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Air Quality Optimization for the Total Life-Cycle of Buildings

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Abstract:

Problem Definition:

Building construction and operation have wide and long-term effects on air pollution status especially in the developing countries. For the building, most of the air pollution prevention and mitigation practices are dealing with its materials and operating systems as sources of air pollution regarding to the ways of production, transportation, construction, and related behaviours during building operation.

So the different decision makers related to the building project delivery stages PDS (from pre-studies, site selection, investment study, TOR, schematic design, construction drawings & specifications, bidding, construction, operation, renovations and demolishing at last) most of them are individually concerning air pollution issues with different levels of awareness.

Keywords: Building, Environmental Management, Project Management,

Objectives: To draw a holistic view of air pollution footprints for building life-cycle to make the optimum reduction of air pollution occurred during building's total life-cycle.

Background Literature:

Exploring air pollution aspects and related consequences; and building related air pollution sources (site modifications, materials, systems) during all stages of PDS; in addition to construction equipments and transportation.

Methodology:

Correlation analysis was used to investigate the relative weightings of the building related sources of different air pollution aspects during all stages to synthesise a matrix of expected air pollution hazards of the building from cradle-to-grave.

Expected Results:

Delivering such a matrix can help to get a holistic comprehension of all air pollution hazards regarding all building aspects along its life-cycle; which can more practically direct the designers to optimize the building design with respectable concern with its air pollution related behaviour along its life-cycle, this multi-parametric way might be objective-oriented and more effective than the linear one that using design checklists extracted from one of EIA rating systems (BREEAM, LEED, …etc).

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1- Introduction & Problem Definition:

Building construction and operation have wide and long -term effects on air pollution status especially in the developing countries. For the building, most of the air p ollution prevention and mitigation practices are dealing with its materials and operating systems as sources of air pollution regarding to the ways of production, transportation, construction, and related behaviours during building operation.

So the different decision makers related to the building project delivery stages PDS (from pre-studies, site selection, investment study, TOR, schematic design, construction drawings & specifications, bidding, construction, operation, renovations and demolishing at las t) most of them are individually concerning air pollution issues with different levels of awareness.

This paper aimed to draw a holistic view of air pollution footprints for building life -cycle to make the optimum reduction of air pollution occurred during building's total life-cycle.

1-Air Pollution

1-1 Air Pollution & Air Quality

Air pollution is the introduction of chemicals, particulate matter, or microscopic organisms into the atmosphere; in particular, when concentrations of those sub stances cause adverse metabolic change to humans or other species. The most common and widespread air pollutants include CO, SO2, NOx and particulate matter (PM).

Presently, the greatest occurrences of air pollution are in China, India, Indonesia, South Africa, Brazil, Mexico and Argentina. Each year, air pollution is the cause of millions of human deaths, and even larger numbers of respiratory, circulatory, and cancer -related disease occurrences. Also, indoor air pollution is a significant source of human death and disease—mortality and morbidity—through indoor burning of wood and charcoal (especially in developing countries), tobacco smoking, radon trapping and a host of chemical substances found in paints, printing supplies and cleaning products. [1]

2-2 Global Dust Budget

The global dust budget refers to an accounting of the emission, atmospheric loading, and deposition of the mineral dust aerosol on a global scale. Soil particles are entrained into the air by wind erosion caused by strong winds over bare ground. While large sand particles quickly fall onto the ground, smaller particles (less than about 10 micrometers [μm]) stay suspended in the air as mineral (or soil) dust aerosol. Billions of tons of mineral dust aerosols are released each year from arid and semi-arid regions to the atmosphere. Mineral dust aerosol can be transported long distances, and can influence their quality far beyond the source region. For example, North African (Saharan) dust is often transported over the Atlantic Ocean, reaching the North or South American continents, and dust from East Asian deserts travels over the Pacific Ocean and occasionally influences air quality in North America. Since these large-scale dust events have been captured by satellite imagery, the issue of mineral dust has been recognized as a global-scale problem. [2]

Mineral dust aerosol can cause air quality hazards such as visibility impairment and respiratory problems, which can pose risks to human health. Mineral dust aerosols also play an important role in the Earth's climate in several ways, including exe rting a significant direct and indirect influence on the atmospheric radiation balance. [2]

2-2-a Locations of dust sources

Dust emission is associated with many environmental parameters. Generally, dust storms are caused by strong, gusty winds-associated with the synoptic-scale disturbances or meso- or micro-scale thermal convective activities. Dust emission is inhibited by surface -covering elements such as vegetation, snow cover, and giant rocks, and soil-binding elements including high soil moisture and salt content. With these conditions, a ctive dust-producing areas are confined to bare ground or sparsely vegetated ground with annual rainfall under 200–250 millimeters (mm), and to regions with strong winds. [2]

The world's largest source of dust is the Sahara Desert, and the estimated range of dust emission from the Sahara Desert is from 160 to 760 Tg yr^{-1}, ranging from one-third to over half of the total global dust emission. [2]

2-2-b Human influence on dust emission

While dust storms are natural events, human activities such as inappropriate agricultural practices, overgrazing, and deforestation cause soil degradation and desertification, thus strongly influencing the availability of dust by surface disturbances. It has been pointed out that the atmospheric dust loading has been increased as a result of such activities. The contribution of anthropogenically disturbed soils to global dust emissions has been estimated to be as high as 30% to 50%. However, recent research suggests that agricultural areas contribute less than 10% to the dust load. Thus, natural causes are currently considered to be the primary source of dust emission on a global scale. [2]

2-3 Greenhouse Gases (GHGs) & Global Warming

Smog hanging over cities is the most familiar and obvious form of air pollution. But there are different kinds of pollution—some visible, some invisible—that contribute to global warming. Generally any substance that people introduce into the atmosphere that has damaging effects on living things and the environment is considered air pollution. [3]

CO2, as one of greenhouse gases, is the main pollutant that is warming Earth. Though living things emit CO2 when they breathe, CO2 is widely considered to be a pollutant when associated with cars, planes, power plants, and other human activities that involve the burning of fossil fuels such as gasoline and natural gas. In the past 150 years, such activities have pumped enough carbon dioxide into the atmosphere to raise its levels higher than they have been for thousands of years. [3]

Most GHGs come from the combustion of fossil fuels in cars, factories and electricity production. The gas responsible for the most warming is CO2. Other contributors include methane released from landfills and agriculture (especially from the digestive systems of grazing animals), nitrous oxide from fertilizers, gases used for refrigeration and industrial processes, and the loss of forests that would otherwise store CO2. [4]

Different GHGs have very different heat-trapping abilities. A molecule of methane produces more than 20 times the warming of a molecule of CO2 and NO is 300 times more powerful than CO2. CFC (which have been banned in much of the world because they also degrade the ozone layer), have heat-trapping potential thousands of times greater than CO2. But because NOx & CFC concentrations are much lower than CO2, none of these gases adds as much warmth to the atmosphere as CO2 does. [4]

In order to understand the effects of all the gases together, scientists tend to talk about all GHGs in terms of the equivalent amount of CO2. Since 1990, yearly emissions have gone up by about 6 billion tons of "CO2 equivalent" worldwide, more than a 20% increase. [4]

2-4 Global Warming Consequences

In the last 100 years, the Earth's average surface temperature has risen by about 0.6 degrees Celsius, and it may climb 1.5 to 6 degrees Celsius higher by 2100. [5]

Some impacts from increasing temperatures are already happening. Ice is melting worldwide, especially at the Earth's poles. This includes mountain glaciers, ice sheets covering at West Antarctica and Greenland, and Arctic sea ice. Some butterflies, foxes, and alpine plants have moved farther north or to higher, cooler areas. Precipitation (rain and snowfall) has increased across the globe, on average. Spruce bark beetles have boomed in Alaska thanks to 20 years of warm summers. The insects have chewed up 4 million acres of spruce trees. Sea level rise

became faster over the last century and are expected to rise between 18 and 59 cm. by the end of the century, and continued melting at the poles could add between 10 to 20 cm. [6]
Species that depend on one another may become out of sync. For example, plants could bloom earlier than their pollinating insects become active.
Hurricanes and other storms are likely to become stronger, so floods and droughts will become more common, and some diseases will spread, such as malaria carried by mosquitoes. Rainfall in Ethiopia, where droughts are already common, could decline by 10 percent over the next 50 years. [6]
Less fresh water will be available. If the Quelccaya ice cap in Peru continues to melt at its current rate, it will be gone by 2100, leaving thousands of people who rely on it for drinking water and electricity without a source of either. [6]
Ecosystems will change—some species will move farther north or become more successful; others won't be able to move and could become extinct. Now, humans have increased the amount of CO_2 in the atmosphere by more than a third since the industrial revolution. These large changes have historically taken thousands of years, but are now happening over the course of decades. [7]
The rapid rise in GHGs is a problem because it is changing the climate faster than some living things may be able to adapt. Also, a new and more unpredictable climate poses unique challenges to all life. Scientists are already seeing some of these changes occurring more quickly than they had expected. [7]
Based on a study made by Dr. Paul Epstein at Harvard Medical School this global warming, could cause more frequent and intense symptoms for the estimated 50 million Americans who suffer from allergies and the approximately 18 million with asthma, which is frequently triggered by allergens. In 1998, at least 5,438 people died of asthma in this country, and 423,000 were hospitalized for it. Hotter weather means more ozone, or smog, is produced from the burning of fossil fuels, and that will cause more respiratory effects, and already, approx. half of all Americans live in areas with unhealthy ozone levels. [5]

3- Air Pollution in Egypt

There are numerous sources to air pollution in Egypt, as in other countries. However, the formation and levels of dust, small particles and soot are more characteristic in Egypt than presently found in industrialized countries. Some of the sources for these pollutants, such as industries, open-air waste burning and transportation, were also well known problems in most countries only 10 to 20 years ago. [8]
Another important source for PM is the wind blown dust from the arid areas. These particles are, however, to be found in the larger particle fraction.
The World Health Organization claims that air quality in Cairo, Egypt, is up to 100 times what is considered a safe limit causing a serious risk of developing serious respiratory disease and cancer from inhaling particulates in the air. [9]

3-1 The Main Causes of Air Pollution in Egypt

- **Transportation**

  Many Egyptians rely upon extremely old vehicles for transportation. These inefficient vehicles cause the carbon present in fuel to ineffectively react with oxygen during combustion, producing CO or condensing to form particles of soot. The hydrocarbons do not combust completely and are released as gaseous hydrocarbons or absorbed by particles, increasing the particulate mass in the air. [9]

- **Industrial**

  Industrial facilities such as factories and plants emit toxic gases into the atmosphere. Another major source of toxic emissions in Egypt is the widespread open-air burning of trash and waste. Waste landfills also give off Methane, which, although not toxic, is highly flammable and can react in the air with other pollutants to become explosive. Major industrial pollutants include SOx, NOx, CO and CO2. [9]

- **Meteorological**

The speed at which pollutants disperse in the air is determined by meteorolog ical conditions such as wind, air temperature and rain. Egypt and Cairo, particularly, have a very poor dispersion factor due to lack of rain and the layout of streets and buildings, which are not conducive to air flow. [9]

- **Waste Burning Problem**

Open air waste burning has been observed in several areas of Egypt. This type of burning at large waste collection areas may create considerable health impact to the population. Presently no measurements have been performed of PAH (Poly Aromatic Hydrocarbons) and dioxins downwind from these sources. [10]

Dioxins are by-products generated from processes when heat is applied to substances containing carbon, oxygen, hydrogen and chlorine. [10]

The main source of dioxins at present is waste incineration. Other sources ex ist, such as emissions from electric steel making furnaces, cigarette smoke, and automobile exhaust. The behaviour of dioxins in the environment is not fully known. Taking the atmospheric pathway, for example, dioxins in the air are associated with particu late matter and fall to the ground, contaminating soil and water. It is thought that over long periods of time these dioxins accumulate in aquatic sediments and enter the food chain when ingested by plankton and fish, thereby starting to concentrate in org anisms. [10]

3-2 Egyptian Air Pollution Typical Sources

Some of the typical sources in Egypt are presented with related air pollutants in Table 1.

Table 1: Some typical source types and their most important pollutants , Source: [10]

Source type	**TSP/PM**	**SOx**	**NOx**	**COx**	**Toxins**
Process Industries	XXX	XX	XX	X	XXX
Oil and fuel in Industries	XX	XX	X		X
Power plants	XX	X	X		X
Commercial	X	X	X	X	XX
Transportation	XX	XX	XXX	XXX	X
Open air (waste) burning	XXX	XX	X	XX	XXX
Natural	XX		X		

Total Suspended Particulate matter (TSP), solid and liquid particles, are emitted from numerous manmade and natural sources such as open air waste burning, industrial processes (large industries and small enterprises) and diesel powered vehicles. Also wind blown dust from arid areas may create particles in the air . SO2 is formed when fossil fuels such as coal , gas and oil are used in large and small industries and for power generation. NOx are mostly generated from automobile traffic and from burning of fossil fuels. Also some NOx generates from natural sources such as lightning, forest fires, volcanoes and microbes in soil. Other pollutants include CO, emitted mainly from gasoline powered motor vehicles; lead, resulting from the use of alkyl lead as an antiknock agent in gasoline, and various toxins generated from open-air burning and a numerous type of small smelters and enterprises. [10]

The larger industries in Egypt are claimed to be the most important sources for air pollution. Related to the amount of emission rates (in tons per year) this may be correct, but when we measure ground level concentrations inside highly polluted areas, other sources emitting pollutants at the surface may be as important for the exposure to the popul ation.

Large diffusive emissions of dust from various large and small industries also contribute to the air pollution measured at ground level. These diffusive emissions are normally at low levels above the surface, and will also be trapped during specific meteorological conditions in the cold stable air, giving rise to very high concentrations. [10]

4- Air Pollution Aspects (Global & National):

Air pollution generally consists of toxic solid and gaseous particles that become suspended in the air. This in turn can cause significant harm to humans, animals, and the environment. Though some air pollutants occur naturally, such as through forest fires, many are added to the air through human activities such as burning fossil fuels, industrial processes, incineration of waste, dry cleaning processes, spraying of aerosol products, solid waste landfills, etc. [11]
The following are the most common individual air pollutants:

- Aerosols
- Carbon monoxide (CO) & Carbon dioxide (CO2)
- Chlorofluorocarbons (CFCs)
- Ground level ozone (Smog)
- Hazardous Air Pollutants (HAPs) (also known as Toxic Air Pollutants (TAPs)) such as benzene, perchloroethylene, methylene chloride, asbestos, toluene, heavy metals (mercury, cadmium, chromium, and lead), and dioxins
- Hydrochlorofluorocarbons (HCFCs)
- Methane
- Nitrogen oxides (NOx)
- Particulate Matter (PM), or solids suspended in air, such as acids, organic chemicals, metals, dust, or allergens
- Propellants
- Radiation
- Radon
- Sulfur dioxide (SO2)
- Volatile Organic Compounds (VOCs)

Individual pollutants can have negative impacts on the environment and human health, but what is of greater concern is how air pollutants react with each other.
Several sub-types of air pollution include:

- Acid rain
- Greenhouse gas emissions (GHGs) which contribute to the greenhouse effect, global warming, and climate change
- Ozone depletion
- Smog or ground-level ozone pollution

On other hand, Air Pollutants can be classified as primary or secondary. [12]
Primary pollutants are substances that are directly emitted into the atmosphere from sources. The main primary pollutants known to cause harm in high enough concentrations are the following [12]:

• Carbon compounds, such as CO, CO2, CH4, and VOCs
• Nitrogen compounds, such as NO, N2O, and NH3
• Sulfur compounds, such as H2S and SO2
• Halogen compounds, such as chlorides, fluorides, and bromides
• Particulate Matter (PM or “aerosols”), either in solid or liquid form, which is usually categorized into these groups based on the aerodynamic diameter of the particles:

1. Particles less than 100 microns, which are also called “inhalable” since they can easily enter the nose and mouth.
2. Particles less than 10 microns (PM10, often labeled “fine” in Europe).

These particles are also called “thoracic” since they can penetrate deep in the respiratory system.

3. Particles less than 4 microns. These particles are often called "respirable" because they are small enough to pass completely through the respiratory system and enter the bloodstream.
4. Particles less than 2.5 microns (PM2.5, labeled "fine" in the US).
5. Particles less than 0.1 microns (PM0.1, "ultrafine").
Sulfur compounds were responsible for the traditional wintertime sulfur smog in London in the mid 20th century. These anthropogenic pollutants have sometimes reached lethal concentrations in the atmosphere, such as during the infamous London episode of December 1952. [12]
Secondary pollutants are not directly emitted from sources, but instead form in the atmosphere from primary pollutants (also called "precursors"). The main secondary pollutants known to cause harm in high enough concentrations are the following [12]:
• NO_2 and HNO_3 formed from NO
• Ozone (O_3) formed from photochemical reactions of nitrogen oxides and VOCs
• Sulfuric acid droplets formed from SO_2, and nitric acid droplets formed from NO_2
• Sulfates and nitrates aerosols (e.g., ammonium (bi) sulfate and ammonium nitrate) formed from reactions of sulfuric acid droplets and nitric acid droplets with NH_3, respectively
• Organic aerosols formed from VOCs in gas-to-particle reactions

In the 20th century, it was recognized that petroleum products are responsible for a new type of "smog", a photochemical summertime smog composed of secondary pollutants such as ozone, that is quite different from the winter sulfur smog. Photochemical smog was first recognized in the city of Los Angeles in the 1940s. After decades of research, the smog was identified as the product of photochemical reactions involving "precursors (NOx and VOC) and sunlight, with the production of ozone and other secondary chemicals. [12]
While NOx are emitted by a wide variety of sources, automobiles mostly emit VOCs, even though contributions can be found from vegetation and common human activities, such as bakeries. Some secondary pollutants – sulfates, nitrates, and organic particles – can be transported over large distances, such as hundreds and even thousands of miles.
Wet and dry deposition of these pollutants contributes to the "acid deposition" problem (often called "acid rain"), with possible damage to soils, vegetation, and susceptible lakes. [12]

5- Air Pollution Consequences:

As air mixes freely between regions as well as between indoor and outdoor air, it is hard to escape air pollution. Here are some common ways people come in contact with polluted air [11]:

- Inhaling contaminated air
- Eating foods that have come in contact with contaminated air (both plant and animal products)
- Drinking water with dissolved air pollutants
- Consuming contaminated soil
- Coming in physical contact with substances (such as soil or dust or water) that has been contaminated with polluted air

In addition to causing many human health problems, air pollution also damages the planet as a whole. Such as when pollutants like SO_2, NOx, ozone, and peroxyacl nitrates enter the atmosphere they are able to damage the leaves of trees and other plants. This impedes their ability to conduct photosynthesis, which is a necessary process for absorbing CO_2.
Air pollution also damages food crops resulting in lower yields, which will become a concern for global food demands in the decades to come. [11]
Many air pollutants are carcinogens. People who breathe in these poisons are at a higher risk for asthma and reproductive-system damage. According to the U.S. Environmental Protection

Agency, birth defects can also be caused by air pollution. A 1995 study found a link between air pollution and increased deaths from cardiovascular and respiratory problems. Humans are not the only living creatures affected by toxic air pollutants. Some tox ins, like mercury, settle onto plants and into water sources that are then consumed by animals. The health effects of these poisons are then magnified up the food chain. Animals that are at the top of the food chain end up with the largest concentrations o f toxins in their bodies. [13]

5-1 Indoor Air Pollution

Indoor air pollutants include things like smoke from wood stoves and cigarettes, but some pollutants, like radon or CO, are odourless, tasteless and unseen. You may assume that the quality of the air in your home is safe, when in reality it poses health threats, such as increased risk of pneumonia or aggravated asthma symptoms. Long -term effects of indoor air pollution include heart disease, respiratory diseases or cancer. [14]
Indoor air pollution refers to the occurrence of contaminants within a home, workplace (or other inhabited enclosure) arising from such sources as fuel combustion for heating or cooking; from stored substances, furnishings and carpeting; or from the particular geology (underlying rocks) of an area. [15]
As cited by the Indian Council of Medical Research Bulletin, the report of the World Health organization (WHO) emphasizes the 'rule of 1000' which states that when a pollutant is released indoors, it is one thousand times more likely to reach people's lungs than a pollutant released outdoors. More than 1.6 million people, mainly women and children, die prematurely each year after breathing high levels of indoor smoke. This represents approximately twice the estimated mortality due to outdoor pollution. Children and senior citizens can be more vulnerable to indoor pollution because their immunity may be compromised. [15]
People in general spend approx. 90% of their time breathing indoor air, so indoor air quality can affect the health, safety and comfort of occupants. Indoor air problems can be subtle and do not always produce easily recognized impacts on health. Nonetheless, poor indoor air quality gives rise to demonstrated short- and long-term health problems. Significantly, [15]

5-2 Sources of Indoor Air Pollutants

Sources of indoor air pollutants can originate within any relatively enclosed structure (for example, an office building, a single family dwelling); of course, problematic pollutants can be drawn indoors from outdoor sources. Since indoor air is recycled over and over, it can trap and accumulate pollutants. Table 2 shows the major sources of indoor air pollution. [15]

Table 2: Major Sources of Indoor Air Pollutants, Source: [15]

Indoor pollutant	**Major sources**
CO	Fuel/tobacco combustion
Fine particles	Fuel/tobacco combustion, cleaning, fumes from cooking oil
NOx	Fuel combustion
SOx	Coal combustion
Arsenic and fluorine	Coal combustion
VOCs & Semi VOCs	Fuel/tobacco combustion, furnishings, construction materials, fumes from cooking, consumer products
Aldehydes	Furnishing, construction materials, cooking
Pesticides	Consumer products, dust from outside
Asbestos	Wear or demolition of construction materials
Lead	Wear of painted surfaces
Biological Pollutants	Moist areas, ventilation systems, furnishings
Radon	Soil under buildings, construction materials
Ozone	Photocopier, printers
Persistent Organic Pollutants (POPs) Brominated flame retardants (BFRs) Polycyclic Aromatic Hydrocarbons (PAHs)	Cables, computers, TVs and household textiles Fuel/tobacco combustion, fumes from food, e.g. from cooking oil

Among all the indoor air pollutants, persistent organic pollutants (POPs) persist in the environmental media and are extremely lethal even in small amounts. Exposure to POPs is recognized as an important environmental risk factor for humans causing cancer, nervous system damages, reproductive and immune system impairments. Once released from the sources, they can remain unaltered and persist in the environment for long periods because of their extensive half-life. They are lipophilic, bio-accumulate in organisms (in their fatty tissue) and may then build up in food chains (bio-magnification). In addition to that, POPs can reach organisms through the long-range transport mechanisms crossing regional and national boundaries. [15]

Biological contaminants like bacteria, molds, viruses and yeasts are usually found in moist indoor environments. They can also act as human pathogens. Their potential health effects include allergies, irritation and sensitivity (because of volatile organ ic chemicals, VOCs, produced during metabolism) and toxicity (due to mycotoxins produced by molds). Molds can cause major structural damage and may lead to financial losses. There have been reports of severe illness as a result of indoor mold exposure, par ticularly due to Stachybotrys chartarum, a toxic black mold. [15]

Dilution of indoor pollutants with outdoor air is effective to the extent that outdoor air is free of harmful pollutants. There is strong evidence to demonstrate the association between ventilation, air movement in buildings and the transmission or spread of such infectious diseases as measles, tuberculosis, chickenpox, influenza, smallpox and severe acute respiratory syndrome. In addition, the odors may result in psychological effects and disruption in work. [15]

Indoor air pollution is a major health concern in today globally. In many developed countries, energy efficiency improvements sometimes make habitations comparatively airtight—with reduced levels of fresh air and elevated levels of pollutants. On a global scale, the use of solid fuels for cooking and heating is likely to be the largest source of indoor air pollution. In developing countries, most indoor air pollutants originate from the combustion of unprocessed solid biomass fuels like wood, dung, coal and crop residues used by poor urban and rural folk for cooking and heating. Approx. 90% of rural households in developing countries still rely on such fuels. Burning such fuels produces a large amount of smoke and other air pollutants in the confined space of the home, resulting in relatively high exposure levels. [15]

5-3 Consequences of Indoor Air Pollution Exposure

Indoor air pollution is responsible for a high degree of morbidity and mortality warranting immediate steps for intervention by the general public and the policy makers.

It is caused by burning traditional fuels such as dung, wood and crop residues and causes considerable damage to the health particularly of women and children. Cataract and adverse pregnancy outcome (LBW and still births) are conditions shown to be associated with the use of biomass fuels. [15]

Health effects from exposure to indoor air pollutants may be experienced soon after exposure or even in some cases after many months or years. Also, immediate effects may show up after a single exposure or after repeated exposures including irritation of the eyes, nose and throat, headaches, dizziness and fatigue. Such symptoms of diseases as asthma may occur soon after exposure to indoor air pollutants. Increases in the incidence of asthma and allergies worldwide during recent years have stimulated research on potential environmental causes

The occurrence of respiratory and pulmonary diseases is the most common outcome of the indoor air pollutants. The most commonly reported health effects of indoor air pollutants are acute respiratory infections (ARIs), especially childhood ARIs, that are the single most important cause of mortality in children aged less than 5 years, responsible for between 1.9

and 2.2 million children deaths annually in this age group globally. Women and children in rural areas of developing countries are exposed often to high levels of pollutants from biomass combustion that is associated with a range of respiratory symptoms. The chemicals resulting from combustion of coal may form residues on household surfaces and food. Children raised in homes using indoor coal for cooking or heatin g appear to be about a half-inch shorter (skeletal growth impairment) at age 36 months than those in households using other fuel sources. In developed countries, smoking is responsible for over 80% of cases of chronic bronchitis (inflammation and swelling of the lining of the airways leading to its narrowing and obstruction), emphysema (damage of lung alveoli characterized by breathing difficulty) and chronic obstructive pulmonary disease (characterized by wheezing, chronic cough and breathing difficulty). [15]
Indoor air pollutants (from cooking for instance), results in exposure of the eyes to the radiating smoke containing toxins that are absorbed by the lens of the eyes. This results in the opacity of the lens. The prevalence of cataracts is higher in females than in males in developed and developing countries and in developing countries cataracts occurs at an earlier age. Contact with indoor air pollutants (as CO) can also result in adverse pregnancy outcomes; still births and low birth weight (LBW) which has severe effects including increased mortality during infancy. [15]
Another set of health problems associated with time spent in a building with inadequate ventilation and contaminants from various sources are commonly referred to as Sick Building Syndromes (SBSs), that include, eye, nose and throat irritation; mental fatigue; headaches; airway infections; coughing; wheezing; and nausea. SBS has been described as having three or more above mentioned symptoms. [15]

5-4 Measures to Reduce Indoor Air Pollution

- Preventing source control (a preventive technique; as, banning smoking in public areas) and source isolation (when source can not be removed; as, separate venting of bathrooms) [15]
- Increasing ventilation and dehumidification to facilitate the reduction of microbial growth.
- Controlling sources of indoor pollutants - as cleaning products, emissions from furnaces and propane heaters or stoves, paint, paint strippers, and glue - to reduce toxins and irritants released into the air.
- Servicing and adjusting heaters and stoves regularly reduce their emissions.
- Reduce or eliminate the use of cleaners and solvents indoors, unless you can ventilate the area properly by moving an adequate amount of fresh air into the building through ventilation with the proper air filtration systems or air cleaners to filter dust and pollutants. [14]

6- Building Related Air Pollution (Site, Materials and Systems):

Construction industry has a significant and irreversible impact on the environment [16]:
- Use of land in competition with other activities, such as agriculture;
- Use of virgin land such as forests, wetlands and coastal areas, which often implies loss of biodiversity;
- Massive use of natural resources, many of which are non-renewable
- Pollution of air during the transportation of materials and site activity
- Consumption of water and pollution of water reserves
- Generation of waste owing to poor resource management
- High energy consumption on site and in completed facilities

Buildings significantly influence the environment in the eight major stress categories: use of raw materials (30%), energy (42%), water (25%), land (12%) and pollution emission such as atmospheric emissions (40%), water effluents (20%), production of solid waste (25%) and other releases (13%). [16]

6-1 Air Pollution Hazards of Major Construction Materials

Extraction of aggregates (sand & gravel) used in making concrete, results in many ecological damage including air pollution, so UK has incentivized the use of recycled products by ordering new aggregates' tax by April 2002. [16]

Cement is one of the basic construction materials and cement production is the third ranking producer of CO_2 in the world after transport and energy generation, it is responsible for 7-10% of the world's total CO_2 emission. [16]

The process of producing concrete whatever on site or at a ready -mixed batching plant involves accurately weighing the required quantity of each constituent material and mixing them together either in the drum of a mixer truck or in a static pan mixer. During the manufacture of ready-mixed concrete, waste arises from three sources[16] :

1. Washing out truck mixer drums at the end of each working day to prevent fresh concrete residue from setting in the drum overnight;
2. Washing down the yard and plant;
3. Occasionally unwanted fresh concrete is returned to the batching plant from site .

6-2 Construction Materials Waste

The causes of waste in construction are numerous, and are usually classified under two headings known as direct and indirect waste. <u>The direct waste</u> are generating in transport, delivery, storage, cutting, spillage, theft, vandalism, wrong use, wrong specification, learning -by-doing waste and inefficient plant, and <u>the indirect waste</u> are associated with the characteristics of the material, bespoke dimension make-up, production waste and poor workmanship. [16]

6-3 Construction Activities Emissions

The construction industry is responsible for around 4% of particulate emissions, through many activities as: land clearing, operation of diesel engines, and unloading of building materials onsite, road laying, demolition, burning, and working with toxic materials. All construction sites generate high levels of dust (typically from concrete, cement, wood, stone, silica) and this can carry for large distances over a long period of time. Construction dust is classified as PM10 - particulate matter less than 10 microns in diameter. [17]

Although the dust is less toxic than the exhaust but if the dust particles not be captured, they'll stick together and conglomerate in the atmosphere, then they can get into the bloodstream and the lungs and have adverse health effects. [18]

Research has shown that PM10 penetrate deeply into the lungs and cause a wide range of health problems including respiratory illness, asthma, bronchitis and even cancer. Another major source of PM10 on construction sites comes from the diesel engine exhausts of vehicles and heavy equipment. This is known as diesel particulate matter (DPM) and consists of soot, sulfates and silicates, all of which readily combine with other toxins in the atmosphere, increasing the health risks of particle inhalation. [17]

Diesel is also responsible for emissions of CO, hydrocarbons, NO_x and CO_2.

Noxious vapors from oils, glues, thinners, paints, treated woods, plastics, cleaners and other hazardous chemicals that are widely used on construction sites, contribute to air pollution. [17]

In 2004, Swiss Agency for the Environment, Forests and Landscape; SAEFL has determined the anticipated impacts of air pollutant emissions from different construction activit ies as shown in Table 3. [19]

Table 3: Anticipated impact of air pollutant emissions from building processes:
◆ High or very high ✣ medium • insignificant

Emissions from	Non-engine Emissions		Engine Emissions
	Dust	VOC, gases, (solvents etc.)	NO_x, CO, CO_2, VOC, HC, particle etc.
Site infrastructure, particularly roads	◆	•	✣
Site clearance	✣	•	✣
Demolition and disassembly	◆	•	✣
Building securing, particularly drilling and spray concrete	✣	•	✣
Sealing subterranean constructions and bridges	✣	◆	•
Earthmoving (inclusive surroundings, topsoil and drainage)	◆	•	◆
Excavation	◆	•	◆
Hydraulic engineering	◆	•	◆
Foundation layers and material extraction	◆	•	◆
Surfacing	✣	◆	◆
Rail track laying	✣	•	◆
In situ concrete	•	•	✣
Underground mining	◆	✣	◆
Trail preparation, particularly traffic marking	•	◆	•
Concrete and reinforced concrete	•	•	✣
Building maintenance and protection of concrete, core drilling and grinding	◆	•	•
Working natural and artificial stone	✣	•	•
Roofing, plastic and elastic surface sealing	•	◆	•
Special sealing and damming	•	◆	•
Exterior plastering	✣	✣	•
Painting (exterior and interior)	✣	◆	•
Floor, wall and ceiling cladding with wood, artificial and natural stone, synthetics, textiles and mineral fibers (sprayed fibers)	✣	✣	•
Site cleaning	✣	✣	•

7- Air Pollution Management along Building Life-Cycle

Whether under construction, in use or being demolished, a building will always affect the environment. It is important to consider the environmental ramifications of a project at each life cycle stage before construction begins so plans can be made to minimize any harmful effects. Figures 1 & 2 show building life-cycle phases and related air pollution Hazards

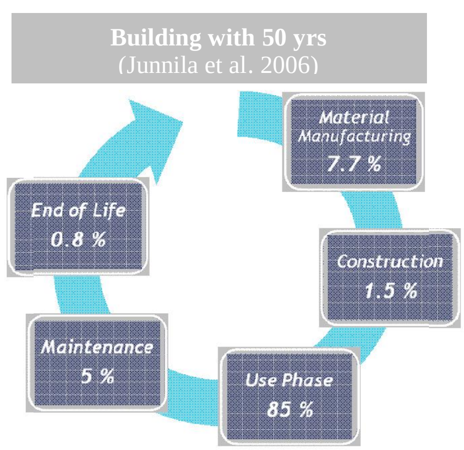

Fig. 1: Environmental Impacts along Building Life-Cycle, Source: [20]

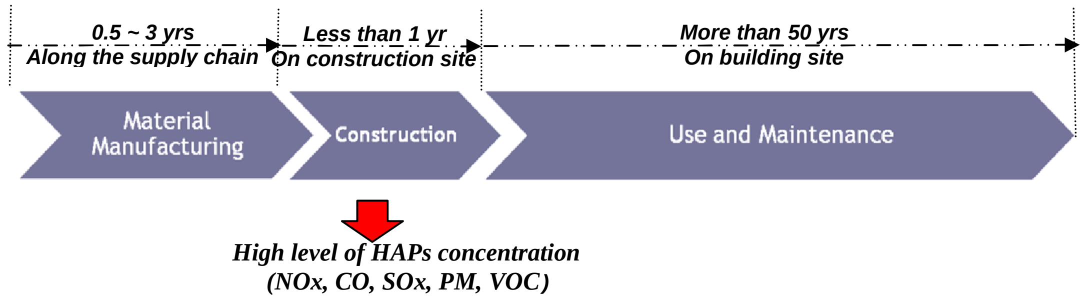

Fig. 2: HAPs Emissions Concentration Levels, Source: [20]

In UK, government consultation with the construction industry produced the ”Ten Themes” for Action (Building a Better Quality of Life) which include many strategies related to air pollution reduction as [21]:

1 Re- use existing built assets, and renovate/refurbish which improves their sustainability, where possible
2 Design for minimum waste. Design out waste at all stages of product, building or structure, think about using recycled materials.
3 Minimize energy in construction, be aware of energy consumption during construction
4 Minimize energy in use; consider more energy efficient solutions in the design stage.
5 Do not pollute, understand environmental impacts and adopt an EMS to manage them
6 Preserve and enhance biodiversity throughout the construction process, from extraction of materials to landscaping buildings.
7 Conserve water resources, design for water efficiency in buildings.

7-1 Pre-Studies & Project Planning

When project planners initially identify the parameters of a project, such as what needs it should meet, where it might be located, available funding, and laws, regulations and permitting requirements that will affect the project, environmental issues should be included in their considerations. [22]

The following list of questions to consider is a summary of pre-studies issues:

- Is the construction project necessary or could existing structures be used with minimal alterations? Is the project over-designed?
- Have sensitive areas, such as wetlands, threatened or endangered species habitats, and cultural or historical resources, been avoided?
- Is the proposed land use compatible with the existing and planned uses of the adjacent areas?
- How will the construction process and completed project affect erosion and sedimentation in nearby waterways?
- Will disturbance to vegetation be minimized, perhaps preserving old-growth trees and limiting erosion?
- What measures will address hazardous materials, such as proper construction-site storage and spill control plans?

7-2 Design Phase

7-2-a Design Phase: Direct Reduction of Air Pollution

- **Selection of HVAC systems**

By selecting the most eco-effective systems and subsystems as: low-temperature heating or high temperature cooling system, and co-generation and energy-recovery strategies.

- **Selection of eco-friendly building materials**

By selecting the eco-friendly materials that has no or less effects on environmental during application or installation and during its life-time operation.

7-2-b Design Phase: Indirect Reduction of Air Pollution

- **Building Mass Orientation and Envelope Design (Articulation, Systems, Materials)**

By optimizing the mass orientation and enhance the performance of building skin with the outdoor environment and finally to minimize the amounts of energies used in HVAC and lighting systems.

- **Using Easy-Maintenance Engineering Operation Systems (Plumbing, HVAC, Electro/Mechanic)**

To reduce the supply materials and waste of maintenance.

- **Balanced Selection of Construction Systems and Materials**

By targeting more durability, less embodied energy and air pollution, easy to be maintained, optimizing less amounts of raw materials with less amount of embodied air pollution of the all used materials

- **Using Reclaimed and Recycled Construction Materials**

The construction materials have a massive indirect impact on air pollution in terms of energy consumption, use of natural resources, pollution and waste. Every year in the UK, construction materials account for around: 6 tones of materials per person, 122 million tones of waste (1/3 of total UK waste) and 18% of CO_2 emissions, a major contributor to global climate change. On top of this, the embodied air pollution associated with the extraction, production, manufacture and transportation of building materials are immense in addition to the embodied energy which producing an extra air pollution. Using reclaimed materials can significantly reduce these environmental impacts, and save up to 95% of the embodied costs by preventing unnecessary production of new materials, and reducing the amount of waste sent to landfill. With the same concept using recycled materials can reduce the embodied air pollution of construction materials. [23]
Although increased reuse and recycling construction and demolition waste can contribute to reduce the air pollution of construction industry, but recycling has its own share of impacts that should be considered in the decision-making process. To ensure that both sides of the equation are carefully considered against a range of social, economic and environmental criteria must be re-checked. [24]
In 1999 Craighill and Powell have developed a lifecycle assessment methodology to measure the environmental, social and economic impacts of alternative methods of managing construction and demolition waste by using a number of case studies; constructing a lifecycle inventory for alternative strategies for construction waste management. The inventory results are translated into environmental and social impacts such as global warming, road congestion and employment, then these impacts are analyzed using economic valuation and multi-criteria evaluation techniques, finally both valuation methods yield similar results, showing that reuse of demolition waste has the lowest overall impact, followed by a combination of reuse and recycling, with landfill the least desirable option, as long as primary materials are displaced. Financial costs follow the same pattern. It is concluded that based on the lifecycle assessment constructed with

data from these case studies, the construction industry could become more sustainable by strategically replacing primary materials with recovered materials. [24]
The following Figure 3 and Table 4 show an application on construction materials management by analyzing life-cycle according to related different embodied energies.

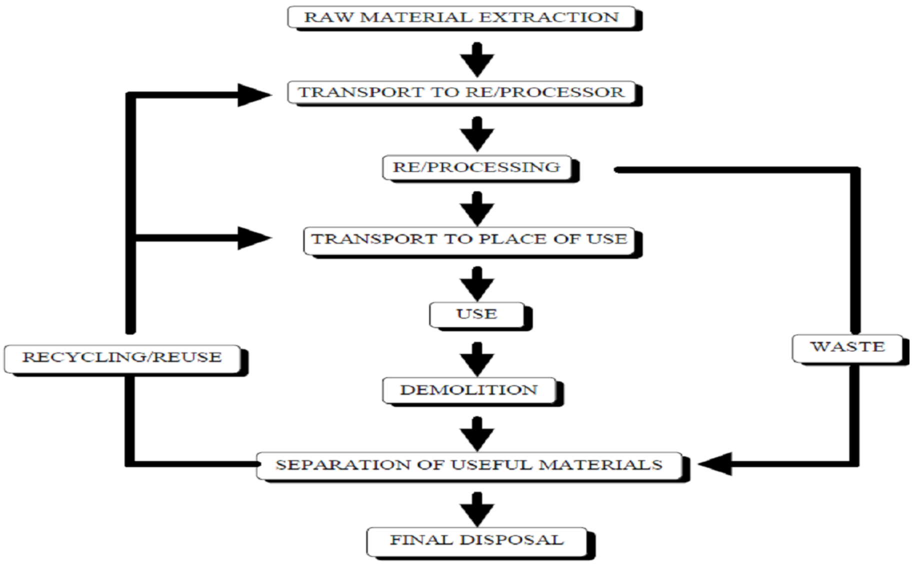

Fig. 3: Construction Materials Life-Cycle, Source: [24]

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Table 4: Embodied Energy of Some Construction Materials', Source: [24]

Material	kWh/tonne	kWh/m^3
Natural sand/aggregate	30	45
Fletton bricks	175	300
Timber (local green oak)	200	220
Local slates	200	540
Lightweight blocks	500	600
Clay tiles	800	1,520
Plaster/plasterboard	890	900
Engineering bricks	1,120	2,016
Timber (imported softwood)	1,450	7,540
Cement	2,200	2,860
Glass	9,200	23,000
Steel	13,200	103,000
Copper	15,000	133,000
Aluminium	27,000	75,600
Plastic	45,000	47,000

a- Using of Reclaimed Construction Materials (Re-use)

Reclaimed materials are those that have been previously used in a building, and which are then re-used in another project. The materials might be altered, re-sized, refinished, or adapted, but they are not reprocessed in any way, and remain in their original form. [23]
Examples of materials that can be reclaimed include: bricks, slate roofing, ceramic tiles, fireplaces, doors, window frames, glass panels, metal fixtures and fittings, stairs, cobbled stones, steel sections and timber. The best place to source reclaimed materials is direct from a demolition or re-modelling project. Many of these projects carefully dismantle buildings in such a way that their materials can be sold and re-used. [23]

b- Using of Re-Cycled Construction Materials
Materials that had been previously used in a building then deconstructed and reprocessed and finally reused in the building industry are referred to as recycled materials.

7-3 Construction Management to Reduce Air Pollution
When considering a building and infrastructure life cyc le—design, material extraction, manufacturing, construction, use, demolition and di sposal, the construction phase accounts for a significant share of the energy use with the associated GHGs emissions, solid waste generation, and use of natural resources. The amount of emissions during construction activities represents 40% of the total CO2 emissions from non-transportation mobile sources as well as 32% of NOx and 37% of PM emissions from all mobile sources as shown in Figure 4.

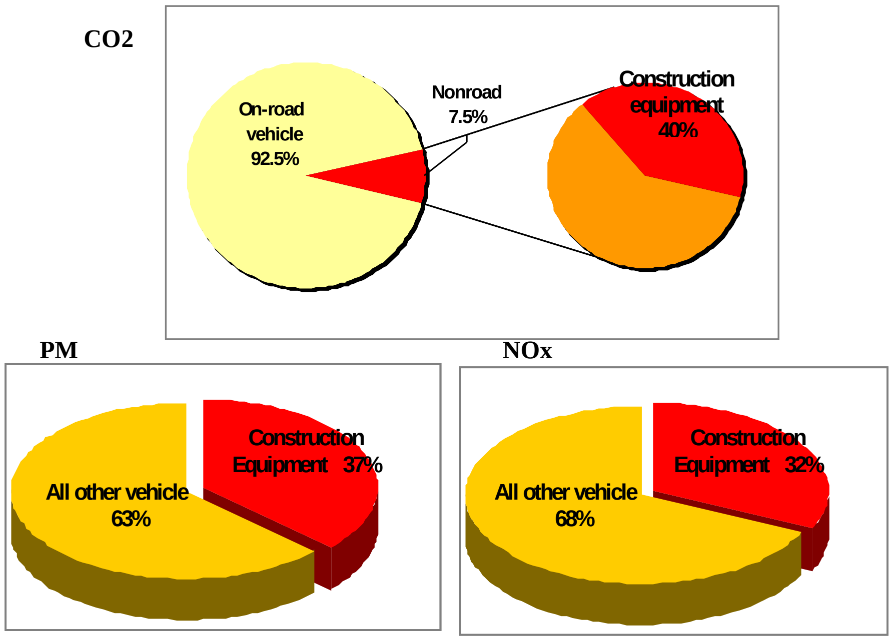

Fig. 4: HAPs Emissions of Construction Equipment Related to Vehicle, Source: [20]

Moreover, the trend of CO2 emissions from construction equipment shows a significantly higher increase than that of on-road vehicles, and the trend of Hazardous Air Pollutants (HAPs) (e.g., CO, NOx, PM, VOC and SO2) emission from construction equipment has remained steady, or decreased relatively slow, in comparison with emissions from that of on-road vehicles over the past few years). In the case of urban construction, such HAPs are concentrated within a short time frame and a relatively small space creating a scenario where the potential for adverse health and environ mental effects could be higher. [20]
The current construction management practices do not account for the environmental aspects of a project when making a decision on operation plans such as selection of construction methods, equipment subcontractors, and equipment types. Instead of more cost effect ive reduction from changes in operations plans, they focus on reduction of environmental impacts under established operation plans. [20]
Figure 5 shows a framework for managing emissions that will use the actual amount of emissions of construction activiti es as environmental performance indicators and set the environmental goals using the estimated emissions of each single project.

This framework also contains a series of management processes: estimating the emissions in the planning stage (this estimation will affects the decision on the operation plans); deriving control target level of emissions from this estimation; monitoring the actual emissions of construction activities; taking corrective actions for reducing emissions based on the control target level of emissions. [20]

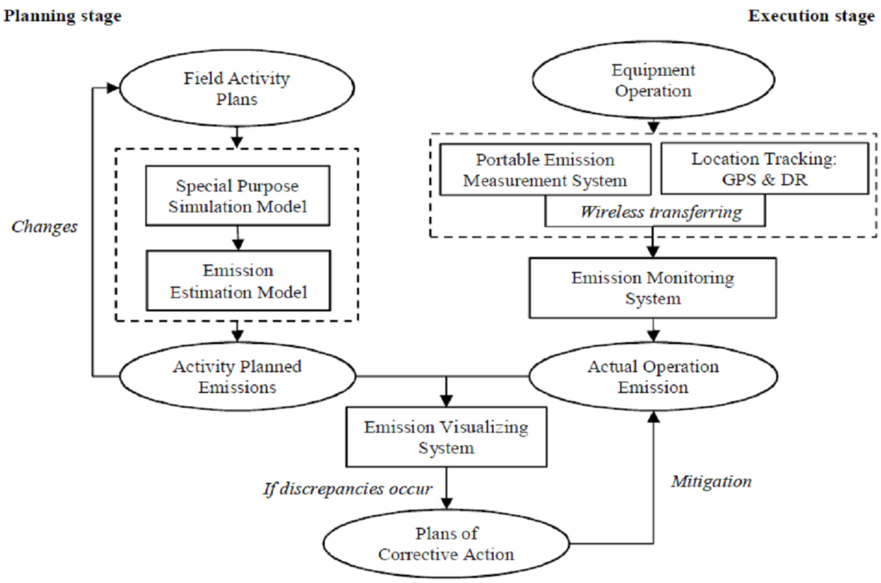

Fig. 5: Emission Management Framework for Construction Processes, Source: [20]

In the planning stage of an activity, the operation hours of construction equipment based on field activity plans are quantified using construction simulation technologies. This detailed operation plans of construction equipment yields the amount of emissions and the environmental cost of an activity. This estimated amount of emissions will be a control target level for the execution stage. [20]

Also, the hidden cost of emissions is taken into consideration to change the field acti vity plans. In the execution stage of the activity, Portable Emissions Measurement Systems (PEMS) which are attached to the tailpipe of construction equipment collect the actual amount of emissions, and send emission information with the equipment location information to the central monitoring system. This actual emission information enables project managers to monitor the environmental performance of an activity compared to the estimated target level and to trace which equipment or which area of a project needs corrective actions for reducing or sequestrating the emissions. In this process, the visualizing techniques of the emission information will help to stress on the discrepancies between estimated and actual amount of emissions. [20]

Dust can be produced not only from vehicle tyres but also from any operation that involves soil, such as foundation excavation and the compaction of an embankment. Often the contractor must dedicate one or more water carriers to the task of wetting the soil surface to minimize the production of dust. Other sources of air pollution include mixing plants that produce asphalt; dust is produced from the drying of aggregate in the plant's rotary kiln. Bag houses may be required to collect the particulates and prevent them from be ing discharged into the atmosphere. Plants that crush aggregates also produce dust; a permit to operate such a plant may disallow its operation in dry or windy conditions. [25]

7-3-a Air Pollution reduction during building construction

The first step is to prepare environmental risk assessments for all construction activities and materials likely to cause pollution and specific measures can then be taken to mitigate these risks [17]:

• Use non-toxic paints, solvents and other hazardous materials wherever possible

• Segregate, tightly cover and monitor toxic substances to prevent spills and possible site contamination.

• No burning of materials on site.

- **Covering the building enclosure by**

- Providing hoardings of not less than 3 m high along the site boundary, next to a road or other public area.
- Providing dust screens, sheeting or netting to scaffold along perimeter of a building
- Covering fully stockpile of dusty material with impervious sheeting.
- Covering dusty load on vehicles by impervious sheeting before they leave the site.
- Transferring, handling/storing dry loose materials like bulk cement, dry pulverized fly ash inside a totally enclosed system

- **Water spraying**

Water spray, whether through a simple hose for small projects, or a water truck for large projects, is an effective way to keep dust under control. Misting systems and sprinklers are mechanisms that can be employed to deliver continuous moisture. It should however be kept in mind that fine mists be used to control fine particulate. The size of the water droplet must be comparable to the size of the dust particle so that the dust adheres to the water. [26]

There are several constraints to using water. Water can be very costly for larger projects in comparison to other methods. Heavy watering can also create mud, which when tracked onto paved public roadways, must be promptly removed. Also, there must be an adequate supply of clean water nearby to ensure that spray nozzles don't get plugged. [26]

Spraying of water can be done on:

- Any dusty materials before transferring, loading, and unloading
- Area where demolition work is being carried out.
- Any unpaved main haul road.
- Areas where excavation or earth moving activities are to be carried out.

- **Using low sulfur diesel oil** in all vehicle and equipment engines, and incorporate the latest specifications of particulate filters and catalytic converters.
- **Provision for Diesel Generator (D.G.) Sets**

By following the specified norms for emission standards from generator sets.

The emission standards for portable generator sets run on petrol and kerosene shall be as shown in Table 5.

Table 5: Std. Max. Emissions of D.G., Source: [26]

Class	Displacement (CC)	CO (g/kw-hr)	HC+NOx(g/kw-hr)
1	≤ 65	519	54
2	> 65 ≤ 99	519	30
3	>99 ≤ 225	519	16.1
4	> 225	519	13.4

The norms for DG sets are that the diesel generator sets should be provided with integral acoustic enclosure at the manufacturing stage itself. There must be sufficient space for Fuel Tank inside canopy. There must be enough space to house panel. There must be Strong and Heavy-duty steel base frame for housing D.G. Set. There must be provision for Air- Intake and Air-Exhaust silencer(s) for preventing leakage of sound. There must be a provision of Operable doors for easy access to virtually every part of D.G. Sets. There must be provision of additional screen and hoods for multi -medium noise suppression. [26]

D.G. Stack Height

The min. height of stack to be provided with each D.G. set can be calculated as [26]: H = h + 0.2 x W , where H = Total height of stack in m., h = Height of the building in m. where the D.G. set is installed, and W = Total D.G. capacity in KVA

In a case study in New York City, construction officials have taken steps to reduce the Manhattanville campus construction project's ecological footprint by cutting down air pollution, the spread of dust, and building material waste as the discussions about green building were part of the earliest stages of the planning process for the project. [18]
The efforts to create a sustainable construction site include a partnership with the Environmental Defense Fund, a nonprofit environmental advocacy group which signed an agreement with Columbia in 2007, and registering the project with LEED–a green building certification system–gave the team a framework for how to address each area of sustainability ensuring that the huge construction project wouldn't worsen air quality in Upper Manhattan. All of the site's construction equipment, including seven cranes, use ultra -low-sulfur diesel fuel, which releases smaller amounts of air pollutants as required by New York law. [18]
The dust (which tracked into the neighborhood and surrounding streets by trucks leaving the work site) has been addressed with a liquid fix as a truck wash device at the site's exit shoots water at the undercarriages of trucks as they drive over it, and the water is recycled afterward.

7-3-b Supply Chain Management (SCM)

The main stakeholders of the construction industry and those who interact with it are very complex and there is not one stereotype of construction supply chain because of the variety of buildings, sizes, technologies and products that can be used.
Within each construction supply chain there are several supply chains, each one with different properties and circumstances. The main types of suppliers can be classified into materials, labour, equipment or machinery and professional services. [27]
SCM was born in the manufacturing industry in the 1990's with the Just-In-Time (JIT) delivery system implemented in Toyota, with the main aim of reducing inventories and regulating suppliers' interaction with the production lines. Nevertheless, since its birth SCM has evolved into a full range of disciplines that involves closer customer -supplier relationships. [27]
SCM could be defined as: "The supply chain encompasses all activities associated with the flow and transformation of goods from raw materials (including extraction), through the end user, as well as information flows. Materials and information flows both up and down the supply chain". [27]
In other words SCM can be defined as the integration of suppliers and customers into the decision-making processes, focusing on the planning, implementation and control of the logistics operations to pull materials through the supply chain. [27]

7-3-c Green Procurement and Purchasing

In construction sector purchasing represents high expenditure, so it is important to facilitate the integration of environmental issues into purchasing via the formation benchmark tools that could be used to compare companies as shown in Figure 6. [28]

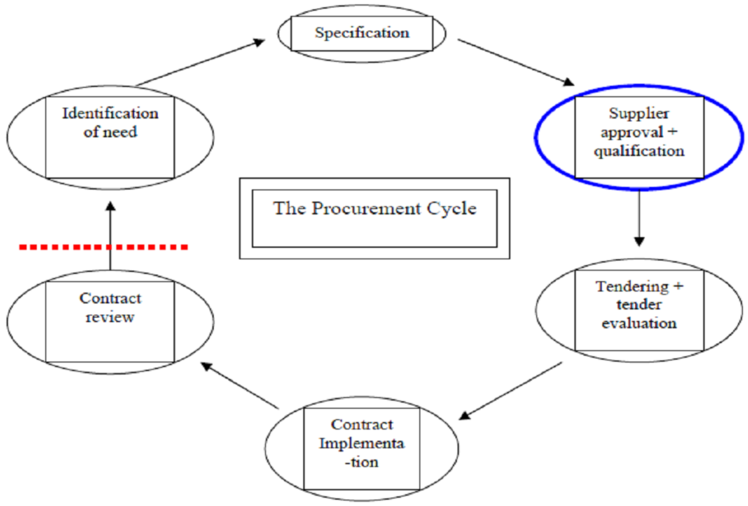

Fig. 6: Procurement Cycle and Application of Benchmarking Criteria, Source: [28]

7-3-d Construction Waste Management

Present waste practice must emphasize waste reduction at source, i.e. waste minimization, in keeping with the waste hierarchy. The waste hierarchy requires actions to reduce waste, or re-use it, or recover value through recycling, composting, or energy from waste, thus preventing 1000s of tons of waste going to landfill sites for disposal, and so changing people's perception of what waste is. As seen in Figure 7 the waste hierarchy encourages policy to move from disposal to reduction: results indicate that the waste hierarchy is valid as a rule of thumb. The treatment of waste is moving from waste as disposal to a perception of waste as a valued non-renewable resource, as the practice pushes up the waste hierarchy. [29]

Fig. 7: The waste Hierarchy in Waste Strategy, Source [29]

The hierarchy suggests that the most effective environmental option may often be to reduce the amount of waste generated. Re-use and recovery of material are considered where further reduction is not practical and only in cases where none of the above solutions are appropriate should waste be disposed of by landfill or incineration. [30]

7- 4 Building Operation Management (Facility Management) to Reduce Air Pollution

Building users' lifestyle affects the amount of emissions that building in operation will create; so we have to:

- Save energy usage in building operation to reduce carbon emissions by setting appliances and lights on a timer to turn off after a certain period of inactivity, and using compact fluorescent bulbs instead of standard light bulbs, and water saving devices.
- Manage heating and cooling systems by turning thermostat down in the winter and up in the summer, checking that the insulation is up to the recommended level, and check windows and doors air leakage, and performing regular maintenance for air-conditioners.
- Recycle everything of the waste: aluminium, paper, glass, plastic and cardboard, and use a safe, eco-friendly method for disposing of chemical-based substances like paint, batteries, pesticides or solvents. [31]

CO & NOx: Consider public transportation and carpooling to reduce two major pollutants. Vehicles are the largest producers of CO and NOx. CO reduces the amount of oxygen available to breathe. It is odorless and colorless, making it very dangerous to humans. NOx is a component of ground-level ozone, which is responsible for many respiratory illnesses, especially in children, the elderly and people with diseases of the lungs. [32]

SOx & NOx: Reducing the amount of electricity usage reduces pollutants and the resulting acid rain, and most electricity in this country is produced by power plants that burn petroleum products. Power plants are the largest source of SO_2 and NOx, which are components of acid rain. Solar, wind and hydro-electric power are alternatives to the polluting methods used to produce electricity. [32]

VOCs: Vehicles and solvents are significant sources of VOCs. When VOCs and NOx combine in the air on a hot, sunny day, ground-level ozone is created. It is a harmful chemical, even though it has the same chemical makeup as the ozone in the stratosphere that protects the earth from solar radiation. [32]

Methane: Landfills release concentrated amounts of methane, a GHG, into the air. Many scientists associate GHGs with global warming. Although it is not a criteria pollutant, it is significant because of the harm greenhouse gases create. Reducing the amount of trash you throw away can help lower methane levels and vehicle emissions from waste transport trucks. Instead of tossing unwanted things into a trash can, consider each item's potential for being repurposed, repaired or recycled. Recycle grass clippings, leaves and vegetable peelings into compost. Send paper, glass and aluminium cans to a recycling center. If a broken device cannot be repaired, its components might be useful for repairing something else. For each thing you could send to a landfill, try to find an alternative destination. [32]

8- Redefining Building Life Cycle Phases

Life cycle systems are inherent to the Building Environmental Assessment (BSA) framework developed and Life Cycle Theory (LCT) needed to be re-defined, or further defined in order to structure conceptual thinking. The re-thinking of LCT was important as it identified critical areas of decision-making for built environment stakeholders who can be targeted as needing effective support in the move towards their sustainability goals. A breakthrough in thinking by Steve Watson, in his thesis on environmental implementation strategies in the building design process, distinguished the temporal design phases as separate to the physical life cycle of the building. [33]

Watson applies the terms to differentiate the building's physical life cycle from actions over a temporal life cycle in design processes and asset management planning that go to build it. His physical life cycle relates to material flows in forming objects such as shown in Figure 8 and his temporal life cycle to sequencing decisions as in Figure 9 Defining the temporal phase separately, decision-making has a distinct space in the building process and distinguishes it for the BEA tools. [33]

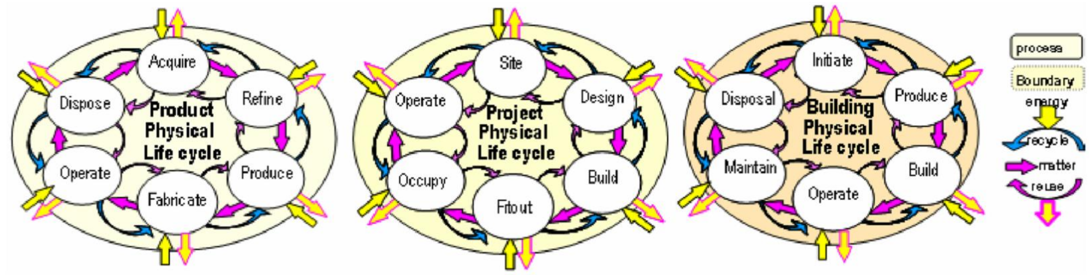

Fig. 8: Flow Diagrams of Products & Building Physical Life Cycle Phases, Source: [33]

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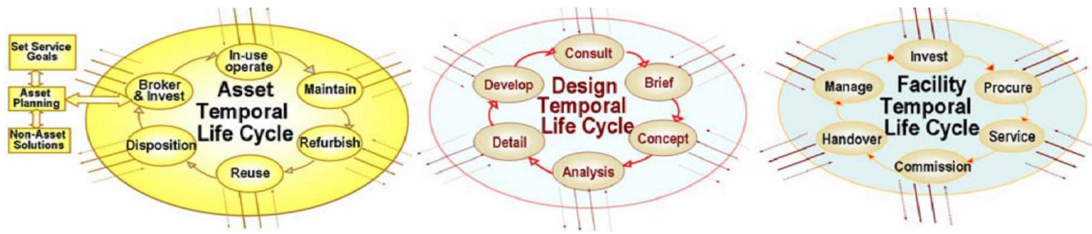

Fig. 9: Flow Diagrams of Asset & Design Temporal Life Cycle Phases, Source: R-[33]

Further to this concept, Jones et al. and Watson had developed models identifying the life cycles within the built environment which the LCA-Design team again used to separate applications and measurements. This was considered essential to facilitate consideration of the numerous up-and-down stream effects and the implications they may have over the building life span. [33]

It was accepted that the philosophical foundation for development of this theoretical framework would be based on considerations of integrated and cyclical interior, shell and built environmental systems as ecological systems. It was asserted that life cycle thinking has lead to more objective strategic planning when used to support decision-making as it can achieve more comprehensive outcomes where economic and environmental assessment can be seen side-by-side rather than obscured by subjective assessment. [33]

The term 'building life-cycle' loosely covers the 'planning and design development process and the building life-cycle from, conceptions through building life and disposition and as shown in Figure 10 for example end of building life is now a focus of urbane renewal as land becomes limited and traffic means people seek to live close to the CBD. [33]

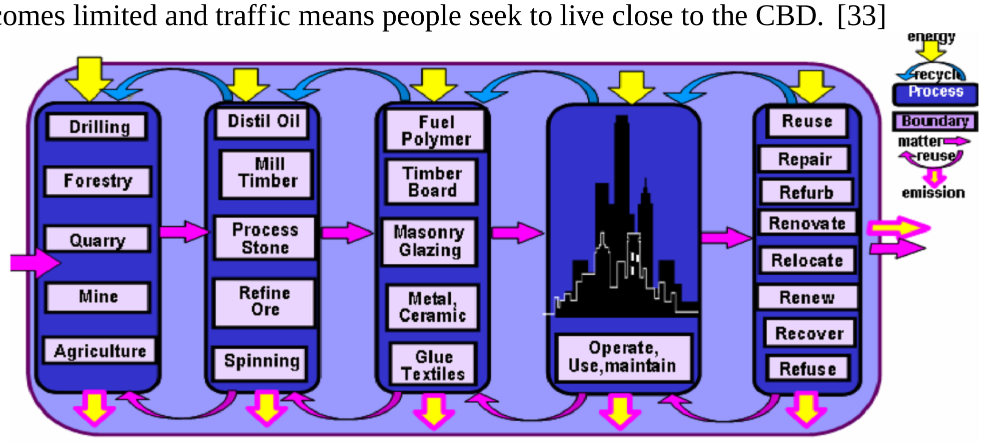

Fig. 10: Operational Flows over the (a) Product Life-Cycle and (b) Built Life-Cycle, Source: [33]

8- Discussion:

Correlation analysis was used to investigate the relative weightings of the building related sources of different air pollution aspects during all stages to sy nthesise a matrix of expected air pollution hazards of the building from cradle -to-grave, Tables: 6, 7 & 8 showing that.

Table 7: Opportunities for Using Reclaimed or Recycled Materials at Project Phases, Source: [28]

ACTIONS

Stage of the project	A	B	C	D	E	F	G	H
Design team selection	*			*				
Concept design		*					*	
Site selection			*	*				
Outline design		*		*			*	*
Environmental appraisal and assessment		*	*	*	*	*		
Detailed design		*	*	*			*	*
Contract documentation					*			*
Contractor selection	*				*			
Materials procurement	*		*			*		
Construction		*		*	*	*		

A. Assess company's approach to and knowledge of reclaimed materials.
B. Review opportunities to reclaim or recycle materials already on site.
C. Assess location of supplies of reclaimed materials.
D. Encourage the design team.
E. Encourage the construction team.
F. Evaluate and propose alternatives to specified materials.
G. Design to allow reclaimed and recycled materials.
H Specify the use of reclaimed and recycled materials.

Building's Air Pollution Performance Indicators [30]

Operational CO_2 equivalent emission (Kg $CO_2/m^2/year$)
Embodied CO_2 equivalent emission (Kg CO_2/m^2)

Table 8: CO2 Equivalent Emissions of Used Energy Unit from Different Energy Sources , Source: [30]

Fuel Type	Amount used per year	Units	x	Kg CO2 per unit	Total kg CO2
Grid electricity		kWh	x	0.43	
Natural gas		kWh	x	0.19	
		therms	x	5.50	
		tonnes	x	3142	
Gas or diesel oil		kWh	x	0.25	
		litres	x	2.68	
Heavy fuel oil		tonnes	x	3117	
		kWh	x	0.26	
Green electricity		N/A	x	0	
Coking coal		tonnes	x	2603	
		kWh	x	0.30	
Coal		tonnes	x	2419	
		kWh	x	0.30	
Others*			x		
Aggregate total emissions from energy use =					

9- Concluded Remarks:

Delivering such a matrix can help to get a holistic comprehension of all air pollution hazards regarding all building aspects along its life -cycle; which can more practically direct the designers to optimize the building design with respectable concern with its air pollution related behaviour along its life -cycle, this multi -parametric way might be objective -oriented and more effective than the linear one that using design checklists extracted from one of EIA rating systems (BREEAM, LEED, …etc).

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Table 6 : Construction Industry Environmental Implications & Relevant Considerations, Source: [16]

What is used	Where it is built	How it is built	What is build
Where raw materials are obtained	Location of facility; nature of terrain and ground conditions; alternative uses	Methods of construction	Planning and design of facility (e.g. potential of daylight and natural ventilation)
How raw materials are extracted	Immediate physical environmental; proximity to water sources and ecosystems (e.g. water pollution, loss of biodiversity)	Construction project management systems (e.g. quality management systems)	Specification, its implication for materials used
How raw materials are processed	Social disruption (e.g. displacement of inhabitants)	Site control measures	Life-cycle economic, quality, maintainability considerations
Whether, and how renewable raw materials are regenerated	Economic disruption (e.g. loss of livelihoods of previous inhabitants)	Welfare of site workers, neighbours and general public	Extent of use of energy and other resources in operation of building
How materials are transported and stored	Present infrastructure, need for expansion, its impact	Resource management (including waste minimization)	Ease of demolition of building
How materials are moved on site	Impact on local vehicular traffic		Recycle and reuse of demolition waste

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