CHANGE OF USER AND FAÇADE ADAPTABILITY

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ABSTRACT

The mismatch between the dynamic society and static buildings can lead to problems, such as the creation of waste and deterioration of the neighbourhood, because of vacancy. Facilitating transformation can prevent such problems. This is why this research focusses on qualities a new façade should have to accommodate change of use of a building in the future. Literature research, case studies and interviews were used to find correlations between façade changes and the change of use. The changes were linked to solutions found in literature and evaluated. It was concluded that a facade that can accommodate change should have certain qualities, the design: makes use of scenario planning, has a good balance between different design considerations, meets the strictest regulations of all the functions and is modular, standardized, prefabricated and demountable. This conclusion is generally applicable and can help architects in creating a more circular economy by designing for change.

KEYWORDS: *FAÇADE, USER, CHANGE, FUNCTIONS, REQUIREMENTS, ADAPTABILITY*

I. INTRODUCTION

'*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*.' (WCED, 1987). To achieve this, the United Nations formulated 17 goals, which include among others climate action and responsible consumption and production (UN, 2020). The construction industry can have a big impact on achieving these goals, since it's responsible for 50% of the raw material consumption, 40% of the total energy consumption and the construction and demolition waste is responsible for approximately 35% of the CO2 emissions in the Netherlands (Nelissen et al., 2018). Creating a circular economy can reduce these numbers. Only 24% of the Dutch economy is currently circular, so there is a big gap to bridge towards a complete circular economy (CGRI, 2020).

Design for change is one of the key elements in creating a circular economy (CGRI, 2020). This is because society is dynamic; we experience physical, economical, functional, technological, social and legal changes (Schmidt & Austin, 2016, p. 48). Buildings can adapt to these developments and meet the demands of occupants, but this brings costs and material waste (Schmidt & Austin, 2016, p. 5-6). This can be reduced if buildings are designed to be adaptable. The problem is that: ''*Most modern and post-modern buildings and their constituent parts are not designed (and accordingly build) to change easily and building products were not designed (and manufactured accordingly) for recovery and reuse*.'' (Debacker & Manshoven, 2016, p. 18). This leads to costly and wasteful transformation projects. In these transformation projects the façade is often one of the highest cost items (Remøy & Van der Voordt, 2009). Lowering façade costs can therefore stimulate transformations and in this way vacancy can be avoided. This is important since vacancy creates economic and social problems, such as income loss for the owner and social uncertainty. This causes the area as well as the building to deteriorate (Remøy & Van der Voordt, 2007). This is why it is important to design façades in a way that function change can easily take place. Literature on possible design criteria for adaptable buildings is already available (Remøy & Van der Voordt, 2009; Bikker, 2016; Nakib, 2010; Sprengers, 2015; Geraedts & Remøy, 2013), but this literature often does not make clear which changes really play an important role in relation to function change and how applicable the criteria are in practice. This will be further explored in this paper, which brings us to the main research question; '*What qualities should a new façade have to accommodate change of use of a building in the future?*'

II. METHODS

The goal of this research is to determine what qualities a façade should have to accommodate change of use of a building in the future. The focus is on buildings with a concrete multistorey skeleton construction, because in this way the results will be applicable to the building 'De Knip' in Amsterdam, which is the location of the design project that this research will support. In this design project the building will be designed to function as a neighbourhood connected within the city. This neighbourhood accommodates the following main functions: housing, offices and educational facilities. That is why this research will also limit itself to these functions.

To answer the main question this paper starts by answering the following sub question; '*What kind of changes occur in the facade when a building is transformed to accommodate a different function?'* The first step in answering this sub question is to create a general overview of the functions of a façade. In this paper the façade function tree of Tillman Klein (2013, p. 112, 113) is used as an overview of façade functions (Appendix 6). He divided the main function; *"a separating and filtering layer between outside and inside, between nature and interior spaces occupied by people*" (Herzog et al., 2017, p. 19), into primary, secondary, supporting and detailed supporting functions. The primary functions include: creating a durable construction, allowing reasonable building methods, providing a comfortable interior climate, responsible handling in terms of sustainability, support of the use of the building and the spatial formation of the façade. This serves as a base to investigate the building code, literature and case studies. The building code as well as literature on function neutral buildings and differences between functions regarding the interior climate or dimensions give direct insights into the façade changes in differing functions. Case studies are used to fill gaps and add to the information found in the building code and literature. The case studies meet the following set of requirements;

Requirement	Explanation
Derived from the submissions from the National Renovation Platform (NRP) Gulden Feniks	The National Renovation Platform is a foundation that promotes the sustainable reuse of existing buildings. Each year a competition is held where renovated, transformed buildings and transformed areas are evaluated on sustainability, sublimation, economic value creation, social value creation and innovation. It is a requirement for the submissions of projects that in the opinion of the submitter the project meets the requirements for this prize (NRP, n.d.). This indicates that the case studies used have been successful in the eyes of the developer, owner or designer of the building.
Located in the Netherlands	The same requirements apply for each of the case studies, such as requirements related to climate, legislations, but also those related to culture.
Have a multistorey skeleton construction, preferably concrete	The found conclusions relate and can be implemented in the design project 'De Knip'.
Transformed after 2012	In 2012 a new building code was installed. This criterium also ensures that the used projects are recent.
Build between 1950-1990	A lot of multi-year vacant offices are available from this time period (Voordt, 2007, p. 215). Besides, these buildings were all build in the modernistic or post modernistic time period (Austin & Schmidt, 2016, p. 9) and have similar typologies. 'De Knip' was built in 1990 and thus also falls within this time range.

Table 1. Case study requirements (source: own)

Sections, floorplans and pictures are analysed on the basis of the overview of façade functions. During this analyses it is important to investigate the correlation between the found façade changes and function change and try to exclude other parameters, such as technological developments. In order to deepen the analysis and to better distinguish between why certain changes took place, I found four architects willing to participate in interviews on the case studies. In addition to this and to get a general overview of façade transformations an interview will be conducted with an expert in the field of façade transformations and the concept of Open Building. The combination of literature, case studies and interviews will clarify the important façade changes related to function change.

The second sub question incorporates the found façade changes of the first sub-question; '*How can be dealt with the changes that occur in a facade due to change of use of buildings?'*. Literature on function neutral buildings and adaptable or flexible buildings can shed light on the different possible solutions. An interview with an expert on the concept of Open Building can add new information to the literature and confirm if the literature is applicable to the architectural practice. Design criteria that could possibly accommodate the change of use are then linked to the different found façade changes and evaluated on appropriateness, which results in a list of general criteria for a façade that can accommodate change of use.

III. RESULTS

III.I Façade changes related to change of use

This sub-question discusses the changes that occur in the façade when a building is transformed to accommodate a different user. The functions of the function tree (Appendix 6) serve as a guideline during the research and the changes found in these functions are discussed in this chapter. Analysed functions that showed no significant relation to the change of use will not be discussed, but an overview of the different functions that were analysed can be found in the appendix (8), as well as the analyses of the case studies (Appendix 11). The case studies and the interviewees have been numbered and alphabetized (see table 2 and 3) and incorporated in the text so that the conclusions drawn can easily be traced.

Case study *Project name, street, city*	**Before transformation** *Architect, building date, function*	**After transformation** *Architect, transformation date, function*	**Number**
Bellavista, Thorbeckelaan 360, The Hague	P. Zanstra, 1968, offices	Rijnboutt, 2014-2016, housing	1
Luna, De Lampendriessen 31, Eindhoven	S.J. van Embden, 1957-1965, education	Diederendirrix, 2014-2017, housing	2
Van Vollenhovenstraat, Rotterdam	H. D. Bakker, 1968-1971, offices	RoosRos, 2018, housing	3
Schubertsingel 32, Den Bosch	Unknown, 1977, offices	Houben/Van Mierlo, 2015-2018, housing	4
Floor Amsterdam, Wibautstraat 80, Amsterdam	F.J.E. Dekeukeleire, 1961, offices and education	Penta Architecten, 2019, housing	5
Lighting, Victoriapark, Eindhoven	Unknown, 1980, offices	Diederendirrix, 2016, housing	6
Wijnhaven-kwartier, Turfmarkt 99, The Hague	Architectenbureau Lucas en Niemeijer, 1973, offices	Geurst & Schulze, 2016, housing/ education	7

Table 2. Overview of case studies (source: own)

Case study	Function	Letter	Appendix
1	Project coordinator at Rijnboutt	A	1
3	Architect at RoosRos Architecten	B	2
4	Architect and project leader at Houben/Van Mierlo Architecten	C	3
7	Architect and partner at Geurst & Schulze Architecten	D	4
	Professor of Architectural Engineering, jury at NRP Gulden Feniks and expert on Open Building	E	5

Table 3. Overview of interviewees (source: own)

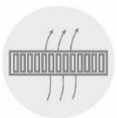
Creating a durable construction

One of the barriers when changing to a different user can be the weight of the façade. This aspect has a strong relation with the structural layer of the building. Offices and educational constructions are often designed for higher loads then residential constructions. This makes transformation from offices to dwelling for example easier (C). Still it became clear during the interviews that weight can be a barrier from offices to dwellings as well. There are different design parameters that have an effect on this barrier: the choice of materials (7), the addition of balconies (1,7), the dimensions of the original construction (7), the aspiration to create additional levels on top of the building (4, 7) and the positioning of the façade relative to the construction (4). The addition of balconies is strongly related to the change of function and the choice of materials can also depend on the change of function. This gives the weight of the façade a situation dependent relationship with the change use.

Provide a comfortable interior climate

The comfortable temperature range differs for each function. In residential buildings, the occupants must be able to feel comfortable with no fixed place, sitting for several hours wearing seasonal clothing. This leads to a minimum comfortable temperature of $20\,^{o}$C and a maximum temperature of $\theta_e+3\,^{o}$C when natural ventilation is applied. This is similar for office spaces, but with fixed places and a maximum temperature for mechanical ventilation of $25\,^{o}$C. For classrooms, the space must be acceptable for people who sit in a room for a maximum of 30 to 45 minutes in seasonal clothing. This leads to a minimum temperature of $18\,^{o}$C and with maximum temperatures that are the same as for offices and housing (Schalkoort, 2009). The impact of temperature regulation for the façade is among others noticeable in the control of the air exchange rate, possible building services integrated in the façade and radiation control of daylight. These elements will be discussed below.

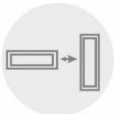
Ventilation has a strong relation with the change of use. Residential buildings often have natural ventilation with mechanical exhaust, but in high-rise residential buildings mechanical supply and exhaust is most suitable (Van der Linden et al., 2015, p. 98). Residential buildings have a low ventilation rate of approximately 2 to 4 h^{-1}. Offices mostly use mechanical ventilation and have a higher ventilation rate of 3 to 6 h^{-1}. For schools mechanical ventilation is preferred, but natural ventilation with mechanical extraction is also possible when costs need to be kept low. The ventilation rate in classrooms should be between 4 and 6 h^{-1} (Schalkoort, 2009). Important parameters for choosing natural ventilation in residential buildings in contrast to the mechanical ventilation used in offices are: the costs, personal control and occupancy of the space (E). When looking at the case studies, the office buildings did not have the possibility to open windows, but the educational and residential buildings did, even when the buildings had mechanical air supply and exhaust (1, 4, 7). The possibility to open windows is thus a very important aspect when it comes to function change, regardless of the ventilation type.



The choice for complete mechanical ventilation in the dwellings is related to the height of the buildings (1, 7), the available budget and noise pollution (4). To the dwellings with natural air supply, ventilation grilles where added (2, 3, 5, 6). Ventilation grilles are therefore also related to the change of use of a building.

When it comes to heating and cooling, residential buildings often use central heating, including radiators or convectors, floor and ceiling heating is also possible. The temperature in modern offices is often regulated through the air systems; the offices from the case studies are more dated and often used radiators placed next to the façade. Educational buildings often use central heating, similar to residential buildings and are sometimes locally cooled (Schalkoort, 2009). The fact that residential buildings and schools often use radiators can impact the façade, since a higher parapet might be applied. The investigated case studies contradict this relation: here the offices have higher parapets and the dwellings have windows from floor to ceiling often with floor heating. The contradiction might be caused by the following parameters: change in technologies, the need for more daylight and visual comfort. This gives heating and cooling an indirect and weak relationship to the change of function.

Daylight has a very strong relationship to the change of function. Dwellings have a minimum requirement of 10% daylight surface per floor surface of the residential area (Dutch Building Decree, 2012). The daylight calculations for residential buildings are very important; it is often a balancing act between legal frameworks and money (E). An optimum is sought to have enough daylight enter the building, but to create good isolation as well. Furthermore, the choice of the amount of daylight surface is influenced by the budget, since glass surfaces are more expensive compared to opaque surfaces. Office buildings often have higher profits than residential buildings and therefore more money can be invested in the façade, which provides some freedom in the choice of open surfaces. In addition, offices have much broader rules when it comes to daylight entry (E). For offices a minimum of 2,5% daylight surface per floor surface of the residential area applies and for educational buildings 5% (Dutch Building Decree, 2012). The daylight surface also strongly relates to the depth of the space plan. The depth of dwellings is often a maximum of 8 meters when sun enters from one side of the building and 16 meters when the sun enters from two opposite sides. Offices often vary from 12,6 meters to 20 meters in depth (Sprengers, 2015, p. 54), but depths of 14,4 meters are most common (Van der Voordt, 2007) and classrooms are on average 7,2 meters deep (Neufert, 2012, p. 308). For transformations from offices to dwelling this can form the need to create more daylight surfaces, which was also concluded from the case studies. However, not all buildings showed an increase in daylight surface. One case study (2) had a curtainwall construction, which can form a barrier when it comes to connecting partitioning walls (Van der Voordt, 2007, p. 219). Thus, closed surfaces had to be added, which reduced the daylight surface. This parameter is also strongly related to the change of function.



The arrangement of windows also has a relation with the change of use. In almost all the case studies (1, 3, 4, 5, 6, 7) the window arrangement changed from a horizontal arrangement with a high parapet, to a vertical arrangement where the window reached from floor to ceiling. This change can be based on multiple parameters. The requirements of the aesthetics committee can determine the arrangement of the window (3); the connection to the context can play an important role in this as well (3,7). It could also be related to the style of the architect (1). All these parameters have little connection to the change of use of the building, but there are parameters with a strong connection too. For example, a horizontal arrangement would already be interrupted by the vertical arrangement of doors for access to outside space in the case of residential buildings (D). Another reason could be the increase of social control, by making it possible to easily view the street from a window (B). In addition, it could increase the visual comfort of the occupant being able to look outside from a couch (A, B, E). Finally, the arrangement of the stuff, in particular desks, can impact the placement of the bottom of a window. Offices and educational buildings place desks next to the facade which can create a less pleasant view from the perspective of the street on the higher floors. These parameters are all strongly related to the change of function, which makes the arrangement of windows an important change.

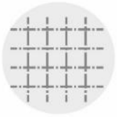
Protection from direct sunlight has a relation to the function a building accommodates as well. For offices and educational buildings it is more important to have protection from direct sunlight then it is for dwellings (E). The personal control of direct sunlight in dwellings seems to be an important parameter. Although only two of the projects had fixed sunblind’s before the transformation (2, 7), the windows where placed more horizontal and deeper in the façades (1, 6) and window cleaner balconies where present that would block the sun (5, 7). After the transformation curtains and personally controlled electric sun blinds are used for protection from direct sunlight.

Support the use of the building

To support the use of a building it is necessary to create a safe environment of which fire protection is an important part. Buildings are obligated to have a fire resistant construction and resistance to fire breakthrough and fire transfer. Buildings where people spend the night, like housing, have stricter fire safety requirements than offices and educational buildings (Sprengers, 2015, p. 63).

Spatial formation of the façade

The spatial formation of the façade can be subdivided in the following secondary functions: responding to the urban context, representing the functional intention of the building and creating an appropriate interior perception. These features translate into design choices of arrangement, shape, proportion, scale, texture, colour, material and rhythm (Klein, 2013). These design choices depend on many different parameters and the relation with the change of function can strongly differ for each situation.



The rhythm of the façade has a strong relation with the structure of the building. The grid size for this structure can differ per function. Offices from the twentieth century mainly use grids of 1800 mm or a multiple thereof. Ground based dwellings often have a grid of 5400 or 6000 mm and apartments a grid of 5000 or 7500 mm, due to the application of underground parking (E). No standard grid has been found for schools, but it is plausible that a multiple of 1800 mm also works well for school buildings. The grid of the main structure can be subdivided in a secondary grid for the façade. The choice for the appropriate grid can be based on several parameters: standard window sizes, the grid choice of the original architect, the addition of doors and the possibility to connect partitioning walls. The last two parameters have a connection to the change of use. The case studies indicate that this connection is not very strong, because in most cases the grid of the original buildings seem to be preserved as much as possible (1, 2, 3, 5, 6). Perhaps a distinction can be made between the grid choice in new construction and the grid choice in transformation projects.

The relation between the choice in materials and the change of use is dependent on the situation. The following parameters are involved in the choice of materials: the context (1, 7), the aesthetics committee (3), a change of style, keeping the original image of the building intact (5), the weight of the materials (7), the available budget and the representation of the function of the building (4, 6). The last three parameters have a relation with the change of use. The influence of the use on the weight of the materials is important, because different functions are designed for different loads as is discussed earlier in this paper. The available budget can create a visible distinction between offices and dwellings. Office buildings bring higher profits for the investors, which creates the possibility to invest more money in the façade and use more expensive materials and details. This is actually one of the reasons that so many residential buildings use brick as façade material (E). Another reason that brick is often used in dwelling façades in the Netherlands is that this material is used in every city in the Netherlands; it is familiar and we feel at home when using brick (E). When looking at the case studies we see that in most of the projects the change of function was not an important element in the material decision. Interviewee D (Appendix 4) said during his interview: ''*I believe that it is not necessary for a façade to show the function of a building. People really like to live in industrial buildings for example, even though these buildings don't represent a housing function.''*. This indicates that the relation between the material choice and the change of function differs strongly for each project and depends on the ideas of the architect.

One of the functions missing in the function tree is providing accessibility between the inside and outside of a building. The addition of doors, galleries and balconies are the most important elements when it comes to representing the functional intention of residential buildings. For residential buildings that are newly constructed direct access to outside space is mandatory, with the exception of student housing and care facilities. The floor area should be at least 4 m^2 and have a width of at least 1.5 m. The outside space should be non-communal for houses with a surface of over 50m2 (Dutch Building Decree, 2012). When it comes to transformation projects it is possible to build housing without balconies, although it is not desirable (Sprengers, 2015). All the case studies, with the exception of the student housing project (2), seem to have paid attention to access to outside space. None of the case studies designed a balcony within the existing support structure, most likely because a lot of interior space is lost in this case. Three of the case studies (1, 5, 7) added a balcony outside of the load bearing structure, which is only possible when the existing support structure is dimensioned to handle the larger moment (Sprengers, 2015, p. 66). Two of the case studies added a French balcony (3, 6), possible reasons for such a solution are: the requirements of the aesthetics committee (3), cantilevered floors (Van der Voordt, 2007, p. 219) or the fact that the construction cannot handle the extra weight. The balconies can also change the façade when it comes to the orientation of the building. In three of the office to dwelling transformations the original building had the same façades on all sides, after the transformation the façades differ (1, 4, 5). We can conclude that balconies and their orientation have a strong relation with the change of use and help represent the functional intention of the buildings when it comes to dwellings.

We can in the end categorize the found changes according to their relationship to change. This categorization that is presented in table 4 gives an answer to the first sub-question; '*What kind of changes occur in the facade when a building is transformed to accommodate a different function?*'.

A strong relationship between the change of use and the façade function is visible	**There is a relationship, but there are other equally important parameters**	**Changes with an indirect or weak relationship**	**Changes where the relationship depends on the context and the ideas of the architect**
Access to outside space	Ventilation grilles	Heating and cooling	Weight
Openable windows	Daylight surface		Material
	Visual comfort		Rhythm
	Sun protection		Arrangement
	Fire regulations		
	Budget		

Table 4. Conclusions on façade changes in relation to the change of use (source: own)

III.II Enabling future change of use

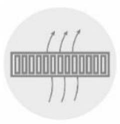
This chapter further explores how can be dealt with the changes that occur in a facade due to change of use of buildings. Thus, the goal is to make an adaptable façade. Adaptability can be defined as: ''*the capacity of a building to accommodate effectively the evolving demands of its context, thus maximising its value through life.''* (Austin & Schmidt, 2016, p. 45). Existing literature has formulated design criteria that can increase the capacity to adapt to different users (Appendix 9). For this research, the design changes found in the first sub-question and the design criteria found in literature where compared and evaluated. The results are discussed below.

Creating a durable construction

One of the changes found in the previous sub-question was the weight change of the façade when changing the use of the building. This change is related to the addition of balconies when a building is transformed to a residential building. No specific solution for the façade was found in literature, the solution of this problem lies more in over-dimensioning the capacity of the structure, which is mentioned as a long life design strategy by Austin and Schmidt and is strongly related to the change of use (2016, p. 111). This strategy increases the material use and costs when constructing the building, but can prevent demolishment and therefore materials and costs in the future.

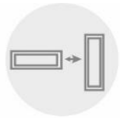
Provide a comfortable interior climate

Another change was from fixed windows for office buildings to openable windows for residential and educational buildings. Gereadts (2016, p. 572) states that the façade is most adaptable when 80%-100% of the windows can be opened. This solution can increase the capacity to provide options for the users in time by adding extra components (Austin & Schmidt, 2016, p. 93). Despite this being the optimal solution for adaptability, other design considerations need to be taken into account. Costs are often an important obstacle when it comes to designing an adaptable building and thus the purchase costs of openable windows could be problematic. However, even though the initial costs are higher, the possible financial benefits during the further lifespan of the building can be significant, which is often not considered (Austin & Schmidt, 2016, p. 6). So it may ultimately be beneficial to have higher initial costs. Another design consideration to take into account is the maintenance of the openable windows. Moving parts in buildings often require more maintenance and have to be replaced sooner than static parts. In this case, making it possible to open every window in the building contradicts the goal of designing an adaptable building, namely the circularity. It is hard to decide what percentage of openable windows should be applied to create an optimum balance. This can differ per context; in the case studies we see a wide variation in the percentage of openable windows ranging from approximately 30% to a 100%. To achieve a more precise estimation of the amount of openable windows that need to be designed, scenario planning for the specific location can be used and possible floor plans can be designed to see what would be logical locations for openable windows. In this way openable windows can be placed between, for example, every beech size or between gridlines. Another option could be to make the windows very modular and standardized, so that a closed window could easily be replaced by an openable window.



The multiple ventilation strategy (Austin & Schmidt, 2016) can be a solution for the change that can occur between natural and mechanical ventilation. This means that, just like openable windows, ventilation grilles in the façade must be standard. The same considerations concerning costs and maintenance apply here as do the possible solutions.

When it comes to daylight, the mentioned solutions are that it is preferred to have a daylight factor higher then 1/5 (Gereadts, 2016) or a daylight admittance of at least the regulations for housing (Remøy & Van der Voordt, 2009). When relating these solutions to the information presented in the first sub-question the second solution seems most suitable. This because insulation is taken into account as much as possible as well as the limited costs of housing construction.



The arrangement of the window shows a contradiction between the results found in the case studies and the possible solution found in literature. The solution for creating an adaptable building is to design a façade with large horizontal openings (Gereadts, 2016). However, this solution does not seem suitable, since the case studies change from a mostly horizontal arrangement to a vertical arrangement. Another possibility to accommodate this change is to create a modular design where horizontal and vertical arrangement can be easily alternated. To make the adjustments as simple as possible, standardization and prefabrication can be applied (Austin & Schmidt, 2016, p. 111).

No solutions for the control over the direct sunlight have been found, but its seems reasonable to assume that the most adaptable solution is to not install fixed sun blinds. Electrical sun blinds could be a solution, because they can be personally as well as collectively controlled.

Support the use of the building
When it comes to fire regulations the requirements for dwellings should be adhered to when creating a building that is as adaptable as possible.

Spatial formation of the façade
When looking at the design criteria, we can see that some of the criteria for the spatial formation of the façade are very open and subjective, for example: no 'office building look', attractive identity and entrances, a high spatial or visual quality issued by the design concept of the materials and colours used (Remøy & van der Voordt, 2009) and giving a building character (Ruimtelab, 2001). These elements are strongly related to the style and beliefs of the architect and the context of the building. A number of other criteria have been formulated more clearly.

One of these criteria is about the rhythm of the façade. Even though the change in the rhythm of the case studies was minor, change in space plans can be made more easily with a smaller grid size (Geraedts & Remøy, 2013), because this gives more connection possibilities for interior walls. A grid from 1800 proves to be beneficial for transformation projects (Remøy, 2007).

When it comes to materials it is questionable if solutions are even needed, as it might not be necessary to show the function of a building in the facade (D). But this is debatable since people often have a general idea or expectation of what different building uses should look like. When a building does not meet these expectations it can be disorienting or confusing (Zimring & Gross, 1991). During one of the interviews it was also mentioned that materials where chosen to create a sense of home (C), this indicates that some materials do not create a sense of home, which could be disadvantageous for the quality of a dwelling. But what solutions can then be used if materials have a relation to the change of function? According to the found literature materials of adaptable buildings should '*weather well and age gracefully*' (Leupen, et al., 2005) and the façade should have no 'office building look' (Remøy & Van der Voordt, 2009). These solutions still give no information on how the materials could connect well with the various functions. Creating modular construction and prefabricated, standardized façade panels could be a solution for this problem, so materials could be changed easily (Austin & Schmidt, 2016, 111).

In order to be able to add a balcony to a facade at a later stage in the buildings lifespan, it is important that a facade is dismountable (Sprengers, 2015, p. 66). In addition, it is important that the arrangement change of the building is considered in advance, because the verticality of the added doors can interrupt the arrangement (D). Other solution can be found in the design of the structure, such as over dimensioning the structure and preventing the use of cantilevered floors (Van der Voordt, 2007, p. 219).

Finally, the available budget was often mentioned as a change between functions. This simply depends on market forces and there is little that can be done about it. Perhaps a building that combines working and living can be a solution in this case.

The found changes and the final proposed solutions which are derived from the research of the paper are presented in table 5 (a more extensive table can be found in appendix 10), this also presents the answer to the second research question; '*How can be dealt with the changes that occur in a facade due to change of use of buildings?'*.

Importance	Change	Final proposed solution
A strong relationship	Access to outside space	Prevent cantilevered floors, design a demountable façade and overdesign the capacity of the structure
	Windows	Scenario planning, modular and standardized design
A relationship	Ventilation grilles	Scenario planning, modular and standardized design
	Daylight	Daylight admittance at least according to building regulations of housing
	Visual comfort	Modular, prefabricated and standardized design
	Personal control of sun	Electrical sun blinds that can be personally as well as collectively controlled
	Fire resistance	At least according to building regulations of housing
	Budget	A building that combines different functions
A relationship that is dependent on the situation	Weight	Overdesigning the capacity of the structure
	The rhythm/grid	Choose a small grid of preferably 1800mm
	Material choice	Modular, prefabricated and standardized design

Table 5. Proposed solutions (source: own)

IV. DISCUSSION

In this paragraph the results, the methods and their limitations will be discussed.

First, the research focuses on the facade, but the results already show that other building layers, such as the structure also play an important role. Solutions for access to outside space and changes in weight for example can be found in the structural layer of the building. This indicates that to create a well-functioning adaptive façade a more thorough investigation of the other building layers is needed.

Second, when it comes to the case studies, some of the results are based on assumptions. During the interviews with the architects of some of the case studies it became clear that assumptions I made during the analyses were not always correct. The choice of brick in the case study of the Vollenhovenkwartier for example seemed to have a strong connection to the change in function, but during the interview (B) it became clear that using brick was a requirement of the aesthetics committee. Thus, the research would have improved if all the architect were interviewed, since this would have created a better overview of the different design considerations. This is an important issue that relates to the small sample group.

Third, even when all the design consideration are clear, it is hard to pinpoint façade changes to the change in function, as was mentioned by interviewee B (Appendix 2)*: ''I would say that it is nearly impossible to say what exactly changes in the façade when function change occurs. That is very dependent on the situation and differs a lot for each project.''*. This also emerged during the investigation and therefore, the different changes and their solutions were divided between four different categories. The first category has a very strong relationship between the change of use and the façade change. In the second category the relationship is important, but other parameters also have an important role in the design considerations. The relationship of the third category strongly depends on the situation and the ideas of the architect. The last category includes the weak or indirect relationships. This categorization makes it easier to prioritize certain criteria during the design process.

It can also be questioned how important accommodating future functions in a façade is. Interviewee B (Appendix 2) for example said in his interview: *''I think the building designed now will still be habitable for the next 100 years.''* This also emerged in the interview with interviewee D (Appendix 4): ''*I believe that it is not necessary for a façade to show the function of a building.''*. However, not everyone shares this opinion and thus it can not be concluded that showing the function in the façade is not important. That is why it is important to investigate the possibilities on accommodating future functions in the façade so that during the design process the considerations can be taken into account and future materials and costs can be saved.

The results found are applicable to all transformation buildings involving housing, offices and educational buildings and are therefore fairly general applicable. When comparing the final conclusion to the results of the literature we can see a few differences. Some solutions found in literature were beneficial for creating adaptability, but took too few other design considerations into account. When it comes to the arrangement of the windows, we also saw that the found change contradicted the solution mentioned in literature. This indicates that the existing literature can be further investigated and improved. A start has been made in this paper by taking into account different factors, but there is still a lot of room for improvement. Further research can be improved by using more case studies and looking into other factors of change as well, such as technological or style changes.

V. CONCLUSION

The goal of this research was to answer what qualities a new façade should have to accommodate change of use of a building in the future. To answer this, the changes that occur in the façade when a building is transformed to accommodate a different function were investigated. It was found that the possibility to open windows and access to outside space had a strong relationship with the change to dwellings. Many other changes in the façade were found during the research, but these changes are often determined by multiple parameters, of which not all are related to the change in function. In the following façade functions this was the case: weight, ventilation grilles, daylight surface, visual comfort, sun protection and the fire regulations. When it comes to the spatial formation of the façade, the material and rhythm, the relation to the change of function can play an important role, but seems to be very dependent on the context, the ideals of the architect, the budget, the design of the original building and the aesthetics committee.

These changes in the façade can be dealt with in different ways, which brings us to the second sub question. A few solutions found in literature were based on overcapacity, such as the maximalization of openable windows. But it is important to realize that other design parameters, such as costs and material use, are not integrated in the design when the focus is only on adaptability and that a balance should be found between the different parameters when applying this solution. Scenario planning can work as a tool for finding this balance. For other changes, the solution was to keep to the function with the strictest regulations as the basis in the design. When it comes to the spatial formation of the façade the solutions found in literature were less straightforward, but modularity, standardization, prefabrication and a demountable façade with a grid of 1800 mm could help accommodate change. From this we can conclude that a facade that can accommodate change should have certain qualities, the design: makes use of scenario planning, has a good balance between different design considerations, meets the strictest regulations of all the functions and is modular, standardized, prefabricated and demountable.

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APPENDIX

Appendix 1: Interview A – Project coordinator at Rijnboutt on Bellavista (08-12-2020)

What where the main barriers related to the façade when it comes to this project?

There were not a lot of barriers when it comes to the transformation of the façade in this project. The original façade had a prefab concrete parapet so it was very easy to remove the facade. Removing the concrete elements also saved a lot of weight, so a lot of weight could be added in the new facade, also in the form of balconies.

Which elements where changed on the basis of the change of function?

All the changes that we made we tried to make in keeping with the style of the original architect. To do this the residential tower located at the Conradkade in The Hague that Piet Zanstra also designed was analyzed and used as an example. This means the use of clean horizontal lines and a lot of daylight openings. We wanted to keep the parapets as low as possible in contrast to the original design, because it needs to be possible to look outside when sitting in your dwelling. We tried to meet the requirements for new construction of the building code and incorporated sun-resistant and acoustic glass. Installations (balansventilatie) are all resolved internally and therefore do not affect the façade.

The material choice was completely based on the style of the original architect and the context of the building, because the building is part of a bigger complex. The structure of the concrete is a little more refined though.

When it comes to the arrangement the horizontal lines of the original design where kept, but we also tried to keep the vertical lines (the connections of the walls to the façade for example) in one line.

What could have made the conversion easier when it comes to the façade?

I think the floor height and elements related to the construction are more important. A big challenge in this project was for example the stability walls, and the corridors in and around the core in relation to the dwelling depth.

Appendix 2: Interview B - Architect at RoosRos on the Vollenhovenkwartier (08-12-2020)

What where the main barriers related to the façade when it comes to this project?

The main barrier was the depth of the building in relation to the (possible) size of the windows. It was difficult to make bigger windows, because a concrete beam that stabilized the building took away a lot of the possible window height. That is why in the end we replaced the concrete beam with a smaller steel one to be able to let in more daylight.

Which elements where changed on the basis of the change of function?

When it comes to materials the choices where mainly based on the requirements of the aesthetics committee (welstandcommissie). The building was built during a period when the requirements where not that strict and therefore differs a lot from its context. Now the requirements are more strict and the building must better fit the context. I do think do that masonry fits well with residential functions, but it was not the main reason for the material choice.

The same goes for the arrangement of the façade. It was required that the windows had a vertical arrangement. In the end these where created in the form of French balconies because it was not possible to create other types of balconies, but we did want it to be possible for the residents to have the feeling of a balcony. So the choice was based on the aesthetics committee as well as living comfort.

What could have made the conversion easier when it comes to the façade?

I think it could have been made more flexible for the future if we build it in prefab, this was our first idea as well, but in the end it was cheaper to build on site. HSB inner surface all around is prefab though. I do feel like it would not be necessary to design it in a more flexible way, because I think the building designed now will still be habitable for the next 100 years.

I would say that it is nearly impossible to say what exactly changes in the façade when function change occurs. That is very dependent on the situation and differs a lot for each project.

Appendix 3: Interview C - Architect and project leader at Houben/Van Mierlo Architecten on Schubertsingel (11-12-2020)

What where the main barriers related to the façade when it comes to this project?

T*he barriers were considerable. It was of course an office building with gravel concrete elements that you saw a lot in the 1980s. The robust facade was ideal for the function and then the question arose whether we could make housing behind it. Initially, we looked at whether a large part of the facade could be preserved for this, more like in a renovation project. The client wanted to tackle it more thoroughly so that it would be usable for a longer time and get a second life. This asks for qualitative better dwellings. That is why we removed the entire façade. In the building relatively heavy partitioning walls made of brick where present. Also the façade elements were very heavy. The building has a very special construction, first you have the basement and then on the main floor there are very heavy columns with ring beams. It is a kind of table construction. The grid of the load bearing structure was an important theme when it comes to transforming the façade. All forces on the facade go to the ring beams and the underlying columns. On the edge beams the consoles of the window-cleaning balcony connected. We have partly added these balconies to the interior of the building. We did this on the east and north sides. We have retained the outdoor space on the sunny sides. We have also made the building slightly larger by hanging the facade elements in front of the consoles. To do this, a lightweight facade construction was required and we used micro concrete for this. The light facade was necessary, because the moment is increased by placing the facade outwards. The grid of the new façade is based on the supporting structure and is 5 meters. The added levels have a grid of 2,5 meters. We also wanted to make the crown clearly different from the original building. The added layers where possible, because of the removal of the heavy bricks. The quality of the original facade elements formed a barrier in preserving the original facade, because and they were not good enough for a high-quality residential facade.*

Which elements where changed on the basis of the change of function?

It is a deep building and the client wanted apartments of approximately 50 m2. This meant that there was little surface contact with the outside, so the facade should be as open as possible. We wanted to create as much air and light as possible.

What about the choice of materials?

We wanted to link the outer facade to the old one. Although it is not a monument, we thought it was an iconic building, so we wanted to keep the concrete look, but add more glass. We wanted to create a very warm atmosphere for the courtyard, which is more suited to a residential building. It had to have a lively look. That's why we also added a lot of stairs for meeting. The indoor space also ensures that residents without a balcony still have an outdoor space.

What can make conversion easier when it comes to the façade?

A construction that leaves room for adjustments, so no load-bearing walls. Sometimes you also have office buildings where the facade is load-bearing. This limits the possibility of making large openings in the facade. Offices must take a high load into account, because filing cabinets must be able to be placed, for example. This is much less with living. So when you would want to design a dwelling that can be transformed to an office you have to design for the loads of the office building. When it comes to materials; the more demountable the better.

Appendix 4: Interview D - Architect and partner at Geurst & Schulze Architecten on Wijnhavenkwartier (09-12-2020)

What where the main barriers related to the façade when it comes to this project?

This differs for each building and depends on the location, the period in time and the construction of the system. One of the barriers of this project was the construction, the building was build according to the so-calles jackblock system. This means that the building is erected by the means of jacks. Standardization was very important in the design as well as creating a light construction. In the design of the original building the context was ignored. In the new design we wanted to create a strong connection with the context and create a heavy façade from masonry and concrete. This was in the end not possible, because the construction could not handle the load.

Which elements where changed on the basis of the change of function? (mention the elements that were found in the analyses):

The materials of the building have no relation to the functions the building harbors. I believe that it is not necessary for a façade to show the function of a building. People really like to live in industrial building for example even though these building don't represent a housing function. The chosen materials in this project where completely based on the context of the building as well as the weight of the materials.

The main element that the change of function demanded was the addition of balconies. There were already window washer balconies present, but we wanted to create more functional balconies. A nice outdoor space is the most important.

When it comes to the arrangement of the building, the original building was designed in a horizontal manner because of technical reasons. In the parapet of the building where ventilation shafts present. Only after the jackblock system was finished the shafts where placed. These horizontal developments actually did not fit in the developments going on in The Hague at that point. That is why we changed the arrangement, to relate it better to the context. Another reason for the changed arrangement is that the doors needed for the balconies would also already break the horizontal arrangement. Finally, we wanted to limit the glass surface in order to insulate the building properly, so we had to include closed vertical surfaces.

What could have made the conversion easier when it comes to the façade?

The technical buildings systems are often hard to alter, to make holes in for example. Making it easy to add balconies, when it comes to weight could also help conversion.

Appendix 5: Interview E - Professor of Architectural Engineering, jury at NRP Gulden Feniks and expert on Open Building (10-12-2020)

What are the main barriers related to the façade of a building in conversion projects?

Money and the investment on a building are very important. Also the detachability. Load bearing façades can be a big barrier, in locating the barriers it is very important to make a distinction between load bearing and non-load bearing façade. Another important component is if the building is a monument and the regulation, these determine if you are allowed to make balconies for example. Other important elements are protected city view, the cultural value of the building or the architectural value and the author right of the architect.

Can a distinction be made between office and housing facades?

Offices have a different market dan residential buildings. The profit of the building is higher for investors in office buildings then in residential buildings. This makes it possible to spend more money on the façade of the building. The facades can be developed with more expensive materials and details. For residential building an important factor is how a facade can be constructed as cheaply as possible, that is why a lot of the time residential façades are executed in brick.

So the choice for brick is not chosen because it suits residential buildings best, but mainly because of the price?

Well, there are two sides to the choice for brick. A part of which is the appreciation of the material. We feel at home with using brick. All the cities in the Netherlands are made from baked material.

Another distinction is the rhythm of the façade. When you look at office building from the twentieth century, especially those from the 80s, the adaptability on the inside of the building was an important part of the design. In office buildings you mainly see grids from 1800mm. Low rise residential building often have a grid of 5400 of 6000mm. Apartment buildings often have to take into account an underlying parking space and therefore often have a grid of 5000mm or 7500mm. The rhythm of the facade is related to the adaptability of the supporting structure and the interior walls.

And how does the change of function relate to the visual comfort of the for example? During my analyses of the case studies I for example often saw a change from a horizontal arrangement to a vertical arrangement of the building.

Well if you sit on the couch for example I do think it is important for that you can see the street, this is also important when it comes to safety and social control. Fall-through protection must also be taken into account when changing to a vertical orientation of the window.

And what about the distinction between opening and closing parts of the façade?

Offices often have a completely closed system. This is related to the higher budget, they can invest in a good ventilation system. This is also important, because offices do not want to have sun and noise pollution. In dwellings there is less need for intensive ventilation and natural supply works, although sometimes this also has to be mechanically ventilated, because of noise pollution.

But was there not a problem with mechanical ventilation without the possibility to open windows when people in the 80s suffered from sick building syndrome?

Yes, but the ventilation system then where very closed, they have improved now.

Would you say that personal control is also an important factor when it comes to natural ventilation and the contrast in this between the different functions?

Yes, houses of course have more person control and when you are in an office it is more collective. You might one to open a window for example, while I would not want that.

What kind of characteristics/requirements/qualities are needed when designing a façade that can change functions easily?

View, whether or not you can apply natural ventilation, the light and the sun protection must be flexible. There must be a balancing act between money and legal frameworks. What is important for housing is the daylight calculations. What happens a lot in housing construction is that an optimum is sought between open and closed parts so enough daylight enters the building, but the isolation of the building is also good. Offices have much broader rules for daylight entry. What also has an impact is that open parts are more expensive than closed parts.

Important is the adaptability, the façade should be separated from the load bearing construction as much as possible. The frame, the grid, if there is a parapet or not. The rhythm is very important, is it horizontal or vertical.

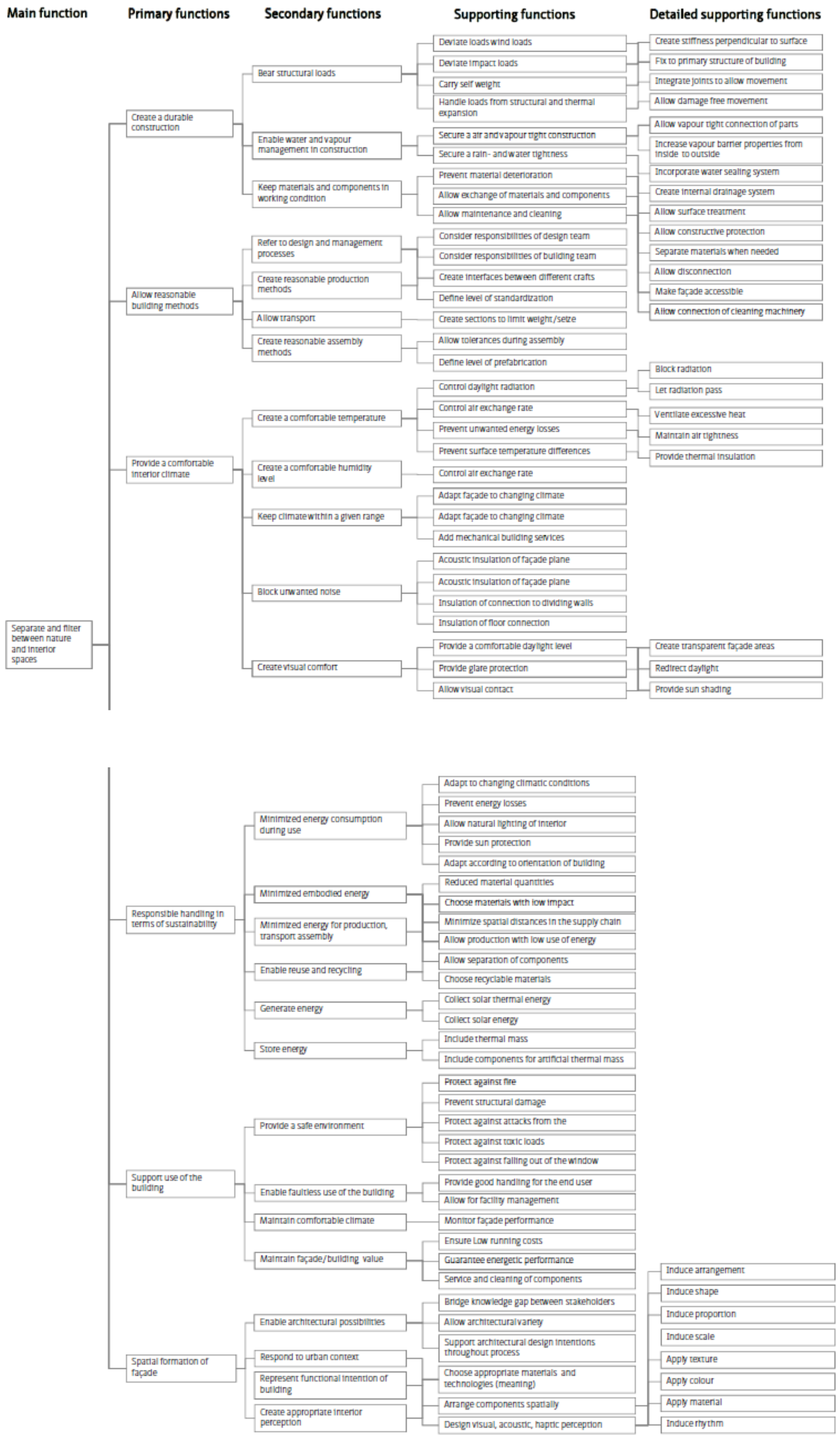
I think twentieth century offices have a clear typology. Office buildings from the 19th century did not have that. Dwelling have Homes have undergone a much more universal development. The dwelling in the city center in Delft are much different than the high rise flats outside of the city center that are more designed to change.

Fire resistance also has to do with it. 60 min fire resistance between one house and another, this is different for offices.

The research showed that many elements are less directly related to function change than I initially thought. An example of this is that the choice of material has a weak relationship with the change of function and, for example, is more prescribed by the aesthetics committee in some cases. What are your thoughts on this relationship?

I think that it is ultimately not the welfare committee that makes the final decision, but the architect.

Appendix 6: Function tree – Klein, T. (2013)



Appendix 7: Parameters of the different functions

Functions	Occupation	Occupancy class	Occupancy	Usable area per person	Floor area of living area pp
	Hours			*m2*	*m2*
Housing	00:00-24:00	x	x	x	x
Offices	08:00-18:00	B4	0,05	> 12 - ≤ 30	> 8 - ≤ 20
Education	08:00-18:00	B2	0,125	> 2 - ≤ 5	> 1,3 - ≤ 3,3
Source	*Own estimation*	*Bouwbesluit, 2012*	*Bouwbesluit, 2012*	*Bouwbesluit, 2012*	*Bouwbesluit, 2012*

		Type	tmin	tmax	vmax	system	Mechanical cooling	Ventilation rate	Ventilation	Opening windows
			ºC	*ºC*	*m/s*			*h-1*	*dm2/s pp*	
House		K	20	θe +3 ºC	< 0,25 m/s	I+IV		2 to 4	x	Yes
Office	Office	L	20	θe +3 ºC (max 25)	< 0,15 m/s	VII (+IX)	vaak	3 to 6	6,5	
	Canteen	G	18	θe +3 ºC (max 25)	< 0,25 m/s	VII	vaak	6 to 8	x	
	Conference room	G	18	θe +3 ºC (max 25)	< 0,25 m/s	VII(+IX)	vaak	4 to 6	x	
Education/school		G	18	θe +3 ºC (max 25)	< 0,25 m/s	VII of II+IV+VI	meestal	4 to 6	8,5	Sometimes
Source		*Schalkoort, 2009*	*Schalkoort, 2009*	*Schalkoort, 2009*	*Schalkoort, 2009*	*Schalkoort, 2009*	*Schalkoort, 2009*	*Schalkoort, 2009*	*Bouwbesluit, 2012*	

Functions		Privat-public	Daylight surface	Daylight surface	Min. depth	Max. depth	Beech size	Min. Height	Surface
		1 to 4	*min %*	*min m2*	*m*	*m*	*m*	*m*	*m2*
Housing		1	10	0,5	x	x	min 6,6 max 8,4	2,6	26 to 120
	Gallery	x	x	x	x	16	x	x	x
	Internal corridor	x	x	x	x	8	x	x	x
Offices		2	2,5	0,5	12,6	20	5,4 or 7,2 or 9,0	2,6	x
Education		2	5	0,5	x	7,2	10	2,6	65 to 70 per classroom
Source		*Own estimation*	*Bouwbesluit, 2012*	*Bouwbesluit, 2012*	*Sprengers, 2015*	*Sprengers, 2015; Neufert, 2012*	*Sprengers, 2015; Neufert, 2012*	*Bouwbesluit, 2012*	

Functions	Privat outside space
Housing	4 m2, width 1,5 m (with the exception of student or care homes)
Offices	x
Education	x
Source	*Bouwbesluit, 2012*

Appendix 8: Researched façade functions and their relation to the change of use

++	A strong relationship between function change and this façade function is visible, other parameters might also influence the design decision made for this function, but function change is one of the most important factors
+	There is a relationship visible between this façade function and function change, but it's equally important as other parameters
O	The relationship is between the change in the façade and the function change is indirect
-	The relationship between the façade function and the function change is significantly less important than other parameters that influence the design decisions for the façade function
--	There is no relationship found with the change of function
X	Change in the façade function was visible, but no relation was found with the change of function
N	No change was visible, but there is still a relationship visible

Type of change	**Bellavista (office to dwelling)**	**Luna (education to dwelling)**	**Vollenhovenkwartier (office to dwelling)**	**Schubersingel (office to dwelling)**	**Floor (education to dwelling)**	**Lighting (office to dwelling)**	**Wijnhavenkwartier (office to dwelling)**	**Wijnhavenkwartier (office to education)**	**Parameters of the design choice**	Notes	**Conclusion:** What **kind of changes occur in the facade when a building is transformed to accomodate a different function?**
Position of the facade in relation to the construction	x	--	--	+/-	-	x	-	-	• Cold bridges/isolation • Appearance of the facade		There is no relationship
Weight	+/++	--	--	--	--	--	+/++	+/-	• Dimensioning of the construction • Preferred materials (function change) • Balconies (function change) • Positioning of the façade (creating a greater moment)	Very dependent on the dimensions of the construction This aspect was only mentioned in the case studies where the new design had cantilever balcony	There is a relationship dependent on the situation
Possibility to open windows	++	N	++	++	N	++	++	++	• Mechanical ventilation • Personal control (function change)	The functions that transformed from education to dwelling already had the possibility to open windows	There is a very strong relationship
Ventilation grilles	N	++	++	N	++	++	N	N	• Mechanical ventilation • Hight of the building • Noise pollution		There is a relationship
Placement of services on façade	N	N	o	-/o	-/o	-/o	-/o	-/o	• Window surface height/parapet/daylight • Access to outside space • Sustainability • Aesthetics • Change of technologies		There is an indirect relationship and weak relationship

Daylight	+	+	++	+/++	+	++	+	-/+	• Good isolation • Money • Daylight norms (function change) • Depth of the floorplan (function change) • Relation with the style of residential building of the original architect (change of function) • Keeping the image of the original building • Make connections with indoor partitioning walls possible (indirect function change) • Visual comfort • privacy		There is a relationship
Visual comfort (window position/size)	+	-/N	-/+	+	-/+	+	-/+	-/+	• Aesthetics committee • Access to outside space (change of function) • Connection with the context • Social control/safety • Visual comfort from the couch (change of function) • No desk/desk (change of function)		There is a relationship
Sun protection	N	+	N	+	N	-/+	+	N	• Personal control • Bigger surface • Less deep placed/horizontal window		There is a relationship
Rhythm/grid	+	N	N	-	N (north) ++ (south)	N	+	-	• Connections of partitioning walls/space plan • Addition of doors • Design/rhythm of the original architect • Load bearing construction	The case studies seem to preserve the original rhythm as much as possible.	There is a relationship, but it is very dependent on the situation.
Context	o	--	-/o/+	--	+	--	--	--	• The material • The orientation of the balconies • Front doors/gallery side		Indirect and weak relationship dependent per situation.
Arrangement	+	-	+	+	N North + South	+	+	+	• More refined (function change) • Aesthetic committee • Access to outside • Load bearing construction	See visual comfort	There is a relationship, but it is very dependent on the situation.
Materials	--	-	-/+	-- (exterior) ++ (courtyard)	--	+	--	--	• Context • Materials of the original building • Aesthetics committee • Money • Weight • Sense of home • Change of style		Dependent on the situation there is a relationship
Access to outside space	++	N	++	++	++	++	++	N	• Also has an impact on the arrangement • Decided by construction • Decided by monument • Regulation • Aesthetics committee		Strong relationship
Budget									• Depends on function • Location • Investors		There is a relationship

Appendix 9: Criteria found in literature

Criteria	Notes	Sources
Openable windows	Preferably 80%-100% Multiple ventilation strategy	Geraedts, 2016 Remøy & Van der Voordt 2009 Austin & Schmidt, 2016
Daylight	Preferably a daylight factor higher then 1/5 Daylight admittance at least according to building regulations of housing	Geraedts, 2016 Remøy & Van der Voordt, 2009 Austin & Schmidt, 2016
Demountability	Preferably 90%	Geraedts, 2016 Bikker, 2016 Sprengers, 2015 Interviewee C (Appendix 3)
Window arrangement	Large horizontal openings with connections according to the planning grid	Geraedts, 2016
Insulation	Preferably above 10% of the current demand of offices, houses and care According to building regulations for housing	Geraedts, 2016 Remøy & Van der Voordt, 2009
No ''office building look''		Remøy & Van der Voordt, 2009
Attractive identity and entrances	Preciousness	Remøy & Van der Voordt, 2009 Leupen et al., 2005
A high spatial/visual quality issued by the design concept of the materials and colours used		Remøy & Van der Voordt, 2009
Replaceable and not load-bearing façade	Preferable more than 90% self-supporting	Remøy & Van der Voordt, 2009 Bikker, 2016 Nakib, 2010 Sprengers, 2015 Geraedts & Remøy, 2013 Interviewee C (Appendix 3) Interviewee E (Appendix 5)
Opportunity to add balconies		Remøy & Van der Voordt, 2009 Interviewee D (Appendix 4)
Materials that weather well and age gracefully	 durability	Leupen, et al., 2005 Austin & Schmidt, 2016
Creating possibilities to connect interior walls to the façade		Bikker, 2016
Rearrangeable elements		Bikker, 2016
Design a versatile envelope able to meet the buildings internal changes	A double façade	Nakib, 2010
Design sober facades and avoid overabundance of ornaments and extravagance while considering details		Nakib, 2010
Modular system		Nakib, 2010
Increase contact and exchange areas of the building by creating an irregular and meandering perimeter		Nakib, 2010
Grid system of the façade	The smaller the grid system of the façade the bigger the parcellation and redistributability of a building. 1800 works well	Geraedts & Remøy, 2013 Remøy, 2007
Place of the columns in relation to the facade	The fewer construction is in the way the better the redistributability of a building	Gereadts & Remøy, 2013
Give a building character		Ruimtelab, 2001
Prefab		Interviewee B (Appendix 2)

Appendix 10: relation between the found changes and the found solutions

Importance	Change	Solutions found in literature on façade adaptability	Notes	Final proposed solution
A strong relationship	Excess to outside space	Opportunity to add balconies	But how?	Prevent cantilevered floors, design a demountable façade and overdesign the capacity of the structure
	Windows	Preferably 80%-100% of openable windows	This is costly and creates an extra need for maintenance	Scenario planning, modular and standardized design
A relationship	Ventilation grilles	Multiple ventilation strategy	This is costly and creates an extra need for maintenance	Scenario planning, modular and standardized design
	Daylight	Preferably a daylight factor higher then 1/5 or daylight admittance at least according to building regulations of housing	A high daylight factor is not beneficial for the isolation or the budget	Daylight admittance at least according to building regulations of housing
	Visual comfort	Large horizontal openings	This is in contradiction with the findings of the case studies where the residential buildings mostly had vertical openings	Modular, prefabricated and standardized design
	Personal control of sun	-	-	Electrical sun blinds that can be personally as well as collectively controlled
	Fire resistance			At least according to building regulations of housing
	Budget	-	Depends on the market forces	A building that combines different functions
A relationship that is dependent on the situation	Weight	-	The solution of this change needs to be sought in the construction	Overdesigning the capacity of the structure
	The rhythm/grid	The smaller the grid system of the façade the bigger the parcellation and redistributability of a building. A grid of 1800 works well	-	Choose a small grid of preferably 1800mm
	Material choice	Materials that weather well and age gracefully or demountability	These solutions still give no information on how the materials could connect well with the various functions	Modular, prefabricated and standardized design

Appendix 11: Case study analyses

This appendix will be handed in by mail separately, because floorplans, sections and any other drawings analyzed in this appendix are retrieved from architectural firms, which makes the information confidential.