MODULE 4

AGE-FRIENDLY BUILT ENVIRONMENT – INTERIOR

UNIT 2

INDOOR QUALITY

Dean Lipovac

DESIRE

DESIGN FOR ALL METHODS TO CREATE AGE-FRIENDLY HOUSING

DESIRE is a European project funded by the Erasmus+ programme.
Project number 2020-1-SK01-KA202-078245.

ISBN 978-80-227-5273-2

DESIRE will provide professionals in the building industry and home furnishings sector with the tools and skills to apply Design4All methods as an integral part of the design process, with the aim to create or adapt age friendly housing as a solution for the wellbeing, comfort and autonomy of the older adults or dependents at home.

The DESIRE training platform consists of six modules and 21 units.

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

PUBLISHED BY:
© DESIRE, 2023, www.projectdesire.eu
Slovak University of Technology in Bratislava by Publishing house SPECTRUM STU, Bratislava 2023

AUTHORS:
Miguel Ángel Silvestre Botella
Zuzana Čerešňová
Carina Dantas
Natália Filová
Juan Carlos Bañón Guillén
Miroslava Hlinčíková
Michal Kacej
Veronika Kotradyová
Dean Lipovac
Nastja Podrekar Loredan
Juliana Louceiro
Soňa G. Lutherová
María Sánchez Melero
Marta Martínez Navarro
Lea Rollová
Matic Sašek
Mária Šimková
Helena Tužinská
Ľubica Voľanská

ILLUSTRATIONS:
Zuzana Čerešňová
Natália Filová
Michal Kacej
Veronika Kotradyová
Markéta Kučerová
Lea Rollová
Lenka Suláková
Barbora Valábeková

GRAPHIC DESIGN:
Mária Šimková

TABLE OF CONTENTS

UNIT 2 – INDOOR QUALITY

2.1 PRINCIPLES OF HEALTHY LIGHTING

IN A NUTSHELL

Proper lighting is essential for even the most basic activities occurring in the built environment, and light plays an important role in human health and wellbeing. Natural light should be abundant in indoor spaces, because it has qualities that are difficult to replicate with artificial light. This can be achieved in a number of ways, such as placing windows on walls facing the sunniest cardinal direction and installing large windows or glass walls and roofs. Despite the importance of natural light, artificial light is necessary to keep buildings fully functional without sunlight. Sources of artificial light should be carefully planned and integrated with room layouts and materials so that the light is evenly distributed throughout the space without causing unpleasant reflections. Lighting should be matched to the intended function of the space. For example, breakfast rooms need light in the morning and should face east, while rooms that need light primarily in the late afternoon and evening should face west. Lighting should also be adaptable, because the same room can be used in different ways, depending on the user, occasion, and time of day.

2.1.1 The importance of natural lighting and its role in buildings

The built environment can hardly serve its purpose without proper lighting. Good lighting is essential for even the most basic activities: for people to move through the building safely, communicate effectively, and perform work, household, and leisure tasks constructively. But the importance of light goes beyond its role in supporting functioning in the built environment. Light has a major role in human health and wellbeing; it is linked to circadian rhythms, sleep, mood, stress, alertness, and vitamin D synthesis. The importance of light is clearly seen in cases of seasonal affective disorder – a type of depressive disorder that typically occurs in winter, when light levels are low, and for which the treatment includes increased exposure to sunlight or an artificial source of bright light (Edwards & Torcellini, 2002; Nousiainen et al., 2016).

The overall guideline is that spaces should provide appropriate lighting to support people's day-to-day activities by using sources of light that are not conspicuous or disturbing. Natural light should be abundant in indoor spaces and serve as the primary source of light during the day. Natural light not only connects building users to the outside world, but also saves electrical energy and has features that are difficult to match with artificial lighting. One of the first steps in trying to optimize natural light in indoor spaces is to consider the orientation of the building and windows relative to the movement of the sun. In the Northern Hemisphere, the sun is always on the south side throughout the day, and orienting buildings along an east-west axis can increase exposure to the sun. The amount of natural

light can be maximized by installing glass walls, tall windows, or windows that are placed higher on the wall. In the northern hemisphere, spaces with south-facing windows will receive the most light, so these should be spaces that are used frequently and require a lot of light, such as kitchens, rather than spaces that are used less frequently or need less light, such as storage rooms or bedrooms (Mahoney, n.d.).

North-facing windows receive the least amount of light compared to any other orientation, and larger windows are needed to let in a comparable amount of light compared to other orientations. The advantage is that the light from the north is indirect and does not cause glare, which can be useful for some spaces, for example, rooms with computers and televisions. Windows facing the east receive direct light in the morning, making them ideal choices for places where people sleep and spend time early in the day, such as breakfast rooms. The opposite is true for windows that face west, which will receive the most direct light in the late afternoon and evening, making them ideal for rooms that are used primarily in later hours of the day, such as living rooms. Both eastern and western light can often cause glare due to the lower angle of the sun after sunrise and before sunset. This can be managed with vertical (rather than horizontal) sun shades (Mahoney, n.d.).

Figure 4.2.1 Transparent walls and roofs allow large amounts of natural light to enter indoor spaces. (Pexels)

2.1.2 Artificial lighting and the importance of adapted and adaptable lighting

Even though natural lighting is essential, buildings should be fully operational even without sunlight. It is especially important to sufficiently illuminate building elements that play an important role in the mobility of the occupants, such as stairs, as otherwise injuries can occur. In the lighting industry, Kelvin (K) refers to the warmth or coolness of the light. Light sources in the lower range tend to appear yellow (orange at the extremes) and those in the upper range tend to appear white (blue at the extremes). Commonly used light sources span from 2000K to 8000K, with 5000K being the most common colour temperature. Cooler colours at the upper end of the spectrum are typically used in spaces that require bright light for people to perform their tasks, including manufacturing facilities, warehouses, and healthcare facilities. Warmer colours at the lower end of the spectrum are typically used in spaces where bright light is not a priority, and the goal is to create spaces that feel more inviting and cosier (Larson Electronics, 2019).

Ideally, lighting should be adaptable in all spaces, because the same space can be used in different ways, depending on the user, occasion, and time of day. For example, playing a board game in the living room may require more light than having a conversation, and older adults may need brighter light for reading than younger people. In places where frequent conversations are expected to happen, such as reception areas, lighting should illuminate people's faces. This is especially important for people who read lips. Adaptable lighting can be achieved with smart light bulbs as well as with blinds and curtains that can control sunlight (Edwards & Torcellini, 2002; Nousiainen et al., 2016).

Light should be evenly distributed and diffused in a space. This can be achieved by having more (less intense) sources of light rather than few (intense) sources. For example, several smaller windows distribute light more evenly compared to few large windows. Light coming from few intense sources can also create strong shadows, which can interfere with people's perception of step edges. The distribution of light is also affected by the layout of spaces and selection of interior materials. Larger spaces can distribute light more effectively than several smaller or subdivided spaces. Subdivided spaces can diffuse more light when the separating elements are transparent (e.g., glass walls). In general, transparent and bright materials allow light to spread through the space more effectively. Some materials, especially artificial and heavily treated ones, can cause unpleasant reflections, making natural materials with matte finishes a preferred option (Edwards & Torcellini, 2002; Nousiainen et al., 2016).

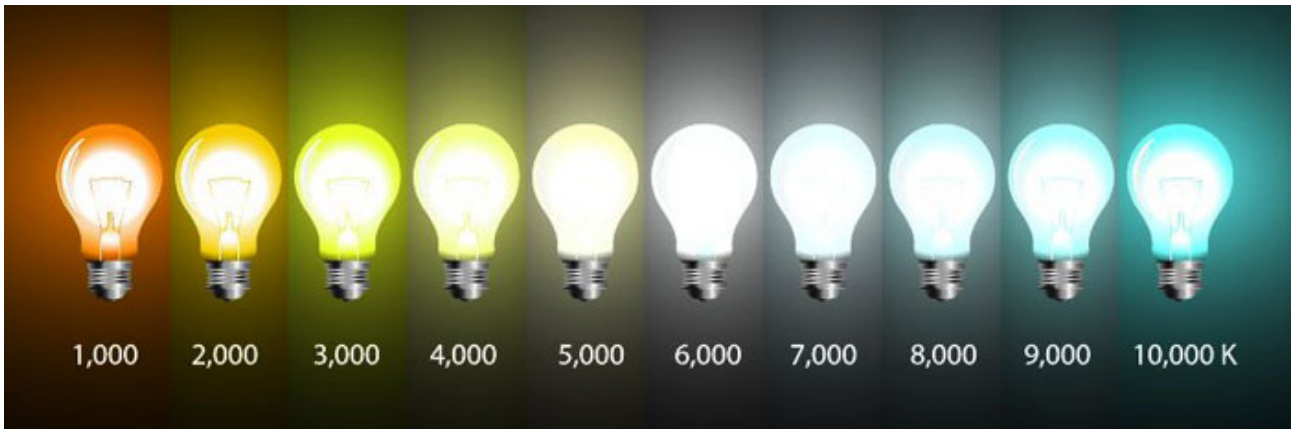

Figure 4.2.2 Warmer lights appear yellow or orange, while cooler lights appear white or blue (Larson Electronics)

2.2 INDOOR AIR QUALITY

IN A NUTSHELL

Poor air quality is responsible for a variety of illnesses, including respiratory diseases, diabetes, and dementia. In the Western world, some of the most important indoor air pollutants are volatile organic compounds emitted by various materials and products, such as paints, furniture, carpets, and cleaning agents. These pollutants contribute to the sick-building syndrome, which is characterised by increased respiratory illnesses, allergies, and decreased immunity. The first step in improving indoor air quality is to reduce emissions of pollutants. It is especially important to avoid materials that contain chemicals on the Living Building Challenge red list[1], such as asbestos or lead. Natural materials, such as wood, are generally preferred, although these materials can also be problematic. A complementary method to using less harmful materials and substances indoors is to remove pollutants from the air. This can be accomplished in part by increasing the amount of indoor vegetation, which can remove toxins, dust, and germs from the air. Harmful substances can also be removed from the air by passive (gravitational) and/or mechanical ventilation. Passive ventilation uses temperature and pressure differences between indoor and outdoor air to bring in fresh air from the outside and remove stale air from the inside by strategically positioning building openings. Mechanical ventilation uses electrical devices that move air from the inside to the outside and, in some cases, also from the outside to the inside.

2.2.1 Poor air quality and health

Poor air quality has been implicated in various diseases and health issues, including cardiovascular disease, respiratory disease, adverse birth outcomes, diabetes, neurodevelopmental deficits, and dementia. Conversely, reducing air pollutants leads to observable health benefits, both within a short time period and over the longer term (Kelly & Fussell, 2019). Because people spend most of their time indoors, indoor air quality is of critical importance. The level of indoor air pollution varies widely in different parts of the world. In rural areas of the developing world, burning solid fuels for cooking and heating without proper ventilation significantly harms health and increases the risk of death. In dense Asian megacities, indoor air is polluted primarily by outdoor pollutants, including industry and vehicle exhaust. In the Western world, indoor air quality is negatively affected by chemicals from cleaning and consumer products, furniture and building materials, and inadequate maintenance of ventilation and air conditioning systems (Kelly & Fussell, 2019).

[1] https://living-future.org/red-list/

Figure 4.2.3 Industrial pollutants are significant contributors to poor air quality (Pexels)

In recent decades, the use of mechanical air recirculation ventilation systems and the constant upgrading of interior furniture have led to an increase in indoor air pollution. The main pollutants are volatile organic compounds such as benzenes, phthalates and formaldehyde, which are emitted from materials and products such as paint, furniture, carpets, cleaning agents, cosmetics, and disinfectants. Most of the emissions come from human-made substances. Perhaps the most harmful substance, however, is naturally occurring radon, which can enter indoor spaces through soil, stony building materials, and household water. The unhealthy conditions created by emissions of various harmful substances contribute to the sick-building syndrome, which is characterised by an increased number of respiratory diseases, allergies, and decreased immunity, with symptoms including headache, fatigue, dizziness, nausea, and eye, nose, and throat irritation (Joshi, 2008).

2.2.2 Improving indoor air quality

The first step in improving indoor air quality is reducing the emissions of harmful substances. It is not possible to create modern indoor spaces without having objects that emit at least some pollutants for at least some of the time, but air quality can be greatly improved if certain materials are chosen over others. It is especially important to avoid materials containing chemicals from the Living Building Challenge red list[2], such as asbestos or lead (The Living Building Challenge, n.d.). Soft materials like carpets and drapes can retain dangerous air pollutants and serve as their reservoir long after the original sources of pollutants have been removed, especially if they are not cleaned regularly. Although natural materials, such as wood, should generally be a preferred choice, it should be noted that even materials like wood can be problematic – the number of emissions is high when wood is fresh or heavily treated with adhesives and coatings. Older materials (and older buildings) generally emit fewer substances which increase when renovation or maintenance work is done, such as when new furniture is added or when walls are painted.

A complementary method to using less harmful materials and substances in indoor spaces is to remove pollutants from the air. One way to accomplish this is to increase the amount of indoor vegetation with large leaves, which can remove toxins, dust, and germs from the air, including air pollutants present in building materials and furniture, such as acetone, ammonia, benzene, and formaldehyde. However, plants can reduce air pollutants only to a certain extent, and proper ventilation is required for good air quality. Ventilation can be divided into passive (gravitational) or mechanical. Passive ventilation relies on temperature and pressure differences between indoor and outdoor air to supply fresh air from the outside and remove stale air from the inside by strategically positioning building openings. Passive ventilation works best in the winter, when the outdoor and indoor air differ considerably. It is much less effective in the summer, when the differences between outdoor and indoor air are much less pronounced. The design of buildings for effective passive ventilation can be complex and needs to consider a variety of factors, such as the location and dimensions of the building, layout of spaces, and the location and type of openings, such as doors and windows (Nousiainen et al., 2016; Spengler & Chen, 2000).

When passive ventilation is inadequate, it can be supported or replaced by mechanical ventilation. Mechanical ventilation uses electrical devices that move the air from the inside to the outside (exhaust ventilation) and, in some cases, also from the outside to the inside (supply ventilation). Supply ventilation allows for the incoming air to be filtered before it enters indoor spaces. The downside of mechanical ventilation is that it requires energy, can be a source of disturbing noise, and contains filtration systems that must be cleaned on a regular basis, otherwise they can become sources of air pollutants themselves (Nousiainen et al., 2016; Spengler & Chen, 2000).

In addition to air pollutants, room temperature and relative humidity are other important aspects of indoor air quality. People tend to feel most comfortable and function at their best when the temperature is around 21 – 22 °C. However, this can depend on various factors, such as physical activity level of people, and it should be possible for building users to regulate the temperature. When the temperature is significantly higher or lower than the preferred temperature, people can become tired and inattentive. Relative humidity should be around

[2] https://living-future.org/red-list/

the range of 40–50 %. Dry air can irritate the skin and respiratory system, while mould and microbes are more common in the humid air. Suitable temperature and relative humidity can be maintained through specific building design approaches, heating, ventilation, and air conditioning systems, and use of certain materials – wood, for example, can regulate both temperature and humidity (Nousiainen et al., 2016).

2.3 ACOUSTIC PROPERTIES FOR WELLBEING

IN A NUTSHELL

Frequent exposure to noise can lead to cardiovascular disease and other stress-related consequences. Conversations of others are sources of unwanted sound that can be particularly distracting for people, especially if the speech is clear enough to be understood. This can be remedied by installing a background noise source that masks intelligible speech. Ideally, these should be sounds from nature, as they not only mask intelligible speech, but can also directly make people more relaxed and focused. In general, the acoustic design of a space should satisfy two conditions: people should be able to hear what they want to hear – most often each other during conversations, and they should be disturbed as little as possible by unwanted sounds. Spaces with acoustic conditions that support conversation should generally have a short reverberation time. Reverberation time is short in small rooms and can be further shortened by using more absorptive materials, such as carpets, and fewer reflective materials, such as brick. One way to protect people from noise is simply to lower the noise level or move people away from the source of noise. Another way is to install products for controlling noise, such as acoustic ceilings. More generally, comfortable acoustics can be achieved through specific construction approaches that consider materials and furnishings, as well as the size, shape, and layout of rooms.

2.3.1 Noise and wellbeing

The ability to listen has been fundamental to the evolution of the human species. Speech is one of the most important means of communication for people, and listening is one of the key abilities they use to examine and understand the environment around them. The importance of sound is already evident in infants, who are able to turn their heads toward a sound source (Altomonte et al., 2017). Soundscape – an environment of sound with emphasis on how it is perceived – therefore plays an important role in the way we experience our environment. Negative soundscapes – those that can be damaging to wellbeing and health of people – are especially important.

Noise – unwanted sound that is perceived as disruptive – can affect both physical and mental health and wellbeing. One obvious way in which noise can negatively affect people is by leading to hearing loss, which can be caused by sudden exposure to exceptionally intense sounds or, more commonly, it occurs gradually with prolonged exposure to loud sounds. However, most built environments

rarely reach the sound levels that can trigger hearing loss, so noise-induced hearing loss is a risk only in noisier places, such as airports (Cowan, 2016). A more common concern is the association between noise exposure and increased risk of cardiovascular disease, where noise leads to stress, and stress puts a strain on the cardiovascular system (van Kempen et al., 2002; Westman & Walters, 1981). Noise-induced stress also leads to a variety of other negative consequences, including worsened cognitive performance, lower mood, sleep disturbance, and reduced learning ability.

Conversations of others are sources of unwanted sound that can be particularly distracting for people, especially when the speech is clear enough to be understandable (Schlittmeier & Liebl, 2015). In some spaces, this issue is addressed by installing a source of background sound that masks intelligible speech. These masking sounds can be simple – for example, sounds resembling ventilation noise – but people prefer sounds emanating from nature, such as sounds of pouring water (Haapakangas et al., 2011). Natural soundscapes are especially promising because their effect can go beyond mere masking of unwanted sound and more directly lead to positive outcomes by making people more relaxed and focused (Ratcliffe, 2021). The soundscapes should ideally be relatively simple, not too loud, and their sources should be easily discernible, otherwise they may confuse or frighten certain people, particularly individuals with dementia.

It should be noted that the degree of annoyance with noise only partly depends on physical acoustic conditions, as several other factors play an important role, including the perceived control over the source of the sound, context and attitudes toward sound sources, and people's personality traits and mood. This opens up an opportunity to decrease the annoyance people feel in response to noise without changing the characteristics of the noise. One way to achieve that is to visually expose people to elements of nature, such as views of landscapes or indoor greenery, which can make them less disturbed by noise (Li et al., 2010).

Figure 4.2.4 Traffic is a problematic source of noise, especially in densely populated cities (Pexels)

2.3.2 Acoustic design for wellbeing

Acoustic design should fit the intended function of the space. Overall, there are two broad groups of potential issues that need to be considered when it comes to acoustic comfort: people need to be able to hear what they want to hear – most often each other during conversations, and they should be disturbed as little as possible by unwanted sound – noise. People should be able to easily understand speech without being bothered by background noise or reverberation – spaces with acoustic conditions supporting conversations should generally have a short reverberation time. Reverberation time is short in small rooms, and it can be further shortened by using more absorptive (softer) materials, such as carpets, curtains, and upholstery, and fewer reflective (harder) materials, such as brick, plaster, and concrete. Another option is to install specific commercially available products for controlling noise, such as acoustic ceilings and vertical screens and barriers. These are usually made of wood-based composite materials (e.g., chipboard), gypsum, polycarbonate, or glass, and they can be treated with paint or a layer of acoustic fabric. However, some reverberation is usually desirable – for example, it can help people hear better in larger spaces when they are located far from the sound source (Altomonte et al., 2017).

The design process for acoustic comfort needs to consider several important factors, including **1)** how sounds generated in a space propagate across the interior surfaces of that space, **2)** how sounds of one space can be heard in another, **3)** noise of mechanical devices, and **4)** how certain activities may require privacy (Grigoriou, 2019). Sources of noise can either be transmitted through the air, such as conversations or music, or they can be generated by impact, such as walking on the floor in high-heeled shoes. One way to protect people from noise is simply to change the noisy activities in a space, place the noise source far away from people, or separate noisy areas from people with buffers, such as lobbies. Another way to create comfortable acoustics is through specific construction approaches – materials and furnishings as well as the size, shape, and layout of the rooms should all be considered. It should be noted that the goals of good acoustic design may clash with other design goals; for example, design intended to improve lighting. Large spaces, for instance, can maximise the amount of natural light entering the interior, but they can also lead to higher transfer of unwanted sound and longer reverberation times. In such cases, it is important to carefully analyse the situation and find a solution that strikes a suitable balance between conflicting design goals.

REFERENCES

Altomonte, S., Rutherford, P., & Wilson, R. (2017). Indoor environmental quality: Lighting and acoustics. In Encyclopedia of Sustainable Technologies. Elsevier, 221-229. https://doi.org/10.1016/B978-0-12-409548-9.10196-4

Cowan, J. P. (2016). The effects of sound on people. Wiley.

Edwards, L., & Torcellini, P. (2002). Literature review of the effects of natural light on building occupants. National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy02osti/30769.pdf

Grigoriou, Elina. (2019). Wellbeing in interiors: Philosophy, design & value in practice. RIBA Publishing.

Haapakangas, A., Kankkunen, E., Hongisto, V., Virjonen, P., Oliva, D., & Keskinen, E. (2011). Effects of five speech masking sounds on performance and acoustic satisfaction. Implications for open-plan offices. Acta Acustica United with Acustica, 97(4), 641-655. https://doi.org/10.3813/AAA.918444

Joshi, S. (2008). The sick building syndrome. Indian Journal of Occupational and Environmental Medicine, 12(2), 61-64. https://doi.org/10.4103/0019-5278.43262

Kelly, F. J., & Fussell, J. C. (2019). Improving indoor air quality, health and performance within environments where people live, travel, learn and work. Atmospheric Environment, 200, 90-109. https://doi.org/10.1016/J.ATMOSENV.2018.11.058

Larson Electronics. (2019, April 19). Understanding Kelvin ranges in lighting and their best applications. https://www.larsonelectronics.com/blog/2019/04/19/led-lighting/understanding-kelvin-ranges-in-lighting-and-their-best-applications

Li, H. N., Chau, C. K., & Tang, S. K. (2010). Can surrounding greenery reduce noise annoyance at home? Science of The Total Environment, 408(20), 4376-4384. https://doi.org/10.1016/J.SCITOTENV.2010.06.025

Mahoney, S. (n.d.). Daylighting 101: Orientation. https://harkahq.com/harka-blog/2017/2/7/daylighting-101-orientation-sun-angles

Nousiainen, M., Lindroos, H., Heino, P., Valta, M., & Häkkinen, J. (2016). Restorative environment design. Kymenlaakso University of Applied Sciences publications.

Ratcliffe, E. (2021). Sound and soundscape in restorative natural environments: A narrative literature review. Frontiers in Psychology, 12, 1-8. https://doi.org/10.3389/fpsyg.2021.570563

Schlittmeier, S. J., & Liebl, A. (2015). The effects of intelligible irrelevant background speech in offices – cognitive disturbance, annoyance, and solutions. Facilities, 33(1/2), 61-75. https://doi.org/10.1108/F-05-2013-0036

Spengler, J. D., & Chen, Q. (2000). Indoor air quality factors in designing a healthy building. Annual Review of Energy and the Environment, 25, 567-600. https://doi.org/10.1146/annurev.energy.25.1.567

The Living Building Challenge (LBC). (n.d.). About the LBC Red List. https://living-future.org/lbc/red-list/

van Kempen, E. E. M. M., Kruize, H., Boshuizen, H. C., Ameling, C. B., Statsen, B. A. M., & de Hollander, A. E. M. (2002). The association between noise exposure and blood pressure and ischemic heart disease: a meta-analysis. Environmental Health Perspectives, 110(3), 307-317. https://doi.org/10.1289/EHP.02110307

Westman, J. C., & Walters, J. R. (1981). Noise and stress: a comprehensive approach. Environmental Health Perspectives, 41, 291-309. https://doi.org/10.1289/EHP.8141291

LIST OF PICTURES

Figure 4.2.1 Pexels. (2016). [Group of people inside building]. https://www.pexels.com/photo/group-of-people-inside-building-301930/

Figure 4.2.2 Larson Electronics. (2019). Understanding Kelvin ranges in lighting and their best applications. https://www.larsonelectronics.com/blog/2019/04/19/led-lighting/understanding-kelvin-ranges-in-lighting-and-their-best-applications

Figure 4.2.3 Pexels. (2016). [Landscape photography of factory]. https://www.pexels.com/photo/air-air-pollution-chimney-clouds-459728/

Figure 4.2.4 Pexels. (2016). [Aerial photography of cars on road intersection]. https://www.pexels.com/photo/aerial-photography-of-cars-on-road-intersection-186537/