出國報告（出國類別：國際研討會）

參加 WASCON2009 國際研討會

服務機關：行政院環境保護署

姓名職稱：黃拯中簡任技正

派赴國家：法國

出國期間：98 年 5 月 31 日至 6 月 7 日

報告日期：98 年 9 月 1 日

摘　要

WASCON 國際研討會是歐洲一個非常重要的研討會，於 1991 年由部分歐洲國家（瑞典、丹麥、芬蘭、荷蘭及法國）與北美國家（美國、加拿大）的專家主導開始舉辦第一屆，其後並每三年定期舉辦研討會，參加會議之專家亦逐漸擴展至歐美其他國家、亞洲、非洲等地區，2009 年第七屆研討會於法國里昂（Lyon, France）舉行。WASCON 成立之主要目的在整合土木工程領域使用副產原料（Secondary raw materials，或稱再生原料）之技術及環境保護相關議題訊息，包括營建廢棄物再利用、污染預測及預防等。本次研討會議題分成 18 類，分別由各國專家就其研究、探討之成果於會中提出報告。

本署近年來加強列管營建廢棄物（含營建混合物），因管制範圍不包括營建剩餘土石方（俗稱廢棄土），無法使用過去營建署慣用之工程廢棄物產出係數，故本署委託中央大學黃榮堯教授進行研究，俾找出不同結構、材料…等狀態下影響廢棄物產出量之參數及產出係數，作為未來營建廢棄物管理之參考。本次即將研究成果以「Investigating the Factors of Waste Generation for Building Construction and Demolition Projects in Taiwan」為題，於研討會中發表，並藉由此機會讓其他國家專家了解我國廢棄物管理具體成效，進行經驗交流。

目　次

壹、目的

WASCON 國際研討會成立之主要目的在整合土木工程領域使用副產原料（Secondary raw materials，或稱再生原料）之技術及環境保護相關議題訊息，包括營建廢棄物再利用、污染預測及預防等。本次研討會議題分成 18 類，分別由各國專家就其研究、探討之成果於會中提出報告，並進行討論、交換意見。

本署自 94 年開始分三階段加強列管營建廢棄物（含營建混合物），因本署管制範圍不同於過去營建署管制時期之管制範圍，並不包括營建剩餘土石方（俗稱廢棄土），故無論新建工程、拆除工程或公共工程之廢棄物產出係數，已無法再使用過去營建署使用之係數，本署乃另委託中央大學黃榮堯教授進行研究，俾找出不同結構、材料...等狀態下影響廢棄物產出量之參數及產出係數，作為未來營建廢棄物管理之參考。本次即將研究成果以「Investigating the Factors of Waste Generation for Building Construction and Demolition Projects in Taiwan」為題，於研討會中發表，並藉由此機會讓其他國家專家了解我國廢棄物管理具體成效，進行經驗交流。

此外，我國近年來亦大力推動事業廢棄物再利用，其中有不少工業廢棄物與營建廢棄物種類被再利用於工程填地材料、工程粒料或工程粒料原料、建材原料…等，惟部份的再利用會被質疑有污染的疑慮，藉由參加本次研討會，亦可稍微了解其他國家之再利用情形。

貳、行程及分工

一、計畫類別：參加國際研討會

二、前往國家：法國

三、出國期間：98 年 5 月 31 日至 6 月 7 日

四、行程表

日期	地點	內容
5/31(日)－6/1(一)	台北→法國里昂	啟程
6/2(二)－6/5(五)	法國里昂	報到、拜訪主辦單位、參加會議
6/6(六) －6/7(日)	法國里昂→台北	返程

本次出席 WASCON2009 研討會成員包括:環保署黃拯中簡任技正(本人)、中央大學陳屏甫研究助理等二位，分工如下：

編號	姓名	服務單位	職稱	任務分工
1	黃拯中	環保署	簡任技正	論文發表中有關營建廢棄物管理之政策、管理面
2	陳屏甫	中央大學	研究助理	論文發表中有關營建廢棄物產出係數之學術面

參、與會過程及內容

一、會議概況

WASCON2009 自 6 月 3 日至 6 月 5 日於法國里昂的 Espace Tête d'Or 舉行，參加者計有 184 位（如附件一），分別來自政府機關、學術研究機構、產業界等。

研討會之序幕於 6 月 3 日早上 9 點由 ISCOWA 的主席 Jacques Méhu 致歡迎辭展開，Dr. Méhu 歡迎與會者於百忙之中來共襄盛舉，並謝謝與會者在廢棄物再利用於土木工程、使用再生產品於工程是否造成環境污染…等相關領域之努力研究與奉獻，致上最深之敬意。此外，大會亦邀請法國研究機構 INSA Lyon 與 ANR 的所長致詞，並簡要介紹該機構的研究領域、方向與成果。接著就分四間會議室分別進行論文發表與專題研討會。

本次研討會投稿論文共計 154 篇（各類別論文標題如附件二），其中現場發表者計 142 篇，張貼者計 12 篇，摘要內容可由 WASCON2009 網站下載（如需進一步了解，可依附件一之參加者名冊聯繫作者）。論文類別如下，研討會每日議程範例如表一所示：

- Laboratory versus field data
- Thermal process residues
- Pozzolanic materials
- Binders
- Sediments
- Used tyres
- Environmental and sanitary impact
- Multicriteria analysis - decision and policy making tools
- Modelling
- Solid characterization
- New concrete and cementbased materials
- MSWI bottom ash

- New developments in civil engineering
- Demolition and construction wastes
- Other waste streams
- Ceramic materials
- Other new construction materials
- Economy, regulation sustainability and territorial metabolism
- Poster Presentations

表一 **Wednesday June 3,2009**

9：00	**Opening and Welcome** **Jacques Méhu INSA Lyon - chairman of ISCOWA** **Alain Storck Director INSA Lyon** **Philippe Freyssinet ANR (French Research Agency)**			
Parallel sessions				
10：00	topic 1	topic 2	topic 3	topic 4
	Leaching : lab vs field data	**Thermal process residues in construction**	**Sediments**	**Environmental et sanitary impact**
	1 Ole Hjelmar	1 Takao Tanosaki	1 Aino Mijala	1 Kristian Hemstrom
	2 Pascal Suer	2 Mathieu Gautier	2 Bruno Lemière	2 Ton Honders
	3 Christian Maurice	3 Andre van Zomeren	3 Vincent Chatain	3 Mieke Quaghebeur
	4 Michel Legret	4 Mieke Quaghebeur	4 Yi-Kuo Chang	4 Bernard Clément
	5 Jiri Hyks	5 Ana Guerrero	5 Andrés/Alonso-Santurde	5 Mohan Sankaralingam
	6 Maria Arm	6 Ioanna Kourti	6 Jean-Luc Aqua	6 Marie Coutand
12：15	Lunch			
13：15	Poster presentation			
Parallel sessions				
14：00	topic 1	topic 2	topic 3	topic 4
	Leaching : lab vs field data	**Pozzolanic materials**	**Used tyres**	**Multicriteria analysis - decision and policy making tools**
	7 Margarida Quina	7 Ahmida Ferhat	7 Farid Belabdelouahab	7 Kosuke Kawai
	8 Christos Lampris	8 Maria Gheorghe	8 Zahir Djidjeli	8 Cong Chen
	9 Carlo Vandecasteele	9 Rachida Idir	9 Robert Moretto	9 Sébastien Lasvaux
	10 Mesay Wolle	10 Inigo Vegas	10 Catherine Clauzade	10 Margarida Quina
16：00	Coffee			
16：20	**Leaching : lab vs field**	**Binders**	**continue**	**continue**
	11 Jaap Steketee	11 Martin Cyr	11 Arnaud Budka	11 Jacques Villeneuve
	12 Sofia Lidelow	12 Zhu Fenfen	12 Akhtar Hafiz	12 Kevin Gardner
	13 Abdelhamid Beshara	13 Lukasz Kolodziej	13 Ulbert Hofstra	
	14 Imyim Apichat	14 Hosseini Payam	14 James Brown	
	15 Albrecht Mueller	15 Sabèha Ouki		

二、論文發表

本次本署發表之題目為 Investigating the Factors of Waste Generation for Building Construction and Demolition Projects in Taiwan（摘要、詳細內容及發表之投影片如附件三），如前言所述，本論文主要在探討環保署加強列管營建廢棄物（含營建混合物）後，找出不同結構、材料…等狀態下影響廢棄物產出量之參數及產出係數，其中亦涉及我國事業廢棄物管理之制度，故論文之發表分成兩部分，即有關參數與產出係數之學術面探討部分，由中央大學發表，有關我國廢棄物管理之政策、制度面部分，由本署人員發表；除此之外，於論文發表一開始，亦簡單介紹我國地理位置及部分景點。

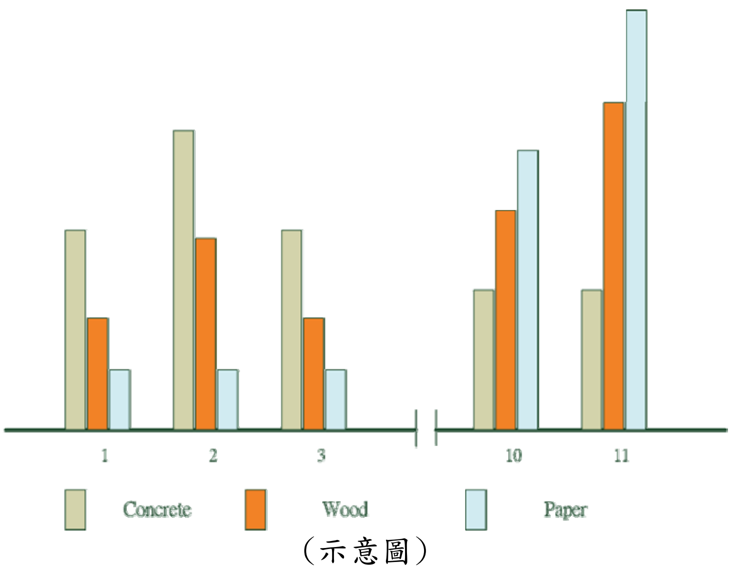
有關本署發表之內容，以色列技術學院的 Dr. Amnon Katz 非常有興趣，尤其是我國的管理制度，據其表示，以色列目前正加強各類建設，營建廢棄物亦常發生任意棄置情形，故我國對廢棄物的管理制度很值得該國參考。經過我再次介紹整體管理架構後，亦邀請 Dr. Amnon Katz 如有機會到我國時，可到本署進一步了解並參觀 GPS 的運作。

三、部分論文摘述

Quantities of construction waste from residential buildings and its development rate

作者：Amnon Katz and Hadassa Baum

以色列因為營建廢棄物產生量多，且後續的清運作業常因為清運距離長、清運成本少或是未能妥善處理廢棄物的技術，因此常可見到營建廢棄物任意棄置的狀況，為了有效控管工程專案營建廢棄物的產出與流向，以色列研究單位鎖定 10 個大型專案，在工地以子車收受直接計算累積營建廢棄物產出量的方式，希望可以得知營建廢棄物產出量與工程專案之關係。在進行計算時，更分門別類的將廢棄物分為紙類、塑膠、混凝土與土方、木材與鋼鐵等，在後續的 8,200 筆資料中對照施工期程，可得知各個施工流程哪一種營建廢棄物產出量比例較高，例如前期以混凝土、土方與鋼鐵所佔比例較高，後期因為開始室內裝修工程，所以紙類、塑膠及木材的比例相對提高；雖然該研究最後以簡單指數回歸 $Q(t)=\alpha t^{\beta}$ 說明了營建廢棄物產出量與工期之關係，不過總體而言，大約可以推估產出係數為 $20m^3/100m^2$，這與我們國內之研究相去不遠。

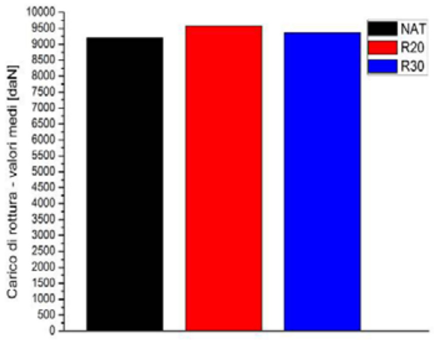


（示意圖）

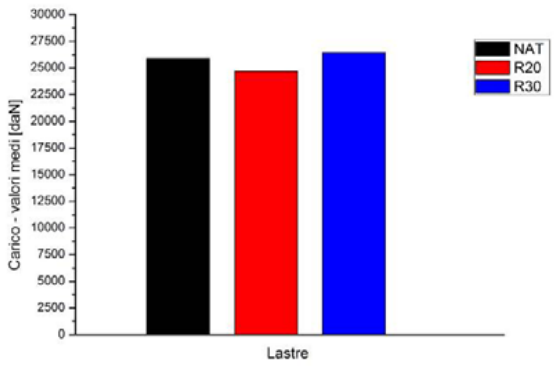
Usability's perspectuves of recycled aggregate concrete(RAC) for structural applications

作者：Mario Bassan, Marco Quattrone, Vittorio Basilico

由於義大利希望可以將營建廢棄物從掩埋處理轉化成資源可再利用的型態，因此對於營建廢棄物資源再利用時，其可能帶來的結構問題亦相當關注。在這個研究中，研究團隊試圖瞭解結構體中使用再生材料比例對於結構行為的影響程度，因此研究團隊製作了試體，並操作水灰比、養護時間等因素，進行彎曲測試與剪力測試（如下圖），該測試結果發現混合比例20%與30%的混凝土試體與原生混凝土試體的表現並無太大差距，均符合一般規範，初步證實營建廢棄物可作為再生骨材混凝土使用，但該實驗並無討論到工程材料本身的健性問題，一般而言天然材料作為骨材的健性應該會優於拆除破碎後的營建廢棄物所做成之骨材，在長時間後亦可能比較不容易發生結構體的脆化剝離，這可能是未來實驗所必須再考慮之重點，如果再生的營建材料均可通過一般之試驗與規範，在產品行銷與推廣上亦有較可以立足之數據支持，以去除大眾之疑慮。



彎曲測試

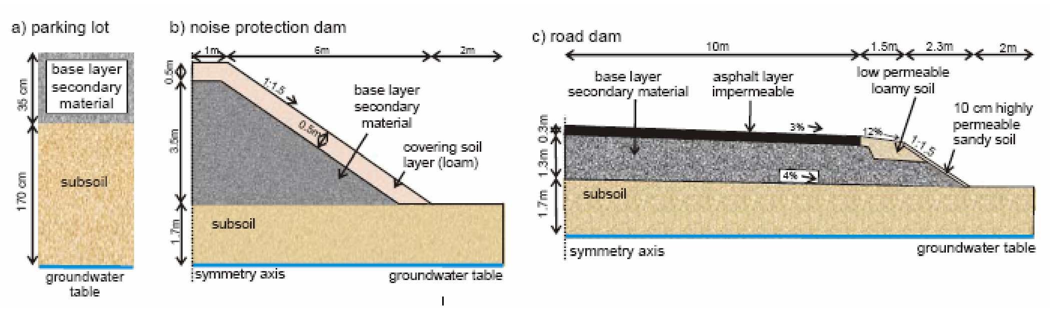


剪力測試

Assessment of contaminant leaching from secondary materials in road constructions – numerical modelling of mass transfer and attenuation processes

作者：Christof Beyer, Uli Maier, Wilfried Konrad, Bernd Susset, Chan Hee Park, Hermann Rügner, Sebastian Bauer, Rudi Liedl, Peter Grathwohl

德國每年的營建廢棄物產生量約有兩億五千萬噸，多數用來做為路基底層鋪設、隔音牆或是回填材料，但是德國相關單位也相當關切該材料是否會對生態或是地下水有影響，而過去的研究已有相當多的定量分析方法，分析在路面鋪設再生材料後，一些化學物質徑流後對地下水的影響成果報告。本研究也將利用三種不同情境來得知營建再生材料對於地下水或環境的影響，三種情境分別為路面、隔音牆和路堤（如下圖），在敏感度測試後，發現如果污染物是可被生物分解或是停留在滲流帶時間夠久，滲流帶將可以有效的阻擋污染物入滲到地下水層，而該研究得知之衰減率（Attenuation factors C/C0）結果對於後續推動聯邦使用礦物回收的材料法令（federal decree for the use of mineral recycling materials）有很大的進展與價值。



肆、結論與建議

由本次 WASCON2009 發表之論文類別，可知廢棄物運用於工程材料被探討之領域很多，其中被特別關切之領域，包括再生材料之使用規範及再生材料使用後是否造成二次污染問題，可見在世界各地，雖然都有共識應該要節約資源、努力發展廢棄物再利用，但是相關疑慮仍存在於管理者與使用者之間，仍需加強了解真相。

我國目前亦積極推動廢棄物再利用，而推動過程所遭遇質疑最多的，也是再生材料之使用規範及再生材料使用後是否造成二次污染問題，未來相關部會仍需在相關領域多加探討，俾減少外界對安全與污染之疑慮，始能順利推動再利用。

WASCON 每三年舉辦一次，國內相關部會或學術研究機構於相關領域亦有很多研究，如有足夠之預算經費，可鼓勵多參與此類研討會，除可了解其他研究之最新方向外，亦可在會中和其他與會者交換意見以加強研究之細節。例如目前本署亦積極推動一般廢棄物焚化底渣，在推動過程已建立很好的管理制度，另外並有針對已執行之工程進行污染監測，未來亦可考慮發表論文。

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184

各類別論文標題

Laboratory versus field data（15）

Measurement of the release of contaminants from roofing felt.
Ole Hjelmar, DHI, Denmark.

Ageing under field conditions- results from a long-term lysimeter study.
Pascal Suer, SGI, Sweden.

Assessment of redox-sensitive element mobility - discrepancy between laboratory and field data.
Christian Maurice, Lulea University of Technology, Sweden.

Environmental assessment of a bof steel slag used in road construction : the eclair research program.
Michel Legret, LCPC, France.

Evaluation of field-scale emissions from utilization of mswi air-pollutioncontrol residues stabilized with feso4
Jiri Hyks, Technical University, Denmark.

Technical and environmental long-term properties of by-products – field study and lab simulation.
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Leaching of inorganic species from apc residues: a comparison of column and batch tests.
Margarida Quina, Polo II University of Coimbra, Portugal.

Metal leaching from apc residues solidified using portland cement and ground granulated blast furnace slag.
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Decrease of cu leaching from mswi bottom ash (sand fraction) by heating, washing and accelerated carbonation, in view of recycling. Relation to doc fractionation in the leachate.
Carlo Vandecasteele, KU Leuven, Belgium.

Evaluation of the distribution of Cr and Mo species in leachates from recycled concretes applied in road construction
Mesay Mulugeta, University of Olso, Norway.

Accelerated carbonation and washing of MSWI bottom ash: pilot experiments and full scale applications.
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Potential for acid leachate formation from air-cooled blast-furnace slag.
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Long term leaching of chloride salts from cement kiln dust bricks.
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Effects of humic acids on the retention of heavy metals in cementbased stabilized soil.
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Environmental impact assessment of the use of industrial construction materials in hydro-engineering on german federal waterways.
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Thermal process residues（6）

Characterisation of IGCC slag for recycles use.
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Influence of the cooling conditions on the nature and the size of the mineral phase in a Basic Oxygen Furnace (BOF) slag.
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Accelerated carbonation of converter steel slag for environmental quality improvement in construction applications.
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Accelerated carbonation to improve quality of recycling materials: a study of the real-time kinetics.
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An Ecoefficient Method for the Valorisation of Municipal Solid Waste Incineration Fly Ash: Effect of cation alkaline.
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Development of geopolymers from plasma treated air pollution control residues from energy from waste plants.
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Pozzolanic materials（4）

Valorisation des roches pouzzolaniques du gisement de Beni-Saf (Algérie) par transformation en granulats pour bétons spéciaux.
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The glass waste as fine aggregate and pozzolana adition in concrete.
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Use of waste glass in cement-based materials.
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Design and performance of masonry mortars manufactured with recycled concrete aggregates.
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Binders（5）

Synthesis of binders using waste materials.
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Sound Recycling System for Fly Ash from Municipal Solid Waste Incinerator to Be Raw Material in Cement Industry.
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Influence of alkaline activator type and its amount on the properties of fly ash binders.
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Investigation on composition effect of using tire-rubber powder and silica fume to reduce amount of cement.
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The use of alternative materials in cement-based solidification/stabilization of electric arc furnace dust (eafd).
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Sediments（5）

In-Situ Stabilisation of contaminated sediments in Finland.
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The GeDSeT project: constitution of a decision support tool (DST) for the management and material recovery of waterways sediments in Belgium and Northern France.
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Assessment of the potential mobilization of inorganic contaminants in a french harbor sediment.
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Valorization of contaminated marine sediments in clay bricks: influence of processing techniques on technological and environmental properties.
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Feedback from programme SEDIMARD on marine sediments treatment at pilot scale.
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Used tyres（8）

Valorization of pneumatic waste uses and environmental protection.
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The way of valuation and reuse of the worn used tires turned out and concretized in the road domain: case of the stability of a road embankment (the National Road No. 11) in Mostaganem-Algeria.
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Use of end-of-life tyres in quarry redevelopment.
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Use of shredded end-of-life tyres in retention/infiltration/drainage of storm water.
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Use of shredded end-of-life tyres for drainage of leachate on the bottom of msw landfills.
Arnaud Budka, SITA, France.

Use of Scrap Tyres in Asphalt Concrete.
Hafiz Akhtar, Progressive International, Pakistan.

Leaching of zinc from recycled rubber taking in account the degradation of the rubber.
Ulbert Hofstra, Intron, The Netherlands.

Laboratory trials to develop specifications for recycled rubber in user friendly rights of way.
James Brown, Scott Wilson, United Kingdom.

Environmental and sanitary impact（6）

Relevant leaching and testing procedures for ecotoxicological hazard and risk charcterisation of ash.
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Risk-based soil quality standards in The Netherlands – a new approach towards the sustainable reuse of soil.
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Health impacts of the use of secondary aggregates in building materials.
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Ecotoxicological risks of road drainage sediments on aquatic ecosystems.
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Environmental impacts of construction sand mining on rivers: a case study.
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Ecotoxic evaluation of mortar leachate using the amphibian larvae (Xenopus laevis).
Marie Coutand, Université de Toulouse, France.

Multicriteria analysis - decision and policy making tools（6）

Effects on waste utilization for depression of natural resources consumption, landfilling and greenhouse gas emission in the cement production process in Japan.
Kosuke Kawai, National Institute for Environmental Studies, Japan.

Environmental evaluation of mineral additions in concrete.
Cong Chen, Université Paris- Est, LCPC, France.

Modeling the recycling processes in the LCA of buildings.
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Life Cycle Assessment as a Tool for Evaluating the Valorization of APC Residues from MSW Incineration in Lightweight Aggregates.
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The FORWAST project: Design of future waste policies for a cleaner Europe.
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Life-cycle assessment of construction and demolition derived biomass/wood waste management.
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Modelling（7）

Development of an environmental behavior prediction model incorporating predominant parameters obtained from leaching tests.
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Reactive transport modeling of mswi bottom ash evolution in road basement, Hérouville (France) and Dåva (Sweden) sites.
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Assessment of contaminant leaching from secondary materials in road constructions – numerical modelling of mass transfer and attenuation processes.
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Identification of leaching-controlling process by differential acid neutralization analysis for geochemical modeling– application to metal hydroxide sludge stabilization with coal fly ash –
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Modelling of leaching in an aged MSWI BA subbase layer: 1. Hydrological conditions
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Modelling of leaching in an aged MSWI BA subbase layer: 2. Geochemical processes.
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Groundwater impact simulations for establishing criteria for the recycling of alternative materials in road construction.
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Solid characterization（5）

Heavy metal and oxyanion binding in fresh and carbonated hydrated ordinary portland cement pastes.
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Heavy metal pollution risk for beneficial reuse of stainless steel slag as cement.
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Sulphate and chromate aft solid solutions; characterization and thermodynamic modelling.
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Alterations of Fe/Al Minerals in Weathered Municipal Solid Waste Incineration Residues and Influences on Leachability of Heavy Metals.
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Emissions flow study in waelz slag recycling into ceramic process.
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New concrete and cementbased materials（8）

The use of fluidized ashes in the technology of autoclaved aerated concrete (AAC).
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Solidification/stabilisation of treated oil drill cuttings as sandcrete construction products.
Babagana Mohammed, Imperial College London, United Kingdom.

The Feasibility Study of Manufacturing Eco- blocks cement by Using Marble Sludge as Raw Materials.
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Technical and ecological compatibility of the secondary aluminium slags with portland cement matrix.
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The study of the mechanical physico behavior of a concrete with limestone sand renforced by synthetic fibers.
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Physicomecanical and thermal properties of clayey cellular concretes to basis of clayey by products.
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Design and performance of masonry mortars manufactured with recycled aggregates from concrete debris.
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Application of nano-technology to improve green concrete (mechanical and microstructural properties).
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MSWI bottom ash（8）

Production and beneficial reuse of MSWI bottom ash in China.
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The use of MSWI-bottom ash as aggregate in concrete – limitations and possible solutions.
Peter Nielsen, VITO, Belgium.

An investigation of RDF bottom ash activation for blended cement formulation.
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Influence of Sulfate on Reusing MSWI Ash in Eco-cement Production.
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Quality improvement of mswi bottom ash: possibilities of input management
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Artificial aggregate made by cementitious granulation of waste incinerator bottom fly ash.
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Undisturbed sampling and material characterisation of a MSWI bottom ash sub base layer.
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Gas adsorption capacity of Municipal Solid Waste Incineration Bottom Ashes based materials.
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New developments in civil engineering（3）

Study of consolidation of soil by the Olive Mill Wastewater.
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New Development of cement-based matrices for the safe disposal of heavy metal: Cadmium and Cesium.
Ana Guerrero, CSIC, Spain.

New lightweight Aggregates from Industrial Waste and Carbon Dioxide Gas.
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Demolition and construction wastes（7）

The Disposal of Construction & Demolition Waste from a Large Project in a Small Island Developing State.
Timothy Lewis, The University of the West Indies, Trinidad & Tobago.

Construction and demolition wastes: innovations, applications and limitations of recycled aggregates in Brazil.
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Quantities of construction waste from residential buildings and its development rate.
Amnon Katz, Technion, Israel.

Investigation of the Factors for Generation of Construction & Demolition Wastes in a Building Project in Taiwan.
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Recycling plant and research center of construction and demolition wastes at metropolitan region of Vitória city (Espírito Santo, Brazil).
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Usability's perspectives of Recycled Aggregate Concrete (RAC) for structural applications.
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Behavior of the Concretes Containing Recycled Aggregates.
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Other waste streams（7）

Treatment methods for shredder waste.
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Development of standardised methods for characterization of wastes from extractive industry – overview of current activities.
Margareta Wahlström, VTT, Finland.

Japanese coal ash guideline for marine construction - Environmental aspect-.
Takao Tanosaki, Taiheiyo cement corporation, Japan.

Performance assessment of stabilised/solidified waste forms: an overview of results from the passify project.
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Mineralization of carbon dioxide by accelerated carbonation of thermal residues.
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Leaching Assessment for the Proposed Beneficial Use Red Mud and Phosphogypsum as Alternative Construction Materials.
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Material analysis of drinking water sludge in terms of environmental impact and decomposition.
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Ceramic materials（3）

Beneficial reuse of dc plasma treated air pollution control residues from an energy from waste facility.
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The Properties of Ceramic Masses and Ceramic Materials Made from Waste Carbon Slate.
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Influence of coal fly ashes grain composition on properties of building materials.
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Other new construction materials（4）

Development of Operating Windows for Treatment of Industrial Wastes using Blended Binder Systems.
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Potential applications of selected wastes from foundry processes to manufacturing of sand-lime bricks.
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Addition’s influence (olive stones and hay) on the physico-mechanical characteristics of clay bricks.
Samia Arezki, Bejaia University, Algeria.

Study of the properties and of some Environmental Impacts of new bio-based additives of Polyvinyl Chloride (PVC) for its Recycling in Constructions.
Valérie Massardier-Nageotte, Université de Lyon, France.

Economy, regulation, sustainability and territorial metabolism（6）

Carbon and financial savings associated with recycling utility trench arisings.
Rebecca Hooper, Scott Wilson, United Kingdom.

Business case for using microwave technology to produce a lightweight aggregate.
David Hann, Scott Wilson, United Kingdom..

Use of Industrial By-Products in Urban Transportation Infrastructure: life cycle argument for increased industrial symbiosis.
Kevin Gardner, Recycled Materials Resource Center, University of New Hampshire, USA.

Environmental sustainability evaluation of secondary materials: Case Study, Secondary materials from felloalloys manufacture.
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Use of Concrete with granulates in The Netherlands : observed barriers in the market and logistics and possible solutions.
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New legislation on the sustainable reuse of lightly contaminated soil in The Netherlands.
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Poster Presentations（12）

Slag expansion: New applications and limitations of a conventional test for aggregates.
Ivan Blanco-García, VITO, Belgium.

Phosphorus speciation in dicalcium silicate polymorphs of basic oxygen furnace (BOF) slag – Preliminary results.
Françoise Bodénan, BRGM, France.

Multicriteria analysis about Var marine sediments treatment process and scenarios - Methodology and some teachings.
Pascal Brula.

Separation and utilization of harbor sediments in southern Taiwan.
Yi-Kuo Chang, Central Taiwan University of Science and Technology, Taiwan.

Suitability of Various Recycled Glass Sources as embankment fill material.
Mahdi Miri Disfani, Swinburne University of Technology, Australia.

Environmental impact assessment of Tehran communication tower (Milad Tower).
Ebrahim Eslami, Sharif University of Technology, Iran.

Appraising of KM abilities to decrease waste of faults of welding in implementation of the Steal Structures.
Mh. Hajikarimi, Sharif University of Technology, Iran.

Influence of different environmental conditions on properties and heavy metals leaching from composites solidifying hazardous waste.
Anna Król, Opole University of Technology, Poland.

Metal Recovery with Plasma Vitrification from Incineration Ash and Physical-chemical Sludge.
Pai-Haung Shih, Fooyin University, Taiwan.

Development of Low activation Design Method for Reduction of Radio-active Waste.
Takao Tanosaki, Taiheiyo cement corporation, Japan.

The use of waste basic oxygen furnace slag and hydrogen peroxide to degrade petroleum hydrocarbons in soils.
Tzai-Tang Tsai, National Sun Yat-Sen University, Taiwan.

Influence of alternative fuel based on MBM and sewage sludge on properties of Portland cement.
Malgorzata Wzorek, Opole University of Technology, Poland.

Methodology and Policies for Environmental assessment of emissions

Workshop Titles and Speaker（9）

Use of recent scientific knowledge in the development of emission limits for construction products in the new Dutch Soil Quality Decree: benefits and limitations
Rob Comans, Energy research Centre of the Netherlands (ECN), The Netherlands.

Improved Leach Testing for Evaluating Fate of Mercury and Other Metals from Management of Coal Combustion Residues.
Greg Helms, Susan Thorneloe, U.S. EPA, USA.

Analysis of Identification for Leaching Toxicity of Hazardous Waste in China.
Jianguo Liu, China.

Environmental and geotechnical acceptability of alternative material as road construction material.
Laurent Chateau, France.

A novel framework of generally applicable release tests for evaluation of the release of dangerous substances from primary and secondary construction products.
Joris Dijkstra, Energy research Centre of the Netherlands (ECN), The Netherlands.

Characterisation leaching tests as basis of reference for quality control and decisions on acceptability of alternative materials in construction.
Hans van der Sloot, Energy research Centre of the Netherlands (ECN), The Netherlands.

Development of environmental criteria for re-use of contaminated soil.
Ole Hjelmar, DHI, Denmark.

Assessment of the potential impact of wastes on the environment through the Dutch Building Materials Decree.
Margarida Quina, Polo II University of Coimbra, Portugal.

Derivation of leaching standards -a regulatory concept for the upcoming German Federal Decree for the re-use of Mineral Waste Materials and By-Products.
Bernd Susset, Consulting Office for Groundwater Risk Assessment, Germany

Application of percolation tests for the assessment of emissions from construction products

Workshop Titles and Speaker（6）

Comparison of percolation to batch and sequential leaching tests: Theory and data.
Peter Grathwohl, University of Tübingen, Germany

State-of-the-art of the column leaching test:performance and critical test conditions.
Ole Hjelmar, DHI, Denmark.

Ruggedness Testing to develop a practicable percolation upflow test - test results, interpretation and application in regulation.
Bernd Susset, Consulting Office for Groundwater Risk Assessment, Germany.

Modelling of Non-equilibrium Leaching in Column Tests.
Rudolf Liedl, Technische Universität Dresden, Germany.

Modelling of unsaturated flow through recycled material in dam constructions.
Uli Maier, University of Tübingen, Germany.

Results of German ring tests on the validation of leaching standards for source term determination.
Ute Kalbe, BAM Federal Institute for Materials Research and Testing, Germany.

Industrial feedback of practical use of waste in civil engineering – critical issues

Workshop Titles and Speaker（8）

Industrial feedback in utilization of different types of waste in road application
Ivan Drouadaine, Eurovia, France.

DIRECT-MAT – sharing knowledge and practices on recycling of road materials in Europe
Maria Arm, Swedish Geotechnical Institute (SGI), Sweden.

Feed-back from industrial applications in civil engineering of non-recyclable used tyres
Eric Fabiew, Aliapur, France.

Feed-back from French industrial developments on steel slags in road-base applications.
Jérémie Domas, CTPL, France.

French industrial feedback from Coal Fly Ash utilization in civil engineering
François Théry, EDF, France.

Use of residues from thermally treated sewage sludges in concrete construction works : preliminary study.
Sylvie Baig, Degremont, France.

Presentation of OFRIR , a French database on wastes used in civil engineering at industrial scale
Yannick Descantes, LCPC-OFRIR, France.

Evaluation of the Impacts of Coal Type and Facility Configuration on Leaching Characteristics of Coal Combustion Residues.
David Kosson, Vanderbilt University, USA.

Investigating the Factors of Waste Generation for Building Construction and Demolition Projects in Taiwan

Huang, Rong-Yau[1], Huang, Ching-Chung[2] and Lin, Jen-Hong[3]

ABSTRACT

There are in excess of several million tons of building construction and demolition wastes (CD&Ws) generated each year in Taiwan. Following the global trend of sustainable construction, efforts are being taken by the Taiwan government to ensure the proper handling and recycling of construction and demolition wastes. The major components of CD&Ws are recyclable materials such as concrete rubble, brick, metal, wood, plastic, paper, etc. In order to ensure that these wastes go into the recycling plants or legal dumping sites for appropriate treatment, the contractor of a building project is required to submit a waste handling plan to the local EPA (Environmental Protection Agency) for review before they can start work on the project. In the plan, they have to estimate the expected quantity of wastes, and to state clearly where these will go, how they will be treated, and so on. Later on, the contractor has to report the actual generation and handling of the wastes online using the EPA Waste Reporting System. The estimated quantity serves as a basis for the local EPA to monitor and control the wastes produced during the remaining process of construction waste management.

The objective of this study is to investigate the major factors influencing the quantity of waste generated during building construction and building demolition. Factors considered include the building's floor area, functional type, structural type, whether with or without a basement, dollar value of the contract, whether there is recycling on site, and so on. Data regarding several thousands of building construction and demolition waste records (cases) from the local Waste Reporting System are investigated and analyzed. Statistical regression analysis is performed on each of the considered factors to identify those which have the greatest influence on the quantity of waste generated during a building project. These factors can serve as the basis for the local EPA to better audit and control the amount of wastes generated during a building project and facilitate the process of waste management.

Key words: Waste, building, construction, demolition, factor, statistical regression

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Key words: waste, building, construction, demolition, factor, statistical regression

1. INTRODUCTION

There are in excess of several million tons of building construction and demolition wastes (CD&Ws) generated each year in Taiwan. Following the global trend of sustainable construction, efforts are being taken by the Taiwan government to ensure the proper handling and recycling of construction and demolition wastes. The major components of CD&Ws are recyclable materials such as concrete rubble, brick, metal, wood, plastic, paper, etc.

In order to ensure that these wastes go into the recycling plants or legal dumping sites for appropriate treatment, the contractor of a building project is required to submit a waste handling plan to the local EPA (Environmental Protection Agency) for review before they can start work on the project. In the plan, they have to estimate the expected quantity of wastes, and to state clearly where these will go, how they will be treated, and so on. Later on, the contractor has to report the actual generation and handling of the wastes online using the EPA Waste Reporting System. The estimated quantity serves as a basis for the local EPA to monitor and control the wastes produced during the remaining process of construction waste management.

The objective of this study is to clarify the major factors influencing the waste quantity generated during building construction or building demolition. Examples of factors considered include: the building's floor area, functional type, structural type, whether with or without a basement, dollar value of the contract, whether there is recycling on site, and so on. Data from several thousand building construction and demolition waste records (cases) in the local Waste Reporting System are employed for the investigation and analysis. Statistical regression analysis is performed on each of the considered factors to identify those having the greatest influence on the amount of waste generated during a building project. Findings and conclusions are reported.

2. LITERATURE REVIEW

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There have been only a few studies investigating the factors related to waste generation for both building construction and building demolition projects. The research results are summarized in Tables 1-4.

Table 1 Factors for waste generation during building construction projects

Author	Taiwan EPA	Chen	USEPA	Yu
Year	1990	1996	1998	2003
Methodology	Questionnaire	Expert Opinions	Expert Opinions	Expert Opinions
Total floor area	◎		◎	◎
No. of stories	○			
Structural type		◎	○	◎
No. of workers	○			
Functional type			○	◎
Region			◎	
Contract dollars	○			◎

○: Factor considered but not significant
◎: Factor considered and significant

Table 2 Factors for waste generation during building demolition projects

Author		Huang	Chen	Lin
Year		1998	1996	2004
Methodology		Question-naire	Expert Opinions	Expert Opinions
Total floor area				○
Building Height	Above ground			◎
	Underground			○
Structural type		◎	◎	◎
Functional type		◎		◎
Region				○

○: Factor considered but not significant
◎: Factor considered and significant

Table 3 Coefficients of waste generation for building construction projects

Year	Author	Structural type	Functional type	Coefficient m^3/m^2
1990	Taiwan EPA	-		0.071
1996	Chen	-		0.198
1998	Chang	-		0.134
2003	Yu	RC	Residential	0.124
			Factory	0.081
			Office	0.098
			School	0.098
		SRC	Residential	0.135
			Factory	0.105
			Office	0.107
		Steel	Residential	0.103
			Factory	0.106
			Office	0.090

As shown in Tables 1 and 2, in past studies the impact factors have been identified based on either expert opinions or questionnaire responses, and are therefore subjective. In addition, in previous studies the coefficients of waste generation were calculated based on a very limited number of cases, due to the difficulty of collecting study data (Tables 3 and 4).

Table 4 Coefficients of waste generation for building demolition projects

Year	Author	Structural type	Functional type	Coefficient m^3/m^2
1998	Huang	-		0.790
2004	Lin	Reinforced Brick	Residential	0.852
			Factory	0.741
		Reinforced Concrete	Residential	0.822
			Factory	0.670
			School	0.704
		Brick	Residential	0.740
		Steel	Residential	0.649
			Factory	0.610

Starting from August 1, 2005, all building demolition projects and building construction projects meeting certain criteria of floor size and contract volume, are required to report online the actual generation and handling of generated wastes to the EPA Waste Reporting System. A database of tens of thousands of records (projects) have been built up since then. This current study is first to tap into the data from the Waste Reporting System, and conduct analysis to identify the factors as well as the coefficient of waste generation for both building construction and demolition projects.

3. DATA PREPROCESSING

Data processing involves several steps described as follows:

Step 1: Data Acquisition

A total of 2890 records of data, with 166 of them being related to demolition and 2624 to construction, were obtained from the Taiwan EPA's Waste Reporting System database. These data covered an 11-month period starting from August 1^{st}, 2007 to June 30^{th}, 2008. Another 25,690 records were also obtained from the database for the same period. However, these were all for demolition + new construction project types, so were not included in the subsequent analysis.

Step 2: Selecting proper data items

There are a total of 61 data items for each case in the database. Those not obviously related to waste generation such as Company ID, Company phone no., Name of manager, Permit no., Industry sector no. etc., are omitted. In addition, only one of those data items closely related to each other, such as Total waste generated, Total waste transported, or Maximum waste transported per month, Monthly average waste transported, are kept for subsequent analysis (in this case, Total waste generated is chosen). As a result, 11 data items, as shown in Table 5, are selected for the subsequent data analysis.

Table 5 Factors selected for analysis of waste generation

No.	Items	No.	Item
1	No. of workers	7	Functional type of building
2	Contract dollars	8	Recycling on site?
3	Project duration	9	Structural type of building
4	No. of floors above ground	10	Company name
5	No. of floors underground	11	Region of the project
6	Total floor area		

Step 3: Cleaning up the data

The 2890 records of data are further cleaned up by deleting those records containing missing data, and by omitting those records that deviate from the normal distribution. To exclude deviations, data are categorized according to those factors identified in a previous study. The mean and standard deviation are calculated for each factor category, so that those data that fall outside of the three standard deviations can be identified and cleaned out. Table 6 shows the resultant numbers of data records.

Table 6 Results after cleaning up the data

No. of records	Demolition	New Construction
Original	166	2624
After removing records with missing values	146	1808
After removing deviating records	145	1673

Step 4: Data conversion

Data of categorical items (items 7-11 in Table 5) are converted into numerical values for subsequent statistical analysis. For instance, a reinforced-concrete (RC) type of building is assigned a value of 1, a brick type is assigned a value of 2, steel 3, and so on. A similar process is conducted for data in other categories.

4. FACTORS FOR BUILDING WASTE GENERATION

The linear multiple regression analysis method and the SPSS (Statistical Package for Social Science) software are employed for factor analysis of numerical items (items 1-6 in Table 5). VIF (Variance Inflation Factor) test and Pearson test are first conducted on the six factors (items) to ensure that they are mutually independent, as is shown in the results.

Linear multiple regression analysis os then conducted on the new construction and demolition data. The six factors are set as independent variables while the unit waste generation (tons per square floor area (m^2)) is the dependent variable. Formulas 1 and 2 are used for linear regression analysis of new construction and demolition data, respectively. All gradients of the six factors in both formulae are less than the 0.05 significance level. In addition, the values of R^2 obtained with formulas 1 and 2 are only 0.019 and 0.172, respectively. Therefore, it is concluded that none of the six numerical factors are significant for the unit waste generation for either new construction or building demolition.

$$Y = 0.125 - 0.0000748X_1 - 0.00000147 X_2 - 0.0000000000046 X_3 - 0.00102 X_4 - 0.00533 X_5 - 0.0001143 X_6 \quad \cdots (1)$$

$Y = 0.17 - 0.05113X_1 + 0.0000037 X_2 + 0.0026 X_3 +$

$0.0002062\,X_4 - 0.00533\,X_5 + 0.002178\,X_6$ ······ (2)

Where
- Y: Unit waste generation (tons/m^2)
- X_1: No. of workers
- X_2: Total floor area (m^2)
- X_3: Contract dollars (NT$)
- X_4: No. of floors above ground
- X_5: No. of floors underground
- X_6: Project duration (day)

ANOVA (Analysis of Variance) testing is employed to analyze the significance of the unit waste generation for the five categories of data items. Tables 7 and 8 show the results.

Table 7 ANOVA results for new construction

	Recycle on site	Region	Company name	Structure type	Function type
Recycle on site	**0.01**				
Region	0.134	0.617			
Company name	0.332	0.832	0.723		
Structure type	**0.025**	0.334	0.377	**0.046**	
Function	**0.012**	0.263	0.476	**0.000**	**0.000**

Table 8 ANOVA results for demolition

	Recycle on site	Region	Company name	Function type
Recycle on site	0.897			
Region	0.279	0.193		
Company name	0.764	0.583	0.873	
Function	0.580	0.438	0.476	**0.038**

For new building construction, the factors structural type, function and recycling on site[debbie1] have a significance level of less than 0.05 and are considered significant factors impacting the amount of wastes generated during a project. The results are consistent with those of previous studies, except for the factor of total floor area. In this study the unit waste generation (tons/m^2) is the target, while in previous studies the total waste generation is the target. That is why the total floor area was a significant factor in previous studies but not in this study.

For building demolition, only building function is a significant factor. Based on previous studies structural type was expected to be a significant factor, but almost all the data records related to demolition projects in this study had a blank space for building type, so there is no way the factor can become a significant one! In addition, interviews with the contractors for building construction and demolition show that many hold very different ideas about what constitutes recycling on site. This somewhat explains why it is a significant factor in new construction, but not in demolition.

5. COEFICIENTS FOR BUILDING WASTE GENERATION

Coefficients for waste generation for building construction as well as demolition are developed from the collected data records in this study. New construction data records are first divided into the two major building structural types which in Taiwan are reinforced concrete and steel. Next, they are further divided according to different building functional types. A mean value in each category can be calculated as the coefficient of unit waste generation. The calculated values are shown as Tables 9 and 10.

Table 9 Coefficients of unit waste generation for building construction (RC)

Building functional type	No. of data records	Unit waste generation (t/m^2)
Public center	45	0.058
Commercial	74	0.047
Industrial Warehouse	166	0.054
Culture and Education	82	0.049
Religious and Funeral	50	0.031
Hygiene and Welfare	0	N/A
Offices and Services	114	0.053
Residential	706	0.046
Dangerous Goods Storage	0	0.068
	Average	0.058

For building demolition, the data records are only divided by building functional type. Due to the limited number of data records, only four combined functional type are employed for dividing the data records. A mean value in each category can then be calculated as the coefficient of unit waste generation. Table 11 shows the results.

Table 10 Coefficient of unit waste generation for building construction (Steel)

Building functional type	No. of data records	Unit waste generation (t/m^2)
Public center	8	0.122
Commercial	5	0.068
Industrial Warehouse	36	0.061
Culture and Education	2	N/A
Religious and Funeral	2	N/A
Hygiene and Welfare	0	N/A
Office and Services	13	0.072
Residential	13	0.096
Dangerous Goods Storage	0	0.072
	Average	0.122

Table 11 Coefficient of unit waste generation for building demolition

Building functional type	No. of data records	Unit waste generation (t/m^2)
Public Center	10	0.157
Commercial and Offices	7	0.440
Industrial Warehouse	6	0.254
Residential	98	0.380
	Average	0.325

6. CONCLUSIONS AND FUTURE RESEARCH

Conclusions

This goal of this study is to investigate the major factors influencing the quantity of waste generated during building construction as well as building demolition projects. A total number of 2890 building construction and demolition waste records (cases) in the local Waste Reporting System are employed for investigation and analysis. Statistical regression analysis is performed on each of the considered factors to identify the major ones impacting the quantity of waste generated in a building project. Findings and conclusions are listed as follows:

1. For new building construction, the factors: 'structural type', 'functional type' and 'recycling on site' have a significant impact on the amount of wastes generated during a project.
2. For building demolition, only building functional type is a significant factor. But 'functional type' and 'recycling on site' could potentially be significant factors.
3. Preliminary coefficients of waste generation for construction of RC and steel type buildings are developed and the results shown in Tables 9 and 10.
4. Preliminary coefficients of waste generation for building demolition are developed and the results shown in Table 11.

The identified significant factors and the developed coefficients of unit waste generation can be used as reference to assist the EPA to better control the amount of waste generated during building construction as well as building demolition projects. They should also help in planning and strategy development for the management of building construction and demolition waste.

Future research

1. The results of this study can be evaluated by experts in the field. Also, the accuracy of the coefficient can be tested with new project cases.
2. More data records can be collected from the local Waste Reporting System for analysis. The trends of

construction and demolition waste generation can be studied.

3. The reporting of the generated construction and demolition wastes in a project into the EPA Waste Reporting System is only in its third year. The quality and quantity of the data records will be improved in future.

ACKNOWLEDGEMENTS

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WASCON 2009
3-4-5 June 2009 in Lyon - France
ISCOWA "Sustainable Management of Waste and Recycled Materials in Construction"
eedems évaluation environnementale déchets, matériaux et sols pollués

Investigating the Factors of Waste Generation for Building Construction and Demolition Projects in Taiwan

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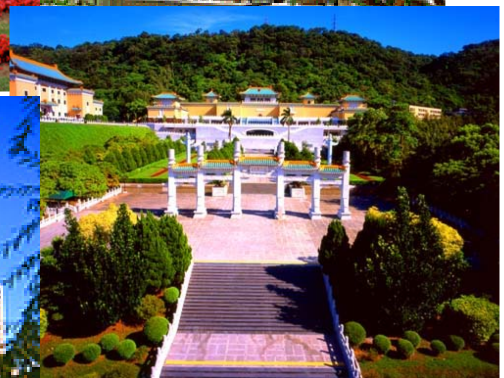
Taiwan


MONGOLIA
CHINA
NORTH KOREA
SOUTH KOREA
Sea of Japan
East China Sea
TAIWAN
HONG KONG
VIETNAM
LAOS
THAILAND
CAMBODIA
South China Sea
PHILIPPINES
Philippine Sea
MALAYSIA
MALAYSIA
INDONESIA

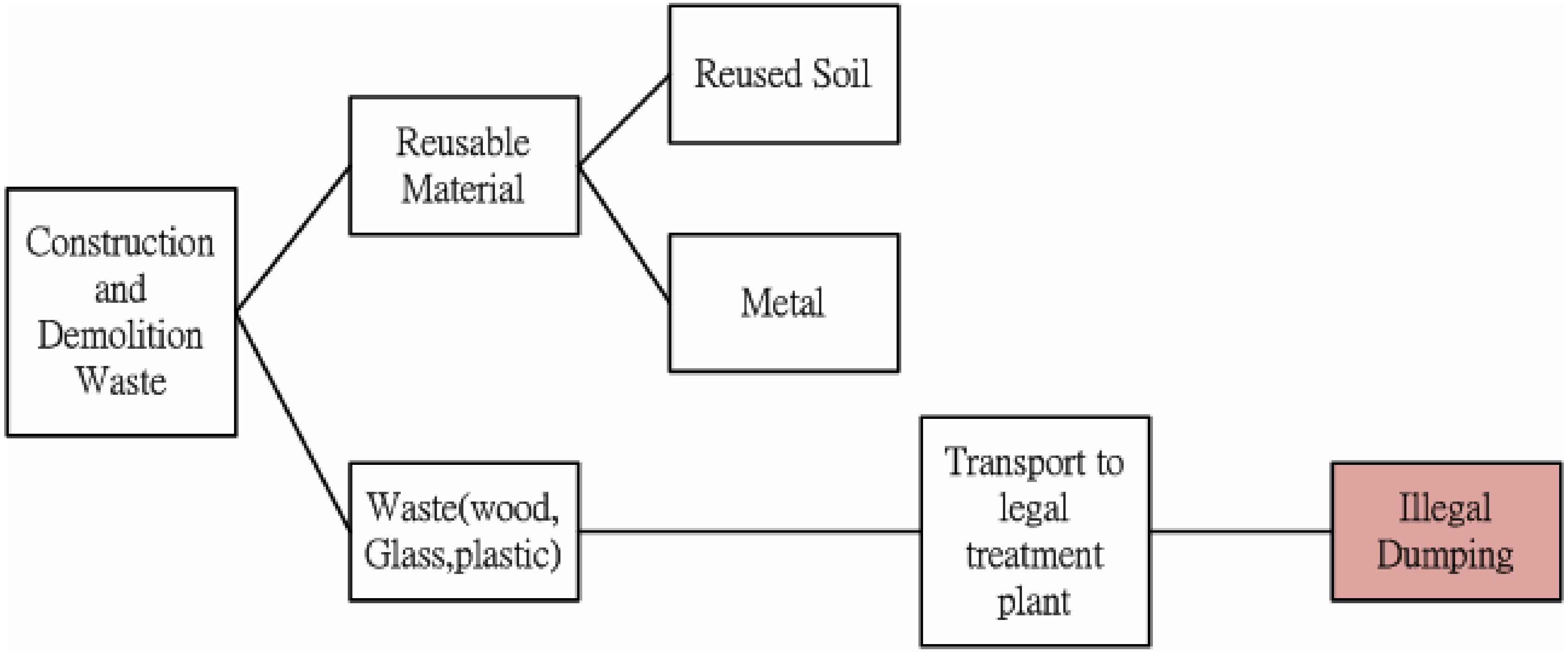


Content

CDW Problems in Taiwan

CDW problems in Taiwan

CDW problems in Taiwan



- Reporting Sheet and fill some information about the project on the website(Usually used in Taiwan)
- RFID technological application

Objective

- Investigate the major factors influencing the quantity of waste generated during building construction and building demolition

- The identified significant factors and the developed coefficients of unit waste generation can be used as reference to assist the EPA to better control the amount of waste generated during building construction as well as building demolition projects.

- Make the database of EPA's waste reporting system more valuable

Literature Review

Factors for waste generation during building construction projects

Author	EPA	Chen	USEPA	Yu
Year	1990	1996	1998	2003
Methodology	Questionnaire	Expert Opinions	Expert Opinions	Expert Opinions
Total floor area	◎		◎	◎
No. of stories	○			
Structural type		◎	○	◎
No. of workers	○			
Functional type			○	◎
Region			◎	
Contract dollars	○			◎

○: Factor considered but not significant

◎: Factor considered and significant

Coefficients of waste generation for building construction projects

Year	Author	Structural type	Functional type	Coefficient m^3/m^2
1990	EPA	-		0.071
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			Office	0.098
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		SRC	Residential	0.135
			Factory	0.105
			Office	0.107
		Steel	Residential	0.103
			Factory	0.106
			Office	0.090

Factors for waste generation during building demolition projects

Author		Huang	Chen	Lin
Year		1998	1996	2004
Methodology		Question-naire	Expert Opinions	Expert Opinions
Total floor area				○
Building Height	Above ground			◎
	Underground			○
Structural type		◎	◎	◎
Functional type		◎		◎
Region				○

○: Factor considered but not significant
◎: Factor considered and significant

Coefficients of waste generation for building demolition projects

Year	Author	Structural type	Functional type	Coefficient m^3/m^2
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			School	0.704
		Brick	Residential	0.740
		Steel	Residential	0.649
			Factory	0.610

Coefficients Used in Taiwan

- **Total floor area × *K* = Total waste generation**
- **Building Construction : *K* = 0.79 (m^3/m^2)**
- **Building Demolition : *K* = 0.134 (m^3/m^2)**
- **Do not concern the difference like**
  - building function type
  - Recycle ability on site

Waste Reporting System of EPA in Taiwan

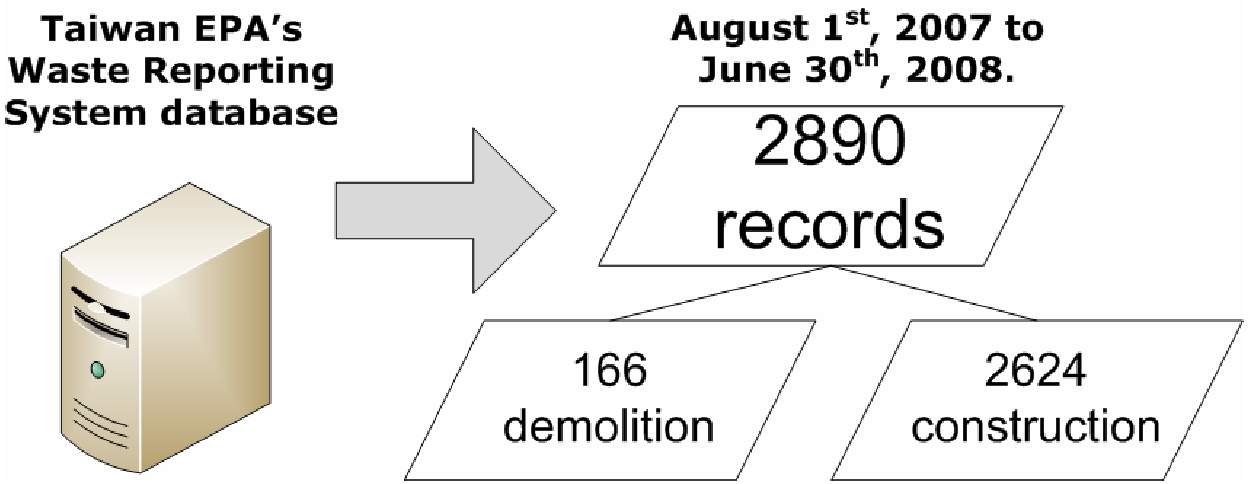
- Starts from August 1, 2005
- All building demolition projects and building construction projects meeting certain criteria of floor size and contract volume
- Require to report online the actual generation and handling of generated wastes to the EPA Waste Reporting System.

Factors and Results

DATA PREPROCESSING

Step 1: Data Acquisition

- Another 25,690 records were also obtained from the database for the same period. However, these were all for demolition + new construction project types, so were not included in the subsequent analysis.



DATA PREPROCESSING

Step 2: Selecting proper data items

- There are a total of **61** data items for each case in the database.
- Those not obviously related to waste generation such as Company ID, Company phone no., Name of manager, Permit no., Industry sector no. etc., are omitted
- As a result, **11** data items are selected for the subsequent data analysis.

No.	Items	No.	Item
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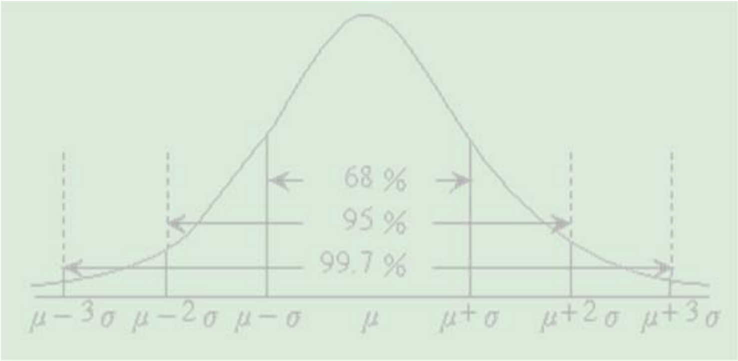
2	Contract dollars	8	Recycling on site?
3	Project duration	9	Structural type of building
4	No. of floors above ground	10	Company name
5	No. of floors underground	11	Region of the project
6	Total floor area		

DATA PREPROCESSING

Step 3: Cleaning up the data

- Missing data
- Fall outside of the three standard deviations



No. of records	Demolition	New Construction
Original	**166**	**2624**
After removing records with missing values	**146**	**1808**
After removing deviating records	**145**	**1673**

DATA PREPROCESSING

❖ Step 4: Data conversion

- Data of categorical items are converted into numerical

EX: Structural type of building

Reinforced-concrete (RC) type	➡	**1**
Brick type	➡	**2**
Steel type	➡	**3**

Factors for Building And Demolition Waste Generation

- **Methodology:**
  - Numerical Data
    - Linear multiple regression analysis method
    - VIF (Variance Inflation Factor) test
    - Pearson test
  - Categorical Data
    - ANOVA (Analysis of Variance)
- **Tool:**

  SPSS(Statistical Package for Social Science)

Variance Inflation Factor Test

	Factors	Significance	VIF < 5	Result
Demolition	No. of workers	0.283	1.417	**Independent**
	Total floor area	0.410	1.800	**Independent**
	Contract dollars	0.457	1.201	**Independent**
	No. of floors above ground	0.607	2.291	**Independent**
	No. of floors underground	0.663	1.155	**Independent**
	Project duration	0.032	1.418	**Independent**
New construction	No. of workers	0.675	1.263	**Independent**
	Total floor area	0.617	1.623	**Independent**
	Contract dollars	0.820	1.001	**Independent**
	No. of floors above ground	0.249	1.660	**Independent**
	No. of floors underground	0.701	1.546	**Independent**
	Project duration	0.342	1.903	**Independent**

Pearson Test-New Construction

Item No.		1	2	3	4	5	6
1	Pearson	1.000	0.287	0.083	0.159	0.028	0.226
	significance	-	0.000	0.028	0.000	0.465	0.000
2	Pearson	0.287	1.00	0.110	0.249	0.078	0.338
	significance	0.000	-	0.003	0.000	0.039	0.000
3	Pearson	0.083	0.110	1.000	0.161	0.036	0.279
	significance	0.028	0.003	-	0.000	0.336	0.000
4	Pearson	0.159	0.249	0.161	1.000	0.062	0.368
	significance	0.000	0.000	0.000	-	0.100	0.000
5	Pearson	0.028	0.078	0.036	0.062	1.000	0.043
	significance	0.465	0.039	0.336	0.100	-	0.261
6	Pearson	0.226	0.338	0.279	0.368	0.043	1.000
	significance	0.000	0.000	0.000	0.000	0.261	-

No.	Items	No.	Item
1	No. of workers	4	No. of floors underground
2	Total floor area	5	Contract dollars
3	No. of floors above ground	6	Project duration

Pearson Test-Demolition

Item No.		1	2	3	4	5	6
1	Pearson	1.000	0.212	-0.026	0.057	0.267	0.151
	significance	-	0.021	0.783	0.543	0.003	0.103
2	Pearson	0.212	1.00	0.193	0.143	0.500	0.204
	significance	0.021	-	0.036	0.123	0.000	0.027
3	Pearson	-0.026	0.193	1.000	0.366	-0.077	-0.063
	significance	0.783	0.036	-	0.000	0.408	0.496
4	Pearson	0.057	0.143	0.366	1.000	-0.064	-0.106
	significance	0.543	0.123	0.000	-	0.449	0.209
5	Pearson	0.267	0.500	-0.077	0.064	1.000	0.475
	significance	0.003	0.000	0.408	0.449	-	0.000
6	Pearson	0.151	0.204	-0.063	-0.106	0.475	1.000
	significance	0.103	0.027	0.496	0.209	0.000	-

No.	Items	No.	Item
1	No. of workers	4	No. of floors underground
2	Total floor area	5	Contract dollars
3	No. of floors above ground	6	Project duration

Results

❖ New Construction

- VIF test : Independent
- Pearson test : Independent
- Linear regression analysis

$$Y = 0.125 - 0.0000748X_1 - 0.00000147\,X_2 - 0.0000000000046\,X_3 - 0.00102\,X_4 - 0.00533\,X_5 - 0.0001143\,X_6$$

where

Y :Unit waste generation (tons/m^2)

X_1:No. of workers; X_2:Total floor area (m^2)

X_3:Contract dollars (NT$); X_4:No. of floors above ground

X_5:No. of floors underground; X_6:Project duration (day)

- R^2=0.019

Results

❖ Demolition

- VIF test : Independent
- Pearson test : Independent
- Linear regression analysis

$Y = 0.17 - 0.05113X_1 + 0.0000037\,X_2 + 0.0026\,X_3 + 0.0002062\,X_4 - 0.00533\,X_5 + 0.002178\,X_6$

where

Y :Unit waste generation (tons/m^2)

X_1:No. of workers; X_2:Total floor area (m^2)

X_3:Contract dollars (NT$); X_4:No. of floors above ground

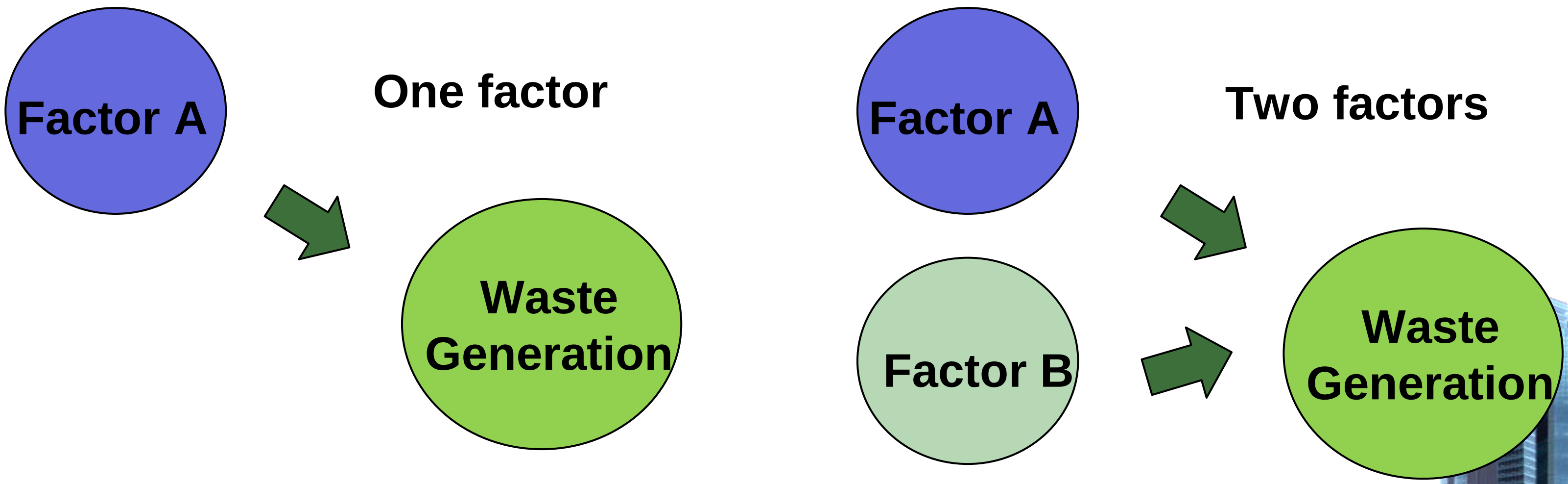
X_5:No. of floors underground; X_6:Project duration (day)

- R^2=0.172

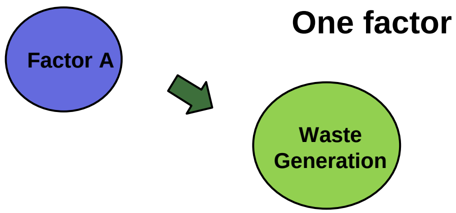
ANOVA (Analysis of Variance)

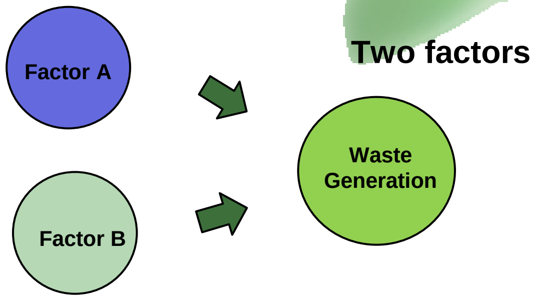
- Analyze the significance of the unit waste generation for the five categories of data items.

No.	Items	No.	Item
7	**Functional type of building**	10	**Company name**
8	**Recycling on site?**	11	**Region of the project**
9	**Structural type of building**		



ANOVA result – New Construction

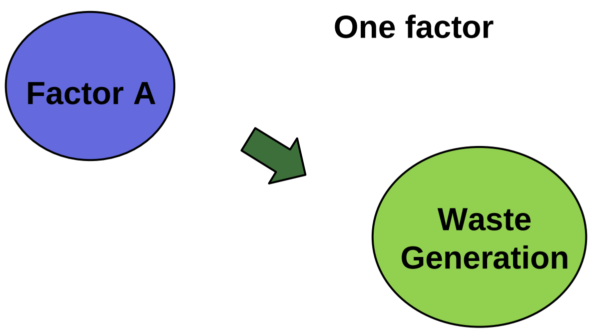


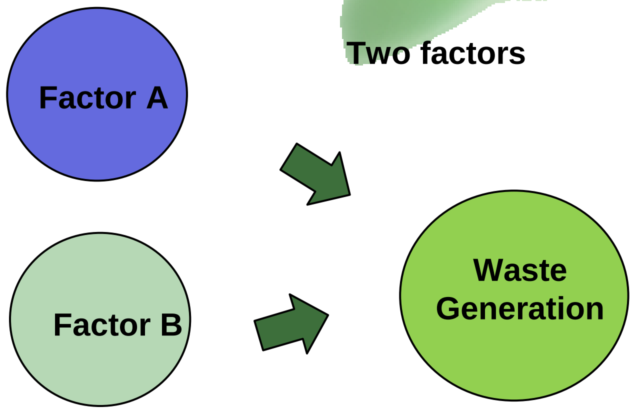


One factor	ANOVA
Recycle on site	**0.010**
Region	0.617
Company name	0.723
Structure type	**0.046**
Function type	**0.000**

Two factors	ANOVA
Recycle on site + Region	0.134
Recycle on site + Company name	0.332
Recycle on site + Structure type	**0.025**
Recycle on site + Function type	**0.012**
Region + Company name	0.832
Region +Structure type	0.334
Region +Function type	0.263
Company name +Structure type	0.377
Company name +Function type	0.476
Structure type +Function type	**0.000**

ANOVA result - Demolition





One factor	ANOVA
Recycle on site	0.897
Region	0.193
Company name	0.873
Function type	**0.038**

Two factors	ANOVA
Recycle on site + Region	0.279
Recycle on site + Company name	0.764
Recycle on site + Function type	0.580
Region + Company name	0.583
Region +Function type	0.438
Company name +Function type	0.476

Coefficients of unit waste generation for building construction

Building functional type	No. of data records		Unit waste generation（t/㎡）	
	RC	Steel	RC	Steel
Public center	45	8	0.058	0.122
Commercial	74	5	0.047	0.068
Industrial Warehouse	166	36	0.054	0.061
Culture and Education	82	2	0.049	N/A
Religious and Funeral	50	2	0.031	N/A
Hygiene and Welfare	0	0	N/A	N/A
Offices and Services	114	13	0.053	0.072
Residential	706	13	0.046	0.096
Dangerous Goods Storage	0	0	N/A	N/A
		Average	0.058	0.122

Coefficients of unit waste generation for demolition

Building functional type	No. of data records	Unit waste generation（t/㎡）
Public Center	10	0.157
Commercial and Offices	7	0.440
Industrial Warehouse	6	0.254
Residential	98	0.380
Average		0.325

Conclusion and Suggestion

Conclusion

❖ **Significant impact factors:**

- For new building construction:

  'structural type', 'functional type' and 'recycling on site'

- For building demolition:

  'functional type'

❖ Preliminary coefficients of waste generation for construction of **RC** and **steel** type buildings are developed as well as building demolition

Conclusions

- ❖The identified significant factors and the developed coefficients of unit waste generation **can be used as reference to assist the EPA to better control the amount of waste generated** during building construction as well as building demolition projects.
- ❖The results should also help in **planning** and **strategy development** for the management of building construction and demolition waste.

Suggestion

- The results of this study can be evaluated by **experts in the field**. Also, the accuracy of the coefficient **can be tested with new project cases**.
- More data records can be collected from the local Waste Reporting System for analysis. The trends of construction and demolition waste generation can be studied.
- The reporting of the generated construction and demolition wastes in a project into the EPA Waste Reporting System is only in its third year. The data recorded by the system users should be identified more clearly . **The quality and quantity of the data records will be improved in future.**

Suggestion


營建再生料源資訊交換網
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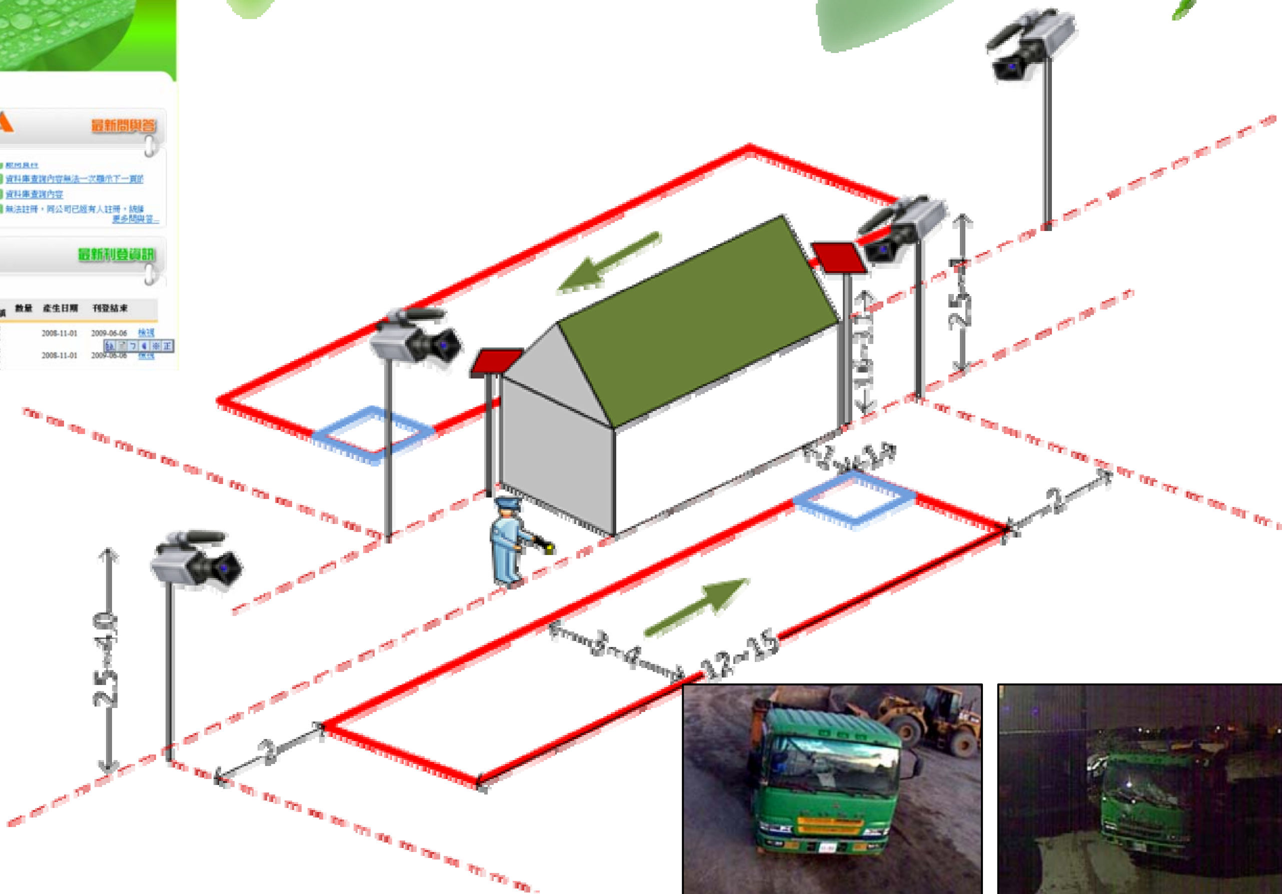
最新訊息公佈
Q&A
最新問與答
POST
最新刊登資訊
MENU


2.5~4.0
2
3~4
12~15

Thank You!

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