AIR POLLUTION IN MEXICO CITY

A DESIGN APPROACH TO A WICKED PROBLEM

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AIR POLLUTION IN MEXICO CITY :
A DESIGN APPROACH TO A WICKED PROBLEM
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ABSTRACT

The topic of air pollution in Mexico City has been extensively researched. More than environmental, therefore, this research drew on the social aspects of air pollution. This project provides a different perspective, that of the citizens, the bottom-up. It delved into the environment as a social system. The research sought to understand how design can have an impact in societal problematics, those that are wicked problems. The results of participatory research methods indicate great potential in terms of the utilization of design in the broader sense to create social change. In short, the project discovered the requirements to effect social change and the way in which design should be applied in this regard, to assist in the change.

ACKNOWLEDGEMENTS

I am never really thankful out loud, so I will take this opportunity to do exactly that.

First of all, I want to thank my principal advisor Ian Clarke for his immense knowledge on research practices, for pushing me to deliver a well written paper with substantial information, for his knowledge and inspiring work.

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To all the people who collaborated, by taking pictures of the city. It is greatly appreciated.

I would like to dedicate this project to my beloved Mexico. Because I see great potential in my people.

Finally, I want to thank life for this opportunity which has made me wiser, more humble and has given me immense joy!

Graciela Guadarrama Baena, Toronto. Canada. 2016

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PREFACE

This MRP came about as I was wondering how I could make a difference in someone's life after completing this degree. As a Mexican citizen, I have grown up in a friendly environment, for the most part of my life. I grew up with enough to survive and thrive, I was lucky. Most of my fellow Mexicans aren't and that won't let me sleep at night. I was brought up in an atmosphere where social commitment was an important part of my everyday life. My father leads a think tank which develops projects for social development in rural areas of the country. We were always surrounded by inequality, we could experience that things are not always just, for that we, as the lucky ones, should help out in whatever we can. I love my country and I love my people. This is the reason why this MRP was about Mexico and a critical situation facing Mexican society in the 21st Century. Finally, the idea of having images as photographs taken by Mexican citizens was the symbolic meaning of this work being collaborative, participative and showing once again, that the input of one individual matters.

Image 1 : Panorama CDMX

INTRO DUCTION

"I discovered very quickly that criticism is a form of optimism, and that when you are silent about the shortcomings of your society, you're very pessimistic about that society. And it's only when you speak truthfully about it that you show your faith in that society."

- Carlos Fuentes

RATIONALE - OVERVIEW

This paper addressed the topic of air pollution from a design standpoint by touching on air pollution as an environmental matter and its relationship with social change, the former understood as a wicked problem. The first approach in regards to the idea of *wicked problem* was formulated by Rittel in the 60's where he states that every wicked problem is unique, *"a class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing"*[1] and which is further described in the paper "Wicked Problems in Design Thinking" by Buchanan (1992).

The objective of this research was to understand the importance as well as the influence of design in social problematics by addressing air pollution in Mexico City as a wicked problem, within the complex dynamics of a social system and the interaction among stakeholders. Through a literature review, several authors' perspectives were discussed describing the context in which the city lies in the 21st Century. The project performed, therefore, a review of both primary and secondary sources such as books, articles, papers, reports and blogs. Within the media explored were also documentaries, case studies and TED talks (non-profit devoted to spreading ideas, usually in the form of short, powerful talks)[61]. It was developed aiming to better understand the ecosystem and be able to identify gaps, by outlining the main issues of air pollution, what has been done to try to solve it and why it is such a complicated matter. Health effects on the population was identified as one of the most critical problems related to air pollution as well as its close relationship with global warming.

Moreover, a problem finding phase helped discover several factors which play an important role in the ability of Mexican society to effect change towards better air quality in the mega city. By investigating the use of design methods to understand and explore the problematic from the perspective of the citizens, the way in which design in the broader sense influences people's behaviour towards social change emerged. The problem of air pollution was then framed as an exploration towards an alternative approach to top-down initiatives. A bottom-up approach where societies' participation and collaboration are key elements. Finally, the research uncovered two main schemes contributing to social change in this context. Thereby, the importance of this research lied on the urgency of the matter and its intent to look into the potential of design towards social change.

CONTEXT - THE LANDSCAPE

According to the United Nations (UN), in the early 90's the atmosphere over Mexico City was considered to be among the most polluted on Earth[21]. Since then, air pollution has been of great concern and an important issue among stakeholders, from citizens to government, as well as the civil society including NGOs and other Institutions. Causes and consequences of air pollution in health, as well as global warming, are dire, thus ways to approach the issue have been plenty and result also quite complex.

Causes that contribute to air pollution are many and include urbanization, industrialization, transportation both private, public and freight, people's daily activities[13] and population growth. The latter being the primary force driving environmental problems. *"Among the most serious environmental problems in cities are air and water pollution, solid waste accumulation and disposal (including toxic and hazardous wastes) and noise"* [14]. One of the widely known reasons for the severity of the City's air quality is its geographic location. Mexico City, at an elevation of 2,240 meters above sea level has intense sunlight, which increases the levels of solar radiation. This, in turn, stimulates the formation of Ozone (O_3)[14]. The City is located in a Valley surrounded by mountains, which create a type of bowl shape. The mountains prevent the dissipation of the air, which consequently forms an enormous layer of trapped pollutants[6], such as Ozone a highly reactive gas and Carbon Monoxide (CO), a colorless, odorless, toxic gas produced by the combustion of hydrocarbons emitted from vehicles.

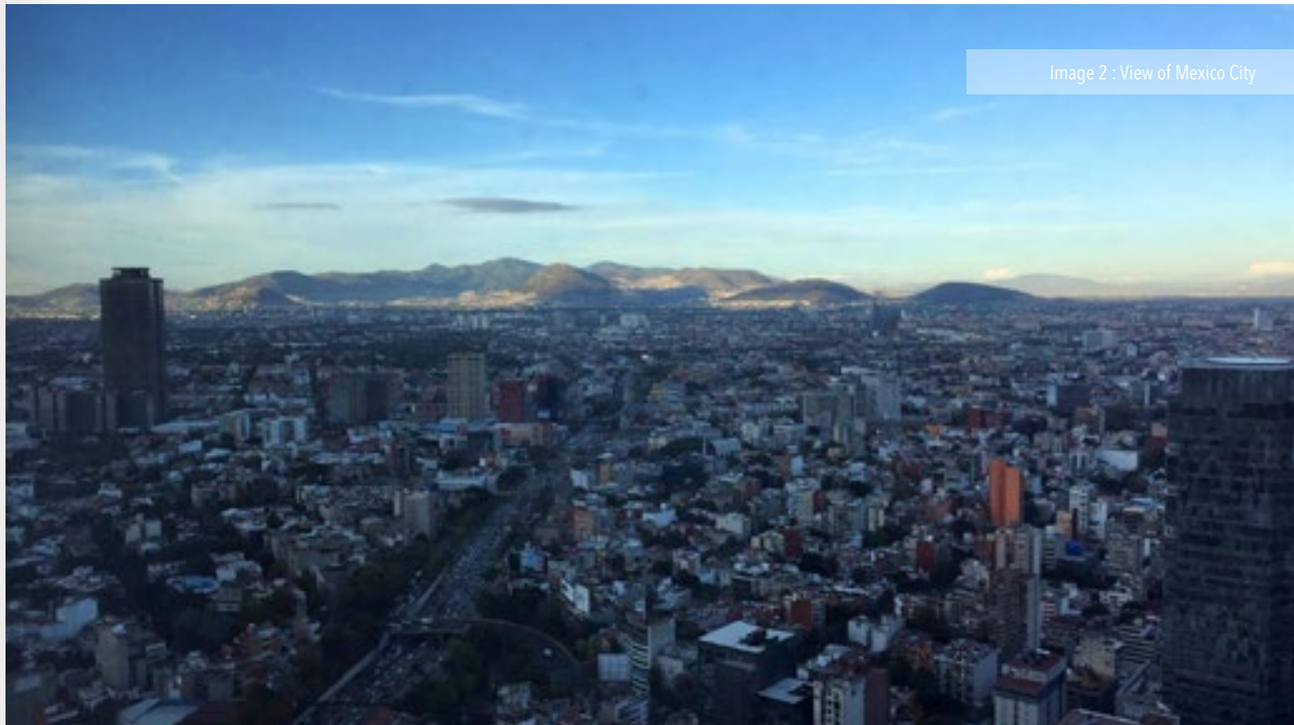


Image 2 : View of Mexico City

Another important pollutant is Nitrogen Dioxide (NO_2), which plays an important role in Ozone formation. The main sources of it are vehicles, industry and natural sources. Sulfur Dioxide (SO_2) is a third pollutant found in air, its main source is industrial activity such as the generation of electricity, extraction and processing of petroleum, manufacturing and petrochemicals.

Image 3 : MCMA Urbanization

Finally, Particulate Matter (PM) as the name says, are solid fine particles present in the air as a result of industrial, commercial, agricultural and household combustion[21]. Because the wind comes usually from the northeast, it blows pollution from the industrial areas towards the residential ones.

Adding to the above mentioned natural conditions, the increase in human population - above 20 million in 2016 and continuously growing[5] - and urban sprawl, plus insufficient mass transportation which encouraged private vehicle use, make air pollution in the City a critical and urgent matter[6]. At this point, it is important to clarify that Mexico City, whose territory now includes 16 delegations and 59 neighboring municipalities is known as Mexico City Metropolitan Area (MCMA). The latter is the acronym utilized by scientists and researchers and the one used throughout this document.

CONSEQUENCES & MANIFESTATIONS

The high levels of air pollution is a growing concern for Mexican population and go beyond the environment. Bad air quality in the MCMA manifest not only in poor visibility but also in respiratory discomfort and has several other consequences[14].

Mexico City ranks as one of the most polluted cities in the world according to several polls. Although, experts declare that it is not easy to find specific data, let alone compare cities because many don't even have monitoring systems in place and thus it makes the measurement inaccurate[49]. Regardless, the World Health Organization (WHO) states that 92% of the world population in 2014 was living in places where their own air quality guidelines levels were not met[50]. It also states, that more that 2 million people worldwide die every year from breathing the various particles present in outdoor air pollution[16]. Hence, Mexico City by being one of the most polluted cities in the world, the amount of people suffering from air pollution consequences is suggestively large. A specific figure can again, not be determined because measuring this type of data is not straightforward. However, according to the National Institute of Respiratory Diseases in Mexico, an estimated of 20,000 people die every year due to respiratory diseases[51]. The population at greatest risk to the exposure of pollutants are children less than 5 years old, elderly (65+ years) and people with heart and respiratory conditions[36].

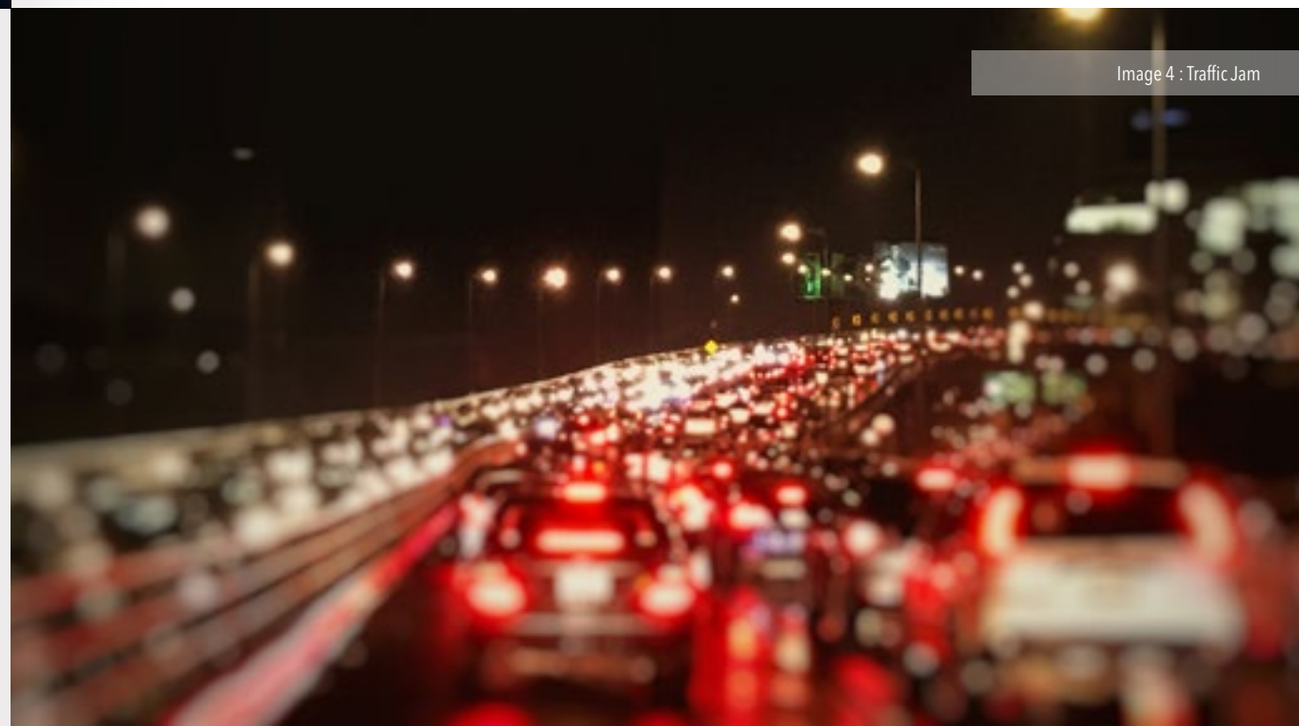


Image 4 : Traffic Jam

Image 5 : Downtown “Torre Latino”

Moreover, different pollutants have specific impacts on health. O_3, for example, due to its ability to oxidize, damages cells in the respiratory tract causing inflammation. Whereas PM penetrates directly the respiratory tract without being filtered, once those particles are inside and based on their size, accumulate in different parts. PM_{10} (diameter smaller than 10 micrometers) penetrate to the bronchial while $PM_{2.5}$ (diameter smaller than 2.5 micrometers) can make their way to the lungs. Health risks associated with the latter are much worse that those with the former[36]. Reports on the severity of air pollutants for public health are released often. A study published in 2016, by the Proceedings of the National Academy of Sciences (PNAS) in the USA, proves that nanoparticles of magnetite were detected in human brains coming from an external source entering the olfactory bulb. These particles are abundant in airborne PM pollution formed by combustion in urban areas. This study has been linked to brain damage and neurodegenerative diseases such as Alzheimer. Samples were taken from 37 human brain subjects who lived in Mexico City and Manchester, UK, the highest magnetite content was found in a 32-year-old Mexico City resident[22].

The relationship between outdoor air pollution and climate change is evident, pollutants in the air include greenhouse gasses. One of these gases is Carbon Dioxide (CO_2), which has been shown to be the main pollutant that is warming Earth. By trapping heat from the Sun in the Earth’s atmosphere, these gases cause global warming. Although living things such as human, plants and other animals emit CO_2 while breathing, it is considered to be a pollutant only when involved in the burning of fossil fuels such as gasoline and natural gas, these associated with cars, planes, power plants, and other human activities. Another important pollutant associated with climate change is sulfur dioxide (SO_2) which is a component of smog caused by industrial activities among other[39].

The National Inventory of greenhouse gases (GHG) released by the National Institute of Ecology and Climate Change INECC (acronym in Spanish for Instituto Nacional de Ecología y Cambio Climático) measures these emissions in different sectors; electricity generation, petroleum and gas, mobile sources of motor transport, industry and agriculture among other. In 2013, the electricity sector reported contributing a 19% of the total emissions of GHG at a national level. Whereas mobile sources of motor transport contributes 26.2%. In that same year, the petroleum and gas sector represented 12.1% of the emissions and finally, industry contributed 17.3% [46].

Image 6 : Stamps, vehicle inspection

INITIATIVES

The government has been continuously working to address the issue of air pollution since 1985. Extensive air quality management programmes have been developed and implemented. Initiatives have ranged from public policies to regulations in mobility, car ownership and public transportation as well as restrictions in other industries.

One of the first actions taken in terms of transportation was the vehicle inspection and maintenance program. Every six months, cars have to go through a series of inspections

Image 7 : Metrobus

to ensure low emissions (image 6). More demanding parameters are often required for higher emitting vehicles, this to incentivise and promote a proper maintenance and fleet turnover. All this after several new requirements in gasoline, such as the removal of lead and the implementation of mandatory catalytic converters in automobiles[38]. Another related initiative implemented in the 80's is the so-called *hoy no circula* (no driving day), which restricts the use of automobiles one day of the week based on the plate's number, low-emitting vehicles are exempted from the rule.

Furthermore, the *Metrobus* (image 7 and 8) implemented in 2005 is yet another important initiative towards the City's mobility and cleaner air. A prime road space was allocated to low-emission, high-capacity buses. The 6-line Bus-Rapid-Transit fleet was aimed to reduce emissions by replacing more than 1,200 old, polluting, unregulated buses with approximately 370 metrobuses[26]. This process involved complex negotiations with microbus operators[6].

Image 8 : Metrobus Station

A third relevant example in this same context is the bike share program *Ecobici* (image 9), a transportation service created for Mexico's City residents as well as tourists. Registered users are allowed to take a bike from any station and return it at another one in a span of 45 minutes, unlimited times. There is a one year, one week, three days or one-day subscription. In 2010, the system was implemented with 84 bike stations and 1,200 bikes. It has grown 400% in the last 6 years due to user's demand. In 2016, *Ecobici* has 452 bike stations and more than 6,000 bikes. Resulting in more than 100,000 users benefiting from this service inside a 35 km^2 area[25]. The newest program is PROAIRE 2011-2020, a very detailed participatory planning document, which relates and integrates urban, transportation, economic and social variables and processes, with those which generate critical, toxic and greenhouse pollutants. It highlights health as the critical factor to address and proposes eight strategies:

1. Expansion and strengthening of health protection
2. Structural reduction of energy consumption
3. Quality and energy efficiency in all sources

Image 9 : Ecobici Station

4. Mobility and regulation of energy consumption of the vehicle fleet
5. Technological change and emission control
6. Environmental education, culture of sustainability and citizen participation
7. Management of green areas, reforestation and urban naturalization
8. Institutional strengthening and scientific research[48]

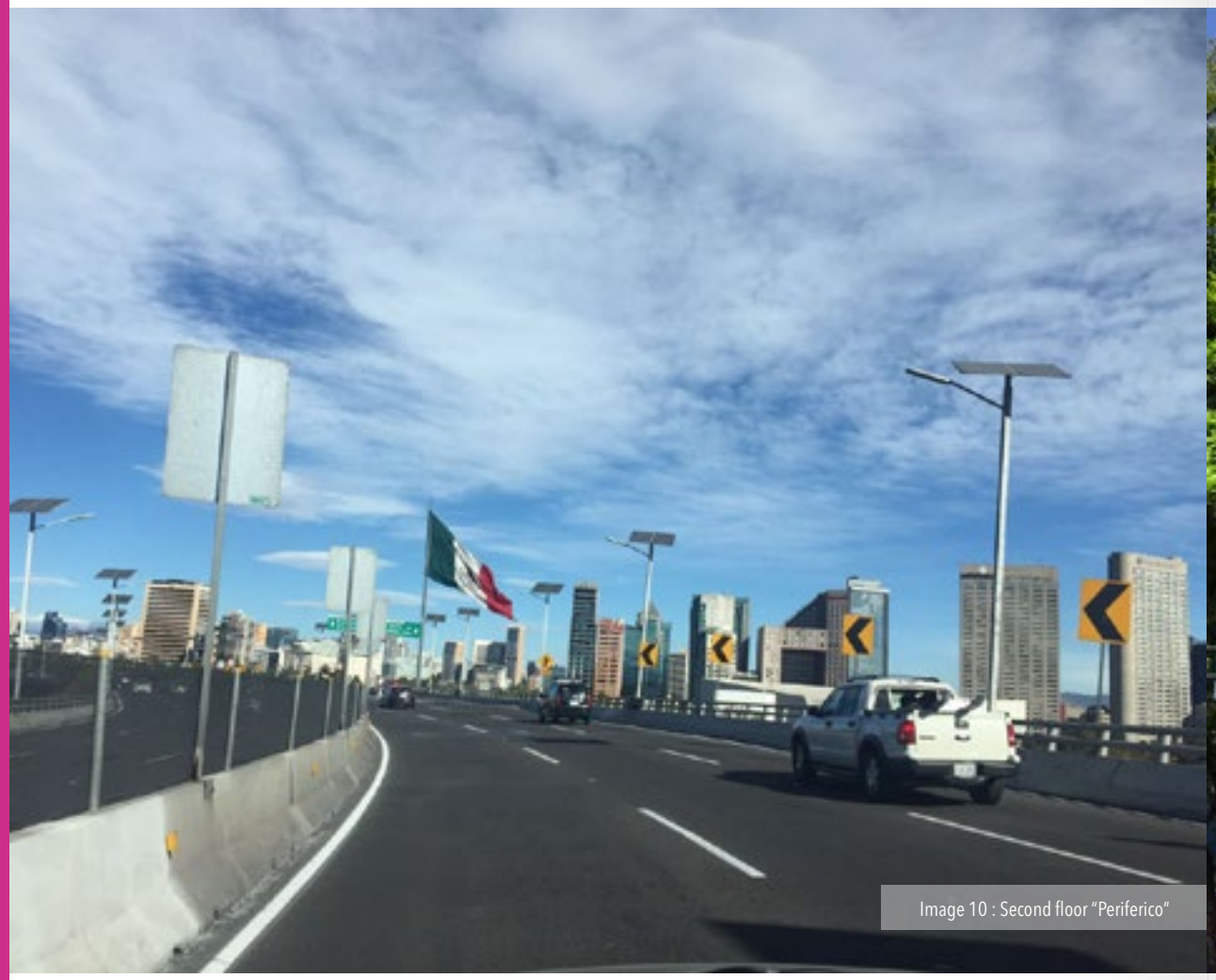


Image 10 : Second floor "Periferico"

On a similar note, regulations in other industries required the substitution of fuel oil in power plants with natural gas and the reformulation of liquefied petroleum gas used for heating and cooking, to mention just a few[38].

However, scientists from the *Centro Mario Molina* - a non-governmental association whose purpose is to provide insights and solutions to environmental problems in the Country, especially air pollution- suggest that the implementation of these programs in an isolated

manner will not resolve the problem of air pollution in the MCMA. There is a latent need of an integrated assessment to guarantee the well-being and health of the population[24]. In this respect, the use of public transport utilized by approximately 75% of the population is a determining factor, which is again not being properly and timely addressed by the government[24]. "*In order to decrease the polluting emissions and maintain the recommended national and international levels, it is necessary to improve and extend public transportation, people's mobility and the quality of fuels as urban developments that privileges pedestrians and clean transportation.*" declared by scientists from the CMM.

Image 11 : Downtown Reforma

Image 12 : Public transport

Image 13: Daily traffic spot

Image 14: Downtown "Madero"

PROBLEM FINDING

The context in which Mexico City lies at the moment regarding air pollution is critical. Despite the efforts, regulations and initiatives described earlier, there have been few improvements in overall air quality since the 70's, which leaves room for interpretation[14]. As presented, substantial challenges remain today. In 2016, March the 17th, after approximately 14 years without formally declaring an environmental contingency, MCMA faced Phase 1. Bad air quality continued for the next few months with fluctuations. The following images illustrate and compare the current state of pollution. Both were taken from the same spot, one year later. Image 15 was taken April 2015, whereas image 16 was taken May 2016.

Phase 1 of environmental contingency, mentioned earlier, means "bad air quality", a third level out of 5 as illustrated by table 1, surpassing 100 IMECAS (acronym in Spanish for Índice Metropolitano de Calidad del Aire), the Mexican reference for air quality index, based on international standards and measurements. The latter was reported in the bulletin released by the Department of Environment SEDEMA (acronym in Spanish for Secretaría del Medio Ambiente) on March 2016[11].

When contingency like this happens, SEDEMA and the Department of Mobility SEMOVI (acronym in Spanish for Secretaría de Movilidad) incorporate a restriction for the circulation of automobiles. It is called "double no driving day". This means that besides the regular "no driving day", a car owner can't drive her/his car one more day of the week[18].

CATEGORY	RANGE	MESSAGE	MEANING	RECOMMENDATIONS
GOOD	0-50	NO RISK	Air quality is considered satisfactory, air pollution poses little or no risk	All outdoor activities are OK
MODERATE	51-100	ACCEPTABLE	Air quiality is acceptable, however, some pollutants may affect unusually sensitive groups	Extremely sensitive groups should reduce exertion outside
BAD	101-150	UNHEALTHY FOR SENSITIVE GROUPS	Sensitive groups may experience health effects The general public is not likely to be affected	Sensitive groups should reduce prolonged exertion outside
VERY BAD	151-200	UNHEALTHY	Everyone may begin to experience health effects Sensitive groups may experience more serious effects	All groups should reduce prolonged exertion outside
EXTREMELY BAD	> 200	VERY UNHEALTHY	Health warnings of emergency conditions. Everyone is more likely to be affected	Avoid all outdoor activities

Table 1: IMECAS

WITHIN THE SOCIAL SYSTEM

The above mentioned environmental conditions, plus the described initiatives and restrictions, create great discomfort among inhabitants of the MCMA. Because of them, people struggle to make their way around it. Added to that, breathing the polluted air surrounding them is not easy. Thus, the topic of air pollution becomes a social problem as much as an ecological one. In order to understand the social system, then, it was necessary to comprehend the relationship between the aforementioned and the social dynamics in the country; identify the different factors in play. Therefore, while trying to understand the context of air pollution within Mexican society, two very complex phenomena arose. So, while questioning what is that which affects the social dynamics of the population; corruption and income inequality came to the surface. These two are factors that play an important role and shape considerably the general sentiment of the population, their behaviour and actions and in turn, the interaction between citizens and government, which is required for this system to work properly.

Image 15 : Mexico City, clean air

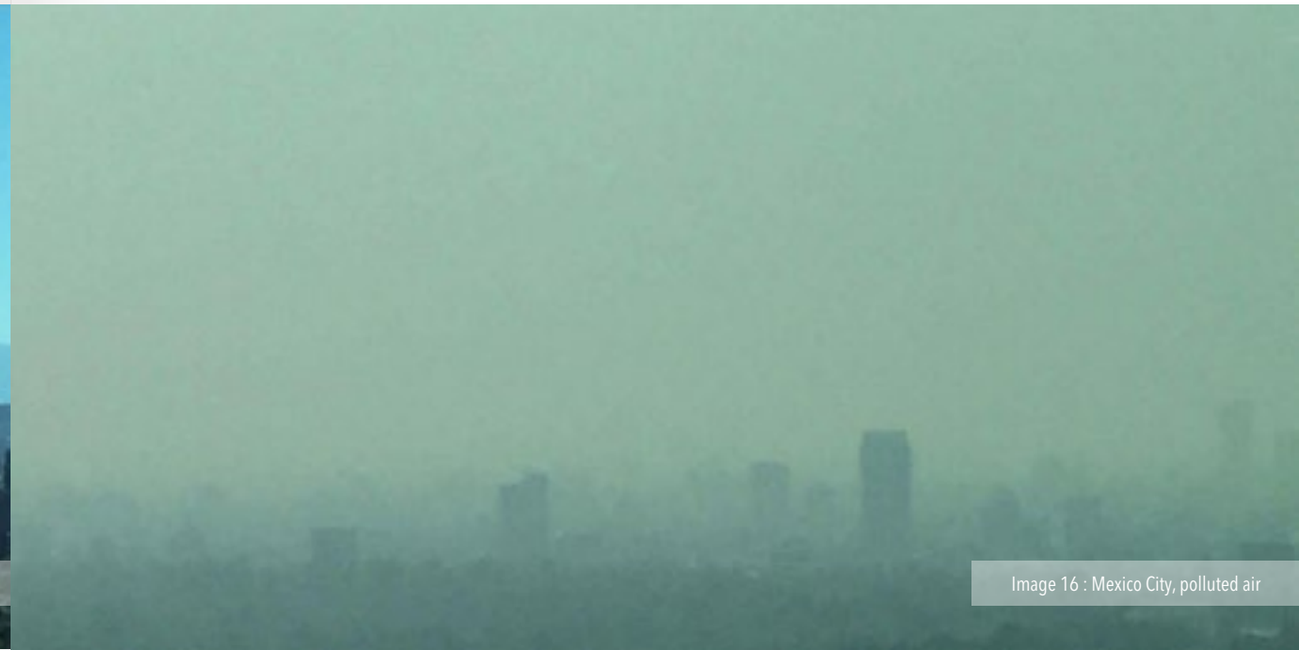


Image 16 : Mexico City, polluted air

Moreover, while visualizing the ecosystem as a whole, the subject of innovation in terms of technology and design emerged as additional matters that determine the success or failure of initiatives such as the ones described earlier, and solution-driven actions taken by decision-makers.

Corruption

Why is it's important to study the phenomenon of corruption? - Corruption understood in this context as [the abuse of public power for private benefit], the definition from *Transparencia Internacional,* an anti-corruption coalition[43]. Why is corruption relevant and associated with air quality?

The Mexican Institute for Competitiveness IMCO (acronym in Spanish for Instituto Mexicano para la Competitividad) and the Centre for Economic Research and Teaching CIDE (acronym in Spanish for Centro de Investigación y Docencia Económicas) along with Dr. Maria Amparo Casar, Ph.D. from Cambridge University and a specialist in issues of Mexican politics and corruption, studied the subject in great detail. Among the reasons stated in the paper is the effect corruption has on national sentiment, mood, on legitimacy and credibility towards the State and their representatives. Also on the whole concept of democracy, the economic performance and the well- being of Mexican families[40].

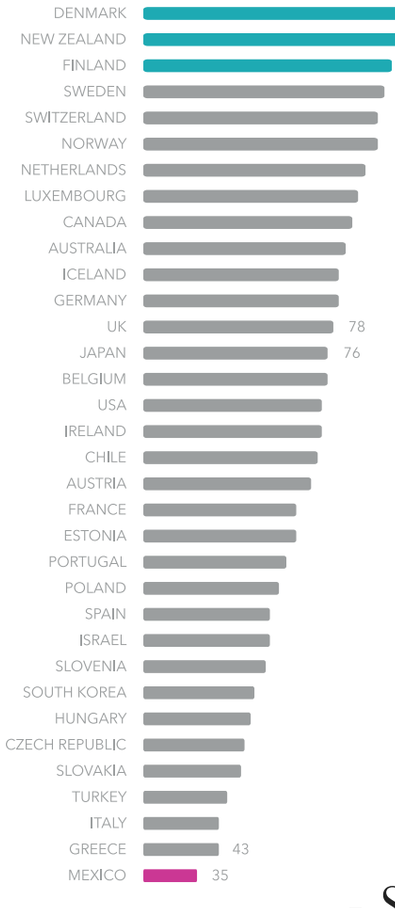


Table 2: Corruption ranking

O who is more to blame:
He who sins for pay -
Or he who pays for sin?

- Sor Juana Inés de la Cruz

Corruption is measured in IPC (acronym in Spanish for Índice de percepción de la corrupción), perception of corruption index by a scale from 0 (perception of very corrupt) to 100 (absence in perception of corruption). As illustrated by table 2, out of 100, Mexico ranked 35 in 2014 and is number 103 out of 175 countries. This data matches numbers from the World Bank, where Mexico has a score of 38 (100) in their indicator on corruption control and is number 127, one of the most corrupt countries in the world[42].

As expressed by Casar (2015) in this paper, *"corruption is without a doubt a multifactorial phenomenon".*[1]* Some factors explored by literature found causes in history, religion and ethnolinguistic as well as natural resources. It has also been correlated with the level of economic development, the degree in which the State intervenes in the national economy and the legal system.

Another frequently posed hypothesis stated in the report is that corruption is a problem of education, therefore countries with lower educational levels tend to have higher corruption levels. By observing the correlation between IPC and the Programme for International Student Assessment (PISA), a worldwide study by the Organisation for Economic Co-operation and Development (OECD) shown in table 3, students below average scored 47 in IPC, that means that they perceive more corruption than the more educated above average students with a score of 72, the previous statement is, thereby, a possibility.

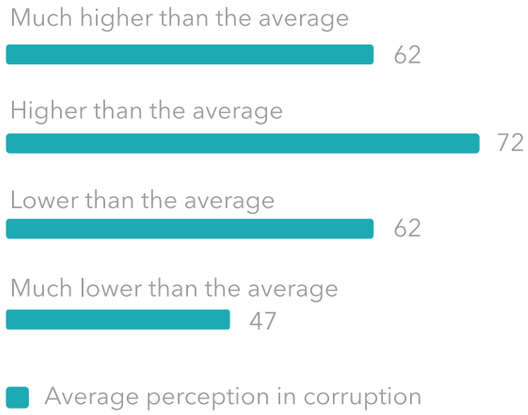


Table 3: Relationship between education and corruption

Moreover, it has also been raised that the higher the levels of corruption, the greater the discontent with democracy. The basis behind the latter is that perception in illegal practices inside the government generates mistrust in institutions and authorities and consequently a low appreciation and discontent with the form of government. However, while analyzing close circles like family, friends, neighbours or work relationships, 76% of Mexicans don't consider them corrupt. For public opinion, corruption's fault is politicians and wealthy business people, whereas citizens are only victims. For an act of corruption to happen, mentions Casar, whatever that may be, there is a need of two equally responsible parts. This interesting point touches on a concept of great importance throughout this research; **agency**. Term described later in more detail and understood in this context as the responsibility and liability to act on something.

[1]*All quotes of Dr. Maria Amparo Casar are Graciela Guadarrama's translations unless stated otherwise.

Inequality

As to the factor of income inequality and why it is even relevant to the problem at hand, Scanlon (2014), Alford Professor at Harvard University, poses an interesting point on the effects of inequality in a broader level, an abstract is relevant in this particular context. "*Economic inequality can undermine the fairness of political institutions. If those who hold political offices must depend on large contributions for their campaigns, they will be more responsive to the interests and demands of wealthy contributors, and those who are not rich will not be fairly represented*"(47).

In Mexico, Dr. Gerardo Esquivel, Ph.D. in economics from Harvard University and Oxfam Mexico released a report on income inequality in 2015. Although measuring inequality is not a straightforward task, there are available estimates. In this report, the Standardized World Income Inequality Database (SWIDD) states that Mexico is part of the 25% of the countries with the higher levels of inequality in the world(41). Moreover, the *2014 Global Wealth Report* points out that the 10% richest concentrate 64.4% of the total wealth of the country. However, these numbers can't reflect the accurate state of the total income distribution in Mexico, because polls in which these estimates are based on, fail in capturing the total income of the people in the highest levels.

Image 17 : Inequality

25%

This due to public policies and laws which reflect the economic power of certain sectors of the population, by allowing them to fail on filing their income and taxes, for example. While consequently benefiting only a few, this accentuates inequality in the country, which, in turn, has a strong correlation with the phenomenon of corruption and mistrust in the system, described in previous paragraphs.

Moreover, while analysing income inequality and its relation to social change, a question of how much change can people effect, arose. The idea of **ability to change** is illustrated here, as "purchasing power". This concept is directly related to the term from economics called "cost-benefit analysis", which purpose is to convert all costs and benefits into a unit of measurement; money. This as a way to translate non-market values – such as the value of cleaner air in this case – into monetary terms to better understand the valuation. This sets the stage towards how much people are willing to *pay* for environmental quality, however, it demonstrates again, the way inequality influences the power of purchase and shows how, in the words of Boyce (2007) *"…the needs and desires of some people count more than the needs and desires of others – not necessarily because their desire for clean air or water is any stronger, but because they wield more purchasing power to back up their preferences…behind differences in willingness to pay lie differences in ability to pay…"*(53)

On this same note, Sunita Narain, General Director of the Centre for Science and Environment (CSE) in India, associates inequality with environmental degradation. She argues that a distinction must be made between emissions created by the poor as a result of survival needs and those the rich create as a consequence of luxurious lifestyles. In her own words, *"… the 'survival' emissions of poor people with no alternative but to walk long distances to collect firewood, sweep the forest floor for leaves and twigs, and do back-breaking work to collect and dry cow-dung, all for some 'oil' to cook their food, and the 'luxury' emissions of those who drive to work and live in air-conditioned comfort."* (54) Narain's idea is tightly related to the described situation in Mexico City. Because of the need of low-income citizens to survive the day, their ability to change is hindered. The possibility of clean transportation, for example, is limited and thus, their activities tend to be more damaging and polluting.

Innovation

In terms of innovation, on the other hand, a gap was also identified. The translation between the technological aspects of described initiatives, proposals and feasible, tangible solutions. It seems that every innovation continues to create a new set of problems when trying to fix the one, over and over again[2]. The invention of the automobile was once fixing the excess of horses on the street. Today, the excess of cars on the streets has to be fixed in order to be able to breathe safely. To exemplify this point; the local initiative "no driving day" mentioned earlier is pushing more affluent people to buy a second car, either new or used, for those days theirs will not circulate. What this causes is instead, an increase in the number of cars in the MCMA[26]. Technology by itself doesn't seem to work because solutions usually do not consider human factors or, the whole social system. An abstract from *Bottom-Up Solutions to Mitigating Climate Change* by Seddon & Ramanathan (2013) highlights the latter. *"Many of the emissions are produced by processes that are deeply embedded in local socio-economic contexts. Unraveling these processes to identify cost-effective solutions that people actually want to adopt requires comprehensive understanding of not just the technology but the broader ecosystem that reinforces its use"*[33]. This idea alludes also to the ability to change. The difference between wanting to engage in change and being able to or have the power of doing so. These are concepts that had come up often throughout the research, concepts which will be discussed in more detail in further sections and appear again as they are of great importance in the whole argument.

The presented context suggests, therefore, that top-down initiatives to combat air pollution in MCMA have not been sufficient[13], they have failed in addressing the problem as it is a wicked problem[1]. Stakeholders as part of the social system are in constant interaction and yet they fail to communicate appropriately. Mexico's unequal society[41] with low levels of education compared to other OECD countries[45] plus a corrupt environment[40] create a gap in information transfer. To illustrate the preceding, one recent and relevant example is the *Via Verde* depicted in image 18. A private initiative, a project to transform the columns of the main road in the City into vertical gardens to increase the amount of green areas required per citizen[28]; a project supported by both the public sector and the local government. The initiative created great controversy, due to the point raised earlier about mistrust among stakeholders, adding to the gap in the understanding of innovation and the required technology to be implemented. To conclude this thought, Gabriela Gómez-Mont from Laboratorio para la Ciudad argues the following. *"It is clear that in Mexico we are caught in an interesting paradox: There is a growing mistrust of institutions and politics, and at the same time there is growing desire on behalf of citizens to be part of the way a city is and how it evolves."*[34]

Image 18 : Vía Verde

Image 19 : Student protest

DESIGN & SOCIAL CHANGE

It is here, where the word design comes into play, the term "design" in this paper, and throughout the project is being used in the broader sense as a practice, a tool, a method, a mindset, a process, an activity and design as a means. Thereby, the evolution of design and its various applicabilities, which are relevant to this paper and this particular situation are described in the next few paragraphs. Also, the use of social change in this project is defined and described taking into account its correlation with design.

Throughout several authors' theories, descriptions and ways to apply design, an agreement has been made about the fact that design is outgrowing itself. Design is every day less concerned with aesthetics and tangible outcomes and focusing more on social dynamics and complex problematics. Buchanan (1992), for example, describes **design** as an integrative discipline due to the changes it's going through as it weaves together science, technology and the liberal arts. He draws on the influence of design in everyday life, by *conceiving* it as an activity more than a noun, applicable towards both tangible and intangible. He describes how design is being utilized in four particular, interconnected areas: (symbolic and visual communications, material objects, activities and organized services, complex systems as environments for living, working, playing, and learning). Finally, he introduces in this context the term *indeterminacy*, by explaining that the wicked problems approach introduced in previous paragraphs, suggest that there is indeterminacy in all design problems, where *"indeterminacy implies that there are no definitive conditions or limits to design problems"*. He justifies this statement by arguing that design has no special subject matter of its own, the subject matter of design is universal in scope, because it may be applied to any area of human experience. Furthermore, these two definitions or descriptions of design capture the latter. *"A goal-directed problem-solving activity"* Archer (1965). *"A creative activity, it involves bringing into being something new and useful that has not existed previously."* Reswick (1965) p. 77[57].

Design is changing

The word design in itself is changing, the meaning of it as well as the objective of designing. As mentioned before, traditionally, designers focused on the look and functionality of products, later on, the focused was on intangible services and nowadays its intent lies on creating whole new systems to deliver those products and services[59]. More recently, design has been tackling complex problems, those that involve business models and alternative ways to create value, as well as other social problematics. From designing strategies for businesses in order

to embrace more innovative processes to nonprofits aiming to develop better solutions to those social problems. Design, therefore, goes through traditional boundaries across many sectors. It is in this sense that the term **Design Thinking** arises[59], to use design as a method to approach a specific problem, whatever that may be. The main differentiation between design and design thinking lies in *"the way designers approach problem-solving."* What this means is the way a designer connects with people as users of the product, service or the subject whose problem has to be solved, from their own perspective. So that, experiences are created through the use of empathy, through a deep understanding of human needs, this is what is called human-centered design[52].

Moreover, the term design thinking is described by Brown (2009) in great detail in his book "Change by Design" and it's also the basis of the methodology utilized at IDEO, a recognized design and innovation consultancy. He argues that *"design thinking as a framework can be applied to problems facing business and society today, but most importantly, design thinking is making us look not just to new ways of solving problems but new problems to solve"*[52]. Also, he affirms design is *"a process especially suited to divergent thinking—the exploration of new choices and alternative solutions."* [55]. Design thinking tools have been developed to tackle social issues based on innovation in technology and robust analysis, it has, therefore, the potential to create disruptive solutions that meet the needs of people in entirely new ways. Those large and diverse social challenges that society faces today, from climate change and everything involved in it, to air pollution, food scarcity, energy supplies, clean water and other health related issues. Brown (2011) emphasizes that it is now when it makes sense to use everything "in the toolbox" to come up with solutions that improve the current state of the world for a better future.

Furthermore, Jones (1992) draws on design as a **changemaker**, he argues that after a design, whether successful or not, the world cannot stay the same. "*All one can say with certainty is that society, or the world, is not the same as it was before the new design appeared. The new design has, if successful, changed the situation in just the way that the sponsor hoped it would. If the design is unsuccessful (which in many cases is more likely) the final effect may be far from the sponsor's hopes and the designer's predictions but it is still a change of one kind or another.*"(p.78)[58]

On a similar note, the Center for Social Innovation at the Stanford Graduate School of Business launched the Stanford Social Innovation Review in 2013. After various revisions and discussions, they defined **Social innovation** as "*a novel solution to a social problem that is more effective, efficient, sustainable, or just*

than existing solutions and for which the value created accrues primarily to society as a whole rather than private individuals. A social innovation can be a product, production process, or technology (much like innovation in general), but it can also be a principle, an idea, a piece of legislation, a social movement, an intervention, or some combination of them."[60] Experts, therefore agree upon social innovation as the best construct for understanding and producing lasting **social change**[60]. The innovation in itself is what creates social value, the set of new ideas that address unmet needs. When using the term social change in this paper, the meaning refers to any significant alteration - meaning changes yielding profound social consequences - over time in behavior patterns and cultural values and norms, according to sociologists.

Social change

At this point it is important to understand how change comes about, thus, a series of theories were examined. An interesting view on social change is that of Dwyer & Minnegal (2010). In their paper "Theorizing social change" they analyse different theories of change and make two first distinctions labeled adaptation and transformation. Changes qualify as **adaptation** when *"quantitative and context-dependent shifts occur in the expression of particular variables without substantive alteration to functional relationships between those variables and the contexts within which they are expressed"*, whereas changes qualify as **transformation** *"when relationships between variables alter to elicit qualitative changes in the structure of the ensemble as a whole."*Dwyer & Minnegal (2010) p.4[74]. Adaptative change alternates the existing variants while transformative incorporates new ones. In adaptative change the form is the object as opposed to being the subject of change in the transformative change[74]. In this paper, they also correlate the previous discussion with the idea of first and second order change described by Watzlawick et al. (1974) in which the first-order change correspond to the adaptation. First-order change examines changes in knowledge, attitudes and practices which *"occurs within a given system which itself remains unchanged."* While the second-order change entails alterations to the system itself leading to the normalization of it. *"The spread of second-order changes occurs over a period of time and ultimately leads to a* ***routinization*** *of new values, norms and actions in a society creating a climate of social support and* ***collective efficacy*** *for audience members to pursue agreed actions to achieve collective goals."*Watzlawick et al. (1974) p.10[73]. Finally, Dwyer & Minnegal (2010) argue about joining these terms and creating instead the new **agents of change**, in which those who are the objects of change are also the subjects of change[74]. In this sense, the notion of agency is often discussed in the domain of social change. Hence, a few definitions follow: agency is the *"intentional causal intervention in the world"* Ratner (2000) p.413 [77]. Moreover, *"it is the capacity, within the context of existing systems of relations, to act on the world rather than merely in the world"* Dwyer & Minnegal (2007) p.8 [74].

Going forward, an important part of creating social change is to understand what motivates humans to engage in the change. Some theories of change talk about motivations and desires. An interesting point of view in the domain of social psychology is the **Social Cognitive theory** coined by Bandura (1989). He explains two modes of learning: the first one, through the direct experience of rewarding and punishing. The other one through the power of social modeling. Social modeling, promotes personal and social change in which the *"motivational function operates through the depicted benefits and detriments of modeled courses of action"* [75]. This by seeing others gain their desired outcomes, their actions serving as positive motivation for oneself. Similarly, punishing outcomes can create negative outcome expectancies working as disincentives for that specific course of action. Thus, the behaviour of others serves as social prompts to activate channel and support behaviour[75]. Moreover, Bandura (1997) developed two concepts which are the foundation of human motivation and accomplishment: self-efficacy and collective efficacy. The latter mentioned in previous paragraphs in relation to agency. On the one hand, *"perceived self-efficacy is defined as people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives, this determine how people feel, think, motivate themselves and behave."* On the other hand, collective efficacy extends the concept of individual agency to a collective one, a sense of improvement through united effort[76].

An example to illustrate this is the use of media towards social change. "*Media representation gain influence because people's social constructions of reality depend heavily on what they see, hear and read rather than on what they experience directly"* Bandura (2004). In the early 80's the Mexican government launched a national self-instruction program to reduce illiteracy, in which skilled people organized self-study groups to teach each other how to read. The program was not quite appealing to the citizens, therefore, Miguel Sabido developed a television serial designed to promote enrollment in the national literacy program. The program called, **Ven Conmigo** (Come with Me) portrayed collective mastery of competencies and the accompanying benefits. Also, they uses epilogues to facilitate the message to enroll in the literacy program. Millions of viewers watched the serial drama, out of those, about 25,000 people went to the distribution center in downtown Mexico to get their reading material after the first epilogue was aired. A year after, the enrollment went up to 900,000[76]. The program narrative, actors, etc. helped persuade and provide motivation to the audience to pursue this education program. The basis of this, as mentioned earlier, is showing people similar to themselves mastering those skills, so that they can relate to them and believe they can do it too[76].

The role of design in social change

The aforementioned theories of change describe the way in which change happens in an individual and a group or a community. In these next few paragraphs the role of design in creating that social change is discussed. Lockton (2015) argues that the way humans understand things affects the way they behave, therefore, design can help with that in lots of different ways and in many different contexts. He says then, that "*… our role as design researchers is to try to understand how the public is understanding the world and how we might use design to improve or change that understanding.*"[56]

In this same vein, some examples in which design has been used to create social change can be taken from simple things like the initiative "The Fun theory"[62]. It creates various installations and interventions with the purpose of changing people's behaviour for the better. A bin made a sound every time trash had been thrown, for example. Also, the design of piano stairs in the subway of Stockholm to encourage people to use them instead of the escalator[68] and which has spread across the globe. Image 20 shows the subway piano stairs located in the station Polanco in Mexico City. To dancing traffic lights in Lisbon, to prevent people from crossing the road and wait for the green light instead[67]. Moreover, policies presented in previous sections that encourage the use of bicycles by closing the roads to motor vehicles in Mexico City, is also a good example of design utilized to change the behaviour of the population. On the same note, design has been used to solve problems in the health industry as well, here, an example from IDEO where hospitals struggled with kids moving too much during MRIs. By redesigning the exterior of the scary machine as a castle or a boat to provide a friendlier environment for kids[64], the problem was fixed. But design can also influence social change in more complex dynamics like organizational change and the relationship between nurses and doctors, the way they communicate can be enhanced by understanding both sides and foster empathy. Some other uses of design as social innovations are, for example, microfinance, which provides financial services to low-income clients. Finally, UN's Peacekeeper is a portal defined by the UN as *"a unique and dynamic instrument developed by the Organization as a way to help countries torn by conflict create the conditions for lasting peace"*, which monitors and observes peace in conflict areas.[63]

The range of design's applicability is as broad as its definition. In terms of environmental sustainability, an example of social innovation worth mentioning in this section is the non-profit Bioneers[65] who is dedicated to restoring people and the planet. It works as a hub for scientific innovators to create solutions towards environmental and social challenges. They host an annual conference in which innovator from around the world

Image 20 : Metro Polanco

present their breakthrough solutions. Also, a good example of participatory use of design is Project Neutral[66], in Canada. This platform allows people to measure their own carbon footprint and compare it to other households. By creating cultural awareness, an average of 20% of the emissions per household have decreased in three years, according to surveys performed by the Organization. This is, then, the result of connecting individuals to real life actions. Finally, the innovation report found in the deliverable section, also outlines and describes good as well as bad practices in which design has been utilized towards combating air pollution.

To conclude, this problem finding section has given a thorough description of the context of air pollution in the MCMA area, which is, without doubt, a wicked problem. Hence, the focus of design towards social change in this project.

PROBLEM FRAMING

Given the suggested problematic, air pollution in MCMA should be understood as a systemic problem. This project was therefore limited in scale and scope, it aimed to explore the issue from a community-based perspective. Hence, the need to address people's daily activities as part of the problem but also as part of the solution, by looking into people's perceptions of the problem as well as emerging innovations arising from it.

Whereas most top-down initiatives - those by the government - propose long-term solutions, an unmet need to act on shorter ones is notable. Consequently, this research looked at the problem with a different lens, with the intention to provide a new perspective. With access to new insights coming from the people that contributed to creating it, but also those who may be able to undertake it. This is where an alternative, a bottom-up approach becomes an essential part of the dilemma, by looking at the impact of a broader spectrum of contributors; the civil society, those involving social entrepreneurs, NGOs, local researchers and the people who are producing pollution themselves[33]. MCMA inhabitants have the right and the obligation to do whatever they can about the air surrounding them. Whether that is becoming more aware of it, mitigating the issue, or maybe even developing their own solutions. Hereof, a very famous quote by 1995 Nobel Prize in chemistry, Dr. Mario Molina is relevant: *"Los científicos pueden plantear los problemas que afectarán al medio ambiente con base en la evidencia disponible, pero su solución no es responsabilidad de los científicos, es de toda la sociedad"*. The translation from the original in Spanish follows. [Scientists can pose problems that affect the environment based on available evidence, but its solution is not the responsibility of scientists, it is of the whole society.][2]*

To illustrate the above-mentioned, several examples are described in a thorough publication "The Pursuit of legible policy. Agency and Participation in the Complex Systems of the Contemporary Megalopolis" [34]. A project which showcases initiatives in Mexico City and London as good practices in which citizens' input and their participation matter and change the ecosystem. The Article "Legible policy in the participatory City", describes how policies in the context of transportation and mobility, can be more legible. An element of policy as an example that encourages cycling is the closure of Paseo de la Reforma (image 21), one of the main roads in downtown Mexico City, on Sundays to all motor traffic (image 22). This, in the words of Lynch (2016) is a good case for "*participation through greater legibility.*"(p. 47)[34]

[2]*All quotes of Dr. Mario Molina are Graciela Guadarrama's translations unless stated otherwise.

Image 21 : Sunday "Cyclothon"

Image 22 : Paseo de la Reforma

Moreover, Ferrarello (2016) in "The ecology of legible urban space"[34], poses the question: *Can inspirational and experiential policies facilitate citizens' engagement and enable new forms of behaviours or behaviour change?* (p.77) To which another relevant example might bring it closer to the answer. *Mapatón* is a public campaign where a group of citizens participated in an android-app game to map their paths and routes daily, creating thereby, the first informal transport network with all his complexity. This would not have been possible without having the people involved in the process itself. It is important to accentuate here again, how the appropriate innovation and technology play an important role in these processes. An abstract by Lynch (2016) encapsulated the former. "*The citizens of a city are its greatest resource. The collective knowledge, the common will, the innovative capacity and the force for change that lies in the population of a city is largely underutilised…*" (p. 46)[34]

Since air pollution is not only an environmental but a social problem, involving citizens is crucial to achieving that which may eventually lead to social change. To conclude this section and in order to develop the appropriate research, a target population was identified. This project was developed by looking at the general population affected by air pollution in the area. MCMA inhabitants, who are non-experts in the field of air pollution or ecology. Within the population described, there are multiple possible audiences to whom this kind of project might serve; "engaged and active" citizens, "engaged and passive", "disengaged and willing" and "disengaged and critical". However, the focus of this research lies on mainly two; "**engaged and passive**" and "**disengaged and willing**". These were the ones utilized for the development of the outcomes and deliverables. It is relevant to note here, that a broader audience was part of the limitations presented at the end of this section.

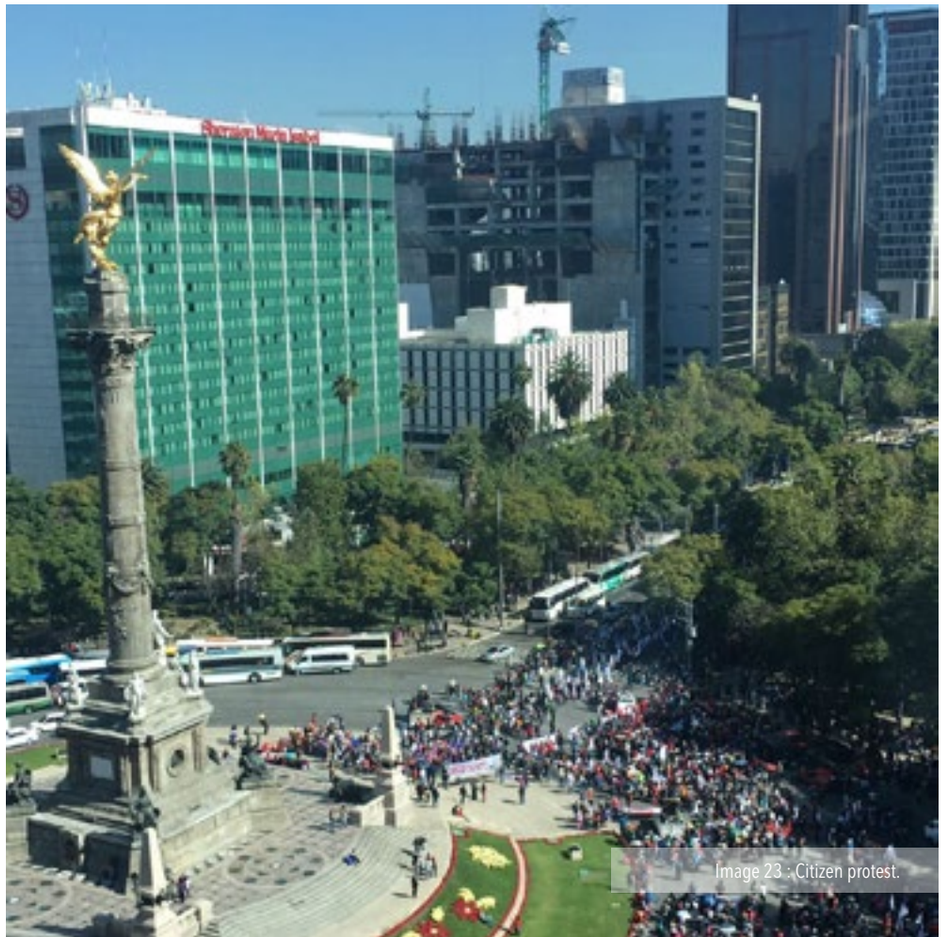


Image 23 : Citizen protest.

RESEARCH QUESTIONS

In consideration of the foregoing, this paper posed few questions regarding design, social change and air pollution as a wicked problem.

How might we utilize design methods in order to effect change in people's behaviour with respect to air pollution?

What are the different layers involved in social change?

How is design in the broader sense being utilized towards better air quality?

How might we apply it towards better air quality?

How might we leverage actions individually and collectively towards larger, scalable solutions?

LIMITATIONS - CONSIDERATIONS

There are several limitations associated with this research. It is important to acknowledge them, as well as the researcher biases and assumptions. Most of them arise as result of academic constraints. The project as Major Research Project (MRP) had to be completed in about three months, from September to December. This time should include the field research which, in this case, had to be done in Mexico as this project is specific to that location.

In terms of the field research, time was an important factor which limited the recruitment process. Since there are ethical considerations to take into account in many countries like Canada, a Research Ethics Board (REB) approval was required prior to conducting a research involving humans. The screening, recruitment and sampling processes were limited, therefore, to one week. Additionally, in order to expedite the process and because the method to be utilized is quite new, the REB had to limit the use of photography and other resources to utilize in the document for participants' identity protection purposes. Another important point to raise here is the influence of the size of the City in the sample. It was not possible to recruit the expected diverse population required for an *objective as possible* sample. Thereby, it was necessary to consider the influence of the small diverse sample in the results and at the same time, highlight its potential for extrapolation. Additionally, since resources were tight the spreading to the masses was more difficult. The screening as well as recruitment relied solely on social media, flyer invitations distribution, acquaintances emails and word of mouth.

On another note, many of the resources, such as papers, articles and the field research itself were originally in Spanish, due to the latter being the first language in Mexico. Thereby, translation of documents, quotes and insights have been translated into English by the researcher throughout the document. Specific quotes will include the following footnote "All quotations of *the author* are Graciela Guadarrama's translations unless stated otherwise."

Finally, as a Mexican citizen and a MCMA inhabitant, researcher's biases were unintentionally embedded in the paper. Those had to be considered along with her particular worldview and few assumptions coming from her experience, not as an expert in the field but as an engaged citizen with a special interest in the topic, social change and social responsibility towards Mexican society.

Image 24 : City Skyscrapers

Image 25: City sky from traffic

DESIGN RESEARCH

METHODS

A significant part of this project was focused on Innovative Design Research Methods. Methods such as embodied storming were utilized for exploration among other purposes, as understanding and discovery. Additionally, a generative design sessions introduced tools which yielded interested and unexpected results; the emergence of the potential of the latter, was a pleasant surprise. Given the presented construct, a citizen-oriented discovery was required, thus the use of participatory methods. Each method presented in this section contains and describes its own process and a specific objective in relation to the project at hand. Also, several tools and frameworks, which were utilized iteratively to make sense of the data in all the steps of the process (from the data gathering to the findings and the analysis) are introduced in the different sub-sections.

Embodied Storming

Embodied storming is an experiential and exploratory method utilized to understand and envision how people would respond to a particular situation and help build meaning around common issues[17]. It is an extension of the participatory design method "bodystorming", which's name derives from and is supported by theories of embodied cognition. The latter "*a growing research program in cognitive science that emphasizes the formative role the environment plays in the development of cognitive processes*"[32]. Bodystorming is a designing method that was first utilized in three ways; the first one as the idea of physically experiencing a situation, spending time in the designed or to be designed space. A second form of bodystorming is called "strong prototyping" which is prototyping in the space in which the product will be used, to test it. The third and most popular one is "use-case theater", this entails the prototyping of and in the space and include living actors and props as well[17].

Embodied storming, on the other hand, focuses on the need states, it can be applied as a "design-research method that helps identify gaps and opportunities." The significant difference between these two is that embodied storming is thought to create empathy with the **user** by experiencing a situation as another person. Table 4 illustrates the difference between both methods in more detail. Being this a still exploratory and quite new method, circa 2010[17], its potential is yet to be discovered.

Embodied storming towards air pollution in MCMA

The purpose of this session was to understand people's behaviour towards the issue of air pollution in MCMA; observe the way in which they react to a critical situation and create inspiration for potential solutions and provocation for reflection.

BODYSTORMING	EMBODIED STORMING
User-needs centered	Rapid communication and generation of ideas around an envisioned scenario
Product-design driven	Developing people, developing cultures through shared understanding
Creative problem-solving	Rapid communication and generation of ideas around what the problem domain should be
Focus on physical problems	Problems are not always technological, also sociopolitical, socioeconomic
Reenacting everyday people's performances and living	Envisioning how people would respond to future scenarios that are presented without extra data
Quality of design ideas is heavily dependent on the quality of documents	Quality dependent on the interactions and breakdown of cognitive and emotional barriers
Participants are researchers and industry representatives	Participants may not know anything about the subject area
Success measured by uptake of ideas by industry representatives	Success is measured by participants' willingness to explore together
Empathy toward users	Shared experiences and collective memory
Role playing and following script	Free flow, not-directed aside from presented scenario
Forced innovation of proper solutions	Not solutions-driven, more experimental and exploratory

Table 4: Types of bodystorming [17]

DATA GATHERING

The first step on the journey to performing the field research is the gathering of desired and required data. The selection of the participants was comprised of 3 stages. Screening, recruiting and sampling.
The screening helps identify and locate people who fit the profile. An invitation letter in the form of a flyer was utilized, in which the required profile was noted. While handing out the flyers outside Universities, questions were asked in order to see whether they were potential participants. During the recruitment, an agreement to participate was established. Here, the use of social media and word of mouth was crucial.

Finally, the selection of the representative population of interest is called sampling. For this project, the sampling was both *opportunistic and purposive*. Moreover, a small *snowball sampling* was identified, the latter due to participants bringing people along[23]. The endeavor was to recruit the audience described in prior sections; a varied group including gender parity and representative members who are differently abled, from different backgrounds, of legal age (older than 18) who live in the MCMA. The sample size is often small in generative design research, thus diversity was important.

Although the aim sample was a diverse group of 20 people in order to form four groups of five, only 14 were able to attend. The sample was comprised of 6 females and 8 males, two groups were formed by 3 males and 2 females and one had 2 and 2 as shown in Diagram 1. While the exact age of participants or any other personal identifiers were not collected during the session, the average age estimate was 30 years old. As to their occupation, some were students, most of them worked full-time and a couple of people were neighbours. Lastly, one participant mentioned working in politics and governmental Institutions, while others had some sort of corporate jobs; characteristics expressed by them during the session.

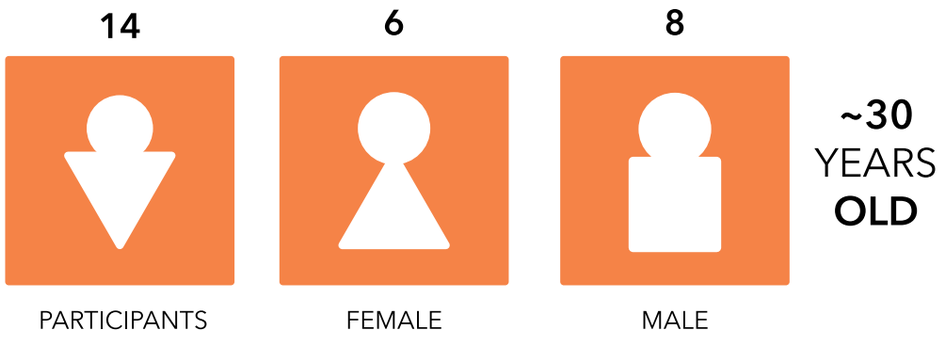


Diagram 1: Sample

Image 26 : Central Library, UNAM

The session was facilitated at the National University's green areas. The atmosphere was an important part to set the stage because the topic this research touches upon is air quality. Additionally, because the method emphasizes the influence of the environment in participants' cognitive processes. The following (image 26) encapsulates the atmosphere. Before the session started, an ice breaking activity was performed. Participants had to share three things about themselves, where two were true and one was a lie. Other participants had to guess which one was the lie. This allowed for trust among participants and created a more comfortable atmosphere.

Moreover, roles showcased in diagram 2 are the following: Secretary of Mobility, Citizen, Community Leader, Air and Scientist. Five roles which were carefully selected, because it was important to consider all stakeholders involved in the situation. A perspective from a scientist who has the technical side of the issue. The secretary of mobility as a government representative who portrays top-down decision-making. The point of view of the people involved and affected by it, such as community leaders and citizens. The air, as the most important component in the system and that which is often undervalued.

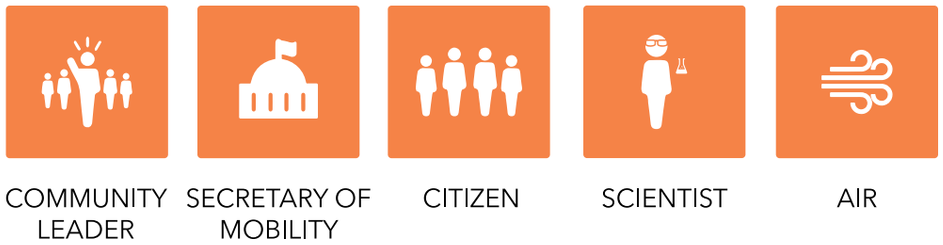


Diagram 2: Roles

In order to begin with the activity, participants were arbitrarily divided into two groups of five and one of four. Roles were randomly selected by picking a paper out of a box. The method encourages the use of material such as paper, post-its, markers, thought-bubbles and the use of the body to express props, movements and feelings. This allowed the activity to be more engaging, easy, playful and fun. The situation to be enacted was presented, followed by a Q&A. It was clear that at this point, people felt more comfortable with their groups and roles and were ready to immerse into the following activities.

Scenario

It is Mexico City in 2020. Pollution is critical, surpassing 200 IMECAS, which means it is time for Phase II[30]. The secretary of mobility along with the government have decided to ban the use of automobiles every other day of the week, public transit is same old and citizens have to continue their daily activities, work, school etc., as always. There is environmental contingency, citizens are advised not to leave home unless it's strictly necessary.

Diagram 3: Scenario

Participants had a couple minutes to plan their short five-minute sketch with the situation to be enacted and their allocated roles. In order to foster empathy, they had to enact the situation as a specific person, not themselves. After planning, each team presented to the other groups. This activity was broken into two parts because the research method requires at least one iteration. Thus, after the first one, both the groups and the roles changed. The last part of this session was the Debrief, where

participants had the chance to express how they felt during the session. This three stages in the session yielded interesting insights, presented in the next sections.

Generative design session

After the embodied storming, 7 participants volunteered for the second part. The purpose was to generate ideas towards mitigating and fighting air pollution. Also, to identify intervention points and help find emerging trends. Additionally, the hidden purpose was for participants to understand the power of an individual as part of a community to impact and effect change. There were two new tools introduced in this part. The first one was a *Persona* profile, which is a realistic representation of a key user-stakeholder. Participants were part of a dialogue to discuss and develop two Persona profiles, which were drawn on a board for everyone to see. The design of the profile required characteristics such as demographics, needs and pain points, behaviour and goals. Diagram 4 and 5 illustrate both profiles. After creating these two personas, their daily activities were mapped on a timeline showcasing one regular weekday; diagram 6 illustrates the tool called *Journey map*. While mapping the activities, participants as part of the conversation generated potential alternatives to be utilized in their community and explored areas of improvement both in the fictitious persona's journey but also in their own lives. Some of these suggestions became part of the trend report described in the deliverables section.

DATA GATHERING

The female persona is **Regina**. She is a 28-year-old woman, who works in management at a big Company. She is single, living with a partner. She owns one compact car that she uses to drive around 45-60 minutes to work. Some of her immediate needs are to pay rent, buy food, have a somewhat creative entertainment life and good health. She also thinks about saving for the future. These savings are required to accomplish some of her goals. A master's degree, travel, have a family and a dog and own her own home. Regina drives to the gym in the morning, at around 7. It takes her 45 minutes to get there. She has breakfast at work because she starts at 9 am. At 12-1 pm she has lunch. She is off by 6 pm and drives back home, it takes her more than 1 hour because it's rush hour in the City. Sometimes she does some entertainment activities or goes home to have dinner. She usually cooks dinner as well as food for the next day. She sleeps at around 10-11pm.

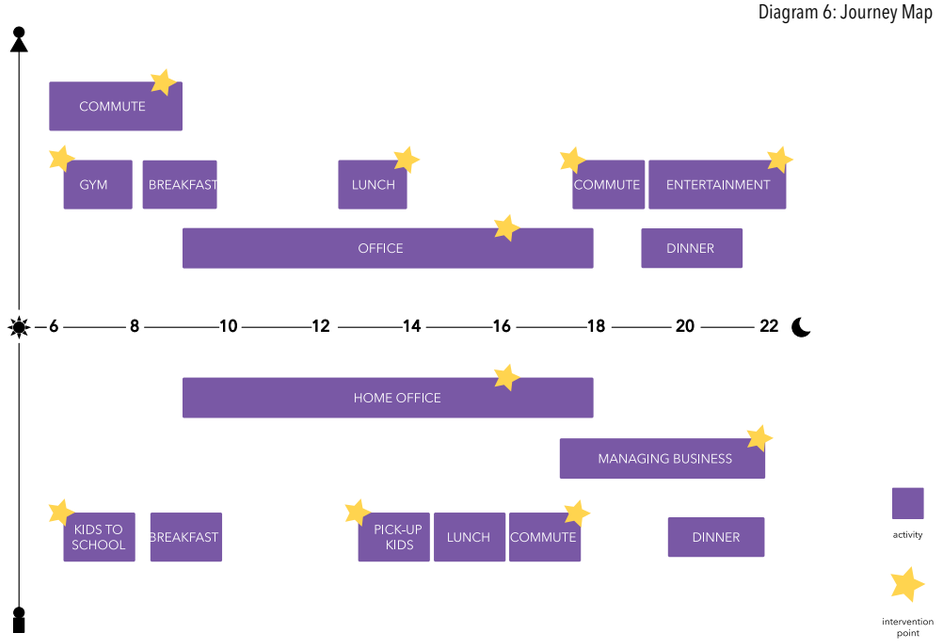
Diagram 4: Female Persona

Diagram 5: Male Persona

The male persona is **Mario**, he is a 40-year-old man. He is an entrepreneur in the service industry. He is married and has two kids and a dog. He owns an SUV and a motorcycle. Since he owns a restaurant he often works from his home office. His needs are mostly family related. His kids' tuition, family health, the house mortgage, family entertainment and savings. Some of his goals include the growth of his business, stability and family travel. Kids' education is key, although he would like to eventually get a beach house. Mario wakes up at 6 am, he has to drop the kids at the bus stop. They use the school bus to get there. At the same time, he walks the dog, some days he goes for a run after it. He eats breakfast at 9 am at home. He usually does home office all morning until he can pick up the kids. The family has lunch at around 2-3 pm. After lunch, he drives his motorcycle for 10 minutes to the restaurant to check up on things. He prefers to use the bike because there is no easy parking spot. At night he comes back home, has dinner and enjoys his family.

Activities in diagram 6 are highlighted in purple, while Intervention points are shown as yellow stars. A few worth mentioning for Regina's day are **transportation**: driving alone for two hours daily is not sustainable, **waste management**: eating lunch out is expensive and not sustainable, **office**: supplies are usually misused, etc. As to Mario's, most of his intervention points were identified as a business owner, **waste management**: restaurants waste a lot of food, create a lot of trash and are easily unsustainable, for example, (for the full description and details review appendix B).

Diagram 6: Journey Map



Process : what to do with what you got

After gathering the data, the evident step is to answer the question: what to do with what you got. The objective in this section is, therefore, to organize, describe and interpret the data, make comparisons, search for patterns and generalize findings. This by blending multiple insights drawn from across all data sets and engagements with participants, from the embodied storming to the generative session. A method (TA) and a framework (Say, Do, Make) describe this in great detail in the next few paragraphs.

The method of data analysis utilized to make sense of the qualitative data was the Thematic analysis (TA)[51]. TA is a method for identifying and organizing insights into patterns of meaning which are called themes. This allows to see and make sense of collective or shared meanings and experiences out from the described session. There are two ways TA can identify, code data and analyse insights:

- **the inductive approach** is driven by what is in the data, codes and themes derive from the content of the data themselves, as compared to the
- **deductive approach,** where the researcher brings to the data a series of concepts, ideas, or topics that are used to code and interpret the data.

In this case, a combination of both approaches was used while identifying content from the data itself and bringing the researcher's experience to connect the dots. In order to be able to analyse this type of data -for its nature being qualitative- a set of codes and themes were given to the insights, based on the TA method. Codes are those which emerged from the interaction between participants and the researcher's observations, taken from what participants said, did and made (***Say, Do, Make!***). Themes are researcher's compilation of relevant codes into clusters. Examples of codes are illustrated in table 5: blaming the other, not wanting to change, not believing in their input, victimizing themselves, not realizing the gravity of the issue, not caring about it (for the complete data transcripts and codes in more detail, refer to appendix B).

I don't care about others well-being	AWARENESS
I don't think people care enough	WILLINGNESS TO CHANGE
I didn't know the situation was so bad	AWARENESS
Transportation and traffic cause air pollution	AWARENESS
It is not my fault, it is someone elses	AGENCY
I don't want to change my lifestyle	WILLINGNESS TO CHANGE
It doesn't matter what I do	AGENCY
Humans cause air pollution	AWARENESS
It is complicated to get a new car	WILLINGNESS TO CHANGE

Table 5: Codes

These codes were later on clustered into three main themes: awareness, agency and willingness to change, which are described below.

Awareness - understanding

Awareness refers to how well-educated people are around the subject, also the amount of information people reach out to. How aware they are about the importance of one person's input but also about how critical things are because immediate consequences and the pollution itself are not always visible.

Responsibility - agency

This theme describes how much influence people feel they have over the subject at hand. How much their individual as well as collective input matters to effect a change. Also, whether people believe in their input being the one to blame for the issue or someone else's.

Lifestyle changes - willingness to change

This theme was assigned to the idea of how much people are willing to change their lifestyle, their habits in order to effect the change needed. It describes how much they are willing to change and how much they feel they can change.

Moreover, in order to visualize the information codified in previous paragraphs across participants and methods in an effective way, the framework ***Say, Do, Make!*** introduced in the book "Convivial Toolbox", Sanders and Stappers (2012) was utilized. Diagram 7 illustrates the way in which the information was organized. The element **SAY** was used for conversations and opinions. In this session, the debrief was the space where people could SAY what and how they felt about the interaction and the issue at hand. Also, a part of the creation of the persona and journey maps allowed them to SAY, express their thoughts. In comparison with **DO**, which entails the observation of video and photos of what the participants do during the session itself. Finally, **MAKE** is utilized to observe the participants during the session and see what they make. In this particular session, participants collaboratively made two sketches during the embodied storming, as well as the persona profiles and the journey maps (for the full description and details review appendix B).

Finally, diagram 8 shows the groups set up for the embodied storming labeled RED, GREEN and BLUE.

Diagram 7 : Say, Do, Make! Framework

Diagram 8: Roles & Groups

FINDINGS

After assigning themes based on the codes identified, a comparison between iterations and groups helped find insights across all methods (embodied storming and generative design). Many levels of interpretations exist in this type of participatory research methods, therefore, initial reflections were based on the observation of participants while enacting the situation in the embodied storming, by utilizing the ***Say, Do, Make!*** Framework presented earlier, the following tables help represent the findings. Tables 6 and 7 illustrate where groups stood for iteration 1 and 2 respectively, regarding the three themes: awareness, agency and willingness to change.

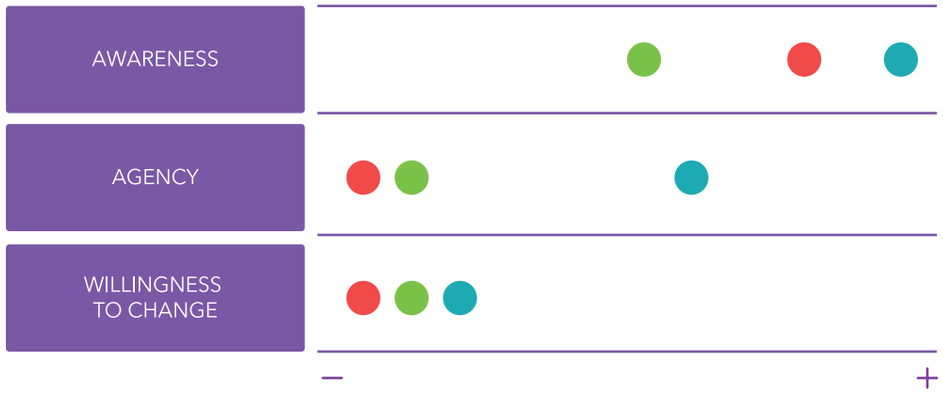


Table 6 : Iteration 1

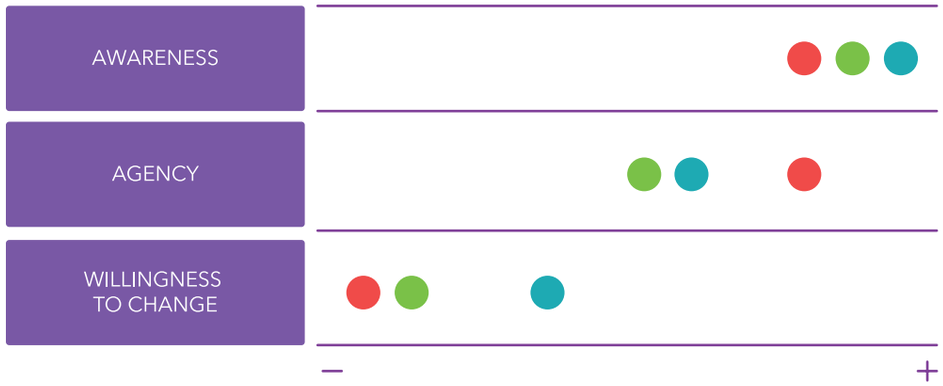


Table 7 : Iteration 2

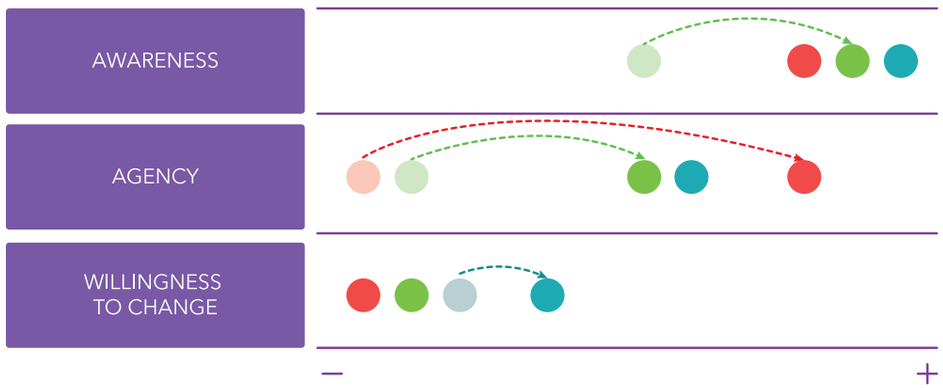


Table 8 : Comparison

As shown in table 8, from iteration 1 to 2, GREEN group's **awareness** increased. As to the theme **agency,** groups RED and GREEN turned from blaming the other-not blaming myself in the first iteration into a shared agency from both the government's and the citizens' side

equally. As to **willingness to change**, from the BLUE group, there was a little improvement from iteration 1 to 2 but not for the other groups.

Shapes such as STAR, TRIANGLE, SQUARE and a CIRCLE were given to participants in this part to be identified and be able to make sense of the data effectively. As to table 9, all four participants agreed that **agency** should be equally shared with all stakeholders, although they also recognized that **willingness to change** is not often present on the citizens' side. As to **awareness**, some participants commented that citizens are not aware enough of what they can do about it, while other two stated that they feel more aware of the issue and citizens' responsibility and agency as they did before, (for more details on the findings and the complete data go to appendix B).

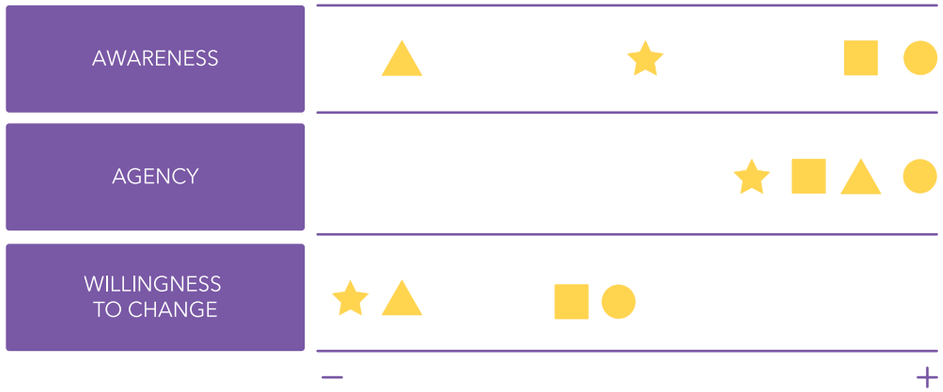


Table 9: Debrief

The second level of reflection was the researcher's observations, by connecting dots between the groups and both iterations. These insights yielded interesting concepts, such as the **shared agency**, an identified perception **shift**, the acknowledgment of the issue as a **wicked problem**, the importance of an individual's **input**. Also recognizing that **change** is not something that comes **easy** and finally the fact that there will always be some **ambiguity**.

A code is relevant to mention here, how people blamed urbanization, understood as highways, transportation and traffic as well, for air pollution. It was very clear that green areas, trees and nature have good air quality. However, throughout time, air has worsened because of citizens activities. In some groups during the first iteration, the "villain" was the air, within the same session, that perception became the complete opposite, the air became the "victim of humanity". Agency changed throughout a 10-minute span between iteration 1 and 2; from

blaming the air and the government for the misfortune of citizens' condition, to a shared agency.
This demonstrated self-discovery in a short span; the method allowed for **perception shift**. The main objective of the embodied storming as a research method is usually inspiration, understanding and exploration through observation of participants' interactions. The aforementioned becomes, therefore, an insight related to the method itself, because after utilizing this method for the first time, the realization was that embodied storming could be utilized as an action creator as well. Some of the observations mentioned earlier, the way perceptions changed in a short span, demonstrate its potential. - Whether that will make people actually change and create a real impact will be discussed in the following sections as future directions taken from this research onwards.- Regardless, a small activation was clearly identified in the participants by enacting the situation. This interaction created "something" in them, exceeding what was expected from the method. Hence, the application of the latter as part of workshops to raise awareness amongst MCMA citizens or, at least, to start a conversation around the topic and begin to address the need for social cohesion arose as a potential next step.

Another important insight from the interaction amongst participants is that it demonstrated air pollution to be a very complicated matter, a wicked problem. It seems that nobody, whether expert scientists, the government or the citizens, knows exactly how to address the problem. There are too many stakeholders involved, several agendas to meet and many elements in the system to consider. Participants while representing any one of the roles, seemed anxious and stressed out by in character situation.

As to the generative design session, the purpose of the utilization of a persona profile was to try to empathize with a larger and diverse audience. With all the limitations that Persona profile has as a tool, its use in this context was merely to illustrate the importance of one individual's input and output to impact and effect change. However, due to the sample in this part of the session being smaller, a bias was obvious. One participant noted that lower income citizens were not considered in this part; regardless of the latter, suggestions were provided as a group. More general observations from this interaction were also identified, one is the fact that people tend to plan their activities based on traffic. If one exercises, for example, going to the gym early is part of the activities that help avoid traffic in the mornings (image 27). Other activities such as grocery shopping, cooking meals, etc. were also mentioned. Several other factors influencing how citizens perceive the issue of air pollution, such as waste management and food waste

Image 27 : Planning activities to avoid traffic

emerged during the conversation. It is from these problematics, where innovations emerge. It was important for citizens to know where and how they can improve on as well as being able to propose solutions in a collaborative open way.

Moreover, by interweaving insights taken from all engagements with participants, a third level of analysis emerged. First, it was notable that there are indeed things people can do or stop doing to improve the quality of the air in the MCMA. Second, the session touched on concepts of change, yet, willingness to change did not seem to increase even when agency and awareness did. Third, the idea of **"ability to change"** which is tightly related to the latter means in this context, how much a citizen can afford to change their daily activities or their overall lifestyle. It is, then, vital to understand and acknowledge that, in many cases, people are forced to do what they do, this means that it is more complicated for some individuals than others to act on them, because of different factors linked with an unequal society, justified in the inequality section. Some of those factors are income, lifestyle, housing conditions, work status, the area of the city, etc. In some cases change is not possible, conditions are not always favorable even when "willingness to change" is present. Especially, people from low-income areas, for example, cannot afford to drive a bicycle to work because

it's often too far or buy a newer, less polluting car, etc. In this sense, the lack of diversity in the sample clearly influenced this insight or the lack thereof. Thus, an interesting insights was that it is not enough to be willing to change but being actually able to. Unfortunately, some people cannot afford to make the change.

Finally, an important realization was that a vital part to design thinking and these type of methods is to be able to manage ambiguity. Qualitative analysis won't yield specific results but instead a wide variety of insights with many levels of interpretation. This data is most often immeasurable, however, it was classified and coded to be analyzed as a whole as described in this last section.

DATA ANALYSIS

PROBLEM SOLVING

In consideration of the foregoing, this project poses three main themes - which are always interconnected and extremely interdependent - awareness, agency and willingness to change, as essential components in the overarching domain of social change.

Awareness

If the argument is being built on the premise that "power is knowledge" then - **awareness-** better communication, plus accessible information is vital for social change. Information and knowledge challenge assumptions; it helps individuals and groups build a better and more informed understanding of the context and their surroundings. But, is awareness enough for social change? In order to answer this question, a Case Study was explored, in which the latter is put in consideration.

The publication "The Pursuit of legible policy" (2016) introduced earlier, is a collaboration between various Institutions from both Mexico City and London. It's a project which intend is to understand, explore and create ways in which more accessible "legible" policies with citizens' participation, can have an impact on the future of both Cities[34].

Thereby, and to bridge the gap, the following statement extracted from the aforementioned publication, in the words of Galik (2016) was taken into account "*…any of these tools are built on the false premise that more information* ***automatically*** *leads to behaviour change and some oversimplify the complexity of these problems altogether". One suggestion is the idea that—similarly to Timothy Morton's concept of 'Hyperobjects' (2013)—phenomena such as climate change are so massively distributed in space and time as to transcend localization…they become "invisible forces" over which we feel little agency, and so little capacity to change. It's a lack of "****response-ability****" and agency that we feel*." (p.69). This abstract uses the term *"response-ability"* which connects back to the comparison between - what in this paper has been called - "willingness to change" and "ability to change".

At the same time, Galik's idea is associated with a thought-provoking concept, first described by biologist Garrett Hardin in 1968, the "Tragedy of the commons". The concept describes the way a shared resource, such as air, is perceived among societies. A shared resource, which is so valuable that people want it for their individual benefit and gain, therefore people tend to misuse it and as a consequence is being overexploited, leading eventually to its depletion[29]. In this sense, the notion of "ability to change" is harder to comprehend. It pushes the individual away from it because the issue at hand is too much for one individual to control and have influence over. The idea of people as agents of change and the belief of what can be done locally does not match the understanding of what is possible at a larger scale in both positive and negative ways. "Tragedy of the commons" Hardin (1968) has to some extent, an impact on this argument and the previous statement where *"response-ability"* in Galik's words is again a complicated phenomenon.

The aforementioned idea brings forward the point where awareness on its own is not enough. Being more informed is not enough when the issue at hand is so large, when it involves many stakeholders, several factors and myriad considerations to be taken into account. Given that air pollution is a wicked, systemic problem, there are quite a few layers to it. **Awareness** is consequently one of them, one part, one step, one level out of several that are required to create and effect social change.

Agency

The participatory research, as well as the literature review and the above-mentioned Case Study, helped in discovering a vital part of social change, that which was also described throughout the paper and in the introduction to the subject of corruption; which is **agency**. A clear need for awareness and information has been identified in Mexican society, but what comes in tandem or even simultaneously is agency. In this respect, Lockton (2015) poses an interesting approach on the way design could and should be utilized from understanding to action, the following quote encompasses the idea: "*The real goal is understanding how to enact change. Understanding how to act to change the systems we're in is arguably the biggest meta-challenge of our age*." His approach is comprised of 5 progressive steps, in which he proposes to use design as a way to:

1. understand the world
2. understand people's understandings of the world
3. help people understand the world
4. help people understand their agency in the world
5. help people use that agency in the world (p.59)[31]

By **understanding the world,** utilize design - in the broader sense - to gather data that uncovers a problem, a need. Which has a close relationship with **understand people's understandings of the world,** "*...explore the different ways in which people imagine, conceptualise and think about how things work.*" In this project, participatory design research techniques (such as the embodied storming) were utilized in order to understand people's understanding of the world. Moreover, **help people understand the world** means *"...designing ways which help change people's understandings of the world and the systems they're in."* In this sense, the development of a resource package along with the workshop sessions proposed earlier were designed to assist people in the understanding of the world. For both steps 4 and 5, **help people understand their agency in the world** and **help people use that agency in the world** is where the concept of AGENCY comes more directly by utilizing design to "*help people understand what they can do to change things, and then helping people do that.*"

Willingness to change

The theme willingness to change results to be a critical level to achieve social change, because awareness and agency are not enough to make the change happen. The participatory engagements showed that most people are not willing to sacrifice things for a greater good and change their lifestyles. This brings to the table, a contrasting point. Although it was mentioned earlier that some people even when willing to change are not able to, the fact that people are willing to change in the first place, is still questionable. Even when the public is aware of the problem, knowledgeable and informed. Even when they have acknowledged their agency in the issue at hand and know that they input matters, they might not be willing to change.

This phenomenon draws on two concepts of human behavior, psychology and social sciences: **cultural cognition** and **cognitive dissonance**. Cognition here refers to any knowledge, opinion, or belief about the environment, about oneself, about one's own actions and feelings, which may be dictated by cultural or group standards[69]. The first one then, is assigned to the tendency of individuals to conform their beliefs about disputed matters of fact, to values that define their cultural identities[72]. In this context, *"Individuals more readily impute expert knowledge and trustworthiness to information sources whom they perceive as sharing their worldviews and deny the same to those whose worldviews they perceive as different from theirs".* In short, people tend to look for information that matches their own beliefs[71].

The latter directly correlates with the second concept, **cognitive dissonance**, a theory coined by Festinger (1957) which explains why humans act in different ways regarding the same subject and with the same amount of information. The way Festinger explains it is that, *"Dissonance and consonance are relations among cognitions".* Thus, *"...two opinions, or beliefs, or items of knowledge are dissonant with each other if they do not fit together, if they are inconsistent, or if, considering only the particular two items, one does not follow from the other* [69]. Festinger explains further that an individual is always looking for consistency within her/himself, between their believes and their knowledge, because an inconsistency is uncomfortable for an individual, "*people do not like to have attitudes and behavior in conflict, this causes dissonance"*and therefore, will do everything to reduce it or avoid it, striving to achieve consistency. An individual will tend to resolve this dissonance in three basic ways. First, they will try to **change their beliefs**, opinions or knowledge. Second, they will try to **change their actions** and third, they will **change their perception of action**. This last one is a more complex method of resolution, which works by changing the way in which the individual views, remembers or perceives the action. It's called rationalizing, however, in order for it to be fully effective, there is a need of the support of others to strengthen the rationalization[35].

In the context of air pollution and the idea that people are not willing to change regardless of what they know demonstrates a great deal of cognitive dissonance. The discussion on Climate change should be used to exemplify. Climate change, in some people, causes a dissonance with their actions and beliefs. It results much easier to change the perception of their own actions rather than changing their actions, the former is therefore, the most common method of resolution. It is easier to think about their actions in a different manner or context so that they no longer appear inconsistent. Festinger's theory, in short, has a strong correlation with the previous discussion on why, regardless of the presence of awareness and agency, achieving willingness to change is the hardest level of all. The reason behind it is also that *"motivations and desired consequences may also be factors in determining whether or not two elements are dissonant*." [69] So, the will to change draws on motivation and desire, which rely completely on an individual.

By analyzing the results that this research yielded and weaving them together with literature and several other expert approaches to the matter, the discovery was validated. Validated in the sense that there are certain steps to follow in order to effect social change and that design is indeed able to be the means to create that change.

Finally, because the overall purpose of this project was to understand people's behaviour towards the issue of air pollution but also to leverage people's actions, a resource package was created to guide them in the complex process towards social change. In the next section, these two concepts (agency and awareness) are translated into tangible deliverables, created for people, to assist them in utilizing their agency in the problem at hand.

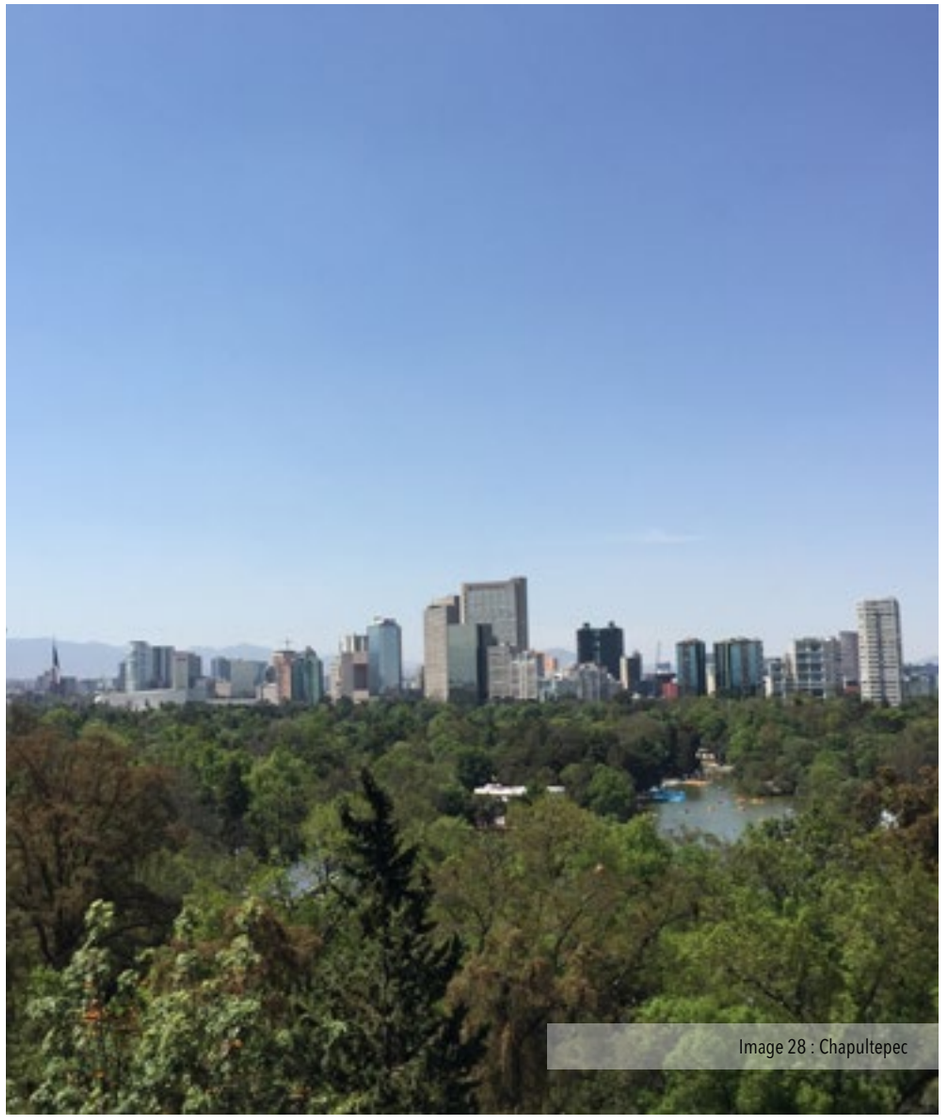


Image 28 : Chapultepec

Image 29 : Palacio de Bellas Artes

RESOURCE PACKAGE

Given the analysis in the last section, the need of design to create awareness and agency is notable. Thereby, a resource package was developed to bridge the gap and get closer to solving the problem of air pollution in the megacity. This resource package for community groups and individuals is comprised of two items carefully designed, focusing on the targeted population. These items were created throughout the project as a way of assisting people in the complex process towards social change.

GUIDE

An intentionally curated guide based on the researcher's experience and understanding of the modern world. The challenges and the role of Mexican society plus the influence of social innovation and design thinking towards social and environmental problematics reflect the selection. This guide was developed through an extensive literature review, designed for non-experts and aimed to provide a better understanding of the problem.

Comprised of a series of bibliographical references in the form of an annotated bibliography, this bibliography contains relevant summaries of the various sources explored. An approximate of 15 references were selected from the sample of ~50 sources in order to provide concise information. Information that was first extensive and complicated is delivered in a more accessible, friendly form through this guide. This booklet was thought to be publicly available in both hard and soft copies to be easily shared and published. The intent of this deliverable was to make information more accessible to the general public and the targeted audience: the "engaged and passive" and the "disengaged and willing". Also, to help individuals and communities to educate themselves around the topic of air pollution, social change and ecology, aiming for positive impact and hoping to improve awareness and agency amongst the "disengaged and willing". It should also serve as a resource for people who might be interested in the topic and do not know where to look for reliable information, the "engaged and passive" audience mentioned earlier. The main objective was to create an easier and more comprehensible tool, a better way for people to be and stay informed.

SEDEMA. (2016, June). *Boletín informativo, calidad del aire en la Ciudad de México.* Retrieved from http://www.aire.cdmx.gob.mx/default.hp?opc=YaBgcpKk&nota=Y2k=

REPORT. Phase 1 of the atmospheric environmental contingency due to high levels of ozone reported in the MCMA area. In March, the double no driving day is in place. Vehicles with a specific plaque numbers are restricted to circulate from 5am to 10pm an extra day of the week, besides the fixed one. This applies to the whole MCMA. Vehicles exempted are those which don't emit pollutants derived from combustion, motorcycles, those from the emergency units, police and fire departments. School buses only with the clearance and public transport vehicles which are accredited. Air quality will continue to be monitored through the monitoring system. Citizens are advised to stay informed about the issue and notifications through the web and other mobile applications.

Joseph, P. (2007). *Zeitgeist: The movie*. United States: GMP LLC

DOCUMENTARY. Examining the world we live in from a different perspective. The way in which religion, the economy and the media have controlled human's lives throughout history. By failing to understand the world as a system, it shows the powerful influence of private interests, while it adds to the lack of consideration as to the consequences of those actions in the world and their inhabitants.

Quotation - abstract
"…if people ever realized the truth of their personal power to effect change, the entire manufactured zeitgeist will collapse, like a house of cards."

Mau, B. (2004). *Massive change*. London: Phaidon.

BOOK. The way in which technologies, inventions and design have affected the human race worldwide. With interviews to experts from different fields, it covers areas of change in urbanism, the invention of the automobile and all that entailed including highways, traffic and pollution. In architecture, how crowded places along with property law and housing developments have changed the life of millions in developing countries. Product design innovations in health and living, as well as scientific breakthroughs, all which have improved human quality of life. War, as a crucial element in the changing world and the innovations in the military arising from it.

Quotation - abstract
"…the main thesis of Toynbee's work is that the well-being of a civilization depends on its ability to respond creatively to challenges, human and environmental".

Centro Mario Molina. (2016, May). *Soluciones de Fondo para Mejorar la Calidad del Aire del Valle de México.* Retrieved from http://centromariomolina.org/

REPORT. The result of many years of research. A thorough description of fundamental solutions to improve air quality in the MCMA. A set of actions as strategic lines such as the acceleration of public transport system with low emissions, integrated to the whole MCMA area. Promoting of rational automobile use and clean tech. Reduction of industrial emissions and containment of urban expansion to prevent mobility demand. A critical ingredient to succeed, however, is the participation of different sectors and government levels, coordinated by effective mechanisms with regional aim.

Quotation - abstract

"We must have a comprehensive package of measures to solve the problem of air quality in the MCMA, attacking all relevant sources of pollution, and focusing short, medium and long term. It is important to avoid the temptation to seek unique solutions or magic, because for this problem in specific, it is clear they don't exist."

Centro Mario Molina. (2014). *Políticas integrales para mejorar la calidad del aire en la ZMVM Programa Hoy No Circula*. Retrieved from http://centromariomolina.org/calidad-del-aire/evaluacion-del-programa-hoy-no-circula/

REPORT. Scientists suggest that the implementation of programs and initiatives by the government in an isolated manner will not resolve the problem of air pollution in the City. There is a latent need of an integrated assessment to guarantee the well-being and health of the population. In this respect, the use of public transport, utilized by an approx. of 75% of the population is a determining factor, which is not being addressed by the government.

Quotation - abstract

"In order to decrease the polluting emissions and maintain the recommended national and international levels, it is necessary to improve and extend public transportation, people's mobility and the quality of fuels as urban developments that privileges pedestrians and clean transportation."

Diaz, R. (2016, July 18). Vía Verde, el triunfo del urbanismo de ocurrencia. Retrieved from https://ciudadpedestre.wordpress.com/2016/07/18/via-verde-el-triunfo-del-urbanismo-de-ocurrencia/

BLOG. The relationship between the public and private sector; the way they interact and do their business lacks clarity. It looks like they have hidden or dubious intentions, its benefits to the city and the citizens are unclear. It questions why these sort of initiatives are not properly presented and performed in terms of offering more detailed background information, more explicit objectives and benefits to the City.

Quotation - abstract

"It's not a matter of being picky, but a project involving commercial concession of 27 kilometers of road deserves more transparency, more participation, more rigor. The plants don't matter. What does matter is the dictatorship of the occurrence."

Molina, L. T., & Molina, M. J. (2002). *Air Quality in the Mexico Megacity, An Integrated Assessment*. Springer.

BOOK. The approach to the problem requires an integrated assessment. Policies on their own will not work. Several policy initiatives have been effective at addressing some parts of the problem (including the decrease in few air pollutants) but there is little improvements in other aspects, including PM. The science, the technical side on how to reduce it is reasonably straightforward, however, the City faces many barriers to effective policy implementation and decision-making, without a strong commitment from both the government and the citizens, technology and science will fail regardless.

Quotation - abstract

"Urbanization was one of the most striking developments of the twentieth century. About 70% of the population of North America, Europe and Latin America now lives in cities…Among the most serious environmental problems in cities are air and water pollution, solid waste accumulation and disposal (including toxic and hazardous wastes) and noise."

Maher, B. A., Ahmed, I. A. M., Karloukovski, V., MacLaren, D. A., Foulds, P. G., Allsop, D., … Calderon-Garciduenas, L. (2016). Magnetite pollution nanoparticles in the human brain. *PNAS 2016*.

REPORT. A study which proves that biologically formed nanoparticles of magnetite were detected in human brains coming from an external source entering the olfactory bulb. These particles are abundant in airborne PM pollution formed by combustion in urban areas. This has large impacts in the brain because of its magnetic behaviour and toxicity. This has been linked to brain damage such as aging, neurodegenerative disease and Alzheimer. Samples were taken from 37 human brain subjects who lived in Mexico City and Manchester, UK.

Quotation - abstract

"Because many of the airborne magnetite pollution particles are <200 nm in diameter, they can enter the brain directly through the olfactory nerve and by crossing the damaged olfactory unit."

Centro de colaboración Cívica. (2013). *Hacia Ciudades saludables y competitivas, moviéndose por un aire limpio* (No. 3). Mexico. Retrieved from http://www.derechosinfancia.org.mx/Hacia_ciudades_saludables.pdf

REPORT. 12 proposals directed by the Federal Government, created in conjunction with the participation of the civil society, experts and the private sector. Their focus was primarily on the factor contributing to air pollution the most which is transportation. Proposals are independent but have to be simultaneously implemented. They are divided into short, medium and long term and follow three action lines:

A. Updates and norms to strengthen its application
B. Vehicle management, fleet renewal, new and green technologies
C. Information, communication and participation.

These range from updates to the norms on the use of fuels and emissions, to the development of high quality public transportation systems, including the reduction in use of the automobile and make freight more efficient. Some others draw on the generation of incentives to renew fleet turnover. Also, it makes emphasis on the strengthening of atmospheric monitoring. Finally it provides a thorough research on the impact on health and the economy and actions to generate awareness and encourage participation.

Seddon, J., Ramanathan, V. (2013). *Bottom-Up Solutions to Mitigating Climate Change*. Stanford Social Innovation Review. Retrieved from http://www-ramanathan.ucsd.edu/files/pr198.pdf

REPORT. The relationship between outdoor air pollution and climate change is very close. An effective reduction in emissions requires a new form of public-private collaboration. Small decisions may be a significant part to the problem mitigation. By highlighting the importance of a broader spectrum of contributors to the problem, is also touches on the opportunity of bottom-up approaches. These with potential catalytic effects at all scales and in many contexts such as those happened in public health, democratization and peace negotiation in some conflicts. Finally, emphasizes the value of design thinking to identify how the performance of the most effective solutions is being affected by their context.

Quotation - abstract

"This is where a bottom-up approach to mitigation, involving social entrepreneurs, NGOs, impact investors, and philanthropy, becomes an essential part of the response."

Newton Fund, the British Council, IIMAS - UNAM and CONACyT.,. (2016). *THE PURSUIT OF LEGIBLE POLICY: Encouraging Agency and Participation in the Complex Systems of the Contemporary Megalopolis*. Mexico City: Buró Buró Oficina de proyectos culturales, S.C.

BOOK. A project, a collaboration between various urban laboratories from both Mexico City and London. A publication which intends to identify, understand, explore and propose ways in which policies could be more accessible, more "legible" with citizens' input and participation. It explores how this approach can have an impact in the future of a City of this magnitude, by compiling several articles from experts in urbanism, design, policies and innovation. Articles suggest that the concept of agency is paramount for policies to function, besides, collaboration and better communication among stakeholders being critical.

Quotation - abstract

"Given the complexity of urban landscapes, legible policy has emerged as an important aim for urban laboratories, suggesting ways to increase citizen participation, heighten impact of policy decisions, allow for greater inclusion in political processes and stimulate citizens' agency."

Benítez-García, S.-E., Kanda, I., Wakamatsu, S., Okazaki, Y., & Kawano, M. (2014). Analysis of Criteria Air Pollutant Trends in Three Mexican Metropolitan Areas. *Atmosphere*, 5(4), 806–829. http://doi.org/10.3390/atmos5040806

REPORT. Data analyzed was collected from 32 automatic air-monitoring stations located in the MCMA, pollutants include: Carbon monoxide (CO): a colorless, odorless, toxic gas produced by the combustion of hydrocarbons emitted from vehicles. High concentrations of CO are particularly present in the mornings during dry-cold season, while the lowest are rainy seasons. Nitrogen dioxide (NO_2): plays an important role in ozone formation. Main sources are vehicles, industry and natural sources. In spite considerable fluctuations, the lowest rate occurs in summer while the maxima in winter. Sulfur dioxide (SO_2): its main source is industrial activity such as the generation of electricity, extraction and processing of petroleum, manufacturing and petrochemicals. High concentrations were recorded during the winter, whereas lower during rainy season. Ozone (O_3): created by the chemical reaction between NO_2 and NO in complex reaction chains. Its concentrations rise in winter reaching a maximum in spring. Usually low in summer and fall, when rain and clouds reduce solar radiation which suppresses NO_2 reaction. Particulate Matter (PM): the result of industrial, commercial, agricultural and household combustion. The lowest concentration rate is in summer due to the rain and usually peaked in winter. Annual trends show reduction of CO and SO_2, however O_3 increased from 2000 to 2011. Mexico City along with Guadalajara and Monterrey are the largest urban areas in the Country, with the highest population, highest growth rates and most industrial establishments. An alarming statistic is that car ownership is exceeding the rate of growth of the population.

Quotation - abstract

"Our analysis revealed that substantially different characteristics of air pollution can exist in different large cities even in the same country due to differences in geography, meteorology, emission regulations, and economic structure. Therefore, area-specific mitigation measures will have to be implemented to improve the air quality efficiently."

Prasad, A., & Segarra, P. (2016, March). How corruption is hurting Mexico City's efforts to tackle air pollution. Retrieved from http://theconversation.com/how-corruption-is-hurting-mexico-citys-efforts-to-tackle-air-pollution-57517

REPORT. Proposes the problem of air pollution as a systemic issue that cannot be solved if institutional corruption is not properly addressed. This becomes one of the toughest barriers to combat the problem in the City.

Quotation - abstract

"For real change to happen, the enactment of public policy must come hand in hand with measures to eliminate institutional corruption."

Duke, B. (~1999). Mexico's Air: A Synopsis on Pollution. *Development, Pollution and the Environment in Developing Countries*. Retrieved from http://web.stanford.edu/class/e297c/trade_environment/energy/hmexico.html

CASE STUDY. Main reasons as to the complexity of the issue of air pollution in Mexico City, its causes as well as possible solutions. The problem is not being properly addressed, long-term solutions are being discussed which require a lot of Government's investment in time and money, thus making them less realistic. It suggest that short-term solutions should be in place. With respect to the perspective of the inhabitants of Mexico City, there is a clear mistrust in the government, which also creates disbelief in the importance of their own actions as citizens and how they can effect change. The lack of awareness in citizens towards the severity of the issue regarding health is also significant.

Quotation - abstract

"The Mexican government has many problems to deal with and pollution is just one of them…the Mexican government has some plans to eliminate this problem, but the situation has gotten to the point where the citizens of Mexico City need solutions. The government is taking some action, but it's clearly not doing enough"

PROAIRE. (n.d.). Los efectos en salud por la contaminación del aire. In *PROGRAMA PARA MEJORAR LA CALIDAD DEL AIRE ZMVM 2002-2010*. Retrieved from http://www2.inecc.gob.mx/publicaciones/libros/394/cap4.pdf

REPORT. The effects of air pollution in the population are complex. Population at greatest risk to the exposure of pollutants are children under 5 years old, elderly (65+) and people with heart and respiratory conditions. Different pollutants have specific impacts in health. O_3, due to its ability to oxidize, damages cells in the respiratory tract causing inflammation. Whereas PM penetrate directly the respiratory tract without being filtered, once those particles are inside and based on their size, accumulate in different parts. PM_{10} (diameter smaller than 10 micrometers) penetrate to the bronchia while $PM_{2.5}$ (diameter smaller than 2.5 micrometers) can make their way to the lungs. Health risks associated with the latter are much worse that those with the former.

INNOVATION REPORT

A report showcasing innovations in the domain of air pollution. It outlines how people, start-ups, researchers, artists and local stakeholders are bringing ideas into the market and are fighting air pollution with innovations in design and technology. This report was developed as an open-source resource: this platform is meant to serve as action creator, to help the audience as inspiration to create something themselves or change the way they are acting altogether. Also, to inform them of what is being done to solve the problem from a design standpoint. Most people who want to engage in the problematic, or change their habits or behaviours more often than not, do not know what they can do. Thus, this list of innovations should allow to cross the bridge between willing and acting. Yet, it doesn't mean everything listed on this report is necessarily a successful idea. Some might even touch on the "innovation gap" described in the introduction of this paper. The motivation for having good as well as bad practices showcased in the report is to allow for critical thinking.

The purpose was to gather ideas and proposals as emerging innovations arising from the immediate need of clean air which is not being met top-down by decision-makers as the aforementioned paragraphs describe. At the same time, this section reaffirms the need but also the offer and demand for alternatives to the problem, the impulse to express, to create; from products to services, art installations and public initiatives to combat air pollution in a more immediate, short-term way.

The report is divided into four categories, social innovation, monitoring, awareness and hi-tech. Social Innovation, the first category, presents the use of nature, such as algae and other plants to capture CO_2. Also, sustainable transportations alternatives like an electric scooter rental system. Lastly, it shows how companies are profiting from selling clean canned-air to the most polluted places such as China, for example. In the Monitoring category, a few systems, sensors and platforms are listed, which are designed to help individuals monitor levels of pollution in many cities around the world. As to the category of Awareness, several art installations and interventions demonstrate the power of emotions to raise awareness in society about the biggest issues. A projection of sad child faces on smoke coming out of factories to raise awareness in powerful companies. Finally, the category Hi-tech shows ways in which organizations and research laboratories capture and repurpose CO_2 and other complex processes to destroy polluting particles in the air. The complete list follows:

SOCIAL INNOVATION

ALGAE FARM

The Cloud Collective. FRENCH-DUTCH. **2014**. An algae farm suspended over a small stretch of highway in Geneva, Switzerland was designed to clean up the environment. Algae, like any other plant, releases O_2 by absorbing CO_2, it literally "eats" pollution from the emissions of cars that pass below it, augmented by direct sunlight. The simple mechanism includes solar panels, pumps and filters which regulate the system. Over time, the algae matures into number of usable products, such as production of food and biomass.

Status
Currently a first approach, a concept, it started as an installation to explore and explain how easy this could be on a larger scale.

Source
http://thecloudcollective.org/#/projects/culture-urbaine/
http://www.iflscience.com/environment/urban-algae-farm-gobbles-highway-air-pollution/

ALGAE : PLANET SAVIOURS

Margoth Marissa Gamboa Lugo. MEXICO. **2016**. A scientific-student project that entails the installation of fountains in public spaces with marine algae to reduce pollution in Cities, given that algae absorb CO_2 and release O_2. Also, by absorbing CO_2 algae grow and can be turn into biofuels. Because fossil fuels release large amounts of CO_2, the utilization of biofuels decreases CO_2 emissions, it becomes a "reduce-prevent" cycle.

Status
A project in the prototype stage, winning many science contests and awards.

Source
http://www.conacytprensa.mx/index.php/ciencia/ambiente/9380-estudiante-propone-reducir-la-contaminacion-con-algas

ALGAE LAMPS

FermentAlg, Pierre Calleja. FRANCE. 2013. A biochemist designed an eco-friendly lamp aimed to light up streets while absorbing CO_2 and solar energy. It is powered by a tube filled with green microalgae, completely free of electricity because the energy is created by the microalgae's own photosynthesis process. The lamps are designed to store the energy from that process for later use where unlit, they can glow without the need for any external power source.

Status
Industrial production of microalgae

Source
http://inhabitat.com/living-microalgae-lamp-absorbs-co2-from-the-air/
http://blog.ted.com/a-streetlamp-powered-by-algae/

WYND AIR PURIFIER

Raymond Wu. CHINA. 2016. Personal and portable air purifier. Pulls in dirty air and pushes clean air out. A sensor monitors the filter's life time which is synchronized to a mobile app. The app gives information on the air around you and sends filter replacement. It has a 8 hour long rechargeable battery and a clip to take it with you.

Status
Kick starter campaign in pre-order stage. Product to be shipping in November 2016.

Source
http://www.businessinsider.com/tiny-air-purifier-cleans-air-anywhere-wynd-2016-6
http://www.businessinsider.com/wynd-air-purifier-kickstarter-2016-6
http://futurism.com/videos/clean-the-air-around-you-with-this-portable-air-purifier/

VITALITY AIR

Vitality Air. CANADA. 2015. Air can bottles capture fresh air from Banff National Park and Lake Louise by using a clean compression system to collect large batches of air. At the headquarters, the air is transferred to individual aluminum cans. Each bottle comes with a spray cap, a type of mask to inhale the fresh air. They come with a certificate of authenticity and are being marketed as perfect for hangover recovery, athletic performance, cramming for exams, etc.

Status
Shipped and sold in China

Source
http://inhabitat.com/bottled-air-from-canada-is-selling-like-crazy-in-china/
https://vitalityair.com/

GREEN & CLEAN

John Dickinson and Theo Ruygrok. AUSTRALIA. 2015. By collecting fresh air and putting it in cans, clean air cans are being sold to customers living in polluted parts of China. The air is collected from various locations across the continent, including the Blue Mountains, Tasmania, and the Gold Coast. They expanded to include pure New Zealand air as well. The can is around 20 Australian dollars and each can hold between 130-140 deep breaths, by using a special face mask that attaches to the nose and mouth.

Status
Being sold in China and as souvenir for tourists.

Source
http://inhabitat.com/australian-entrepreneurs-are-selling-fresh-canned-air-to-polluted-china/
http://www.greenandclean.com.au/

GREEN - LIVING ROOFS

Building roofs that are partially or completely covered with vegetation planted over a waterproofing membrane. It may also include additional layers such as a root barrier and drainage and irrigation systems. Since plants reduce CO_2 in the atmosphere and produce O_2, the purpose of green roofs is exactly that. They also reduce the heat island effect which is the main cause of ozone production. These roofs help remove heavy metals, airborne particles and volatile organic compounds. By appropriately capturing these particles from the roof, they do not enter the water system either which improves the water quality as well.

Status
Germany, early 70's. Trend growing.

Source
http://livingroofs.org/air-quality/

VÍA VERDE

Fernanda Castillo, Luis Gerardo Méndez and Roberto Carlos. MEXICO. 2016. A project to install vertical gardens in columns on the second floor of the ringway. It aims to produce O_2 for citizens by filtering harmful gases and capturing suspended powders as well as process heavy metals. It has an automated irrigation and a remote monitoring system to keep the vegetation in perfect conditions. The water to be utilized will come from the rain caught on the surface of the second floor. The project aims to generate multiple environmental benefits for residents, besides improving the urban image of one of the busiest roads in the City.

Status
Prototype phase, 10 columns installed.

Source
http://viaverde.com.mx/v1/
http://www.mexiconewsnetwork.com/adventure/via-verde-cdmx-clean-air-initiative/

ECONDUCE

Eduardo Porta et al. MEXICO. 2016. Electric scooter rental system which allows users to rent per day, a month or have a yearly subscription. These electric bikes can be used in contingency days. With a fool charge it can go up to 40 km at 55 km/h. The service includes induction to driving a scooter as well as how the electric vehicle works plus insurance, yet transit rules and fees are the driver's responsibility.

Status
Increasing about 300 user every month, anticipating to surpass 3,500 users by the end of the year and expand their stations.

Source
https://econduce.mx/#preregistro

MONITORING

PLUME AIR REPORT

Plume labs. FRANCE. 2015. Urban free air pollution forecasting app works just like a weather app. It showcases live pollution levels and hourly updates. Its aim is to help in protecting citizens from urban outdoor pollution and plan activities accordingly.

Status
Available in 300+ cities worldwide.

Source
https://www.plumelabs.com/en/products/air-report

PLUME AIR SENSOR

Plume labs. FRANCE. 2015. A personal, small and light wearable sensor monitors and measures those main pollutants that matter for health. It collects micro-local data which helps map pollution in a specific area, it also connects through Bluetooth to a smartphone's app.

Status
In progress, prototype phase.

Source
https://www.plumelabs.com/en/
https://www.plumelabs.com/en/products/air-sensor

PLUME AIR CLOUD

Plume labs. FRANCE. 2015. A free air quality data platform which access concentration levels for the most important pollutants. It also develops predictive models based on the latest data science technologies.

Status
In progress, prototype phase.

Source
https://www.plumelabs.com/en/products/air-cloud

AIR QUALITY EGG

Ed Borden. NY-AMSTERDAM. 2012. A sensor system designed to allow anyone to collect very high resolution readings of NO_2 and CO concentrations outside of their home. These two gases are the most indicative elements related to urban air pollution that are sense-able by simpler sensors. A community-led air quality sensing network that gives people a way to participate in the conversation about air quality.

Status
No notable update since 2012.

Source
http://airqualityegg.com/

AIRCASTING

HabitatMap. USA. 2011. Open-source platform for recording, mapping, and sharing health and environmental data using a smartphone application comprised of wearable devices and digital media that enables people to independently and accurately collect and broadcast air quality data. Each AirCasting session lets you capture real-world measurements, annotate the data to tell your story, and share it via the CrowdMap. It is a DIY air monitoring movement that uses information about local environments to inform, educate, share, and ultimately improve health in communities around the world.

Status
Company claims that over 1,000 AirBeams are in use worldwide and more than 100 million data points, one of the largest open-source databases of community-collected air quality measurements ever created

Source
Aircasting.org
www.takingspace.org/aircasting/airbeam/

AWARENESS

AIR POLLUTION BRICK

Brother Nut. CHINA. 2015. A Chinese performance artist transformed air pollution into a brick by vacuuming the air, sucking up the dust and particles that make up air pollution. He spent 100 days walking around Beijing with a large, industrial-sized vacuum. The purpose of his performance was to make a point about China's air quality, to create awareness about the severity of the issue, to better understand the "relationship between human and nature" and to push government to act on it, because breathing clean air is a right and they had it taken away.

Source

http://qz.com/562319/a-chinese-artist-vacuumed-up-beijings-smog-for-100-days-and-made-a-brick-from-what-he-collected/

VEL O_2

Loop.pH. TAIWAN. 2016. An installation in Taipei, a BMX track with a lung-like structures changes LED light colour while revealing the presence of airborne pollutants. The installation uses an advanced air quality sensor provided by a third party (Change London) to collect the data live, measuring six different air pollutants (3 gasses and 3 different particle sizes). The data is translated into seven different breathing rhythms and colours, from green to a dark red as progression into dangerous levels of pollutants. It allows the public to see real-time changes in the quality of the air, as a warning system based on the international standard Air Quality Index, aiming to inspire residents to adopt low-emission practices.

Source

http://inhabitat.com/bmx-track-features-lung-shaped-led-lights-that-change-color-based-on-air-quality/
http://loop.ph/portfolio/velo2/

SMOKE INTERVENTION

Xiao Zhu. CHINA. 2015. A company dedicated to providing clear air to Chinese citizens presented a social project which uses China's biggest cause of pollutants as a medium to raise awareness. Huge beams of light pointed directly into factories' smoke cloud-like canvases project a series of images during the dark of the night. These pictures show Chinese youth in numerous stages of dismay, pain and ultimately suffocation. Xiao Zhu filmed the performance and released it to the masses as a social movement with a simple message: "clean the air. Let the future breathe again."

Source

http://www.designboom.com/art/xiao-zhu-air-pollution-project-china-06-11-2015/
https://www.youtube.com/watch?v=1e1qGc66W9k

MOSS ART INSTALLATION

grOCAD. CANADA. 2016. An affective environment was created by immersing visitors in a humidified, verdant structure that holds and displays moss in an intimate way. The aim was to build a suitable environment to keep it, and allow people to interact with it closely. Mimicking the ecological niche of mosses as a soil builder and 'pioneer' species on barren environments, the sheer faces of the wooden structure were made hospitable to life through the mosses gentle green carpeting. Photo-documentation and samples were presented on wall space, which looked at the diverse species of mosses that have filtered air and built soil.

Source

http://www.reconstructingresilience.ca/?page_id=43

HI-TECH

TORRE DE ESPECIALIDADES

Elegant Embellishments. GERMANY. 2013. The "Torre de Especialidades" facade in Mexico City is shielded with a facade of Prosolve370e, a new type of tile whose special shape and coating can help neutralize the molecules that compose smog, the equivalent produced by an approx. of 1,000 cars driving by each day. The modules are coated with a superfine titanium dioxide (TiO_2), a pollution-fighting technology that is activated by ambient daylight. Besides the chemistry, the shapes of the tiles, a "quasicrystalline grid" create omni-directionality, and surface enlargement, which enhances their ability to receive and scatter UV light.

Status
Technology utilized in buildings around the world.

Source
http://www.fastcoexist.com/1681660/this-beautiful-mexico-city-building-eats-the-citys-smog
http://www.medicaldaily.com/mexico-city-hospital-eats-pollution-torre-de-especialidades-features-innovate-facade-tiling-265942
http://www.prosolve370e.com/

THE CARBFIX PROJECT

Reykjavik Energy, the University of Iceland, Columbia University and CNRS. ICELAND. 2012. Scientists and engineers working at a major power plant in Iceland have shown for the first time that CO_2 emissions can be pumped into the earth and changed chemically to a solid within months, radically faster than anyone had predicted.

Source
http://www.earthinstitute.columbia.edu/articles/view/3292
https://www.or.is/english/carbfix-project

THE SMOG FREE PROJECT

Studio Rosegaard. NETHERLANDS. 2013. A project supported by the Chinese Ministry of Environmental Protection, a 7 meter tower installed in Beijing that captures and collects $PM_{2.5}$ and PM_{10} airborne smog particles and releases clean air. A 360-degree coverage creates a circular zone by cleaning 30.000m^3 air per hour. The system works with a patented ozone-free ion technology, which uses green electricity to power itself. Jewelry products for sale are made from compressed smog particles collected from the tower.

Status
After its successful pilot in Rotterdam, the project is now starting a tour across the globe starting with Beijing.

Source
https://www.studioroosegaarde.net/project/smog-free-project/info/
http://www.wired.co.uk/article/smog-free-tower-china

AIRBOL

ConTREEbute. COLOMBIA. 2011. An 11 meter high tower was installed in Cities to clean the air in a radius of 80 meters. The structure imitates the natural process of trees, captures CO_2 and transforms it in O_2, but it also captures PM, SO_2 and NO, as well as virus and bacteria. The system has a fan that absorbs polluted air which takes it through a plasma field where particles are split and ionized simulating natural cycle conditions like rain, wind and thunder. After this process, the air comes out clean.

Status
News spreading to Mexico and other countries. Currently three towers installed in Colombia, two in Medellin and one in Bogota.

Source
http://contreebute.com/airbol/
http://contreebute.com/

CARBON CAPTURE PLANT

Climeworks. SWITZERLAND. 2016. A commercial carbon capture and storage plant sucks up air and filters CO_2. The technology is based on a cyclic adsorption-desorption process where the CO_2 binds with a filter, to be released only by heating it. The aim is to sell the stored gases by the tone to third parties, such as agricultural industries and beverage manufacturers for carbonated drinks.

Status
Pilot plant expecting to start operations October 2016.

Source
http://futurism.com/coming-soon-carbon-capture-plants-that-suck-co2-out-of-the-air/
http://www.climeworks.com/

THE GREEN JUNKIE

AMS Institute, MyEarth, and Wageningen UR. NETHERLANDS. 2016. Researchers are looking at a new type of honeysuckle plant, the Green Junkie. It naturally has lots of "hairs," which take in pollutants. Work has been done to change a gene in the Green Junkie to increase its number of plant hairs and make the plant "crave" more CO_2. A nutrient-rich mixture switches on a gene that creates that change in the hairs, it also stimulates them to be super-fast growers.

Status
Prototype phase. They're starting to test the Green Junkie on Amsterdam streets

Source
http://inhabitat.com/dutch-researchers-grow-carbon-hungry-plants-to-suck-up-extra-pollution/
https://www.fastcoexist.com/3061328/in-amsterdam-researchers-are-testing-a-flower-grown-to-suck-up-smog

CO_2NCRETE

UCLA Luskin Center for Innovation. USA. 2016. Researchers are turning CO_2 into sustainable concrete. The idea is to create a closed-loop process by capturing carbon from power plant smokestacks and using it to create a new building material. These "bricks" will be fabricated using 3D printers. By looking at carbon as a resource, the project aims to replace the production of cement, which is responsible of a large amount of greenhouse gas emissions.

Source

http://newsroom.ucla.edu/releases/ucla-researchers-turn-carbon-dioxide-into-sustainable-concrete
http://www.kurzweilai.net/how-to-turn-carbon-dioxide-into-sustainable-concrete

KAALINK

Graviki Labs. INDIA. 2013. The project harvests black smoke and converts it into printer ink. Blackened smoke pigmentation is actually unburned carbon from incomplete combustion. By taking it through a simple chemical process, the result is a really high-quality raw material for printing and ink industries. In order to capture the carbon, handheld devices will be attached to cars. To generate two cartridges of ink, the carbon produced by a car that travels six miles is required.

Status

KAALINK™ is currently in manufacturing trials.

Source

http://www.citylab.com/tech/2016/03/the-innovative-ways-people-are-recycling-air-pollution/471999/
http://www.graviky.com/kaalink.html

GIANT AIR VACUUM

Envinity Group, NETHERLANDS. 2016. Designed an 8 meter long industrial filter made of steel, which works like a big vacuum cleaner. The system has a filter from which air coming in from one side will come out clear from the other. It's designed to be placed on top of buildings to suck up toxic PM from the air in large quantities.

Status

Envinity Group unveiled their device at the Offshore Energy 2016 Exhibition & Conference in Amsterdam

Source

http://inhabitat.com/dutch-startup-unveils-enormous-vacuum-to-suck-pollution-out-of-the-air/
http://www.bbc.com/news/world-europe-37773746

GPAO

AIR Lab. DENMARK. 2015. A process discovered by researchers from The University of Copenhagen could be used to remove pollution from the air with the atmospheres natural self-cleaning process called the Gas Phase Advanced Oxidation method (GPAO). By infusing O_2, magnetic charges and UV Light to polluted air pulled in from the sky, those gas molecules are transformed into dust. The nature of the pollutants as gas molecules make them difficult to remove, because they are apart from one another. Thus, by replicating this cleansing process, those particles will be easier to remove.

Source

http://chem.ku.dk/research_sections/airlab/
http://inhabitat.com/copenhagens-air-lab-wants-to-eliminate-air-pollution-by-turning-it-to-dust/
http://www.aimspress.com/fileOther/PDF/environmental/environ-03-00141.pdf

In these final steps, this report as a result of bottom-up, participatory engagements intends to create that, to cross the chasm. Inspire and empower people to utilize design as a way to influence the issue at hand, which may mitigate and combat air pollution.

CONCLUSIONS

"…we need design that enables people to understand the wider contexts of their actions, their agency within society, and how they can act to create different outcomes, different futures."

- Dan Lockton

This paper had the purpose of providing an understanding of the issue of air pollution in MCMA from a different standpoint, the perception of the citizens. Also, to explore what has been done in its regard, to discover insights with a design thinking perspective. Its intent was to be a contribution to the domain of social change, to comprehend the nature of air pollution as a systematic, wicked problem. It drew on participation and collaboration as paramount elements in problematics like these.

Moreover, given the complexity of the problem, it established the various layer involved in the matter and it discovered that in order to effect social change, there are a series of steps that can be followed.
With regard to the first point, awareness, agency and willingness to change were set up as the different stages or levels which form the structure of the social change process. The second important idea was that there are steps that should be followed in order to effect social change, in which design in the broader sense can be utilized to assist an individual, a group and a community. These stages and steps are not meant to be a linear or sequential process but intended to be a cyclical iterative one, where awareness has to be followed by agency, directly linked to willingness to change, that in turn should lead to more awareness and so forth. Hence, design should be utilized to understand, to inspire, to change people's behaviour, by contemplating design as a catalyst.

This research served, therefore, as an evaluation of design; design tools and methods utilized to effect positive change in people's behaviour. Because design has the potential of assisting people on taking those steps which will eventually lead to social change, this project facilitates them by using design to UNDERSTAND. Understand the issue from a citizens' perspective, understand the reason behind it. Understand what they feel and why they do what they do. Understand how the issue can also improve upon itself when all stakeholders understand each other and foster empathy. Moreover, this project created ways to help people understand the world by creating something that can raise awareness, something that helps people understand the world they live in and they have help in creating. Strengthening the idea of the power of an individual. People often forget about the agency they have in their own lives because of the way they have grown up, their surroundings, their limitations, their social system. The lack of communication and trust that this system creates, makes, in turn, an individual input harder to grasp. This project, therefore, helped understand the notion and the power of an individual to effect that change. As to scalability, since the research helped in the realization of the importance of the input of an individual, it then proves the overall influence in a community for determining success.

Additionally, this project utilizes design to INSPIRE, this project offered a way to empower people into acting by giving them concrete real life examples to look for, to question and to be critical about, it also demonstrates the potential of creativity and design to solve social and environmental problems. In this respect, this quote from the book "Massive Change" by Mau et al. (2004) encompasses the idea "*…the main thesis of Toynbee's work is that the well-being of a civilization depends on its ability to respond creatively to challenges, human and environmental*"(p.15)[2].

Moreover, this research validates the use of design to create social CHANGE. It shows how people's behaviour can change for the better. Given that the social systems involves people's dynamics and interactions, by changing negative behaviors for the better, dynamics will change. In this sense, design can influence people's motivations and desires to engage in social change. As one of Lockton's quotes mentioned earlier in the paper, design researcher's' job is to understand people's behaviours and actions, because how people understand things affects how they behave. Hence, design can change and shape their understanding, to consequently change their behaviour for the better.

In short, this research has helped in the comprehension of the complexity of the issue of air pollution in the MCMA, but rather, help to understand the reason why it is so complicated and learn what can be done from the bottom-up as opposed to top-down. Finally, the following quote by Lockton (2015) illustrates the previous point in a romantic and powerful way: "*…we need design that enables people to understand the wider contexts of their actions, their agency within society, and how they can act to create different outcomes, different futures.*"[31]

FUTURE DIRECTIONS

Innovation plan

The project, because of its presented limitations, should pursue further work with a few recommendations following. This stage of the research should intend to prove the potential of the design research methods presented to effect social change towards better air quality. By proving whether it created changes in the behaviour of MCMA inhabitants, whether they lead to action and finally, if pollution decreased. The research should be taken forward as an Innovation-action plan. Several short as well as long term strategic pathways are proposed in order to continue the research.

What is being proposed in the short-term, is to prototype and probe the tools and methods introduced in this project. Three

particular activities should be contemplated, one after the other in a span of 6 months. The first one will be to share the resource package widely. Publish both the innovation report as well as the guide in social media and open source platforms, this to reach out to more people but also to a more diverse group. The package will be shared with social and environmental Organizations and Institutions in Mexico City, as well as schools and social movements, who have a wider range of connections and are able to target a broader audience.

The second strategy will be to conduct several embodied storming workshops across the MCMA. This could be done side by side with the first one (Research Package sharing). Again, the idea is to aim for a larger and more diverse audience, from all the different areas of the city, include low, medium and high income participants. The audience should aim for the general public, different age groups, students, professionals, workers, business owners, etc. To avoid assumptions and biases as much as possible and have a better understanding of the general sentiment of the whole population and be able to influence a larger sample.

A third strategy entails to conduct a survey, 6 months after having performed the first two activities, this with two main purposes. First, to prove whether people changed their behavior as a result of their participation in the workshops and the access to the resource package. Second, a feedback form will help improve the resources and the whole process. In this sense, feedback is required in order to be able iterate and improve as much as possible before continuing with the long-term pathways. However, the exact timeframe for this stage cannot be established, because this type of methods are not completely straightforward. They will rely on the samples' performance and feedback, therefore, a minimum of one iteration after 6 months is necessary.

Because these three pathways will have to reach many and more diverse groups of people, a partnership with other organizations is suggested. The "Lab for the City" (Laboratorio para la Ciudad, in Spanish)[70] is an Urban Innovation Hub (mentioned several times throughout the paper) who specializes in participatory activities to improve the City. It has the ability and reach to be the platform and channel to achieve this.

As to the long term strategies, the idea will be to perform an impact assessment, in which pollution will be measured and monitored through the many monitoring stations spread across the city. This to see if pollution levels decreased after a certain amount of time. This next stage should aim to empirically measure the impact from state X (prior to implementing the short term strategic pathways) to state Y (after the implementation of them) and prove the influence of this research on the quality of the air. The way in which this process would work is to perform two types of measurements. The first one should measure the pollution in the MCMA area in IMECAS as well as the emissions of specific pollutants and mark that number as **State X**. After the implementation of the short-term strategies, in a span of 6 months, a second measurement should be performed, this will be named **State Y**. This data will have measured whether the pollution in the MCMA decreased after utilizing DESIGN to create social change. This whole process, the implementation of the described short as well as the long strategic pathways is a process that should be again, iterative.

Extrapolation

To conclude, the aim of this project was to assist in the process of social change for a particular purpose, towards environmental sustainability, to change the state of an environment, the air. This research, although developed and probed in Mexico City, can be extrapolated to many other locations and situations, other domains and other social as well as environmental problematics. The general principle of design towards social change is applicable to anything relating human interaction, human behaviour and social change, across all wicked problems, wherever people are involved. In this same vein, as to the domain in ecology, this research could be applied to waste management and water purification, for example. In other domains, education and sexuality, to mention just a few. The general idea is to be able to use design to change the behaviour of the people to then change their futures for the better. Finally, it is important to consider that extrapolation begins with a Problem Finding phase. That first stage establishes a real problem to solve, identifying a real need and go forward with the Problem Framing, to eventually approach a Problem Solving phase.

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APPENDIX

APPENDIX A : LIST OF ACRONYMS

A list of the acronyms utilized throughout the paper. From chemical compounds to Institutions, etc.

TED Technology, entertainment, and design. A non-profit devoted to spreading ideas, usually in the form of short, powerful talks.

UN United Nations

NGO Non-governmental organization. A not-for-profit organization that is independent from states and international governmental organizations.

O_3 Ozone

O_2 Oxygen

CO Carbon Monoxide

CO_2 Carbon Dioxide

NO_2 Nitrogen Dioxide

SO_2 Sulfur Dioxide

PM Particulate Matter

PM_{10} Particles which diameter is smaller than 10 micrometers

$PM_{2.5}$ Particles which diameter is smaller than 10 micrometers

MCMA Mexico City Metropolitan Area

WHO World Health Organization

PNAS Proceedings of the National Academy of Sciences

GHG Greenhouse Gases

INECC Instituto Nacional de Ecología y Cambio Climático

IMECAS Índice Metropolitano de Calidad del Aire. Mexican reference for air quality index.

SEDEMA Secretaría del Medio Ambiente

SEMOVI Secretaría de Movilidad

LEZ Low Emission Zones

SLCP Short Lived Climate Pollutants

IMCO Instituto Mexicano para la Competitividad

CIDE Centro de Investigación y Docencia Económicas

IPC Índice de percepción de la corrupción

PISA Programme for International Student Assessment

OECD Organisation for Economic Co-operation and Development

SWIDD Standardized World Income Inequality Database

CSE Centre for Science and Environment

IDEO Innovation, Design Engineering Organization

MRI Magnetic Resonance Imaging

MRP Major Research Project

REB Research Ethics Board

TA Thematic analysis

LED Light-emitting diode

GPAO Gas Phase Advanced Oxidation

TiO_2 Titanium dioxide

APPENDIX B : PARTICIPATORY RESEARCH DATA

Data file with the details of the participatory design research session. Includes transcripts of participants' interactions and observations. Also, includes detailed analysis of codes and themes, as well as more elaborate intervention points in the generative session. Transcripts, Codes and themes, Persona Profile details, Journey map intervention points and suggestions.

EMBODIED STORMING (transcripts of the session)

Iteration 1

RED 1
Observations: DO & MAKE
Utilized a tree as a prop and made notes to follow.
While urbanization is happening, the community leader is being ignored by both gov and citizens.
After urbanization, the air is polluted again. Both citizens and gov don't care about affecting another environment.

Scientist: -
Leader: indigenous community living joyful life outside the City. Wants to be heard.
Air: approaches the City annoying the citizens
Gov: ignoring the citizens complains. Thought: *"I feel lazy."*Later suggest to the citizens to move to a healthier environment, a rural area where the air is clean and pure
Citizen: complaining about the traffic but not willing to switch to a different type of vehicle or change lifestyle or daily activities

GREEN 1
Observations: DO & MAKE
Since they were the first group to participate they still felt a little self conscious, the sketch was short but the message was sent.

Scientist: did not interact much. Thought: *"I told you so"*
Leader: expressing the citizen being a part of the problem not the solution, citizens are not willing to change their lifestyle
Air: annoying everyone silently, while everyone starts coughing
Gov: presents the environmental contingency to the public, where only electric cars will be able to circulate. Thought: *"I will get a part of the money from the sales of the cars"*
Citizen: it's hard and expensive to be part of the solution

BLUE 1
Observations: DO & MAKE
The air is dying, people don't care enough about it.

Scientist: diagnosing the air, studies show bad quality. Bringing the analysis to the Gov attention, also recommends the improvement of public transport and to listen to what citizens have to say.
Leader: taking the complaints into consideration but not doing much about them

Air: the scientist patient, very sick
Gov: asks the scientist what to do, revises suggestion brought by citizens. Thought: *"I want money."*Quickly dismisses complaints, later suggest a change in automobile utilizations but citizens don't like it.
Citizen: complaining to the gov with posters, but they hate bikes, don't want to verify their cars, not willing to cooperate.

Iteration 2
General Observations:
Everyone wanted to play the role as the air. The air is now the center of attention.

RED 2
Observations: DO & MAKE
A narrator is included: *"In 1920 the air was a happy person, the citizen started to attack and hit the air. Everyone is hurting the air. Citizens were just having fun, they didn't realize it was hurting them as well. After some years, the air got sick, very sick."*

Scientist: diagnosing the air, the issue is very delicate. Action is required immediately, if this continues like that, humans will cease to exist. Requires the gov to talk to the citizens.
Leader: not willing to change their habits, still having fun without consequences
Air: happy before the citizens hurt it, over and over again
Gov: asks the scientist for a diagnosis, proposes new policies for the utilization of automobiles. *"It's the only way to save the air from humanity."*
Citizen: kept on hurting the air, careless

GREEN 2
Observations: DO & MAKE
The use of environment props such as a tree to illustrate nature.

Scientist: flora and fauna are needed to survive, don't cut down trees.
Leader: coming to the scientist telling that gov wants to add a highway in the middle of a green protected area. Asking what do to.
Air: happily dancing around next to a tree and green areas, when highway is being built, the air gets sick
Gov:-
Citizen: they want the highway, they don't care about polluting, they want to get to work.

BLUE 2
Observations: DO & MAKE
The air is dead on the floor. They play it less seriously, taking the issue with humor.
Both sides want results. Citizens require immediate solutions from the gov. The gov needs proposals from the citizens as well. They can't do this alone. -it is a very complicated matter. Nobody really knows what to do.

Scientist: everyone helping the air. Approaching the gov.
Leader: goes with the secretary to ask for help, they want to join forces.
Air: really sick, it's dead and getting worse
Gov: first feels pressure bringing all together to suggest and contribute. Citizens have to be responsible as well. suggesting
Citizen: being hurt by the air, trying to help it

Debrief: SAY

General Observations: DO & MAKE
There was a strong difference in opinions from two people. One who works in the Government offered the point of view from the side of the decision-makers and another one as a citizen requiring more participation from everyone involved. People were nodding as an understanding of another person's point of view. There was no argument or discussion but only offering different points of view. At this point, participants were less active and seemed too tired to discuss further.
Other people thought that a balance is important, it's not only one side's fault.

STAR: S/he never imagined her/himself living the current lifestyle with no car, walking or biking everywhere. Her/his life changed in a good way because of the new job and now s/he acknowledges that as a citizen people complain and are angry about the issue but no one is willing to make that change, to sacrifice.
The situation is critical but people don't realize it enough. His observations on the sketches show how Mexican society looks at thing in a humorous ways. There are so many factors involved in the issue. The gov should motivate citizens, the way they act is not fair because they don't explain the situation to citizens, resulting in people not understanding how much it affects. Gov should not impose solutions, people don't do things because they don't understand the whole story. Agrees that people have to understand why and have a motivation to act differently.

TRIANGLE: As a government making decisions is complicated, very complicated. Citizens demand solutions but are not willing to change. There is information out there . Living in a healthy environment is a right we have as citizens. There are forums created by gov institutions to inform the citizens. But people are lazy to go or they don't have the interest so it gets complicated. The state has an obligation but there is also a lack of motivation and interest, gov shouldn't have to push people. It goes both ways. Sometimes one person things that is not worth the effort. Mexicans think that the gov takes advantage of the citizens while it is also the other way around. If there is no interest from the citizens it's hard for things to happen. Don't ask for things we are not ready for.

SQUARE: Having enacted this situation makes one more conscious already. I anyways try not to pollute and I use my bicycle, public transportation, etc. But I never took it like the air is that bad, I think is good that we do this activities, because it shows that someone cares about this. There are probably a lot of things happening in this regard but nobody goes or cares, doing this activity makes me feel different.

CIRCLE: Representing the air gives you a different perspective. Different roles, gave different perspectives like the Government's. Also, because it's the leader and you don't trust them you go against them without knowing. I think it's too much to see the bad guys and corruption and you go thinking everything is the same while it's not. Duality in all suggestions or proposals.

FINDINGS

FIRST THEMES:
- Awareness / understanding
- Responsibility /agency
- Lifestyle changes, willingness to change
- Caring / engagement
- Attitude towards the issue

PERSONA - JOURNEY MAP

REGINA. The female is a 28 year old woman, who works in management at a big Company. She is single but living with a partner. She owns one compact car that she uses to drive around 45-60 minutes to work. Some of her immediate needs are to pay rent, buy food, have a somewhat creative entertainment life and good health. She also thinks about saving for the future. These savings are required to accomplish some of her goals. A master's degree, travel, have a family and a dog and own her own home.

Regina drives to the gym in the morning, at around 7. It takes her 45 minutes to get there. She has breakfast at work because she starts at 9am. At 12-1pm she has lunch. She is off by 6pm and drives back home, it takes her more than 1 hour because its rush hour in the City. Sometimes she does some entertainment activities or goes home to have dinner. She usually cooks dinner as well as food for the next day. She sleeps at around 10-11pm.

Intervention points:
Transportation: driving alone for two hours daily is not sustainable
Waste management: Eating lunch out is expensive and not sustainable
Office: supplies are usually misused

Suggestions:
She could carpool with people from her office who live close-by. She could plan her activities the day before in order to do so.
She could cook lunch the night before and take tupperwares to avoid waste. She could even start growing her own veggies at home. She should buy local products and consume responsibly.
She should turn off the computer and other devices in the office while not using them to save energy. She can suggest not to print and waste paper unnecessarily.

MARIO. The male persona was a 40 year old man. He is an entrepreneur in the service industry. He is married and has two kids and a dog. He owns an SUV and a motorcycle. Since he owns a restaurant he often does home office. His needs are mostly family related. His kids tuition, family health, the house mortgage, family entertainment and savings. Some of his goals include the growth of his business, stability and family travel. Kids education is key, although he would like to eventually get a beach house.

Mario wakes up at 6 am. he has to drop the kids at the bus stop. They use the scholl bus to get there. At the same time he walks the dog, some days he goes for a run after it. He eats breakfast at 9am at home. He usually does home office all morning until he can pick up the

kids. The family has lunch at around 2-3pm. After lunch, he drives his motorcycle for 10 minutes to the restaurant to check up on things. He prefers to use the bike because there is no easy parking spot. At night he comes back home, has dinner and enjoys his family.

Intervention points:
Most of his intervention point were identified as a business owner.
Waste management: restaurants waste a lot of food

Suggestions
He should propose recycling and reusing at home. Kids stuff, plastic and food.
At the restaurant, he should promote education towards less waste. Try not to have a food stock, always fresh to prevent food waste. Buy local products to close the loop. Grow own products to avoid food waste and allow for fresh products. Respect and promote rules and regulation towards organic and solid waste.

General Observations:
People plan their activities based on traffic. If one exercises, going to the gym early is part of the activities that help avoid traffic in the mornings. Other activities such as grocery shopping, cooking meals, etc.
Factors like waste management and food waste were discovered, landfill pollution causes air pollution as well.

AIR POLLUTION IN MEXICO CITY

MAJOR RESEARCH PROJECT

Graciela Guadarrama Baena

December 2016