Designing of an Eco-Friendly Foldable Bicycle using basic concepts of engineering: E-Compaq Bike

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Abstract

Technology is trying to inculcate new features in the field of automobiles and making them more powerful and artificially intelligent. Pollution is also increasing day by day which is an alarming situation and degrading air quality leads to global warming. Considering these things researcher tries to come up with a solution and made a bicycle which is ecofriendly and of nominal cost too. This E bike is different from all other bicycle as charging of battery is possible during pedaling with the usage of a dynamo and also from direct supply using a charger which is able to run on battery power later on. Hence as there is no combustion of by products as there is no usage of fuel for its running. Also regular increase in prices of fuels and scarcity of these fuels, the modes of transport are becoming expensive. Increase in number of vehicles, parking is another issue to ponder upon, so the only solution to this entire situation isa bike which requires less parking space. Keeping all this in mind, the researcher designed and introduced a bike which is Foldable with capacity of getting Self Charged. As it runs on electric power so produces no harmful gases.

Keywords: **Fabrication, e – bikes, eco-friendly, bicycle**

1. Introduction

Whole world is shrinking to a global village with the advent of modern technologies especially in the field of electronics and automobiles. Automobiles are becoming more powerful and artificially intelligent with inculcation of new features but on other hand pollution is growing at alarming rates which is a great concern as quality of air degrading day by day leading to global warming. A bicycle, also known as a cart or a cycle, is a human, pedal- single track vehicle with two wheels, one behind the other attached on a frame, which was introduced to Europe in the late 19th century. More than 1 billion cycles were produced worldwide at the beginning of the 21st century. These figures are even higher than the car figures. Therefore, in many regions bicycles are the prime mode of transport. They are also a common form of recreation for use as toys, exercise, postal, cycling and stunts. Maleque, et al., in 2011 worked on material properties of bicycle and design aspects of bicycle with folding frame . A bicycle had very low carbon footprints on the environment as compared to a car. A bike can be built with a portion of a car's inventory, energy and transportation costs. By reducing road wear even a bicycle, save money of taxpayers.

Global warming is one of the major problems and the major contributors towards this are vehicles like bike or cars which runs on petrol or diesel, by emitting harmful gases.. Recently there are studies on air pollution of big cities and results proved that air pollution is increased in general.

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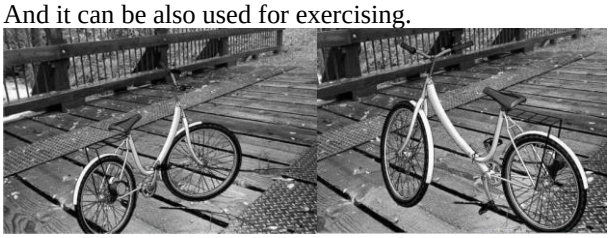
Many research scholars worked on patent in the same field like Paget Jr (1970) and Graber (1989). . Optimum inventory rates at bike-sharing stations were estimated by Parikh and Ukkusuri (2015). Tak, et al., (2010) conducted design sensitivity analysis of bicycle stability and experimental validation. This problem is the base of our research and so we should try to decrease this. Regarding to the point that some people for solving this problem use bicycles as a transportation. The very first step to solve this problem is the introduction of an electric vehicle, Also the prices of diesel and petrol are going up day by day which make all modes of transport expensive. If the destination is far away from the main roads, it becomes difficult to reach there from the main transport station. In some cases public transportation may not be available due to small roads. To avoid all these, best solution is to use one's own private vehicle, but this again leads to the issue of parking the vehicle, traffic congestion etc. Even not all can opt for their own vehicle due to high cost of the cars and bikes. So the only idea to tackle all these problems is to come up with a bike which is of low cost, foldable and electrically driven.

The bicycle which researcher had fabricated is an electrically driven, foldable and low- cost bicycle named ECOMPAQ bike. 1 shows two sides of E-Compaq Bicycle in two distinct environments. Some of the researchers worked on power generation by cycling, as Grant, et al., in 2011. The bicycle fabricated by researcher uses man power to charge the batteries so that later this power can be used to drive the bike. Since the bicycle is being folded, it can be carried anywhere and as it occupies very less space so does not require any special parking space. Also, it is not exposed to the weather since it can be carried inside buildings with ease and hence prone to less maintenance. This bicycle can also be used for charging your mobile phones or as a power bank because it is easily portable to your working place. And it can be also used for exercising.



1: Two Views of E- Compaq Bike

The fuel price in particular is continuously rising day after day as we are all conscious. Yet again, emissions from automobiles is rapidly increasing pollution in metropolitan and urban areas. The attempt is made to find other alternative energy sources or switch back to the traditional energy sources to solve these problems. Mc Loughlin,et al., (2012) conducted research on campus mobility for the future of electric bicycle. Jouhri, et al., in 2016 worked on designing and fabrication of 4-fold foldable bicycle. Cycle is the most efficient and most feasible vehicle in all the respect the only drawback with the cycle is the space requirement and to fix this issue the foldable cycles came into use. Pirnat, et

al., measured dynamic loads on a foldable bicycle. Some of the researchers also worked on optimization of the design on foldable bicycle like Hyeong, et al.,in 2016 optimized the design. Arunachalam, et al., in 2014 evaluated the existing design and proposed a new design for the foldable bicycle.

In this paper a simple mechanical power-driven battery charging system is introduced. A hand operated device for recharging batteries with small-scale electricity supply has specifically been developed. Instead of using any fossil fuel, the system can provide enough electrical energy to charge a battery for domestic applications. The charging unit can be used to provide limited electric supply in the remote and isolated areas where there is no national power grid connection. In addition, the system can be used for mobile charging, indoor lighting and such applications in emergency situation of power failure.

The goal of this paper was to use industrial design approach to create an innovative foldable pedelecs focusing the customers. Modern methods of design include consumer study, business analysis and contextual evaluation, idea drawing, prototyping and design principles. Anthropometric data and literature of bicycle riding positions were considered during the product development of the foldable pedelec. The final idea outlined in this paper is a modern design focusing on the driver's ease of use, comfort and practicality and spatial efficiency.

2. Motivation for proposed design

The feature, material properties and production process should be considered for a successful design of the folding bicycle. A systematic analysis was therefore performed on the relationship between material properties and foldable bike design. For a better understanding of the material properties and nature, the advantages and disadvantages matrix between traditional bicycles and folding bike are discussed. The material properties of the folding bike frame, including fatigue and tensile strength, were found to be critical for the improved frame performance. The relationship p between material properties and design is not simple because the materials behavior vary from that of raw materials to the finished product. To start research, one must first determine which kind of research will have a beneficial impact on nature, society or be special/ unique. While contemplating various subjects, the scientist chose to work on a bike that is both electrical and foldable for the ordinary public. And the researchers wanted to develop an electric bicycle in order to solve one of the big problems of pollution. Day after day parking also becomes one of the big challenges around the world, provided that researchers need to develop a compact design so that less space is conveniently parked. Finally, a bicycle is reached to solve this issue which is foldable. Some basic criteria such as weight, flexibility, comfort, price and so on need to be centered so that everyone is ready for the market. Thus researchers tried their best, without modifying the performance and characteristics, to reduce the cost of a bike. The concept of designing and manufacturing a bicycle that is inexpensive, foldable and electrically powered together results in the cooperation in all aspects. The main parts of an E-Compaq bike therefore include: motor, dynamo and battery.

3. Design considerations of present study

After facing lots of challenges and getting confused with the various design software like Creo, Solid Works, Fusion 360, etc., researcher decided to use Solid Works for the designing of E- Compaq Bike. The next challenge in designing is to collect different parameters like material, dimensions, etc. for preparing the basic design of normal bicycle, after which some of the dimensions may be changed to make the bicycle easy to fold and suitable for required parts. Subsequently the compatibility of the final design is also to be checked and analyzed.

Only after this one need to focus on manufacturing of parts along with this concentration must begiven to on one of the main constraints which is overall cost of E-Compaq Bicycle, which should not be high. One also needs to focus on the specifications of the products as this is the most important part of the research. The main problem arose is about the type of dynamo to be used in bicycle to produce voltage during pedaling so that bike gets charged with efficiency during the pedaling. A normal bicycle is then modified into an E-Compaq Bicycle by using various operations like cutting, welding, etc.

One of the biggest challenges faced is to attach the dynamo on bicycle so that it will be produced high voltage output, as high voltage is directly proportional to the rotation of dynamo (RPM), after considering many solutions researcher found that adding dynamo at the edge of tire dynamo produces high RPM. Along with this another challenge is the addition of motor to the wheel, battery and dynamo while maintaining same compactness After successful completion of cycle one need to test various it on various factors like backup time, comfort ability, that too under real conditions.

Work had been started thinking about a unique type of bicycle, as these days a lot of options are there in the market which is either only foldable or only electrical and just keeping in mind this, a new bicycle is fabricated which is both foldable and electrical. The uniqueness of the E- Compaq bike is that it can be charged even when we are riding it and afterwards it can be used to run on electrical supply from batteries.

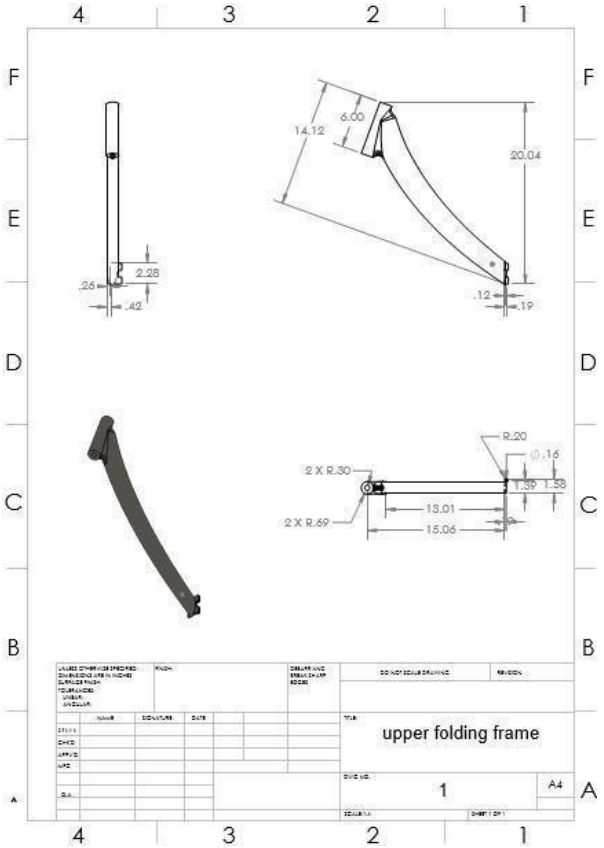
One of the major constraints is maintaining the proper tension on belt drive because this can affect the efficiency of bicycle. Also to make a bicycle foldable according to the concept, one have to make both wheels unaligned. For light and cheap, one needs to eliminate some elements while maintaining the same rigidity.

4. Parts to be considered for proposed Bike

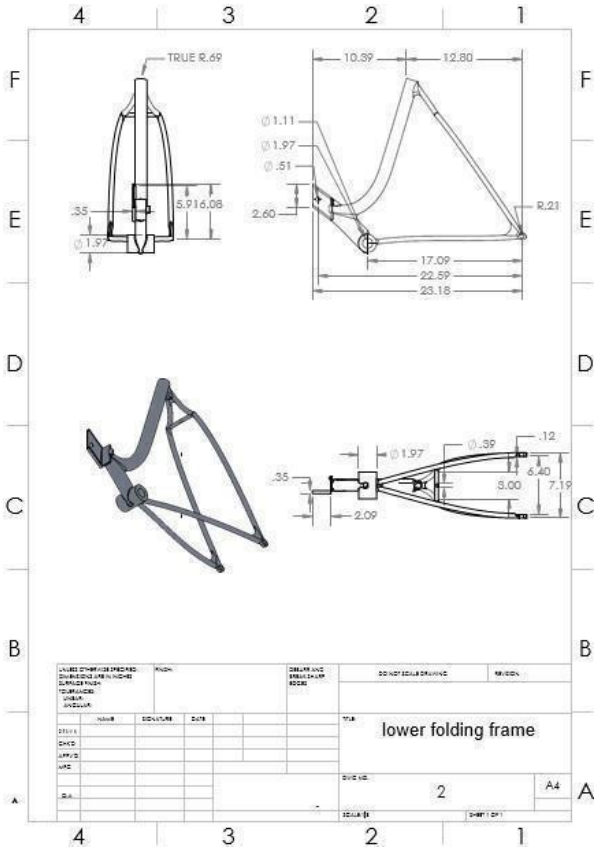
4.1 PMDC Motor: DC motors operate on the same principle, that is when a current transmitter is located in a magnetic field, has a spinning power. This ultimately gives energy to turn the wheel, resulting in bicycle movement.

4.2 Dynamo: A dynamo is an electric generator that uses a commutator to produce direct current. It works, in theory, as the law of Faraday, that an electromotive force is produced in the magnetic flux in an electric conductor. A generator or a dynamo is a mechanical power transmission tool.

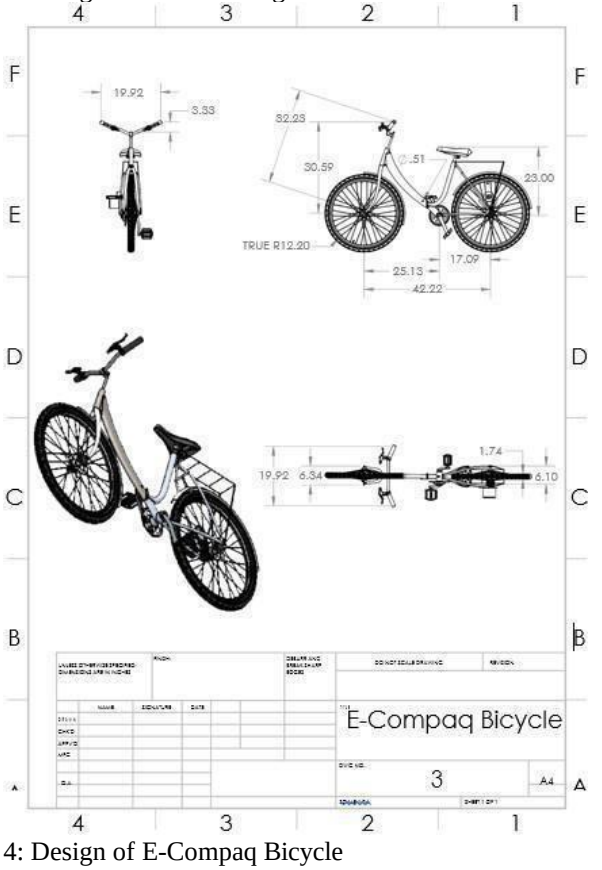
4.3 Seat Post: The seat is mounted and set to a variable depth and placed into the seat tube to change the height of the seat.
4.4 Battery: A lithium-ion battery or Li-ion battery is a type of rechargeable battery in which lithium ion moves during discharge and recharge from the negative electrode to the positive electrode. Through their high energy capacity, small memory effect and low self discharge, these rechargeable batteries are among the most common types of mobile electronics.
4.5 Seat: Triangular little seat linked to the frame of the bike on which a rider rests while driving the bicycle.
4.6 Handle Bar: Two handles for bicycle control, connected to a frame by a tube
4.7 Headlight: A powerful light at the front of a motor vehicle to make object visible upto some extent during night time.
4.8 Brake Lever: A lever on the handlebar that is connected to the brake cable and thus operates the braking mechanism.
4.9 Accelerator: It is used to accelerate or decelerate the body by varying voltage and current.
4.10 Rim: The metal circle on which the tire is placed is formed equal to the wheel's circumference. 2 below shows the design of upper folding frame of the bicycle while 3 shows the design of lower folding frame of bicycle and 4 shows the overall design of an E-Compaq Bike.



2: Design of upper folding frame



3: Design of lower folding frame



4: Design of E-Compaq Bicycle

5. Design and Fabrication

Aruna chalama and Rajesh (2014) have developed a conventional conceptual and embodiment approach to foldable bikes, which was the most important part of this research. Innovative design for easy, rigid folding bicycles was proposed by Hsieh and Chen (2012). In order to build the proposed E-Bike, the author

considered all the factors and design consideration.

5.1 Design Specifications and calculations

Motor: Permanent Magnets Direct Current Motor (PMDC) is used, which is basically similar to that of a normal DC motor. The working theory of a PM DC motor is that, in a magnetic field, when a current carrying conductor is mounted, it experiences a force. In different applications, permanent DC motors from battery- equipment, from wheelchair and power tools to transport systems and door openers, etc. are suitable. The PMDC motors are often the best solution for power transmission and motion control applications, where compact size, small working speed range, adaptability to a wide range of power supplies or low- protection are important. One benefit when choosing such an engine is that you need high start-up and acceleration torque, consistent driving rate characteristics, compact size and performance, permanent magnet DC (PMDC) motors may be the best solution.

Rating of Motor used:

Voltage: 24V

Power: 250W (0.33 Horse Power) Motor

Type: PMDC

No load RPM: 3850 rpm No load current: 2.2A

Battery: A lithium- or Li- battery is a type of rechargeable battery in which lithium ion moves during discharge and recharge from the negative electrode to the positive electrode. They are one of the most common rechargeable batteries with high power density, small memory effect and low self-discharge for portable electronics. In terms of military, electric vehicle, and aviation applications LIBs are also rising in popularity.

Rating of Battery:

Voltage: 3.7V each Current: 2200mAH Type: Li-ion Battery

Battery in parallel: 7 pieces Battery in series: 5 pieces

After adding all the batteries to make a single suitable battery for operating required motor in normal load conditions are as follows:

Total Voltage: V = 3.7V * 7 batteries V = 25.9V

Total Current I = 2200mAH * 5 batteries I = 11000mAH

As researcher joined many batteries to make a single battery to meet required specifications, one need to use battery along with Battery Management System. Here 7S 24V BMS is use. A Battery Management Systems (BMS) is any computer device controlling a rechargeable battery, such as battery safety, status tracking, secondary data processing, reporting, environmental monitoring and authentication. Main power voltage, Battery or cell voltage, Charging and discharge rates, Temperatures of the batteries or cells and Battery and cell health are the variables monitored by BMS.

Dynamo: A dynamo is an electric generator that uses a commutator to produce direct current. Dynamos was the first power generators to be able to provide electricity to industry and the basis on which many other later power conversion devices, such as the electric engine, alternating current alternator and the rotary converter, were based.

Dynamo operates on theory called the Law of Faraday which is that in an electrical conductor that surrounds a varying magnetic flux, an electronic force is produced. A generator or a dynamo is a mechanical power transmission tool.

Nikola Tesla built the generator originally. It operates on the electromagnetic induction principle. An induced emf is set in a spindle whenever the magnetic field associated with a spindle is modified.

Rating of Dynamo:

Motor Output voltage: 5V-24VMaximum load voltage: 40V Max. output current exceeds: 500mA

Max. load power: 20watts Length: 130mm

Motor diameter: 35mm Shaft length: 22mm Shaft diameter: 8mm Weight: 400gms

5.2 Calculations:

Battery Discharge:

As we already specified and calculated about battery specifications that is, Voltage: 25.9V Current: 11000mAH

Time to discharge the battery:

T = Ampere Hour (AH) of Battery / Current taken by motor(A) As, P = V * I

250W = 25.9V * I I = 250W / 24V

I = 10.41A (Amount of current taken by motor)

T = 11000mAh (Ampere Hour of Battery) / 10.41A (Current needed by motor) T = 11Ah (Ampere Hour in Battery) / 10.41A (Current needed by motor)

T = 1.05 Hours

According to calculation the battery will take 1.05 Hours to fully discharge the battery in ideal condition.

Battery Charge:

To charge the battery we need a Charger which gives direct supply to BMS only.

Time to charge the battery:

T = Ampere Hour (AH) of Battery / Battery Current(A)

T = 11000mAh (Ampere Hour of Battery) / 2A (Battery Current)T = 11Ah (Ampere Hour in Battery) / 2A (Battery Current)

T = 5.5 Hours

According to calculation the battery will take 5.5 Hours to fully charge the battery in ideal conditions.

6. Fabrication of proposed bike

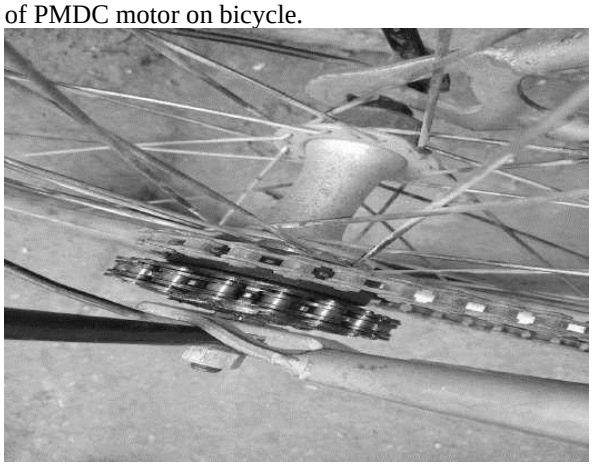
Frame Selection: The frame chosen is of a ladybird cycle because of its lightweight which makes it easy to work as per the folding requirements. 5 below shows the frame of an E- Compaq bike.

5: Frame of E-Compaq Bike

Folding: The folding is accomplished by hinge joint used in such a way that the cycle folds from left to right ensuring that other components of the cycle do not get harmed. 6 below shows the folding mechanism used in the cycle.

6: Folding of Cycle

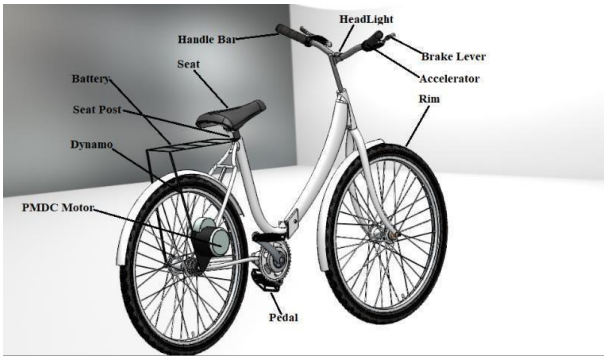
Fitting: To fit all the components in bicycle one need to perform various steps so that it will be able to meet our components requirements. 7 below shows the distinct sprockets for motor and pedal while 8 shows adjustment of PMDC motor on bicycle.



7: Sprockets for Motor and Pedal

8: Adjustment of PMDC

Assembly: All parts are assembled using screws, nuts & bolts. The Battery & BMS are fitted on the carrier of the cycle & Dynamometer and PMDC motor is fitted on the rear wheel of the cycle. 9 shows the final assembly of an E-Compaq Bike.



9: Final Assembly of E-Compaq Bike

7. Results and Discussion

In this bicycle motor is attached to multi sprocket axle, when power is given to motor using battery it results in rotation of axle and make bicycle to run and all the rest of accessories is connected to battery using motor controller. While pedaling, the dynamo will rotate and generates current which will directly charge the battery through BMS. Here we use multi sprocket axle which will help to reduce friction in power transmission which results in increased efficiency of bicycle. This bicycle is foldable from the center of bicycle using hinge joint which will make the bicycle to cover less space compared to ordinary bicycle.[4] Hinge joint basically limits the angle of rotation and having one degree of freedom which makes it suitable for this bicycle. In addition to this it can be easily portable from one place to another. Battery will also be charged from charger (24V, 2A) from direct supply of electricity through BMS. It can be used as an ordinary bicycle because transmission is different for pedaling which eliminates the additional friction. During pedaling the dynamo will rotate and generates current of 1.5A (maximum) and voltage (5V- 24V) which will directly passes through BMS and charges the battery [Hsieh, L. C., & Chen, T. H.]. Here, when you accelerate, the current will increase and results in increased speed of motor and when brakes are applied it will cut out the supply of current and pulls the brake wires to stop the bicycle.

8. Conclusion and Future Scope

At the end of this research, researcher is successfully able to manufacture the E-Compaq bicycle with all its mentioned features:

- Electric Bicycle: This bicycle is consisting of three major parts i.e. motor, battery and dynamo which makes it capable to run on battery power.
- Self-Generation: It will be able to generate the electricity using dynamo which can be used to charge the battery and it suitable for long distance purpose.
- Foldable: Folding in this bicycle is done accomplished using hinge joint which makes it cover half space compared to ordinary bicycle. It also tackles parking issue which is the serious problem nowadays.

It will run on battery power which makes it this eco-friendly bicycle will able to overcome many problems like pollution, vehicle parking, etc. and will encourage society to provoke the use of electric vehicles. This bicycle can't eliminate the use of vehicles which produces harmful gases and results in pollution which is the major cause of global warming but it can be wise step towards increasing pollution which simultaneously degrades the quality of air.

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