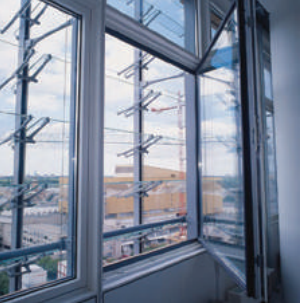
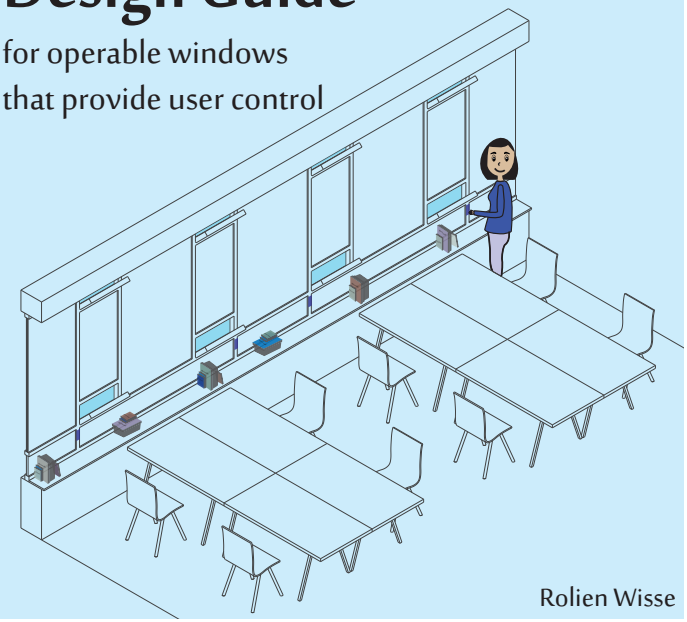


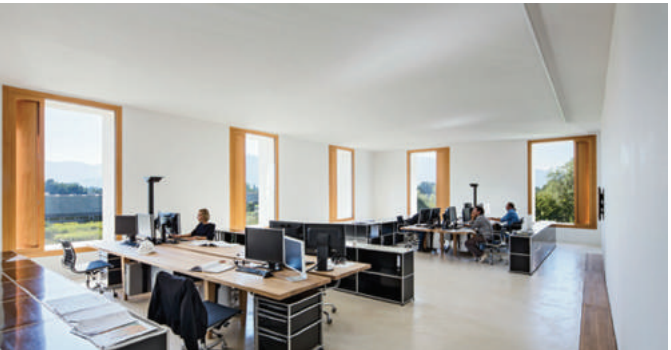


Design Guide

for operable windows
that provide user control



Rolien Wisse


Design Guide

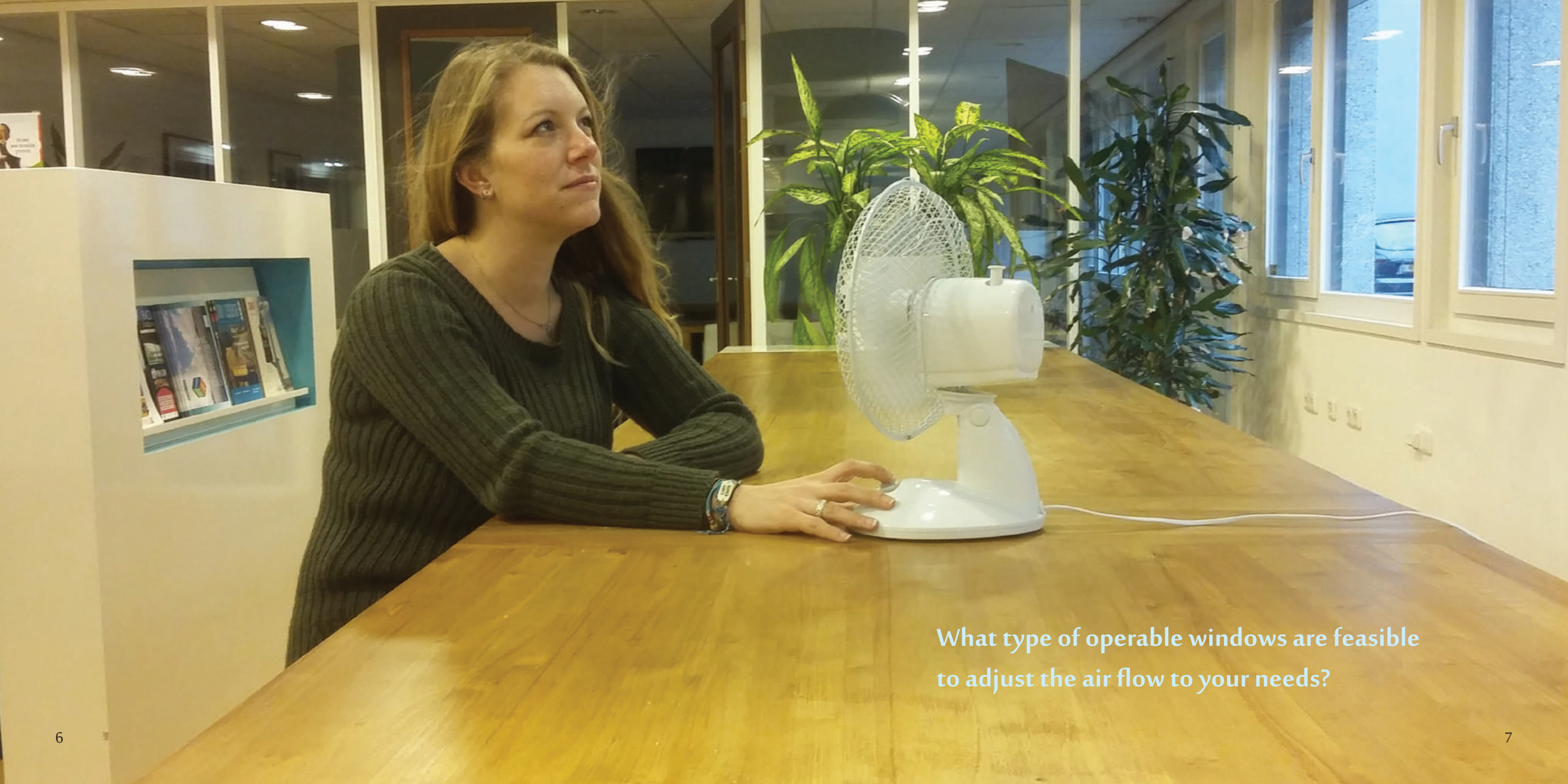
for operable windows

that provide user control

Rolien Wisse

April 2017

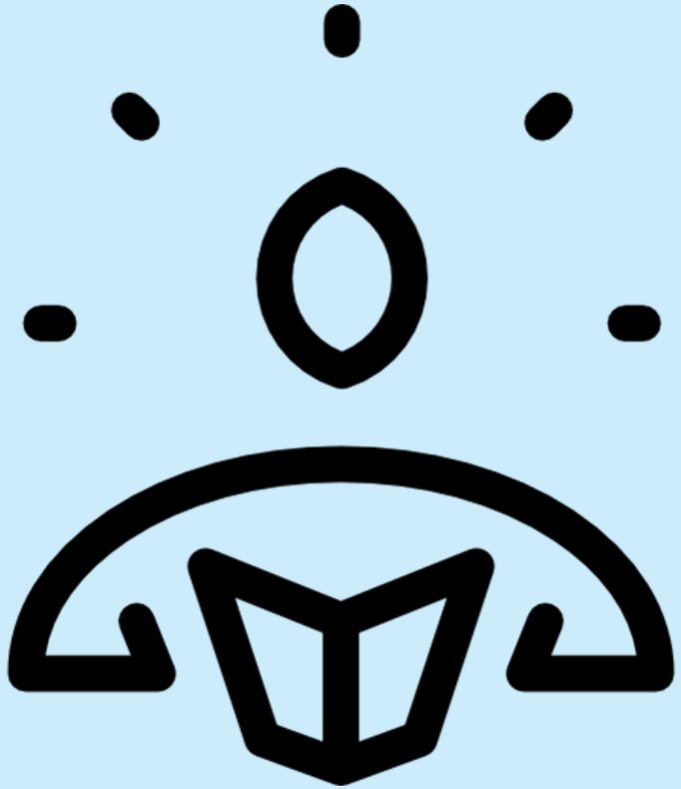
Which aspects should be considered designing an operable façade element on a high location in the facade?



What type of operable windows are feasible to adjust the air flow to your needs?

What kind of operable windows
reduce noise from outside?

Contents



Introduction

This design guide is made for architects and façade designers or anyone interested in operable windows. Many offices in the Netherlands have operable windows. In general the option to personally influence the indoor environment by operable windows is highly appreciated by occupants. Operable windows can provide fresh air, contact with outside, offer personal control options and reduce symptoms related to poor indoor air quality such as a headache or dryness and irritation to eyes, nose, throat and skin.

In practice, operable windows often do not have a good usability. This Design Guide provides an overview of reasons for this decreased usability and can be used as help to design good usable windows. The information used in this booklet is based on my graduation thesis (Wisse R, 2017). As part of the thesis a literature survey, database analysis and context mapping study are conducted to find which aspects affect the usability of operable windows. Eleven requirements for good usable windows are described and illustrated. Including, examples meeting the requirement, design suggestions, examples from practice not meeting the requirement and building technical examples.

In every stage in the design process other aspects become important to consider. Therefore a step-by-step approach “Designing with sub-choices” is made whereby effects of a certain sub-choice and points of attention are given.

At the end of the booklet suggestions are made for further reading, within the booklet is referred to this list.

Why operable windows?

User benefits

Operable windows offer the option to influence the indoor environment, let in fresh air, feel fresh, feel cooler and compensate for poor conditions (e.g. dilute indoor air pollutants or bad smell). A control action (such as opening a window), which responds to your needs, can provide a relieved feeling, sensory pleasure and satisfaction.

In the context mapping study some participants mentioned additionally that they feel more free, happy and safe and feel more secured that they can work pleasantly if a room has operable windows. Especially, in case of stale air and warm temperatures.

Health and performance gains

The option to control the indoor environment tends to reduce sickness symptoms and increase productivity, acceptance of thermal variation and robustness of the building. Higher acceptance of thermal variation and robustness of the building can save costs and energy because of lower risks on unexpected high energy costs and temperature ranges may be less narrowed.

Fresh Air

The indoor air is often more polluted than the outdoor air, due to diverse pollutant sources in the indoor environment combined with low ventilation levels. Examples of these pollutant sources are carpets, painted walls, furniture and people itself. People for example breath, sweat, loose hair and skin particles and sneeze. While breathing we inhale O_2 and exhale CO_2. Therefore the more people are in the room, the higher the CO_2 concentrations will be, in case of the same amount of ventilation.

Ventilation is important for people, to provide fresh air, and for the building. For example to prevent mould growth. Though in practice it occurs that flow rates are not properly adjusted in ventilation and air conditioning systems, rooms offer space to more people than they were originally designed for or that fresh air enters a room through unclean air ducts.

Especially in those circumstances a window can be of great help to provide the so desired fresh air and reduce complaints. Though also in buildings were the air quality and ventilation rates are good a window can help to adjust the environment to personal preferences.

The option to adequately open a window improves personal control over indoor climate

Personal control

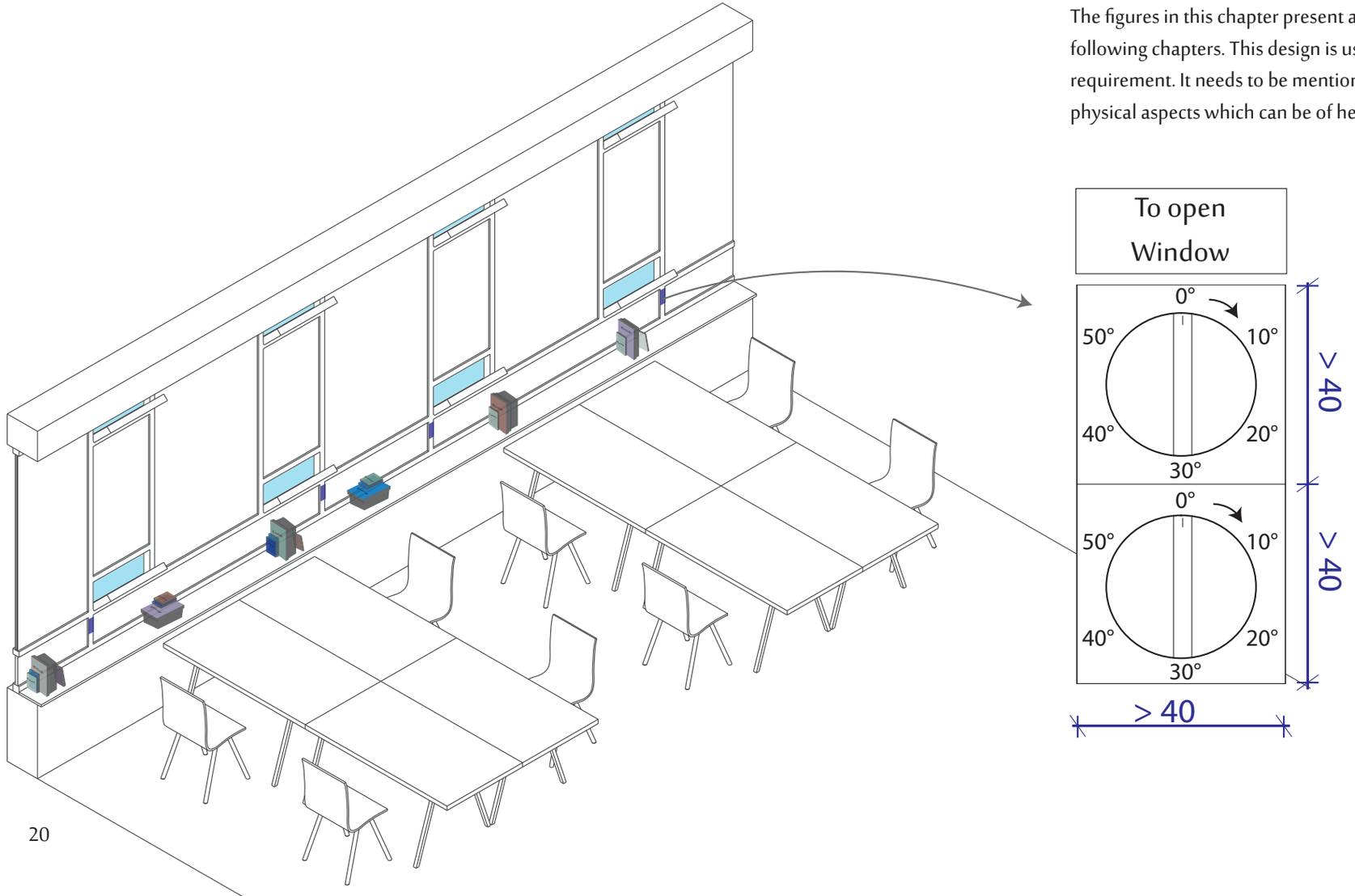
The ability to open or close a window and to position it in a preferred level is a way of control over the indoor environment. In general people prefer to be in control instead of being dependent. Especially if they know from experience that dependency of indoor climate can cause complaints such as a headache or dry eyes. The knowledge itself that there is a possibility to open a window already is of positive influence.

Thereby, personal factors and people their experiences and preferences differ. For example some are more sensitive to air quality (e.g. because they have hay fever), others are more sensitive to distraction by noise while still others are more sensitive to temperature.

Besides, preferences are also influenced by the clothing level and differ over moments and time. Straight after physical effort such as cycling to work or walking up a stairs, lower temperatures are preferred than while sitting still for a long period. The same counts for state of mind, for example; while feeling stressed lower temperatures are preferred than while feeling relaxed.

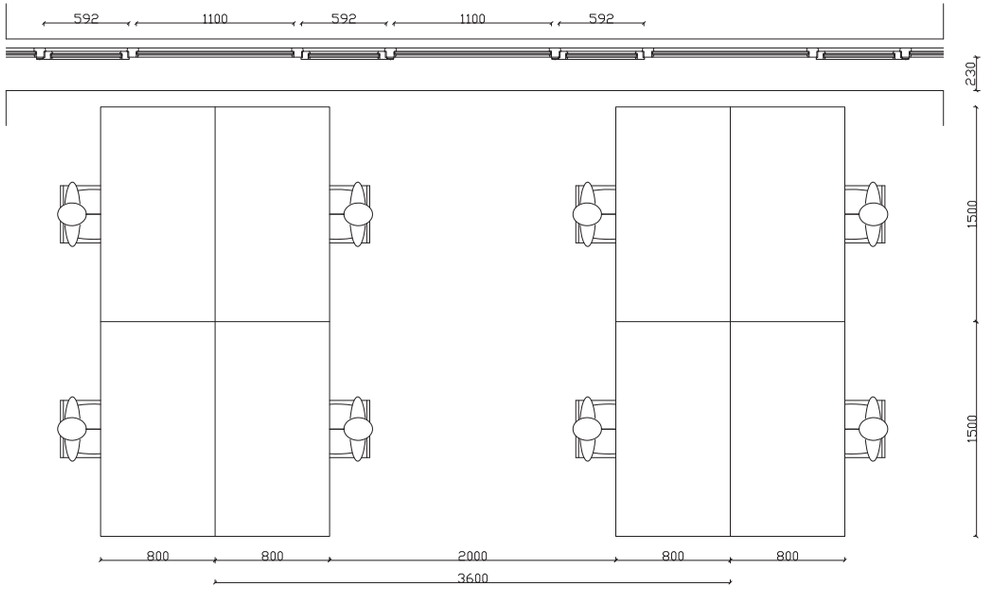
Operable window design example

The figures in this chapter present an operable window design which integrates the requirements in the following chapters. This design is used in the following chapters to illustrate suggestions to meet the requirement. It needs to be mentioned that these are ‘suggestions’ aiming to inspire and attend to practical or physical aspects which can be of help, not claiming to be the only solution.

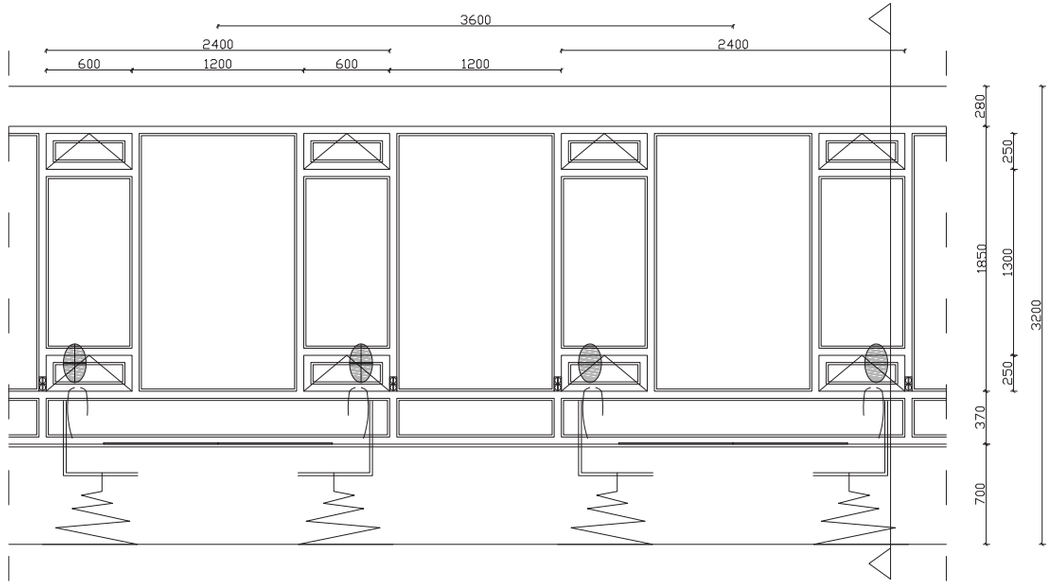


Operable window design example

Floorplan

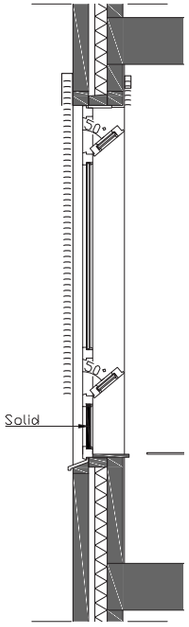


Elevation seen from inside

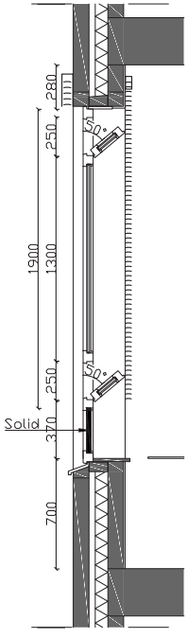


Operable window design example

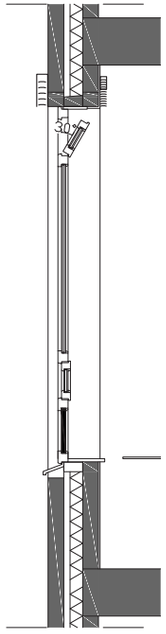
Sunshading down
&
windows open



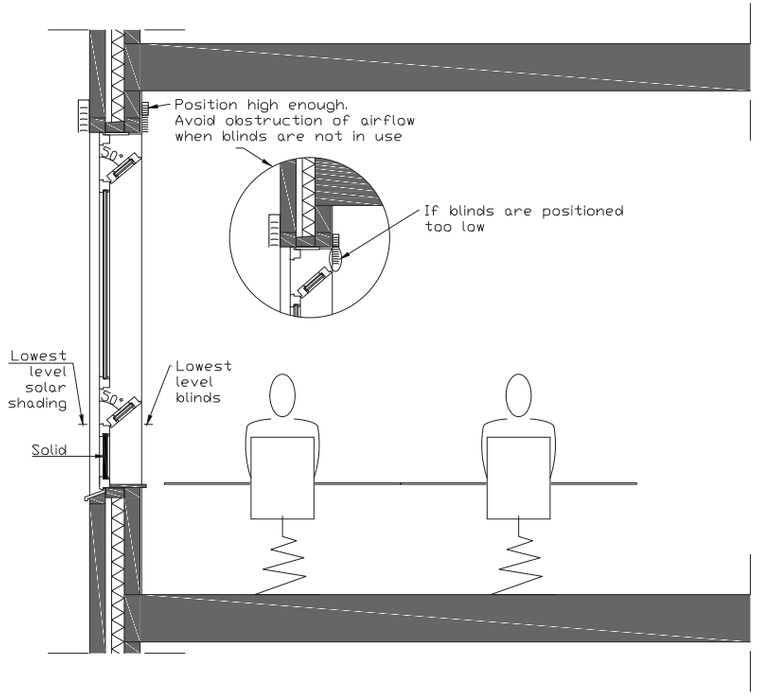
Blinds down
&
windows open

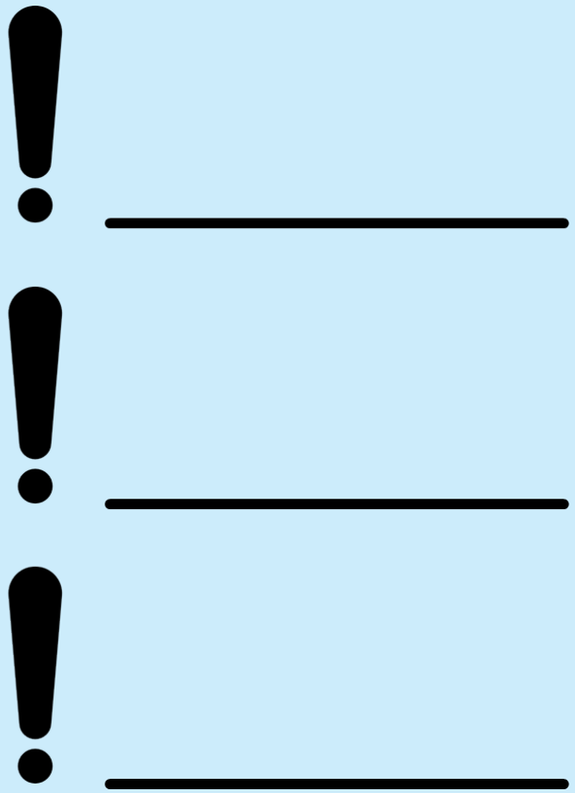


Upper window open



Situation section





Requirements

Good usable operable windows provide high levels of personal control and reduce risk on interfering factors. The following 11 requirements help to design good usable windows and are described in the following chapters:

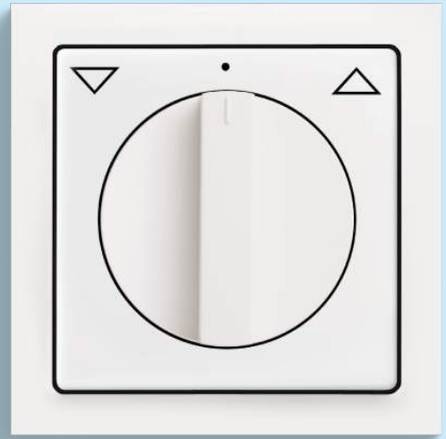
1. User-friendly
2. Clear design intent
3. Effective
4. Supply is fresh air of sufficient quality
5. Adjustable
6. Low noise ingress
7. (Mental) connection with outside
8. Proximal
9. Robust
10. Parallel use of windowsill and window
11. Align design and management & security policy

Examples of user-friendly window (controls)

Project (1.PA)
Haagse
Hogeschool

Architect
Atelier PRO

Location
The Hague,
the Netherlands



Project (1.PB)
Switch

Architect
-

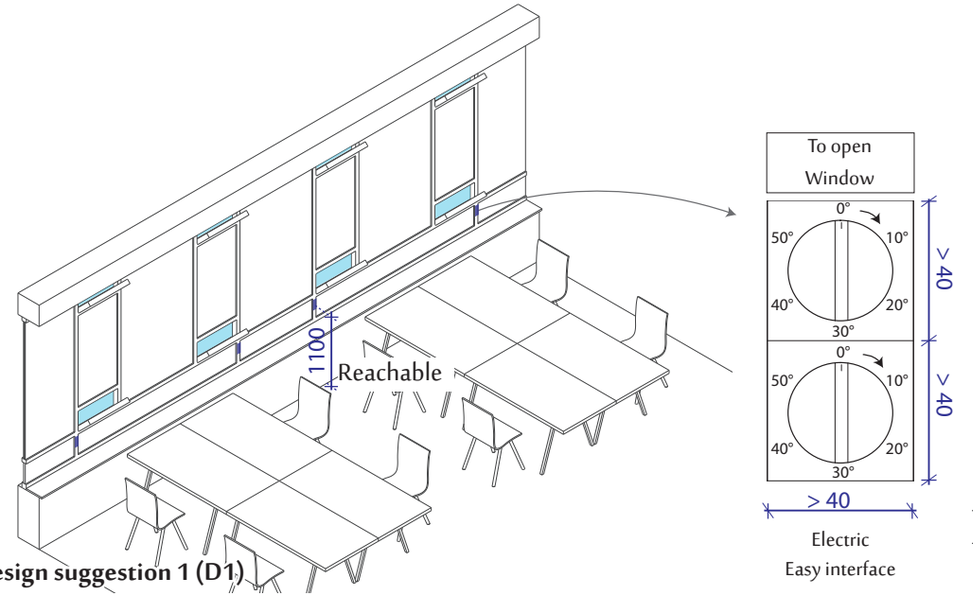
Location
-

1. User-friendly

A user-friendly operable window is easy to use, understand and reach (fig. D1), requires low effort to control, works well and provides occupants a high perception of controllability. Fig. 1.PA and 1.PB are examples of easy to use and understand windows. An example of an operable window that is out of reach, but with a good reachable control is presented in fig. 4.PA.

In case of electric control, such as in the presented design suggestion underneath, it important that it is clearly indicated, easy in use and adequately sized for the human hand. At least 40mm is needed for the control underneath, a suggestion is to test switches or control handles before ordering.

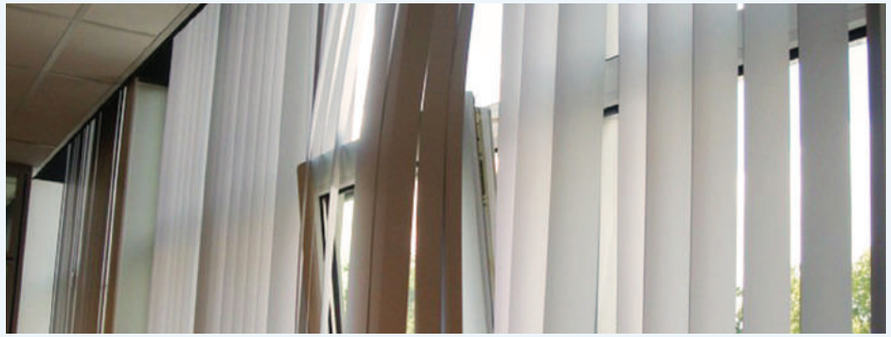
Electric control which automatically closes at the end of the day prevents users from the need to close the windows when they leave the room or fear that they forget to close the window.



Design suggestion 1 (D1)

Examples of non user-friendly window (controls)

1Ea. Limited opening possibility



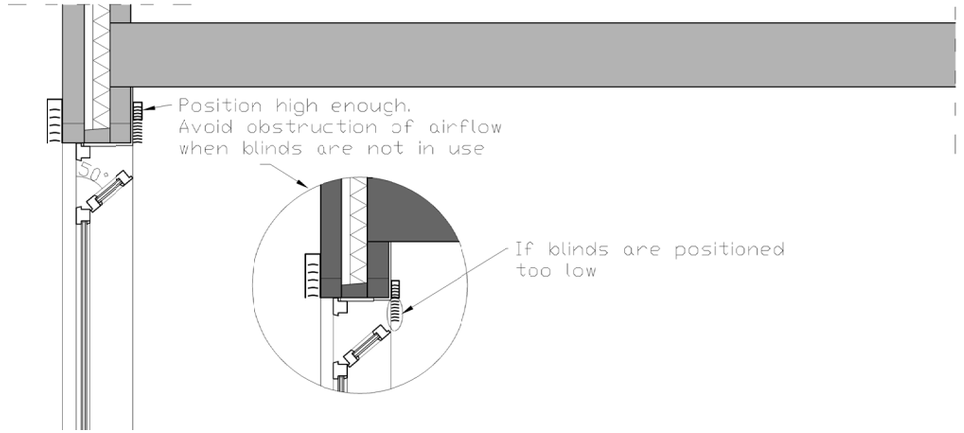
1Eb. Obstructing blinds/ fluttering blinds

1Ec. Obstructing sunshading

1b. Non user-friendly

To achieve user-friendly operable windows some extra attention can be helpful to avoid non user-friendly situations.

Situations to avoid:
Complicated usable operable windows (for example because of choice overload (fig. 2E)), heavy controls and hard to reach or obstructed openings. Examples of building related obstructions are fig. 1Ea, b and c on the left page. Fig. BT1 top illustrates an example of how such obstructions by blinds can be avoided. Horizontal blinds generally flutter less than vertical ones because they are not loose at one end.
People can forget to close the windows and feel afraid of forgetting to close the windows if they have to close it by leaving. (Electric controlled windows can prevent this by automated closing at a desired time)



Building technical examples 1 (BT1)

Examples of windows with a clear design intent

Project (2.PA)
Bella Donna

Architect
Heymen
Westerveld

Location
Amstelveen,
the Netherlands

Project (2.PB)
BK-City (TU Delft)

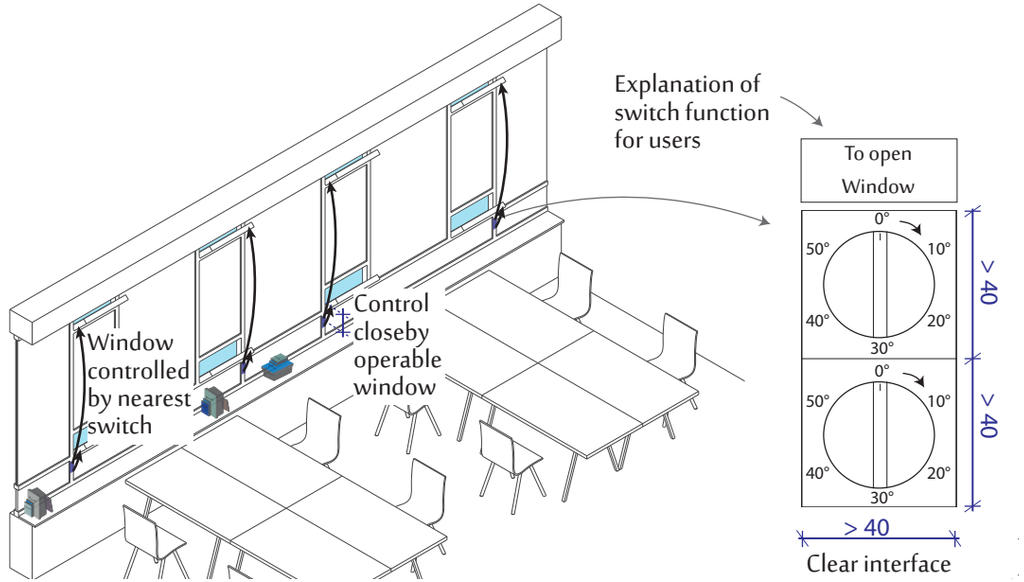
Architect
Jan Vrijman

Location
Delft,
The Netherlands

2. Clear design intent

An operable window with clear design intent has a clear purpose; they offer personal control over air quality and thermal environment. Fig. 2.PA and 2.PB are recognizable window designs of which the purpose is easy to understand.

For electric controlled windows is it important to have a clear interface, the control should be close by the operable window, explanation what the switch is for can be helpful (fig. D2) and the window the switch controls should be the nearest window for intuitive use.



Design suggestion 2 (D2)

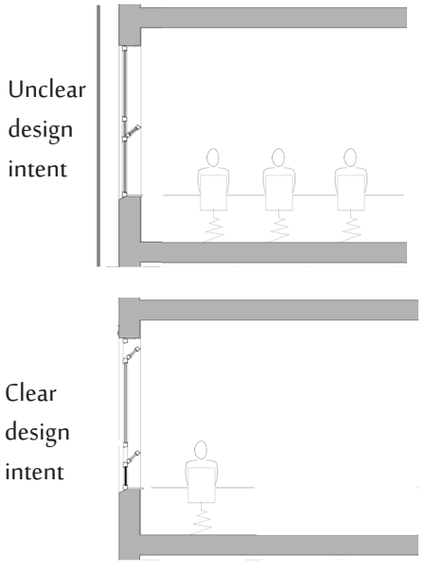
Example of a window without clear design intent

2E. Operable windows with many components and adjustable parts potentially cause choice overload.

2b. Non clear design intent

To achieve operable windows with a clear design intent some extra attention to avoid situations where the design intent is not clear can be helpful.

Situations to avoid:
Operable windows with choice overload (fig. 2E), which are complex or hard to understand, are located along indoor areas (fig. 3E&4E) or have low levels of personal control. Besides miscommunication or unclear rules of use should be avoided.
Double façades should get extra attention because it can be hard for occupants to understand the design intent, for example if it works differently in different seasons for energy reasons.



Unclear design intent

Double façade
Low proximity
Difficult to adjust to your needs

Clear design intent

Single façade
High proximity
More likely that control behaviour responds to your needs

Building technical example 2 (BT2)

Project (3.PA)
Debis Tower

Architect
Renzo Piano

Location
Berlin,
Germany

Project (3.PB)
Art Stable

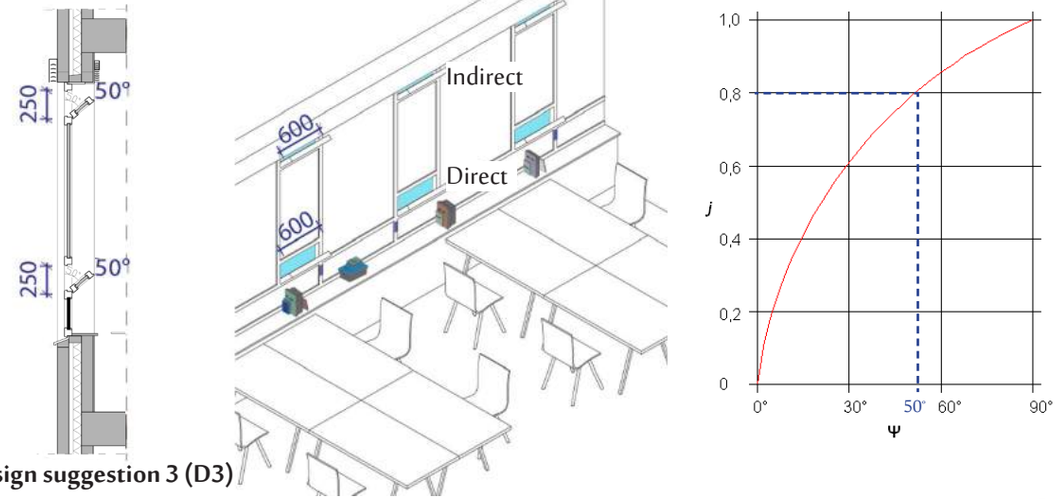
Architect
Jeff Ocampo

Location
Seattle, United
States of America

3. Effective

An effective operable window has an effective opening area sufficient to dilute internally generated pollutants, provide fresh air and to make people feel cooler by air movement. Examples of projects with large effective opening areas are fig. 3.PA and 3.PB.

The size and maximum degree of opening are taken into account for calculating the effective opening area; A_{eff} (m^2) =A xj(Ψ). The airflow rate q_v(dm^3/s) is calculated by the sum of the effective area A_{netto} (m^2) multiplied by the air velocity v (m/s) in the purge component multiplied by 1000 ($q_v = A_{netto}$ x v x 1000). According to the NEN 1087:2001 the air velocity (v) in the purge component becomes 4 times higher in case of cross-ventilation (purge components in non-adjacent façades) than in case of single-sided ventilation, from 0,1 m/s to 0,4 m/s. For example the effective opening area per window of fig. D3 is: (0,25x0,6)x0,8=0,12m^2.
As well exhaust ventilation is a driving force, both caused by pressure differences. Note that it can also cause draught or undesired high airflows.



Design suggestion 3 (D3)

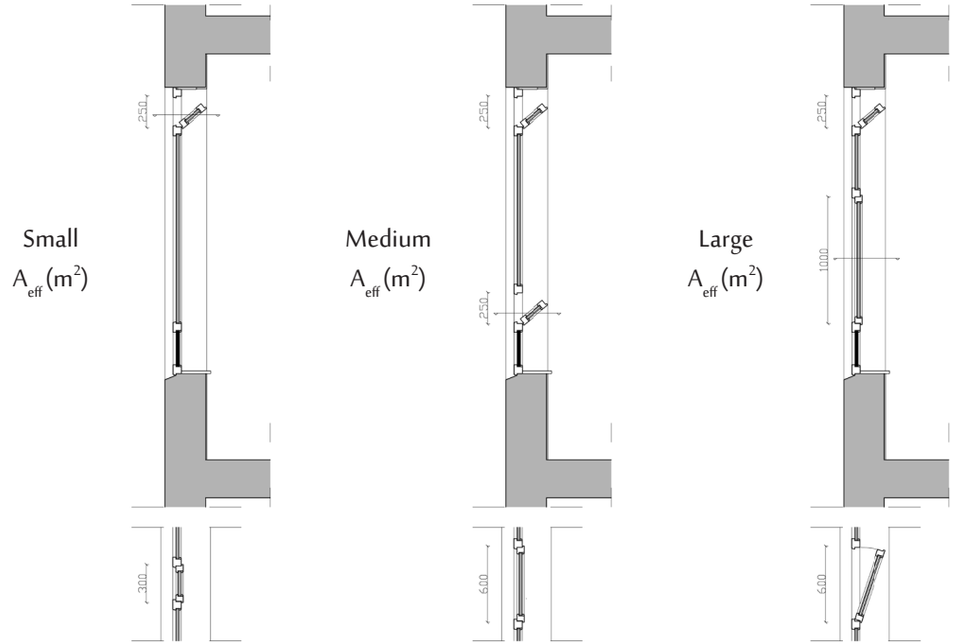
Example of an ineffective window

3E. Ineffective window. It does not respond to users needs because it opens into an atrium.

3b. Ineffective

To achieve effective operable windows some extra attention to avoid situations with ineffective windows can be helpful.

Situations to avoid:
Placement of operable windows along indoor areas such as hallways or atria (3E), too small effective opening areas or long distances between occupants and operable parts.



Building technical examples 3 (BT3)

Examples of windows which supply fresh air of sufficient quality

Project (4.PA)
Unknown

Architect
Unknown

Location
Unknown

Project (4.PB)
Office building
2226

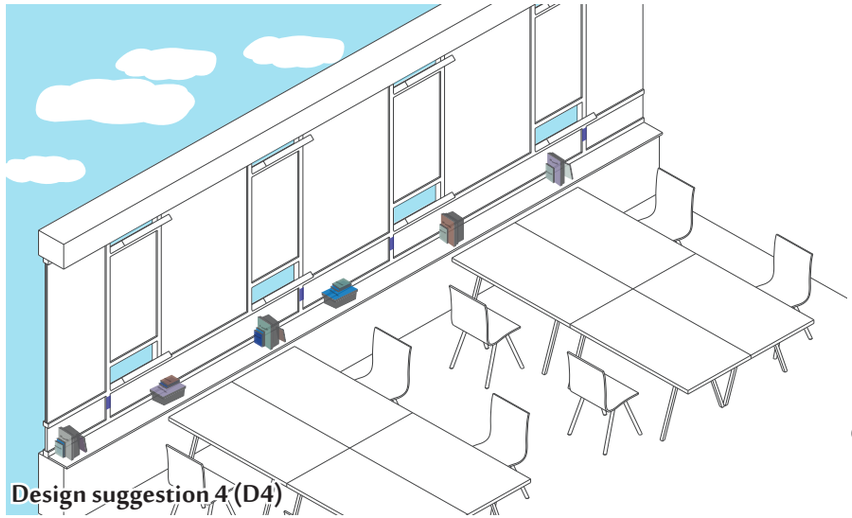
Architect
Baumschlager
Eberle

Location
Lustenau, Austria

4. Supply is fresh air of sufficent quality

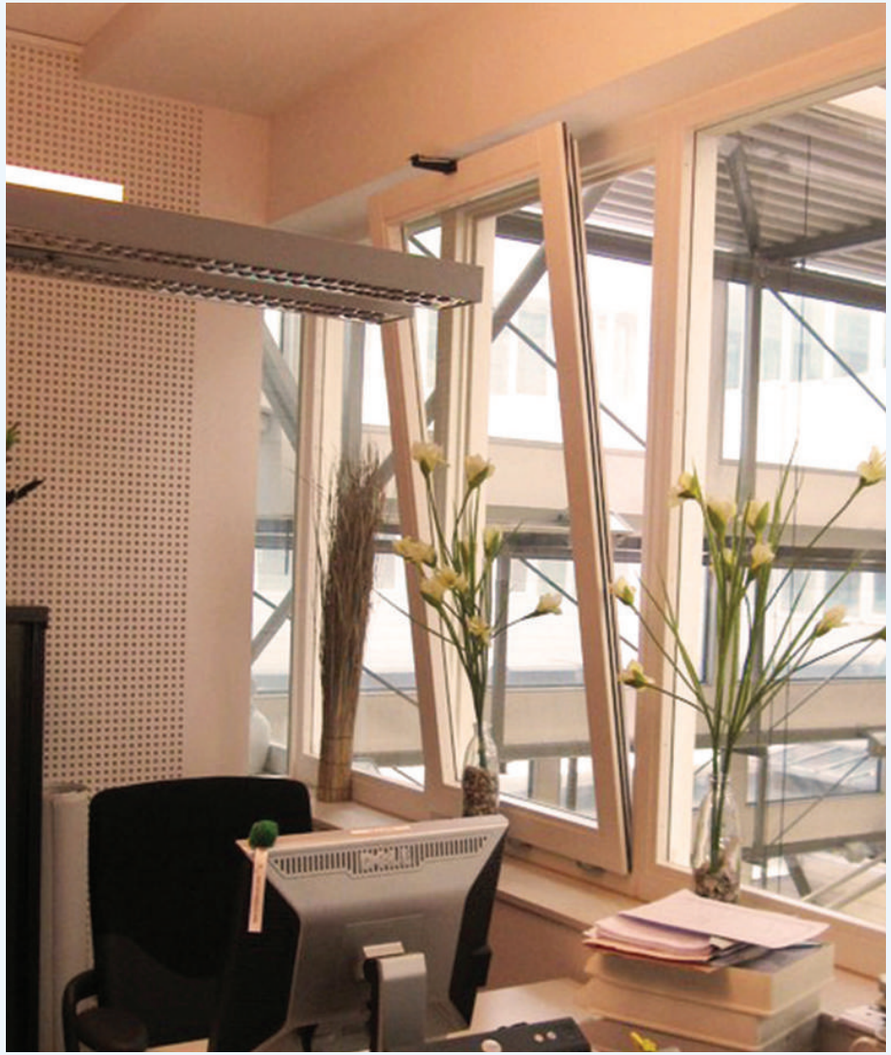
An operable window provides fresh air and dilutes indoor air pollutants. Fig. 4.PA and 4.PB are environments where operable windows are situated along an outdoor area where the outdoor air is most likely of sufficient quality.

The easiest solution, positioning the operable windows along an outdoor area, can be hard to realize. In case of occasional highly polluted outdoor air, for example because of a traffic nearby, a signal light with automated system which can be overruled by occupants can be of help (fig. D4). For example, before traffic jam extra fresh air can get in while during the traffic jam the windows remain closed.



Design suggestion 4 (D4)

Example of a window not supplying fresh air of sufficient quality

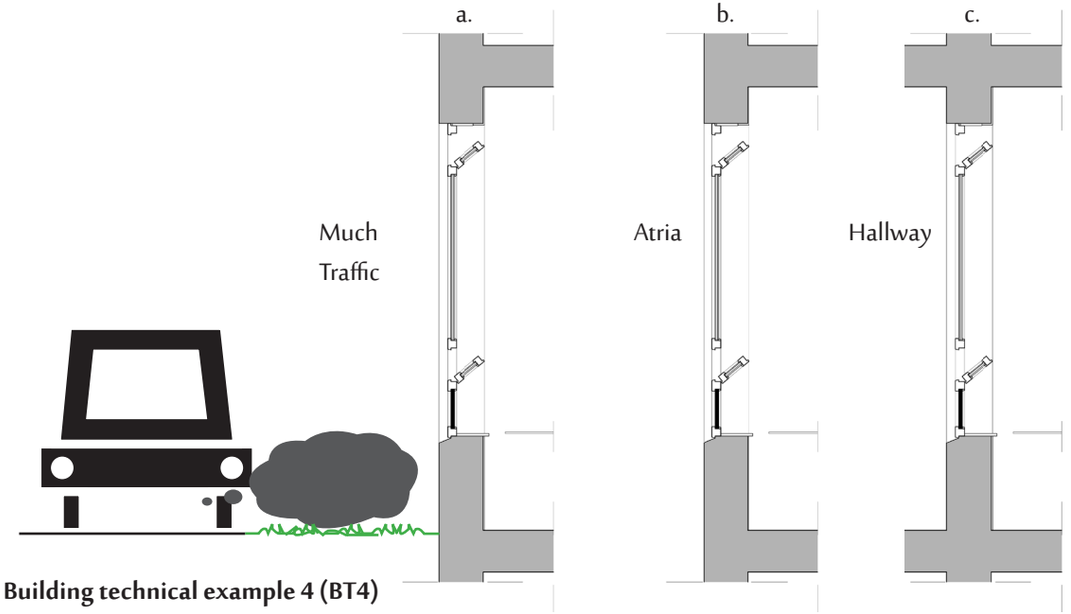


4E. Operable window along atrium.

4b. Supply air of insufficient quality

To achieve operable windows which provide fresh air of sufficient quality some extra attention to avoid situations where the supply air is insufficient can be helpful.

Situations to avoid:
An operable window which is positioned along an atrium (fig. BT4.b) or hallway (fig. BT4.c) will not provide fresh air and often causes disturbing noise of for example conversations.
Operable windows along roads (fig. BT4.a) with (occasional) much traffic without user guidance.



Building technical example 4 (BT4)

Example of adjustable windows with fine-tuning capability

Project (5.PA)
Unknown

Architect
Unknown

Location
Unknown

Large opening for direct ventilation and small opening for indirect ventilation. Remark; the outward opening upper window has larger risk on draught.

Project (5.PB)
3me (TU Delft)

Architect
Ad van der Steur

Location
Delft,
the Netherlands

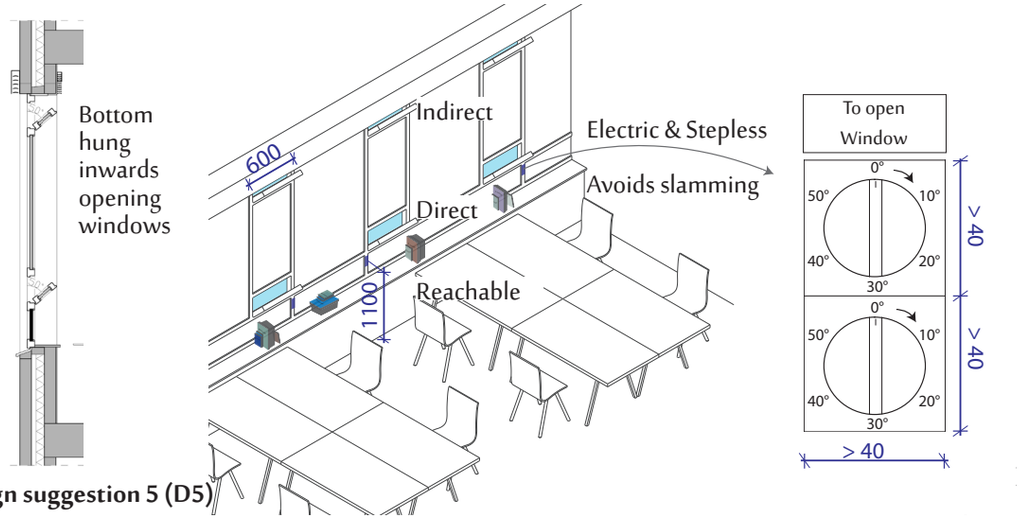
Direct and indirect control.

5. Adjustable

An operable window which is adjustable has fine-tuning capability and offers the option to control the amount, place and direction of the air flow to user's needs. Besides an adjustable window should be fixable in diverse levels to avoid slamming windows.

In fig. D5 occupants have the opportunity to ventilate directly and/or indirectly with operable windows which are stepless controllable (without restrictions in opening dimensions). Besides inwards opening bottom hung windows are better controllable in terms of air speed and amount of air than for example inwards turning windows (Heiselberg, 1999).

Controllability of the air flow through the window depends on the type of window (fig. BT5 right). Situation A is better feasible in winter because the outdoor air mixes more before it reaches the occupant zone than in situation B (Heiselberg, 1999). Besides, heating under an operable window helps to reduce draught (fig. BT5 left), this can especially be desirable in winter.



Design suggestion 5 (D5)

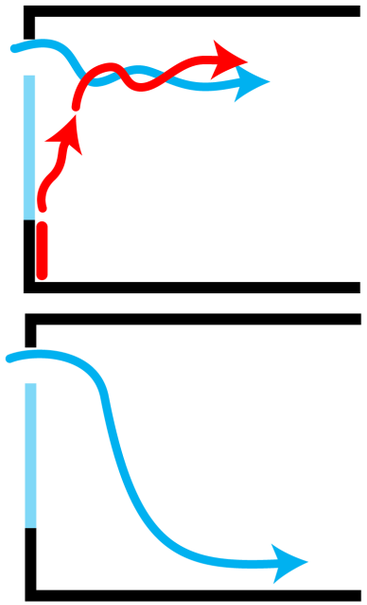
Example of a non-adjustable and non-finetunable window

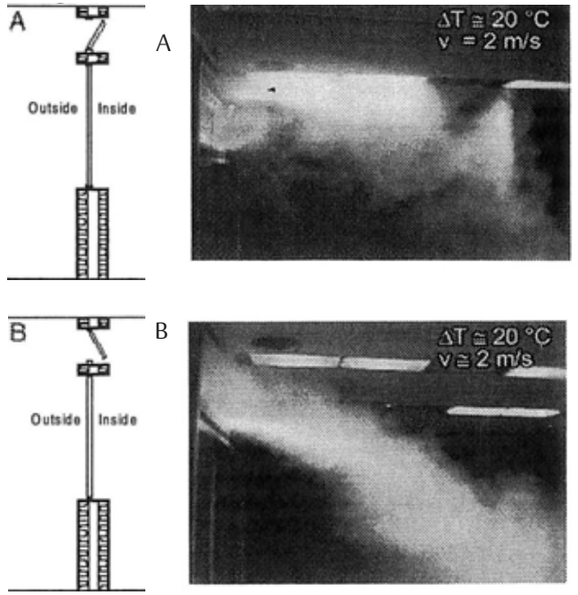
5E. Hardly controllable operable window (top hung outwards opening), only operable in one way at one level.

5b. Non-adjustable

To achieve adjustable windows with fine-tuning capability some extra attention to avoid situations with non-adjustable windows with too low fine-tuning capability can be helpful.

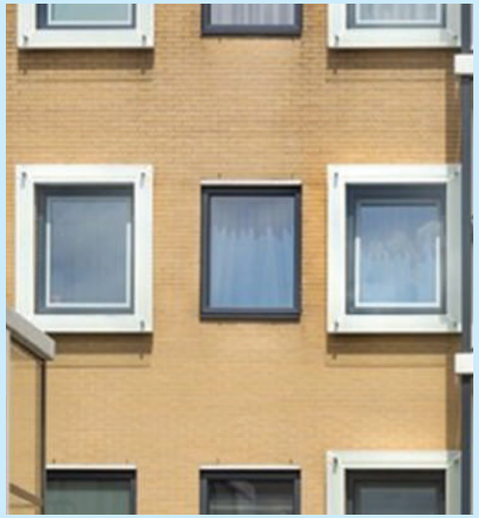
Situations to avoid:
Not fixable and slamming windows, draught and blowing away of papers (which both cannot be avoided by opening differently) should be avoided. In the example of a non-adjustable window situation (fig. 5E) occupants complained about blowing away of papers and not being able to properly control the level of opening.

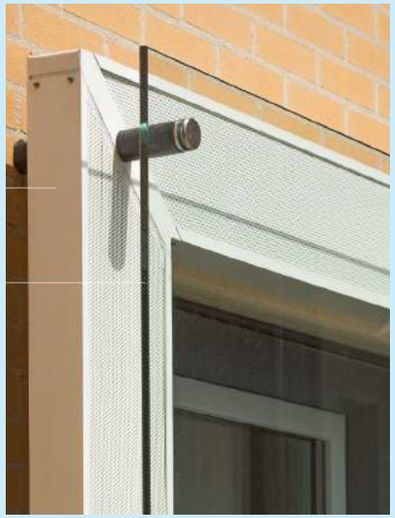




Building technical examples 5 (BT5)

Examples of windows with high acoustical performance





Project (6.PA)
Jutphaas wonen

Architect
A3 Architecten

Location
Nieuwegein,
the Netherlands

'Silentair' a product of Metaglas, developed with LBP Sight, used to reduce noise ingress while windows are open.

Project (6.PB)
Unknown

Architect
Unknown

Location
Unknown

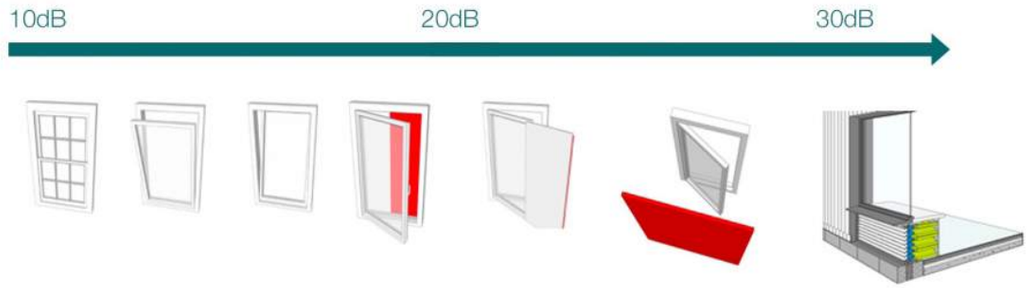
(Mach Acoustics)

External baffles reduce noise ingress into the building while windows are open.

6. Low noise ingress

An operable window with good acoustical performance reduces noise ingress and can thereby reduce distraction by noise from outside. Acoustical absorption levels and opening directions influence the acoustical performance. A window opening in the opposite direction of a sound source reduces more noise than a window opening towards a sound source.

High noise levels outside and /or quite zones inside can require extra reduction of noise ingress. Options can be to place glass in front with an acoustic border between the glass and façade (fig. 6.PA), placing external baffles in front (fig. 6.PB) or extend the window frames (BT6 right). Placing acoustical absorbing material on the inside of the extended part (fig. BT6 right & third from right in D6) increases the acoustical performance. External baffles can be placed to reduce noise in the design example (fig. BT6 left). Inwards opening windows are less feasible to extend (takes more space), besides will it be less effective than extending outwards opening windows. Mounting 'Silentair' on a glazed facade, as would be the case in the design example, does not seem feasible and would conflict with the sun shading.



Design suggestions 6 (D6)

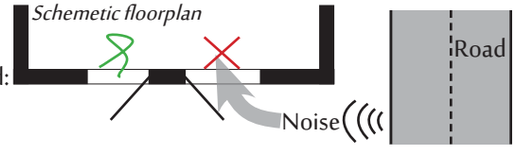
Example of a window with noise ingress

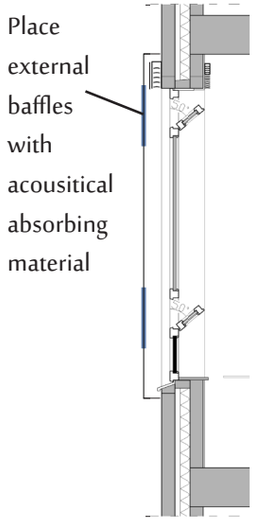
6E. Large operable window with low acoustical performance along noisy side; narrow street with much acoustical reflections between the buildings.

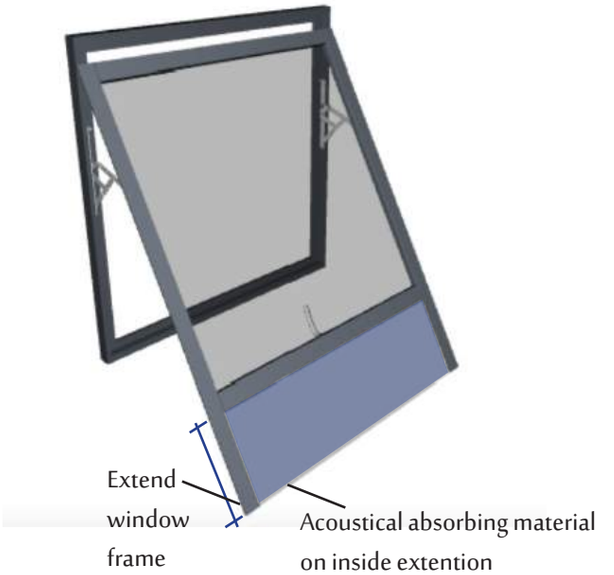
6b. High noise levels

To achieve operable windows with low noise ingress some extra attention for situations with high noise levels outside can be helpful. In case of high noise levels outside external baffles and extended window frames reduce noise ingress (fig. BT6), especially if acoustical absorbing materials are used.

Opening towards the main sound source should be avoided:

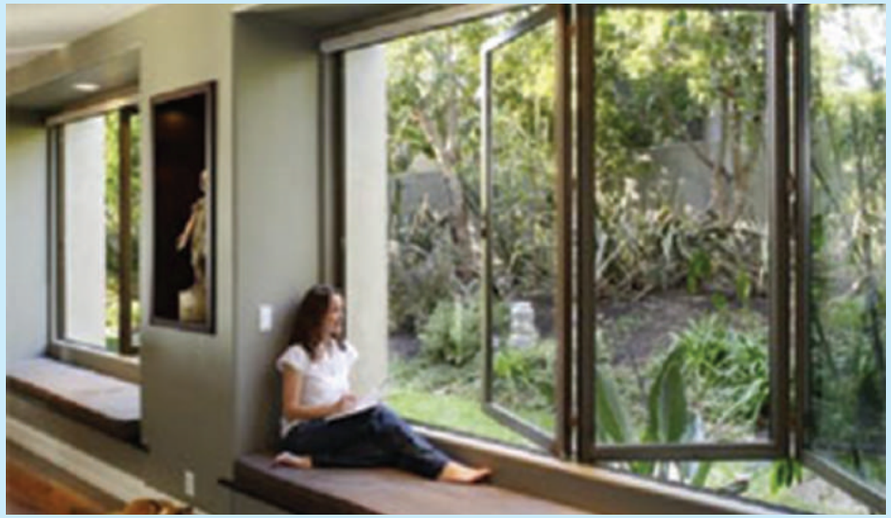






Building technical examples 6 (BT6)

Examples of windows with (mental) connection to outside



Project (7.PA)
Unknown

Architect
Unknown

Location
Unknown

Project (7.PB)
Florijnveste

Architect
Unknown

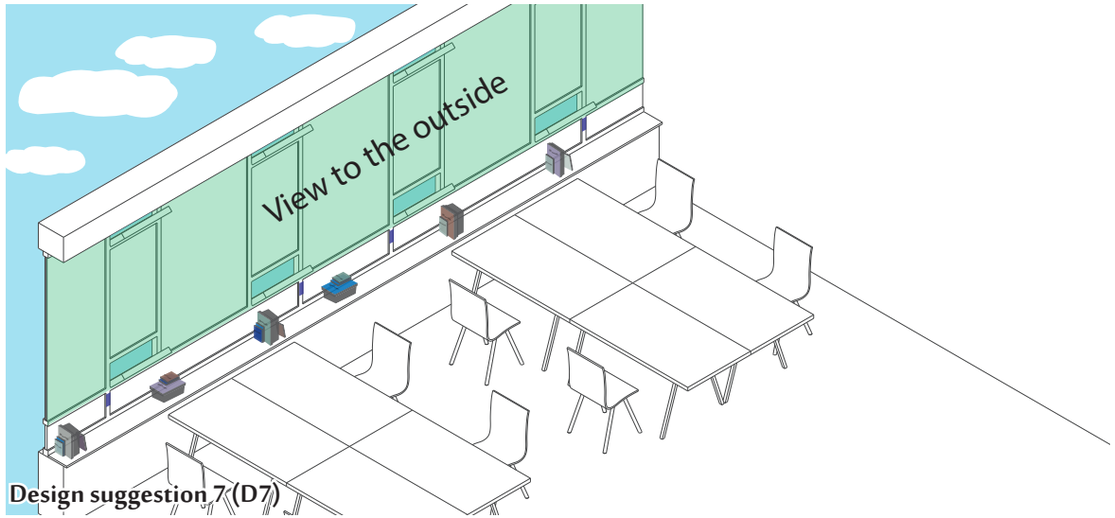
Location
Velp,
the Netherlands

7. (Mental) connection with outdoor climate

A (mental) connection with outside, for example a view to the outside, can increase forgiveness to inadequacies and acceptance to thermal variation. A view of the sky and for example trees seems to increase the (mental) connection with the outdoor climate.

Fig. 7.PA and 7.PB are examples of operable windows where a high (mental) connection with the outdoor climate occurs. In the design example (fig. D7) a view to the outside is provided as well.

Fig. BT7 presents different types of sun shading and their influence on the view of occupants.



Design suggestion 7 (D7)

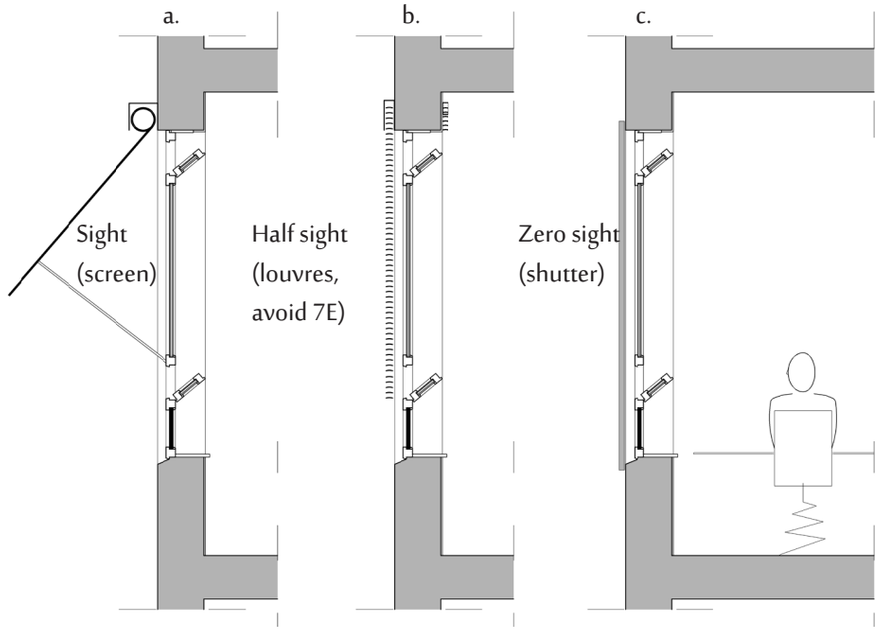
Example of a window with low connection to outdoor climate

7E. Window situation without view to the outside

7b. Low connection with outdoor climate

To achieve operable windows with (mental) connection with outdoor climate some extra attention to avoid situations with low connection with the outdoor climate can be helpful.

Situations to avoid:
Large operable windows which are hard to control and cause large thermal variation with a low connection to the outside. Fig. 7E is an example of a situation with a low connection to the outside.



Building technical examples 7 (BT7) Sights with different types of sunshading

Examples of proximal windows

Project (8.PA)
BBA Office
(DGMR Building)

Architect
Fokkema & Partners

Location
The Hague,
The Netherlands

Project (8.PB)
BK-City

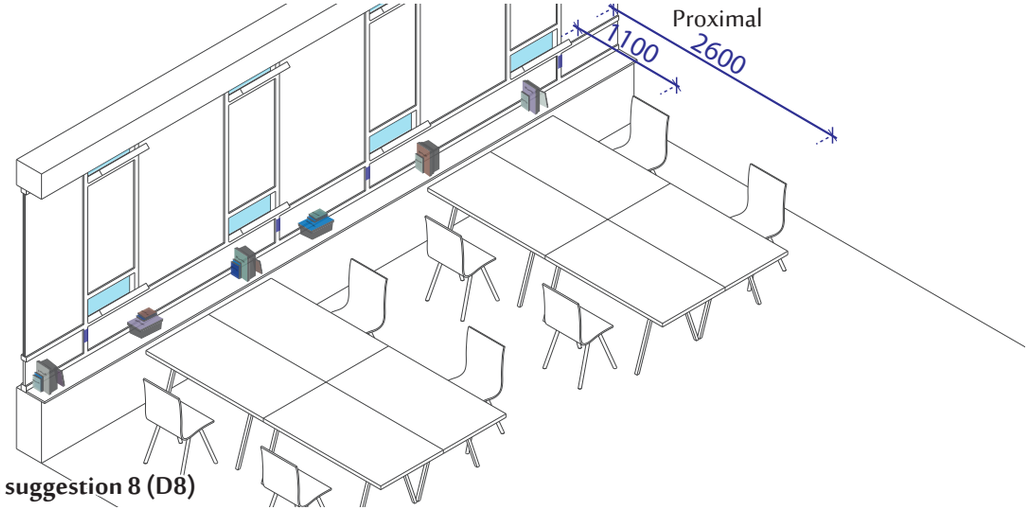
Architect
Jan Vrijman

Location
Delft,
The Netherlands

8. Proximal

Operable windows which are proximal and highly controllable by occupants are easy to reach and control. Direct access to operable windows increases perceived control, thermal adaptation, forgiveness to inadequacies and satisfaction with the indoor environment. The occupant that is most affected should have most control over the operable window to reduce objections of roommates.
If occupants are situated far away from operable windows would it cost much effort to open the window and the effect will be relatively low. Besides, occupants close by the window are mostly “in charge”.

In this case the solution should be found in the perimeter of the building and/or the floor plan. The more proximal an operable window is, the higher the benefit on user control. Proximity is integrated in the design example (fig. D8). Examples of proximal windows are fig. 8.PA and 8.PB (though, lower user control situation 8.PB is than in 8.PA because of the larger amount of occupants per operable window). In general, the larger the building depth the less robust (Kurvers S.R. et al., 2013) and the less proximity to operable windows.
The façade pattern is of influence for the proximity as well (see requirement 11).



Design suggestion 8 (D8)

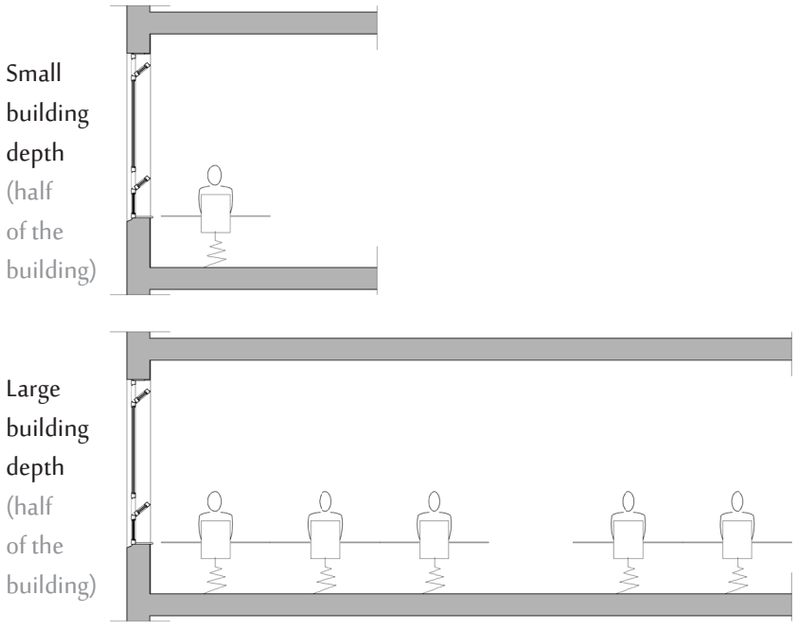
Example of non proximal windows

8E. Large distance to operable window which are shared with many occupants

8b. Low proximity

To achieve proximal operable windows which are highly controllable by occupants some extra attention to avoid situations where occupants have low proximity to the window can be helpful.

Situations to avoid:
Large distances to operable windows and 'sharing' a window with many others, this reduces personal control and increases objections of roommates by opening or closing a window.



Building technical example 8 (BT8)

Project (9.PA)
Office building
2226

Architect
Baumschlager
Eberle

Location
Lustenau, Austria

Project (9.PB)
BBA Office
(DGMR Building)

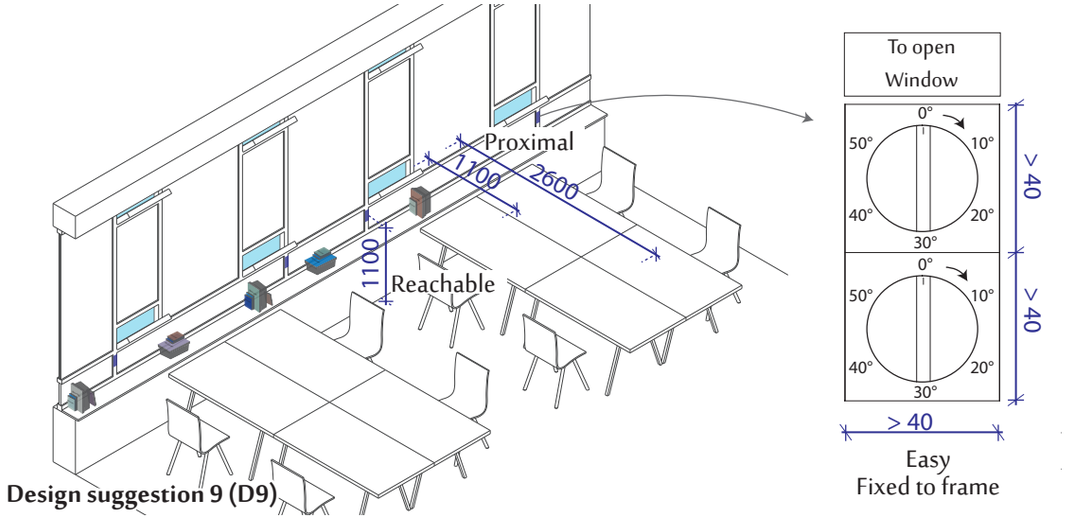
Architect
Fokkema &
Partners

Location
The Hague,
the Netherlands

9. Robust

Robust operable windows offer a high degree of personal control, can be used intuitively, are easy to use and of reliable quality. Fig. 9.PA, 9.PB and D9 illustrate robust operable window situations of reliable reachability, complexity, size and quality.

The electric controls in the design example (fig. D9) are fixed to the window frames to prevent damage and getting lost.



Design suggestion 9 (D9)

Example of a non-robust operable window

9E. Non robust window control with fragile control element which can get lost.

b.

9b. Non-robust

To achieve robust operable windows some extra attention to avoid non-robust can be helpful.

Situations to avoid:
Separate and fragile (control) elements (fig. BT9), these can get lost and damaged (fig. 9E). Complex operable windows, with for example choice overload and which are difficult to clean and maintain, should be avoided as well. Controls which are out of reach or windows where (wind driven) rain easily comes in is also considered non-robust.

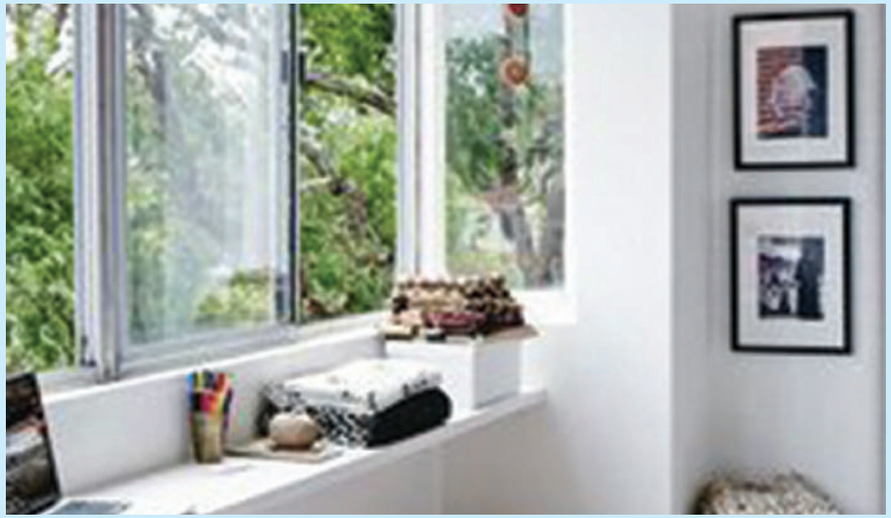
Building technical example 9 (BT9)

Whether a control is fragile or not is influenced by its material, size, shape (of the section) and if it is fixed or not. Not intuitive use can cause that people put forces in different directions than meant, which can raise the risk on damage (fig. 9Eb).

On the left an example of a not robust control element is presented which is applied to fix large operable windows. The combination of the small-sized control element compared to the large windows, movement along the element and not intuitive use result in a not robust situation.

The so called section modulus and moment of inertia can provide insight in the strength and deflection of the shape (of the section) and whether it can be improved.

Examples of parallel usable operable windows



Project A (10.PA)
Unknown

Architect
Unknown

Location
Unknown

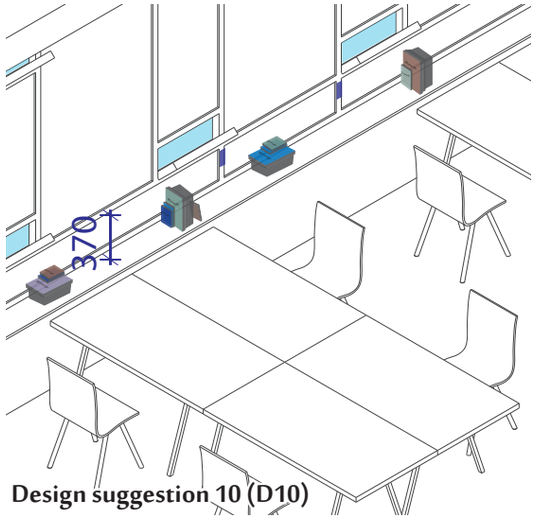
Project B (10.PB)
Office public prosecution service

Architect
Hootsmans

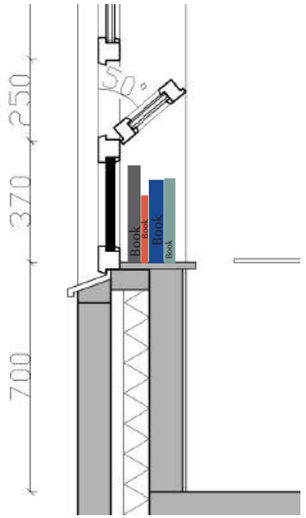
Location
Lelystad, the Netherlands

10. Parallel use of windowsill and window

Use of windowsills seems to be highly appreciated. Designing space to facilitate parallel use of windowsill and window (fig. 10.PA) prevents obstruction objects located in windowsills. Inwards turning windows, situated just above the windowsill, will obstruct opening if the windowsills are in use (fig. 10E). Operable parts without windowsills prevent obstruction of opening by stuff in windowsill as well (fig. 10.PB).



Design suggestion 10 (D10)



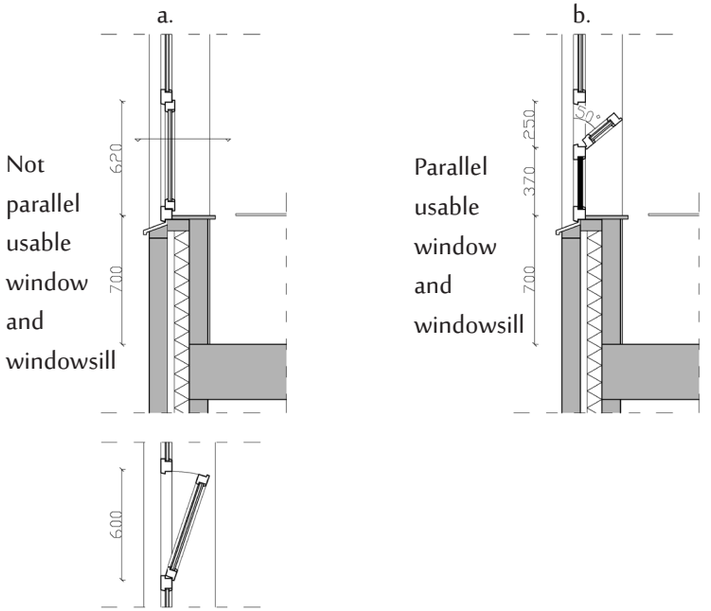
Example of an operable window and windowsill which are non-parallel usable

10E. Objects located in windowsill obstruct opening of window.

10b. Non-parallel use of windowsill and window

To achieve operable windows which can be used parallel with the windowsills some extra attention to avoid situations where window opening is obstructed objects placed in windowsills can be helpful.

Situations to avoid:
Low storage space and inwards turning windows just above windowsills (fig. BT10a).



Building technical example 10 (BT10)

Examples of aligned operable windows

Project (11.PA)
Unknown

Architect
Unknown

Location
Unknown

The operable elements are divided in small parts which reduces burglary risk compared to large operable parts.

Project (11.PB)
Ricoh Nederland

Architect
Herman Hertzberger

Location
's-Hertogenbosch, the Netherlands

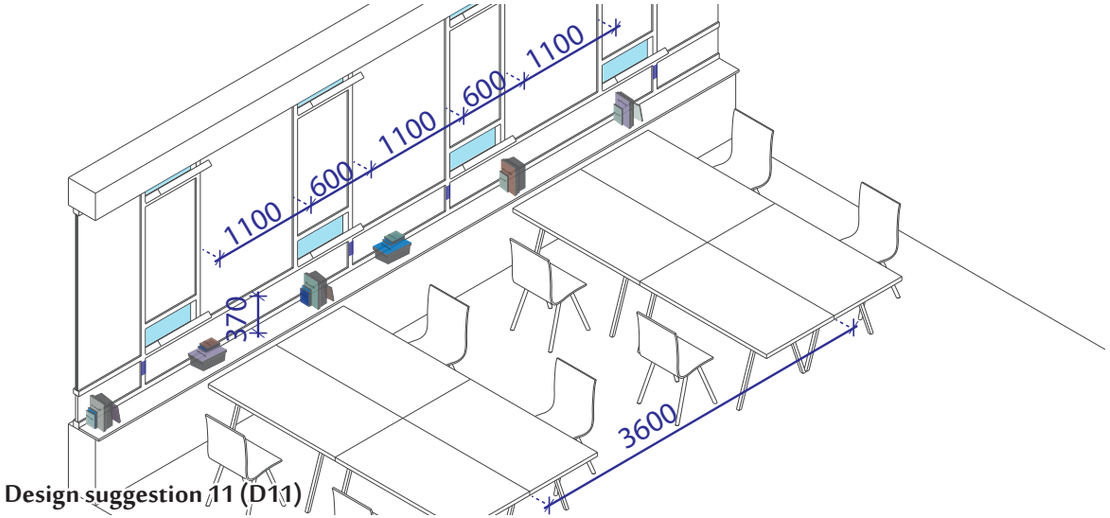
Easy to align facade pattern, the operable parts will not be obstructed in case of reasonable layouts.

11. Align design and management & security policy

Opening operable windows will be allowed if the company's management and security policy and window design align. Opening can become not allowed for security or climate control reasons if it does not align. Restriction in opening windows can cause frustrations by occupants. Especially if the occupants are not satisfied with the indoor environment.

If aligning is not possible, for example because the user is not known: Design a façade pattern which fits common layouts or where at least desks can be positioned out of the window swing (fig. 11.PB). Fig. D11 presents a common office layout and fitting façade pattern. The façade in fig. 11E has small spaces between the large, inwards opening, operable windows which makes it difficult to position desks without placing them in the window swing.

Increased burglary risk by open windows can be a security reason for opening restrictions, windows with low burglary risk, while open, can prevent this (fig. 11.PA).



Design suggestion 11 (D11)

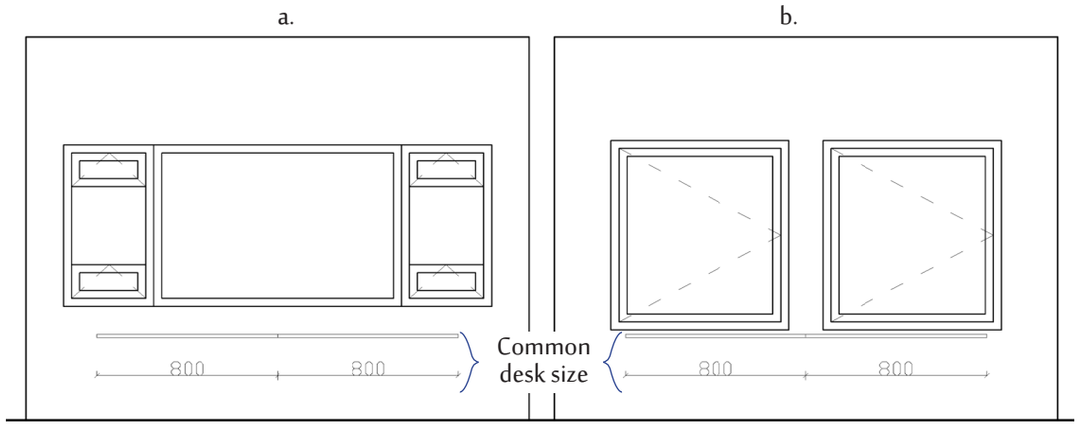
Example of non-aligned window design and layout

11E. Operable windows are hard to align with desks. In this non-aligned situation opening requires movement of pc's.

11b. Non-aligned design and management & security policy

To achieve operable windows which align with the management and security policy of the company using the building some extra attention to avoid situations where the design is not aligned with the management and security policy can be helpful.

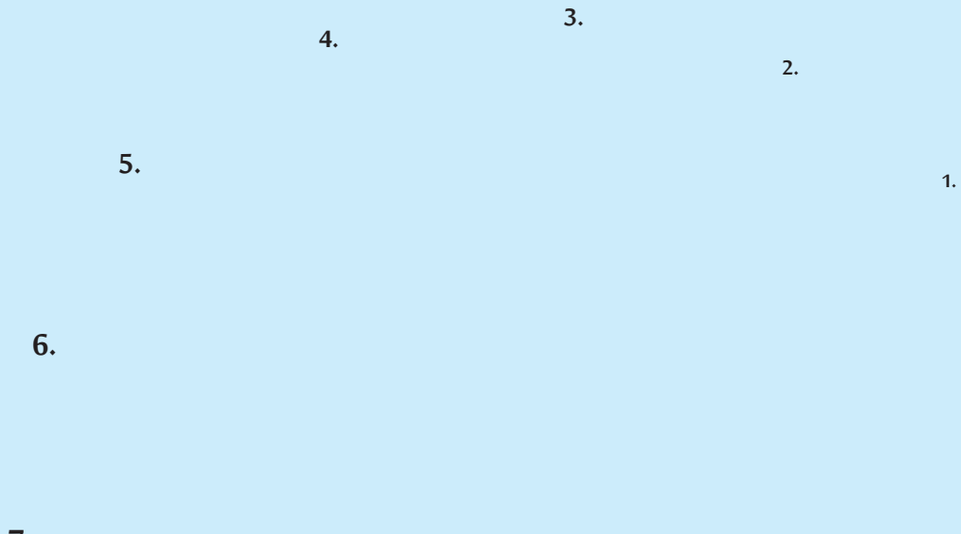
Situations to avoid:
Façade patterns and window type combinations which are hard to align with office layouts (as for example in fig. 11E and BT11b). Large operable façade elements at ground floor in rooms with valuables and strict policy for climate control.



Operable windows are
easy to align with layout

Operable windows are
not easy to align with layout

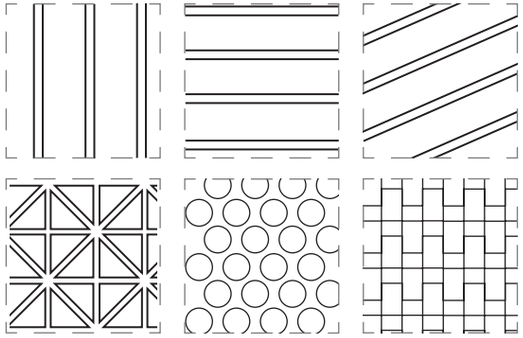
Building technical example 11 (BT11)



Designing by sub-choices

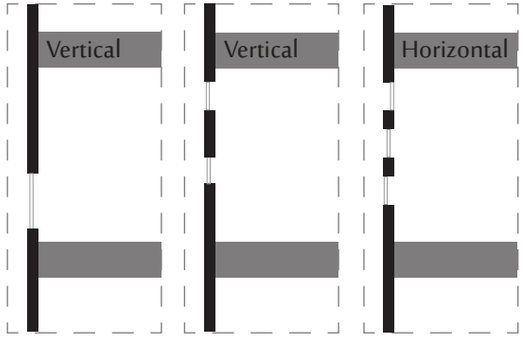
Designing by sub-choices can help to design a good usable operable window. It helps to meet the requirements and avoid the 'to avoid situations' in different stages of the design. Every sub-choice is illustrated with schematic examples of elevations or sections. Follow the sub-choices on the next page, ask yourself the questions and pay attention to the comments underneath. The comments refer to the most relevant requirements for the design phase.

1. Pattern and side



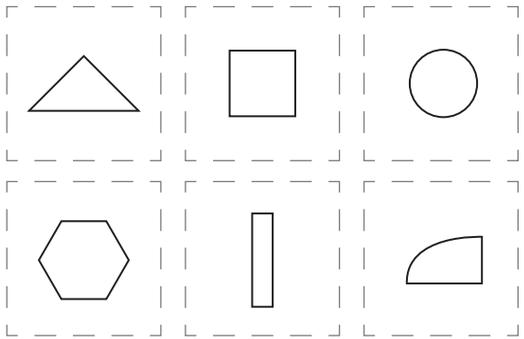
Which parts will be operable? Can this pattern be aligned with layout in such a way that the one who is most affected has most control over the operable part? (11) What is the noise exposure (6) and outdoor air quality (4)?

2. Position



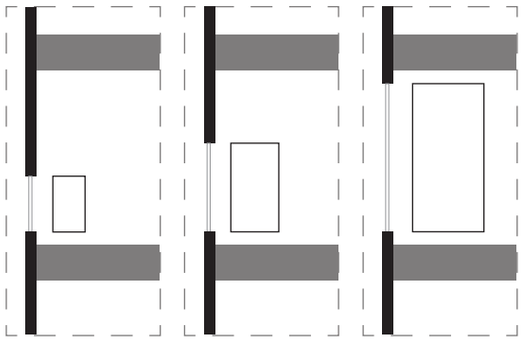
The position in vertical direction determines if it is possible to choose between direct & indirect effect (5&10). The position in horizontal direction deterimines the width of windowsill. How is the (mental) connection with outside? (7).

3. Window shape



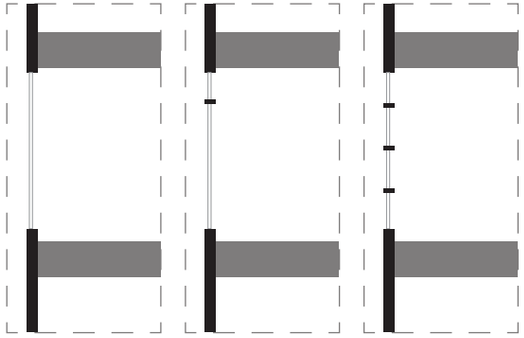
The shape of the window influences the direction of the air flow. Will the shape guide the air in the right way? If direct effect: Is the occupant where the window is directed to in control? (5) If indirect: Will mixing with indoor air occur? (5)

4. Size



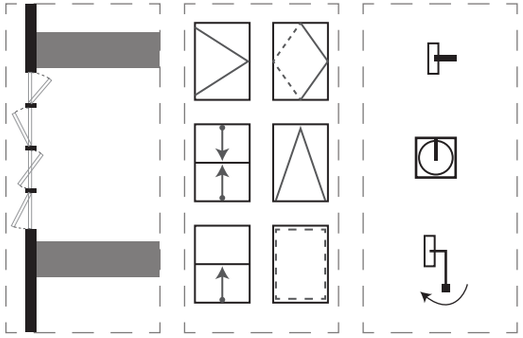
The size influeces the amount of air and air speed. Is it effective enough and controllable? (3&5)

5. Devision



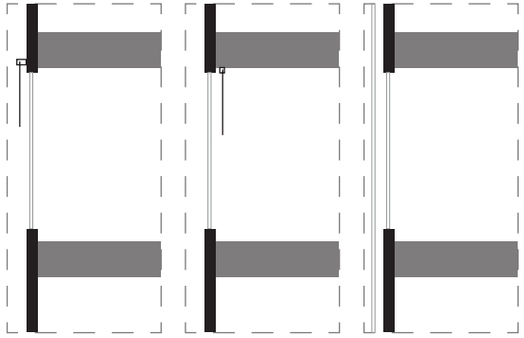
Is it possible to choose between direct & indirect effect? (5). Is it operable while objects are placed in the windowsill? (10)

6. Opening direction, - manner & control



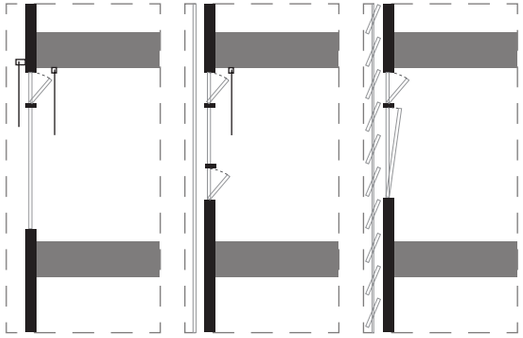
Influences whether it is; robust (incoming rain avoided?) (9), within reach (1), easy to open (2), noise reducing (6) and adjustable (are slamming windows and blowing away of papers avoided?) (5). If inwards opening; check blinds (1), if outwards; check sun shading (1). Has the occupant most affected most control ?(5)

7. Protectors

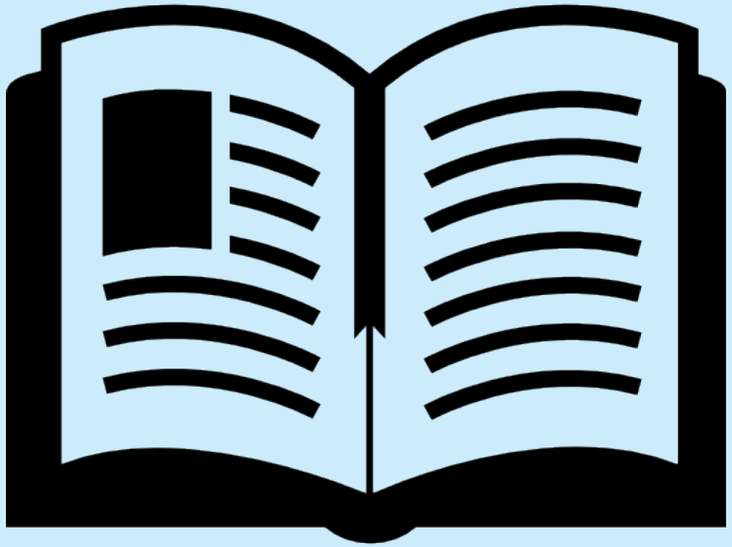


Which protectors are needed? How can the protectors be integrated in such a way that the operable parts can be opened while the protectors are in use? (5)

Combining sub-choices



Is it still manageable? (2&9&11)



Read more..

The following books and publications are interesting for more information about the indoor air, personal control and effects, aspects and use of operable windows:
My graduation thesis, where this booklet is based on, is: Wisse, R. (2017). **Design Guide for better usable operable facade elements for offices in the Netherlands**. Technische Universiteit Delft, 2017.

And further..

Bluyssen, P.M. (2015) **All you need to know about the indoor air**. Delft Academic Press VSSD.

Boerstra, A. C. (2016) **Personal control over indoor climate in offices: impact on comfort, health and productivity.** Technische Universiteit Eindhoven, 2016.

Brager, G., Paliaga, G., & De Dear, R. (2004). **Operable windows, personal control and occupant comfort**. Center for the Built Environment.

Kurvers, S. R., Raue, A. K., Van den Ham, E. R., Leijten, J. L., & Juricic, S. M. M. (2013). **Robust Climate Design Combines Energy Efficiency with Occupant Health and Comfort**. In ASHRAE IAQ 2013 Proceedings: Environmental Health in Low Energy Buildings, Vancouver, Canada, 15-18 October 2013. ASHRAE.

Heiselberg, P., Dam, H., Sørensen, L. C., Nielsen, P. V., & Svidt, K. (1999). **Characteristics of Air Flow through Windows**. Aalborg: Dept. of Building Technology and Structural Engineering, Aalborg University. (Indoor Environmental Engineering; No. 103, Vol. R9940).

Herkel, S., Knapp, U., & Pfafferott, J. (2006). T**owards a model of user behaviour regarding the manual control of windows in office buildings**. Building and environment, 43(4), 588-600.

Hellwig, R. T. (2015). **Perceived control in indoor environments: a conceptual approach**. Building Research & Information, 43(3), 302-315.

Nunes, Zé (05-2016). **How to design sustainable buildings on noisy sites**. MACH Acoustics. Accessed on July 27, 2016. Retrieved from https://www.linkedin.com/pulse/how-design-sustainable-buildings-noisy-sites-ze-nunes?trk=pulse-det-nav_art

Credits

About the author

Rolien Wisse was a graduate student of Delft University of Technology within the master track Building Technology. Her graduation is in cooperation with BBA Binnenmilieu and combines the fields indoor environment and facade engineering.

This booklet is made as part of my graduation project at the TU Delft under leading of supervisors prof. dr. ir. Philomena Bluyssen and ir. Frank Schnater. In corporation with BBA Binnenmilieu with dr. ir. Atze Boerstra as guest supervisor.

Photography credits

BBA Binnnenmileu	Examples;	1Ea, b, c; 3E; 4E; 5E; 7E; 8E; 9E; 10E and 11E.
Rolien Wisse	Pages:	6; 8; 16; 18. Projects; 1.PA; 2.PB; 5.PB; 8.PA; 8.PB; 9.PB and 6E; BT9.
www.flaticon.com	Icons on pages:	12; 14; 26; 63; 72, 76 and 78.

1.PB Busch-jaeger (n.d.). Jaloezieschakelaar/-impulsgever met draaiknop. Accessed on March 7, 2017. Retreived from https://www.busch-jaeger.de/nl/producten/productoplossing/jaloeziemanagement/jaloezieschakelaar-impulsgever-met-draaiknop/
2.PA Tom de Vries (2012). Project renovatie. Accessed on March 17, 2017. Retrieved from http://www.adamsbouwadviesbureau.nl/uploads/bella-donna.pdf
3.PA Efficient Windows Collaborative (2015). Debis tower. Accessed on March 7, 2017. Retrieved from http://www.commercialwindows.org/case_debis.php
3.PB Olson Kundig (2017). Art stable. Accessed on March 3, 2017. Retrieved from http://www.olsonkundig.com/projects/art-stable/
4.PB European Business (2017). Baumschlager Eberle Lustenau GmbH. Accessed on March 7, 2017. Retrieved from https://www.european-business.com/baumschlager-eberle-lustenau-gmbh/interviews/the-future-of-architecture/
5.PA Ban quyen thuoc nhà máy nhôm Viet Pháp (n.d.). PHU KIEN CUA NHÔM. Accessed on March 7, 2017. Retrieved from http://nhomvietphap.com/san-pham.aspx?type=9
6.PA Transmedianet (2017). Transformatie kantoorgebouw Einsteinbaan, Nieuwegein. Accessed on March 7, 2017. Retrieved from http://www.dearchitect.nl/projecten/transformatie-kantoorgebouw-einsteinbaan-nieuwegein
6.PB & BT6 Ze Nunes (2016). Look to Facade and Window Design for Quiet, Low Carbon Buildings on Noisy Sites. Accessed on March 7,2017. Retrieved from https://www.linkedin.com/pulse/look-facade-window-design-quiet-low-carbon-buildings-noisy-ze-nunes
7.PA Solarlux (n.d.). Vouwwanden en balkonbeglazing. Accessed on March 7, 2017. Retrieved from https://www.alumiant.nl/solarlux/vouwwanden-en-balkonbeglazing/
7.PB Alterweb (2015). Florijnveste. Accessed on March 7, 2017. Retrieved from https://www.alterweb.nl/blog/verhuisd-naar-de-florijnweg-13-15
9.PA Eduard Hueber (2015). Passive Office Building 2226 by Baumschlager Eberle. Accessed on March 7, 2017. Retrieved from http://ideasgn.com/architecture/passive-office-2226-baumschlager-eberle/
10.PA Makeover.nl (2016). 8x een werkplek bij het raam. Accessed on March 7, 2017. Retrieved from https://makeover.nl/inspiratie/inrichting/thuiskantoor/8x-werkplek-bij-het-raam#
10.PB Metaglas (n.d.). Metaplus Clima. Accessed on March 7, 2017. Retrieved from http://www.metaglas.nl/producten/metaplus-achterzetramen/metaplus-clima/
11.PA Technical (n.d.) Cliquez sur l'image pour l'agrandir. Accessed on March 7, 2017. Retrieved from https://www.technal.com/fr/fr/accueil-professionnels/Les-Produits-Technal/Les-fenetres-et-porte-fenetres-batantes/Jalousie-Safetyline/34380/Jalousie-mixte-lames-orientables-verre-et-aluminium/
11.PB Teun Suijkerbuijk (2014). De werkplek van Patrick Roelandt, Ricoh Nederland. Accessed on March 3, 2017. Retrieved from http://dewerkplekvan.nl/de-werkplek-van-patrick-roelandt-ricoh-nederland/
2E Unique window services (2016). Wynnum State High School. Accessed on March 7, 2017. Retrieved from http://uniquewindowservices.com/project/wynnum-state-high-school/
D6 Mach Acoustics (2015). Forms of noise control. Accessed on March 7, 2017. Accessed on http://www.machacoustics.com/explore/books/open-windows/modelling-testing-results/
Page4. Discovering disegno (2015). Dessau Bauhaus. Accessed on March 3, 2017. Retrieved from https://discoveringdisegno.wordpress.com/2015/08/05/dessau-bauhaus/

This Design Guide is a practical guide for inspiration and points of attention while designing operable windows that provide user control. This booklet is a must read for architects and façade designers or anyone interested in operable windows. It assists in designing appropriate usable operable windows.