Wind based urban design in dense urban context. Prefacing wind nuisance and optimizing the human wind comfort for outdoor relaxation.

A CASE STUDY - Tim Ras - 1512676

This research paper aims on the problem of wind nuisance in the urban sphere of Amsterdam Teleport. In a world in which we continue to build higher and denser, we continue to disregard the effect of the built environment on the urban micro-wind climate. Numerous incidents can be found on casualties due to strong wind velocities around high-rise buildings. Also, there are enough examples of shops and bars that went bankrupt just because the wind comfort in front of their facilities wasn't suitable for pedestrian shoppers.

Of course, here in the Netherlands, we've got the wind regulations on the built environment. In these “NEN-normen” rules are given in what cases wind danger may occur and wind nuisance reducing efforts needs to be taken. The NEN 8100 regulations focus on the chance that the wind speeds become uncomfortable for urban relaxation or dangerous wind speeds may occur. Wind tunnel testing and CFD modeling then, can envision the effect of the wind on it's surroundings. This graduation research focuses itself on wind comfort in the dense urban context and creating a method on designing for wind comfort: “smart wind designing”.

To give an answer to this question a research by design method is applied. Research will be done on the Dutch wind regulations. In addition, the pedestrian wind experience will be attended in relation to the sun. Hereafter the Dutch wind climate will be explored on finding the statistical data needed for analyzing. Furthermore some case studies are done on different wind engineering projects in order to set apart some applied wind engineering. Hereafter a design method on “designing with wind” or “smart wind design” will be set up before performing a CFD case study on Teleport. The CFD simulations itself will be analyzed and conclusions will be drawn on creating a wind comfort based urban design. This results in the question: (How) can we design a wind comfortable station square in a dense urban context like Amsterdam Teleport, given an architectural predesign?

Concluding that the design outcome is correct, simulated wind climates are subject to change. Every effort we take now can be false for the future, for the urban context is subject to change. When accepting the given context a wind comfortable design is possible. A comfort class of category A is achievable by adjusting two different points in the urban context; one porous screen and one building mass. Though, these interventions place the problem of wind nuisance on a neighbour buildings facade. A third options on building shape could create a local, though smaller, wind comfortable area. On the building scale wind comfort can be achieved by wind screens and porous facade elements for specific interventions.

Keywords: Amsterdam Teleport, Pedestrian Wind comfort, Smart wind design, Wind engineering, CFD analysis

1.1 Amsterdam Teleport

Amsterdam Teleport is an area meant to give space to the numerous of telecom companies founded in the 90’s. The founding of the Internet caused policy makers to expect that in the future all telecom companies would have to work at the same place and be wired with each other. Time proves that this idea of working together at one place hasn’t come true. In fact, the contrary came true; we are able to work together even from the other side of the world without wires etc. This made that the Teleport area has approximately 47% vacant office space. These are designed with a strongly outdated typology (DRO, 2008). To get all these telecom workers to their work places, the Sloterdijk railway station was given a new place in the center of the Teleport. These railway tracks, along with the A10 highway, are the main cause of this Teleport area turning into an island of densely built empty offices with an empty public sphere (DRO, 2008).
Vision
The infrastructure in the area, railway and highway, are one of a very high urban hierarchy. This clash of the macro scale, national scale, and the local neighbourhood, is in my vision, the cause of the alienation that spectators experience when visiting the area. There is no clear and explicit structure that gives shape and direction to the area which causes lot's of visitors to get lost in this rather small piece of Amsterdam. In addition, the station square isn’t a square due to its lack of surrounding buildings and the urban street life is dominated by public transportation, parking places and emptiness. Even though the macro-scale infrastructure seems to increases the boundary formation in the area, my personal opinion is that the real reason to the fragmented and bordered area lies in the void formed by this macro scales. This piece is where emptiness, scaleless, insecurity, and a high vacancy rate are main subjects (figure 1).

The affected area is, at the moment, been taken care of by the municipality. Currently this is only on the scale of landscape interventions and not by a more radical urban redesign. Though a more radical intervention is expected in better economical times. Also, there is the difference in height in this area caused by the structure of the, old, Sloterdijk dike and the more modern raised railway station complex. This elevated railway station is the reason huge “fly-overs” are situated in the area. It is here, underneath the fly-overs, where the main focus of this research lies. In addition the area has a sense of “unfinished” over it. This is backed up by the Amsterdam Structural vision for the next 20 years in which an area is described of great density with new housing development in the northern context of this plot. To anticipate on the future plans, this structural visions (van Zanen, 2013) on the future are taken as being true. This situation and further analysis are given in appendix 1

1.2 Wind engineering context
In this context, it is according to NEN8100, expected that the wind velocities will rise when encountering this southern orientated canyon of Teleport (figure 2 between the red lines). This could be one of high values because of the emptiness and rather high buildings surrounding it. This wind makes it that a low urban climate is expected in the area based on NEN 8100. To accommodate future development in this area, a better wind climate could be required. Further investigation on this subject is needed to define its necessity and values. Literature on this subject is better known in the civil engineering and aerospace engineering under the name of “wind engineering”. The current wind engineering research has been done on how wind reacts to buildings that stand in its way in a certain context. This research aims to go further then this testing after designing to a “smart-wind design”. Creating a method on wind based designing on turning it into a wind comfortable urban design.
2.1 Dutch wind nuisance regulations: NEN8100
At first the Dutch regulations on wind will be attended in order to create a smart wind design. The Dutch regulations on wind engineering are found in the NEN 8100 regulations. The NEN 8100 is based on a chance of exceeding the 5.4 m/s wind speed limit. This 5.4 m/s is found as being the maximum acceptable wind velocity on which urban life can normally continue working. This wind speed will have the following results: waving of clothing, windblown hair. Though, a child or an elderly respond differently to the wind than a healthy adult. The experience of wind nuisance is dependent on the activity which are taken at that time. The probability that a random wind nuisance occurs is greater when a person is sitting then when this person is running. The Dutch wind regulations is, as said, based on the chance that this 5.4 m/s level is exceeded. This chance is then calculated into comfort classes. These classes go from A until E (figure 3).

2.2 Urban climate appreciation
Though this empirical values give a clear vision on the wind climate of an area, they aren’t taking in account that a brief wind in summer time creates a higher appreciation of the urban climate. This experience of the wind as a nuisance or as a satisfying factor has been researched by M. Tacken of the Delft university of technology. In his research on a comfortable urban wind climate he questions a great amount of participants on their notion on the wind while relaxing in outdoor urban areas. This “relaxation” has been defined as tranquil behavior such as; sitting, sunbathing, standing and chatting, looking into shop windows etc (Tacken, 1989). His research states that the main parameters for creating an urban comfortable area are; humidity, temperature, solar irradiation, wind velocity and wind turbulence. In these tests, normal people in average office clothes sat outside for 20 minutes next to a solarimeter and anemometer. At the end they where asked to fill in a short questionnaire about their comfort while sitting outside for 20 minutes. The questions where asked in three different sections; (I) a series of contradictory concept about the weather in which the participants had to choose. (II) their willingness to stay outside longer (III) the participants had to choose 3 out of 16 perceptions on how they experience the weather. These perceptions where then analyzed and compared to the data from the anemometer and solarimeter. This test has been repeated 105 times in a 4 year range.

From this research a table has been made attending the climatic perception with the following results: By estimating the percentage of the test subjects who were willing to stay outside longer at a certain score on the rating scale, it is possible to obtain an indication of the score at which the majority of people consider it comfortable to relax out-of-doors. It is found that with a score of 4.0, 70% of test subjects would be willing to stay outside longer, while at a score of 3.5 the percentage has dropped to 32%. A score of 4.0 is consequently considered the higher limit for a comfortable climate.

Appendix 4 shows the average perception of climate, given a reasonable average of solar irradiation, namely 400 W m-2 (the average for all measurements in our tests was 395 W m-2), for a number of combinations of wind velocity and temperature. It is found that at a temperature of 18°C and almost no wind (less than 0.5 m s -), perception of the outdoor climate exceeds the critical limit of 4.0. With a velocity of 3 m/s, perception only positive at a temperature of 25°C.
3.1 The micro wind scale and aerodynamic information

Before attending to the wind flow around buildings it is important to see how the wind flows in general in urban areas. Here for we first attend to the wind flow on an object to get a better understanding about the wind and its terms. In figure (5) is seen that when wind clashes into an object it always tries to find the shortest way around it. When wind strikes an object, wind speeds on the surface is 0 and the wind speed on the other side of the boundary layer is the average wind speed. Between the surface and the point where the wind speeds continue their normal speeds, there is a zone that is called the boundary layer. In this area the smoothness of the surface, the overall shape and the wind speed determines how the main wind speed gets afflicted.

In this example it is shown that an increasing roughness of the surface, also increases the boundary layer. In addition, enlarging the boundary layers thickness increases the area of wake behind the object. This gives us directly the most important facet of the boundary layer: its thickness (Anderson 2005). When the boundary layer thickens, the forces on the surface of the object will increase. When this leads to a critical point, the wind wont “stick” onto the surface anymore and it will lead to flow separation. This then has a negative side effect on the overall wind and creates noise (Anderson 2005).

This boundary layer on the golf ball of fig. 6 can also be applied to the earth’s atmosphere (fig. 6). The macro winds that flow around our planet get disrupted by the earth’s terrain roughness creating a boundary layer. This boundary layer is called ABL; Atmospheric Boundary Layer. The rougher the earth’s surface gets, the larger this ABL becomes (Fig 6). Just as with the golf ball, the ABL goes from the 0-point until the point where the wind speed matches its macro speed. The bottom 20% of the ABL is called the surface layer and this is the wind where the main subject of this thesis is dealing with. The wind above this point gradually approaches the values of the ABL top. As said, the ABL changes along the changing surface. The measured wind speed at the meteorologic station is mostly at 10 meters high in an open landscape (Bottema, 1993). To use this data in a surface where the ABL is large the amplification factor (y) is applied:

\[ U = U_{pot} * y \]
\[ U_{pot} = \text{wind speed above a grass covered plain} \]
\[ U = \text{wind speed at target area} \]
\[ y = \text{amplification factor} \]

In addition, due to the wind speeds the wind around buildings is almost always incompressible. This means the wind speeds will not be exceed 0,3 Mach from where the wind will be show compressible behavior. Due to this fact the continuity equation for steady fluid flow is a basic rule. In this rule the air density is always the same and if the area doubles at one side the wind speed halve at the other side as shown in below formula (Anderson 2005).

\[ p1 * A1 * v1 = p2 * A2 * v2 \]
\[ p1 = p2 = \text{air density (kg/m3)} \]
\[ A1 = A2 = \text{Area (m2)} \]
\[ v1= v2 = \text{wind velocity (m/s)} \]
3.2 Teleport wind climate

Wind statistics are being measured by meteorologic stations in open field on 10m height, or in cities on 60m height. This is to make sure the main wind speed is measured without interfering effects. So understanding the way the ABL transforms along a terrain gives us knowledge on how we can read the information we find in our urban situation (Bottema, 1993). Main aspects in this ABL are firstly the wind statistics which are hourly averages of winds that gust longer than 5 seconds. Secondly, the terrain roughness of the surrounding 10 km is essential in formulating expectations in the local influence of the built environment.

In Appendix 5 the wind statistics are given as calculated by Peutz(2010) for the VU medical center in Amsterdam. For actual wind statistics they used the NPR 6079:2006 given by the NEN8100 regulation. These statistics are by their knowledge on the ABL transformed to an usable wind statistic for the VU medical center location. Making this transition, next to the wind statistics, the terrain roughness has been made visible. Meteorologic values are always given in percentages of possible appearance. Therefor the statistics of the Teleport area are recalculated into the values of figure 7. These 5 chosen directions are based on the 4 main wind directions and the most frequently applied northern wind. Choosing this 5 directions is part of the method on “smart wind designing” the calculation time of CFD would make it impossible to implement into a design process. Reducing the wind directions gives room for more variables in research.

In figure 30 the, based on NPR6079, calculated wind rose is given. This wind rose is, as is the scheme of Appendix 5. The main wind directions are given in figure 8. All measurements are averaged for one hour resulting in the ‘hour average wind velocity. From these hour averages a year average can be calculated, the ‘year average wind velocity. Obstacles around the wind station introduce a deviation by which these data are not immediately applicable in neighboring locations. A correction has to be made by adding the terrain roughness coefficient (de Jong, 2008).

<table>
<thead>
<tr>
<th>Wind direction*</th>
<th>Angle°</th>
<th>Av. Wind sp.</th>
<th>P(wind flow)</th>
<th>P(U &gt; 5 m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West</td>
<td>270</td>
<td>6,1 m/s</td>
<td>14,7%</td>
<td>65,9%</td>
</tr>
<tr>
<td>South West</td>
<td>240</td>
<td>7,0 m/s</td>
<td>17,7%</td>
<td>69,4%</td>
</tr>
<tr>
<td>South South West</td>
<td>210</td>
<td>6,3 m/s</td>
<td>18,1%</td>
<td>62,4%</td>
</tr>
<tr>
<td>South</td>
<td>180</td>
<td>5,2 m/s</td>
<td>14,1%</td>
<td>48,1%</td>
</tr>
<tr>
<td>North East</td>
<td>60</td>
<td>4,8 m/s</td>
<td>9,8%</td>
<td>42,1%</td>
</tr>
<tr>
<td>Other</td>
<td>--</td>
<td>4,6 m/s</td>
<td>25,6%</td>
<td>35%</td>
</tr>
</tbody>
</table>

Figure 7: Recalculated wind statistics for Amsterdam Teleport showing a +/- 75% coverage from 5 wind directions (Own diagram based on NPR6079)

3.3 Terrain roughness

Each terrain can be described by an aerodynamic roughness length $Z_0$ and a displacement length D (Bottema, 1993). The $Z_0$ is the classification calculation number of the terrain the wind is flowing before arriving at the project area. This roughness length is taken for a 10 km radius around the project area. The $Z_0$ value can be seen as the vertical displacement the wind is experiencing due to the presence of obstacles and gaps in the landscape. The roughness length isn’t a real obstacle height but more a simulation of the number of “eddies” the wind flow will find on its path. The roughness parameter $Z_0$ isn’t just influenced by the height of obstacles, but also by obstacle spacing and other, negligible, factors. The $Z_0$ can roughly be calculated by dividing the height of an object by 10. For a grassland with a height of 0,3 m the $Z_0$ value then is 0,3/10 = 0,03.

Wieringa(1992) categorized these different types of landscape into 8 different classes. The here for calculated roughness length $Z_0$ corresponds with the roughness classification 3. Wieringa, however, didn’t present values for the zero displacement length D. The zero displacement length is the height at which the zero wind speed is achieved due to the obstacles in its way such. As a rule of thumb, the D-value is roughly $2/3$ of the average obstacle height (Bottema, 1993). For example, if estimating winds over a city landscape with an average height of 30m, the D-value will then be give or take 20m. The terrain roughness of the Teleport surroundings are given in Appendix 3.
4.1 wind engineering methods

In wind engineering there are two ways of research. Firstly there is the science part of wind engineering. Secondly there is the applied science part of wind engineering. Both methods are mostly used at a later stage in the design process. This happens when the NEN:8100 regulation states that the necessity factor is reached. The wind engineering research process is a high time-consuming one. Therefore a faster method is needed for integration into the design process: smart wind designing.

The science part of wind engineering research is one of great uncertainties. This part of the science tries to find better methods on simulating the wind into computer models (CFD), wind tunnels, roughness length ect. The science part asks specific method related questions to improve the applied part of the wind engineering (Blokken, 2009).

The applied science part of wind engineering is one of very direct questioning. It finds an exact problem, high wind nuisance between two buildings, to simulate this wind pattern very precise and find a solution in an engineering kind of thinking; windscreens, walls etc.

Smart wind designing tries to combine these two ways of thinking in a “designerly” way of thinking. Here for, as the design process knows lots of variables, the applied science methods needs to be repeated multiple times while being reflected by the scientific literature. This process, as being a design process, needs to be repeated multiple times. Therefore, because this graduation is of limited time, a fast way of simulating is required. This means that the wind comfort is only calculated for 5 wind directions covering 75% of the total wind flow. In addition, the focus of the method lies not only on the target wind problems but also on the effect an intervention has on its surroundings. This is then again a very scientific way of looking in the wind engineering.

The Smart Wind Design method gives the designer information in case of the building shape and urban configuration which he then can implement in his design. Here after, the process of CFD starts over again, step by step to a smart wind design.
4.2 Wind engineering methods
For proceeding on this “smart wind designing” there are 3 main methods in validating and simulating. They all have their own purpose, shortcomings and possibilities. The first two, full-scale measurements, and wind tunnel testing, won’t be discussed because of its clear purpose. CFD, as mainly used method will be attended in a deeper way because of its shortcomings and because this entire research is based upon it.

4.2.2 CFD computer models
This, rather new, technique in the urban research tries to simulate the wind flow and velocity in order to predict the impact of wind on buildings and their surroundings. Its a technique that’s very much dependent to the scale and accuracy you have modeled and the grid that is used in the model (Franke, Hellsten, Schlunzen, & Carissimo, 2011).

The CFD (computer fluid dynamics) is increasingly being used as a tool for simulating the wind flow around buildings and therefore it is increasingly being used as a tool on predicting the pedestrian wind comfort around high rise buildings. However, the questions on how accurate the CFD modeling is able to predict the wind climate and its reaction on the built environment is still not thoroughly understood. At the Tokyo faculty of architecture, R. Yoshie and his companions compared three different basic wind engineering case study results with the values they would expect from intensive wind tunnel testing (R. Yoshie et al., 2007).

Without fully going into the method, results and comparisons, the conclusion of this study was that; the overall distribution of measuring wind velocity is much stronger and more detailed, mechanical wind tunnel errors are left out and even the smallest strong wind points can be found. Summed up, CFD can be called stronger in outcome though wind tunnel testing is more accurate when it comes down to the input (R. Yoshie et al., 2007).

4.2.3 Autodesk Ecotect
Understanding the limitations of the software is of great importance. In the case of this research it shapes the method used in validating and calculating the wind speeds in Teleport. In the validation research of Yoshie (2007), it is show that with the same data input and method still different outcomes can occur in wind flow simulation. This is caused by the simple fact that the CFD software is human programmed simulation with integrated calculations that can only try to simulate the truth.

This graduation research is executed by the free Autodesk Ecotect CFD software. Most important functions to validate in this program are, according to the article of Yoshie, the input possibilities and the grid detail possibilities. The grid options of Ecotect is one of very poor quality. As the grid in professional CFD software can be adjusted, the Ecotect wind tunnel grid can only be adjusted in size, not in intensity. Only the three mayor grid intensities can be adjusted: course, medium, fine. Intensifying the grid at the points of question is essential in getting reliable results because one grid cell correspondents with one calculation (Blocken, 2008). This research question is one of great scale and therefore the grid size can be rather course. To put this into perspective; if the area of question is approximately 30 meters broad then, with a coarse grid size and 6 cells covering this area, the wind flow received will only give the wind direction on every \((30/6) = 5\) m². It’s imaginable that when the research question is one of a smaller scale, lets say the effect of the corner of a building or wind speeds on pedestrian height, the grid size must at least be one of 1 grid cell every 1 - 2 m². So, intensifying the simulation grid gives a more accurate and reliable outcome. Though, intensifying the grid will greatly increase the calculation time the model needs to give an outcome. This fives a great contradiction with the design process. As Yoshie (2007) says: “The CFD model can be exceeding the wind tunnel modeling, as long as the data input and usage is one of great accuracy”.

As said, this fives a great contradiction with the design process. In designing, a great amount of variations in building options must be discovered. Though, the calculation time for simulating these models wont allow this. So, to implement wind engineering into the urban or architectural design. Conclusions have to be made onto rougher 2D results then wind engineering is used to. Intensive 3D calculations can only be used when more information has to be pulled out of a 2D model. This using of CFD is the only way of using wind engineering in designing. This will be done in the earlier mentioned 5 wind directions.
5.1 Urban Design proposal
Before creating a smart wind design on Teleport a preliminary “0-hypthesis” need to be created. To create a new Teleport, the city of Amsterdam has summed up some visions of improvement for the area. In their plan Amsterdam (2008) the municipality talks about Teleport to grow on three different functions: working, housing and education. In their visions they talk about a densification of the urban structure in order to create an iconic area with its own identity. In addition, the area needs to become more clear in its hierarchy of local and macro scale beginning with the railway station.

The working aspect in Teleport is one of lower priority. It must be taken into account that the “plan Amsterdam” was written in 2008. Due to the current economic crisis and high vacancy rating adding more office space to this area would be highly discouraged.

Housing, on the other hand, is an aspect that is highly favoured by the municipality. In their visions the Teleport area becomes a mixed use area. This mixed use area was already taken into account at the first design of 1983. Though, because of the many macro scale infrastructure the area has never been attractive for dwelling. Creating identity in the area is of most importance. This identity could be found in the educational function of the area. Momentarily multiple schools for the crafts are situated in the area. These schools are still growing and in need of more space. In addition, the municipality envisions a educational atmosphere in the area.

The biggest problem, according the Plan Amsterdam (2008) is found in its identity. The intended identity of Teleport has always been the silicon valley of the Netherlands. Though due to a vastly changing wireless world, this hotspot isn’t needed anymore. To give new life to this area we must not thrive for a new idea of Teleport. We just have to accept that atmosphere we find and bring it to a new level. Use the knowledge we have now on the visions of this high rise city.

Therefor the urban plan has been densified and intensified. To give these high buildings the space they need, the central zone underneath the fly overs needs to stay clear of build forms and used to unify this broken piece of Amsterdam. A mayor difference will be, next to the adding of housing, a new hybrid culture building that, in combination with the railway station, needs to spice up the dead public life in Teleport!

This newly added building will be in a composition with the railway station. This will create a new railway station square on multiple levels. This multiple leveled urban space works with a layered principle, the lowered station square is one of urban transport where different ways of transport will be combined. To higher deck is one of urban relaxation and gives space to large groups to come together for festivities and other activities. This highly urban sphere gives a clear hierarchy to the pedestrian who wants to stroll around and the traffic that goes by. Conceptual idea and building measurements are given in Appendix 6.
5.2 Assessment framework
The method used for this case study is created from intensive studies on wind engineering methods and design methods. The above given methods and techniques are necessary for putting the data from analyzing in perspective. They give handholds for understanding CFD. Combined, these facets will form the assessment framework. The assessment of framework is a compilation of shortcomings in available tools, regulations, interpretation and given methods. This method will be called “smart wind designing”. The parts that have been attended are:

- Methods in wind engineering research
- The Dutch regulations on wind comfort
- The influence of solar radiation on wind comfort
- The Dutch wind Climate statistics
- Terrain Roughness
- Mapping the shortcomings of this research
- Way of analyzing CFD results

There are two main analyzing assessments that will be tested in the 5 main wind directions: The wind velocity laid against the regulations, the wind flow and influence of this flow.

First of all in wind engineering outcomes will always be in terms of a relative chance that a situation will occur. The chance that the input wind velocity occurs may not be higher then 2.5% if the output wind speed is higher then 5.4 m/s. This is according the NEN regulations. The wind statistics will be used from Peutz engineering. The outcome will be put in perspective using the solar radiation factor of M. Tacken. This first framework is for testing the wind velocity and gives absolute numbers about wind speed.

Secondly the wind mapping will give us information on how the building configuration and building shape affects the wind flow in this area. This will give us information on how to act the next step in the wind designing process. The output will always be analyzed in two perspectives. Firstly the target area (red cross in figure 10) will be analyzed on wind comfort and flow fields. Secondly the intervention effect on the surrounding buildings will be analyzed.

The way of reading the CFD models is shaped by the shortcomings of Ecotect and the necessity in the architectural design to create more then one variable. The Analyzing will be done by abstracting the design and testing it 2D in 5 different wind directions: 4 between West and south and one from the north east (main wind direction and coldest wind). This selection of wind directions is based on the speed difference between designing and engineering. This method enables the testing of more models. When a remarkable 2D simulation is found it is put to test in 3D and in flow lines. Analyzing the effect of the building configuration will always be done in comparison with the 0-hyphothese.

The analyzed building configurations and shapes will then be validated with generalistic academic sources. Giving insight and possibilities for the next steps.
White lines indicate the calibration wind flow.

Figure 11: 0-hypothese: the future context as given by Plan Amsterdam (2008) including a building for culture.

Figure 12: CFD of wind based design for urban relaxation around the city square.
5.3 Smart wind design CFD

To create a wind comfort based optimal design, a calibration model has been setup on the urban context as proposed in the visions of the city of Amsterdam. In this model a new cultural centre is added in a linear setting with the other buildings to create a more or less symmetrical calibration point. The calibration process is described in Appendix 7. From this calibration model different modifications have been simulated, analyzed and concluded. From these studies on different modifications general conclusions have been drawn to create a wind “optimized” simulation.

5.3.1 The calibration model is being simulated in the five wind directions as spoken of in the assessment framework. When comparing the ZZW situation with the Z situation, the greatest difference is found in the wind velocity. As the main wind speed in the Z situation is 9 m/s in the target area (1)(3), in the ZZW situation that wind velocity has been increased to +/- 11.5 m/s (2)(4). In general, the input wind is 6.7 m/s so the amplification factor (read below) is one of 1.85 in this area. So, for this area to be a comfortable, the wind may only flow with a speed of around 2.5 m/s. Apparently, this only happens 3% of the time from this direction and 9.8% from the entire southwest (Peutz(2010). Wind modifications for this area are required!

Comparing the West with the SouthWestWest, it shows that somewhere between these two directions the connection is made between this north-south wind connection (5). When this connection is made the width of the main wind flow (4) is much broader then when the wind flows from the SWW. An explanation can be found in the fact that the wind flow, when coming from the West, is separated and therefor has lost some of its speed. This way the building corner isn’t “throwing” the wind flow as far. When the wind is coming from the colder north east, it seems that the wind gets launched by the newly added building and then bounces of against the wall (8). This shows the mayor impact of building corners and positioning. In addition the railway station (10) is causing the wind to make a diversion, pushing it towards the east.

This configuration should be adjusted in lowering wind speeds at certain points naming the; newly added building shifting (11), the area “entrance” (2), the area of target (1) (7) and the building shape (11).

5.3.2 Concluding of models from the different researched configurations given in Appendix 7:

A. Wind is focused more into one flow at the western side of the canyon. The greatest wind nuisance is created by the SWW and W wind coming trough the gaps between the buildings creating velocities of more then 2 times amplification.

B The building is decreasing the wind velocity from the SWW, W and S. though this option is increasing the wind velocity on the northern part, at the target location.

C. The building shifting gives more “room” to the wind lowering the wind velocity by approximately 10%. though its main positive effect is the creation of a wind still area near the new building. Creating the thought of creating an urban relaxation point here.

D+E. This rather radical proposition tries to block the wind at the ground floor and “throwing” the wind over the target area. CFD modeling proves this to work. Though due to a less accurate CFD program the vortex and falling wind isn’t properly given. Given the article by Chang(2003) the question can be asked if this option won’t create turbulence and twisters on the station square.

F. A similar conclusion can be found on a lesser scale in simulation F. though the blocks force the wind to slow down and split up. The turbulence created isn’t given in the CFD model. We can conclude that the blocks do have a lesser turbulence and vortex impact on the area then the blocks in model D and E have.

5.3.3 In the wind comfort optimized design the wind is forced to go up in the area due to this blockade (12). The shifting of the building creates a wind still in front of it (13). Though the biggest point of creating a better comfort class is closing the gap next to the railway station (14). The forced wind flow trough this gap has been stilled. Multiple options on closing this gap can be found though the main focus must lie on creating turbulence. Porosity can be a welcome option (S.J. Lee,1999). This wind comfort design is showing that when approaching the building configuration more as one solid block a higher wind comfort can be achieved.
Problematic gap for target area in 38% of the time on a yearly basis.

Lower floor vortex creation, suppressed by greenery.

Pavilion for small retail companies.

Walking promenade for vortex downward wind capture. Lays on a 50% leeward facade.

Gives a greater chance on throwing the wind around the canyon.

Great wind pressure in minimal 60% of the time. No pedestrian movement required.

Tree line emphasizing wind still zone for Urban Relaxation.

Gives a greater chance on throwing the wind around the canyon.

Figure 13: wind based urban design

Figure 14: CFD section
5.4 Smart wind design
Analyzing the possibility of shifting buildings and adding mass to the public space by using the assessment framework, maps out the shortcomings of trying to shape the wind flow with building mass. The different directions the wind is coming from makes it almost impossible to create a wind comfortable area for urban relaxation by only building reconfiguration. Even in this case extra wind-screen applications will be needed. Though the conclusions are listed below and a smart wind design is given concluding this. Corresponding calculations are found by analyzing the CFD outcome of figure 13. Corresponding wind roses can be found in appendix 5.

5.4.1 Calculating comfort classes
Point A: amplification factor of 0.2 means a local wind flow of 25 m/s is allowed. The chance this wind will flow is Ca. 0.01% further calculation isn't needed: Comfort Class A.

Point B upper station square (including closing the gap) (1): This gives an amplification factor of 0.7 meaning a max wind speed of 7.6 m/s is allowed. Chance on this wind to flow: 3.75 % giving comfort class B. This is acceptable for walking and shopping

Point B upper station square (excluding closing the gap (1): Wind nuisance from W and SWW giving amplification factor 1.8 and 1.5, allowing respectively wind speeds of 3 m/s and 3.6 m/s. Chance on occur is 12 % and 14.4% giving a total of 26% chance on trespassing the 5 m/s rule giving it comfort class E. Extra wind protecting modifications are needed

Point C upper station urban relaxation: general amplification factor of 0.3 reducing the chance of high wind velocity. Further calculations aren’t needed: Comfort Class A.

Point C upper station urban relaxation (excluding the gap): gives a 32.4 % chance on an amplification factor of 1.8 and a 40% chance of an amplification factor of 0.2. This 32.4% gives a maximum wind speed of 2.6 m/s. The chance that this occurs is 11% giving a comfort class C. For optimal urban relaxation extra wind protecting modifications are needed

5.5 Concluding
This research was expected to give answer to the question: (How) can we design a wind comfortable station square in a dense urban context like Amsterdam Teleport while adding numerous dwellings and leisure, given an architectural predesign? For this, the wind statistics, terrain roughness, aerodynamic information, the contextual specifications and the building engineering references for the Teleport area has been set apart. This has been formulated into a assessment framework. In this framework a method is described to “design with wind” calling it smart wind designing. This is a process of quick 2D simulations in the main wind directions in order to find “eye-catching” results before analyzing in 3D. This method gives more speed to the wind engineering process and makes it suitable for use in the architectural predesign. In addition the research specific method, CFD, is set apart on its shortcomings and specifications.

The assessment framework is then used on different CFD simulations as given in appendix 6. Concluding that there are urban modifications needed on three different places. The first two are of priority and are focused next to the railway station (1). A total closure of this gap would be of great influence though the option of porosity can be taken in account. Then the canyon entrance (2) is one of great concern. Building shifting in this area can focus the wind flow on one point and “direct” the wind into a desired place. Though creating a ramp for the wind flow so a turbulent field (fig 15) is formed can be seen as a less radical option.

The third point of attention can be found at the shifted building (3). When the points of attention 1 and 2 can’t be modified, an extra attention can be given to the wake created by the shifted building. Where a comfort class C is created by shifting the building. Extra modifications on the level of the building will be necessary to create a comfort class A here.

Though these three modifications can create a comfortable urban wind climate, the wind will always find its ways. Creating a wind wake on this side will probably create a higher wind pressure on the other side of the railway track. “smart wind designing” will always be a case of laying the problem in a other place. Last, the corresponding design is given in appendix 8.
6.1 Buildings and wind engineering
As an addition on this case study, different options on wind comfortable building design are attended. The building shape and different function of shape will be discussed. Though, as announced, the CFD method is very much dependent of its grid size and intensity to give accurate results. So, in case of the facade elements this means that the cfd model isn’t able to calculate wind flow on elements smaller then 2m². Therefore on this level of scale, the building level, only case study information will be summed up and expectations on use will be formulated. Giving different options in building wind comfort in case of the building facade.

6.1.2 Shape modifications
Two different shapes are being researched in this stage; the ellipse and the square. In case of the square, the greatest argument in favor is the fact that the wake created by the building corners lowers the wind velocity. At the other hand, this also causes the wind to amplify a bit and cause nuisance in other directions. In Aerodynamic modifications (Amin, 2010) gives options on adjusting these wind “throws” with the building corners. The “fins and vanes” are mostly used to reduce the wind pressure on facades. Examples are in figure 18. In general his conclusions where:

- Small fins/vanes fitted to the corners of a prismatic building with a gap between the vanes and the corner can help to alleviate negative pressures under the separated shear layers on the side faces. However, the added drag introduced by these vanes increases the along wind responses
- Slotted corners and chamfered corners were causing noticeable reductions in both the dynamic alongwind and crosswind responses as compared to plain rectangular shape building. Venting through the slotted corners appears to be effective in reducing the drag force without undesirable effect of using vented fins

Secondly there is the ellipse shaped building. Here for we attend the aerodynamic information of Anderson(2005). If we look at the controlled testing of this shape a greater guiding is expected. When the wind is coming from the south and southsouthwest (a) and when the wind is coming from the southwestwest and west (b) it is shown that the shape indeed is acting as the literature describes. This guiding the wind is guiding the wind but isn’t slowing it down. In addition a wake isn’t created for urban relaxation.

Concluding we could say that there are two ways to “handle” wind around buildings. Firstly there is the case of wind nuisance in which the square shaped building creates more turbulence with a low wind velocity. When using the build environment for wind energy production or natural ventilation, turbulence isn’t acceptable. The turbine blades need a laminar flow comparable to the upper picture of figure 16. Though building shape can reduce wind nuisance on higher levels, the results are very much dependable of the wind direction. An other solution can be found in the facade engineering.
6.1.3 Facade on wind nuisance

In line with the building shape story, when looking at the facade two options are given; reducing turbulence and create a smooth flow or creating turbulence.

The smooth flow is very much dependable of the wind direction. As seen in the aerodynamics of Anderson (2005), a laminar flow on a smooth ellipse object gives the least turbulence and a small wake. When the outer spaces of figure 19 are in line with the wind direction different types of comfort can, expected, be achieved. When wind flows past the, let’s say, balcony, an air bubble (A) is created which could cause a local air pollution (B). This could be fixed with a manual ventilation shaft (C). Though when a the balcony is in the opposite direction of the wind flow a turbulence field is created (D).

As said, when creating wind comfortable places it’s desirable to create as much turbulence as possible. Turbulence means a huge dropping in wind velocity and therefor a higher comfort class. The one proven method on creating turbulence on facades is found in the porosity of materials.

6.1.4 Facade case studies

This principle of creating turbulence is done in Westraven (CEPEZED) (a). In the Westraven building a Teflon-facade is created with numerous gaps in it. The facade of Westraven has a porosity of 45% (Koekebakker, 2008). This facade is using the porosity principle in which the laminar wind flow is transformed into a turbulent one. This turbulent wind field behind the facade (figure 20a) creates a soft border which reduces wind velocity and makes it possible to open up the office windows and even walk outside. According to S.J. Lee (1999) this porous screens work at its optimum with a 40% porosity due to its better flow pattern.

Secondly the wind screens of high rise platforms, like the Burj Dubai (b), may cause a wind comfortable atmosphere, the wind pressure and velocity is moved up or down and the problem of wind nuisance is moved to the neighbour living above or under.

Third the DUO building in Groningen (c) tries to break the wind flow on the facade in larger turbulence fields. Though scientific results aren’t at hand, this principle reduces the wind velocity so that windows can be opened. This method may be adequate for opening windows, outside relaxation isn’t achievable.
1 Amsterdam Teleport


2. Wind comfort regulations: NEN-8100


3. Wind statistics and aerodynamic information


4. Wind engineering methods


5. Smart wind design


6. Buildings and wind engineering


Wind based urban design in dense urban context. Prefacing wind nuisance and optimizing the human wind comfort for outdoor relaxation.

Appendix
Appendix 2: The 10 km radius around Teleport (Source: maps.google.nl (edited))
### Classes of Roughness

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Open sea</td>
</tr>
<tr>
<td>2</td>
<td>Pond with free bush length of at least 1 km.</td>
</tr>
<tr>
<td>3</td>
<td>Land surface without obstacles or vegetation</td>
</tr>
<tr>
<td>4</td>
<td>Pond with free bush length of approximately 1 km</td>
</tr>
<tr>
<td>5</td>
<td>Flat land with shallow vegetation</td>
</tr>
<tr>
<td>6</td>
<td>Air strips</td>
</tr>
<tr>
<td>7</td>
<td>Farmland with regular low crops</td>
</tr>
<tr>
<td>8</td>
<td>Grassland with ditches on mutual distance less than 20x W</td>
</tr>
<tr>
<td>9</td>
<td>Dispersed obstacles on mutual distance of more than 20x H</td>
</tr>
<tr>
<td>10</td>
<td>Farmland with alternate high and low crop &lt;2m</td>
</tr>
<tr>
<td>11</td>
<td>Influential obstacles with mutual distance 15x their H</td>
</tr>
<tr>
<td>12</td>
<td>Groups of obstacles with a mutual distance of 10x their typical height</td>
</tr>
<tr>
<td>13</td>
<td>Large farmsteads or parcels of forest</td>
</tr>
<tr>
<td>14</td>
<td>Bottom regularly and fully covered with mutual distance not larger than 2x their H</td>
</tr>
<tr>
<td>15</td>
<td>Centre of a large city with alternating high rise and low rise buildings</td>
</tr>
<tr>
<td>16</td>
<td>Heavy forests with many irregular open spaces</td>
</tr>
</tbody>
</table>

### Description

- **N**: 0,0002
- **A**: 0,005
- **B**: 0,03
- **C**: 0,10
- **D**: 0,25
- **E**: 0,50
- **F**: 1,0
- **G**: 2,0

### Appendix 3: The surrounding terrain roughness coefficient $Z_o$
Appendix 3: The surrounding terrain roughness coefficient $Z_0$
Appendix 4: Validation of Wind comfort classes considering sun and season (values above the 4 are considered as a bad urban climate.)

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>0.50</th>
<th>1.00</th>
<th>1.50</th>
<th>2.00</th>
<th>2.50</th>
<th>3.00</th>
<th>3.50</th>
<th>4.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>3.11</td>
<td>2.81</td>
<td>2.51</td>
<td>2.21</td>
<td>1.91</td>
<td>1.61</td>
<td>1.31</td>
<td>1.01</td>
</tr>
<tr>
<td>14</td>
<td>3.32</td>
<td>3.02</td>
<td>2.72</td>
<td>2.42</td>
<td>2.12</td>
<td>1.82</td>
<td>1.52</td>
<td>1.22</td>
</tr>
<tr>
<td>15</td>
<td>3.54</td>
<td>3.24</td>
<td>2.94</td>
<td>2.64</td>
<td>2.34</td>
<td>2.04</td>
<td>1.74</td>
<td>1.44</td>
</tr>
<tr>
<td>16</td>
<td>3.75</td>
<td>3.45</td>
<td>3.15</td>
<td>2.85</td>
<td>2.55</td>
<td>2.25</td>
<td>1.95</td>
<td>1.65</td>
</tr>
<tr>
<td>17</td>
<td>3.97</td>
<td>3.67</td>
<td>3.37</td>
<td>3.07</td>
<td>2.77</td>
<td>2.47</td>
<td>2.17</td>
<td>1.87</td>
</tr>
<tr>
<td>18</td>
<td>4.18</td>
<td>3.88</td>
<td>3.58</td>
<td>3.28</td>
<td>2.98</td>
<td>2.68</td>
<td>2.38</td>
<td>2.08</td>
</tr>
<tr>
<td>19</td>
<td>4.40</td>
<td>4.10</td>
<td>3.80</td>
<td>3.50</td>
<td>3.20</td>
<td>2.90</td>
<td>2.60</td>
<td>2.30</td>
</tr>
<tr>
<td>20</td>
<td>4.61</td>
<td>4.31</td>
<td>4.01</td>
<td>3.71</td>
<td>3.41</td>
<td>3.11</td>
<td>2.81</td>
<td>2.51</td>
</tr>
<tr>
<td>21</td>
<td>4.83</td>
<td>4.53</td>
<td>4.23</td>
<td>3.93</td>
<td>3.63</td>
<td>3.33</td>
<td>3.03</td>
<td>2.73</td>
</tr>
<tr>
<td>22</td>
<td>5.04</td>
<td>4.74</td>
<td>4.44</td>
<td>4.14</td>
<td>3.84</td>
<td>3.54</td>
<td>3.24</td>
<td>2.94</td>
</tr>
<tr>
<td>23</td>
<td>5.26</td>
<td>4.96</td>
<td>4.66</td>
<td>4.36</td>
<td>4.06</td>
<td>3.76</td>
<td>3.46</td>
<td>3.16</td>
</tr>
<tr>
<td>24</td>
<td>5.47</td>
<td>5.17</td>
<td>4.87</td>
<td>4.57</td>
<td>4.27</td>
<td>3.97</td>
<td>3.67</td>
<td>3.37</td>
</tr>
<tr>
<td>25</td>
<td>5.69</td>
<td>5.39</td>
<td>5.09</td>
<td>4.79</td>
<td>4.49</td>
<td>4.19</td>
<td>3.89</td>
<td>3.59</td>
</tr>
<tr>
<td>26</td>
<td>5.90</td>
<td>5.60</td>
<td>5.30</td>
<td>5.00</td>
<td>4.70</td>
<td>4.40</td>
<td>4.10</td>
<td>3.80</td>
</tr>
<tr>
<td>27</td>
<td>6.12</td>
<td>5.82</td>
<td>5.52</td>
<td>5.22</td>
<td>4.92</td>
<td>4.62</td>
<td>4.32</td>
<td>4.02</td>
</tr>
</tbody>
</table>
Appendix 5: The Sloterdijk wind climate according to NPR6097 (Peutz, 2010)
Appendix 2: Schematic concept for the area.

1. Emptiness
2. new railway station square
3. newly added building
4. high rise walls
5. new courtyard for house of culture
6. railway station

Appendix 6: Conceptual starting point of "smart wind designing"
0-hypothesis: calibration model

Local wind amplification factor roses indicating the maximum values on the station square.
blocks (C) causes the wind flow to be dispersed in the red circle area with a dispersion in the flow lines through the high wind velocity building from turbulence with upward wind flow.

When observing the center building in (B) the three buildings have gotten the same direction of wind. Therefore the model forms step by step starting with these basic blocks. Reflecting them to aerodynamic information it is shown that the three different buildings laminar flow affect each other and the leeward wind flow rapidly starts waving in the east and west direction (A). Furthermore is seen that the separation point finds itself in the building corners and the boundary level is minimal.

When observing the center building in (B) the three buildings have gotten the same dimensions, though the center building got a 2 floors high horizontal building added. This change in building configuration causes, next to a smaller wake (1), that the separation point and main amplification factor of the wind velocity lies on the west side of the buildings (2). This could be caused by the upward wind velocity caused by the horizontal building slab (3). The section shows this increased upward wind velocity.

When placing a slab with its full width in front of these blocks (C) causes the wind flow to be thrown against the western (left) building (4) and then “bouncing” back eastwards into the void (5). The range that the wind is “tossed” by this wind perpendicular building has greatly increased in comparison with a building that is straight on the wind direction. Also, when comparison (B) and (C), the wind velocity caused by this perpendicular block has increased with almost 2 m/s. In addition a turbulent field was created in the leeward drag field (6).

Finally the current urban configuration (D) has been given. This can be seen as rather a mayor step from (C) to (D) thought the three steps before gave us enough information to do it.

Calibration model

Using the approach discussed in chapter 5, the urban configuration firstly will be directed from a symmetric setting to validate and compare what we see in the preliminary design. This has to be done because the Ecotect model has to be calibrated. Generalistic data on wind flow around buildings is only available for basic shapes in a laminar wind flow. Therefore the model forms step by step starting with these basic blocks. Reflecting them to aerodynamic information it is shown that the three different buildings laminar flow affect each other and the leeward wind flow rapidly starts waving in the east and west direction (A). Furthermore it is seen that the separation point finds itself in the building corners and the boundary level is minimal.

When observing the center building in (B) the three buildings have gotten the same dimensions, though the center building got a 2 floors high horizontal building added. This change in building configuration causes, next to a smaller wake (1), that the separation point and main amplification factor of the wind velocity lies on the west side of the buildings (2). This could be caused by the upward wind velocity caused by the horizontal building slab (3). The section shows this increased upward wind velocity.

When placing a slab with its full width in front of these blocks (C) causes the wind flow to be thrown against the western (left) building (4) and then “bouncing” back eastwards into the void (5). The range that the wind is “tossed” by this wind perpendicular building has greatly increased in comparison with a building that is straight on the wind direction. Also, when comparison (B) and (C), the wind velocity caused by this perpendicular block has increased with almost 2 m/s. In addition a turbulent field was created in the leeward drag field (6).

Finally the current urban configuration (D) has been given. This can be seen as rather a mayor step from (C) to (D) thought the three steps before gave us enough information to do it.
After analyzing the step by step approach of the area until the first design setup, the next step is to put the analyzing method into test. This will first be done by comparing the preliminary design setup in the five wind directions as spoken of in the assessment framework. The white lines drawn indicate the major wind flow. These lines will be used to compare these results with the results on the next pages.

When comparing the ZZW situation with the Z situation, the greatest difference is found in the wind velocity. As the main wind speed in the Z situation is 9 m/s in the target area (1)(3), in the ZZW situation that wind velocity has been increased to +/- 11.5 m/s (2)(4). In general, the input wind is 6.7 m/s so the amplification factor (read below) is one of 1.85 in this area. So, for this area to be comfortable, the wind may only flow with a speed of around 2.5 m/s. Apparently, this only happens 3 % of the time from this direction and 9.8 % from the entire south-west (Peutz 2010). Wind modifications for this area are required!

Comparing the West with the SouthWestWest, it shows that somewhere between these two directions the connection is made between this north-south wind connection (5). When this connection is made the width of the main wind flow (4) is much broader then when the wind flows from the SWW. An explanation can be found in the fact that the wind flow, when coming from the West, is separated and therefore has lost some of its speed. This way the building corner isn’t "throwing" the wind flow as far.

When the wind is coming from the colder north east, it seems that the wind gets launched by the newly added building and then bounces against the wall (8). This shows the major impact of building corners and positioning. In addition the railway station (10) is causing the wind to make a diversion, pushing it towards the east.

This configuration should be adjusted in lowering wind speeds at certain points naming the newly added building shifting (11), the area "entrance" (2), the area of target (1) (7) and the building shape (11).

Due to its huge calculation time the 3D wind flow simulation gives different flow fields then the 2D method. Though, the calculated wind speeds are much more accurate, the ecotect program doesn’t support intensive 3D calculations. As an example of the difference the amplification factor is given in 2D and 3D in the area between the railway station (10) and the new building (11):

Amplification factor $y = \frac{U}{U_0}$

2D: $y = 12.5 / 6.7 = 1.85$

3D: $y = 8.5 / 6.7 = 1.3$

The amplification factor can be used in describing different situations and wind velocities from one model.

The amplification factor can be read in the legend of figure 8.
7.2 Wind design A: Building configuration

7.2.1 Goal
The goal of this analysis is based on the finding that the railway station is diversing and pushing the wind to the south (pp 79). Therefore the question rises if this shifting of buildings can effect the wind such that the wind velocity at the target area drops. This presumption is based on the fact that when the terrain roughness in the y-z-direction can effect the wind (Bottema 1992), it may be possible in the x-z-direction. In this case the south-western building has been broadened.

7.2.2 Analyzing
The eye-catching facets are summed up below.

1. The amount of wind from the railway station directed towards the east has significantly been reduced in case of wind coming from; NEE, SWW, SSW. These three directions act for 45% of the yearly main wind direction Upot. From the NEE, SWW and the SSW the amplification factor changes in respectively; 0.2 : 0.8 : 1.0.
2. An increasing wind velocity is expected from the S: 14% chance on an amplification of 1.8 W: 15 % chance on an amplification of 1.8 SSW: 18% chance on an amplification of 1.6 NEE: 10% Chance on an amplification of 0.9.

3. A decreasing wind velocity is expected from the SWW: 17 % Chance on an amplification of 0.8 NEE: 10% Chance on an amplification of 0.9.
4. This means a wind velocity increase for AT LEAST 47 % of the time.
5. The wind flow trough the area is redirected into the smaller streets of the 6-blocks. This wind has an amplification factor y of: 0.8 and reduces the wind speed Upot for the W, SWW, SSW. For the S and NEE, an amplification of 1.3 is expected.
6. The wind flow chances from a swirling flow into this straight line from the south to the north.

7.2.3 Concluding
Broadening this building creates a narrowing effect on the canyon, as seen in figure 10 only a few flow lines enter the canyon. Though these lines have a high wind velocity. In addition the building makes the wind flow become more focused onto one point. This can be an way of directing the wind into one place before leading it to a less harmful place. Though it will always be a point of laying the “problem” on another point. Only from the SSW this option creates a wind still zone in the canyon. The target area still has a wind velocity going from an 1.7 amplification factor (SSW) unto 2.1 (W). This corresponds to an average flow percentage of NEEN100 trespassing of 5.1% to 13% creating a comfort zone C-D. To create a Comfort zone A - B at the target area more modifications are required.
7.3 Wind design B - Building configuration

7.3.1 Goal
The goal of this analysis is based on the founding that the railway station is diversing and pushing the wind to the south (pp 79). Therefore the question rises if this shifting of buildings can effect the wind such that the wind velocity at the target area drops. This is presumption is based on the fact that when the terrain roughness in the y,z-direction can effect the wind (Bottema 1992), it may be possible in the x,z-direction. In this case, the bottom central building has been broaden, blocking a part of the canyon (1).

7.3.2 Analyzing
1. The Southern wind direction seems to be pushed away by the broader 6-block blocking its way into the canyon. This phenomenon is described by Blocken (2008) and shown in figure 2. That a greater mass has a greater amount of wind redirected around its surface. This increases the wind velocity at the corners and increases the distance the wake behind the building will be.
2. From the SSW the “throw” of wind is only increased against the building on the other side of the railway track. This represents a amplification factor of 1.8 and has a 18% chance of flowing on yearly base.
3. Though the canyon wind climate experiences a decreasing wind velocity, the target location still has an amplification factor of 1.8 - 2.0 due to the gap next to the railway station. This amplification factor counts for 4 wind directions that represent 60% of the yearly wind direction.
4. When the wind comes from the West, an almost symmetrical situation occurs directing the wind flow around the entire plot. This creates great wind speeds at the borders where the highway is situated.
5. The connection of the north-south canyons gets disrupted by this building shifting. Decreasing the average wind speed in the canyon from an amplification factor of 2.0 to an amplification factor of 0.3. Though the target area keeps a local wind amplification of 2.0.

7.3.3 Concluding
Because of the enlarged building on the west side of the cluster of 6, a large “throw” is created creating a wind still zone from SWW, W and S. This is decreasing the wind nuisance in the southern part. Though everything has its cost. This option is increasing the wind velocity in the middle and the north. Cutting off the passage to the north makes it that the wind had to find another way increasing wind speeds in that direction.

So, shifting this volume does have its effect on the southern part and parts of the border. Though the gaps between the buildings (3) make it that the wind gets a huge velocity boost. Creating an amplification of 1.8 calculated in a comfort class C at the target location (Peutz, 2010).
7.4 Wind design C - Building Configuration

7.4.1 Goal
The calibration model shows a continuing high amplification factor near the railway station. When looking at the pressure model from Anderson (2005), it is expected that the wind speeds increase because of this "bottleneck" (X). This part asks the question if twisting this block gives more space to the wind for passing through, reducing wind amplification at the target area.

7.4.2 Analyzing
1. From the South the 6-block clearly "throws" all higher wind velocities around the newly added building, following the same wind pattern as the calibration model. Though, the wind flow does change at the northern part of the plot from going west to eastwards.
2. From the NEE the wind is increasingly going straightly southwards. This may be caused by the angle of attack at the rotated building. The effect of the building corner has been reduced and so the wind speeds have dropped from an amplification factor of 1.8 to 1.6.
3. The wind velocities around the railway tracks are lowered for the S, SWW, W, NEE winds from an amplification of 1.8 to 1.5-1.7. This accounts for 60% of the time on an early base.
4. In front of the new twisted building a wind "still" area occurs for (Peutz, 2010):
   W: Amplification factor 0.8 // max wind speed Upot: 6.5 m/s // P(flow) 5.25% // Comf. Class: C
   NEE: Amplification factor 0.1 // max wind speed Upot: 10 m/s // P(flow) 1.6% // Comf. Class: A
   SWW: Amplification factor 1.8 // max wind speed Upot: 3 m/s // P(flow) 13.6% // Comf. Class: D
5. Though from the 2 other directions a higher amplification factor is given
   S: Amplification factor of 1.8 // max wind speed Upot: 3 m/s // P(flow) 6.4% // Comf. Class: C
   SWW: Amplification factor 1.8 // max wind speed Upot: 3 m/s // P(flow) 13.6% // Comf. Class: D
6. The building itself won't cause any wind nuisance as long it stays underneath the wake of its surrounding buildings: figure 17

7.4.3 Concluding
The shifting of the building does give more "space" to the wind flow. In case of the W and SWW the wind velocity drops from an amplification factor of approximately 1.8 to 1.6. Though this isn't the greatest achievement. The shifting of this building makes it that a wake, wind still area is created at the area in front of the building.

This result raises the question if the function of "stayin" for the target area should be moved to the front of the building. Creating a "walking" area in staid.
7.5 Wind design D - Building Configuration

7.5.1 Goal
The simulations here-fore show that the gap between railway station and the new building (area of target) keeps on having a high amplification factor. This stimulates the thought to completely shut of the canyon with a building slab of 2 stories high. Asking the question if this is a solution to the wind nuisance.

7.5.2 Analyzing
1. The new blocking facade seems to lower the wind speed and sometimes block it completely. Though looking at the point flow of figure 19 shows us the wind does still flow in this area. The blocking of the area seems to have two different functions. Firstly there is the wind "choosing" to go another way. Secondly there is a part that flows over the blockade and is "launched". In case of this 20 meter high blockade the wind is pushed over for aproximatley 70-80 meters.

   The wind flow diversion is roughly divided in relatively going over the blockade, choosing an other way:
   - S: 40 - 60%
   - SSW: 50% - 55%
   - SWW: 65% - 35%
   - W: 10% - 20%
   - NEE: 60% - 40%

2. From the West and SWW an amplification factor of 2.0 is reached creating a 12% chance to go over the NEN8100 regulation making it a Comfort class D on a yearly base.

3. The newly added building seems to create a vortex. Though after 3D modeling this is less problematic then anticipated. The vortex on the front of this building causes an amplification factor of 1.1 creating a comfort class of B. This area is assigned as shopping area and therefore Class B would suffice.

7.5.3 Concluding
Firstly the entire system obstructs the canyon flow, increasing the roughness of the canyon floor. This creates an upward wind flow. Though, recalling Bottema (1992), this also causes around 80% of the wind going downwards creating a vortex. This vortex must be "placed" on the, by the design acceptable spot. This upward wind can be used to lay specific areas in a wake position and others in a windy position.

Furthermore, the amplification factor on the ground floor is 0.6, this means a max wind speed U of 5.5 / 0.6 = 8 m/s chance on < 8 m/s = 20% wind direction = SSW = 18% means a chance of trespassing NEN 8100 of 3.6 = Comfort Class A - B
7.6 Wind design E - Building Configuration

7.6.1 Goal
As seen in simulation A and B, making the entire surrounding act as one block, increases the chance the wind will flow around the block. This stimulates the thought to completely shut of the canyon with a building slab of 2 stories high. Asking the question if this is a solution to the wind nuisance.

7.6.2 Analysis
1. The new building starts to act as a wind screen forcing the wind around the entire block. As seen in Figure 68, the throw of the wind is around the 60-70 meters before reaching back to the ground.
2. From the North, wind is captured and twisted in the bowl that is created in the south. This wind has a 10% chance on flowing and the wind twisting has an amplification factor of 0.4. Creating an average Comfort class A.
3. From SSW and W, the wind velocity is increased creating a wind amplification factor of 2.2. This may be caused by the fact that the wind pressure can’t be released in the south increasing the pressure and logically then increasing the speed.
4. As seen in Figure 23, the wind thrown by the blockade is directly thrown on top of the target area (station square). This gives the question if the position of the blockade is on the proper position.
5. From the W, the wind amplification factor seems to stay at 1, not affecting the wind velocity.

7.6.3 Concluding
Just as the last one the entire system obstructs the canyon flow, increasing the roughness of the canyon floor. This creates an upward wind flow. Though, recalling Bottema (1992), this also causes around 80% of the wind going downwards creating a vortex. This vortex must be “placed” on the, by the design acceptable spot. This upward wind can be used to lay specific areas in a wake position and others in a windy position. Chang (2003) writes about this phenomenon in his research on urban canyons and their wind behaviour. He found that when a street becomes broader, the main wind flow increases and the canyon turbulence decreases. This was research in a standard urban grid as given. The wind flow and turbulence is given also given.

This option has an approach of creating a cast solid wall around the target area. This would be the best option on creating a high wind comfort, filling the gaps between the buildings. Though, Architectural this would completely border this area. A mediator has to be found. In addition, this option creates a larger wind velocity on the outskirts of the plan. This area contains a highway and a channel and therefore redirecting the wind wouldn’t be a disaster.
7.7 Wind Design F - Building Configuration

7.7.1 Goal
Going deeper into this street canyons forces us to look at an equally distributed urban grid. According to X. Xie (2007), the dimensions of a street canyon has a huge effect on the wind quality. According to Wieringa (2006) the terrain roughness will force the wind flow upwards creating a larger boundary layer and surface layer where the wind speeds are slowed down. This makes us ask the question in what extend a equally distributed block forces the main wind speed upwards.

7.7.2 Analysis
1. Looking at the target area, in case of the S, SSW, SWW and NEE, the wind speeds are slowed down from an amplification factor of 1.8 to respectively; 0.8, 1.4, 1.2, 1.3. These wind flows are representative for 51 % of the time on a yearly base. Giving, respectively, a chance of flowing of 3.6%, 13.5%, 12%, 4.3%. This is corresponding to a comfort class of B, D, D, B.
2. The wind velocity behind every "block" is being reduced with approximately 40% going from an amplification factor of 1.8 to one of 0.8 to 0.1 on the ground. Creating a wind comfort class A behind the blocks.
3. From the NEE, the wind flow that was flowing trough the canyon is directed out of the canyon.
4. From the S, the wind flow seems to be split and wind velocity seems to decrease.
5. From the SWW and SSW, it seems that this new blocks don’t have a lot of influence in wind flow. Though wind speeds has been reduced and in case of the SSW, the highest wind velocity flows on the eastern facades instead of the western. Creating a comfortable place on the eastern part.
6. Especially from the west, the wind speeds at the target area stay at a very high amplification factor. This creates a wind comfort class D (NEN 8100)

7.7.3 Concluding
The adding of the 4 blocks forces the wind to split into two parts and reducing its velocity. Looking at the section (Figure 27), it shows that the main wind speed is pushed up a bit enlarging the surface layer. The canyons between the building can expect some leeward turbulence as written by Xie (2007) and Chang (2003). Figure 28 shows in different ways this turbulence, and the effect of temperature on the facade, and the patterns it shows. Measurement (a) shows a normal situation and there for we can expect a leeward turbulence on the conditions of the Xie (2007) research. Though, Looking at the research of Chang (2003), if the distance becomes to large, as it is with this research, the main wind speed could reach the bottom of the canyon and other wind patterns are expected as given in Figure 29 (pp 89)

Figure 70: 2D slice research on Building Configuration: From different wind directions.
Figure 72: Theory by Wieringa (2006) own picture.
Figure 73: 3D point flow still.
Figure 74: Section
Figure 75: Research by Xie (2007) on the wind decreasing and turbulence in urban canyons.
Appendix 8: Design principle

1. THE URBAN SQUARE
   - MOVEMENT
   - ACTIVE
   - TRANSFERIUM
   - TARGETED
   - BUSSTOP

2. THE PUBLIC PLINTH
   - PUBLIC ENTRANCES
   - TRAVEL RELATED RETAIL
   - PARKING (bikes & cars)
   - DUAL LAYRED

3. THE CONNECTING ELEMENT
   - CONNECTING DIFFERENT LAYERS
   - ORGANIC (WOOD / BAMBOO)
   - INTEGRATING BUSSTOP/BIKE STORAGE/- SUBWAY
   - "MANAGING" WIND COMFORT

4. MIXED CITY: DWELLING / CULTURE / EDUCATION
   - HIGH QUALITY LIVING
   - LINE OF SIGHT ON AMSTERDAM / HAARLEM/ HARBORS