Updated Urban Facade Design

Techen, Holger; Krimm, Jochen; Knaack, Ulrich

Publication date
2018

Document Version
Final published version

Published in
Facade 2018 - Adaptive!

Citation (APA)
Techen, H., Krimm, J., & Knaack, U. (2018). Updated Urban Facade Design. In A. Luible, & S. Gosztonyi (Eds.), *Facade 2018 - Adaptive!: Proceedings of the COST Action TU1403 Adaptive Facades Network Final Conference* (pp. 453-461). TU Delft OPEN Publishing.

Proceedings of the COST Action TU1403 – Adaptive Facades Network Final Conference:

Facade 2018 - Adaptive!

This book is based upon work from COST Action TU 1403 adaptive facade network, supported by COST
(European Cooperation in Science and Technology).

COST (European Cooperation in Science and Technology) is a pan-European intergovernmental framework. Its mission is to enable break-through scientific and technological developments leading to new concepts and products and thereby contribute to strengthening Europe's research and innovation capacities.

It allows researchers, engineers and scholars to jointly develop their own ideas and take new initiatives across all fields of science and technology, while promoting multi- and interdisciplinary approaches. COST aims at fostering a better integration of less research intensive countries to the knowledge hubs of the European Research Area. The COST Association, an international not-for-profit association under Belgian Law, integrating all management, governing and administrative functions necessary for the operation of the framework. The COST Association has currently 36 Member Countries.

www.cost.eu

Editors in Chief
Andreas Luible
Susanne Gosztonyi

Cover image
Susanne Gosztonyi

Layout
Usch Engelmann

Publisher
TU Delft Open

Proceedings of the COST Action TU1403

Adaptive Facades Network Final Conference

Facade 2018 - Adaptive!

Lucerne University of Applied Sciences and Arts
Lucerne, Switzerland
26-27 November 2018

Editors in Chief
Andreas Luible (Lucerne University of Applied Sciences and Art, Lucerne, Switzerland)
Susanne Gosztonyi (Lucerne University of Applied Sciences and Art, Lucerne, Switzerland)

Editors:
Mauro Overend (University of Cambridge, Cambridge, United Kingdom)
Laura Aelenei (Laboratório Nacional de Energia e Geologia, Lisbon, Portugal)
Aleksandra Krstic-Furundzic (University of Belgrade, Belgrade, Serbia)
Marco Perino (Politecnico di Torino – DENERG, Torino, Italy)
Francesco Goia (NTNU, Trondheim, Norway)
Frank Wellershoff (HafenCity University, Hamburg, Germany)
Shady Attia (Université de Liège, Liège, Belgium)
Uta Pottgiesser (University of Antwerp, Antwerp, Belgium)
Ulrich Knaack (TU Delft, Delft, Netherlands)
Christian Louter (TU Delft, Delft, Netherlands)

Updated Urban Facade Design

Holger Techen 1, Jochen Krimm 1, 2, Ulrich Knaack 2

1 Frankfurt University of Applied Sciences, Department 1/Architecture-Civil Engineering- Geomatics, Frankfurt , Holger.Techen@fb1.fra-uas.de
2 Delft University of Technology, Faculty of Architecture and The Build Environment, Architectural Engineering

The increasing migration into cities leads to an increasing number of people stressed by noise. More and more people are moving into urban settings comprised of multiple noise sources and hard reflective glass and steel facades. The omnidirectional arrangement of noise sources like airborne noise or car traffic noise and their reflection on the facades neither composes urban arrangements with silent indoor areas nor comfortable quiet areas outdoor. To come up with requirements for silent areas inside and outside of buildings further design parameters have to be introduced. The facade is not only a shelter for the inside. It can also provide comfort spaces outside the building. As engineers and architects we cannot change the noise source, but we can influence the impact on the surrounding urban space by controlling the reflection of noise emissions on the urban surfaces like facades. In a facade design the capability of reflecting noise can be tuned by modifying the surface. In order to come up with the acoustical needs no radical new way of facade design has to be introduced. Mainly a shift of attention to the acoustic parameters is needed. Based on acoustic measurements of basic geometry principles this research presents known facade designs and their acoustic parameters regarding the reflection capabilities and the functions in a facade.

Keywords: Façade design, parameter, acoustics, urban, noise source, reflection, noise.

1 Introduction

The silhouettes of metropolitan areas are characterized by a high density of skyscraper facades made of glass, metal or stone. On the one hand, this high skyscraper density, which can be seen in Figure 1, stands for economic power, growth and work. On the other hand, these reverberant façade surfaces in urban space are responsible for increasing noise levels in their direct surroundings. In an urban development situation with reverberant façade surfaces, the most common source of noise by road traffic is increasingly perceptible.

Fig. 1 High rises with hard reflecting glass facades around an inner city park of Frankfurt

The processes in the growing metropolises that confront the architecture with tasks that it can not solve with the help of its own tools. Since re-densification in metropolises usually relies on areas of former industrial and commercial spaces, these are subject to increased noise emissions. Figure 2 shows a typical situation of a secondary consolidation project, using the example “Bürostadt Niederrad” in Frankfurt.

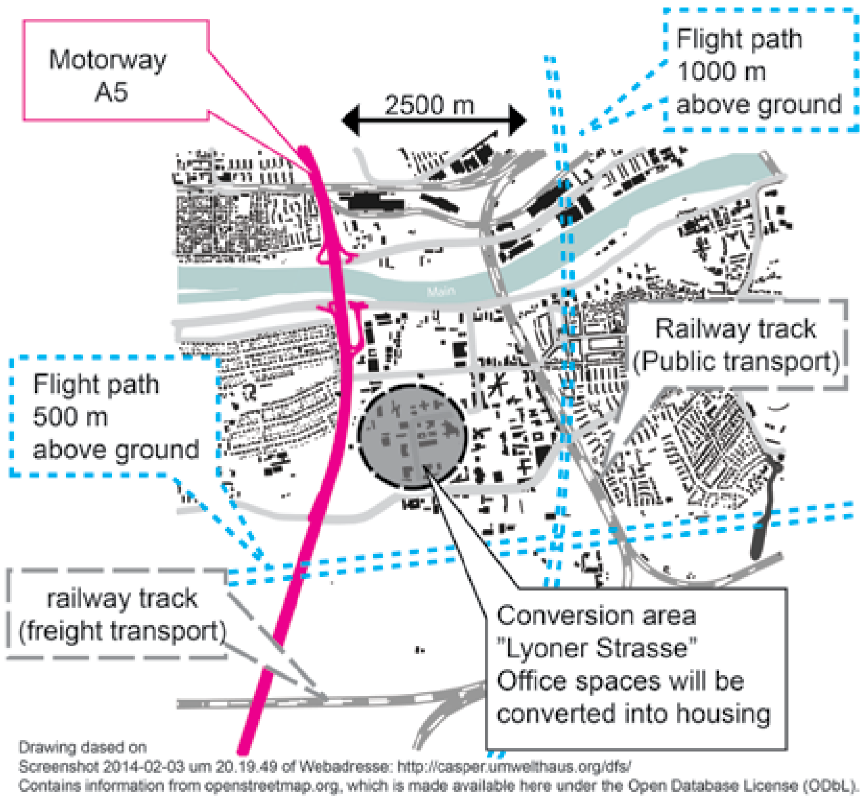

Fig. 2 Location of noise sources around the conversion area “Bürostadt Niederrad” in Frankfurt

Around the former commercial area are several traffic routes. The traffic noise sources such as road, rail and aircraft noise affect the area from different directions. Here the situation further exacerbated by aircraft noise since this type of noise generally acts from above on the urban space. In such characterized areas, the architecture is at its end with its general design tools. So the principle of the arrangement of the bedrooms on the quiet side of a building is only possible if there is still a quiet side. A quiet courtyard is affected by the influence of aircraft noise from above. The only option that is considered here is usually the use of highly sound-insulated facades and window constructions. However, such soundproof constructions generally prevent direct contact with the outside area.

2 Facades as a Noise Modulator in Urban Space

The direct sound and the sound reflecting off the façade surface add up in the urban space. The reflection of a direct signal from a noise source on a reverberant surface increases the measured level at the location of the receiver by up to 3 dB. This level increase is generated by the addition of incoming direct sound and reflected sound. A special arrangement of several reverberant surfaces makes this effect even more powerful. This phenomenon, as shown schematically in Figure 3, is well known.

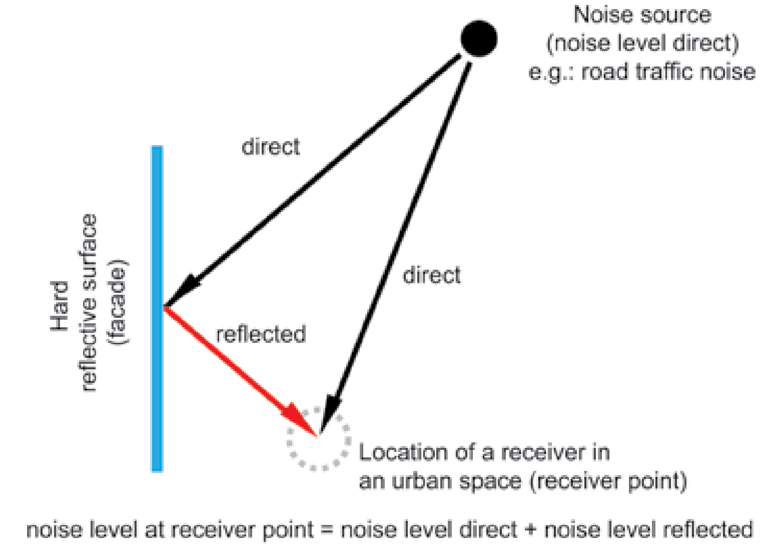

Fig. 3 Acoustical reflection principle

The effect of increasing the level by reflection on reverberant surfaces has been researched in acoustics for a long time. Scientific articles of the last 50 years were evaluated in a literature study by the authors (Krimm, Techen, Knaack, 2017 and Krimm 2018). It can be concluded from the study that intervention in the urban scale bear nearly the same potential as interventions in a building scale. The potential of the interventions ranges from maximum 10 dB level change in the urban planning scope to 12 dB in the building planning scope. In architecture, on the other hand, the topic of the reflection of noise on reverberant facades has so far received no attention. This status quo in urban spaces was used in several research projects at the Frankfurt University of Applied Sciences to deal with the topic of the façade and its acoustic qualities. In the course of the ongoing research, numerous field measurements were carried out in cooperation with the „Office for environmental affairs“ of the City of Frankfurt in order to record the effect of the acoustic reflection behavior of facades in urban space and to develop acoustically effective design parameters for façade surfaces.

3 Project Study: Refurbishment of an Office Building

This study of a former office building in the “Bürostadt Niederrad” shows the necessary steps in the facade design process with a focus on special acoustic effects. Figure 4 shows how close the approach route to Frankfurt Airport passes the building. The 100 m long, 8-storey high building is almost perpendicular to this approach route. For the vacant object a conversion was intended into an apartment building. In order to come along with the trend towards acoustic hard surfaces in architecture, only the influence of altered facade geometries was investigated in this study.

Fig. 4 Former office building in "Bürostadt Niederrad", Frankfurt

3.1. Design Basics

On-site inspections and noise measurements are imperative, as they can provide data on the time response of noise sources and the direction of their impact on to the building. Noise mapping data sources can only show tendencies in this context. They hardly provide acoustical information's for a detailed facade planning. This is partly due to the coarse resolution of the 10m grid, which makes it very imprecise to detect the direction of noise. On the other hand, reflection parameters used in noise mapping models are strongly location-dependent and lead to strong fluctuations in the resulting noise levels. Furthermore, the places of acoustic interest must be defined for the planned outdoor use. A higher quality of outdoor places can be for e.g. a coffee, playground or rest areas. In this case, such an outdoor place with higher acoustical demands was intended for the east side oft he building. In Figure 5 this position is marked at the measuring point "EAST 2".

3.2. On-Site Measurement

In the on-site measurements, several receiver positions must always be measured simultaneously in order to be able to read the influence of the facade from the comparison of the level-time curves. Figure 5 shows the measurement values for a typical flyby. Significantly the differences in the level-time curves for the different sides of the building can be seen. The measurements show a level difference of about 5 dB between east and west side of the building. The level-time curves with a lower peak measured on the west side indicate that the passing aircraft is audible over a longer period of time.

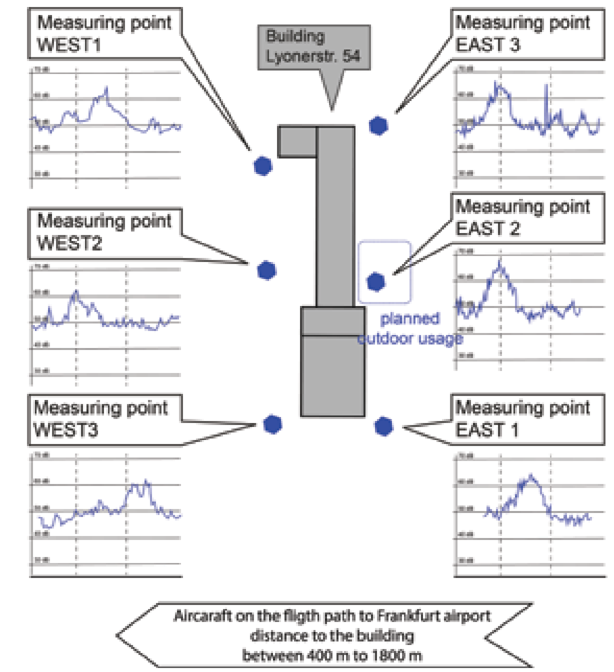

Fig. 5 Level-time curves of the 6 receiver positions / measuring points around the building

3.3. Façade Design

In this step, the first façade design variations are developed, which offer different facade geometries and structures from flat, reverberant facades. In the context of this study, a curtain-wall facade with story-high, folded glass surfaces was proposed, which effects by its geometry a different reflection direction. The differently inclined façade surfaces are shown in Figure 6.

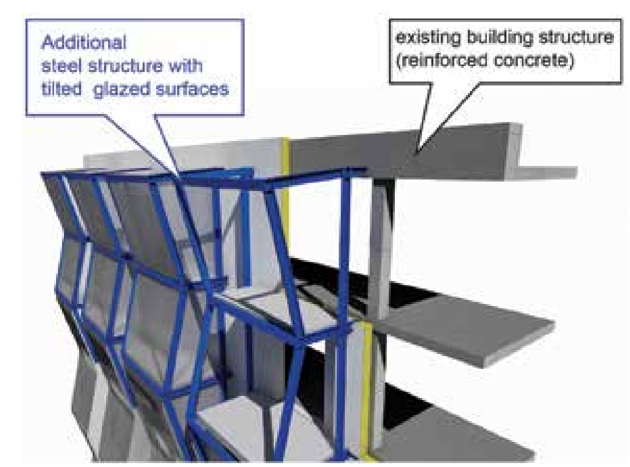

Fig. 6 Perspective of the facade design

3.4. Laboratory Tests for Façade Modifications

Since it is rarely possible to test façade alternatives on site on a scale of 1: 1, model studies are necessary for this step. With the scaled acoustic measurement method, models can be acoustically measured in scales from 1:10 to 1:100. In cooperation with the "Federal Highway Research Institute" (BAST) the scaled measurements were carried out in the Laboratory for Acoustic Measurement Technology. For the scaled measurement, the dimensions of the buildings as well as the occurring sound wavelengths were scaled with the same scale factor. The floor plan and the arrangement of the measuring points of the on-site measurement serve as a basis for the scaled model structure in the measuring laboratory (Techen, Krimm, Knaack 2016). Due to the very high frequencies that are required for the measurement and the limitation by the measuring room, the traffic noise spectrum can only be reproduced up to 2,000 Hz. For the scale 1: 100, the traffic noise with a frequency range of 100 Hz to 2,000 Hz is scaled for the measurement to a frequency range of 10,000 Hz to 200,000 Hz. The moving noise source is replaced in the laboratory by a moving pneumatic generator and a high-frequency loudspeaker. By comparing the measurement results of the smooth façade with the measured values of a façade modification, statements can be made about the change in the noise input at the measuring points. The potential for noise input in the outdoor area, which can be achieved through a change in geometry, is shown in Figure 7 for the façade presented here. The largest level reduction is achieved at the measuring point “EAST 2”, for which an outdoor café is planned.

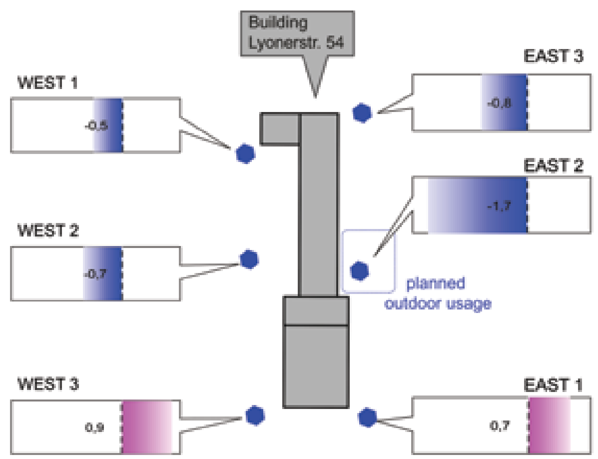

Fig. 7 Perspective of the facade design

The level changes shown here for the folded façade surface clearly show the need to always consider all measuring points. Thus, the folded façade reduces the level by up to -1.7 dB at four measuring points, but in two measuring points the level increases by up to 0.9 dB. For the facade construction, it is therefore imperative that these must be individually tailored to the places with defined outdoor use. The frequency curve shown in Figure 8 shows the level change per frequency band at the measuring point “EAST 2”.

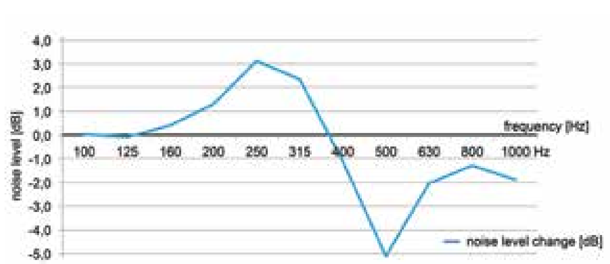

Fig. 8 Frequency response for the change in the noise input during a flyby at the measuring point “EAST 2”

The difference in the individual frequency bands makes it clear that single values are not sufficient to describe the acoustic effect of a facade. Decisive for a acoustical effect of the facade are level changes in the range of the highly sensitive hearing range of humans between 500 Hz to 4,000 Hz.

The level change shown here occurs in the frequency bands from 400 Hz. The level reduction at the measuring point “EAST 2” would ensure that aircraft noise events would not only be perceived as quieter but also as less disturbing.

4 Case Studies - Facade Surfaces

An alternative to changing the reflectivity of reverberant cladding surfaces is the introduction of absorbent material properties or internal geometries.

4.1. Facade absorber

The introduction of absorbent materials is not easy for a variety of reasons. Thus, most known absorbent materials are open-pored. This means that they do not have a closed surface, which meets the architectural desire for a slightly closed, less polluting and sufficiently resistant surface. An exception here is a special form of a green facade. This fully façade integrated revegetation, using substrate mats are from the acoustical point of view highly absorbent surfaces. Among others the effect of vertical greenery for acoustic purposes was investigated in numerical simulations by Smyrnova, Kang, Hornikx, Forssén (2012) or in case studies by Wong et al. (2010).

Fig. 9 Detail of the Green Façade at the Frankfurt University of Applied Sciences

The full façade integrated revegetation of 90DEGREEN® meets the requirements of a flat absorber. In order to determine the acoustic potentials of this system, a mock-up was installed in cooperation with the manufacturer on a busy inner-city street in at the Frankfurt University of Applied Sciences. The road traffic noise was measured in front of the green facade at time intervals with approximately constant resulting noise levels. The first measurement was made before the wall was attached. After establishment of the green facade, measurements were carried out without planting and subsequently with fresh planting. With more vegetation, another measurement was taken to get information about the influence of the density of the vegetation.

Fig. 10 a) Existing building b) Installation of substrate surface c) Green facade with fresh vegetation

From the locally measured traffic noise levels a noise reduction potential of -3 dB can be derived. In a frequency range of 100 Hz to 3,000 Hz, the measured level reduction remains in the range of -2.5 dB to -3.2 dB. The measurements with more or less vegetation show only very small differences. This means that in the case of using a green facade as a surface absorber, the substrate material decides the acoustic quality and not the planting. In order to use green façade systems acoustically effectively, system selection is crucial. The vertical green façade principle presented here, offers ideal absorber properties due to the full-surface coverage of the façade surface with absorbent materials. The green facade not only helps to improve the acoustic situation, it is also able to bind fine dust and to positively influence the urban climate by increasing the humidity in its environment.

4.2. Absorption through a highly structured surface geometry

As an alternative to a surface-bound vertical greening strongly structured surfaces can be used. Picaut & Simon investigated that to some extent, an absorption effect can be represented by these highly structured surfaces. (Picaut, Simon, 2001). In such surfaces, the sound field is deprived of energy by multiple reflections on many differently angled inner surfaces. Figure 11 shows a study of a precast concrete element with cuboids of 4 x 4 cm.

Fig. 11 Heavily textured surface of a prefabricated concrete façade element

The expected effect here is about a level reduction of -1.5 dB. The frequency of the level reduction is dependent on the size of the cuboid. The “grin-grid” should be on the order of the wavelength

of the frequency to be influenced. Many such structures are currently being installed, but without taking the acoustic effect into account. The surfaces in Figure 12 and Figure 13 show examples from current architectural façade designs.

Fig. 12 Heavily textured surface of a suspended stone element

Fig. 13 Creation of a highly structured surface through vacancies in the closed clinker wall dressing

5 Summary

The listed case studies show opportunities to reduce the noise input into the urban space by the facade. The study presented here of a folded reverberant facade surface clarifies that projects with acoustically effective facades must be designed differently.

- As a basis for this, sites have to be considered acoustically by on-site measurements
- Places with special acoustic qualities and demands must be defined
- It is always necessary to find individual solutions for individual locations.
- The effects achieved must always be considered for individual frequency bands in the highly sensitive human hearing range from 400 Hz to 4,000 Hz

A quieter city is possible!

6 Reference list

Knaack, U., Techen, H., Krimm, J., (2017) Der urbane Raum in der Akustik als architektonische Gestaltungsgrundlage für leisere Städte, Fortschritte der Akustik - DAGA 2017, Deutsche Gesellschaft für Akustik e.V. (DEGA), Berlin

Krimm, J. (2018) Acoustically effective facades design, TU Delft

Knaack, U., Techen, H., Krimm, J., (2016) Tuning acoustical facade designs aiming for a controlled influence on the urban soundscape, Proceedings of the INTER-NOISE 2016, 45th International Congress and Expositionon Noise Control Engineering, Deutsche Gesellschaft für Akustik e.V. (DEGA), Berlin

Picaut, J., & Simon, L., (2001) A scale model experiment for the study of sound propagation in urban areas, Applied Acoustics 62, 327-340 Smyrnova, Y., Kang, J., Hornikx, M., & Forssén, J., (2012) Effect of Vegetation of noise propagation in streets and squares, Proceedings of the

Institute of Acoustics, Vol. 34. Pt.1.

Wong N.H.,Tan A. Y. K., Tan P. Y., Chiang K., & Wong N. C., (2010) Acoustics evaluation of vertical greenery systems for building walls, Building and Environment, Volume 45, Issue 2, Pages 411-420

Strategies for Design

A Redesign Procedure to Manufacture Adaptive Façades with Standard Products

Bahar Basarir 1, M. Cem Altun 2

1 Graduate School of Science Engineering and Technology, Istanbul Technical University, Turkey, baharbasarir@gmail.com
2 Department of Architecture, Istanbul Technical University, Turkey, altunce@itu.edu.tr

Although their potential for high environmental performance is largely accepted, adaptive façades have not yet become widespread in practice. Most of the current examples are developed by engineer-to-order design processes, as project-oriented, custom, and complex solutions. More simple and reliable solutions are needed to support the reuse of technical solutions between projects and increase the feasibility of adaptive façades. Therefore, this research aims to develop a procedure to design adaptive façades whose parts are based on engineered standard products with the least number of parts and layers. The research is initiated through the generation of concepts for designing adaptive façades to be manufactured using standard products. From several concepts, 'redesigning dynamic adaptive façades' has been selected for further investigation, as it pursues the goals for a solution determined for this research. A preliminary case study is conducted to redesign an adaptive façade to be manufactured with standard products. Its process steps are captured and analysed, and the steps that need improvement are revealed. To systematise and improve the captured redesign process, façade design and product design methodologies are analysed in the context of adaptive façade design. Redesign and reverse engineering processes used in product design are adapted and merged with façade and adaptive façade design processes, and a 5-phase adaptive façade redesign procedure is outlined. Each phase is developed based on mature tools and methods used in product and façade design. An iterative loop of development, application test, and review process is carried out for development of the process steps. Thus, a redesign procedure is generated by the combined application of DFMA and TRIZ in the synthesis of reverse engineering and redesign processes. Consequently, the application of the redesign procedure is demonstrated through a case study. The case study revealed that the procedure has the ability to generate a façade redesign that has a higher constructability index than the reference façade.

Keywords: adaptive façade, constructability, redesign, standard product, reverse engineering, DFMA

Full paper available in the Journal of Facade Design and Engineering, Vol 6 No 3 (2018): Special Issue FAÇADE 2018 – Adaptive!