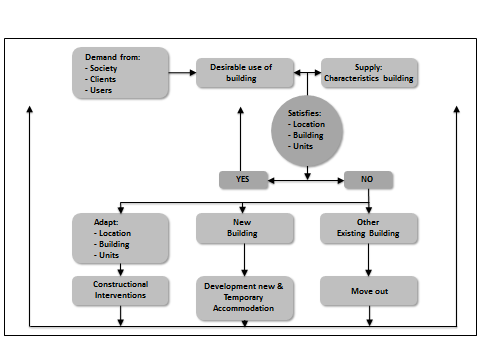
There are three basic ways to act when a building no longer meets the users’ needs: adapt the location, building and/or unit (transformation/conversion), design and construct a new building, or move to another and more suitable existing building, see Figure 10.1.

This chapter first discusses the state of the art regarding the concepts of adaptability and flexibility and the need for adaptable buildings. Then it presents possible benefits and sacrifices of typical interventions, The next section discusses ways to measure the adaptability capacity of buildings and includes both a long list and a short list of KPIs. The assessment criteria for adaptability are based on previous research by [Geraedts and Van der Voordt (2007](#_ENREF_17)), [Remøy and Van der Voordt (2007](#_ENREF_25)) [Wilkinson et al. (2009](#_ENREF_29)), [DGBC (2013](#_ENREF_9)) and [Geraedts and Remøy (2014](#_ENREF_15)). The chapter ends with some suggestions for further research.

**STATE OF THE ART**

**Definitions and relations**

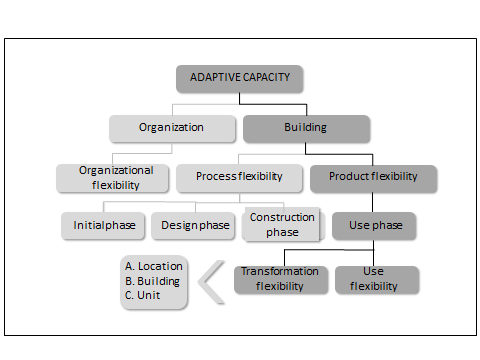
According to Hermans et al. (2014) the adaptive capacity of a building includes all characteristics that enable it to keep its functionality during the technical life cycle in a sustainable and economic profitable way withstanding changing requirements and circumstances. The adaptive capacity is considered a crucial component when scrutinizing the sustainability of the real estate stock.

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*Figure 10.1* The accommodation cycle of real estate and the demand for change (Geraedts et al., 2014).

Flexibility in a project can be associated with the decision process or the final product ([Gill et al., 2005](#_ENREF_19); [Olsson, 2006](#_ENREF_24)). Flexibility in the decision process is based on an approach where commitments in projects are made sequentially. This philosophy is developed further by combining the concept of layered building designs ([Brand, 1994](#_ENREF_7)) and adaptability to a layered decision process ([Blakstad, 2001](#_ENREF_5); [Arge, 2005](#_ENREF_2)). The adaptive capacity can be split into three different aspects (see also Figure 10.2):

* *Organisational flexibility*; the adaptive capacity of an organisation or user to respond adequately to changing demands of the built environment, including strategic, structural and operational flexibility ([Volberda, 1997](#_ENREF_28)). Strategic flexibility of an organisation is one of the most crucial assets to respond to changing market circumstances like increasing unemployment in the sector, technological innovations, economic competition, new legislation and changed relation with customers. Structural flexibility incorporates the ability to transform the aims of the organisation to changing circumstances on a more or less permanent way. For instance by producing multifunctional teams or the collaboration with suppliers in the design. Operational flexibility mainly incorporates changes in the amount of activities of an organisation. Examples are the creating of a stock, the use of temporary human resource or the reservation of capacity at suppliers. Financial and contractual flexibility are both also strongly related to organisational flexibility. Financial flexibility is related to the financial situation and arrangements of owners and users of the building and in the real estate market in general. Contractual flexibility depends on the types and length of contracts and the ruling practices in the market, own/lease strategies as well as on available alternatives (both for owners and occupants) ([Gibson, 2000](#_ENREF_18); [Blakstad, 2001](#_ENREF_5)).
* *Process flexibility*; the adaptive capacity of a process that enables to react to changing circumstances, wishes or demands during the initiative, the design and the construction phases, including planned flexibility and response flexibility (Olsson, 2006; Genus, 1997; Verganti, 1999).
* *Product flexibility*; the adaptive capacity of a building (the product) that enables to respond to changing circumstances, wishes or demands during the use phase of the building without complex and costly technical interventions.



*Figure 10.2* Different aspects of adaptive capacity and the focus within this chapter (marked dark) (Geraedts et al, 2014).

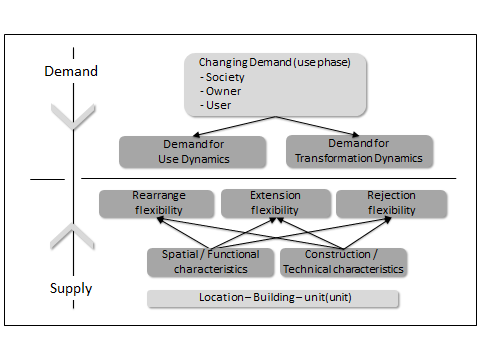
Adaptability is considered to be a value. Flexibility is considered to be a set of possible measures that could be taken to create the value adaptability.

**Demand for adaptability: use dynamics and transformation dynamics**

The changing market demand is a driver to take flexibility measures and as such precedes the input part of the Value Adding Management model that was presented in chapter 1. The focus of the adaptable capacity determination method that is presented later in this chapter is exclusively the product flexibility during the use phase of buildings. Target here is the translation of the demand into transformation and use dynamics on three different levels: location, building and unit, see Figure 10.3. The split in goals (demand) and means (supply) is also described by Van der Voordt and Van Wegen (2000; 2005).

A building must be able to cope with changing user demands. This may lead for instance to the demand in a brief or program of requirements that the building must be parcelled into smaller units (e.g. compartment ability in smaller units), or that specific facilities can be added to the units or building. This is called use dynamics (end-user perspective).

Transformation dynamics concern the demands for a building that is able to accommodate totally different user groups or different functions in the near future. This may lead to specific demands for being able to rearrange the building for different user groups. This is called transformation dynamics (client perspective).



*Figure 10.3* Framework of the adaptive capacity method for the demand (for use and transformation dynamics), and the supply (of rearrange, extension and rejection flexibility) on three different levels (location, building and unit) (Geraedts et al, 2014).

**The supply: rearrange, extension and rejection flexibility**

The flexibility of the supply can be translated into three spatial/functional and construction/technical characteristics (also including the technical services as installations). They determine if a building can meet the requirements, see Figure 10.3:

* Rearrange flexibility; the degree to which the location, the building or the unit can be rearranged or redesigned.
* Extension flexibility; the degree to which the location, the building or the unit can be extended.
* Rejection flexibility; the degree to which (part of) the location, the building or the unit can be rejected.

**Adaptive building**

Designing flexible and adaptable buildings is an established practice; see for example Brand (1994). The main approaches are to either design the building to allow cost-effective changes later on or designing the building to allow flexible use of it without having to make adaptations. As discussed by De Neufville et al. (2008) and Miller and Swensson (2002), flexibility is a key design criterion for buildings. With a life span of forty years or more, it is likely that changes will be required before the building is abandoned. Such flexibility can, according to Pati et al. (2008) and Bjørberg and Verweij (2009), be achieved through different approaches.

The adaptive capacity of a building has been addressed in the literature to a very limited extent. More attention is paid to aspects like flexible, extendible, multifunctional, reusable or removable. These aspects often have strongly overlapping meanings ([Geraedts, 2013](#_ENREF_14)). Schuetze (2009) defines the adaptive capacity of a building as being easily adaptable to different functions or changing requirements, constructed with components and products, which allow re-use and recycle with a minimum of effort and loss of quality. It mainly concerns function neutral buildings, which have a user related transformation potency. Use has been made of reusable construction components, based on the different life cycle of the different components. Richard (2010) states the following: nobody can predict the demands, wishes or different tastes of the current and the future users of a building during its lifespan. Adaptable systems are necessary to taking up this challenge, to develop user friendly buildings open to change with freedom of choice for the first generation of users and possibilities to adapt for next generations of users.

**Flexibility**

Flexibility is generally related to managing effects of uncertainty. Bahrami and Evans (2005) list 11 concepts related to flexibility: adaptability, agility, elasticity, hedging, liquidity, malleability, mobility, modularity, robustness, resilience, and versatility. According to the Merriam-Webster Online Dictionary ([Merriam Webster Online Dictionary 2006](#_ENREF_23)), being flexible is ‘characterised by a ready capability to adapt to new, different, or changing requirements’. According to Schneider and Hill (2007) flexibility enables real estate to adapt to changing needs and patterns, socially and technically as well. These needs can be personal (expanding family situation), practical (as a result of aging) or technical (renewal of old services). The changing patterns can be caused by demographical, economical or environmental changes. Flexible housing means that they are adaptable to different users during the whole lifespan. According to Groák (1992) flexibility is accomplished by changing the physical composition, to combine or expand rooms or units. Adaptability has to deal with the use of rooms and units, flexibility concerns the technical aspects. Prins (1992) defines flexibility as the physical property of a building to be able to be adaptable or changeable for technical, spatial and social.

Habraken (1961) already proposed in 1961 a subdivision of a building in different layers or levels; the support level with construction components with a long lifespan and the infill level with construction components with a short life span. It was based on a distinction between collective components for the community to decide (support level) and individual components for the individual user to decide (infill level). Flexibility in the decision process is based on an approach where commitments in projects are made sequentially. This philosophy is further developed by combining the concept of layered building designs ([Brand, 1994](#_ENREF_7)) and adaptability to a layered decision process ([Blakstad, 2001](#_ENREF_5); [Arge 2005](#_ENREF_2)). Another perspective on process flexibility is found in real options theory. In real options, the ability to wait to commit to an investment until more information is available can serve as on option and have a corresponding value ([Brach, 2003](#_ENREF_6)). An option is the right, but not the obligation to take an action in the future ([Amram et al., 1999](#_ENREF_1)). Uncertainty can increase the value of a project as long as flexibility is preserved and resources are not irreversibly committed. Van Reedt Dortland (2013) has shown how real options can be used in strategic real estate management decision making related to healthcare facilities.

*Organisational flexibility*

Changing circumstances and demands of an organisation don’t necessarily need to lead to changes in a building. A new good match between organisation and building can also be found by adapting the organisation instead of the building. This could be possible by another way of working, a different distribution of activities within the available spaces, or by outsourcing certain activities. In that case we speak about organisational flexibility ([Geraedts, 2013](#_ENREF_14)). According to Volberda (2007) organisational flexibility concerns the extent to which an organisation is capable to respond adequately to changing demands. The concept of flexibility in hospital buildings has recently been developed further, and now includes a variety of principles and solutions. According to Rechel et al. (2009), flexibility should encompass a wide range of building characteristics, supporting infrastructure such as transport links, and relationships to other parts of the healthcare system, and it should also occur in relation to financing.

*Process flexibility*

Process flexibility relates to the whole lifespan of buildings: development, construction, operation and use phase, from the first initiative and briefing phase until the final use. Decision-making processes need to be structured in such a way that the freedom for changes is maximized ([Geraedts, 1998](#_ENREF_12)). Lean construction emphasises the concept of “last responsible moment”. According to Ballard (2000), the last responsible moment is the ‘point at which failing to make the decision eliminates an alternative’. This means that decisions must be made within the lead-time for realizing alternatives. The term last responsible moment implies that it would be irresponsible to delay a decision furthermore. On the other hand, a decision should not be made until it has to be made, in order to allow for flexibility ([Ballard and Howell, 2003](#_ENREF_4)). A common tool for achieving flexibility in projects is the use of option-based contracts, which enable a continuous locking of the projects. Mahmoud-Jouini et al. (2004) point out that a key factor in creating win-win situations between the stakeholders in Engineering, Procurement and Construction (EPC) contracts lies in the flexibility created by the contracts. Flexibility also has to do with politics. In general, stakeholders are less likely to favour a continued flexible decision process when an initial decision has been taken in their favour. Consequently, a continued flexible decision process is valued by those who do not prefer an initial decision. Flexibility options might be used as a tool for stakeholders who want decisions to be remade. Flexible decision processes can be used to justify that decisions do not need to be taken or can be revised, thus becoming a tool for irresoluteness.

*Product flexibility*

Product or object flexibility concerns the changeability of the product. If the product is a building, then the product flexibility concerns the changeability of that building, not only during the development phase, but also in particular during the exploitation or use phase. Product flexibility concerns de spatial and technical properties of the product, the building. Product flexibility enables use flexibility and transformation flexibility ([Geraedts, 1998](#_ENREF_12)).

Pati et al. (2008) made a distinction in three types of product flexibility: adaptability, convertibility, and expandability. A similar classification has been used by Arge (2005) and Bjørberg and Verweij (2009). Adaptability can be defined as a building’s ability to meet shifting demands without physical changes. Convertibility can be defined as the possibility for construction and technical changes with minimum cost and disturbance. The third type of flexibility, expandability, can be defined as the ability to add (or reduce) the size of a building. In this chapter, all three characteristics are seen as subsets of flexibility. Flexibility can be related to modularity. Modularity refers to the possibility of dividing a project into more or less independent sub-units. Design modularity is a common approach to achieve flexibility by decoupling physical and functional components ([Thomke, 1997](#_ENREF_26): [Hellström and Wikström, 2005](#_ENREF_21)). The two dimensions of flexibility of the design process and in the product can be applied independently, but also in combination. This has been analysed by researchers previously ([Brand, 1994](#_ENREF_7); [Gill et al., 2005](#_ENREF_19)). Flexibility in the decision process and the product may interact for any given project.

**BENEFITS AND SACRIFICES**

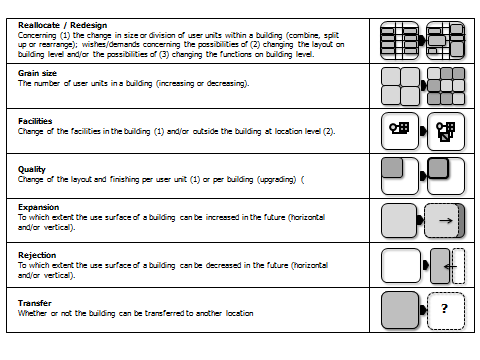
Added value comes with the possibility to adapt to changing market or user demands, to reduce the risk of future vacancy of the building, less adaptation costs, higher rental income, more happy users, less pollution of environment (or a more sustainable building), and possible re-use of building construction components. The largest unknown factor is estimating whether provisions made for future adaptability will actually be used in certain given period. If not, most of the accompanying extra investment costs will not be profitable. Table 10.1 shows an overview of 17 flexibility interventions in connection to the shortlist of most important Key Performance Indicators that are presented in the next section and that could lead to different forms of future added value (benefits) against certain costs (sacrifices).



**HOW TO MEASURE**

**Flex 2.0: indicators of transformation dynamics and use dynamics**

Flex 2.0 is a method to formulate the demand for flexibility in the briefing and design phase, and to assess the supply of flexibility of buildings in the use phase. Due to the lack of a widely accepted method with criteria or indicators for the potential for adaptation during the life cycle of a building (to be used in the briefing, design phase and the use phase as well), an extensive international literature survey has been conducted, resulting in 147 indicators that are more or less connected to flexibility of buildings ([Geraedts, 2015](#_ENREF_16)). Seven important transformation dynamics indicators from the perspective of the owner of a building were formulated. They can be used to express the owner’s wishes and demands for the adaptive capability of the building and the user units, see Figure 10.4. Also seven use dynamics indicators from the perspective of the users of a building were traced to express their wishes and demands of the adaptive capability of the units and the building, see Figure 10.5.

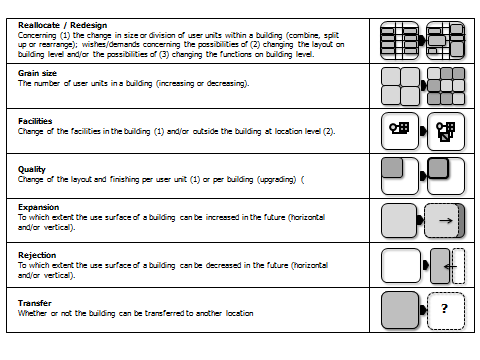


*Figure 10.4* Seven important transformation dynamics indicators from the perspective of the owner of a building (Geraedts et al., 2014).

**Layers and reduction of indicators**

Blyth and Worthington (2010) and Hansen and Olsson (2011) discuss layered design and a layered design process. In order to identify independent responsibilities of parties involved in transformation of built environment Habraken (1998) introduced levels of control/decision making, while Duffy (1998) and Brand (1994) defined functional levels within a building in order to identify functions with different changing rates in a building ([Durmisevic, 2006](#_ENREF_10)). To structure, cluster and reduce the large number of possible indicators, use has been made of the distinction in different layers of the building and its environment according to Brand (1994). Brands model consists of site, structure, skin, services, space plan, and stuff:

* Site: the urban location; the legally defined lot whose context lives longer than buildings. According to Brand and Duffy, the site is eternal.
* Structure: the foundation and load-bearing elements, which last between 30-300 years. However, few buildings last longer than 50 years.
* Skin: the exterior finishing, including roofs and façades. These are upgraded or changed approximately every 20 years.
* Services: the HVAC (heating, ventilating, and air conditioning), communication, and electrical wiring. They wear out after 7-15 years.
* Space plan: the interior layout including vertical partitions, doors, ceiling, and floors. According to Brand, commercial space can change every 3 years.
* Stuff: the furniture that is moved daily, weekly or monthly. Furniture, in Italian is called mobilia, for good reason.



*Figure 10.5*Seven important use dynamics indicators from the perspective of the users of a building (Geraedts et al., 2014).

By analogy with the model of Brand (1994) different levels were created in Flex 2.0 to structure, locate and cluster all possible flexibility indicators that were previously found. Figure 10.6 gives an overview of the 5 layers and the 83 flexibility performance indicators that influence the adaptive capacity of buildings. The term services has been replaced by facilities, and the space plan and stuff have been combined and rephrased as space plan/finishing.

**Flexibility scores**

Next to a column with the layers, sub-layers and performance indicators, Figure 10.6 includes a column to mark the score or level of the specific indicator concerned and a column to allocate a weight to this score. The multiplication of the assessment value and the weighting factor for that specific indicator leads to the flexibility score. Figure 10.7 shows an example of how this works.

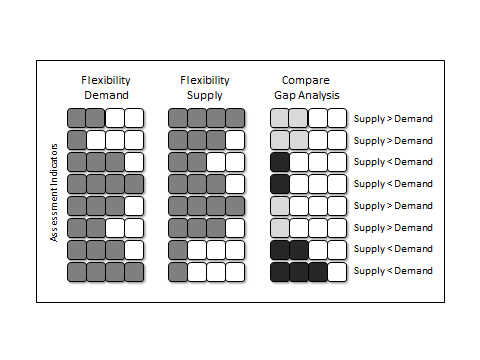
*Figure 10.6* Overview of the general requirements (a-g) and the 83 performance indicators that influence the adaptive capacity of buildings(Geraedts, 2015)*.*

*Figure 10.7* An example of how the assessment method works: indicator no. 11 (surplus of free floor height) has 4 assessment values from bad to good.

The addition of all scores of the individual indicators results in a total score of the adaptive capacity of a building. With this method it is possible to develop a score range, from a theoretical minimum flexibility/adaptability score till a maximum score. Within this range it is possible to identify different adaptability classes.

**Adaptive capacity: demand and supply profiles**

The described method enables the users to make so-called demand or supply profiles. A demand profile can be made for a specific programme of a new adaptive building or a programme for an existing building that needs to be transformed into a new, alternative function. This can be used in the briefing and design phase. A supply profile can be made to map the adaptive capacity of an existing building in the use phase. The profiles can be compared to each other to see if a match between the flexibility profiles is possible, see Figure 10.8.



*Figure 10.8* Example of a demand and supply profile with a comparing gap analysis to evaluate if there could be a match between the demands for future adaptability and the supplied flexibility by the building (Geraedts et al., 2014).

**Flex 2.0 Light: 17 most important indicators**

As a default setting with the possibility to switch to other priorities and another selection if needed by the user, 17 most crucial indicators are showed in Figure 10.9.

*Figure 10.9* Flex 2.0 Light, a default setting with a limited number (17) of the most important indicators to assess the adaptability of a building; the numbers between brackets refer to the number of the indicator in the long list (see figure 10.7) (Geraedts, 2015). Figures 10.10a-b (next pages) show a detailed overview of the assessment values and related remarks regarding these 17 most important performance indicators.

Figures 10.10a-b show a detailed overview of the assessment values and related remarks regarding these 17 most important performance indicators.

**PERSPECTIVES**

Just a few methods exist to map the costs and benefits of flexibility measures for future adaptability. One of them is called Flexcos ([Geraedts, 2001](#_ENREF_13)). This method with several scenario/strategy combinations allows organisations to consider the effects of different construction strategies at an early planning stage. The relative costs of investing in future flexibility and possible future savings can be compared with each other. Further research is needed to collect empirical data about cost-benefits effects of various adaptability interventions. The largest unknown factor in cost-quality research is estimating whether provisions made for future flexibility will actually be used in any given period and the trade-off between the costs of flexibility measures and financial benefits. Case studies of projects, in which extra measures were provided for future flexibility, could offer added insights. Which measures have been used successfully and which not? What can we say about the initial costs versus the the benefits? The Flex adaptive capacity method is a first important step in the development of instruments to formulate adaptive demands and to assess adaptive supplies of buildings. In the next steps this method has to be discussed and evaluated with building owners, users and construction companies. Further developments will also look into the implementation of this method for small and rather simple projects and large complex projects as well. The method could be specified for different sectors within construction (hospitals, schools, office buildings and residential housing). Finally further research is necessary on the drivers behind change and the need for adaptability.

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| **01. Surplus of site space**  Does the site have a surplus of space and is the building located at the centre? | **Assessment values surplus of site space**  1. No, the site has no surplus of space at all  2. 10-30% surplus  3. 30-50% surplus  4. The site has a surplus space of more than 50 | **Remark**  The more surplus space on site, the better the building is expandable. |
| **02. Surplus of building space / floor space**  Does the building or the user units have a surplus of the needed usable floor space? | **Assessment values oversized building space in % of oversize**  1. No, the building or user units have no surplus of floor space at all  2. 10-30% surplus  3. 30-50% surplus  4. The building has a surplus of floor space of more than 50% | **Remark**  The more surplus space a building or user units have (for instance by the use of a zoning system with margin space), the more easily a building can be rearranged or transformed to other functions, the easier the grain size can be changed, the better a building can meet to changing demands, the easier parts of the building or units can be rejected and the easier the building or units are expandable. |
| **03. Surplus of free floor height**  How much is the net free floor height? | **Assessment values of the free floor height**  1. < 2.60 m  2. 2.60 - 3.00 m  3. 3.00 - 3.40 m  4. > 3.40 m | **Remark**  The higher the free floor height, the better a building can be rearranged or transformed to other functions, the better a building can meet to changing demands of facilities and the quality of the building or units. |
| **04. Access to building: location of stairs, elevators, core building**  To what extent a centralized and/or decentralized building entrance (location entrances, cores, stairs, elevators) has been implemented? | **Assessment values access to building**  1. Decentralized and separated building entrance and core.  2. Decentralized and combined building entrance and core.  3. Building divided in different wings, each with a centralized/combined entrance/core.  4. Building with one centralized entrance, divided in different wings, each with a centralized/combined entrance and core. | **Remark**  The more a building entrance system can be used for a more independent use by different user groups the easier a building can be rearranged or transformed to other functions, the better a building is horizontal expandable, the better parts of a building can be rejected. |
| **05.** **Surplus of load bearing capacity of floors**  How large is the load bearing capacity of the floors in the building? | **Assessment values of load bearing capacity of floors**  1. < 3 kN/m2  2. 3 - 3,5 kN/m2  3. 3,5 - 4 kN/m2  4. > 4 kN/m2 and several areas > 8 kN/m2. | **Remark**  The larger the load bearing capacity of floors, the easier a building can be rearranged or transformed to other functions, the better a building can meet to changing user demands, the better possibilities for vertical expansion of the building, the more possibilities to change the location of user units within the building. |
| **06.** **Extendible building / unit horizontal**  Is it possible to expand the building horizontally for new extension to the building or user units? | **Assessment values horizontal extension building / unit**  1. Horizontal extension is not possible at all.  2. Horizontal extension of building/unit is very limited possible (f.i. only at one side).  3. Horizontal extension of building/unit is limited possible (f.i. only at more sides).  4. Horizontal extension of building/unit is easily possible at all sides. | **Remark**  The more a building or unit can be expanded for new or larger existing functions, the easier a building can be rearranged or transformed to other functions or expanded, the better a building can meet the changing user quality demands, the more possibilities to expand the space of the units in the building. |
| **07.** **Extendible building / unit vertical**  Is it possible to expand the building vertically, for adding new floors (topping) or a basement? | **Assessment values vertical extension building**  1. Vertical extension is not possible at all.  2. Vertical extension of building is limited possible, only possible for a few units in the building.  3. Vertical extension of building with added floor and basement is possible at more units after total rearrangement of building.  4. Vertical extension of building with new floors and basement and individual vertical extension of the user units is rather easy without disturbing other user units (implementation of zoning-margin system and fontanel constructions in supporting floors. | **Remark**  The more a building or unit can be vertically expanded with new floors or basement, the easier a building can be rearranged or transformed to other functions or expanded, the better a building can meet the changing individual user quality demands, the more possibilities to expand the space of the units in the building, including new extra internal stairs/elevators. |
| **08. Dismountable facade**  To what extent can facade components be dismantled in case of transformation of the building? | **Assessment values dismountable facade in % of dismountable.**  1. Facade components are not or hardly dismountable and have to be fully demolished and removed (<20%).  2. A small part of the facade components is dismountable (between 20 en 50%).  3. A large part of the facade components is dismountable (between 50 en 90%).  4. All facade components are easily dismountable (> 90%). | **Remark**  The more facade components are easily dismountable, the easier a building can be rearranged or transformed to other functions, the better a building can meet the changing individual user quality demands, the more a building can be horizontally extended. |

*Figure 10.10a* Overview of the assessment values of indicator 1 to 8(Geraedts, 2015).

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| **09.** **Customisability and controllability of facilities**  To what extend can facilities (heating, cooling, electricity, ICT) respond to changing functional requirements? | **Assessment values customisability and controllability of facilities**  1. Not customisable and individual controllable (mono functional of fixed use).  2. Limited customisable and individual controllable.  3. Partly customisable and individual controllable.  4. Easy customisable and individual controllable. | **Remark**  The more facilities are customisable and controllable to respond to changing functional requirements, the easier a building can be rearranged or transformed to other functions, the easier the grain size can be changed, the better a building can meet to changing demands of facilities and the quality of the building or units, the easier parts of the building or units can be rejected and the easier (parts of) the building or units are expandable. |
| **10. Surplus of facilities shafts and ducts**  Do the facilities shafts and ducts have a surplus of space (heating, cooling, electricity, ICT)? | **Assessment values surplus of facilities shafts and ducts**  1. Shafts and ducts have no surplus at all  2. 10-30% surplus  3. 30-50% surplus  4. Surplus of space of more than 50% | **Remark**  The more surplus space facilities shafts and ducts have, the easier a building can be rearranged or transformed to other functions, the easier the grain size can be changed, the better a building can meet to changing user demands, and the easier the building or units are expandable. |
| **11.** **Surplus capacity of facilities**  Does the capacity of (the sources of) the facilities have a surplus (heating, cooling, electricity, ICT)? | **Assessment values surplus of capacity of facilities**  1. Capacities of facilities have no surplus at all  2. 10-30% surplus  3. 30-50% surplus  4. The surplus capacities of facilities > 50% | **Remark**  The more surplus capacity the facilities have, the easier a building can be rearranged or transformed to other functions, the easier the grain size can be changed, the better a building can meet to changing user demands, and the easier the building or units are expandable. |
| **12.** **Disconnection of facilities components**  Can the components of the facilities be disconnected? | **Assessment values of disconnection of facilities**  1. Facility (parts) can not be disconnected or unmounted; ‘wet’ connections  2. Hardly be disconnected, unmounted  3. Partly be disconnected, unmounted  4. Facility (parts) can be disconnected very easily (completely demountable, pluggable). | **Remark**  The more facility parts can be disconnected or demounted, the easier a building can be rearranged or transformed to other functions, the easier the grain size can be changed, the better a building can meet to changing user demands of facilities and the quality of the building or units, and the easier the building or units are expandable. |
| **13. Distinction between support - infill**  What is the % of the application of project independent produced infill construction components (and therefore well demountable and exchangeable), with respect to the % of support construction parts is used? | **Assessment values in % of application of project independent produced infill construction components**  1. < 10%  2. 10 - 50%  3. 50 - 90%  4. > 90% | **Remark**  The more construction components belong to the infill domain, the easier a building can be rearranged or transformed to other functions, the easier the grain size can be changed, the better a building can meet to changing user demands of facilities and the quality of the building or units, and the easier the building or units are expandable. |
| **14. Horizontal routing, corridors units**  In what way is the horizontal disclosure of the units in the building accomplished (for instance by internal corridors, single double, gallery)? | **Assessment values horizontal routing**  1. Disclosure of the building by only a single internal corridor.  2. Disclosure by a double internal corridor.  3. All disclosures directly by a central core in the building with a surrounding corridor.  4. All disclosures directly by a central core in the building, or an external gallery | **Remark**  The more the horizontal disclosure of the units is limited by a central core the more easily units in a building can be rearranged or transformed to other functions. |
| **15.** **Removable, relocatable units in building**  To what extend are the user units in a building removable, relocatable? | **Assessment values removable, relocatable units**  1. Units are not removable/reusable  2. Units are removable/reusable as a whole with drastic constructional and costs consequences  3. Units are pretty removable/reusable; constructed with demountable 3D modules or components  4. Units are good removable reusable. | **Remark**  The more building units are constructed with demountable and reusable, the user units can be easier relocated in the building or elsewhere. |
| **16. Removable, relocatable interior walls in building**  To what extent are the interior walls easily **r**emovable, relocatable? | **Assessment values removable, relocatable inner walls**  1. Interior walls are not removable, reusable without drastic, expensive constructional interventions.  2. Interior walls are not replaceable, but good destructible.  3. Interior walls are removable/reusable by dismantle them and rebuild them at another location.  4. Interior walls are easily removable, reusable without radical, expensive constructional interventions (f.i. system walls). | **Remark**  The more inner walls are easily removable/reusable, the easier a building can be rearranged or transformed to other functions, the better a building can meet the changing user demands of facilities and the quality of the building or units, and the easier parts of the building or units can be rejected and the easier the building or units are expandable. |
| **17.** **Disconnecting/detailed connection interior walls; hor./vert.**  Which detailed construction is applied between the connection of interior walls and support structure, columns, façade, floor and ceiling? | **Assessment values detailed connection interior walls**  1. Penetrating connections  2. Wet connections (like mortar, sealant, glue).  3. Specific project bound produced connection elements  4. Project unbound dismountable connections | **Remark**  The easier the connection of interior walls can be dismounted, the easier a building can be rearranged or transformed to other functions, the easier the grain size can be changed, the better a building can meet to changing user demands of facilities and the quality of the building or units, and the easier the building or units are expandable. |

*Figure 10.10b* Overview of the assessment values of indicator 9 to 17(Geraedts, 2015)*.*

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