UNIVERSITI PUTRA MALAYSIA

AN EXPERT SYSTEM FOR ESTIMATING COST AND ANALYSIS OF AIR POLLUTION CONTROL

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BY

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LIST OF ABREVIATIONS

W_L	Welfare Loss
Q	Quantity of Emission
TC	Total Cost of Control
P	Unit cost
NO_2	Nitrogen Dioxide
SO_2	Sulfer Dioxide
A_{Si}	Accumulation of concentrations
S_{Si}	Average Concentration Standard
E	Standard Exceeding

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Faculty: Engineering

Expert System for Estimating Cost and Analysis of Air Pollution Control was developed using CLIPS. The developed Expert Systems facilitate decision making involving selection of the best available technology as control measure. It was discovered that at equilibrium, total cost of reduction is equal to total cost of damages. It was further found that change in quantity of Air pollution is positive. This shows direct relationship. Total excess damage is directly proportional to total cost of reduction. When excess damage is increasing the total cost of reduction is increasing as well. In the same way, when total cost of reduction is decreasing, the excess damage is decreasing as well. The total cost function is dependent on the quantity of emission of the form: TC=f(Q) where TC is the total cost and Q is the quantity of emission. Hence TC=QxP where P is the unit price. There was also a break-through in the estimation of Welfare loss due to excess pollution. The relationship between quantity of excess pollution and Welfare loss due to

excess pollution was derived. This devoted and faithful research has further developed Emission Elasticity.

Abstrak thesis diserahkan kepada senat Universiti Putra Malaysia
sebagai memenuhi syarat-syarat yang diperlukan Untuk pengijazahan Ijazah
Master Science

SISTEM KEPAKARAN PENGANGGARAN KOS DAN ANALISIS PENGAWALAN PENCEMARAN UDARA.

Oleh

BONIFACE EKECHUKWU

April, 1998

Pengerusi : Dr. Ir. Mohamed Daud

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Sistem kepakaran penganggaran kos dan analisis pengawalan pencemaran udara telah dimajukan menggunakan CLIPS. Perkembangan sistem kepakaran ini melibatkan pemilihan keputusan terbaik melalui teknologi pengawalan saiznya. Didapati bahawa pada keseimbangan, jumlah kos pengurangan adalah sama dengan jumlah kos kerosakan. Seterusnya perubahan dalam kuantiti udara yang dicemari adalah positif. Ini menunjukkan hubungannya secara langsung. Jumlah lebihan kerosakkan juga adalah seimbang dengan jumlah kos pengurangan. Apabila lebihan kerosakkan ini meningkat, jumlah kos pengurangan juga meningkat. Jumlah fungsi kos bergantung kepada kuantiti penyebaran : TC = f(Q) di mana TC adalah jumlah kos dan Q ialah kuantiti penyebaran. Oleh itu, TC = QxP di mana P ialah harga unit. Hubungan antara kuantiti lebihan

pencemaran dan kehilangan kebajikan tepat kepada lebihan pencemaran diperolehi. Penyelidikan ini seterusnya membawa kepada perkembangan keanjalan.

CHAPTER I

INTRODUCTION

Expert Systems are computer programs enriched with profound knowledge based intelligent system but constructed by knowledge Engineers with the help of human experts in such a way that they are capable of functioning at the standard higher than human experts in a given field to simulate decision.

Cost estimation on the other hand is a fundamental activity of many engineering and business decisions, and normally involves estimating the costs and quantity of Labour, materials, utilities, and costs of other things necessary for a project. These estimates are used typically as inputs to deterministic analysis methods such as net present value or internal rate of return calculations.

Air Emission, however, include evil oxides,ozones, tiny bits of dust, soot, and other materials called particulate which find their way into the atmosphere. Diesel engines, power plants, construction projects, wood-burning stoves, fireplaces, and the burning of forests are main sources of particulate.

These substances can cause respiratory diseases, like cancer and other health problems in people. Sometimes pollutants interact with each other, other components of the atmosphere, water vapor. Nitrogen oxides and other pollutants from fossil-fuel combustion react with sunlight to form ozone, a toxic gas. Ozone can irritate a person's throat and eyes and damage crops and forests.Acid rain starts with fossil-fuel combustion mostly from power plants and vehicles. Sulfur dioxide, originating mainly from coal-burning power plants, and nitrogen oxides, from both power plants and vehicles are the gases resposible for Acid rain. Once in the air, these evil gases combine with water droplets and form sulfuric and nitric acids. The acids can now fall as rain or snow or can hover near the ground as fog. Acid "rain" can even fall to earth as dry particles.

Sources of Emission: Automobiles and power plants are two major responsible generators of air pollution. Power is generated from Fossil fuels including coal, oil, and natural gas. Power which is indispensible for Manufacturing companies is also reponsible for air pollution. The Manufacturing companies burn the fuels to make energy which creates a lot of waste. Most of the waste is in the form of toxics or potentially harmful gases. The most dangerous gases which Manufacturing companies produce in effort to generate power include: carbon monoxide, nitrogen oxides, and sulfur dioxide. The worse of them is carbon monoxide because very small amount of it is very poisonous to life. Yet Manufacturing companies produce it in huge concentrations daily.

Statement of the Problems

The desired interest of the project involves application of Expert Systems to cost estimation on Air pollution analysis. Determination of total control cost, unit control cost and total quantity of emission are the centre of this research. It has been a serious problem on how to estimate the effect of Air pollution especially in dollar values. So often people are deprieved of their intention or prevented from carrying out their proposed plan by haze and general pollution. It is not easy to compute the exact cost of these social problems. Hence, there is a very urgent need to estimate the dollar equivellent of the Social Welfare damage. In some cases and in some university like Universiti Pura Malaysia, a renound Professor may decide to travel abroad during holidays only to be prevented by the haze problems. This is an example of social welfare damage and should be computed in estimate of dollar value. In some countries there is often significant change in their cost of control of the air pollution. Solution for this significant change in the cost of control should be determined.

Research Objectives

The objective of the work is to develop an Expert System for cost estimation in Air pollution Control Systems. It will facilitate decision making, and selection of the best available technology as control measure. The work is to be done based on **Deterministic System**. The deterministic system is a relation between variables that are known with certainty, eg TC=QxP. Once the levels of Unit Price of control and Quantity of emission are known with certainty, Total Cost of emission can be exactly determined. In the same way, when Unit Price of control and Total Cost of emission control are known, Total Quantity of emission can be exactly determined too. In this case, predictions can be made with high level certainty. There is no error term in this case. The stochastic system which is not going to be used here has error term and makes use of random variables. In the case of stochastic system, prediction is done without certainty.

Scope and Limitations

Cost estimates involve using a number of different factors to try to determine the overall cost of a system. Cost estimates are usually only approximate statement of the cost of a job to be done. Despite the terminology, cost estimation, sometimes do not refer to dollar figure associated to it, because of variations in quantitative and qualitative inputs, input costs, and other peculiarities. This work is limited to five selected qualitative inputs. Five knowledge-base files and five data files. This system cannot run on it's own without clips environment.

Outcome of the Research

The inputs are the control measures for Air Pollution control. The outputs are the total cost, unit cost, and quantity of emission. The developed Expert Systems facilitate decision making involving selection of the best available technology as control measure. It was discovered that at equilibrium total cost of reduction is equal to total cost of damages. It was further found that change in quantity of Air pollution is positive. This shows direct relationship. Total excess damage is **directly proportional** to total cost of reduction. When excess damage is increasing the total cost of reduction is increasing as well. In the same way, when total cost of reduction is decreasing, the excess damage is decreasing as well. The total cost function is dependent on the quantity of emission of the form:

$$\mathbf{TC=f(Q)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where TC is the total cost and Q is the quantity of emission. Hence **TC=QxP** where P is the unit price. There was also a break-through in the estimation of **Welfare loss** due to excess pollution. The relationship between quantity of excess pollution and Welfare loss due to excess pollution is given by:

$$QuantityofExcessPollution = \frac{WelfareLossduetoExcessPollution}{Unit\,PriceofEmission}$$

$$Q = \frac{W_L}{P} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, Q is the quantity of Excess pollution, W_L is the Welfare Loss due to Excess Pollution, and P is the unit price of Emission.

The above expression shows that quantity of emission is given by the quotient of welfare loss and unit cost of emission. The unit cost in this case refers to dollar equivelent of one unit of emission to the social welfare.

$$WelfareLossduetoExcessPollution = QuantityofExcessPollutionxUnit\Pr iceofEmission$$

$$W_L = QxP \qquad \text{...(3)}$$

Where W_L, is the Welfare Loss due to Excess Pollution, Q is the quantity of Excess pollution and P, is the unit price of emission. Total Welfare loss is like total cost function. This devoted and faithful research has further developed **Emission Elasticity** which is given by:

$$EmissionElasticity = \frac{ChangeinQuantityofEmission}{ChangeinCostofControl} x \frac{TC}{Q} \qquad \text{.......................(4)}$$

The function of this Emission Elasticity is that it determines the effectiveness of the control measure. The Emission Elasticity is also useful for appraisal of air pollution control measures.

CHAPTER II

LITERATURE REVIEW

Air Pollution Overview

Environmental Standards for air quality have been established in various countries of the world under the basic environmental law regulation to protect human health and conserve the proper living environment. Air Emission, however, include evil oxides,ozones, tiny bits of dust, soot, and other materials called particulate which fmd their way into the atmosphere (Ashuvud.J, 1991). Diesel engines, power plants, construction projects, wood-burning stoves, fireplaces, and the burning of forests are main sources of particulate (Bogen J, 1974). These substances can cause respiratory diseases, like cancer and other health problems in people. Sometimes pollutants interact with each other, other components of the atmosphere, water vapor or sunlight (Feicht.E, 1992). Nitrogen oxides and other pollutants from fossil-fuel combustion react with sunlight to form ozone, a toxic gas. Ozone can irritate a person's throat and eyes and damage crops and forests (Bojo J, et al 1991). Many people have written many books and papers on Environmental impact assessment. Among many books and journals reviewed the relevant ones to this work include

Karvonen M.J (1974) who states that in Finland, the mean concentration of lead in clean air was 0.025μg/m^3 . He further states that the activity of erythrocyte aminolevulinic acid dehydratase (AL-D) is suppressed by lead in blood at all levels. Increased cadmium levels have been found in dust precipitating around some cellulose factories. Mercury from industrial emitters enters water, partly directly, partly via the air. Yao Z (1985) writes that the monitoring and evaluating of ambient air quality is an important first step in controlling air pollution. To investigate the quality of ambient air, Bojorquez .T L. A et al. (1992) argued, routine air monitoring should be regularly conducted mainly through manual intermittent operations. As a result, substantial amounts of aerometric data should be accumulated. The ambient air quality can be evaluated from these data by statistical methods by the newly developed method of the air quality index (Cosson P.R, 1992). In Osaka Prefecture, total volume of automobile Nitrogen Oxides reduction plan targets the reduction of annual Nitrogen dioxide emission from motor vehicles by 9,960 tons from the level 31,380 tons so as to nearly satisfy the Nitrogen dioxide environmental standard by the end of march 2001 (Arsen J.D, 1994). Osaka Prefecture intends to realize this target, by regulations on the emission of each motor vehicle and restrictions for specified vehicles, promotion of low-emission vehicles, and rationalization of the use of vehicles through various measures on passenger and cargo traffic (Arsen J. D, 1994). These means are being implemented under close liaison with related organizations. The Prefecture enacted motor vehicle NO_X control law in 1992 which stipulates emission level standards for specified motor vehicles such as cargo vehicles and buses in addition to existing emission control and includes unprecedented control measures such as regulation of vehicle types such as refusal of registering non-qualifying vehicles in the designated area, promotion of low-emission vehicles and guidance on rationalization of motor vehicle use. Because past emission concentration regulations failed to be effective in areas with a large number of smoke and soot emitting facilities, the air pollution control law introduced the so-called "K-Value regulation" on Sulfur Oxides. The k-value regulation is a method of regulating allowable emission level for Sulfur Oxides based on stack height. Specifically, the constant K of the equation is determined by the degree of concentration of facilities emitting smoke and soot in the area to ensure that concentration on the ground will be below a certain level. Regulation is tightened gradually while monitoring the actual enforcement of the regulation and the level of environmental pollution, with a view to reaching the environmental standard by the target year 2001.

Allowable Emission level for Sulfur Oxide is given by: $q = Kx10^{-3}xHe^2$ where q is allowable emission level for Sulfur Oxides (Nm^3/h, with N as standard level). K is constant for each region where He is effective height of stack(m). $He= H_O +0.65x(Hm +Ht)$. H_O is actual height of stack, where Hm is ascent height of upward momentum at stack exit. And Ht is ascent height based on temperature difference between stack gas temperature and atmospheric temperature (Arsen J.D, 1994).

On the application of economic control instrument (Kampmann, 1985) shows that so far economic control instruments have been used only to a small extent in the Danish environmental protection efforts.

Recycling , Charges and General Environmental Support Scheme. Apling .A

States the dangerous effects of: carbon monoxide(CO), hydrocarbons(HC) and the oxides of nitrogen (NO and NO_2, usually refered to together as NO_x). Bogen.

his work trace-element concentrations in atmospheric aerosols which are of interest for critical examinations of local air pollution situations and for the detection of toxic elements in the earth's atmosphere. Writing on Pollution control for small and medium industries (Taylor D.F, 1985) mentained that the overwhelming majority of industrial polluters are small and medium sized enterprises. For such companies the installation of individual treatment systems pose several problems on account of low capital investment in business (Ferrari L, et al. 1985), (Graham B, et al. 1992). The cost of a pollution control system therefore represents a relatively additional investment. Low profit margins also constitute problems to such companies because of the intense competition from other companies in the same business (Roy P.L, 1985). In addition to the above such companies have small size of operation, high cost of infrastructures, inadequate management structure and other limitations (Greig-Smith P.W, 1991). (Andersson M, et al. 1992) stated that Environmental problems are functions of process of economic development and the ability to mitigate the problems through regulations. The objective of this study is to present an overview of environmental problems and the corresponding regulations. Ahmad.A et al. (1991) pursues three fundamental themes, first it focuses on why environmental economics in practice is not primarily an excercise in estimating the value of pollution damages and then promulgating taxes to make polluters internalize those harms, but consists mainly of applied cost-benefit analysis. Although many researchers are occupied with valuing environmental damages using a variety of techniques, but that is not the central analytical support support environmental economics contributes to the regulatory and policy making process (Bojarski S, et al. 1988). Also it shows that much of the hard work in practical applications of environmental economics involves fashioning a coherent set of questions for analysing questions that reflect multiple policy goals and constraints the complexity of real-world pollution problems and the limitations of available information, (Bower J.S, 1985). It emphasis how practical environmental policy analyses often pose some deceptive theoretical questions, particularly problems in measuring the social cost and benefits of environmental regulations (Harris P, 1990). The book communicates the richness of practical economic analyses of environmental regulatory policy. Tombach.I (1985) stresses that many air pollution measurements can be made with automated insruments which are capable of measuring specific pollutants sensitively, precisely, accurately, and with a response time of a few minutes or less. The paper reviews the measurement of gaseous and particulate pollutants in ambient air (Ishwar.K.P, 1993). On the same air quality monitoring (Bower.J.S, 1985) analysed the data covering from April 1983 to March 1984 during which period both long-and short term concentrations of sulphur