FLEX 3.0

An instrument to formulate the demand for and assessing the supply of the adaptive capacity of buildings

Geraedts, Rob; Prins, Matthijs

Publication date
2016

Document Version
Final published version

Published in
Proceedings of the CIB World Building Congress 2016

Citation (APA)
Geraedts, R., & Prins, M. (2016). FLEX 3.0: An instrument to formulate the demand for and assessing the supply of the adaptive capacity of buildings. In N. Achour (Ed.), *Proceedings of the CIB World Building Congress 2016: Volume V: Advancing Products and Services* (pp. 679-690). Tampere University of Technology.

FLEX 3.0: an Instrument to Formulate the Demand for and Assessing the Supply of the Adaptive Capacity of Buildings

Rob P. Geraedts and Matthijs Prins

Faculty of Architecture, Delft University of Technology, Netherlands
Email: r.p.geraedts@tudelft.nl

Abstract

Market developments show increased demands for flexibility and sustainability by users and owners of buildings. A direct connection can be made between adaptive building and sustainability. The longer a building can keep its functional life cycle instead of becoming vacant or being demolished, the more sustainable a building will be. One way of looking into this phenomenon is the more a building is flexible and able to adapt to changing user demands, the longer it will keep its functional life cycle. In 2014 a paper was presented at the International Union of Architects World Congress UIA2014 in Durban SA, titled Adaptive Capacity of Buildings. A report was given of an extensive international literature survey and the development of a method to determine the adaptive capacity of buildings. In total 147 flexibility indicators were described with accompanying assessment values. The most important recommendation for the next step was the development of an easy to use assessment method in practice with a limited number of important adaptability performance indicators.

Further research led in 2015 to a renewed assessment method with 83 indicators, clustered in five layers with different life cycles. This method was called FLEX 2.0 and a derived version was called FLEX 2.0 LIGHT with only 17 of the most important indicators. This was presented in 2015 at the CIB Conference - Going North for sustainability in London. At the same time this method was used in two separate research projects for an evaluation with experts in practice. One research project concerned the development of school buildings; the other project was related to the development of office buildings. The main conclusions and recommendations of both research projects to evaluate the FLEX 2.0 method in practice with two different types of real estate will be described in this paper. Questions will be answered about the differences and similarities between the two different categories of real estate when using this flexibility assessment method. This will lead to some important conclusions for the next version of the method: FLEX 3.0. Finally a renewed framework for this next version will be presented.

Keywords: assessment instrument, adaptive capacity, building, flexible, sustainable

1. Introduction

Market developments show increased demands for flexibility and sustainability by users and owners of buildings. A direct connection can be made between adaptive building and sustainability. The longer a building can keep its functional life cycle instead of becoming vacant or being demolished, the more sustainable a building will be. One way of looking into this phenomenon is the more a building is flexible and able to adapt to changing user demands, the longer it will keep its functional life cycle. In 2014 a paper was presented at the International Union of Architects World Congress UIA2014 in Durban SA, titled Adaptive Capacity of Buildings (Geraedts 2014). A report was given of an extensive international literature survey and the development of a method to determine the adaptive capacity of buildings (Geraedts 2013). In total 147 flexibility indicators were described with accompanying assessment values (Hermans 2014). The most important recommendation for the next step was the development of an easy to use assessment method in practice with a limited number of important adaptability performance indicators. Further research lead in 2015 to a renewed assessment method with 83 indicators. They were clustered in five layers with different life cycles. This method was called FLEX 2.0 and a derived FLEX 2.0 LIGHT version with only 17 of the most important indicators. This was presented in 2015 at the CIB Conference - Going North for sustainability in London (Geraedts 2015).

At the same time in two separate research projects the method FLEX 2.0 was used for an evaluation with experts in practice. One research project concerned the development of school buildings (Carlebur 2015); the other project was related to the development of office buildings (Stoop 2015). The main conclusions and recommendations of both research projects to evaluate the FLEX 2.0 method in practice will be shortly described in this paper. Questions will be answered about the differences and similarities between the two different categories of real estate when using this flexibility assessment method. This will lead to some important conclusions to develop the next version of the method: FLEX 3.0. Finally a renewed framework for this next version will be presented.

2. Previous Developments

2.1 Determination Method for Adaptive Building

Definition of Adaptive Capacity

The adaptive capacity of a building includes all characteristics that enable the building to keep its functionality through changing requirements and circumstances, during its entire technical life cycle and in a sustainable and economic profitable way. The adaptive capacity is being considered as a crucial component when looking into the sustainability of the real estate stock (Hermans 2014).

Adaptive Capacity Determination Method

In 2014 a method for determining the adaptive capacity of buildings has been developed after an extensive survey of international literature on the characteristics, definitions and assessment instruments of adaptive building and on boundaries of adaptive capacity, sustainability and financial business cases for real estate. The literature survey has resulted in a number of basic schemes with relevant flexibility indicators and their mutual relationships. Next to the literature survey, a substantial number of experts from practice have been consulted. The basic schemes formed the input for discussions in two different expert panels: one with representatives of the clients (demand side) and one panel with representatives of construction companies and suppliers (supply side) in the construction process (Geraedts 2013, Hermans 2014). The adaptive capacity method consists of three different modules:

1. The determination of the adaptive capacity.
2. The determination of the financial-economic viability.
3. The determination of the sustainability impact of the measures chosen.

FLEX 1.0: 147 Indicators to determine the adaptive capacity

In the further research only the first module was elaborated: the adaptive capacity of buildings (the AC Method). This method delivered a clear insight in and an overview of aspects that needed to be taken into account when assessing the adaptive capacity of buildings. The method combined existing knowledge on flexibility and sustainability (Berg 1981, Houtsma 1982, Geraedts 1989, REN 1992, Geraedts 1998, Geraedts 2001, Geraedts 2007, Schneider 2007), Beadle 2008, Geraedts 2009, Wilkinson 2009, DGBC 2013) amongst others into one overview of important aspects to determine the adaptive capacity.

For the owner of a building in total 36 different indicators were formulated with associated values for assessing the spatial/functional flexibility characteristics, and 49 different indicators to assess the construction/technical flexibility characteristics of a building. For the user of a building in total 29 different indicators were formulated with associated values for assessing spatial/functional flexibility characteristics, and 33 different indicators for assessing construction/technical flexibility characteristics. The total addition finally led to 147 indicators to determine the adaptive capacity of a building from an owners and a users point of view. It was the first step in the development of instruments to assess specific projects. Although it was not mentioned as such, one can identify this first version with the 147 flexibility indicators as FLEX 1.0.

The steering group behind this research project and the two already engaged expert panels played an important role for addressing the next research aim: the translation of this first developed instrument into a more accessible and easy to use instrument in the daily construction practice, with less indicators to deal with. This resulted in a renewed condensed method called FLEX 2.0 that will be briefly described in the next paragraph.

2.2 FLEX 2.0 and FLEX 2.0 LIGHT

Combining and clustering in five layers

First of all the double flexibility indicators described for the owner and the user of the building as well, were combined together. To structure and cluster the remaining large number of possible indicators any further, use has been made of the distinction in five layers with a different life cycle of the building and its environment (Brand 1994). As a consequence the number of flexibility indicators in FLEX 2.0 was reduced from 147 to 83 indicators, spread over five layers: Site, Structure, Skin, Facilities and Space plan/Finishing (Geraedts 2015).

Structure of FLEX 2.0: General requirements

To be able to actually use the adaptive capacity of a building or to change the use of a building is it necessary to recognize a number of common important preconditions. Especially some legal, organizational and common constructional preconditions have to be mapped before further actions can take place. Is it possible to change the function of the building or to extend the building according to the actual development plan of the local government? What is the general technical condition of the building, what is the age, when was the last renovation of the building, what type of user utilized the building?

Assessment level, weighting and scores

In this method values are given for each assessment aspect of flexibility performance indicators. Next to the indicator, the related assessment values and remarks, a column is shown to give a personal weight to the various indicators (varies from 1 = not important to 3 = very important) and finally a column to mark the score or level of the specific indicator concerned. There are four possible values for the score: 1 = Bad, 2 = Normal, 3 = Better, 4 = Best. Figure 1 shows an example of the four assessment values of indicator nr.11: Surplus of free floor height. The final score is calculated by multiplying the assessment value and the weighting factor for that indicator (see example in figure 2).

11 Surplus of free floor height	Assessment values of the free floor height	Remark	Weighting	Score
How much is the net free floor height?	1. < 2.60 m (Bad) 2. 2.60 - 3.00 m (Nromal) 3. 3.00 - 3.40 m (Better) 4. > 3.40 m (Best)	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.	1 = less important 2 = important 3 = very important	Score = assessment x weighting

Figure 1: Example of the four assessment values of flexibility indicator nr. 11: Surplus of free floor height, the assessment values, remarks, weighting and score (Geraedts 2015)

FLEX 2.0 LIGHT: The 17 most important indicators

After the clustering of 143 indicators to 83 indicators, in the next step a second clustering was carried out to find a limited number of the most crucial indicators. This lead to FLEX 2.0 LIGHT with 17 indicators in total, a very easy and fast to use instrument to assess the adaptive capacity of a building. Figure 2 shows an example of a fictive assessment of a certain building with FLEX 2.0 LIGHT. Each of the 17 indicators has been given a weight relative to the other indicators (weighting 1 - 3). Also each indicator is assessed (assessment level 1 - 4). This leads to a score per indicator and summed up to a total Adaptivity Score. At the same way a theoretical minimum score can be found of 17 and a maximum score of 204. With these two borders a class table can be made with five different classes of adaptivity with the total range from 17 to 204.

FLEX LIGHT 2.0				WEIGHTING	ASSESSMENT VALUE				SCORE
LAYER	SUBLAYER	Nr.	FLEXIBILITY PERFORMANCE INDICATOR		Bad	Normal	Better	Best	
1. SITE/LOCATION		01(2)	Surplus of site space	1			3		3
2. STRUCTURE	**2.1 Measurements**	02(5)	Surplus of building space / floor space	2		2			4
		03(11)	Surplus free of floor height	3				4	12
	2.2 Access	04(17)	Access to building: location of stairs, elevators, core	2	1				2
	2.3 Construction	05(21)	Surplus of load bearing capacity of floors	3			3		9
		06(29)	Extendible building / unit horizontal	3		2			6
		07(30)	Extendible building / unit vertical	1	1				2
3. SKIN	**3.1 Facade**	08(42)	Dismountable facade	3				4	12
4. FACILITIES	**4.1 Measurement & control**	09(53)	Customisability and controllability of facilities	2	1				2
	4.2 Dimensions	10(56)	Surplus facilities shafts and ducts	2	1				2
		11(57)	Surplus capacity of facilities	3	1				3
		12(65)	Disconnection of facilities components	2			3		6
5. SPACE PLAN/FINISHING	**5.1 Functional**	13(70)	Distinction between support - infill (fit-out)	3		2			6
	5.2 Access	14(73)	Access to building: horizontal routing, corridors, gallery	1		2			2
	5.3 Technical	15(77)	Removable, relocatable units in building	3	1				3
		16(78)	Removable, relocatable interior walls in building	3			3		9
		17(79)	Disconnecting/detailed connection interior walls; hor/vert.	3				4	12
			Total Adaptivity Score:						**95**
			Adaptivity Class:						**3**

CLASS TABLE Adaptivity Scores	Score Range
Class 1: Not adaptive	17 - 54
Class 2: Hardly adaptive	55 - 92
Class 3: Limited adaptive	93 - 130
Class 4: Good adaptive	131 - 168
Class 5: Excellent adaptive	169 - 204

Figure 2: FLEX 2.0 LIGHT, a practical and easy to use light version of the assessment method with a limited number (17) of the most important indicators (Geraedts 2015)

In the example of figure 2 the total Adaptivity Score is 95. When looking up this score in the class table, the related Class = 3: the building is Limited Adaptive.

2.3 Matching Demand and Supply: Gap Analysis

With the instrument FLEX 2.0 LIGHT as described in paragraph 2.2 four assessment levels of the different flexibility indicators are possible from 1 = Bad to 4 = Best (see figure 3).

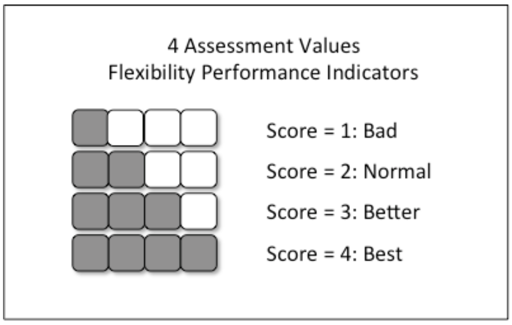

Figure 3: Visual representation of the four possible assessment values of the flexibility indicators, from 1 = Bad to 4 = Best (Geraedts 2014)

A very important aspect of this method is that owners and users of buildings can formulate a flexibility demand profile based on the chosen assessment flexibility indicators and compare this with the supplied building flexibility profile (see figure 4).

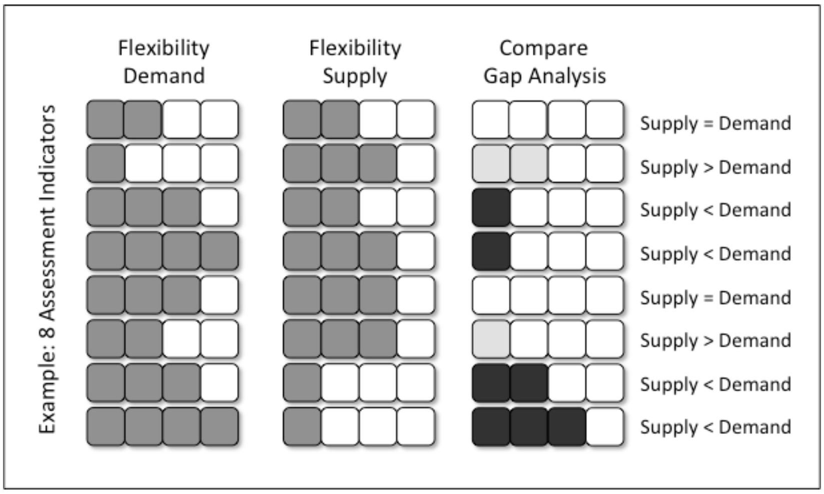

Figure 4: The comparison (gap analysis) between the demand for flexibility and the supplied flexibility in a building; in this example based on 8 flexibility indicators (Geraedts 2014)

3. Evaluation by Research in Practice

At the same time when FLEX 2.0 LIGHT was developed, the more extensive method FLEX 2.0 with 83 flexibility indicators was used in two separate research projects for an evaluation with specific experts in practice. One research project concerned the development of (high) school buildings (Carlebur 2015); the other project was related to the development of office buildings (Stoop 2015). The results of these research projects are briefly presented in the next paragraphs.

3.1 Adaptive School Buildings Determination Method

Methodology

The main research question in this school buildings project was as follows: which indicators determine the adaptive ability of educational real estate and how can these be implemented to create an assessment method which can review the current real estate, and can also be used as a standard for formulating the program of requirements? In order to answer these research questions three research methods were used: a literature review, a panel survey and a Delphi research. A panel of 30 professionals working in the educational sector contributed in this survey. The panel consisted of both users and owners and also experts from the developmental sector. The survey used 83 adaptivity indicators from FLEX 2.0 and the experts reviewed the indicators on their importance for adaptive building in the educational sector (Carlebur 2015).

Results

The experts of the educational sector selected 21 of the most important flexibility performance indicators. They also ranked the indicators based on their importance for increasing the adaptivity of the educational real estate (high school level). Figure 5 shows an example of a fictive assessment of a certain high school building. Each of the 21 indicators has been given a weight relative to the other indicators (weighting 4 - 1). Also each indicator is assessed (assessment value 1 - 4). This leads to a score per indicator and summed up to a total Adaptivity Score (121 in the example). At the same way a theoretical minimum score can be found of 55 and a maximum score of 220. Within these two borders a class table can be made with four different classes of adaptivity (see figure 5). When looking up this score in the class table, the related Class = 2: the school building is Hardly Adaptive.

EDUCATIONAL REAL ESTATE			WEIGHTING	ASSESSMENT VALUE				SCORE
LAYER		FLEXIBILITY PERFORMANCE INDICATOR		Bad	Normal	Better	Best	
CONSTRUCTION	1	Positioning obstacles / columns in load bearing structure	4	1				4
	2	Extendible building / unit horizontal	4				4	16
	3	Extendible building / unit vertical	4		2			8
	4	Rejectable part of building / unit horizontal	4			3		12
	5	Access to building; location of stairs, elevators	4				4	16
	6	Surplus of building space / floor space	3	1				3
	7	Surplus free floor height	3		2			6
	8	Measurement system; modular coordination	3	1				3
FACILITIES	9	Overdesign/surplus of facilities (E, H, ICT)	4			3		12
	10	Modularity of facilities	3		2			6
	11	Customisability and controllability of facilities	3	1				3
	12	Disconnectability of facilities components	1		2			2
SKIN	13	Day light facilities	2				4	8
	14	Location and shape of daylight facilities	2		2			4
	15	Facade windows to be opened	1				4	4
SPACE PLAN	16	Distinction between support - infill/fit-out	3	1				3
	17	Removable, relocatable interior walls in building	2		2			4
	18	Disconnecting/detailed connection interior walls; hor./vert.	2	1				2
	19	Multifunctional building	1			3		3
	20	Horizontal routing, corridors, access	1	1				1
SITE	21	Expandable site / location	1	1				1
							Total Adaptivity Score:	121
							Adaptivity Class:	2

CLASS TABLE EDUCATIONAL REAL ESTATE Adaptivity Scores	Score Range
Class 1: Weak. Not adaptive	55 - 92
Class 2: Moderate. Hardly adaptive	93 - 132
Class 3: Acceptable. Limited adaptive	133 - 172
Class 4: Good adaptive	173 - 220

Figure 5: Example of the fictive assessment of a certain school building, the total Adaptivity Score (121) and the Adaptability Class (2) of the school concerned (Carlebur 2015)

3.2 Adaptive Office Buildings Determination Method

Methodology

This research by Stoop was founded on two perspectives: on the one hand the current context of the office market (vacancy) and on the other hand the absence of a practical and manageable measuring instrument to assess the adaptive capacity of office buildings. The goal of this research project was to elaborate the method from FLEX 2.0 into a manageable version for the office sector with the focus on two research questions: which indicators of the FLEX 2.0 method characterise the adaptive capacity of office buildings? What does an instrument that measures the future value of office buildings based on these indicators look like? To answer these questions, different research methods have been used: a literature study, interviews with experts from practice and a test in two pilot cases.

OFFICE BUILDINGS			SPECIFIC PRIORITY	
LAYER	NR	FLEXIBILITY PERFORMANCE INDICATOR	TRANS	USE
SITE/LOCATION	1	Multifunctional location	x	x
	2	Expandable location	x	
STRUCTURE	3	Building entrance, location of elevators, stairs, cores	x	x
	4	Positioning pipes and shafts	x	x
	5	Storey height	x	x
	6	Insulation between stories and units	x	x
	7	Bearing capacity of floors	x	
	8	Column layout	x	x
	9	Positioning obstacles supporting structure	x	x
	10	Availability of stairs and elevators	x	x
	11	Expanding / reusing stairs and elevators	x	x
	12	Division support - infill		x
	13	Fire resistance supporing structure	x	
	14	Oversized building space/surface	x	
	15	Available floor area	x	x
	16	Size of storey		x
	17	Horizontal grid size	x	
SKIN	18	Daylight entry	x	x
	19	Openable windows	x	x
	20	Insulation facade	x	
	21	Dismountable facade	x	x
SERVICES	22	Overdimensioning capacity installations	x	x
	23	Measurement and control technology		x
	24	Overdimensioning pipes and shafts		x
	25	Location of the supplying installations (heating, cooling)		x
	26	Independance user units		x
	27	Adjustable and controlable installations		x
	28	Distribution / modularity installations	x	x
	29	Distribution heating and cooling installations		x
	30	Dismountable facility components	x	x
SPACE PLAN	31	Accessible facility components	x	x
	32	Horizontal routing, corridors, units	x	x
	33	Detailing joints inner walls - horizontal/vertical		x
	34	Possibility suspended ceiling		x
	35	Possibility elevated floor		x

Figure 6: The 35 most important flexibility indicators for office buildings (Stoop 2015)

Results

In figure 6 the presented indicators characterise the adaptive capacity of office buildings. The first column represents the layers that cluster the indicators. According to Brand these layers distinguish themselves by different life spans (Brand 1994). The second column shows the 35 most important indicators of the adaptive capacity of office buildings. The next two columns address the specific priority of that indicator: Transformation Dynamics (the capacity of a building to react to a change demand of the building function) or Use Dynamics (the capacity to react to a change in user demands). In contrast to FLEX 2.0 LIGHT and a similar instrument for educational real estate as described in paragraph 3.1, the instrument for office buildings does not use a weighting factor between the different flexibility indicators, nor calculates a final flexibility score.

4. Next generation: a new framework for FLEX 3.0

At this moment three different instruments are more or less derived from FLEX 2.0 (the one with the original 83 flexibility performance indicators). In figure 7 these three instruments are presented and combined with each other:

1. FLEX 2.0 LIGHT with 17 indicators and generally applicable (Geraedts 2015),
2. An Assessment instrument for school buildings with 21 indicators (Carlebur 2015),
3. An Assessment instrument for office buildings with 35 indicators (Stoop 2015).

FLEX 3.0 COMBINATION 3 ADAPTABILITY ASSESSMENT INSTRUMENTS				INSTRUMENT			DYNAMICS		
LAYER	Sub-layer	Nr	Flexibility Performance Indicator	Light	Schools	Offices	T	U	
1. SITE		1	Surplus of site space	x			x		
		2	Expandable site / location		x	x	x		
		3	Multifunctional site / location			x	x		
2. STRUCTURE	Measurements	4	Surplus of building space / floor space	x	x	x	x	x	1
		5	Available floor space of building			x	x	x	
		6	Size of building floors			x	x	x	
		7	Surplus free of floor height	x	x	x	x	x	2
		8	Measurement system; modular coordination		x		x	x	
		9	Horizontal zone division / layout			x	x	x	
	Access	10	Access to building: location of stairs, elevators, core building	x	x	x	x	x	3
		11	Presence of stairs and/or elevators			x	x	x	
		12	Extension / reuse of stairs and elevators			x	x	x	
	Construction	13	Surplus of load bearing capacity of floors	x		x	x		
		14	Shape of columns			x	x	x	
		15	Positioning obstacles / columns in load bearing structure		x	x	x	x	
		16	Positioning of facilities zones and shafts			x	x	x	
		17	Fire resistance of main load bearing construction			x	x		
		18	Extendible building / unit horizontal	x	x		x		
		19	Extendible building / unit vertical	x	x		x		
		20	Rejectable part of building / unit horizontal		x		x		
		21	Insulation between stories and units			x	x	x	
3. SKIN	Facade	22	Dismountable facade	x		x	x		
		23	Facade windows to be opened		x	x	x	x	
		24	Day light facilities		x	x	x	x	
		25	Location and shape of daylight facilities		x		x	x	
		26	Insulation of facade			x	x		
4. FACILITIES	Measure & Control	27	Measure and control techniques			x	x	x	
		28	Customisability and controllability of facilities	x	x	x	x	x	4
	Dimensions	29	Surplus of facilities shafts and ducts	x	x	x	x	x	5
		30	Surplus capacity of facilities	x		x	x	x	
		31	Modularity of facilities		x	x	x	x	
	Distribution	32	Distribution of facilities (heating, cooling, electricity)			x	x	x	
		33	Location sources of facilities (heating, cooling)			x	x	x	
		34	Disconnection of facilities components	x	x		x	x	
		35	Accessibility of facilities components			x	x	x	
		36	Independence of user units			x	x	x	
5. SPACE PLAN	Functional	37	Multifunctional building		x		x		
		38	Distinction between support - infill (fit-out)	x	x	x	x	x	6
	Access	39	Access to building: horizontal routing, corridors, gallery	x	x	x	x	x	7
	Technical	40	Disconnectible, removable, relocatable units in building	x	x		x		
		41	Disconnectible, removable, relocatable interior walls	x	x		x	x	
		42	Disconnecting/detailed connection interior walls; hor/vert.	x		x	x	x	
		43	Possibility of suspended ceilings			x	x	x	
		44	Possibility of raised floors			x	x	x	
				17	21	35	44	32	

Figure 7: FLEX 3.0, the integral combination of the three developed instruments to assess the adaptive capacity of buildings with 44 flexibility performance indicators in total

Next to the ‘Instrument’ column the ‘Dynamics’ column is shown. The ‘T’ stands for Transformation Dynamics, the capacity of a building to react to a changed market demand of the building function from an owner’s point of view. The ‘U’ stands for Use Dynamics, the capacity of a building to react to a changed user demands from a users point of view.
This new FLEX 3.0 framework has in total 44 flexibility performance indicators that are all applicable for assessing the transformation dynamics while 32 of them are also suited for assessing the user dynamics of a building. Figure 7 also shows the seven general applicable flexibility performance indicators (most right column). They can be used for each type of real estate. The other 37 more specific indicators can be used for the assessment of specific real estate like schools or office buildings.

4.1 Support - Infill theory for a generic assessment instrument

This paragraph formulates an additional point of view on the gained results so far for explaining the potential future development. Habraken developed in the sixties a theory to distinguish construction components by different life spans (long and short life cycles), by different decision levels (community or individual), by different building levels (urban tissue, support, infill), or by differences in dealing with components (fixed or variable components). This is also known as the so-called Support-Infill theory (Habraken 1972). Similar to this theory it could be possible to distinguish flexibility performance indicators that are general applicable (on ‘support’ level for each building type (the seven indicators in the most right column of figure 7) and the other 37 indicators (on ‘infill’ level) that are more specific for a special type of real estate; in this case school buildings or office buildings. Further research in the near future will be necessary to elaborate this theory further and to develop the next version of this flexibility assessment instrument to be very useful in practice (FLEX 3.0).

5. Conclusions

In 2014 report was given of an extensive international literature survey and the development of a method to determine the adaptive capacity of buildings (Geraedts 2014). In total 147 flexibility indicators were described with accompanying assessment values. The most important recommendation for the next step was the development of an easy to use assessment method in practice with a limited number of important adaptability performance indicators. Further research led in 2015 to a renewed assessment method with 83 indicators, clustered in five layers with different life cycles. This method was called FLEX 2.0 and a so-called FLEX 2.0 LIGHT derived version with only 17 of the most important indicators (Geraedts 2015). At the same time in two separate research projects this method was used for an evaluation with experts in practice. One research project concerns the development of school buildings (Carlebur 2015), the other project relates to the development of office buildings (Stoop 2015).
In this paper the three different instruments derived from FLEX 2.0 are described and combined with each other to model the frame for the next version of a general and easy to use instrument to formulate the demand for adaptability on the one hand and assess the supply of the adaptability of buildings on the other hand: FLEX 3.0.

One of the main conclusions of this research project is that real estate experts from practice found the developed methods very useful. Furthermore, more additional research is required to improve the concept. One very good applicable development will be based on Habrakens support and infill theory as explained in the conclusions before (Habraken 1972).

Also financial effects of the costs and benefits of flexibility measures will have to be subject of further research, especially to convince owners and developers of buildings. Some indicators probably require lower initial investments than others. The relation between the investments and the extent of adaptive capacity will have to be studied, with a better judgement about the financial consideration to invest in adaptive capacity as a result.

Finally the assessment values of the indicators were not taken into account in this research. It would be interesting to evaluate if the assessment values are still valid, or if they should be strengthened or expanded. Weighting factors could be linked to the assessment values. Then it would be possible to work towards a certification of adaptive capacity.

References

Beadle, K., Gibb, A., Austin, S., Fuster, A., Madden, P. (2008). "Adaptable futures: sustainable aspects of adaptable buildings", *Proceedings 24th Annual ARCOM Conference 2008,* A. Dainty. Cardiff, UK.

Berg, H. C. v. d., Noorman, Th.M. (1981). *Design an adaptable building* - Een aanpasbaar gebouw ontwerpen, SBR 82, Stichting Bouwresearch: 95, Deventer, The Netherlands.

Brand, S. (1994). *How buildings learn; what happens after they're built*. Viking, New York, USA.

Carlebur, O. F. D. (2015). *Adaptive School Buildings Determination Method* - Adaptief onderwijsvastgoed; Beoordelingsmethode voor schoolgebouwen, Delft University of Technology, Delft, The Netherlands.

DGBC (2013). *Concept flexibility assessment module*. Dutch Green Building Council, Rotterdam, The Netherlands.

Geraedts, R. (1989). *Dividable support structures and costs* - Verkavelbare Dragers en Kosten, SBR, Stichting Bouwresearch, Rotterdam, The Netherlands.

Geraedts, R. (1998). *Communication about and assessment of flexibility between buildings and facilities Flexis* - Communicatie over en beoordeling van flexibiliteit tussen gebouwen en installaties, Stichting Bouwresearch: 68, Rotterdam, The Netherlands.

Geraedts, R. (2001). "Upgrading the flexibility of buildings", *Proceedings CIB World Building Congress 2001*, Wellington, NZ.

Geraedts, R. (2009). “Future Value of Buildings”, *Proceedings 3rd CIB International Conference on Smart and Sustainable Built Environment*, A. v. d. Dobbelsteen, Delft University of Technology, Delft, The Netherlands.

Geraedts, R. (2013). *Adaptive Capacity - Literature Survey;* Adaptief Vermogen; brononderzoek - literatuurinventarisatie, Centre for Process Innovation in Building & Construction: 62., Delft, The Netherlands.

Geraedts, R., Prins, M. (2015). “The CE Meter; an instrument to assess the circular economy capacity of buildings”, *Proceedings CIB Going North for sustainability*. C. Egbu, London South Bank University: 10, London, UK.

Geraedts, R., Remøy, H., Hermans, M., Van Rijn, E. (2014). “Adaptive Capacity of Buildings; a determination method to promote flexible and sustainable construction”, *Proceedings UIA 2014 Architecture Otherwhere,* A. Osman, Bruyns, G., Aigbavboa, C., UIA 2014 Durban: 1054., Durban, SA.

Geraedts, R., Van der Voordt, T. (2007). “The New Transformation Meter; A new evaluation instrument for matching the market supply of vacant office buildings and the market demand for new homes”, *Proceedings Building Stock Activation* 2007, Tokyo, Japan.

Habraken, N. (1972). *Supports: an Alternative to Mass Housing*. Originally published in Dutch under the title: De Dragers en de Mensen. Amsterdam: Scheltema en Holkema, 1962, London: The Architectural Press; New York: Praeger.

Hermans, M., Geraedts, R., Van Rijn, E., Remoy, H. (2014). *Determination Method Adaptive Capacity of Building to Promote Flexible Building - Bepalingsmethode Adaptief Vermogen van gebouwen ter bevordering van flexibel bouwen*. Leidschendam, Brink Groep.

Houtsma, E. O. (1982). *Flexibility in Buildings* - Flexibiliteit in gebouwen; SBR C22-1. SBR, Stichting Bouwresearch. C22-1: 154, Rotterdam, The Netherlands.

REN (1992). *Real Estate Norm*, Stichting Real Estate Norm, Nieuwegein, The Netherlands.

Schneider, T., Hill, J. (2007). *Flexible Housing*, Architectural Press Elsevier, Oxford, UK.

Stoop, J. (2015). *Office up to date; development of an instrument to determine the adaptive capacity of office buildings* - Het ontwikkelen van een instrument om het adaptief vermogen van kantoren te bepalen, Delft University of Technology, Delft, The Netherlands.

Wilkinson, S. J., James, K., Reed, R. (2009). "Using building adaptation to deliver sustainability in Australia". *Structural Survey* 27(1): 46-61.