Introducing a ‘highway-residential’ typology with a neighbourhood concept in the dense city

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Abstract
The city Utrecht is currently growing towards the A12 Highway and the city Nieuwegein. It is facing complexity problems such as increase in density, population and traffic intensities. However, the Highway (A12) has become a physical barrier and separates the urban fabric of Utrecht. This has a negative impact on the city’s qualities due to noise pollutions (over 65 dB) and air pollutions (exhaust fumes of particulate matter and nitrogen dioxide). Objective of this paper is to propose a residential typology configured with the highway that can transform the unhealthy highway environment into a healthy environment. The highway should be seen as a part of the city instead of dissociates it. Technical solutions for noise and air pollution will be introduced on an urban and building scale that enhances the liveability of the dense city and introduces a neighbourhood where people can also live outside.

Keywords
Residential highway environment, neighbourhood concept, air pollution, noise pollution, social interaction, highway, electrostatic field reduction system, double façade, A12 zone

1.0 Introduction
This paper focuses on increasing the liveability in a dense city by transforming the Utrecht A12 highway into a healthy and residential environment. Big cities such as the Randstad in the Netherlands are growing in density and turning in a big metropolis and where there’s high traffic congestion, a possible loss of greenery and the public spaces. More people are living individually in city with their own needs and requirements. This results to an unpleasant, unhealthy environment and a possible loss of social interaction. Public spaces are getting less and people inside the city aren’t that close connected to each other anymore, since everyone is living on its own and no more pleasant outdoor spaces to meet, relax or interact. Sooner or later, the city’s density will expand to the highway environment, which can turn the city’s liveability into a more unhealthy and discomforting environment due to the traffic noise and the air pollution. The dynamic city and its density will dominate over our social lives. Citizens will be strangers to each other since there’s no place for relaxation and stress relief. As a result, buildings nearby the highway are designed as walls along the lanes that don’t have any spatial qualities. With the future density growth, these spaces along the highway have a lot of potential of use, but will be very problematic concerning its unhealthy environment. Furthermore, this unhealthy environment will cause a separation within the city due to the avoidance of the highway pollutants and will disadvantage the qualities of the city. It is separating the urban fabric.

1.1 Gravity of problems: Particulate matter
Letting people living nearby or along the highway is not the most pleasant way to live due to the traffic noise, exhaust fumes of particulate matter (PM10 and PM2.5), ultrafine particles, nitrogen and nitrogen dioxide (NO & NO2), and ozone (O3). The highway consists a variety of vehicles such as motor vehicles, cars, busses and truck vehicles. Each of them has their own production of sound and fume exhaustion and unfortunately this contributes to noise and
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Air pollution. A pollutant such as particulate matter, an ultrafine particle arises in the combustion engine of the vehicles. They are very small inhalable airborne particles that also occur in the wear down of tires and the influence of the road surface (see figure 01 and 03). The amounts of ultrafine particles that are released into the air are not only from human activities. There is always a certain amount of ultrafine particles in the air by chemical reactions in the atmosphere and descent from natural sources such as sea salt or sand. Emissions of particulate matter and ultrafine particles are most prevalent in road traffic.

According to the pie chart (see figure 01), this is almost 60% of the total emission. Road traffic is also the most common source for the emission of numbers of particles in the surrounding countries. Ultrafine particles decrease in concentration at a distance of 200 to 300 meters of the source. This is explained by the fact that the ultrafine particles clump together and thus form larger particles, which has dimensions not covered by ultrafine particles. For particulate matter, the concentration decreases gradually with increasing distance from the source (RIVM, 2013b, p. 17).

Fig. 01: illustration scale of particulate matter, ultrafine particles and a pie chart that displays the origins of the particles (RIVM, 2013b, pp. 7-17)

Fig. 02: schematic overview effect on our body when inhaling particulate matter and ultrafine particles (Kelfkens, 2007, p. 19).
Currently, there’s an excess of particulate matter in the Netherlands mainly caused by road traffic, which has a negative effect on our health. People and can inhale the excess of particles that will penetrate into our bloodstream. The particles can transport to our brains, our nervous system, and our lungs (and can even penetrate in our lung alveoli). This will result to inflammation in our lungs, irritation of the nerve system, heart rhythm disorder, blood clot formations and infections. Eventually this can lead to acute effects on heart and blood vessels and lung cancer(Kelfkens, 2007, p. 19). According to the Nationaal Samenwerkingsprogramma Luchtkwaliteit (NSL), the Netherlands doesn’t meet the standard requirement of maintaining the particles below the 50 microgram/m3 within the 35 days. With their proposed program, NSL stated that the Netherlands will eventually meet the standard requirement for the year 2015(Rijksoverheid, 2013). However, it turns out that even at lower concentration, particulate matter can still cause severe damage to our health and has been officially declared carcinogenic recently(AlgemeenDagblad, 2013).

Fig. 03: possible influences of the road surface that contributes to the concentration of particulate matter(van Blokland, Hooghwerff, & Tollenaar, 2009, p. 8).

Fig. 03: months of life lost in 2000 in Europe as a result of particulate matter. The darker red parts is equivalent to 36 months(van Zeebroeck, 2008, p. 7)
1.2 Gravity of problems: Nitrogen and Ozone
Nitrogen is also a product of the engine combustion. When Nitrogen enters the air, it creates a fast reaction with O3 and produces NO2: \( NO + O_3 = NO_2 \). The road traffic thus causes direct and indirect NO2. Through a slower process, this is again put in nitrogen: \( NO_2 + UV \text{ rays} = NO + O_3 \) (see figure 02). The effect of this equilibrium reaction ensures that the nitrogen near the motorway is still high, but further away from the motorway away, there is a decrease in nitrogen and forms nitrogen dioxide (Lanser & van Ooststroom, 2009, p. 6).
Unfortunately, there’s also an excess of NO, NO2 and O3 in the Netherlands. According to NSL, the standard requirement for nitrogen (and NO2) should not exceed more than 40 microgram/m3 on an annual basis. Currently, the nitrogen concentration is between 40 and 50 microgram/m3 (RIVM, 2013a). This has an adverse effect on the nature. The excessive intake from plants and trees will result to eutrophication of soil and surface water. Nitrogen dioxide can give immediate symptoms and may cause damage to the lungs. In the long term, Nitrogen dioxide is also an indicator for the presence of a mixture of harmful substances originating from traffic emissions such as Ozone. This can result to more respiratory symptoms, headache, irritation of throat, nose, and eyes, chest pain, dizziness, an increased burden of asthma and reduction of lung function (VROM, 2006, pp. 12-13).

Fig. 03: production of NO2 and particulate matter shown in a diagram (own ill.)

1.3 Gravity of problems: Noise pollution
The Netherlands is a country with more than 3300 kilometres of national roads and has increasingly less quiet areas as the years go on due to the increase in traffic. The main source of noise pollution is from the highway traffic roads. Noise from vehicles is originated from the engine, the tires of the car and by the car’s aerodynamic (see figure 04).

Fig. 04: noise production from a car vehicle (own ill.)

Noise is however inevitable, because it’s everywhere. People can hear global levels between 0 and 140 decibels. Noise of sound level between 45 and 50 dB is acceptable and is equivalent to a vibrant urban street. A sound level of 140 dB is however equivalent to a starting jet fighter and can cause severe hearing damage. We speak of noise pollution when...
there’s a sound level above 55 dB. Noise from the highway is currently above the 65 dB (see figure 05). People who stay more than 8 hours at a highway may also run risk of hearing damage (Rijkswaterstaat, 2006, pp. 2-3). This can be very problematic since the city’s density is expanding to the highway environment. Almost 40% of the population experience road traffic as one the main noise pollution in the living environment (see figure 05) and can negatively affect our health. Noise pollution can cause symptoms such as:

- Nausea / dizziness
- Headache
- Irritability
- Labiality
- The need of arguing
- Reducing sexual feelings
- Fears
- Depressions
- Nervousness
- Sleep problems (insomnia and abnormal sleepiness)
- Reduce appetite
- Fatigue
- Strong stress symptoms include high blood pressure

Another problem that might occur, when living nearby the highway, is that people will less likely open their windows and kept them closed to isolate the noise pollution. This will create an unhealthy indoor climate and may cause allergic reactions, headache, eye and nose irritations (Arendshorst, 2004, p. 1). It’s clear that noise pollution not only lead to health problems, but also to psychiatric problems. Moreover, recent statistics has shown that more people are living in the city individually, which results to more households. People tend to choose to define their own lifestyle without having a community to ensure themselves. People challenge themselves to face the uncertainties of today's risk society (Schnabel, 2004, p. 57). However, Combining these health and psychiatric problems with the increase of individualism may negatively affect our social live. The dense city may give us the feeling of being locked without knowing our surrounding people and the unhealthy living environment is only enhancing this feeling.

Fig. 05: an overview of noise pollution of national roads and a chart showing different sources of noise pollution (CBS, 2013)
1.3 Research question
This paper’s objective is to transform an unhealthy environment into a healthy environment with content of a program that can take the city to a next level by tackling the future density growth problem, the pollution problems and connect the highway with the city. The goal is to introduce a residential typology with neighbourhood concept inside the highway environment that enhances the social interaction and changes the highway’s disadvantages into benefits were people could provide this to the residences and boost up the liveability. The pollutants of the highway are a huge conflict to the urban fabric of the city. Designing the highway and city as one unity should solve this.

Overall design and technical research question:
How can we introduce a residential typology with a neighborhood inside the highway environment that reconnects the city again as a whole and convert the highway pollutants, such as air and noise, into benefits as a contribution to the residences and city’s spatial environment?

Sub questions:
1. What are the Technical solutions for the environmental problems?
2. What is the neighborhood concept?
3. What type of housing block is best suited to the highway?
4. How can we integrate the residences with the technical solution and introduce a connection?

Fig. 05: mission statement based on Duerk’s cyclical model of inquiry in architectural programming (Groat & Wang, 2002, p. 109)
The value of the paper in the larger social and scientific framework is more specific. This problem statement is very close related to the A12 zone of Utrecht and its current situation. The A12 highway is now separating the urban fabric of Utrecht.

Big cities such as Hong Kong, Tokyo, Shanghai or Seoul are already facing this density problem: pollution of air and noise and the lack of space for social interaction (a place to meet, for recreation, for sport, to relax). The Netherlands will soon have to confront this kind of complexity. My fascination is to transform this unhealthy environment into usable area where people can live healthy, increase the social interaction and embrace the highway as part of the city. People should have the ability to open their windows nearby the highway without affecting their health or social lives. By challenging this, I hope to improve the city’s qualities and take it to the next level.

What if we can convert the disadvantages of the highway into benefits and introduce a neighbourhood concept contribute the social interaction? Introducing an area where people can escape from the dense city? This could be a place where people could experience the city peacefully, a place to meet each other and recreate. Away from all the traffic congestions and intensities. What if we introduce this kind of efficient use of space that can connect the city as whole again?
2.0 Research Methodology

The research is focused on the urban scale and building scale. The outcome of the research question should tell which residential typology and technical solution is most suitable for highway. Because of the different scales, it’s very important to distinct these scales during the research process. To structure this, a combination of two methodologies is used:

1. Research by literature reference
2. Research by design (the object varies and the context follows)

Firstly, all the theory about the residential typology, the neighbourhood, and the technical solutions should be analysed in order to have clear understanding about the different scales. Finally, the collected theory will be applied for research by design, whereas the object (in this case, the residential typology) varies and the context (the A12 Highway) follows. The two research methodologies will be combined and divided in different phases (see figure 06).

2.1 Phase 1: literature analysis & determine boundary conditions

as mentioned before; the research approach starts with an analysis on the literature. In this phase, the analysis will consist out two parts:

- Architectural: a brief theory on the neighbourhood concept, urban ensembles and residential typologies. Four residential typologies will be analysed to get a better understanding on how the social coherence can be achieved and how it is related to the neighbourhood.
  The analysis will determine what the boundary condition will be for the neighbourhood and residential typology.

- Technical: theory on solution for air and noise pollution. The analysis will be briefly focused on the behaviour of sound and how it reacts with the different scales. Six or more technical solution will be analysed for each topic (air and noise) and define in types. The defined types will give a clear overview of which technical solution is suited for the different scales.
  Next to that, a short case study will be analysed for each type. The analysis will determine what the boundary condition will be for each topic.

2.2 Phase 2: setting criteria

After determining the boundary conditions for the two topics, a set of criteria will be set for each of them to prepare for the next phase. The criteria will be based on the three layers: context, program and technic. The criteria are supported with phase one, where all the literature and boundary conditions has been defined.

So each topic (architectural and technical) will confront these layers in order to evaluate them properly. This will result in a multiple criteria analysis. To prevent that the answers on the criteria will be too subjective, the criteria can only be answered with yes or no and will be displayed in a table in order to keep a clear overview from the different scales (urban scale or building scale)

2.3 Phase 3: Evaluation and elimination

In this phase, the different residential typologies and technical solutions for air and noise will be evaluated with the multiple criteria analysis. The weakest typologies and technical solutions will be eliminated and the strongest will continue to the last phase. This is done to prevent to frame the last phase and to keep a clear focus on the residential typology and the technical solution. Otherwise the outcome of possibilities will be too widely.

The strongest possibilities are the one that counts now. The two strongest residential typologies will move on to the last phase. Phase two and three are very close related to each other since phase two is only a brief moment to set criteria accordingly with the theory.
2.4 Phase 4: Research by design
The final phase will be based on research by design with the two remaining residential typologies and technical solution (for air and noise). As mentioned before, the object varies and the context follows. This is the case when a design intervention is made (under constant circumstances otherwise) in order to study its consequences on and to introduce the programmatic and formal potential of that area (de Jong & van de Voordt, 2002, p. 455). The variants will be drawn in a section and will be compared and discussed like a case study afterwards. The outcome of the brief discussion will introduce two new stronger variants that can determine how the residential typology is configured with the highway and the technical integration.
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Fig. 06: an overview of the proposed research methodology subdivided in different phases (own ill.)
3.0 Literature analysis (phase 01)
In this chapter, the following literature will be analysed:

1. Theory sound
2. Technical solution for noise pollution and determine boundary conditions
3. Technical solutions for air pollution and determine boundary conditions
4. Theory neighbourhood and determine boundary conditions
5. Theory residential typology and determine boundary conditions

The results of the analysis will be displayed in a table.

3.1.0 Literature analysis: characteristics of sound in road traffic
This chapter will give a theoretical overview on how sound behaves in road traffic. So as we know now, road traffic is one the main source of noise pollution. In order to control the sound in the environment, understanding the occurring processes is indispensable.

A model is needed that shows which aspects and elements determine the occurring noise and how we can influence it. The model in general, it is to be recognized in three parts:

1. The source from which the sound is produced (emission)
2. The transmission path, along which the sound propagates (transmission)
3. The receiver, where the sound comes and assessed (imission).

Sound is actually energy that is produced by a source in the form of vibrations (pressure fluctuations) and which is moved as sound waves in a medium (such as air) and which is collected by a receiver: SOURCE (vehicles on highway) – TRANSMISSION (for instance air) – RECEIVER (city dwellers).

The sound level reduces when the distance between the source and receiver is getting bigger and bigger (an increase of transmission).

So in all cases, we need three types of data:

- How much and where sound is produced: source data
- How does sound propagates: everything between source and receiver

Sound has different tones, which is expressed in frequencies. This is the number of vibrations per second and is expressed in hertz (Hz). Low tones have a low frequency (a small number of vibrations per second or a large wavelength) and high tones a high frequency (a large number of vibrations per second or a short wavelength).

When sound falls on a structure, a portion is reflected, a portion is transmitted and a portion remains behind in the structure. What is not reflected will be absorbed and vice versa. The harder the structure, the more sound is reflected. Porous surfaces can absorb more sound. Structures like trees or grass along the highway is are soft material with lots of fragmented surfaces that has high absorption ability. Absorption coefficients of \( a = \) from 0.7 to 0.9 have good absorbent structures. One important structure of the highway is the road surface.

Fig. 06: road as a reflective element (Martin, 2008, p. 25)
Since this is a hard material, sound will be reflected (see figure 06).

A single car acts as a point source of sound where the sound energy will expand spherical (in all direction the same amount of energy). But a collection of those point sources (a group of car vehicles on the highway) can be seen as a line source of sound, since it’s traveling from point A to point B and there are a lot of sources (such as car and truck vehicles) at the same time going in the same opposite direction (van der Linden, 2006, pp. 144-155).

The amount of energy that is determined in this way is referred to as the sound intensity (I). For a line source applies:

\[ I = \frac{W_{\text{line}}}{((2\pi r)^{1/Q})} \]

I = intensity in Watt per m²
W = sound power of the source in W
r = radius of the cylinder in meters
Q = direction factor

Fig. 07: road traffic as a Line Source (Martin, 2008, p. 16)

Sound can also be expressed as in sound pressure level:

\[ L_p = E_{\text{line}} + 10 \log \left( \frac{1}{r} \right) = E_{\text{line}} - 10 \log (r) \]

\[ L_p = \text{The sound pressure level in dB} \]
\[ E_{\text{line}} = (\text{Traffic intensity } Q, \text{ speed of the vehicles}, \text{ source strength of the vehicles}) \]
\[ r = \text{radius of the cylinder in meters} \]

Factors that affect sound are:
- Wind velocity
- Temperature

Wind velocity has the ability to influence the sound propagation. Downwind will push the sound rays downwards and wind against will push the sound rays upwards (see figure 08).

Fig. 08: wind velocity influencing the sound waves (Martin, 2008, p. 22)

Temperature has the ability to ‘bend’ the sound waves. A negative temperature gradient (in vertical direction) will bend the sound upwards on both sides of the source. A positive temperature gradient (vertical direction) will bend the sound downwards on both sides of the
source (see figure 09).

**Fig. 08: temperature gradients influencing the sound waves** (Martin, 2008, p. 23)

When there is a lot of noise is produced, in a room, the sound pressure level can be lowered by the fitting of additional sound absorption. The term \( 10 \log \left( \frac{4}{A} \right) \) will be smaller and eventually negative. The sound pressure level \( (L_p) \) will decrease. Doubling of the amount of absorption will ensure that there will be twice as much noise is absorbed. This represents a reduction of 3 dB. When lowering a sound pressure level of 6 dB, the amount of sound absorption must be quadrupled (van der Linden, 2006, p. 163).
3.1.1 Literature analysis: technical solutions for noise pollution

This chapter gives an overview about the available solutions for noise pollution. The solutions are structured as follows:

1. The type with description
2. How it works with description and boundary conditions
3. Finally a reference with a short description

Will also be done the same with the following chapter: technical solutions for air pollution.

<table>
<thead>
<tr>
<th>Type 1</th>
<th>Description</th>
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<td>Screen as noise barrier for the highway.</td>
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**How it works:**

Sound level is reduced by absorption and reflection by the properties of a certain material on a screen configuration.

**Maekawa model:**

The attenuation of the sound at a high (semi-infinite) and thin screen, that in the horizontal direction is assumed, infinite long for a given frequency read from a graph in the additional turning of the sound through the top of the screen apart from the wavelength. High frequencies are easier to reflect or absorb than low frequencies (Martin, 2008, p. 26).

To reduce the sound level, the material must have the ability to reflect or absorb sound, but should be resistant to water and fluctuations of temperatures. Also height is an important factor. For the city’s environment the minimum screen height should be around 2 meters. This can also be calculated with the Fresna-getal (see figure 09). This Fresna-getal is basically:

\[ N = \frac{2}{\text{wavelength of sound}} \times (d_1 + d_2 - d_3) \]

The distances d1, d2 and d3 (in meters) can be constructed as shown in figure 09 and the wavelength of sound can be constructed as: \( c / \text{frequency} \) with c as 343 m/s (speed of sound). The higher the screen gets, the more sound it will reduce.

Hard material reflects the sound, such as concrete. Soft and porous materials, such as a curtain, can absorb sound and convert it into heat. This can be determined by the absorption coefficient of the material. Concrete has for instance a low absorption coefficient and tends to reflect the sound. A cotton-
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Can be calculated of the sound level per octave (Bouwfysica, 2013).

A pleated curtain has a high absorption coefficient and converts sound into heat (Nijs, 2013). Materials with relief or pleated materials can enhance the absorption/reflection of the sound level. Thickness is an important factor. To reduce or reflect sound, you will need a very thick material, or sound will go through the material due to the wavelength property (van der Linden, 2006, p. 156).

Fig. 10: concrete noise barrier screen at the A2 in Den Bosch (Romein, 2013, p. 1).

This reference shows a concrete screen configuration with a pattern in it. It’s prefabricated and can be designed in many ways. This pattern actually has the ability to shatter the noise and absorbing it. The relief pattern introduces more surface area on the screen that enhances the noise reduction (Romein, 2013, p. 5).

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<th>Type 2</th>
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**Screen of tubes as noise barrier for highway**

**How it works:**

Sound level loses its energy in the tubes due to shattering of sound, resulting in a reduction of noise. (Absorption).

The material has to be weather-proof, strong enough for fluctuations of sound pressure levels and consists of a certain depth that can reduce the sound level. A sound frequency is an important factor in this type. High tones have high frequencies and low tones have low frequencies. So not only the depth, but also the size of the hole is important.

The material of the tubes should not vibrate by itself due to the sound level. Otherwise it will produce sound by itself (van der Eerden, 2000, pp. 12-13).

This reference shows a noise barrier that is made out of bamboo tubes.

The noise barrier will be an interface between road and city space. Bamboo used is known for its sustainability and his capability to reduce noise. Bales of three types is made of tightly bound bamboos were explored to perform a specific function. The first type was a regular hollow bamboo...
that transforms noise directly. The second type was irregular hollow bamboo with an infill of fibre optic cable. The third type was the irregular solid bamboo that provides maximum sound protection. A steel grid is also used to provide space so that bamboo bales can fit. This could be a very flexible system that can be parameterized digitally. If it is successful it can have wide range of applications (Sadarvuga, 2013).

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<tr>
<th>Type 3</th>
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<td>Coulisse screen as noise barrier for the highway; a façade type.</td>
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**How it works:**

Sound level loses its energy in the lamellae, resulting in a reduction of sound (absorption and reflection).

The screen consists of sound absorbing vertical slats that hung on the facade. These screens repel the underlying facade off of the sound. Rule of thumb for this is that soundproofing matches sightlines. For a wall parallel to the road can be achieved as a noise reduction of about 8 dB, for a wall perpendicular to the road even 13 dB.

The scenes designed by Cauberg-Huygen, are a meter deep and 20 cm thick. The perforated surface is filled with a sound absorbing material with inside a closed core. This is to prevent the sound bounces off and still go through the blades back. The core of the blades ensures that this does not happen.

The distance between two blades is centre-to-centre 1 meter by 80 centimetres as residual space. This is done because of the daylight. Also, this is done because the wavelength of the traffic noise. In this way we reduce the sound of 250 Hz, which corresponds to the noise spectrum of traffic (Bouwwereld, 2013a).
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This reference shows a coulisse screen façade that is integrated with the apartment building in Rotterdam. Windows on that side can still be used and still allows you to interact between the interior and exterior space (Caubergen-Huygen, 2013).

Fig. 14: Coulisse screen configured as a façade (Caubergen-Huygen, 2013).

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<th>Type 4</th>
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<tr>
<td></td>
<td>Urban deployment as noise barrier for the highway</td>
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<td></td>
<td><strong>How it works:</strong> Sound level is redirected and shatters its energy through the composition of the building environment. Factors that should be taken into account: - Wind velocity and direction - Low tech or high tech? - Sight view - Height - Experience driver/city dwellers - Distraction</td>
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<td></td>
<td>Buildings can be used to redirect or reflect sound in order to reduce noise. Sound that’s being redirected has to make more distance to reach the receiver. The bigger the distance, the more it loses its energy. When sound hits a surface at a certain angle, it will reflect back with the same angle. Thus angle of coincidence is the same as angle of reflection, just like how light behaves when it hits a surface. The façade of the building just act like a mirror (see figure 14e).</td>
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<td><strong>Buildings</strong> that introduce a view opening of 90° will give a sound reduction of 3 dB and with a 45° angle view opening a sound reduction of 6 dB as shown in figure 14b and 14c (van der Linden, 2006, pp. 161-163).</td>
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Fig. 14c: 45° opening will give sound reduction of 6 dB (own ill.)

Fig. 14d: sound can travel over the building mass (own ill.)

Fig. 14e: composition of buildings can also result in sound reflections (own ill.)

Fig. 15: building used as a wall to reduce noise (Bouwwereld, 2013c).

This reference shows a housing strip block with a long façade clad with bricks. Bricks are hard materials and will reflect noise back from the highway. The buildings are designed as a continuous wall configuration (Bouwwereld, 2013c).
<table>
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<th>Type 5</th>
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<tr>
<td><img src="image" alt="Soil and vegetation as a landscaping noise barrier for the highway." /></td>
<td>Soil and vegetation as a landscaping noise barrier for the highway.</td>
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<tr>
<td><strong>How it works:</strong></td>
<td>Cheap solution when much excess soil around exists, &quot;natural&quot; view, especially when the berm is overgrown with plants, extremely durable, life is unlimited; impervious to graffiti.</td>
</tr>
<tr>
<td><img src="image" alt="How it works" /></td>
<td>It takes much more space than a typical &quot;thin&quot; screen. One can, however, reduce the space required by placing one or both ramps are enhanced manner, so that the slope can be made steeper than 45 ° a berm, and the acoustical shielding is less effective than by a thin screen with the same height, relatively a lot of maintenance (pruning, mowing), yet blocks the vision of local residents and road users. This system can contribute to the ecological values inside the city(BIM, 2013).</td>
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<th>Type 6</th>
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<tr>
<td><img src="image" alt="Double façade as noise barrier for residences." /></td>
<td>Double façade as noise barrier for residences.</td>
</tr>
<tr>
<td><strong>How it works:</strong></td>
<td>Sound level is reduced through a buffer zone. The sound level has to be reduced to the desired value (48 dB for outside environment and 35 dB for living environment). The buffer zone should be smoke free for escape possibilities.</td>
</tr>
<tr>
<td><img src="image" alt="How it works" /></td>
<td>The ventilated air in the buffer zone should be free of particulate matter and exhaust fumes of cars. Fresh air has to be extracted from a car free area or has to be mechanically ventilated(Knaack, Klein, Bilow, &amp; Auer, 2011, pp. 29-30).</td>
</tr>
</tbody>
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This reference shows The edge of the block the Funen (in Amsterdam) serves as a sound wall to rail and reflects the dynamics of the train. The scaly is added as a second skin to the building and works as a noise barrier. The coloured scales create the rhythmic effect with the ability to shatter noise(ArchitectenCie, 2013).

<table>
<thead>
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<th>Type 7</th>
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<td>Layered structure (façade) as noise barrier for the residences.</td>
</tr>
</tbody>
</table>

How it works:
The mass-spring-mass law. The starting point is of two masses, which are separated, from each other by a spring. That spring can be air or an insulating material. The thickness of the spring is determined by the degree to which the vibrations are damped.

The sound collides with the first mass and brings it to vibrate. The spring between the two layers captures this vibration and acts as a shock absorber. The sound is then strongly attenuated transmitted to the second mass. In the application of the mass-spring-mass principle, there are four parameters, which are decisive for the values of insulation obtained.

(1) Mass increase:
When the masses are increased in both walls we keep more decibels.

(2) Cavity Width:
The larger the cavity width, the better the acoustic insulation.

(3) Filling level: It is advisable to fill the cavity with insulation completely. Reduplicate walls: at a brick wall, you should use no wall ties. Build a double wall in drywall, and then put each wall against its own metal support. A metal support structure is preferable to wood because metal is more flexible and thus dampens vibrations. This type can reduce the weight and thickness without affecting much of the sound insulation(van der Linden, 2006, pp. 172-174)
Fig. 20: a sculptural building-wall along the A58 in Tilburg (Bouwwereld, 2013b).

This reference shows a sound wall that is integrated with the housing block. The wall consist of several layers to reduce to noise from the road traffic of A58 in Tilburg (Bouwwereld, 2013b).
### 3.1.2 Literature analysis: technical solutions for air pollution

<table>
<thead>
<tr>
<th>Type 1</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Screen as pollutant barrier for the highway and residences.</td>
</tr>
</tbody>
</table>

**How it works:**
A screen for air quality mainly provides effective increase of the noise barrier, by giving more interference background air. For average circumstances in a display of 4 m to 5.5 m, the effective increase is 6% in concentration. For stable conditions, the screen increases by the air shield and more effective, the reduction in concentration estimated to be about 30%.

Increasing the dilution processes of the air above the road with sky of larger height is an effective way in means of the concentrations decrease. Ambient level the effect is depends in part on the already present in the background upper air (city background).

Behind the screen occurs turbulence resulting in additional intrusion of polluted air background with cleaner air thus decreasing concentrations.

Screen prevents partially distribution of particulate matter, CO2 and NOx, but does not remove pollution of air.

The screen works best vertically placed (and otherwise up to 10 °). Minimum length of 100 meter from field measurements is shown that the screens provide a positive effect to the concentrations of NO2 and PM10 (V&W & VROM, 2009c, pp. 6-11).

This reference show a screen with an integrated filter system that absorbs particulate matter and nitrogen dioxide (with a titanium dioxide layer). The Venturi roof enhances the wind circulation inside the system. This also enhances the absorption of the pollutants (CleanScreen, 2013).
Introducing a ‘highway-residential’ typology with a neighbourhood concept in the dense city

<table>
<thead>
<tr>
<th>Type 2</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vegetation pollutant <strong>absorber</strong> for the highway and residences. This is applicable for screen and façade.</td>
</tr>
</tbody>
</table>

**How it works:**

There is the influence by upsetting the approach flow, air partly forced on the to flow. Vegetation This leads to dilution by additional turbulence and the mixing of air from different heights (a positive effect) and a reduction in the wind speed (a negative effect).

Deposition. A portion of the air flows through the vegetation (as a result of the porosity = permeability). In addition, two effects occur:

(a) Adsorption: During contact with vegetation to dust (fine) the leaf linger and later leach into the soil. This effect is most evident present in conifers or deciduous trees with rough leaves;

(b) Absorption: NOx can are taken up by the stomata of vegetation. This effect is most evident present in deciduous trees. Deciduous trees have leaves only in summer; conifers have throughout the year needles.

The vegetation is dependent on the movement speed and the wind. The higher the traffic speed and stronger wind, the better the vegetation is absorbing. Also, the vegetation is seasonal and that should be taken into account with defoliation.

Maintenance is required. Type of vegetation is important. Safe distance is also required (V&W & VROM, 2009b, pp. 33-36).

The combination of a solid prefabricated core, green screens and the essential spaces between them takes care of the purification of the air and the mute of sound. Screen2clean ® and ® Wall4life both take relatively little space and no larger than a traditional sound barrier. The green appearance creates harmony with the landscape and a gentle touch of the city.

The double green screens are designed to absorb noise and particulate matter, but also background PM concentrations. By slowing down the flow of air through the dense vegetation the particulate matter can be absorbed through the leaves and the ground. The purifying power is designed so that the airflow is controlled on the screen. The solid core creates turbulence and pressure, making the particles precipitated (Green4roads, 2013).
## Type 3

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tunnel or canopy as pollutant <strong>barrier</strong> and <strong>absorber</strong> for the highway and residences.</td>
</tr>
</tbody>
</table>

### How it works:
When a highway is provided with a (slight) canopy, the surroundings of the road will not directly being exposed to air pollution as a result of the road. Therefore, a light canopy provides solution for an existing constraint, in terms of the air quality.

With canopies and tunnels is often require the tunnel air treat at the tunnel mouths the limits for to meet air quality. When air is distinction between:

1. **Ventilation** (passive or active)
   - Passive: dilution (vent)
   - Active: extraction (with fan)

2. **Air cleaning**
   - (Extracted from air, or of the entire tunnel content). With a downstream technique, air is cleaned and emitted through chimney outside or in the tunnel itself treated with detergent equipment.

Tunnel must be at least 200 m long and 7 m high, has to be accessible for maintenance and escape routes has to be includes as well for the drivers. Above 500 m, the tunnel has to be mechanically ventilated (RDVS, 2009, pp. 51-57).

Factors that should be taken into account:
- Safety
- Weight of the system

System that can be integrated:
- Non thermal plasma
- Corona reactor (cold plasma)
- Movares Duurzame weg
- Solar Serpent
- Bio scrubber

---

![Fig. 25: a diagram of different tunnel configurations that displays the airflow. (1) Normal, (2) open roof tunnel, (3) tunnel with two chimneys, (4) tunnel with one chimney](RDVS, 2009, p. 50).
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Fig. 25: Movares duurzame weg (Movares, 2013).

This reference is the Movares duurzame weg. With the use of filter units inside the covered highway abstract exhaust fumes. This reduction is achieved by recirculation of the air at location of the lanes and purification of circulating air under the roof. As a result of the movement of traffic namely, airflow is generated. The air velocity and the cross-section of the roof ensure that large amounts of air are set in motion. With the combination of heat storages from asphalt, Movares introduces a very sustainable solution (Movares, 2013).

### Type 4

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalytic decomposition as pollutant absorber for the highway and the residences. This system is applicable for façades, screens or tunnel configurations.</td>
</tr>
</tbody>
</table>

**How it works:**

With reaction of sunlight, TiO2 absorbs NO2 and converts it into NO3. This can then be washed away by rain and may be absorbed by plants.

This system only works with sunlight. When there’s no light, artificial UV-light should be added. The system doesn’t absorb particulate matter or CO2 (Reynobond, 2013, pp. 2-3).

Wind velocity is very important. Without wind, there won’t be any absorption of NO2.

The Netherlands has low light intensity, high humidity and a low temperature that negatively influence on the functioning of this system. This system is applicable in combination with a tunnel system (V&W & VROM, 2009a, pp. 39-40).

Factors that should be taken into account:
- Maintenance
- Height of the system

This reference shows a façade consisting of tiles coated with Titanium oxide that freely react with the nitrogen dioxide and nitrogen oxide that removes the smog in the air with the help of the sun’s ultraviolet rays and atmospheric humidity.

Experts estimate that the 10-meter Torre de Especialidades wall or façade will be able to neutralize the equivalent of smog produced by 8,750 cars on a daily basis. The best part is that the titanium oxide itself remains unaffected, so the tiles do not have to be constantly re-coated (DOGOnews, Alcoa, 2013).
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Fig. 25: a façade coated with TiO2 to absorb smog in Mexico (DOGOnews, 2013).

<table>
<thead>
<tr>
<th>Type 5:</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Electrostatic field reduction system as pollutant absorber (particulate matter) for the highway and the residences.</td>
</tr>
</tbody>
</table>

**How it works:**

Wires of electrical voltage are applied. The positively charged particles of these wires 'shoot' the neutral particles, which then gets a positive charge. A negative charge, such as the earth, attracts a positive charge. The mesh that is then placed beside the road in the earth is negatively charged. This mesh ensures the 'capture' of the positive particles.

The system doesn't absorb NO2 and CO2 but uses a very small amount of electric energy. Latest test results show that the system can absorb up to 50% of the particulate matter. It’s stated that if there were more electrical wires, the results would be even better (BAM, 2013).

It is applicable in combination with other systems such as the tunnel or the catalytic decomposition.

Factors that should be taken into account:
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- Maintenance
- Height of the system
- Very Strong wind can have a negative impact during the attraction process

<table>
<thead>
<tr>
<th>Type 2</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
<td>Bio scrubber as pollutant-eating system for the highway and the residences.</td>
</tr>
</tbody>
</table>

**How it works:**

Air pollution is extracted and converted into a liquid that through microbes is consumed. These results in clean air and sludge as residue.

Bio scrubber can treat emissions containing particulate matter.

It is a chemical process. Over feeding can cause excessive biomass growth, which can plug the bio scrubber. It needs expensive and complex feeding and neutralizing systems. To control biomass growth, toxic and dangerous compounds must be inventoried and handled (CATC, 2003, pp. 33-35).

The system is very big and demands a huge surface. The question is whether it is capable to clean a huge area such as the highway.

Factors that should be taken into account:
- Maintenance
- Height of the system
- The amount of time it needs to purify the air

Fig. 27: a diagram of the bio scrubber system (CATC, 2003, p. 26).
3.1.3 Literature analysis: theory neighbourhood

This chapter gives you a brief overview of the neighbourhood characteristics and is structured in a table. This is also done in chapter 3.1.4 for the residential typologies.

<table>
<thead>
<tr>
<th>Neighbourhood</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>The definition of neighbourhood comes from the urban planning. Urbanism is composed of the following layers:</td>
<td></td>
</tr>
<tr>
<td>1. Territory</td>
<td></td>
</tr>
<tr>
<td>2. City plan</td>
<td></td>
</tr>
<tr>
<td>3. Public space</td>
<td></td>
</tr>
<tr>
<td>4. Buildings</td>
<td></td>
</tr>
</tbody>
</table>

The neighbourhood in the post-war were planned as the third articulation (public space) of the urban planning as shown in figure 28. Main goal of the neighbourhood was to introduce social coherence inside the residential environment and to introduce slow transition process going from a city to home.

Characteristics of the neighbourhood are:

- District structure (grid structure, ring structure, axes)
  Goal: creating a structural and social coherence in residences
- Parcelling of residences (with front and/or back yard)
  Goal: creating a private exterior space and own territory
- Access of routes and streets
  Goal: to have clear direction and access to the residences
- Playground
  Goal: introducing social interaction
- (Parking)
  Goal: storage
- Public facilities (grocery store, fitness, hair salon, café, etc.)
  Goal: reduce distance between public and household and enhance social interaction
- Greenery
  Goal: Aesthetic perception of space and having lively environment.

Very essential for the neighbourhood is the transition from public domain to private domain (Meyer, et al., 2008, pp. 29-53).
### 3.1.4 Literature analysis: theory residential typology

<table>
<thead>
<tr>
<th>Typology</th>
<th>Characteristics</th>
</tr>
</thead>
</table>
| Strips (Fig. 29a)   | One of the earliest forms of the buildings are detached houses next to each other along a road or canal. Independent management of its own property is associated with the company of neighbours and collective interest in the maintenance and use of the access road. New buildings will be added to the end of the existing sequence, the next line of the road. This almost organic way of cultivation is found in the roads of many towns and villages. The newer houses are moving away from the historical centre with urban amenities, but also increasingly in an open environment with still good accessibility (Leupen & Mooij, 2008, p. 204). Strips:  
  - There is no indoor area that is shielded from the street to the outdoor spaces facing the street. There is no longer a private domain, but an open domain.  
  - Good daylight entrance  
  - With the addition of more height, the strips will act as a ‘wall’ in the urban environment. In return, you will get more exterior space, less low-rise density and more view of the city.  
  - Very strict monotone structure. |
| Housing Block (Fig. 29b) | The closed block is characteristic of the classic European city, which has taken shape. During and after the Middle Ages Essential characteristic is a continuous development along all edges of the urban block. The exterior of this building defines as the streets and public areas, while the open space is protected within the block of city life. Originally composed of terraced town houses is the same structure filled by stacked housing later.  
Although the closed block is part of nearly all-European cities, there are clear differences in the organization to be appointed. Thus arose from the eighteenth century in many foreign cities apartment complexes around a small courtyard, which concatenated form a block that contains many small light wells (Leupen & Mooij, 2008, pp. 200-203). Housing Block (courtyard):  
  - A continuous formal facade along all edges of the courtyard block, while the inner... |
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façade is very informal and private.
• The exterior of this building defines as the streets and public areas, while the open space is protected within the block of city life.
• Access is through courtyards, also seen as a collective transition zone between the city and housing.

The residential towers make housing to very high densities possible. However, the high quality of living in a tower (free and unhindered views) benefit from a lot of free space around the tower. Towers are therefore often placed in strategic places with a lot of views waterfront or prominent point in an urban plan. The large amount of houses in a relatively small area makes a good parking solution to absolute necessity.

Houses in a tower have little relationship with the street or the immediate vicinity of the building. Instead, they focus on the further up view and the quality of life within the home. Large outdoor spaces can potentially compensate for feeling trapped, although the climate boundaries to set again at high altitude. Common areas and facilities elsewhere in the building can increase the residential area within the towers. Because of the distance to the street, the houses often provide additional services, ranging from waste treatment to electronic ordering of messages (Leupen & Mooij, 2008, pp. 194-195).

Towers:
• The vertical access by a lift allows stacking of homes to large heights
• More height will give more uninterrupted view to the city, but less connecting with the surface level. Houses in a tower have hardly any relationship with the street or the immediate surroundings of the building.
• The large amount of houses in a relatively small area can make a good parking solution
• The higher you live, the less you will be affected with noise and air pollution. But feeling of being locked may occur.

When freestanding volumes as strips, blocks and towers form together a larger compositional unity, it is also called an ensemble. Often the ground between the volumes of a collective or public area, where the lack of private gardens is compensated by a larger-scale facility for all residents. The
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various blocks due to their relative positioning on alternating open spaces in the city often sheltered from the bustle and noise of traffic (Leupen & Mooij, 2008, p. 197).

Ensemble:
- A combination of different residential typologies can make the neighbourhood very vibrant and lively. People experience different building heights, shapes and materialisation.
- The dimensions of the individual volumes and the way they relate to each other, determine the capabilities of views and natural light from the house, but also between the ratio of public, corporate and private area and the extent of foreclosure.
- The surface level between the volumes is a collective or even a public area that is compensated by a larger-scale facility for all residents due to the lack of private gardens.

Fig. 29d: ensemble of different typologies (own ill.)
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<table>
<thead>
<tr>
<th>Residential configuration</th>
<th>Possible Residential configurations with the Highway</th>
<th>Low-rise density: covering (Random configuration intended as idea)</th>
<th>High-rise density: height (Random configuration intended as idea of suggestion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strips</td>
<td>The residential configurated as a &quot;summer wall&quot;</td>
<td><img src="image1" alt="Low-rise density: covering" /></td>
<td><img src="image2" alt="High-rise density: height" /></td>
</tr>
<tr>
<td>Housing Block (courtyard)</td>
<td>The residential configurated as a &quot;resonance box&quot;</td>
<td><img src="image3" alt="Low-rise density: covering" /></td>
<td><img src="image4" alt="High-rise density: height" /></td>
</tr>
<tr>
<td>Towers</td>
<td>The residential configurated as a &quot;height dependent towers&quot;</td>
<td><img src="image5" alt="Low-rise density: covering" /></td>
<td><img src="image6" alt="High-rise density: height" /></td>
</tr>
<tr>
<td>Ensemble</td>
<td>The residential configurated as a &quot;resonanceensive&quot;</td>
<td><img src="image7" alt="Low-rise density: covering" /></td>
<td><img src="image8" alt="High-rise density: height" /></td>
</tr>
</tbody>
</table>

Fig. 30: overview of different configurations and density possibilities from the four residential typologies as small case study (own ill.)
3.2 Setting criteria (phase 02)
After analysing the different technical solutions for air and noise pollution, the neighbourhood and the residential typologies, the following criteria to determine the highway residential typology resulted in:

- Does it contribute to the neighbourhood structure?
- Is there a strong transited zone from residence to neighbourhood (within 5 minutes)?
- Does it introduce a metaphorical/physical connection in the city?
- Does it contribute to the private and public space?
- Does it provide a clear accessibility?
- Advantages?
- Disadvantages?

These main criteria were then subdivided and distributes in the following three tables:
1. Criteria for noise solution
2. Criteria for air pollution solution
3. Criteria for the residential typology (see table 1 t/m 3

<table>
<thead>
<tr>
<th>Criteria for noise solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does it contribute to the physical experience of the driver?</td>
</tr>
<tr>
<td>Does it contribute to the physical experience of the habitants and city?</td>
</tr>
<tr>
<td>Low maintenance?</td>
</tr>
<tr>
<td>Does it actually absorb pollutants?</td>
</tr>
<tr>
<td>Can it interact with the neighbourhood?</td>
</tr>
<tr>
<td>Noise converted to sound as ambience?</td>
</tr>
<tr>
<td>Efficient use of space?</td>
</tr>
<tr>
<td>Flexible configuration?</td>
</tr>
<tr>
<td>Does it reduce the barrier effect in the city?</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Table 01: criteria for noise solution

<table>
<thead>
<tr>
<th>Criteria for air pollution solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does it absorb particulate matter?</td>
</tr>
<tr>
<td>Does it absorb nitrogen dioxide?</td>
</tr>
<tr>
<td>Does it introduce an experience to the driver?</td>
</tr>
<tr>
<td>Low energy consumption?</td>
</tr>
<tr>
<td>Potential energy harvesting?</td>
</tr>
<tr>
<td>Is there a potential reuse?</td>
</tr>
<tr>
<td>Low maintenance?</td>
</tr>
<tr>
<td>Does it contribute to noise reduction?</td>
</tr>
<tr>
<td>Does it benefit the outdoor spaces towards the city (appearance)?</td>
</tr>
<tr>
<td>Is wind velocity a positive/negative factor?</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Table 02: criteria for air pollution solution

<table>
<thead>
<tr>
<th>Criteria for the residential typologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advantages</td>
</tr>
<tr>
<td>Disadvantages</td>
</tr>
<tr>
<td>Is it reducing the barrier effect inside the city?</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>-----------------------------------</td>
</tr>
<tr>
<td>Is it a flexible configuration?</td>
</tr>
<tr>
<td>Does it contribute to a clear distinction between the private and public space?</td>
</tr>
<tr>
<td>Does it contribute to the neighbourhood (social coherence)?</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Table 03: criteria for residential typologies
## 3.3 Evaluation and elimination (phase 03)

### Table 04: multiple criteria analysis for noise solutions (own ill.)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Bufferzone</th>
<th>Greenwall</th>
<th>Type of facade</th>
<th>Type of urban deployment</th>
<th>Type of screen</th>
<th>Type of vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>01. Can it contribute to the experience of the driver?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>02. Can it contribute to the experience of the inhabitants and city?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>03. Low maintenance?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>04. Can it absorb pollutants?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>05. Can it interact with the neighbourhood concept?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>06. Noise converted to sound as ambiance?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>07. Efficient use of space?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>08. Flexible configuration (typical appearance)?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>09. Does it reduce the barrier effect in the city?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**TOTAL:**

- Bufferzone: 0
- Greenwall: 0
- Type of facade: 3
- Type of urban deployment: 0
- Type of screen: 0
- Type of vegetation: 0

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Table 05: multiple criteria analysis for air pollution solutions (own ill.)

<table>
<thead>
<tr>
<th>Type System</th>
<th>Type Screen</th>
<th>Type Vegetation</th>
<th>Type Tunnel (air ventilation)</th>
<th>Type Catalytic decomposition</th>
<th>Type Eectromotive field</th>
<th>Type Noiseless Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>01. Does it absorb Particulate Matter?</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>X</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>02. Does it absorb Nitrogen Oxides?</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>X</td>
<td>O</td>
</tr>
<tr>
<td>03. Can it contribute to the experience of the driver?</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>X</td>
<td>O</td>
<td>X</td>
</tr>
<tr>
<td>04. Low energy consumption?</td>
<td>O</td>
<td>O</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>X</td>
</tr>
<tr>
<td>05. Potential energy harvesting?</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>06. Is there a potential reuse/energy/peak?</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>07. Low maintenance?</td>
<td>O</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>08. Does it contribute to noise reduction?</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>09. Does it benefit the outdoor space/compactness?</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>X</td>
<td>O</td>
<td>X</td>
</tr>
<tr>
<td>10. Is wind velocity an positive/negative factor?</td>
<td>NEGATIVE</td>
<td>POSITIVE</td>
<td>POSITIVE</td>
<td>POSITIVE</td>
<td>POSITIVE</td>
<td>POSITIVE</td>
</tr>
</tbody>
</table>

TOTAL

|               | 3 | 6 | 5 | 4 | 7 | 2 | 5 | 4 | 6 | 3 | 8 | 6 |

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Table 06: multiple criteria analysis for residential typologies (own ill.)
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3.4 Research by design (phase 04)

Technical Configuration Type: Tunnel + Courtyard (Case study)

What technical configuration is best suited for the Courtyard typology?

Technical Configuration Type: Screen + Courtyard (Case study)

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Technical Configuration Type: Tunnel + Ensemble (Case study)

What technical configuration is best suited for the Ensemble typology?

Technical Configuration Type: Screen + Ensemble (Case study)

Interaction between indoor and outdoor spaces

Neighborhood as a “fragmented landscape distributed from different heights”

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Tunnel configuration is optional if the length is less than 500m. Transforming the whole highway to a tunnel would be very expensive and very high CO2 production due to maintenance and energy use for the mechanical ventilations.

The screen should now interact with the urban environment and the residential typology.

The neighborhood should be the connecting element, more open, interactive, with the highway (land) and should be smaller than scale to maintain the social coherence and reduce the large span.

The residential typology have to maintain the social coherence and share a clear private area to distinct the urban environment. The residence will still have the freedom to choose one interacts with the neighborhood or with the dense environment. The Ensemble is well suited for life.
4.0 Discussions

Unanswered Question:

- Daylight problem has to be considered. Daylight is a very important factor when it comes for living. Daylight or sunlight is also when applying a catalytic decomposition.

- Wind velocity is a very important factor that has to be taken into account when applying vegetation or greenery. Wind has to be guided to the vegetation in order to increase the absorption of air pollutants. This could be a very interesting when it comes to designing masses or shapes that somehow can enhance the wind velocity or daylight entrance.

- The integration with lots of different systems may not give a stronger solution. It’s necessary to define which systems can collaborate and which can’t collaborate. The danger of conflicting systems may occur.

- Maintenance requirements of different systems are still very unclear during the literature analysis. The most important criteria should the accessibility and the lo-tech approach (no special tools needed to maintain it).

The core ingredients of the residential typology configured on the highway are cleaning or reducing the pollutants and maintaining the social coherence. By missing one of these, the whole residential configuration wouldn’t come to it’s fullest. The question now is whether those techniques should be visible or invisible to the residences. Should it really have to interact or should it be hided?

The core of the neighbourhood isn’t a square or a court that relates the most with the residences, but actually the streets are defining the relationship with residences and the neighbourhood. The streets are the closest to them residences and guides towards the square, court or the city. Narrow or wide streets may engage a dialogue of which is private and which is public. So it’s very important to define the streets very accordingly to the program of needs in order to create the social coherence.
5.0 Conclusion

Overall design question: How can we introduce a residential typology with a neighbourhood inside the highway environment that reconnects the city again as a whole and convert the highway pollutants, such as air and noise, into benefits as a contribution to the residences and city’s spatial environment?

(1) The residential typology should be a hybrid consisting of a social coherence, social facilities and a pollutant barrier that is configured as a pivot point of the urban fabric and will reconnect the city again as a whole. A hybrid is a mix of two things to form one. Usually, the goal of a hybrid is to gain some advantage that neither of the two originals could achieve alone. The term hybrid can be used to classify a wide variety of things.

(2) The air pollutants will be reduced and absorbed with the use of electrostatic field system, catalytic decomposition system and vegetation that is configured in the urban and residential layer.

(3) Noise can be converted into sound (of 48 dB) as ambience with a wall of tubes, double façade (buffer zone) or coulisse screen and also configured in the urban and residential layer.

The above-mentioned points will define the Highway residential typology with a neighbourhood that will increase the liveability and social interaction inside the dense city.

Benefits: (1) traffic sound as ambience, (2) Interacted view between Highway and Neighbourhood, (3) reductions of pollutions that will make the outdoor space liveable and pleasant again, (4) heat storage from asphalt roads since living nearby the highway is possible.

5.1 Perspective

(1) Residential layer: The Highway-residential typology will be configured with double façades that will contribute to the exterior spaces and the neighbourhood concept. The Façades will functions as a clear transition zone between private and public and the reduction of traffic noise.

(2) Urban layer: the highway lanes will be covered with Screens that reduces the noise and pollutants of the traffic (electrostatic field, catalytic decomposition panels and greenery). These screens will connect seamlessly with the double façades of the residential typology.
5.2 Sub questions

1. **What are the Technical solutions for the environmental problems?**
   - Noise:
     - (1) The double façade as the buffer zone,
     - (2) wall of tubes,
     - (3) Coullisse screens,
     - (4) Urban deployment.
   - Air pollution:
     - (1) the tunnel configuration,
     - (2) the catalytic decomposition,
     - (3) electrostatic field system,
     - (4) vegetation

2. **What is the neighborhood concept?**
   That’s the outdoor space/ground of the residential configuration that defines the social coherence with:
   - (1) streets as the core ingredient,
   - (2) playground,
   - (3) social facilities,
   - (4) greenery as perception of aesthetics,
   - (5) clear distinction and transition zone between public and private.

3. **What type of housing block is best suited to the highway?**
   - (1) The Courtyard housing block, as a resonance box
   - (2) Ensemble of residences as a composition for a pollutant barrier

4. **How can we integrate the residences with the technical solution and introduce a connection?**
   By dividing the technical configuration in two layers:
   - (1) the urban layer (screen/tunnel/greenery)
   - (2) and the residential layer (façade systems/greenery) the two layers should eventually complement each other. The streets could be bridges that connect the residences and the urban fabric. The residential typology could act as a pivot point of the urban fabric, where the social coherence is being introduced that improves the liveability of the dense city.
5.3 Design tools

**Surface as:**
1. screen: barrier for pollutants
2. Platform: neighborhood
3. façade: buffer zone
4. transparent, solid, perforated

**Mass as:**
1. screen: barrier for pollutants
2. housing program
3. indoor spaces
4. transparent, solid, perforated

**Lines as:**
1. streets
2. bridges

**Zoning as:**
1. neighborhood (private area)
2. outdoor spaces
3. distinction between city and residence

1. Mass (program) as ‘resonance box’
2. Fragmented ‘resonance box’

3. Highway dressed with screens that absorb the pollutants with bridges (increasing the accessibility for pedestrians)
4. Highway dressed with screens that absorb the pollutants with bridges and coved openings beneath it

5. Highway dressed with screens that absorb the pollutants with bridges and integrated terraces for different programs
6. Highway dressed with screens that absorb the pollutants with footpath beneath it (increasing the accessibility for pedestrians)
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6.0 Reference


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