環境衝擊對軍品壽命週期之改善思維—線性規劃模式之應用

New Concepts about Reducing the Environmental Impact of Military Equipment during Life Cycle-Application of Linear Programming Model

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提　要

一、人類的文明及科技持續發展，不管是生產、消費而至最後的廢棄物，使產品壽命週期內的外在負面因素愈來愈多，對環境產生直接或間接之衝擊。

二、整個軍品壽命週期中，從投入「資源」、「生產流程」、「消費者需求」、「環境衝擊因子」及「政策制定」等規劃模式與思維，透過非強制性手段，誘導與改善企業可能造成環境破壞各項因子之檢視與規範，降低產品整體作業流程對環境的衝擊。

三、軍品或武器系統之研發、產製而至部署與汰除，雖涉及國家安全有不得不爲之因素，然如何降低對環境之衝擊，也是國軍幹部應該周詳考量之因素。

關鍵詞：壽命週期、溫室效應、外部成本、環境衝擊因子

Abstract

1. With the continuing development of human civilization and technology, the life cycle of a product, from production, consumption to final waste, is involving more and more external adverse factors which bring about direct or indirect impact on the environment.
2. Throughout the life cycle of military equipment, linear programming and concepts should be applied in all aspects, including the input of resources, the process of production, the demand of consumers, factors of environmental impact, and the formulation of policies. Noncompulsory measures should be employed to guide the enterprises to inspect and regulate every factor that could cause damage to the environment so as to reduce the environmental impact of military equipment.
3. The research and development, production, deployment and replacement of military equipment or weaponry systems are necessary for the sake of national security. However, the military authorities should also consider how to minimize environmental impact.

Keywords: life cycle, greenhouse effect, external cost, factors of environmental impact

壹、前　言

最近非常熱門的電影「明天過後(The Day After Tomorrow)」，敘述著人類在著重短期利益，無止盡的發展經濟之際，漠視對大自然的保護，加諸長年累積的破壞環境行爲，使「溫室效應(Greenhouse effect)」造成氣候變異，全球隨即陷入第二次冰河時期的故事；描述人類在這遠比想像中來得震撼、恐怖及無所適從，也來得非常快、非常有切身之感的災難中，感受到人們的無力感，使我們突感不是一兩千年以後才會發生的事，而是在您我有生之年即將面臨的場景，而此巨大的反撲將使我們努力建設之成果，毀於一旦、一切歸零，又將回復冰河時期。總之，由於電影之張力，大家或許有些許的震撼與感同身受，但我們若回想一下，已有專家學者提出有關「溫室效應」可能引起各種影響及警告，如「澳洲研究報告指出大堡礁珊瑚50年內大半將死亡」、「2007年，年復一年增強的狂風暴雨將衝破荷蘭引以爲傲的堤防，海牙等大城市將淪爲風雨中的廢墟」（如表一）等，影響未來人類之生存與發展。

1.Introduction

The popular movie 'The Day After Tomorrow' shows a scenario about how human's pursuit of short-term interests and endless economic development, neglect of the protection of nature, and decade-long accumulated destruction to the environment have so seriously aggravated greenhouse effect as to trigger dramatic global climate change; as a result, the world slips into the grip of the second ice age. The movie depicts a shocking and horrible disaster far beyond our imagination. It comes so quick that the human beings

表一　「溫室效應」造成之影響及後果

現　象	後　果
礁珊瑚死亡[註一]	科學家預測21世紀中，大堡礁附近水溫將上升2到6度。若出現最壞的情況，至2020年，珊瑚白化現象將造成高達80億澳幣的經濟損失，12,000人失業。
海平面上升	1.2010年到2020年間，歐洲平均氣溫每年可能會降低攝氏3.3度。英國則變得越來越冷、越來越乾，最後可能會成爲「北海上的西伯利亞」[註二]。 2.最早可能在2007年，年復一年增強的狂風暴雨將衝破荷蘭引以爲傲的堤防，使得許多低於海平面的地區無法居住，海牙等大城淪爲風雨中的廢墟[註三]。 3.氣候異常變遷，油源供不應求，核武擴散勢難避免，而整個地球的「承載力」也將萎縮可能在20年後引發全球資源爭奪戰爭，國際間可能爆發衝突及侵略[註四]。 4.當海平面上升1公尺時，中國大陸沿海將12萬平方公里土地被淹，7,000萬人口需要內遷，嚴重影響經濟較爲發達的中國大陸沿海地區[註五]。 5.全球持續暖化恐在1000年內融化格陵蘭冰原，淹沒太平洋島嶼等低地[註六]。

註一　「澳洲研究：大堡礁珊瑚50年內大半死亡」，中時電子報（臺北，2004.2.21（法新社雪梨21日電））。

註二　美國國防部「淨評估辦公室」主任安德魯．馬歇爾主導，委託專家完成一分機密報告，指出全球氣候變遷將在20年內引發人類浩劫，自然災害與戰爭可能將導致數百萬人死於非命，其影響遠比恐怖主義嚴重。中時電子報（臺北，2004.2.23，英國《觀察家》周報報導）。

註三　同註二。

註四　同註二。

註五　北京「瞭望」週刊報導，受海平面上升影響最大的是珠江三角洲。珠江三角洲的總面積爲6,932平方公里，如果未來海平面再上升30公分，按照歷史最高潮位，在無防潮設施情況下，珠江三角洲淹沒面積將達5,500多平方公里，中時電子報（臺北，2004.4.13（中央社臺北13日電））。

註六　英格蘭南部瑞丁大學(University of Reading)的氣候科學家葛萊哥利(Jonathan Gregory)表示：「……到時任何低於海平面不到七公尺的地區都將會被淹沒。」；此使孟加拉、太平洋上的島嶼及部分佛羅里達州等地區陷入被海水淹沒的威脅，中時電子報（臺北，2004.4.8（路透倫敦電））。

are literally unprepared, stupefied and powerless. The movie warns us that the disaster is not something that would only occur a couple of thousand years later. Instead, it will strike before we depart this life. Moreover, the backlash by the great nature would be so harsh that the human civilization as a whole would be completely destroyed and sent back to the glacial epoch. In short, people may be shocked by the episode and impressed with the tension of the movie. Actually, some scholars have raised their concerns and warnings about the consequences of fast increasing greenhouse effect. For instances, according to an Australian report, the coral reefs in the Great Barrier will perish within 50 years; as early as in 2007, the increasingly powerful storms would destroy the banks that make the Dutch so proud of themselves and might ruin such big cities as the Hague (see table 1). Consequently, global warming will have very serious impact upon the existence and development of the human beings.

國立臺灣大學環境工程研究所於幼華教授[註七]表示：「人是陽光做的，因爲陽光照在地球上，綠色植物接受後，把光能轉變成化學能，陽光促成二氧化碳與水結合，變成細胞質；人吃綠色植物，或吃綠色植物的動物，『它們是陽光做的，我們等於是陽光做的』」。但是，全球人口持續不斷的上升，由1100年全球5億人口，到1804年10億人口，而至2006年的65億人口，侵略性、擴張性及繁殖性太強，就如同「蟑螂、螞蟻一樣」；人類把地底下所有累積之陽光都用到自己身上，造成已持續供地球能量40多億年的能源，預計2040年就會用光地球上的石油，更將幾億年時間累積的煤、天然氣及石油等石化燃料使用殆盡。

"Human beings are made out of sunlight," said Professor Yu You-hua of National Taiwan University. "Green plants on earth take in sun-

Table 1 The results and impacts of greenhouse effects

Phenomena	Results
Perish of coral reefs	Scientists forecast that the water temperature around the Great Barrier will rise 2-6℃ in the 21st century. In the worst scenario, in 2020, coral bleaching, or the whitening of coral colonies, will result in the economic loss of 8 billion Australian dollars and make 12,000 people jobless.
Rise of sea level	1.Between 2010 and 2020, the temperature in Europe will drop 3.3℃ annually. The UK will become colder and drier; at last, it could turn into Siberia in North Sea. 2.As early as in 2007, the increasingly powerful storms would destroy the banks that make the Dutch so proud of themselves; floods would make many below-sea-level areas uninhabitable. Such big cities as the Hague might end up as ruins in the relentless storms. 3.Due to dramatic climate change, oil demand could not be met and the proliferation of nuclear weapons would be inevitable. The load capacity of the earth would shrink. Wars for global resources might erupt in 20 years. There would be conflicts and invasions in the international community. 4.When sea level rises 1 meter, an estimated area of 120,000 km^2 on the coast of China would be inundated and 70 million people would be forced to relocate inland. This would bring a grave impact upon the economic prosperity of the coastal provinces of mainland China. 5.Continuous global warming could melt the ice field of Greenland within 1000 years. Many lowlands such as those islands in the Pacific Ocean would be submerged as a consequence.

註七 於幼華教授演講，「需索無度，嚴重消耗地球能源──新人類出現才7千年，已將數億年累積的煤及石油使用殆盡，唯有修正取用的文化，才能延緩危機」，聯合報（臺北，民國93年5月30日。）國科會與聯合報、公共電視、科學人雜誌、中廣公司、NEW98合辦、中央大學理學院科學教育中心承辦「2004展望演講春季系列人與環境」，第七場由臺灣大學環境工程研究所教授於幼華博士主講「環境與能源－利用古代或今日之陽光」。

light and transfer it into chemical energy. Photosynthesis facilitates the combination of carbon dioxide and water which produces carbohydrate, the substance of plant cell. Human beings eat green plants and animals that eat green plants. The green plants and animals are made out of sunshine. Therefore we can claim that human beings are made out of sunlight." As the global population continues to rise, from 0.5 billion in 1100, to 1 billion in 1804, and to 6.5 billion in 2006, so do the aggressiveness, expansiveness and productiveness of the mankind, "just like cockroaches and ants." The human have monopolized and utilized the subterranean energy resources accumulated over four billion years. It is estimated that gasoline would be depleted in 2040. The mankind would soon use up such petrified fuels as coal and natural gas deposited over the past hundred million years as well.

顯然地，這些環保問題與經濟發展之衝突，是大家都耳熟能詳的事情，「信者恆信、不信者恆不信」，可能不是一場電影、一次宣導或教育就能讓人們深刻體驗而身體力行的；畢竟，經濟代表者麵包、環境破壞卻無法使人們立即感受其後續影響之深遠性。所以，爲政者如何設計法令加以規範，而國軍組織在開發產品或新武器系統時，如何將可能造成社會之無形成本（如污染）計算於產品或武器系統開發成本中，落實於壽命週期成本與管理內，對我們生存之地球或環境，必將有所助益。如歐盟頒布之「廢電子電機設備管制指令(Waste Electronics and Electrical Equipment, WEEE)」，主要在降低生命週期短暫之電子電機物品廢棄後對環境所帶來的危害，並鼓勵該類物品之再使用(re-use)或材料再生，達到資源回收之目標，降低廢棄電子電機物品的產量與處理量。而國軍之武器系統（電戰設施）之壽命週期中，若能多一分降低環境衝擊之思維，運用線性規劃之作業模式，除能眞正了解任一武器系統於產製、部署，而至汰除所可能產生之有毒物質外，亦能透過規劃，有效反映於後續之處理作業，對生存環境，也能貢獻一分心力。

Obviously, most people are familiar with the conflicts between environmental protection and economic development. Those who are convinced of the consequences of global warming will remain convinced, while those suspicious will remain suspicious. A single movie or educational film can hardly change the perception of the suspicious and convert them into true believers and vanguards of environmental protection. After all, economic development means bread, while the mankind cannot immediately appreciate the deep implications of damage to the great nature. Therefore, politicians should be aware of the environmental implications of legal provisions and regulations. Likewise, the military authorities, when developing new products or new weaponry systems, should consider the intangible social cost of pollution as a part of the overall cost and deal with the issue of pollution as a part of life cycle management. So that such considerations and practices will benefit our earth. Waste Electronics and Electrical Equipment (WEEE) is issued by the European Union. WEEE encourages recycling of electronic and electrical goods and facilitates reduction of the waste of such goods, so as to minimize the damage of the short-lived electronic and electrical products to the environment. The concept of reducing environmental impact and the employment of linear programming model should be

introduced into the life cycle of the weaponry systems (electronic warfare equipment) of the ROC armed forces. This will further our understanding of the potential poisonous substances to be produced in production, deployment and replacement stages, and will help us minimize pollution and thus contribute to environmental protection.

本文主要翻譯《新產品對環境的衝擊[註八]》一文爲藍本，以企業新產品開發之環保考量爲主軸，隱喻國軍軍品之壽命週期可能對環境之衝擊與影響，以及其隱含成本之計算模式，提供國軍幹部之重視與思考，如廢彈、廢油、報廢武器設備等之再利用、再循環或再生，重點在啓發而非軍品壽命週期實例說明，藉其將武器系統研發過程所可能造成之不利環境因素，運用線性規劃模式，量化爲可供評量之指標，反應於武器壽期成本中，以促使武器系統於其購料、生產、儲存、部署、使用、汰除等壽命過程中，各項有害環境之因素降到最低。

Translating 'The Environmental Impact of New Products' as a blueprint, this study explores enterprises' main considerations about environmental protection in the process of developing novel goods. It is hoped that the military authorities may draw an analogy between military goods and business goods in terms of environmental impact during their individual life cycle, that they may appreciate the calculation model of implicit cost, that they may value the reuse, recycling and recovery of expired ammunition, fuel, weapon and equipment, that they may employ linear programming model to investigate the previously ignored environmental cost throughout the life cycle, so as to minimize the damage caused by negative factors.

貳、科技發展的負面因素

至21世紀來，隨這人類的生活進步，科技的日新月異與突飛猛進，相對地對我們生存的環境產生極大的破壞與殺傷力；近來，科學界也愈來愈關注並投入心力研究與環境保護有關之議題，如殺蟲劑與除草劑對水源之影響、氟氯碳化物(CFCs)對臭氧層之影響、長期熱帶雨林燃燒之影響等課題；甚至包含科技、資源使用、有毒物質與產品對環境造成負面衝擊等問題。但是，非常明顯地，不管是開發中國家或是未開發中國家，上述之社會成本並無法顯現於各企業之損益平衡表內。而這些被稱爲所謂的「外部成本(External Cost)或負面因素(Negative Externalities)，就是對企業員工、生產者、消費者，甚至從未參與生產或消費之大眾所產生的疾病與傷害之成本。無論何時，這些成本都是存在的，科技所帶來的損益計算方式，並無法正確描繪出實際的社會成本，並將其有效納入產品成本中。

2.Negative factors in technological developments

The 21st century has witnessed the advancement of human life and technology, which, however, also brings serious negative impacts to our living conditions. Recently, the scientists have paid more attention to issues regarding envi-

註八 Thore S. and Ferrão P. C., The Chapter 9 of The Environmental Impact of New Products for Sten A. Thore, Technology Commercialization: DEA and Related Analytical Methods for Evaluating The use and Implementation of Technical Innovation, Kluwer Academic Publishers(2002), pp.277-290.（本文主要翻譯、小部分修改此文章之構想，期能提供國軍在武器系統壽命週期中，增加環境保護之觀念與作爲）

ronmental protection, such as the effect of insecticide and herbicide on water resources, the effect of CFCS on the ozone layer, and the result of the burning of tropical rain forests, the side-effect of technology, and the problems caused by toxic substances and products. However, it is obvious that the social costs of the aforementioned issues are not presented in the balance sheets of enterprises. These costs, called external costs or negative externalities, are diseases and injuries suffered by producers, consumers and even the general public that have nothing to do with the production or consumption of the products at all. These costs exist all the time. However, the calculation of profits and costs brought about by technology cannot correctly reflect the practical social costs; nor can the social cost be included in the costs of products.

若無法有效訂定空氣或水資源之使用財產權，其對生存在這塊土地上的生物皆會產生影響，而負面因素將持續發生與惡化，侵蝕我們周遭環境於無形；被使用之資源若屬無財產權擁有者，則表示製造有毒物質污染空氣之事件將層出不窮，其對環境之影響將求償無門，也無法有效嚇阻企業的生產行爲，而如此訂定之產品價格對製造有毒物質之廠商言，任何製造有毒物質之成本皆爲零。

If we cannot effectively formulate property right for the use of air and water resources, all living things on this piece of land will be affected, and aggravation of negative externalities and pollution will continue. If no property right needs to be assigned to the utilized resources, it implies that there will be innumerable cases of producing toxic substances and pollutants, that there will be no way to ask for compensation for environmental pollution, and that there will be no deterrent for manufacturers that cause pollution problems. Accordingly, such manufactures do not have to bear any pollution cost.

參、產品之壽命週期評估

壽命週期評估是一種評估產品或服務對環境影響程度的技術，此壽命週期包括原材料投入生產一直到產品被使用至汰除與拋棄的整個期程。圖一描述了整個壽命週期之主要流程，方塊圖內表示其作業或活動；而方塊圖與方塊圖間之箭頭表示流動的能源或產品，閱覽此圖時由左至右，隨著產品流路，從資源而至最終產品使用與拋棄，透過兩個迴饋圈加以顯示可再重複使用的流程，使已廢棄之產品，經處理或加工後再一次投入生產線中，使資源再一次被運用；而再循環運用或製造之模式亦同。

3.Assessment on life cycles of production

Life cycle assessment (LCA) is a technique of assessing the environmental impacts associated with a product or service, during its life cycle. The life cycle covers the entire time span from the extraction primary resources employed for manufacturing the good to the end of its useful life and its disposal. Figure 1 illustrates the principal phases of the life cycle. The blocks of the diagram represent processes or actions; between the blocks flows energy or products. Reading the diagram from the left to the right, one follows the conventional production chain from resources to the use of the finished product and the eventual disposal of it. Two feedback loops are illustrated: the reuse of goods returning the discarded product to the distribution block, and the recy-

cling and the return of the discarded product as input into production.

若以「玻璃瓶」之製造、配銷與使用流程之壽命週期爲例，其玻璃瓶之原材料是矽砂，經由電源趨動電力設施，而此電力設施需要燃燒煤及原油，並排放出硫及其它有毒物質污染空氣，這些造成負面之影響因素或成本，應列入收支平衡表內；但現有的研究中，分析人員必須判斷及追蹤產品鏈上游廠商之影響程度，並判斷產品鏈上之負面因素是內部亦或是外部產生的，做爲組織改善方向與追求卓越之依據。

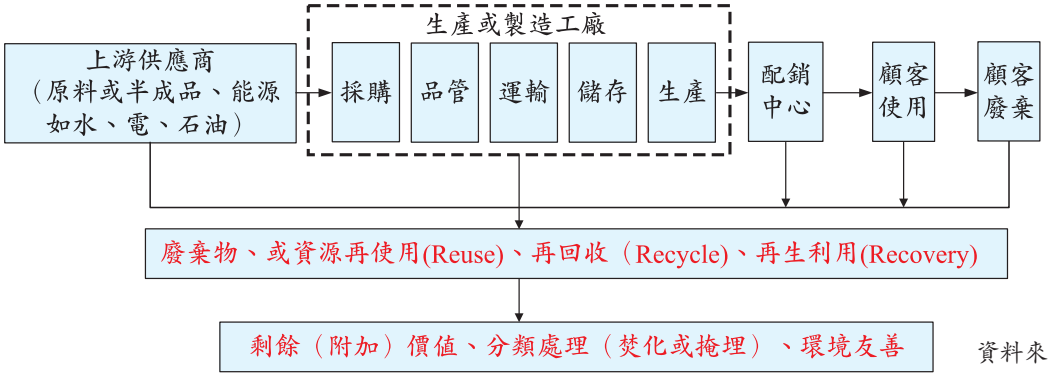
As an example of the life cycle, consider the manufacture, distraction and consumer use of glass bottles. The main raw material in the glass mills is silicon sand. The needed electric power is provided by an electric utility. The electric utilities burned coal or oil and discharged sulfur and other pollutants into the air. Should these negative impacts be included in the balance sheet? For any given study, the analyst has to decide how far back upstream in the production chain it is desired to track the effects. Somewhere, the lines has to be drawn between endogenous and exogenous factors.

就玻璃瓶生產製造言，既然我們日常生活中必須有玻璃瓶，其源頭乃透過原材料玻璃砂、經層層作業流程轉變爲玻璃瓶。實際上，這轉換過程在供應鏈(Supply Chain)是非常重要的界面，每一個過程皆可能消耗能源並產生廢氣。另外，其最終產品將被配銷至倉庫或超市，最後再販售給消費者；消費者使用後，這些玻璃瓶將會被如何處理呢？有些玻璃瓶將被回收與重新清潔（如使用水或洗潔劑清洗），其他被收集並被重新磨成玻璃砂，剩下的則當成垃圾掩埋。

Once the glass bottles have been manufactured, they are transported from the glass mills to the bottlers. Actually, transportation is an important feature at every link of the logistic chain. Also, there is use of energy and discharges into the air. Next, the final consumer product is distributes to warehouses and supermarkets, eventually to be sold to the consumers. What happens to the glass bottles after they have been used? Some bottles may be collected and cleaned, others are collected and recycled back to the glass mills, and the remainder ends up in the landfills.

由產品壽命週期評估過程中，讓我們進一步了解其對環境可能產生影響之種種原因，藉此我們可以透過自然回收或處理之方式，降低其對環境之衝擊。事實上，所有對環境的衝擊因素都應該進行確認，如對自然或實體的危害（及可能產生獲利情形），唯有如此，才能眞正判斷出產品最終所應付出之

綠色產品壽命週期流程圖



資料來源：作者自繪。

環保成本。而此產品之整體壽命週期分析流程中，如國軍之彈藥、槍枝、電池、膠質產品等生產，又何嘗不是如此呢！整體作業流程及其可能對環境之破壞，若無適當之防護或預防作爲，其實我們不知不覺中也在破壞我們所居住的環境。

In the assessment of life cycles of production, we further understand the environmental impact caused by the production. We use re-cycle system to reduce the negative externalities. Actually, all negative externalities should be understood and be prevented from environmental impact. On other hand, with analyzing the life cycles of military equipment of artillery, batteries, plastics, we found the same situation. The whole life cycle of production keeps damage our living environment if we do not have proper protection or prevention on it.

肆、主要環境衝擊之因子

任何重視環境保護國家，必然有許多衡量對環境影響之系統、罰則與方法，如二氧化碳、二氧化氮、二氧化硫、一氧化碳、甲烷、氯及鉛等有毒物質的排放量；且已對所有有害物質實際排放比例，律定排放標準值，若超過此標準值，將對人體產生危害，如地球臭氧層的破壞、癌症及鉛中毒等；若排放值低於標準值，則不會有立即之危險發生；但是，排放之物質在某一特定區域內，經長年的累積到達某一水準後，亦會產生嚴重的危害，所以必須經過各種法規或管理手段加以規範與監控，才能降低對生物之危害。以下概述有害環境物質之清單：

- 溫室效應。
- 臭氧層稀薄化。
- 酸雨。
- 湖泊藻化。
- 煙霧(Smoke and Fog)。
- 殺蟲劑。
- 鉛與其它重金屬。
- 人類的癌症。
- 消耗無法再複製之自然資源。
- 固態廢棄物。

4. Major factors of environmental impact

The countries that pay attention to the environment protection have many assessment methods and regulations to environmental impact. There are different ways of systematizing the various discharges into the environment. Once is to record the chemical substances released, such as CO2, NO2, SO2, CO, methane, chorine, lead and so on. For each substance, the actual release will be compared with the total 'critical' volume beyond which some particular damage will occur, such as destruction of the ozone layer of the earth, cancer, or leading poisoning. As long as the actually volume is well below the critical volume, there is no immediate cause for concern. But if current releases push the concentration of some chemical substance at a given geographical location close to the critical level, a warning bell should be sounded.

- The greenhouse effect
- Thinning of the ozone layer
- Acid Rain
- Eutrophication (dying lakes and waterways)
- Smog (=smoke+fog)
- Pesticides
- Lead and other heavy metals
- Cancer in humans
- Exhaustion of non-reproducible natural

resources

・Solid residuals

一、溫室效應

二氧化碳是全球生物平衡的最佳微調因子，因爲人類吸進氧、呼出二氧化碳，驅動引擎燃燒碳氫化合物，釋放出二氧化碳。所有的綠色植物及微生物正好與其相反：透過光合作用，它們轉換二氧化碳回復爲碳氫化合物與氧氣。但全球性的平衡已受到影響，如石化燃料的燃燒或熱帶雨林放出之二氧化碳，其總量超過綠色植物之需要量，使二氧化碳大量排入大氣層造成嚴重失衡，溫度節節升高，這就是所謂的溫室效應。

(1) Greenhouse effect

Carbon dioxide is part of fine-turned global ecological balance. Humans breathe in oxygen and breathe out carbon dioxide. Combustion engines burn hydrocarbons and release CO2. All green plants microorganisms do the opposite: through photosynthesis they convert carbon dioxide back to into time. The burning of fossil fuels and tropical rain forests spews more CO2 into the air than the dwindling reservoir of green plants is able to break do again. The result is pyramiding of carbon dioxide levels in the atmosphere: increasing levels of greenhouse gases trap more heat from the sun inside the atmosphere. The average temperature rises-global warming

趨勢顯示，每10年全球平均溫度升高0.2℃，若一直到2050年，歐洲的西部與北部的冬天平均溫度將升高5度，而歐洲的南部將增加4度。而如此之改變將使許多易受影響之區域受到傷害，暖化將對高海拔之高度產生劇烈影響，造成世界穀物生產區的大規模乾旱及升高海平面高度，影響低窪地區人民生活。

According to the current trend, the average temperature of the globe increase by approximately 0.2 degree Celsius every 10 years. By 2050, the winters in the North and West of Europe should be about 5 degree warmer and the summers in Southern Europe about 4 degrees warmer. The geographical area most vulnerable to such change are precisely those that have the least capacity of adapting. The warming will be most intense at high latitudes; the world's grain belts will become drier, and rises in the sea level will affect people living deltas and low-lying area.

二、臭氧層稀薄化

臭氧層產生在同溫層上，用於阻擋對人類有害的紫外線進入大氣層內或地表，否則將嚴重影響人類生活。然高空飛行器之排氣，其產生的二氯二氟代甲烷及碳氫化合物如含氟氯碳化物，將對臭氧層產生破壞。在1978年美國簽署了《蒙特利禁用含氟氯碳化物草案》，並在本世紀內，有許多國際性會議再次重申，世界各國不應再使用氟氯碳化物，然成效不彰。

(2) Thinned Ozone layer

Ozone is formed in the stratosphere when oxygen is exposed to solar ultraviolet radiation. The ozone layer blocks most of the radiation from reaching low atmospheric level and the earth's surface and is thus important for the existence of life on earth. Exhaust from high-flying aircraft damages the layer; so do the propellant Freon and other hydrocarbons containing chlorine and fluorine (CFCs). In 1987 the US government signed the Montreal Protocol banning CFCs by the end of the century and several international conferences have later reaffirmed the goal of discontinuing the use of CFCs, but worldwide implementation is still lacking.

三、酸雨

酸雨的發生來自於石化燃料的燃燒所產生的硫及氮氣進入空中所引起，而其大部分有毒氣體乃來自發電廠與大鋼鐵廠所產生的排放物，由於排放之硫及氮氣與空氣接觸後，產生具硫及氮化學物質之酸性薄膜，若遇到下雨，雨滴穿過酸性薄膜時就產生了所謂的酸雨，風力帶動著酸性薄膜飄到各區域，而使酸雨侵蝕了森林、湖泊、河流及生物。

(3) Acid Rain

Acid rain develops as the burning of fossil fuels pours millions of tons of sulfur and nitrogen into the air. Most of these emissions are from power stations and the steel industry. In contact with air, sulfur and nitrogen are oxidized to form sulfuric and nitric acids. An acidic haze is formed. When it rains, the droplets pass through the haze and acid rain falls to the earth. Winds carry acid clouds over great distances. Acid rain kills forests and lakes and rivers.

四、湖泊藻化

湖泊等被燐、氮等物質污染而致藻類急速繁殖而藻化，乃由於農業大量使用化學肥料，過度施肥，特別是磷酸鹽及硝酸鹽類肥料所引起；其刺激水（海）藻的快速成長，造成水中含氧量大幅降低，水中生物與微生物大量死亡，打破生物平衡；最後，使水中之生物面臨生存危機甚至死亡。

(4) Eutrophication

Eutrophication of lakes and waterways occurs as a result of excessive fertilization in agriculture. It involves a buildup of concentration of nutrients, in particular of phosphates and nitrates. The growth of algae is stimulated (even to the point of algae "bloom").increase level of organic matter and of microorganisms lower the oxygen content in the water, causing higher organisms to die. The ecological balance is disrupted. Eventually, all biological life in the afflicted waterways dies. Eutrophication is common in the waterways of the Low Countries, in parts of Germany, and in northern Italy (the Po river basin).

五、煙霧

煙霧危害是全球共通問題，由於汽（機）車及工業生產所引起，並發生於周遭與我們息息相關。在此至少有兩種不同的煙霧：㈠「含硫磺的煙霧」來自於空氣中瀰留過多的含硫磺化合物，其主要來自燃燒含硫之燃料，目前由於懸浮粒子飄浮於空氣中，而使此問題愈來愈嚴重；㈡「光化學物質煙霧」之影響不在煙及霧，其乃由汽（機）車或其他來源，使碳氫化合物與氮於低大氣層內混合而致，使大氣層呈現淡褐色的煙霧，降低能見度，危害植物、刺激眼睛與呼吸的困難。

(5) Smog

Smog is community-wide polluted air. It describes the pall of automotive or industrial origin that lies over my cities. There are at least two distinct types of smog: sulfurous smog (winter smog) and photochemical smog (summer smog). Sulfurous smog results from high concentrations of sulfur oxides in the air and is caused by the combustion of sulfur-bearing fuels. It is aggravated in the presence of dampness and high concentration of suspended particulate matter (SPM) in the air. Photochemical smog requires neither smoke nor fog. It is caused by photochemical reactions in the lower atmosphere prompted by hydrocarbon and nitrogen oxides emitted by automobiles and other sources. The atmosphere becomes lightly brownish there is reduced visibility, plant damage, irritation of the eyes and

respiratory distress.

六、殺蟲劑

殺蟲劑是人類製造與有害的動物對抗的產品，其主要分殺蟲劑、除草劑、殺眞菌劑及消毒劑，它們大部分無法自然分解。殺蟲劑殘留在水與食物的可能毒性一直廣受討論與研究。少量的殺蟲劑殘留問題，經科學家以老鼠進行實驗，而發現老鼠產生腫瘤情形，而少數的除草劑含量卻使受實驗之猴子，其血液停止白血球與紅血球的製造；同樣地，這些人類研發用於殺蟲之化學藥劑，卻也對人類之健康產生後遺症。

(6) Pesticides

Pesticides are man-made products used to combat agriculture pests. The main categories of pesticides are insecticides, herbicides, fungicides and disinfectants. Most of them are not broken down when released into nature, and thus eventually enter the ground water and the food chain. The contamination of the water table is a serious problem in the European Union and about 65 percent of the regions exhibit concentrations above the maximal recommended levels. The toxic effects of pesticides present in the water and in foods are still debates. Small does of the herbicides dioxin cause rhesus monkeys to stop their production of red and white blood cells.

七、其他

許多重金屬是有害的，主要包括如鉛、鎘、砷（砒霜）及水銀等重金屬，例如「鉛」將沉積於人體的血液中，影響神經系統。「鎘」存在於現有的肥料中，影響腎臟；即使「銀」質填充物也被廣泛運用於牙齒的鑲牙或療程中，其水銀含量將影響人類的大腦。

(7) Others

Many heavy metals are poisonous to man. Lead, cadmium, arsenic and mercury belong to this category. Lead intervenes with the biosynthesis of blood in the human body and it attacks the nervous system. A major lead pollutant used to be leaded gasoline. Cadmium is present in many fertilizers. Mercury causes cerebral damage. Even mercury fillings teeth are dangerous.

伍、管理環境衝擊因子之線性規劃

楊超然教授曾指出構成線性規劃問題的要件有[註九]：明確的目的、多種交替方案、有限的資源、問題的關連性及線性的假設。而本文在假設線性生產技術下，我們提出一個明確的產品需求與環境影響的分類。開始針對企業的生產作業，進行作業分析並使用下列符號：

・x：表示一個公司的未知活動水準的行向量，每項活動表示不同的生產方式；

・w：表示資源廠商的行向量，並假設其爲固定和已知的；

・A：表示投入係數矩陣，表示每一元素在每一單元水準下，任一活動之資源需求量，不同投入的需求向量則以Ax表示；

・B：表示產出係數矩陣，表示每一元素在每一單元水準下，任一活動之產出量，不同生產的產出向量則以Bx表示；

・p：表示產出價格的列矩陣，一公司所有產品產出之市場價值，則以pBx表示；

在線性規劃的基本模式[註十]中，有一種隱含的假設，即企業僅存在於一種目標，或

註九 楊超然，作業研究，三民書局，民國71年，頁298。線性假設表示其目標函數與限制條件必須爲線性函數，也就是模式中之決策變數均以一次程式出現，而沒有高次方程式或交叉乘積數。

註十 高孔廉、張緯良，第四章線性規劃之偶題及敏感度，作業研究，五南圖書出版股份有限公司，民國93年，頁134-135。

爲利潤（收益）、或爲成本、或爲效率等；但是現代企業經營大多具有多重目標(Multiple Goals)：例如，利潤、經濟成長、市場佔有率、員工滿意度、環保責任、投資報酬率、風險、……等，然此多重目標，有些是一致，有些卻是相互衝突的，如風險與報酬率；而此類問題之解決可透過㈠決策理論或效用理論(Decision or Utility Theory)；㈡目標規劃(Goal Programming)等方法解決。然爲求簡單化、單一化，本研究之線性規劃模式以追求利潤最大化爲單一目標，也就是企業生產之產品必須先將環境衝擊因素或其他因素，納入成本考量（或扣除）或限制因素中，求算總獲利或最大利潤；而其線性規劃模式如后：[註十]

$$Max \quad pBx$$
$$subject \ to \ \ Ax \le w, \ x \ge 0 \quad \cdots\cdots (1)$$

5. Linear programming for factors of environmental impact

Porfessor Yang, Chiao-znn indicates there are several major components to construct a linear model; clear objective, alternatives, limited resources, relations and assumptions. Assuming linear production technologies, we provide a brief classification of the environmental impacts of production and demand. The starting point is a simple activity-analysis type model of the production activities of a corporation. Use the following notation:

・x is a column vector of unknown activity levels operated by a company, each activity representing an alternative method of production;

・ w is a column vector of supplies of resources, assumed fixed and given;

・A is a matrix of input coefficients; each element denotes the quantity of a resource required to operate an activity at unit level, the vector of requirements of the various inputs is then Ax;

・B is a matrix of output coefficients; each element is the quantity of an output obtained when an activity is operated at unit level, the vector of quantities of the various outputs obtained from production is then Bx;

・p is a row vector of prices of outputs, the market value of all output produced by the company is then pBx;

The task of maximizing the total revenues of the company. Subject to the given availability of resources can then be written as the simple linear programming problem.

$$Max \quad pBx$$
$$subject \ to \ \ Ax \le w, \ x \ge 0 \quad \cdots\cdots (1)$$

一、「資源」使用對環境之影響

資源有限，一直是規劃者必須考量的，對企業言，限制資源（如發電量、用水量）即表示要降低產能，對外貿易額下降，失業率可能上升，且透過政府力量限制某地區、某產業某項資源之使用量或有效分配並不容易，對國際言更是困難重重。因此，將資源使用之限制反應於產品成本或稅金中，不失是一種良好的思考模式與方法。

過度使用許多與環境有關的稀有礦物質如原油及地下水；這些資源是無法重複生產的。既然這些物質使用後，終將耗盡，在考量國家安全（戰略物資）或經濟獨立自主的石油，應該不要過度開發，以供未來使用。地下水對許多物質言，是公有財而不是私有

註十 Hillier F. S. and and Lieberman G. J., Part Two: Linear Programming, Introduction to Operations Research, Holden-Day, Inc. Oakland, California, pp.27-285.

財富，其價格（主要來自鑽探機或邦浦的成本）乃是社會的機會成本。一個低水價的區域或不當的土地開發（如高爾夫球場），將造成水資源的浪費；加諸，砍伐森林與城市的不斷擴增，皆改變了環境。但若此爲公有財，也就是非私人擁有者如空氣，則此稀有資源無法訂定價格，在競爭的市場中，可被視爲無匱乏的供給資源，然在某城市或受污染之湖泊，則需付出環保或清潔之成本。

(1)Environmental impact to resource users

Designer should consider the limitation of natural resources. For industries, to limit the usage of resources (power generating, water consuming) means to decrease the production abilities, decrease the export, and increase Unemployment Rate. It is not easy to limit certain regions and resources, especially worse for international nations. So it is a good way to reflect the cost of resource limitation in product cost or governmental taxes.

Ground water is many instances a public good rather than a private good, and its price (essentially the unit-drilling and pumping cost) may grossly underestimate the true opportunity cost of it to society. A lowering of the water table may occur at the result of excessive use of water, or unsuitable land developments (golf courses); it may also take place as a result of environmental changes prompted by actions of man such as deforestation and urban growth.

模式(1)所述，而我們所關心的是，企業是否能免費的使用這些資源，政府應該干涉或訂定資源使用上限$w \le r^*$：

In model (1) above, the concerns now discusses translate into questions whether corporations should be free to make use of the entire supply of resources w available to them or whether society somehow should intervene, formulating a column vector of goal w and imposing the restrictions.

$$Ax \le w,$$
$$w \le r^*, \quad x, r^* \ge 0$$

此限制式不涵蓋所有資源，乃針對非私有財之元素$w \le u^*$而設定的適當可用量。在實務上，此限制式上限值，應由政府與企業協調，如二氧化碳排放量，以不影響公司營運爲考量；修訂企業生產線性規劃問題，經上述使用「資源」限制式，並修正模式(1)爲：

In the first instance, we shall assume that these goals w are "hard" upper limits, which may not be violated by the companies. Later we shall also deal with "soft" goals that may be violated, but at a cost. The linear programming problem of the corporation, earlier written as (1), now takes the form

$$\begin{aligned} &Max \quad pBx \\ &subject \quad to \quad Ax \le w, \\ &\qquad\qquad w \le r^*, \quad x, r^* \ge 0 \\ &Ax \le w, \\ &w \le r^*, \quad x, r^* \ge 0 \end{aligned} \qquad \text{.....(2)}$$

二、「生產流程」對環境之影響

在生產流程中，雖短期間看不出不良影響，但卻可能危及員工健康，如除草劑及殺蟲劑使用，在使用過程中被發現其將進入食物鏈中；以殺蟲劑DDT言，其在食物鏈中累積到某種有害程度後，將可能毒死鳥類及魚類。在其他實例中，科技的產出已出現我們不希望得到的負面效果，如生產或運輸工具所使用的石化燃料（如石油及煤）破壞環境，而燃料來源，涉及探勘、挖掘及配銷作業；每種燃料需要透過不同產品之混合及數千瓦小時的燃燒而成，然其產製過程產生二氧化碳、一氧化碳、硫及太多複雜副產品。所有生產能源之手法皆會危害環境，造成環

境負擔。

(2) Environmental impacts of the operations production activities

Sometimes the current inputs into production processes pose grave dangers to workers, or even to the community at large. Herbicides and pesticides used in agriculture contain toxic elements that may find their way into the food chain eventually or enter the ground water. One of the first synthetic pesticides was DDT, which accumulates the lethal levels in the food chain, killing birds and fish. In other instances, outputs of technologies have undesired side effects. Consider the industrial use of fossil fuels (natural gas, oil or coal) for production and for transportation. All technology using energy generated from the burning of fossil fuels weaken damage to the environment. Each of these fuels involves long networks of exploration, extraction, distribution and marketing. Each fuel requires its own combustion technology, delivering a unique mix of outputs, kilowatt-hours together with carbon dioxide, carbon monoxide, sulfur and a plethora of other byproducts with long complicated chemical names.

還有一些無法保證或可能危及環境的例子，此科技發展具有潛在危險，如核能科技、化學物質或油輪運輸，皆有可能因爲小的意外而對環境造成衝擊。以上我們所提到之問題，政府已經要求企業應該有責任運用不同科技或管理技術予以克服，或限制一些可能產生危害之作業。我們再回到數學式(1)中來看，若探討生產過程或工業活動$x \le f^*$時，也應該限制：

Yet other example can be quoted when the concern does not necessarily relate to the release of unwarranted or dangerous substances into the environment, but to other potential dangers associated with technology. Some production technology involves small risks of very serious accidents, such as nuclear technology or the transportation of oil in single-hull tankers. In all examples now mentioned, public opinion has risked whether corporations should be at liberty to operate these various technologies at will, or whether society should impose limitation on activities that entail harmful consequences. Returning to model (1), one shortcut way of representing such intervention would be to lay down goals on the operation of agriculture and industrial activities, say x and insist on restriction of the type

$$x \le f^* \quad x, f^* \ge 0$$

目標並不一定要針對所有的活動進行限制，我們可以設定適當的活動目標f^*，使其等於一個非常大的正值，並修正模式(1)爲：

Goals may be necessary be formulated for all activities. Formally, one may then put the corresponding elements of x equal to a very large positive number.

$$\begin{aligned} &Max \quad pBx \\ &subject\ to\ \ Ax \le w, \\ &\qquad 0 \le x \le f^* \end{aligned} \quad \cdots\cdots (3)$$

在特別的限制下（一個富想像的「工業政策」），若設計得宜，其角色不僅可促使企業避免使用有害之技術或有效率的管理其生產流程，也能引導他們朝向對環境有力之科技發展或引進。爲了解這些作業，我們要儘可能的運用數學式描述出有害科技並加以限制，如此之措施將促使企業更努力研究新技術以取代那些被禁止或限制之技術。

Note in particular that such constraints (a more fanciful word is "industrial policy") may actually, if properly designed, serve the role not

only of deterring corporations from employing harmful technology but inducing them to switch to new and more environment-friendly technology. To see how this works, it is enough to consider the mathematical possibility that some harmful technologies are entirely banned and the engineers are left with the task of designing new technologies that would replace the banned ones.

三、「消費者需求」對環境之衝擊

在公共論壇中，私人企業就如同做錯事的小孩，被控訴爲所有環境殺手的元兇；但往往應被控訴者應爲廣大的消費大眾，他們大量使用高科技之產物。在我們使用的消費產品或汰除品，其將經過一段冗長的旅程才能回歸自然，如污染空氣、水源、森林砍伐或廢棄物掩埋。

使用d符號表示對某項產品消費者需求，若價格依然可被視爲免費，那此消費者需求就如同企業之產出；同時，爲了消除過多不當需求，應該少有害產品之需求，限制產品需求量：

(3) Environmental impacts of consumer demand

In the public debate, the private corporation often becomes the whipping boy, accused of all the environmental sins of our material civilization. But some of the most serious culprits are common men and women, the consumers of all the bounty of model technology. Examples of consumer products that harm the environment are everywhere to be found. To see this, one needs only to ask the question what happens to an everyday consumer good after it has been used or used up. It then starts a long and zigzagging journey back to nature, as pollution in the air, in the water, in the forests, or accumulating in the landfalls.

Use the notation d to denote the column vector of consumer demand for the products of the corporation. If prices are left free to clear markets, consumer demand will equal industrial output.

$$d \le d^*$$

不對所有的活動（或消費）限制，我們可以設定適當的活動目標d^*，使其等於一個非常大的值，並修正模式(1)爲：

Now, to stave off the harmful effects of excessive demand, society may be interested in activity demand for the harmful products, insisting on limitations of the type

$$\begin{aligned} & d=Bx \le d^* \quad x,d \ge 0 \\ & Max \quad pBx \\ & subject \ to \ \ Ax \le w \\ & \qquad\qquad Bx \le d^*, \quad x,d^* \ge 0 \end{aligned} \qquad \cdots\cdots\cdots\cdots\cdots\cdots (4)$$

模式(4)旨在激勵人們多使用可回收或再製之產品，限制或降低危害環境之產品。

Once of the purpose of model (4) may be to study the conditions under which it is possible for society to simulate the recycling of consumer products, thus limiting the harmful effects on the environment.

四、「環境衝擊因子」

在經濟活動x之向量已知下，這些活動對環境之衝擊可透過每一活動與其影響因子之乘積而得。爲了增加業者對危害環境所應付出之代價，將其審查標準單一化，如有害物質排放及廢棄物處理之標準，乃載述於資源保護與再生法案中。令E是環境影響係數的矩陣，每一元素代表在每一單元標準下，任一作業所產生廢棄物與排放之數值，而不同之排放量，其所造成之環境危害程度爲$h=Ex$。利用政策限制此有害物質之使用，可以下列限制式表示：

(4) Environmental impact coefficients

Given a vector of economic activities x, one

may calculate the environmental impact of these activities by multiplying each activity with one or several impact coefficients. A crude way of accomplishing this is to lump all environmental burdens together in a single measure, such as kilograms of Hazardous Waste and Toxic Release Emission as defined in the Resource Conservation and Recovery Act, subtitle C. Much to be preferred, however, is to spell out a detailed list all wastes and emission of various greenhouse gases, of poisonous metals etc. Let E be a matrix of environmental impact coefficients; each element is the quantity of a particular waste or emission produced when an activity is operated at unit level. The quantities of the various hazardous discharges resulting from production are then $h=Ex$. Impose now policy restrictions on the hazardous discharges

$$h \le h^* \quad h^* \ge 0$$

此模式亦能納入模式(3)中，改寫線性規劃模式：

This relation can be seen as mathematically equivalent to (3), and the resulting linear program can be written as program as before;

$$\begin{aligned} &Max \quad pBx \\ &subject\ \ to \ \ Ax \le w, \\ &h=Ex \le h^*, \ \ x,h^* \ge 0 \end{aligned} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (5)$$

五、「政策制訂」對環境之影響[註十三]

一般政府試圖解決環境問題的兩種方法，由政策考量來看區分爲：㈠訂定法律規章：如汽、機車排放、發電廠及鋼鐵工廠排放標準及食品與藥物管理與審查標準；㈡課徵環保稅：如課徵汽車燃油稅、課徵玻璃瓶的環保費用（激勵其產品再循環使用）、香菸稅、停車費；另一個較有趣之例子是，主要針對工廠提出排放二氧化碳之稅收。

(5)"Policy making" to environmental impact

When policy-makers try to grapple with environmental problems two alternatives approaches to policy usually present themselves: (1) Direct regulation. Examples: Government regulation of automobile carburetors and exhaust systems, and regulation of exhaust systems in electric power stations and the steel industry. The licensing of new pharmaceutical products by the Food and Drug Administration. (2). Environmental fees and taxes. Examples: excise taxes on motor oil (financing the collection of dirty and spent motor oil), environmental fees on levied on glass bottles used for beer or wine (stimulating recycling) taxes on tobacco, parking fees in cities. Another interesting example is the proposed carbon-dioxides tax.

從政策與行政部門來看，「訂定法律規章」可以引導企業規範其產品之經濟行爲，將其限制放入線性規劃模式中。課徵稅收部分，透過數學模式以調整生產者行爲，經由線性規劃模式之對偶[註十三](dual)方式直接評估。

爲此，我們應該了解環境限制因素的對偶意義，並使課徵稅收之設計能運用於限制式，限制資源使用情形，並使其所支出之成本超出市場價格，則生產者將努力限制此類資源之應用。顯然地，課徵稅收等於增加產生投入成本，使其調整生產策略。

From a political and administrative point of view, these two approaches work in very differ-

註十三 高希均、林祖嘉，第十一章要素供給、第十二章市場失靈、政府職能與法律，經濟學的世界：中篇個體經濟學理論導引，天下遠見出版股份有限公司，民國87年，頁253-306。

註十三 同註十，頁85-98。

ent ways. Yet, in a certain sense, they can be seen as mathematically equivalent. Direct regulation induces producers to modify their economic behavior by imposing constraints on their linear programming problem. Excise taxes, when correctly assessed, caused mathematically equivalent adjustments of producer behavior on the dual side of the linear programming problem. TO understand this, it suffices to note that the dual variable of an environment constraint can typically be interpreted as an excise tax designed to implement the constraint. Why the dual variable of a resource constraint in a producer linear programming problem can always be interpret as the highest price that the producer would be willing to pay to acquire one more unit of the constrained resource. The dual variable of an environmental constraint, limiting the use of a resource, is the highest subcharge above the free market price that the producer would be willing to pay for the constrained resource. Apparently, an excise tax equal to this subcharge would cause the producer to adjust equivalently.

爲了將上述意見各詳細描述，考量求出數學式(1)之對偶規劃：

To develop the argument in slightly more detail, consider the dual program corresponding to (1),

$$Min \quad qw$$
$$subject \quad to \quad qA \geq pB, \quad q \geq 0 \quad \cdots\cdots\cdots (6)$$

q爲對偶變數列向量，表示資源的影子價格，使用數學式(6)爲起始點，即可寫出不同環境限制式(2)的對偶線性規劃式如：

The letter q is used here to denote a row vector of dual variables, denoting the shallow prices of the resources. Using (6) as a starting point, it is then easy to write down the dual formulation of the various environmentally constrained programs listed. For instance, the dual to program (2) reads

$$Min \quad qw+\tau w^*$$
$$subject \quad to \quad (q+\tau)A \geq pB, \quad q \geq 0 \quad \cdots\cdots\cdots (7)$$

τ表示課徵稅收之列向量，爲了解釋數學式(7)我們首先應該注意投入資源的目標限制式，如此資源目標限制式可視爲可用的供給源，若對特定之投入資源，其稅賦課徵爲零。但若目標資源少於供給量，則課徵稅收則爲正值。換言之，模式(7)規範生產者以最小化所有可用之資源，將課徵稅加入產品之價格內，並反應於市場價格上，以降低不必要的浪費與污染。

where τ is row vector of excise taxes. To interpret (7), note first that it no goal constraint has been imposed on a resource, so that that resource goal equals the available supply, the excise tax levied on that particular resource is zero. But if the goal is less than the available supply, the excise tax is positive.

不用驚訝！當我們指出資源投入生產後對環境之負面影響愈來愈嚴重時，這些財產權更應被明確的定義，一些經濟誘因促使人們使用稀有資源而不必反應在其產品成本上，然此產品的價格應該包含或規範不屬於任何人的稀有資源運用成本，更不能由私人企業獲利，全民買單。而這些稅收或規範可刺激廠商減少一些不當使用資源之作爲。

This should not surprise because as we have pointed out, negative externalities arise when property rights have not been defined. Some economics agents can then make use of scare factors without paying their full price. The "full price" would have included payment for those scarcities that have no owner. The excise tax simulates the payment that would have been charged by

such a fictitious. This does not necessarily mean that the government steps in as the nominal owner of those scarcities for which property rights have not been defined.

這並不意味著政府應針對這些不歸屬任何人的資源，採取任何措施，有時候政府有效收集與計算環保稅收，透過自由市場的運作機制，即可達到規範之目標。爲達到上述之貿易許可，像美國電廠的硫排放標準，「清潔空氣法案(Clean Air Act)」，若電廠之污染過於嚴重，信譽破產，則可能被迫關廠或銷售給其他電廠。

Sometimes it is possible for the government to set up institutional frameworks that lets the free market mechanism take over both the calculation and the collection of the governmental tax. One way to accomplish this is to issue tradable permits, like the sulfur emission allowances traded by electric utilities in the US. The institutional framework was defined in the Clean Air Act. Electric utilities that make extra-deep pollution cuts get credits that they can keep or sell to other power plants. The resulting market price of the pollution permit equals the shallow price of the pollution constraint.

然本文運用線性規劃模式進行生產者與消費行爲之研究，即表示這些接受適度污染之市場機制，就如同污染限制式的影子價格一般，使生產與消費、破壞與復原等作爲能取得平衡點，最終目的乃在促使人類共有的地球能更適合生存。

In words, program instructs the producer to minimize the value of all available resources, adding the excise tax to the market price on the actual use of each resource. The producer should minimize this value subject to the constraint that no activity must be operated as a loss. By the dual theorem of linear programming, programs are mathematically equivalent. The other direct linear programming formulations listed have similar duals, and the equivalence of the direct and the corresponding dual formulations can be demonstrated thoughtout.

陸、結　　語

經濟學家言[註十四]：「減緩地球暖化不能等」，溫室效應會鎖住熱能，使全球溫度上升，萬一溫度上升5度，可能會影響農作物收成，海平面上升，不僅孟加拉和其他開發中國家，包括倫敦、上海、紐約沿海城市都可能遭殃，且用水短缺，勢必衝擊10億以上人口之生活。「金融時報」首席經濟評論家馬丁．沃夫表示：「制定溫室氣體排放率、投資新技術及立法監督能源使用效率，三項必須並行」，才能有效減緩溫室效應。「地球只有一個—友善環境」。我們可能都參與破壞生存環境的地球；讓我們又回到「明天過後」電影場景，也許大部分的人認爲影片中之導演過於悲觀，甚至杞人憂天。雖然不至於在我們有生之年見到如此災難，但若那樣的場景可能百年後發生時，我們皆無法逃避現有的責任，防患於未然，才有能力克服這些難題，生生不息的綿延下去。

6.Conclusion

Economists said 'we should stop aggravation of globe warming now.' Greenhouse effect locks heat in the atmosphere and contributes to the rise of global temperature. A rise of 5℃ will influence the harvest of crops and cause the rise

註十四 馬丁．沃夫，「經際學家：『減緩地球暖化不能等』」，商業週刊，頁26-30。

of sea level; as a result, not only developing countries such as Bangladesh, but also the coastal metropolitan cities such as London, Shanghai and New York, will be flooded; besides, shortage of fresh water will bring about a serious impact upon the lives of over 1 billion population. To alleviate global warming, Martin Wolf, chief economic commentator of the Financial Times, suggests that three measures, setting effluence rate for greenhouse gas, investing in new technology and legislating for the supervision of energy efficiency, must go hand in hand. There is only one earth; be environment friendly. We could all participate in the destruction of the living environment of the earth and the mankind might be heading for the catastrophe like "The Day after Tomorrow." Some people may think that the director of the film is too pessimistic or too worrisome. We may not live to see the occurrence of the disaster, but we must make every effort to prevent the disaster. Only preventive efforts can save the earth from the doomed destiny and guarantee our offspring an ever-lasting living environment.

不管政府、國軍單位、企業界，甚至爲供應鏈最末端的消費者言，其間生產所需的「資源投入或轉換過程」、「生產流程、運輸或傳遞」、「消費者爲求舒適的過當需求」、「大量開發、破壞與挑戰大自然，衝擊環境平衡」等作爲，其實在我們周遭，甚至小至個人，無時無刻不在發生。所以，在國軍各類武器系統保修、生產製造過程，汰除、回收與再生流程，如何透過有效地規劃，並將非屬私人企業或組織所獨有之資源如乾淨空氣及地下水源，藉由政府或國軍相關政訂外，將可能涉及衝擊環境之因子，有效納入規範或組織開發產品之成本考量。

For the government, military units, enterprises, and even the consumers at the end of the supply chain alike, actions for production such as input of resources, transfer process, transport or delivery, consumers' excessive demands for comfort, mass exploitation, destruction, challenge to the nature, and impact to environmental balance, take place all day long. Therefore, throughout the maintenance, production, replacement, recycling and recovery stages of military equipment, it is necessary for the government and the military authorities to formulate policies to govern the use of resources non-exclusive to private enterprises or corporations, such as clear air and subterranean water, so as to integrate the factors incurring environmental impact into the overall cost of developing new products.

總結，針對國軍整體後勤管理而言，從原物料的取得、運輸、加工成爲半成品，再透過轉換與製造，完成國軍所需之武器系統或經理產品，最後分配或部署使用等一系列之系統壽命週期中，也必然會產生許許多多上述侵犯屬於全民之公有財，而如何降低這些種種的污染行爲，本文翻譯、修訂與運用Thore and Ferrão教授所提出之線性規劃模式，非常值得國軍幹部在武器系統規劃壽命週期與運作時宜深思與警惕。

In conclusion, as far as the ROC integrated logistics management is concerned, in the various stages of the life cycle of weaponry systems or military equipment, including acquisition of raw material, transportation, processing to semi-finished product, transfer, finish, distribution, deployment and usage, violations of the property right of the public goods will arise. How to minimize environmental pollution is the focus of this study. This study translates, revises and utilizes the linear programming model offered

by Professors Thore and Ferrão. It is sincerely hoped that the military authorities take the model into serious consideration when they draw plans for the life cycle of weaponry systems.

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