出國報告（出國類別：國際會議）

第 19 屆環境與生態影響國際研討會（ICEEI 2017 : 19th International Conference on Environment and Ecological Impacts）出國報告書

服務機關：行政院環境保護署
姓名職稱：賀志殷技正、邱景昆薦任技士
派赴國家：阿拉伯聯合大公國杜拜
出國期間：106 年 2 月 23 日至 106 年 3 月 1 日
報告日期：106 年 7 月 20 日

摘　要

第 19 屆環境與自然資源國際研討會(ICEEI 2017 : 19th International Conference on Environment and Ecological Impacts)是由全球知名之世界科學工程與技術學院(WASET , World Academy of Science, Engineering and Technology)每年於世界各地所舉辦專業交流活動，該研討會主要係針對環境、經濟、生態、資源、糧食生產、醫療、健康風險與流行病學等相關議題提出相關研究成果，供學術界、產業界、教育界、非政府組織（NGO團體）、政府組織等專業人士與會共同交流平台，每年會議地點分布世界五大洲，遍及各大城市，該工程與技術學院相當重視學術交流與各國經驗分享，藉由本次的參與及與其他國家經驗交流過程中，瞭解先進國家對於本國環境生態、經濟成長與環境影響關係及永續發展政策執行力，以及如何運用最新的創新技術，面對我國環境影響評估制度面臨問題思考可行解決方案。

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壹、出國目的

世界科學，工程與技術科學院(WASET，World Academy of Science, Engineering and Technology)為國際性學術組織，於西元 2017 年 2 月 23 日至 3 月 1 日於阿拉伯聯合大公國杜拜舉辦第 19 屆環境與生態影響國際研討會（ICEEI 2017 : 19th International Conference on Environment and Ecological Impacts)，本次會議分成 2 天舉行，討論議題包括最新科學技術發表，能源域經濟、環境管理策略、環境影響與風險分析等內容，共有來自世界 10 餘國近 70 人與會，發表約 32 篇。另外會議期間因適逢假日，自行安排參訪杜拜人工造島工程海域環境生態保措施及人工島嶼與城市間輕軌工程營運環境問題，由這些成功案例，提供環境影響評估修法及未來國內推動輕軌計畫環境影響評估審查之參考。

本次會議有來自世界各國不同領域的專家學者、企業代表出席發表專題研究成果，並接受與會人員提問進行互動交流，也與主辦單位深入暢談臺灣在經濟發展與環境保護間如何取得衡平，尤其是環境影響評估制度所扮演的決策角色。以下精選 2 篇論文簡略介紹：1、傳統製造業增長與經濟成長間之關係分析（南非)。2、以多維方法分析移動污染的環境影響。

藉由本次出國機會，實地觀察杜拜產業成功轉型所面臨經濟發展與環境保護間如何取得衡平，瞭解環境影響評估制度設計因不同國家政治體制有所差異，亦因國家產業發展政策而略作調整，這是目前我國環境影響評估制度修法過程必須審慎考量。另外針對杜拜推動國家經濟發展、能源產業轉型過程，如何塑造並結合城市觀光旅遊生態，降低對海域生態衝擊所作的努力經驗，值得我國未來推動相關產業型借鏡。

貳、行程表 1

日期	地點	工作內容
106 年 2 月 23 日至 106 年 2 月 24 日	臺北至阿拉伯聯合大公國杜拜國際機場	啟程（香港轉機）
106 年 2 月 25 日	準備會議、朱美拉櫚島（Palm jumeirah）	參訪人工島嶼環境影響與所採保護對策、都市連結人工島輕軌工程
106 年 2 月 26 日	第 19 屆環境與生態影響國際研討會：08：15～報到、杜拜舊城區（Crowne Plaza Dubai Deira;P.O Box 8668,Dubai,UAE）	研討會（參考第 1 天議程表）
106 年 2 月 27 日	第 19 屆環境與生態影響國際研討會：杜拜舊城區（Crowne Plaza Dubai Deira;P.O Box 8668,Dubai,UAE）	研討會（參考第 2 天議程表）
106 年 2 月 28 日	杜拜國際機場至香港轉臺北	白天：人工造島案例、沙漠地區都市環境改造案例 晚上 12 時班機至香港轉機
106 年 3 月 1 日	臺北	回國（桃園國際機場）

參、關於阿拉伯聯合大公國-杜拜

阿拉伯聯合大公國（Uuited Arab Emirates）是由杜拜、阿布達比、夏爾迦、阿吉曼、富吉拉、歐姆古溫、哈伊馬角 7 個酋長國組成的聯邦制君主國，地理位置位於阿拉伯半島東南部，與阿曼、沙烏地阿拉相鄰，首都阿布達比也是境內面積最大的酋長國。阿拉伯聯合大公國採聯邦制度，最高委員會由 7 個酋長國的酋長組成，選舉組總統、副總統、內閣與議會來管理國家，所有酋長部落擁有自己的伊斯蘭教的法律，用於民事、刑事和高等法院的運作；整體而言，阿拉伯聯合大公國是以宗教立國的國家，人民生活習慣與回教教義息息相關。阿拉伯聯合大公國於 1971 年 12 月 2 日獨立（英國殖民地），目前我國在阿拉伯聯合大公國杜拜設有商務辦事處，是少數在非邦交國家使用中華民國國號的駐外機構。在人權與文化方面，杜拜屬伊斯蘭教國家之一，以尊重伊斯蘭教為原則，其雖一法治國家，但仍實施回教律法（Shariah），Shariah 除規範人的行為，更強調人在面對阿拉時應有的良知，因此即使在開放的回教地區進行商務或自由旅行，也務必入境隨俗，避免觸及當地回教戒律與文化禁忌。

杜拜早期是一個吸引（以印度人為主）外國人定居的城市，為外國商人的重要港口所在地。1930 年以前，杜拜經濟仰賴珍珠出口為其主要外匯來源，1966 年發現石油並取得開採權後，改善了國內經濟條件。1970 年以後，杜拜利用石油所帶來的經濟收益迅速發展城市基礎建設，該國考量石油蘊藏量並不十分豐富，且即將開採殆盡，其石油出口收益難以持續維持基礎建設，因此在國家發展定位政策上做了重大改變，利用該國既有國際貿易蓬勃發展趨勢，引進國外資金全力發展觀光旅遊事業，近 20 年來，每年都有很多來自世界各國的國際游客來此觀光與度假，遊客人數每年持續成長中。綜觀杜拜國家的經濟發展與環境的改變，從初期仰賴石油出口獲得利益，走向觀光旅遊服務業，而隨者杜拜樂園及其他主題公園、度假勝地、體育運動休閒遊憩設施完成來轉型利益，不僅是重要的觀光勝地，更是全世界資訊產業與商業金融重鎮，目前該國石油出口經濟收益僅占國內 GDP 的一小部分，其轉型過程中政策的形成與行政部門執行力，值得臺灣學習。

杜拜位屬亞熱帶氣候，夏季（4 月至 10 月）氣溫有時高達攝氏 40 度以上，局部沙漠地區有小沙暴，每年 11 月至次年 3 月為冬季，最低氣溫介於 11 度至 13 度間地區 C，其年雨量稀少約 200 毫米左右，因水資源缺乏，杜拜所有生活用水來均自海水淡化或自國外進口，在杜拜水資源比汽油昂貴可想而知，因此生活廢（污）水經處理後回收再利用於都市綠美化植栽使用。杜拜為阿拉伯聯合大公國的第二大國家，面積約 3,885 平方公里，僅占全大公國的 5%左右，惟其進出國貿易額卻占整個大公國的 70%以上，大公國總人口數中約有 75%的人為外籍人，本地阿拉伯人僅占 25%左右，這些外籍人士主要以市場服務業與勞工為主。近年來，杜拜非石油類產值已遠超過石油類產值，占總 GDP

之 97%以上，其政府之行政管理、市容整潔、社會治安井然有序，讓人記憶深刻。今日的杜拜地位，已成為中東地區之金融、商業觀光及交通中心，居處歐、亞、非三洲之貨運轉運樞紐重要城市，目前有 100 餘家航空公司班機飛往杜拜。在文化上，阿拉伯聯合大公國憲法第 25 條雖然提到要平等對待不同宗教民族文化，但對於外籍勞工人權的保障，卻相當不人道，且由於杜拜政府法令不允許永久移民，使得來自各國服務人口複雜，形成種族、飲食、行為等多元文化的社會族群。

杜拜是阿拉伯聯合大公國之第二大聯邦，其土地劃分為 9 區，分為住宅區、商業區、郊區等，每區以社區規模與主要公路界線來劃分，其都市土地使用項目非常清楚，除上、下高速高路可見紅綠燈外，在市區幾乎看不到紅綠燈管制號號誌，因長年雨量稀少，市區很難看到雨水下水道，為其特色之一。杜拜近 20 年來致力轉型發展國際觀光旅遊與自由貿易為其主要外匯來源，因此建造了很多人工島嶼與高層大樓。其重要產業包括：填築 4 座大型人工島嶼與私人小島、興建杜拜港與購物中心、世界最高建築物哈里發塔（又稱杜拜塔）、杜拜生物科技中心、國際媒體中心、杜拜濱水城區等。這些開發案歷經 20 年努力，已轉型為以觀光旅遊服務產業、貿易金融為主的經濟策略，成為全世界物流貿易樞紐為中心地區。

淺談杜拜產業發展與環境保護對策

阿拉伯聯合大公國為聯邦君主國，除外交、國防事務隸屬聯邦政府管轄外，各邦各自有行政體系及經濟發展計畫。聯邦君主國因宗教信仰關係，伊斯蘭教人民需嚴格遵行並奉獻伊斯蘭律法（shariah），公務部門雖訂有一般世俗法律（secular law），但也必需不違背基本伊斯蘭教義精神。在開發行為環境保護等公共事務上，係以家族部落合議制（majlis）方式決策，並無特別設計環境影響評估制度，也因宗教教義嚴格，一般企業不敢任意違反道德規範。至開發行為進行前是由開發單位（即投資經營者）提出環境保護規劃報告書，送經主管開發計畫部門審批同意即可，其決策過程無提供公民參與程序，亦無需提供相關資訊公開或徵詢民眾意見。

在經濟發展策略上，杜拜雖出產石油，但不煉油，國家產業政策不鼓勵石油化學及重工業設廠（含煉鋼、水泥產業等）。杜拜與臺灣地理條件不同，甚少發生天然災害（例如颱風、地震、暴雨），為了發展觀光產業，提供免稅及優惠誘因吸引外資建很造很多人工島嶼（人工造島），像已完工營運杜拜帆船飯店（圖 1）、朱美拉棕櫚島、傑貝阿里棕櫚島、德拉棕櫚島、世界群島等 4 座島嶼是典型代表鉅作。而為提供國外遊客便利交通，杜拜城市與人造島間以高架輕軌捷運連結，減少都市大量交通運輸造成的空氣污染問題。杜拜公務部門除全力發展高產值觀光遊憩、生技產業，同時也營造開放的貿易政策，提供外國人安全舒適地的生活環境，其配套全仰賴較其他邦國更為有效率的執行力，也因引進外資企業投資基礎建設，自然形

成一個自由貿易與觀光服務產業鏈。

杜拜在短短 20 年推動產業轉型計畫，其內閣會議決策效率展現了相當魄力，相關重大開發行為仰賴一般常規法律管制，並無特別環境影響評估程序，但對都市環境與環境保護工作卻不遺餘力，也強制推動了幾項重大城市發展手策略：

一、藉由都市計畫更新程序，落實都市計畫使用分區管制，將住宅區、商業區、遊憩區、工業區等區位定位清楚，不允許重疊容許使用情形，這對營造都市環境美學、社會治安與維生系統皆有相當助益。

二、在交通系統設計上，除上下高速公路有交通號誌管制外，市區進出道路幾乎看不到紅綠燈號誌，因為市區道路動線只提供車輛進或出的方向，沒有十字路口規劃設計，這對都市交通動線流暢度與空氣污染管制發揮實質成效。為提供國外旅客交通運輸方便性，城市與人造島之間以輕軌捷運系統連結，展現城市安全的另一種風貌。

三、杜拜經濟命脈以發展觀光產業政策為首，除少數民生工業，嚴禁高污染、高耗能產業進駐，由於進出口貿易相當自由流暢，對於都市維生所需電力、水資源、糧食等大眾民生物資，大部分購自鄰邦或其他國家，因此平均物價水準是台灣的 5 到 10 倍之間。杜拜是一個沙漠化地區，年均雨量稀少，水資源相當匱乏，城市並無雨水下水道設計，其生活用水全數來自海水淡化廠，為節約用水，生活廢（污)水全數回收再利用，並設計貯存回收與澆灌系統，以專管、專線連結用於都市綠化植栽所需水源。

四、除了大型購物中心提供觀光客使用外，均嚴格管制一次性塑膠袋使用行為，這對民眾消費行為並未造成不便，值得我國未來規劃推廣限塑政策學習。

五、除了一般消費稅制，對於外來住宿旅客另課徵消費者約 5%環保稅賦，專款提供境內處理環境保護事務所需費用來源，真正落實使用者付費原則。

六、為解決杜拜境內電力需求成長與長期供應問題，規劃利用沙漠強烈日照特色，引進外資在高速公路兩側沙漠地區廣設太陽能發電設施，是杜拜未來另一新興產業。

七、杜拜大型建築均位於沙漠化地區，夏季高溫炎熱，都市更新的新興住宅區、商業區、遊憩區等均面臨綠化嚴重不足問題，為營造優質、安全舒適城市景觀，目前正引進國外技術進行土壤改良、育苗試驗等經驗，並選擇合適樹種進行綠化工作。

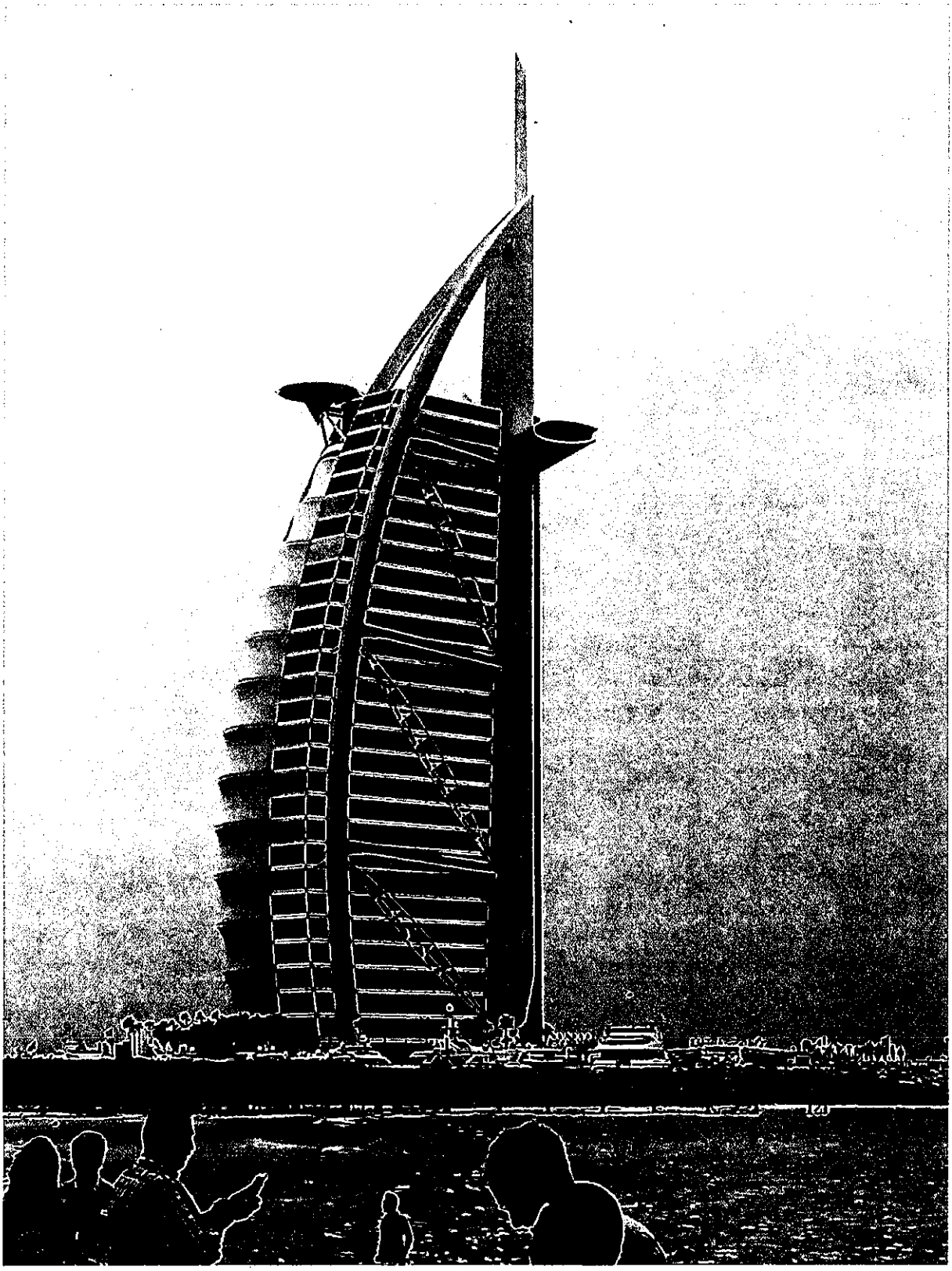

圖 1 人工造島－杜拜帆船飯店

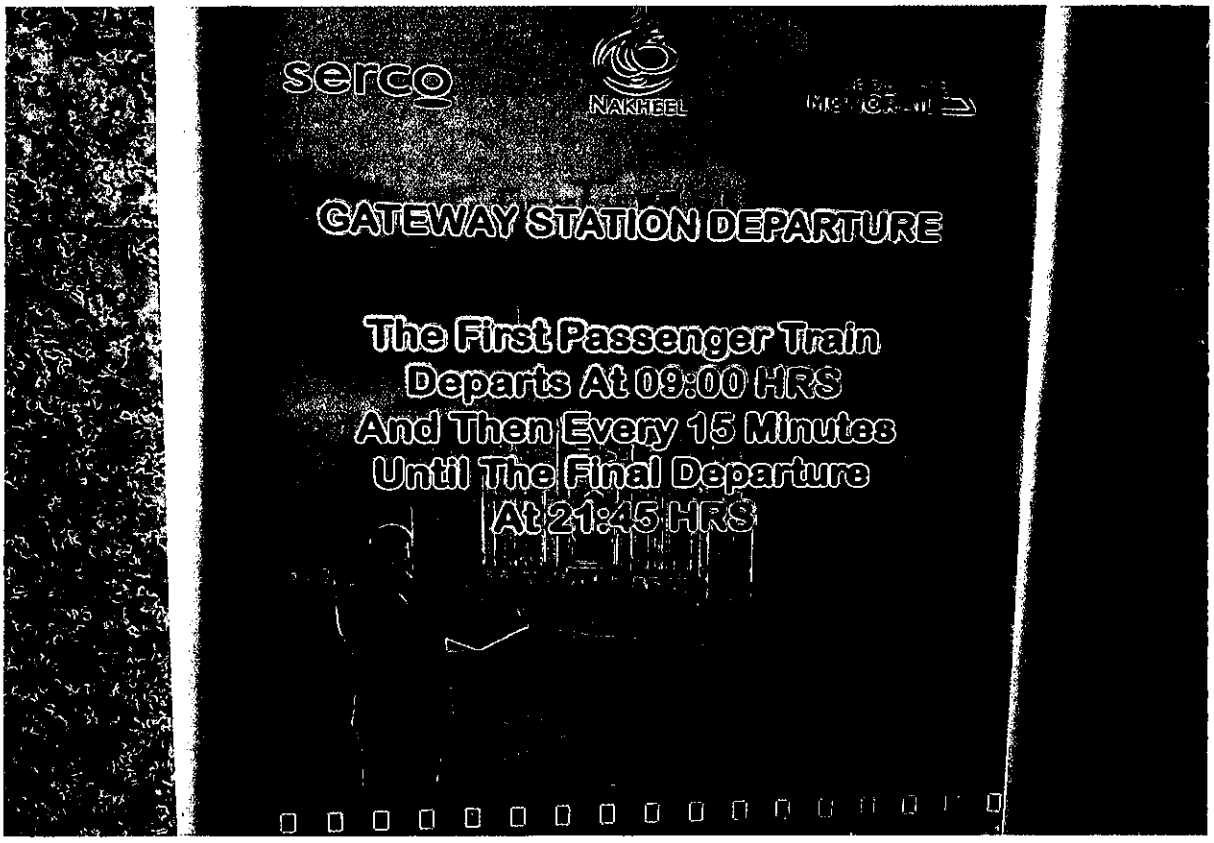

圖 2 輕軌計畫－杜拜城市與人工島間交通運輸計畫

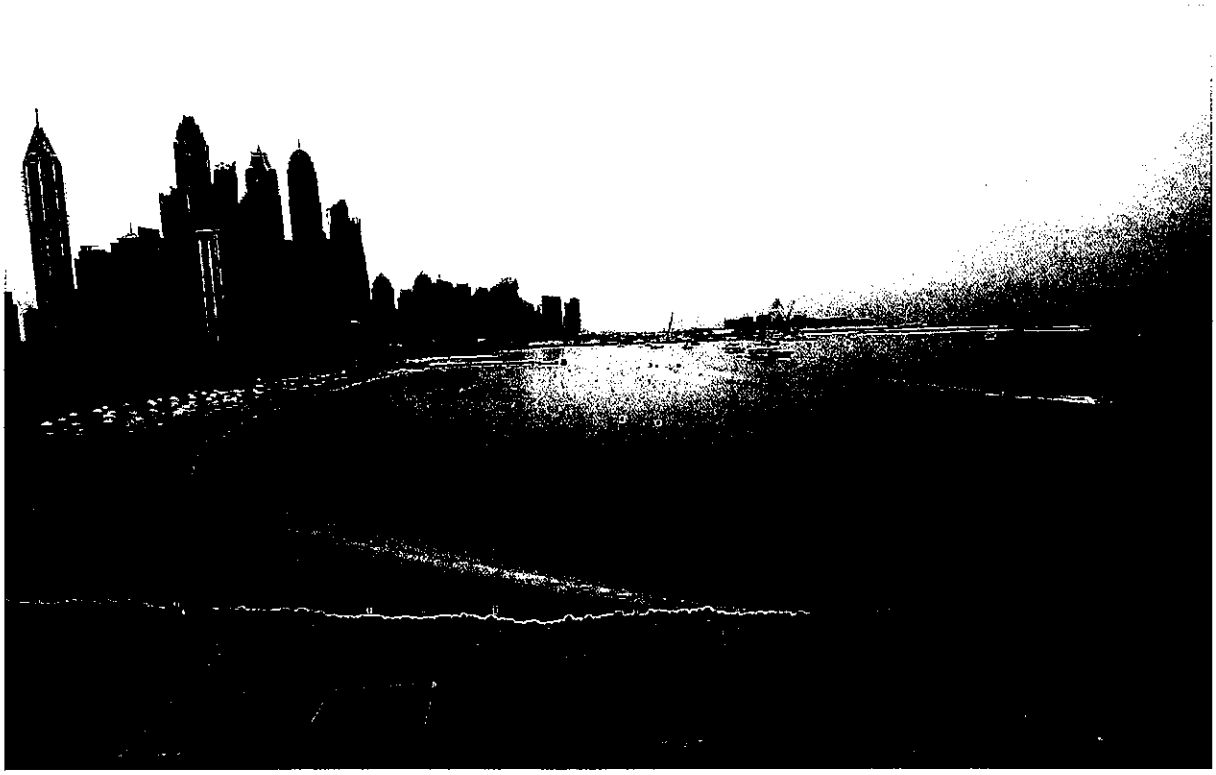

圖 3 杜拜城市與人工島間沿線輕軌工程鳥瞰景

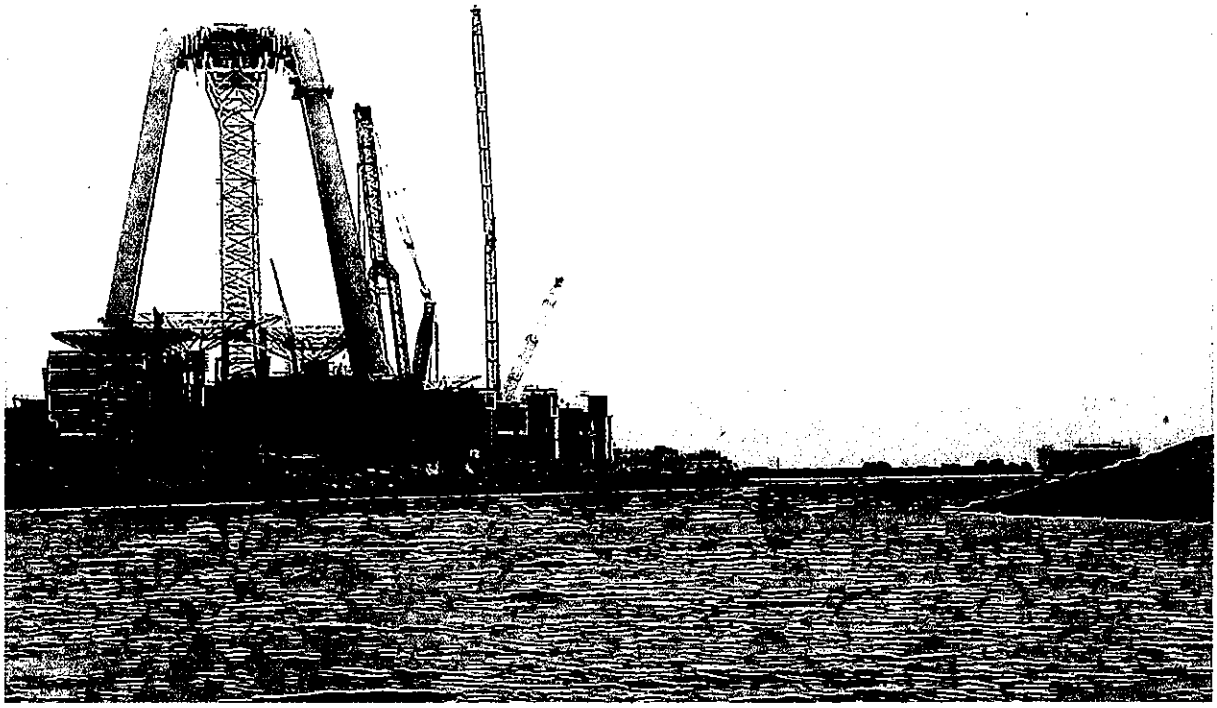

圖 4 人工造島－海岸之護岸工程

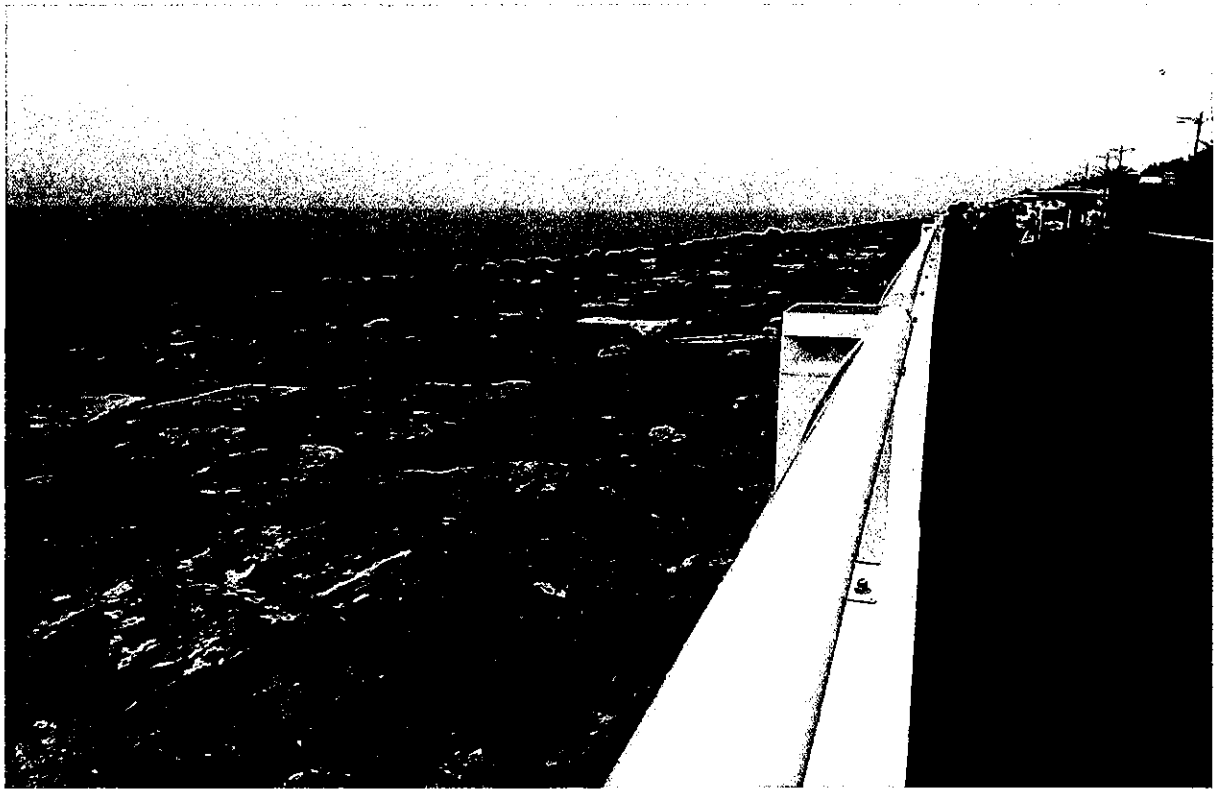

圖 5 人工造島-填築海岸之生態工法

圖 6 人工造島－土壤改良與育苗植栽試驗

杜拜海岸工程包括填海造地（陸）、濱海圍堤、港灣碼頭等工程，對海岸及海域環境生態衝擊有不同影響程度。杜拜人工造島使用材料係以當地料石為主，除強調海岸工程安全性，也相當重視與當地景觀之融合，其大量人工造島對海域生態造成相當大衝擊，包括潮間帶棲地消失，導致生物族群數量減少，物種消失，而棲地型態大幅變動，改變生物多樣性，這樣的現象對於杜拜強調觀光政策而言是一種價值觀選擇。另外，杜拜因長年雨量稀少，夏季高溫炎熱衍生熱島效應，加上填海造地後之土壤改良技術、樹種與育苗試驗等技術未能突破，一直困擾著觀光產業公部門，未來城市植栽與綠美化工程是永續觀光產業政策必須克服的問題。

圖 7 人工造島－遊樂區鳥瞰景（一）

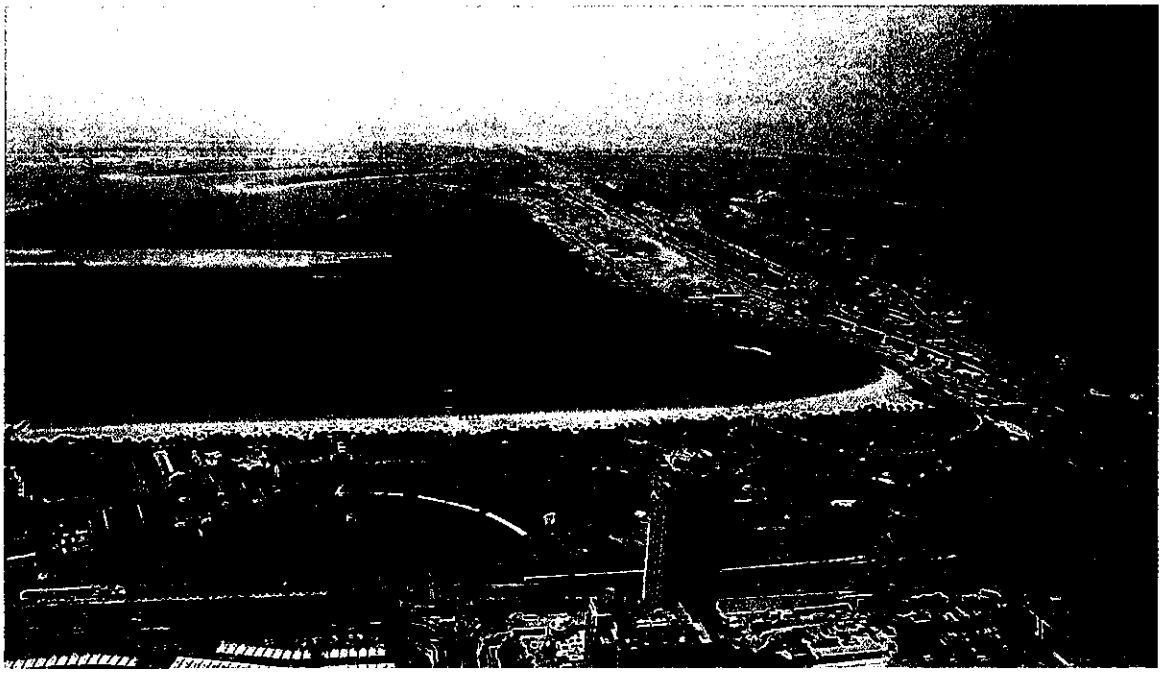

圖 8 人工造島－遊樂區鳥瞰景（二）

各國人工造島目的不盡相同，對於海岸管理決策工具各有不同，根據調查研究，若將海岸開發相關議題區分為管理(management)、社會(social)、經濟(economic)和環境(environmental)四個層面，從受訪者問卷調查結果顯示，以生態、棲地與物種維護為首要，其次環境影響評估作為管理工具者排名第 2。表 2 為受訪者對海岸管理形式排名調查參考項目。

表2 受訪者對海岸管理形式排名調查表

排名	環境議題與管理工具	百分比(%)
1	以生態、棲地與物種(Ecosystems,habitats and species)	44.4
2	以個案為基礎的環境影響評估(EIA)	43.2
3	以河流、海洋與港灣環境狀態(Condition of rivers,Oceans and estuaries)	41.8
4	以娛樂與觀光(Recreation and tourism)	33.9
5	以社區重點(Community priorities)	33.0
6	以政策計畫(Strategic Plans)	26.7

環境影響評估制度發展趨勢

相較於杜拜城市發展，我國因地理環境特殊，市鄉鎮並無明顯區隔或界線，重大開發計畫對環境之影響非侷限於開發行為所在地，多數開發行為衍生區域累積性環境影響值得重視。因此，自 1985 年開始推動環境影響評估制度（Environmental Impact Assessment；簡稱 EIA)，期間歷經三個階段：1.第一階段：由行政院 1985 年 10 月 17 日核定「加強推動環境影響評估方案」，此方案係 5 年之試辦性質，以累積辦理之經驗、技術、人力為目標。2.第二階段：1990 年 4 月 17 日行政院核定「加強推動環境影響評估後續方案」，為期 6 年間，期間持續透過立法程序，朝向建立 EIA 法制化制度。3.第三階段：立法院三讀通過「環境影響評估法」，自 1994 年 12 月 30 日發布實施迄今已 20 餘年。

美國為實施環境影響評估制度歷史最悠久的國家，但近20年來，其他國家或地區在政策環評（簡稱SEA）方面的發展，較美國更為積極，尤其加拿大與歐盟對於政策環評的積極態度最受矚目；澳洲政策環評制度流程顯得十分清晰明確，值得我國未來修法與增訂相關規則的參考；此外紐西蘭與我國同為海島國家，其對於海洋相關政策環評之作法值得借鏡。依各國EIA法制發展趨勢，先進國家相當重視政策環評所扮演之角色與地位，以美國與歐盟經驗，SEA是以部門為基礎，其政策、計畫與方案EIA為支持永續發展的一項重要工具，主要應用於實體開發計畫、大尺度區域計畫、建設基金方案、交通運輸網路、政府法規或其他重大政策之決定等。SEA

重點在於討論政策而非評論政策，且強調其透明與資訊公開程序，因此我國未來EIA制度發展趨勢，將由個案環評連結至其他政策工具，朝向整合性環境影響評估制度發展，表3為各國環境影響評估制度發展趨勢之分析。

表3 各國環境影響評估制度發展趨勢分析

國家	應用範圍	規則/位階	方針(Guidelines)	發展趨勢
美國	方案Programmes 政策Plans	1970年NEPA對SEA所訂之條款	CEQ方針	健康風險評估與風險管理
加拿大	政策Policies與內閣方案(Programes to cabinet)	1990年六月所發布之內閣指令(Cabinet directive)	政策環評程序為依據	政策環評於溫室氣體之減輕對策、工業區污染土地整治
紐西蘭	方案Programmes 計畫Plans 政策Policies	1974年公布之EPEP與1991年所公佈RMA中所訂定之條款	環境部門發佈之非法定(Non-statutory)方針	朝向以政策為導向的環境影響評估
澳洲	方案Programmes 計畫Plans 政策Policies	沒有正式的規定	沒有特定的方針	政策環評為主，個案環評為輔
歐盟	方案Programmes 計畫Plans 政策Policies	1985年環境影響評指令(85/337/EEC)；2001年六月通過政策環境影響評估指令	各會員國有個別之方針，並持續研發中	規定各國應實施政策環評，廣泛應用於健康風險評估、風險管理、跨國性諮商
台灣	計畫Plans 政策Policies	環境影響評估法、政府政策環境影響評估作業辦法	政府政策評估說明書作業規範、審議規範、各類評估模式	應提升政策環評法律位階，引導個案環評，建立專業證照與評鑑制度；環境影響評估與其他管理工具連結
日本	計畫Plans	環境影響評價法	環境影響評價技術方針	逐步累積計畫環評經驗，發展中央與地方政策環評系統化
中國	計畫Plans 政策Policies	建設項目環境管理條例	計畫Plans	區域性政策環評理論與個案環評實務之整合

肆、活動地點內容及參加人員

2017 年 2 月 26 日至 2 月 27 日第 19 屆環境與生態影響國際研討會舉辦地點位於阿伯聯合大公國杜拜舊城區（Crowne Plaza Dubai Deira Salahuddin Road,Deira P.O.Box 8668,Dubai,UAE），此次年會共有來自世界 10 餘國家，包括伊朗、匈牙利、希臘、馬來西亞、芬蘭、科威特、喬治亞、南非、土耳其、加拿大、印度、紐西蘭、韓國等近 70 餘人與會，就學術研究成果與商業發展發表數十篇論文，內含如何運用 CIS 資訊系統管控油污染、電動車發展技術與潛力、傳統製造業與經濟成長關係、冷凍系統與地球暖化、能源最佳化、運用網路移動學習研究、都市安全與社會永續發展等議題，本署由綜合計畫處賀志殷技正與邱景昆薦任技士代表參加。研討會期間也與負責本次活動主辦單位交換意見，他本人對臺灣垃圾分類回收成效與環境影響評估制度印象深刻。

圖 9 第 19 屆環境與生態影響國際研討會海報

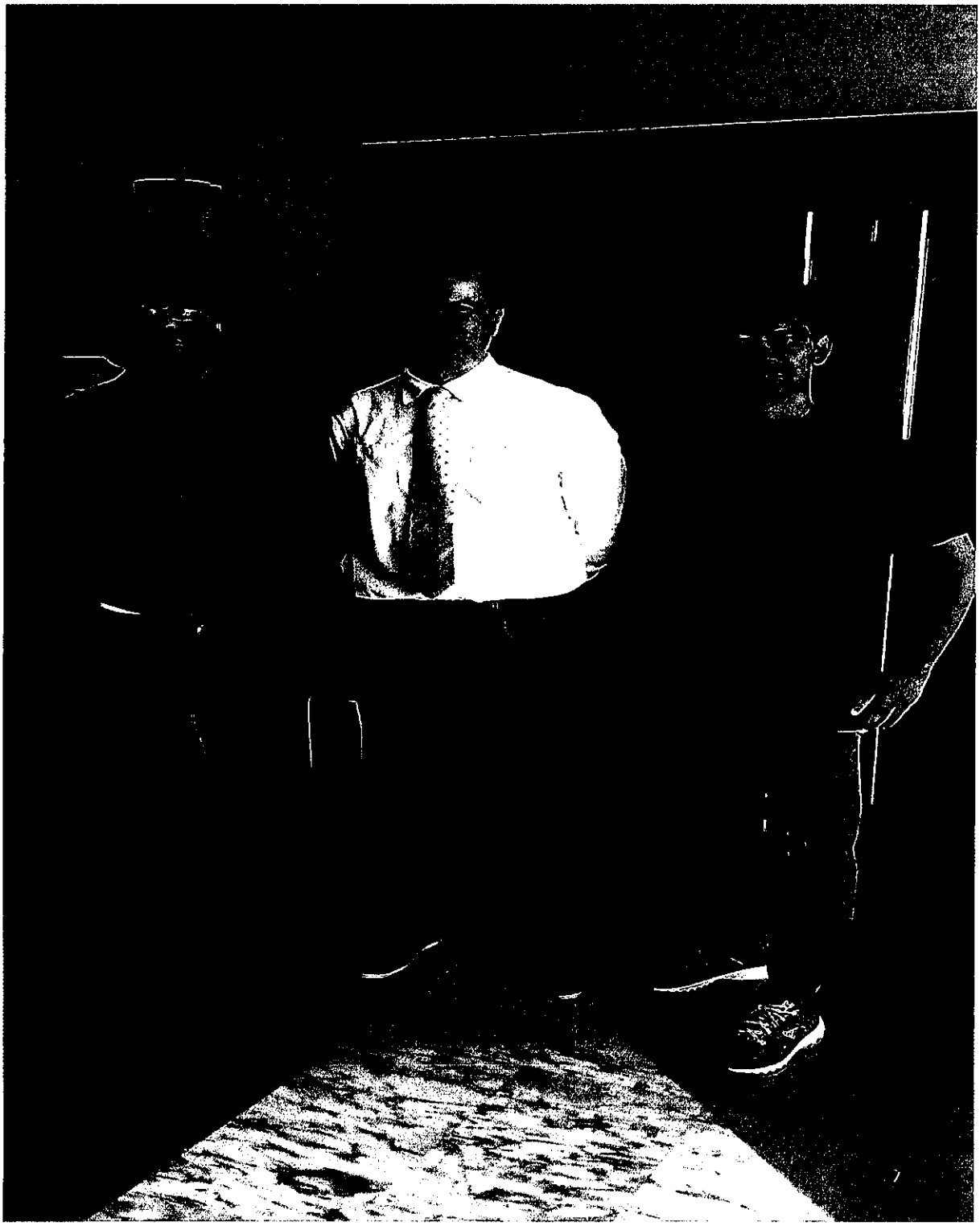

圖 10 本署賀志殷技正、邱景昆薦任技士與主辦單位留影

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伍、2017 年第 19 屆環境與生態影響國際研討會

本次研討會來自各國不同領域的專家學者就研究成果提出發表，其中精選兩篇重要論文，摘要如下：

一、 南非製造業增長和經濟成長關係分析（An Analysis of Relationship between Manufacturing Growth and Economic Growth in South Africa)

本文主要研究製造業績效與經濟成長間之關係，研究團隊參考了 86 個國家的橫斷面數據，以南非國家統計局、儲備銀行（SARB) 每季國內生產總額（GDP)數據，就南非國內就業與服務統計資料，運用卡爾多（Kaldor)定律來分析南非自 2001 年至 2014 年製造業增長與國內生產總額（GDP)之關係，整體研究結果證明 Kaldor 的第一個增長定律適用於南非整體經濟發展模式，而在維持經濟成長過程中，製造業是扮演著關鍵發動機角色，且製造業技術不斷精進，可以帶動就業與服務機會。即 Kaldor 的第一成長定律證明製造增長與經濟發展彼此間是正向的因果關係，此觀點是基於三個價值觀：

（一） 製造業是特殊的經濟活動，為國家不可或缺產業，製造業創造了許多回報與經濟奇蹟，其產值高低與國民教育水準提升有直接因果關係，而同一 Kaldor 定律運用於印度、美國亦得到同樣論述證明。

（二） 製造業不僅是產業發動機角色，其增長可重複反映在經濟成長表現，改善南非貧窮困境，而製造業技術持續提升，同一單位的耗損產生更高產值，可使製造業獲益占 GDP 的比重更大。

（三） 製造業產出（產值)多元化，將帶動其他產業發展與提升周邊服務產業，降低國家整體失業率，普遍提升南非國民所得與生活價值。

我國經濟發展過程與其他開發中國家大致相同，最初經濟是以農業為主，稱之為初級經濟時期(Primary Economy)，然而隨著國民所得水準的提高，屬於生活必需品的農產品消費比重下降，而奢侈品的消費比重逐漸上升，產業結構便因此產生了變化。其次是工業經濟時期(Industrial Economy)，經濟以工業為主。最後進入了以高科技產業、跨國金融商業及服務業為主的服務性經濟時期(Servicing Economy)，即所謂的後工業化經濟時期(After Industrial Economy)。而隨著科技產業發展蓬勃，國家能源政策改變與國內環境保護意識型態高漲之際，我國傳統製造產業正面臨轉型時機，經濟部門與環境保護機關如何輔導產業，滿足社會各階層人民期待，正考驗新政府的智慧與決策能力。

二、 以多元方法分析移動的環境影響（Multidimensional Approach to Analyse the Environmental Impacts Mobility)

本文研究團隊認為全世界發展電動車技術趨勢已相當明朗化，未來 20 年或 30 年不斷發展使用創新的動力與能源資源循環利用，將澈底改變傳統石化燃料使用模式與人民生活習慣。而電動車發展趨勢因受政府產業政策影響，公部門如何提供誘因並結合企業力量，是目前面臨的一大課題。本文研究者以複雜系統方法（System of Systems)，嘗試建立一個區域性模型，採座標系統分析區域環境影響，並提供使用者方便性服務選項，為發展區域性電動車產業尋找解決方案：

（一）電動車產業發展強調後勤維修服務，廣泛推動電動車產業過程，如何規劃完善、方便充電設施、緊急維修與考量救援時效性。

（二）政府推廣部門與汽車產業應扮演的角色，直接影響電動車市場能否徹底改變人民習慣，及解決移動性環境污染問題關鍵因素。

（三）研發技術創新與服務組織建立、電池續航力（單次充電里程數）、生命週期與電池最終處理方式，是另一新興的環境污染問題，須想想配套處理方案。

（四）過去 30 年來電動車發展採用混合動力，電動與汽油、能量電池混合類型，其主要考量能源價格成本，經營費用增加是否可取代性。

（五）城市發展電動車係為降低環境負擔，本研究所用模型最重要是分析環境影響，未來發展電動車市場的支持力量取決於經濟與社會各階層接受程度。

（六）最後本研究團隊提出一重要觀念，對於電動車改善環境績效已經過充分研究得到驗證，但是否能永續性發展改變舊思維，端看既得利益者態度與道德良知。

陸、心得及建議

環境影響評估制度因各國政治環境不同，具有多樣性操作方式，目前有內閣決議制、顧問程序制、行政命令及立法等不同政策手段。我國「環境影響評估法」屬「程序法」，因具有「否決權」特色，經過 20 餘年來制度運作施，確實為環境與資源保育盡到把關功能；但相對因冗長的審查時間、高標準的要求，對開發計畫能否順利推動存有不確定之風險，因此被投資者認為環境影響評估制度是經濟發展的絆腳石，扭曲環評制度設計美意。為改善現況問題，目前正進行環境影響評估各項修法工作，相關具體修法方向建議如下：

一、參考先進國家作法，對於重大國家政策，應強化政策環評功能，藉以引導開發行為

環評方向，回歸專業討論；同時相關法令如已有禁止開發規定下，應檢討廢除環評法「否決權」設計。

二、經濟發展與開發行為許可過程，應回歸由「目的事業主管機關」決策，其決策過程將環境保護責任納入考量；並明定目的事業主管機關轉送環評書件時，應將開發行為與上位政策契合度、區位篩選合理性，以及將環評書件資料正確性等納入確認事項。

三、環評書件「補正及展延」部分，如有資料缺漏不足，認有應補正釐清情形時，應明定補正期限及展延次數。如有逾期者，得由目的事業主管機關駁回開發行為許可之申請。

四、檢討環評審查結論效期，規定環評審查通過後逾若干年未實施開發行為時，應提送環境現況差異分析及對策檢討報告送主管機關審查；環評審查通過後逾若干年未開發者，其審查結論應自動失其效力。

五、環評追蹤與監督機制方面，檢討環評追蹤監督退場機制。即一般開發行為完成營運，屬影響輕微且無違規紀錄者，回歸相關環保法令管制；開發規模較大且影響廣泛之開發行為，加嚴追蹤監督作業頻次。另考量環評法為預防性法規，開發行為環評審查通過後，對已有專業管制法規部分，回歸專業管制法規管制。

六、依司改國是會議結論，將不法利益追繳與罰鍰併行、吹哨者條款及公開環境數據資訊，納入修法範疇。

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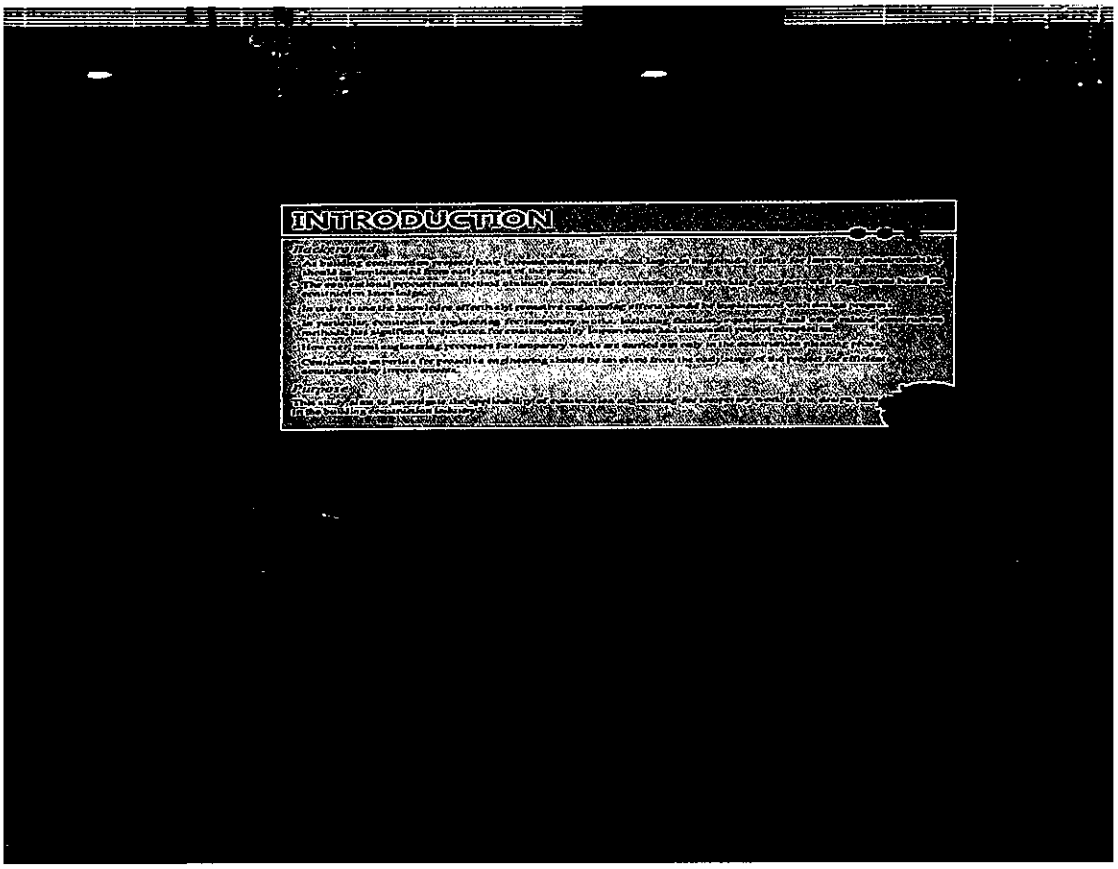
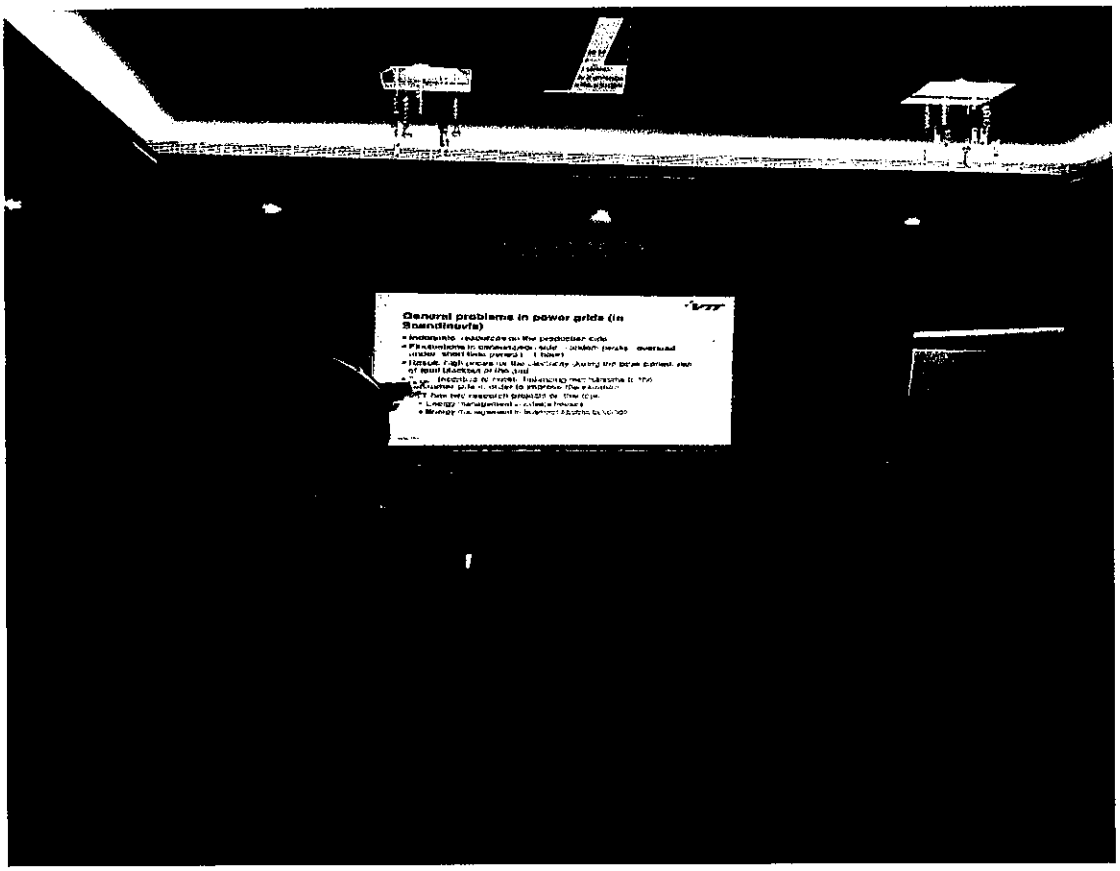
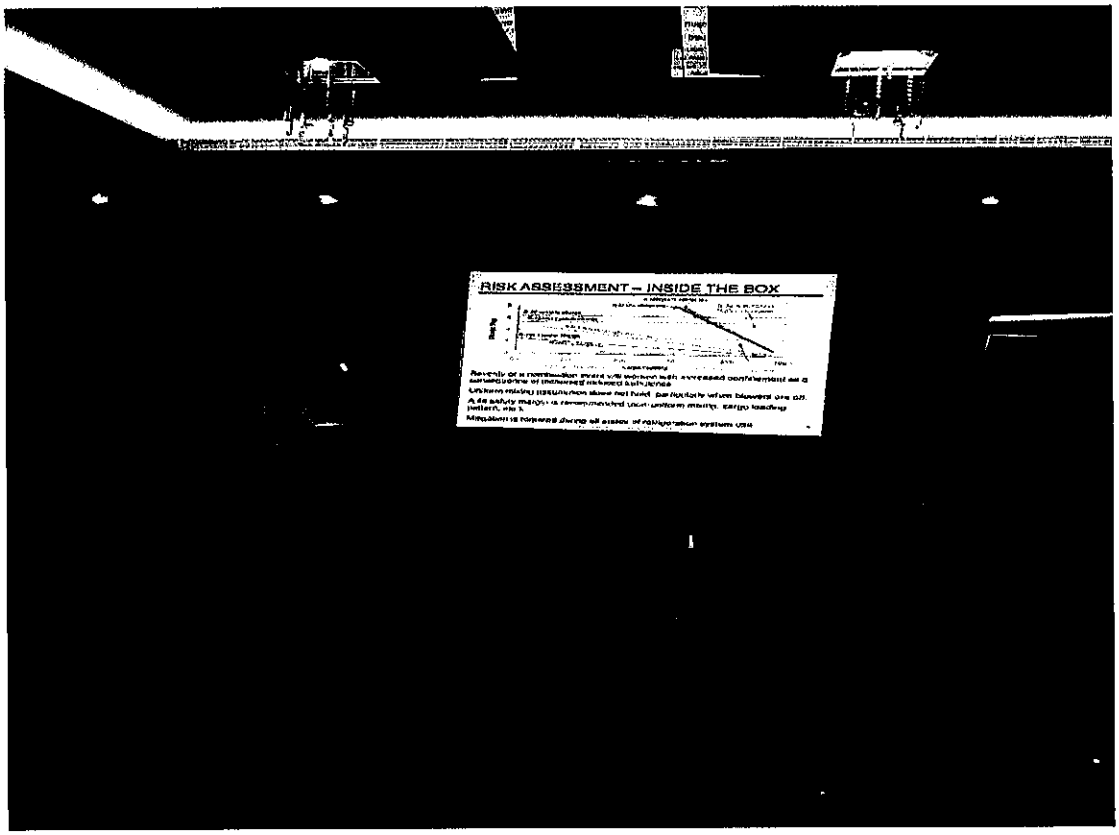
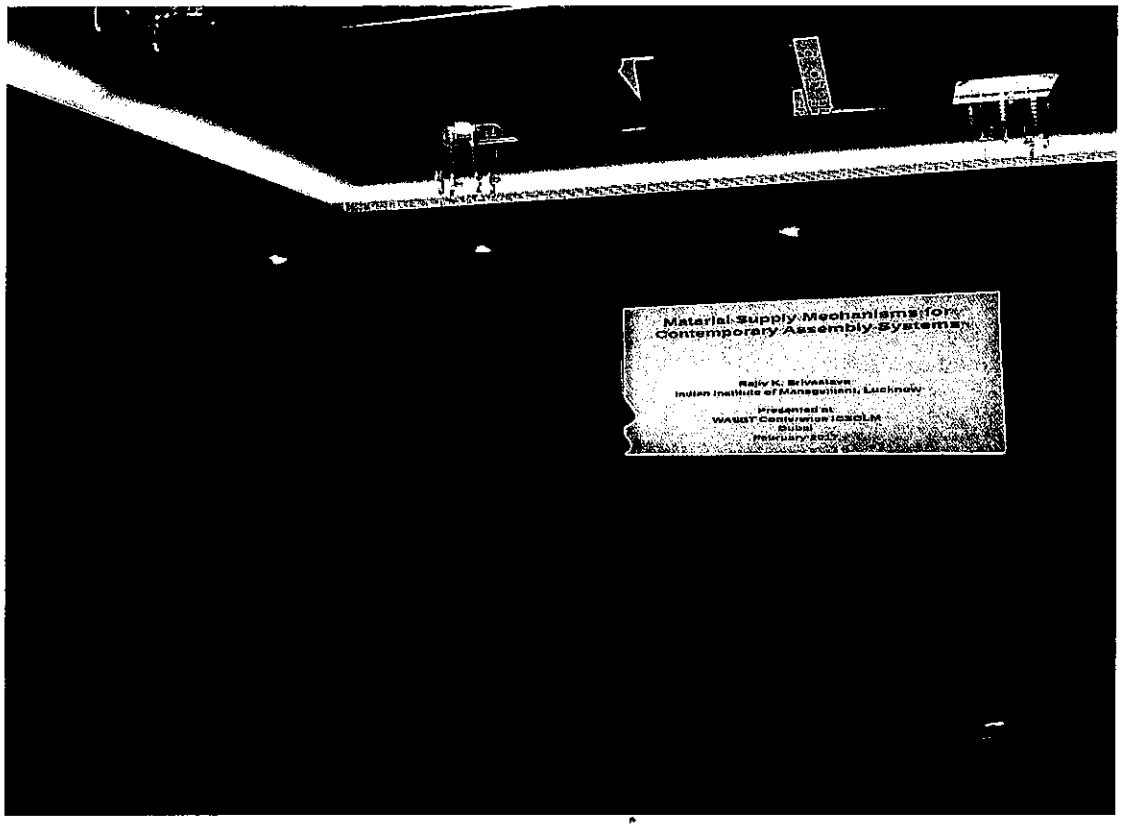


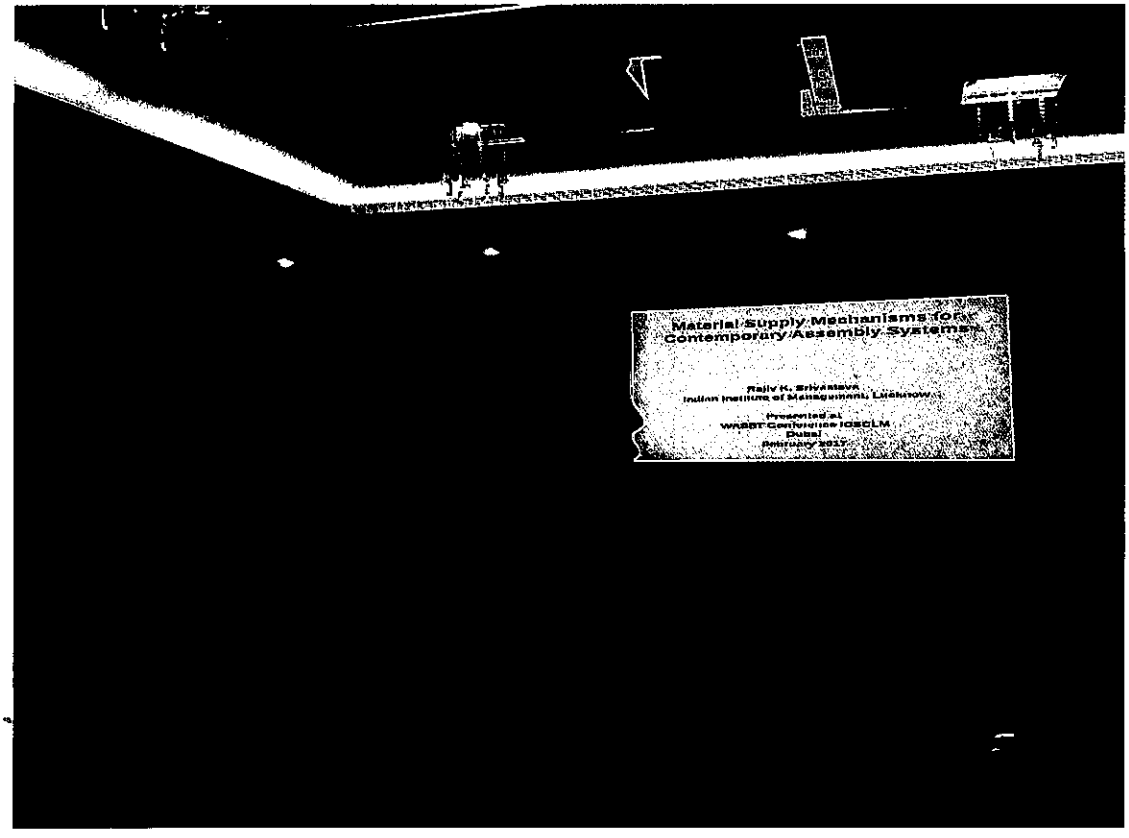
第 19 界環境與生態影響國際研討會現場發表（一）





第 19 界環境與生態影響國際研討會現場發表（二）





第 19 界環境與生態影響國際研討會現場發表（三）

CERTIFICATE OF ATTENDANCE

This certificate is awarded to

Ching-Kun Chiu

in oral and technical presentation, recognition and appreciation of research contributions to ICEEI 2017 : 19th International Conference on Environmental and Ecological Impacts

WORLD ACADEMY OF SCIENCE, ENGINEERING AND TECHNOLOGY

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DUBAI, UAE

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INVITATION LETTER

January 19, 2017

Mr. Ching-Kun Chiu
Environmental Protection Administration
Taiwan

To Whom It May Concern,

The International Scientific Committee has the pleasure of inviting you as listener delegate to the ICEEI 2017: 19th International Conference on Environmental and Ecological Impacts to be held in Dubai, UAE on February, 26-27, 2017.

We look forward to your participation in the ICEEI 2017: 19th International Conference on Environmental and Ecological Impacts.

Since
International Scientific Committee
ICEEI 201
Dubai, UAE

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Crowne Plaza Dubai Deira
Salahuddin Road Deira, Dubai, 8668, United Arab Emirates

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PROGRAM GUIDELINES

1.GUIDE FOR ORAL AND e-POSTER PRESENTATIONS

We kindly ask ORAL presenters to prepare electronic presentations of 15 minutes (allowing 5 minutes for discussions) and e-POSTER presenters to prepare short electronic presentations of 5 minutes (allowing 5 minutes for discussions) (NO PRINT OUTS). A Linux-based operating system is used for both Oral and e-Poster presentations. All presenters should make a PDF file version of their presentation and upload it to the system.

2. PRESENTATION SET UP

Laptop Computer, Projector, USB Flash Drive (No CD Drive), MS. PowerPoint/AcrobatReader

3. SYSTEM SECURITY ALERT

As many delegates insert their USB devices into the laptop computer provided for the presentations, we cannot avoid Cyber/Computer viruses. You are kindly advised to bring a USB Flash Drive containing ONLY your .ppt, .ptx or .pdf presentation file or risk other files being corrupted or made permanently inaccessible.

4. ROLE OF THE SESSION CHAIR

The duties of the Session Chair include the following:

1. Arrive at the conference hall at least 10 minutes before the session begins. Identify the paper presenters and discussant(s) in advance, and introduce yourself. Remind each presenter of the time limits that apply, and describe the method you will use to alert them of time limits during the actual presentation.
2. At the start of the session, introduce yourself to the audience, announce the session/title, and offer a brief overview indicating how the papers are related.
3. Prior to each presentation, introduce the speaker, announce the paper's title, the name(s) of the author(s), and provide brief comments regarding the affiliation and/or background of each presenter. Identify the individual who will be speaking if it is someone other than the first author.
4. During the presentations enforce time limits strictly so that no author (or audience member) monopolizes someone else's time. Oral paper presentations each have 20 minutes (15 minutes for full presentation papers, 5 minutes for discussions), and 10 minutes for e-Poster (electronic poster) presentations (5 minutes for poster presentation, 5 minutes for discussions).
5. Once presentations are complete (oral paper presentations and e-Poster presentations), the remaining time can be used for informal discussion between the audience and session participants. It is your job to field questions from the audience.
6. Try to conduct the session as informally as possible (e.g., use first names when addressing participants and members of the audience) to encourage as much audience participation as possible.

5. BEST PAPER AWARDS / BEST PRESENTATION AWARDS

A 'Best Paper Award / Best Presentation Award' will be conferred on the author(s) of an abstract or a full paper presented at the conference. Selection is made based on the best combined marks of the abstract / paper review and presentation quality appraisal conducted by the Session Chair at the conference venue, and assessed by the Program Committee. Award winners will be announced after the conference. The author(s) of a selected paper/presentation will receive a signed and stamped official Best Paper Award / Best Presentation Award e-certificate.

□IST OF PAPERS IN T□E CONFERENCE PROCEE□INGS C□

Important Dates

Abstracts/Full-Text Paper Submission Deadline	January 10, 2017
Notification of Acceptance/Rejection	January 15, 2017
Final Paper (Camera Ready) Submission & Early Bird Registration Deadline	January 26, 2017
Conference Dates	February 26 - 27, 2017

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Please refer to the Paper Submission GUIDE before submitting your paper.

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completely empty (0 percent cargo loading) to when it is completely loaded. On the other hand, the high-risk region for the A2L classification refrigerants, R-32 and R-1234yf, is relatively smaller and extends from a cargo loading of about 70 percent and higher. For a 20-foot reefer container, still common in many trade lanes, all the aforementioned refrigerant leak limits are halved. This simple analysis highlights the need for mitigation during all states of the refrigeration system, including the powered and non-power modes.

The probabilities of leak and ignition events also need to be addressed. A probability risk assessment is beyond the scope of this paper, but the probability of occurrence for a leak will decrease with increasing hole size or leak rate. The dependency of a choked vapor propane leak with hole size in a refrigerant pipe is shown in Figure 2. The upstream leak stagnation temperature was taken to be 38 degrees Celsius and the stagnation pressure corresponding to the refrigerant saturation pressure at that temperature. Other details can be found in Papas et al. (2016). [8] As shown, the R-290 leak rate from a 0.08cm hole, which is several times larger than those forming from corrosion, would be about 0.1 kg/min. For the transport container application, it is important to emphasize that, because the box is tightly sealed, even a low (non-catastrophic) leak would pose a problem over time in this enclosed space. For the normal cargo loading range, the concentration build-up would be particularly problematic given the leaked amount needed to reach LFL would be a small fraction of the total system charge. In addition to evaluating the extent of flammable regions, the probability or likelihood of a combustion event, which requires the occurrence of both a leak and the presence of a competent ignition source, must also be determined. The ignition probability can be related to the minimum ignition energy (MIE) required for ignition of a given flammable refrigerant-air mixture; the MIE for A2L refrigerants is considerably higher than A3 refrigerants such as propane.

IV. Mitigation

Within Container refrigeration special focus is placed on the safety associated with the use of refrigerants. FMEA (Failure Mode and Effect Analysis), system modeling, field and laboratory testing and data collection by refrigerant equipment manufacturers (Carrier Transicold, Daikin, MCI and Thermo King) and shipping lines has identified areas of higher risk for events to occur. These include stacking and running units in areas of low/lower airflow (such as below deck), the need to repair units while they are on ship, the need to repair units in remote locations and the need to load and unload flammable cargo. The risks are further increased with the fact there can be limited ability to isolate the unit. To ensure safety in each of these conditions, among others, it is essential that a refrigerant leak inside or outside of the box must not exceed the lower flammability limit (LFL) of the refrigerant. More specifically, the requirement is the probability of occurrence and potential impact of these events must be the same or lower than with the incumbent A1 refrigerants, R-134a or R-404A.

Today's container units use A1 refrigerants with minimal risk of having a combustion event when in use or service. Introducing an A2 or A3 flammable refrigerant into this environment requires review, analysis, and potential changes to the requirements for designs, operations, and service procedures in use today to mitigate the risk of a combustible incident. The first step in this mitigation process begins with the design.

The most straight forward methodology for mitigating risk associated with A2 and A3 refrigerants is to employ a design that limits the charge levels to below the LFL for the refrigerant when well-mixed, as discussed in the previous section. However, the charge levels today within a container are significantly higher than these levels, as shown in the drop-in charge assessment in Table 1.

Three design concepts have been identified to build safety measures into the units and realize opportunity for charge reduction. The three design concepts are outlined below and it should be noted that none of the design concepts achieved the recommended charge level called out in the current standards, as detailed in Table 2. Several strategies were employed to reduce the charge in addition to the design concepts to be detailed, including: the introduction of new coil technologies, line length and diameter reductions and the use of advanced air management systems.

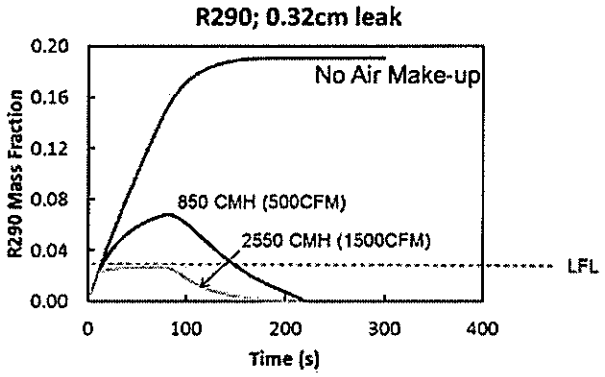

Fig 3: R-290 Concentration Evolution for Uniform Mixing with Fresh Air at Different Ventilation Rates inside a 40-foot Reefer Container. Cargo Loading= 86 percent, Choked vapor leak rate from 0.32 cm dia. hole = 1.6 kg/min, System charge = 2.45 kg.

A. Concept 1: Improved Ventilation

Using a standard container unit with no major changes in system architecture, components and capability are added to the unit to reduce the risk of ignition resources and improve ventilation targeted at reducing the opportunity for the flammable refrigerant to exceed LFL., These items would include methodologies to determine leak occurrence, notification to operations and service personnel of leak occurrence, limiting access to the unit/inside the box during the leak occurrence and increasing ventilation to reduce the refrigerant level below the LFL. The design changes associated with this concept include:

1. Limiting ignition sources by introducing explosion rated components: motors, fans, contactors, flame arrestors, wiring in conduit with explosion proof connections and seals,

compressor, condenser, control box, etc.

2. Expanding the refrigerant unit safety features to include the addition of normally closed valves to limit the refrigerant available at the site of the leak and a nitrogen cylinder to be released when a leak is detected in support of bringing the mixture below LFL. Additionally, to ensure safety of the personnel working around the Container, expanding the Container box safety systems to include an automatic interior door locking mechanism that upon detection of a refrigerant leak automatically seals the door from the inside not allowing entry to the box until the concentration level has been brought below the LFL, battery power back-up for the automatic door locking mechanism when a leak occurs and the unit is not connected to power, and the addition of alarms, audible and visual, to notify operational and service personnel that a refrigerant leak has occurred.

3. Increasing ventilation by making automatic fresh air exchange a unit standard.

As illustrated in Figure 3, the introduction of outside fresh air into the container will be required to prevent LFL from being reached in worst-case scenarios. The magnitude of the ventilation rate will depend on several factors, including the worst-case leak rate (which can be estimated assuming choked flow from a ruptured refrigerant line) and the LFL. As shown in Figure 3, the temporal evolution of the R-290 concentration in a standard 40-foot reefer container at 86 percent cargo loading, assuming uniform mixing, was computed to determine the fresh air ventilation rate needed for mitigation, or keeping the R-290 concentration below LFL at all times without any safety factor. The R-290 leak rate was assumed to be sustained at 1.6 kg/min, corresponding to a computed choked vapor mass flowrate ensuing from a 0.32 cm dia. hole. The upstream leak stagnation temperature was taken to be 38 degrees Celsius and the stagnation pressure corresponding to the R-290 saturation pressure at that temperature. The methodology employed here is similar to the framework developed for machine room mitigation [8] and currently being adopted by ASHRAE Standard 15. For these conditions, the analysis shows that a fresh air ventilation rate of 2,550 CMH, assuming no safety factor, would prevent LFL at all times throughout the chosen catastrophic leak process. This analysis was also performed for R-32 and R-1234yf under the same conditions, indicating that 170 CMH would be sufficient to prevent LFL for such catastrophic leaks. For comparison, currently installed fresh air vents are capable of 250 CMH.

B. Concept 2: Indirect System

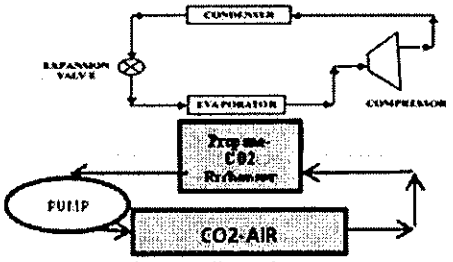

Fig 4: Indirect System

The fundamentals behind the indirect design concept are to develop a "chiller type" system that has R-290 (propane) in the first cycle and R-744 (CO2) in the second cycle (figure 4). With this concept as CO2 is the second cycle the risk of an indirect leak into the box would be eliminated. With R-290 in the first cycle and the fact with a leak LFL can still be achieved outside the box design changes will be required to minimize the safety risks. The design changes associated with this concept include:

1. Limiting ignition sources by the introduction of explosion proof components in the compressor section, the condensing section including the fans, the control box including the contactors, etc.;

2. Increasing the unit safety features by adding alarms -- audible and visual -- to notify operational and service personnel; and,

3. the addition of a propane-to-CO2 heat exchanger and pump.

While this design eliminates the additional components and cost associated with them inside the box there would still be added cost in the system to incorporate the indirect system design in parallel with maintaining the safety elements for the R-290 cycle.

C. Concept 3: Dual Circuits

The fundamental principle behind the parallel circuit concept is to introduce multiple refrigeration circuits into the Container unit targeting reducing the charge-level within a single circuit below the refrigerant LFL when well-mixed (figure 5). The refrigerant charge levels for Container units today are high (see Table 2). Additionally, a Container refrigeration unit is space constrained limiting the number of circuits this system can be divided into to two circuits. With that, this concept was not successful in reducing the charge levels within an individual circuit below the refrigerant LFL. As the charge levels are not reduced below LFL, this system design would incur the additional cost of the dual circuits and still be required to have all the safety items identified in Concept 1. This concept was evaluated with special focus on A2L refrigerants.

In addition to unit level design changes, from an operation and service perspective the policies and procedures that are followed would need to be evaluated and changed as appropriate. If a leak occurred, a cloud could form with flammable refrigerant concentration levels above LFL. Operating and servicing the units during this condition is not advised as unit operators and service technicians can introduce several potential ignition sources, including: electrostatic discharge (ESD), flame and/or torch, and ignitions from the use of standard service tools (vacuum pump, etc.), among others.

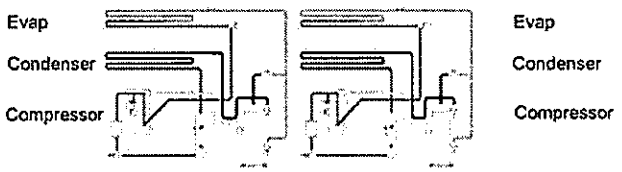

Fig 5: Dual or Parallel Circuit System

D. Operation and Service Standards

While precise operational and service standards for container refrigeration units do not exist today, the mitigation of risks associated with servicing a unit using a flammable refrigerant will require that at minimum service practices must be evaluated and recommended changes introduced. These changes include:

1. Evaluate and determine which service certifications are required to service a refrigerant unit.
2. The service technician / operator needs to carry a flammable refrigerant sensor with alarm on his/her belt and approved leak detection device.
3. Anti-static and grounding devices will be required for service.
4. All service will need to be conducted in a well-ventilated area; no service underdeck or in a warehouse with insufficient ventilation.
5. Prior to performing any service, it is recommended that the service technician take the following actions:
   a. Lock out/tag out possible ignition sources within 3 meters of the unit being worked on prior to performing any service – this would include adjacent units
   b. Always remove charge (with explosion proof vacuum pump). This item will need to be done even in the case of verifications/service not associated with refrigerants, including but not limited to - electrical verifications, due to the risk of leak/explosion in proximity of the service technician.

The items listed above would represent significant changes to standard service industry practices today. Instituting these practices in the container industry will require standard work, training and monitoring to ensure that they are being implemented. There will be a cost associated with implementing these items, and each organization responsible for implementation would need to calculate these costs accordingly.

From an operations perspective, there would be a need to store flammable refrigerants on the ship for re-charging refrigeration units, as required. Flammable gas refrigerant storage should follow these precautions at a minimum:

1. Ensure the storage area is well-ventilated.
2. Ignition sources should be at least 3 meters away.
3. Keep the gas cylinders out of the sun and away from sources of heat.
4. Protect gas cylinders from falling or being knocked over.
5. The storage area must be free of combustible or waste materials.
6. All gas cylinders must be secured to prevent theft or tampering.
7. Ensure service and operations personnel are trained in the storage and handling of flammable refrigerants.

The recommended requirements for design, operations and service procedures outlined above should be considered minimum acceptable actions and additional guidelines added as development activities continue. Each of these items adds complexity into the design, operations, and servicing of the container units. Table 2 outlines the estimated complexity levels for container units with alternate refrigerants relative to an R-134a baseline.

TABLE II
SUMMARY OF STUDY RESULTS OUTLINING COMPLEXITY OF USE

Refrigerant	Mitigation Strategy	Charge (kg) per loop	Design Complexity	Manufacturing Complexity	Service Complexity	Mitigation Level
R-134a	Baseline	5.45	Baseline	Baseline	Baseline	-
R-744	None	5.45	Medium	Medium	Low	Mitigated
R-32	Dual Circuit	1.55	Medium	High	High	Not adequately mitigated
R-1234ze(E)	Dual Circuit	1.92	Medium	High	High	Not adequately mitigated
R-1234yf	Dual Circuit	1.79	Medium	High	High	Not adequately mitigated
R-1234yf	Indirect: Pumped Loop	3.09	High	High	Medium	Box ok, external to unit not mitigated
R-290	Ventilation	1.78	High	High	High	Not adequately mitigated
R-290	Indirect: Pumped Loop	1.54	High	High	High	Box ok, external to unit not mitigated

V. Conclusion

The results summarized in Table 2, combined with the flammability analysis described in the previous sections, lead us to the following conclusions:

1. To date, A1 (nonflammable) refrigerants are the only refrigerants ever used by the container industry. While R-290 (propane) is an attractive refrigerant forenergy efficiency, a propane design has not been identified for container refrigeration equipment that adequately mitigates flammability risks and complies with today's and anticipated future standards.[9]
2. The least risky approach with propane is the "indirect system" design. However, cost and complexity, in this case, offer no substantial advantage over a unit using dioxide-744 (CO2) refrigerant (classified A1 for flammability and toxicity), while safety risks outside the box, complexity in service practices and regulatory compliance present challenges.
3. The double circuit/double compressor design reduces the charge of mildly flammable refrigerants, but charge/circuit still reaches the LFL limit, leading to explosion risks. The indirect cycle eliminates the risk inside the box, but is not able to adequately mitigate the risk in the condensing section for the operator/service person.

4. Given the safety risk and operational and service complexity associated with the use of either mildly flammable or flammable refrigerants in transport refrigeration, R744 (CO2) emerges as the best alternative among the options analyzed in this paper.

It is also important to point out that the conclusions are specific to container transport refrigeration, and the methodology can be applied to truck and trailer refrigeration. Other refrigeration and air conditioning systems have different charge levels, leak volumes and application risk profiles, so the results of this study cannot be extrapolated outside the specific segment analyzed.

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An Analysis of the Relationship between Manufacturing Growth and Economic Growth in South Africa: A Cointegration Approach

Johannes T. Tsoku, Teboho J. Mosikari, Diteboho Xaba, Thatoyaone Modise

***Abstract*—**This paper examines the relationship between manufacturing growth and economic growth in South Africa using quarterly data ranging from 2001 to 2014. The paper employed the Johansen cointegration to test the Kaldor's hypothesis. The Johansen cointegration results revealed that there is a long run relationship between GDP, manufacturing, service and employment. The Granger causality results revealed that there is a unidirectional causality running from manufacturing growth to GDP growth. The overall findings of the study confirm that Kaldor's first law of growth is applicable in South African economy. Therefore, investment strategies and policies should be alignment towards promoting growth in the manufacturing sector in order to boost the economic growth of South Africa.

***Keywords*—**Cointegration, economic growth, Kaldor's law, manufacturing growth.

I. Introduction

ECONOMIC growth is essential because it enhances the standard of living of the whole population and it also creates revenue and employment opportunities in the country [16]. Reference [5] indicated that the long run economic growth is considered healthy in the economy of the nation However, in South African economy, the main sectors that stimulate and keep economic growth sustainable are mining, agriculture, manufacturing, communication, tourism, wholesales and retails, finance and business services and investment intensives. Amongst the key sectors of economic growth in South Africa, manufacturing sector plays a very important role in sustaining growth and economic development. It was revealed by Statistics South Africa in 2014 that manufacturing sector contributed a share of 13.9% on South Africa's gross domestic product (GDP), making it the second biggest contributor on the GDP growth in South Africa [14].

J.T Tsoku with the Statistics Department, North West University (NWU), Mafikeng campus, South Africa, 2735, E-mail: johannes.tsoku@nwu.ac.za, Tel: +2718 389 2805,

T.J Mosikari with the Economics Department, North West University (NWU), Mafikeng campus, South Africa, 2735, E-mail: tebza.minus@yahoo.com or teboho.mosikari@nwu.ac.za , Tel: +2718 389 2654, Fax: +2718 389 2597,

L.D Xaba with the Statistics Department, North West University (NWU), Mafikeng campus, South Africa, 2735, E-mail: diteboho.xaba@nwu.ac.za , Tel: +2718 389 2195.

T Modise with the Statistics Department, North West University (NWU), Mafikeng campus, South Africa, 2735, E-mail: tjmodise90@gmail.com.

This paper employs the cointegration framework to examine the role that the manufacturing sector has played and continues to play in the economic growth of South Africa. Cointegration framework is used to establish the long run relationship among variables. Economic theories frequently suggest that two or more of economic or financial variables should have an economic long run relationship [18]. Many authors emphasised that manufacturing plays a very important role in the economy of unindustrialised and industrialised nations including South Africa. They also stated that manufacturing growth stimulates not only economic growth, it also creates indirect employment. Nevertheless, there are facts that have not been fully explored insofar as manufacturing growth and economic growth have the long run relationship particularly in South African context. South African economy is dependent on manufacturing for growth and sustainability.

The paper is set out as follows. Section II discusses literature review. Section III briefly outlines the methodological framework. Section IV presents the discussion of results. Concluding remarks are given in Section V.

II. Literature Review

Kaldor's first law of growth states that there is a strong positive causal relationship between manufacturing output growth and the growth of aggregate output (GDP) [8], [9]. Kaldor's law again argues that direction of causation between manufacturing and GDP growth runs from manufacturing to GDP. Furthermore, the relationship between manufacturing growth and GDP growth is not simply a repetition reflecting the fact that manufacturing contributes a larger share of GDP; rather it is based on the fact that manufacturing is the engine of growth and this view is based on the three values. Firstly, manufacturing is the exceptional economic activity as it generates returns for the country. Secondly, manufacturing products embody continually improving technology. Lastly, manufacturing output results in the increase of employment which in turn involves transfer of labour from lower productivity land-based activities.

Most of the studies such as [1], [11] concentrated on the international context to analyse the impact of manufacturing sector growth on economic growth. There is however, a lack of empirical studies concerning manufacturing performance and economic growth in South African context. The existing literature is mainly concerned with the short run relationship and the impact of manufacturing sector on economic growth. However, this paper will examine the short and long run

relationship between manufacturing sector performance and economic growth in South Africa.

Reference [13] used cross-sectional data of 86 countries for the period of 1970 to 2009 to examine the relationship between manufacturing exports and growth using regression tree analysis. The author argued that in order for a country to consider manufacturing sector as a benefit for economic growth it firstly needs to be developed. The study revealed that manufacturing exports are positively related to economic growth in countries with higher education and manufacturing exports are negatively related to economic growth in countries with lower education. The Kaldor's law in the United States of America (USA) was tested by [2] using the Johansen's cointegration and Granger causality tests. The study investigated the manufacturing sector output and labour productivity using parametric quarterly data for the period of 1987 to 2007 in USA. Reference [2] realised that in most studies, authors have been testing the Kaldor's law using different methodologies and encountered a number of statistical problems. The study found that there is cointegration between manufacturing output and labour productivity in manufacturing sector. The study further concluded that the Kaldor's law is applicable in the USA.

Reference [3] tested the Kaldor's law in India. The study investigated the evidence of deindustrialisation in emerging economies with low levels of income, unemployment growth and fast growth in informal sectors. The study also analyzes the manufacturing growth in the formal and informal sectors in the Indian economy. Their study revealed that manufacturing sector continues to be a key sector in Indian economy. It was also found that manufacturing and services sectors improved the balance of payments in India. Reference [19] conducted the study to seek to address the interrelated questions of what is the role of manufacturing in boosting economic growth and employment in South Africa. More precisely, does manufacturing continue to be the engine of growth in South Africa? The study by [19] argued that manufacturing growth continues to be the engine drive of fast economic growth in association with creation of employment. By testing the Kaldorian hypothesis using the econometric approach the study found that manufacturing heavily continues to play an important role in stimulating economic growth and employment creation in South Africa.

The study by [15] examined the contribution of manufacturing and services sectors to employment creation and economic growth in South Africa. The study used the input and output data to investigate the relationship between manufacturing, services and the economic growth. Reference [15] used various methods for the analysis in his study and found that decrease in manufacturing could negatively affect South Africa's medium and long term growth. Furthermore, manufacturing was found to be more important as a source of demand for services. On the other hand, services sector was found to be a higher significant multiplier for employment creation than manufacturing sector. Nevertheless, the study found that manufacturing is more important for economic growth while services sector is important for labour absorption.

The Kaldor's three laws of growth in the South African economy was tested by [12]. The study adopted econometric methodology using the ordinary least squares (OLS) to estimate linear regressions. The study found that South Africa's economy supports the Kaldorian growth laws, therefore manufacturing was found to be the key to economic growth in South Africa in the 21st century. Reference [17] analysed the relationship between direct foreign investments in manufacturing sector and economic growth in Asian economies using the regression model. The study found that foreign direct investment in manufacturing sector has a positive significant effect on economic growth in the host countries.

III. Methodology

The paper used seasonally adjusted quarterly data ranging from 2001 to 2014. Data was obtained from the South African Reserve Bank (SARB). The principal series used are GDP growth and manufacturing growth. Employment and services sector are used as the additional variables. All variables are transformed using the logarithmic transformation in order to stabilize variance. Eviews 8 software was used to run all the analysis.

In most cases, macroeconomics variables are non-stationary in their nature and it is said that non-stationary time series produce spurious results. According to economic theories, time series variable(s) are stationary when its mean and variance are constant and do not change with time [6]. It is therefore important to test whether the time series variables are stationary or non-stationary. Unit root test is a commonly used test of stationarity. In this paper, the Augmented Dickey Fuller (ADF) [4] test is used to test the presence of unit root in the concerned time series variables. The ADF test is based on the null hypothesis that the time series variable has a unit root. The ADF test is estimated using the following regression:

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-1} + \varepsilon_t \qquad (1)$$

where ε_t is the white noise residual term, $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$, $\Delta Y_{t-2} = (Y_{t-2} - Y_{t-3})$ and so on. The null hypothesis test that $\delta = 0$ (meaning there is unit root, the series is non-stationary) and the alternative is $|\delta| < 0$ (meaning there is no unit root, the series is stationary). If the τ (tau) p-values are less than 5% significance values, the null hypothesis is rejected in favour of the alternative. The relationship between manufacturing and GDP growth is estimated using the following linear regression model:

$$LnGDP_t = \beta_0 + \beta_1 LnMAN_t + \beta_2 LnSER_t + \beta_3 LnEMP_t + \varepsilon_t \quad (2)$$

where GDP in the dependent variable and MAN (manufacturing), SER (services) and EMP (employment) are independent variables, the regression coefficients are denoted as β_i and ε_t is the stochastic error term. However, the long run relationship among the variables will be estimated using the

Johansen [7] cointegration technique. Vector Autoregressive (VAR) results are sensitive to the selection of lag length. Therefore, the optimal lag length 'p' must be sought [10]. VAR lag order selection methods employed in the paper are Akaike Information Criterion (AIC), Schwartz Bayesian Information Criterion (SBIC) and Hannan-Quinn (HQ). In choosing the optimal lag length, researchers faced the trade-off between the two opposite considerations, the expletive of dimensionality and current model specifications [10]. Once the lag length is selected, the next step is to compute the Johansen cointegration technique.

To determine the number of cointegrating vectors, Johansen derived two tests: Trace and Maximum Eigenvalue statistic. Trace statistic and Maximum Eigenvalue statistic are expressed as:

$$\Lambda_{trace}(r) = -n\sum_{i=1}^{m} Ln(1-\hat{\lambda}_i) \quad (3)$$

$$\Lambda_{max}(r+1) = -n\sum_{i=1}^{m} Ln(1-\hat{\lambda}_{i+1}) \quad (4)$$

where r is the number of cointegrating equations or vectors, $-n$ is the number of the observations, m is the number of characteristic roots and $\hat{\lambda}_i$ is the estimated values of characteristic roots and $\hat{\lambda}_{i+1}$ succeeding estimated value of characteristic roots. If the presence of cointegration is established, the next step is to estimate the error correction model (ECM). The ECM is represented by:

$$\Delta GDP_t = \beta_0 + \sum_{i=1}^{n-1}\beta_i GDP_{t-1} + \sum_{i=0}^{m-1} Y_t \Delta MAN_{t-1} - \prod \hat{e}_{t-1} + \varepsilon_t \quad (5)$$

$$\Delta MAN_t = \beta_0 + \sum_{i=1}^{n-1}\beta_i MAN_{t-1} + \sum_{i=0}^{m-1} Y_t \Delta GDP_{t-1} - \prod \hat{e}_{t-1} + \varepsilon_t \quad (6)$$

where $\prod$ is the error correction coefficient, ε_t is the equilibrium error and Δ represents the first difference operator. GDP_t and MAN_t are the level terms in the model that represents the long run parameters of the two variables. Furthermore, error correction model (5) and (6) presented above allows us to use it in the long run information and short run disequilibrium. ECM allows testing for short run or dynamic causality. In economics, causality is defined as the ability of one variable to predict the other. The study adopts the Granger causality test to examine the causality relationship among the concerned variables. The Granger test of causality estimates the following pair of regressions:

$$GDP_t = \sum_{i=1}^{n}\alpha_i MAN_{t-i} + \sum_{j=1}^{n}\beta_i GDP_{t-j} + \mu_{1t} \quad (7)$$

$$MAN_t = \sum_{i=1}^{n}\lambda_i MAN_{t-i} + \sum_{j=1}^{n}\delta_i GDP_{t-j} + \mu_{2t} \quad (8)$$

where μ_{1t} and μ_{2t} are called impulses in the language of VAR and it is assumed that μ_{1t} and μ_{2t} disturbances are uncorrelated. The Granger causality test the hypothesis of no causal relationship. The test statistic for Granger causality analysis is as:

$$F = \frac{(ESS_R - ESS_U/p)}{ESS_U/(n-2p-1)} \quad (9)$$

The null hypothesis is rejected if the value of the F test statistic is greater than the critical value or if the p-value of F test statistic is less than 0.05 level of significance. The residuals from the cointegration model must be normally distributed, serially uncorrelate and be homoscedastic. If these assumptions are encountered, it is declared that the chosen model is a fair presentation of reality.

IV. Discussion of Results

The starting point of time series analysis is the visual inspection of the series plot of GDP, manufacturing, service and employment. The graphical presentations of the series are presented in Figs. 1-4.

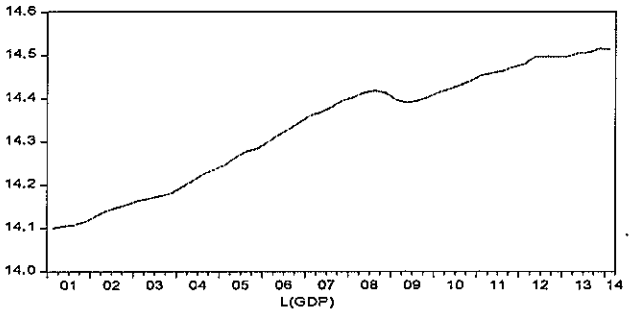

Fig. 1 GDP

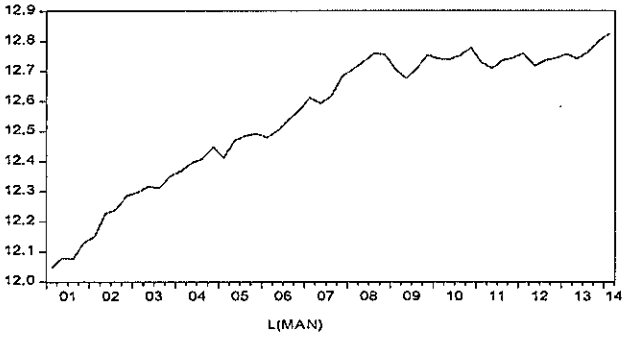

Fig. 2 Manufacturing growth

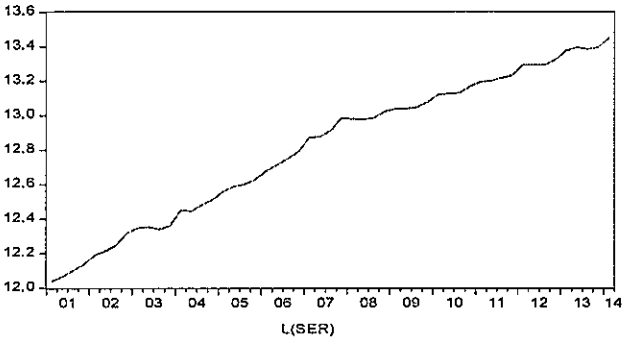

Fig. 3 Services

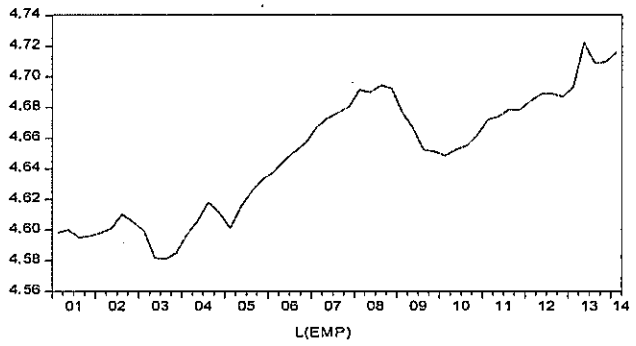

Fig. 4 Employment rate

The plot of GDP, manufacturing and service have risen consistently since 2001 to 2014 with slight fluctuations. The employment series has also risen consistently since 2001 until the first quarter of 2009 where it was recessional and started booming in 2010. The employment rate have irregular fluctuations as compared to GDP, manufacturing and services. By visual inspection, all the four series are nonstationary therefore differencing was then applied. The first differenced series are presented in Fig. 5.

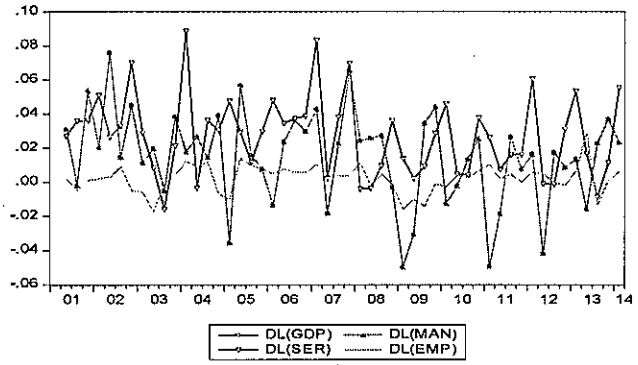

Fig. 5 First differenced series

Fig. 5 depicts that all variables roughly fluctuate around a constant mean of zero, implying that they are stationary. Graphically, these series may be stationary but this will be confirmed by the formal ADF test for unit root. Unit root results are summarised in the following Table I.

The results in Table I indicate that the null hypothesis of unit root cannot be rejected at levels with intercept, trend and intercept and none. The p-values of the ADF test of all the first difference series are significant at 5% significance level. Therefore, it is concluded that all the series are stationary at first difference. Since all the variables are stationary after integrated with the same order, *I (1)*, Johansen cointegration can be applied. The AIC selected optimum lag length as 6. Therefore 6 will be used for further analysis.

The results presented in Table II revealed that GDP growth, manufacturing growth, services and employment are found to be cointegrated. There are two cointegrating vectors as shown by the trace and maximum eigenvalue. Equations (10) and (11) present the long run relationship economic growth and manufacturing respectively.

TABLE I
UNIT ROOT RESULTS

Series	Model	t-statistics	Prob.	Critical values	Conclusion(s)
LGDP	Intercept	-1.704	0.423	-2.920	Non-stationary
	Trend + intercept	-1.126	0.914	-3.500	Non-stationary
	None	2.674	0.998	-1.947	Non-stationary
DLGDP	Intercept	-3.570	0.010	-2.920	Stationary
LMAN	Intercept	-2.633	0.093	-2.919	Non-stationary
	Trend + intercept	-1.794	0.694	-3.499	Non-stationary
	None	3.866	0.999	-1.613	Non-stationary
DLMAN	Intercept	-6.898	0.000	-2.920	stationary
LSER	Intercept	-2.530	0.115	-2.921	Non-stationary
	Trend+ intercept	-1.672	0.749	-3.499	Non-stationary
	None	8.196	1.000	-1.947	Non-stationary
DLSER	Intercept	-6.693	0.000	-2.921	Stationary
LEMP	Intercept	-0.312	0.916	-2.919	Non-stationary
	Trend + intercept	-1.715	0.731	-3.499	Non-stationary
	None	1.970	0.987	-1.947	Non-stationary
DLEMP	Intercept	-5.553	0.000	-2.598	Stationary

TABLE II
JOHANSEN COINTEGRATION RESULTS

Hypothesized No. of CE(s)	Trace Statistic	Critical values	Prob.**	Max-Eigen Statistic	Critical values	Prob.**
None *	78.935	47.856	0.000	40.895	27.584	0.001
At most 1 *	38.040	29.797	0.005	27.948	21.132	0.005
At most 2	10.092	15.495	0.247	9.804	14.265	0.225
At most 3	0.289	3.841	0.591	0.289	3.841	0.591

Note: Trace test and Max-eigenvalue test indicates 2 cointegrating equations at the 0.05 level, * denotes rejection of the hypothesis at the 0.05 level, **MacKinnon-Haug-Michelis (1999) p-values.

$$LGDP_t = C + 0.046LMAN_t - 0.214LSER_t - 1.416LEMP_t + \mu_t \quad (10)$$

$$LMAN_t = C - 1.991LSER_t + 3.852LEMP_t + \mu_t \quad (11)$$

The results further revealed that there is a positive long run relationship between manufacturing and GDP growth as it is expected from Kaldor's theory of growth. The coefficient for services and employment are both negative implying that both services and employment have a negative long run relationship with GDP growth as calculated in (10). The results estimated in (11) revealed that there is negative long run relationship between manufacturing and service and there is positive long run relationship between manufacturing growth and employment.

The results in Table III indicated that about 32.3% of disequilibrium has been corrected. This coefficient also implies that manufacturing growth, services and employment slowly adjust back towards long run equilibrium with GDP growth.

The results in Table IV suggest that there is a unidirectional causality running from manufacturing growth to GDP growth, from GDP growth to employment and from service to

manufacturing growth. This results are in line with the Kaldor's first law of growth.

TABLE III
ERROR CORRECTION MODEL

Variable	Dependent Variable: GDP
Constant	9.843*(0.267)
ECM(-1)	-0.323*(0.158)
DMAN(-1)	-0.007(0.082)
DSER(-1)	0.419*(0.154)
DEMP(-1)	0.372(0.283)
MAN(-4)	0.065(0.042)
SER(-3)	0.287*(0.023)
DGDP(-1)	1.299*(0.399)
R-squared	0.988
Adjusted R-squared	0.986
S.E. of regression	0.013

Note: * indicates significant at 5 percent. Parentheses indicate standard errors.

TABLE IV
GRANGER CAUSALITY RESULTS

Null Hypothesis:	Obs	F-Statistic	Prob.
MAN does not Granger Cause GDP	47	2.995	0.019*
GDP does not Granger Cause MAN		1.530	0.198
EMP does not Granger Cause GDP	47	1.362	0.258
GDP does not Granger Cause EMP		3.578	0.007*
SER does not Granger Cause GDP	47	0.673	0.672
GDP does not Granger Cause SER		1.011	0.435
EMP does not Granger Cause MAN	47	0.698	0.653
MAN does not Granger Cause EMP		1.653	0.163
SER does not Granger Cause MAN	47	2.738	0.028*
MAN does not Granger Cause SER		0.708	0.645
SER does not Granger Cause EMP	47	1.997	0.093
EMP does not Granger Cause SER		0.686	0.662

Note: * indicates statistical significance at 5% level of significance.

TABLE V
DIAGNOSTIC RESULTS

Test	Test statistic	Prob.
Breusch-Godfrey (BG)	18.880	0.275
White's test	169.452	0.703
Jarque-Bera (JB)	0.497	0.780

The BG test statistic revealed that there is no presence of serial correlation in the residuals. There is also no presence of heteroscedasticity since the probability value of the White's test is greater than 5% level of significance. This implies that residuals are homoscedastic. The probability value for JB test statistic is greater than 0.05. Therefore, the null hypothesis cannot be rejected and it is concluded that the residuals are normally distributed.

V. CONCLUSION

The paper employed the Johansen cointegration methodology. The unit root test rejects the null hypothesis and clearly confirms that the variables under consideration are stationary after first differencing. Johansen cointegration results provided the evidence that there is existing cointegration relationship between manufacturing growth, services, employment and GDP growth in South Africa. It is concluded that the Kaldor's first law of growth is applicable in the South African economy since the direction of causation between manufacturing and GDP growth runs from manufacturing to GDP.

Since there is evidence that the cointegration between the concerned variables, ECM was applied. The ECM results revealed that 32.3% of disequilibrium is corrected. The diagnostic testing of the classical linear regression assumptions were met and confirms that the model is not spurious. The paper recommends that the policy makers in South Africa to update the industrial policy and to import talent and skills in order to develop the manufacturing sector. The most important contributing factor for manufacturing growth is infrastructure and foreign investments. Thus, South Africa should consider foreign investments and improvements in infrastructure in boosting manufacturing growth in the country.

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[4] Dickey, D., and Fuller, W. (1979). Distribution of the Estimators for Autoregressive Time Series with a Unit Root, Journal of the American Statistical Association, Vol. 74, pp. 427-431.

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[10] Ray, P. (2008). Commercial banks and monetary policy in India. Business and economics. Vol. 1, pp. 279.

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[17] Wang, M. (2009). Manufacturing FDI and economic growth: Evidence from Asian economies. Applied Economics, 41(8), pp. 991-1002.

[18] Zakrajsek, E. (2009). Cointegration: Basic ideas and key results. Divisions of Monetary Affairs. Federal Reserve Board. University of Ljubljana.
[19] Zalk, N. (2014). What is the role of manufacturing in boosting economic growth and employment in South Africa? Reviewed from: http://www.polity.org.za/article/what-is-the-role-of-manufacturing-in-boosting-economic-growth-and-employment

Climate Change and Human Migration

Sungwoo Park is with the Choate Rosemary Hall, United States (e-mail: sungwoopy@gmail.com).

Abstract

The paper attempts to investigate the correlation between climate change and migration that has caused violent disputes in some regions of the world. Recently, NGOs and educational institutions have proposed claims that migratory patterns and violent uprisings are intertwined with climate change. Thus, the paper is primarily concerned with collecting evidences provided from scholars, validating this significant connection between climate change and migration, and evaluating and suggesting current and future research approaches respectively to enhance the acknowledgement and protection of environmental refugees.

In order to examine the linkage of environmental migration, primary sources, such as political speeches, and secondary sources like theses from environmental policy analysts, books, and reports are used. More specifically, the investigation focuses on an civil war in Syria to draw a connection between environmental migration and violent dispute that threatens the global security.

The examination undertaken specifically analyzes examples where forced migration occurred due to climate change. In Bangladesh, Pakistan, and Kiribati, residents have been at risk of fleeing their countries because of abnormal climate patterns, such as the rise of sea level or an excessive heat stress. As the brutal uprising in Syria has proven that climate change can pose a significant threat to global security, correlation between climate change and migration is surely worth delving into.

I. Introduction

Disputes have always threatened stability and harmony. Groups constantly battled against one another for survival and conquest; everlasting peace never existed on this planet. Wars erupted from competition between civilizations, and victims were gradually replaced by the stronger conquerors like the Mongols. Recently, climate change has been triggering violent conflict, like the recent Syrian crisis, and competition even more as excessive industrialization has destroyed the environment that us humans settled in.

Over the past century, the world has faced massive change in the climate. The average global temperature has risen by around 0.1°C every decade since 1950; only 90% of snow precipitation is recorded each year compared to the data from 1950, and sea level increased by 20cm.[1] Although these changes might seem trivial, humans living far from the equator have experienced tropical weather, and unexpected natural disasters, such as earthquakes and hurricanes, have demolished defenseless communities and killed numerous casualties. Moreover, senseless slashing and burning of trees caused deforestation and desertification. Amazon Rainforest, which represents most of the rainforest area in the world, lost 27,423km^2 in 2004,[2] but the rate of desertification is projected to fasten because 10-30% of water availability is

[1] Rafael Reuveny, "Climate Change-induced Migration and Violent Conflict," Political Geography 26 (2007): 657, PDF.

[2] Frederic Achard and Matthew C. Hansen, eds., Global Forest Monitoring from Earth Observation (Boca Raton, FL: CRC Press, 2013), 180, PDF

predicted to decrease in drylands near the equator and the tropics.[3] Quite frankly, the pictures one could see of kids starving to death after an earthquake in Haiti are not the main concern to the human population anymore. The Environmental Protection Agency (EPA) pinpointed the emission of greenhouse gas, such as carbon dioxide, as the primary cause of global warming and climate change, and the concentration of carbon dioxide increased from 280 ppm to 379 ppm during the twentieth century.[4] Thus, the fundamental problem is that climate change and the concentration of carbon dioxide will show aggravating trends as economy and technological development will inevitably emit more pollutants and destroy nature.

Recently, climate change created a rippling effect as it has not only influenced climate but also menaced global security and politics. Hillary Clinton, former Secretary of State, labeled climate change as "an urgent threat to our economy, our national security, and our children's health and futures."[5] In this regard, one of the most problematic issues that has caused instability and conflicts among countries is climate migration.

A 1985 report from the UN Environmental Programme defines environmental refugees as "people who have been forced to leave their traditional habitat, temporarily or permanently, because of a marked environmental disruption that jeopardized their existence and/or seriously affected the quality of their life,"[6] and definitions of environmental refugee are too broad for the international society to take actions based on the situation that the refugees are placed in. Yet, the concept of climate migration has not received any spotlight although there are numerous victims in the Pacific Islands and the Middle East who are forced to leave their motherland because climate change demolished their home. In this devastating situation, the fact that LDCs (Less Developed Country) are more vulnerable and are more struggling to environmental problems increases the need of international attention and active aid from developed countries who can utilize advanced technology and fast response to react to unexpected disasters.[7]

Thus, this paper seeks to discuss about the correlation between climate change and migration. First, in Chapter II, this correlation will be thoroughly addressed through elaborating on the scientific background behind climate change and how this instance has forced migrations. Chapter III will then pinpoint the limitations to current research and activism because more effort should be made by the international society to prevent more environmental refugees from losing their motherland, and Chapter IV will delve into the causality between climate change and the Syrian civil war since it best exemplifies how climate change can cause bloodshed and pose a big threat to global security. Lastly, Chapter V will include policy recommendations that can provide environmental refugees with international attention and protection, and Chapter VI will conclude the paper through summing up the correlation and its evidence.

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[3] *Climate Change and Desertification* (Geneva, Switzerland: World Meteorological Organization, n.d.), 3, accessed November 27, 2016, http://www.wmo.int/pages/prog/wcp/agm/publications/documents/wmo_cc_desertif_foldout_en.pdf.

[4] EPA, "Causes of Climate Change," Environmental Protection Agency, accessed November 5, 2016, https://www.epa.gov/climate-change-science/causes-climate-change

[5] Philip Hainbach, "An 'Expensive Hoax' vs an 'Urgent Threat,'" Melbourne School of Government, accessed November 12, 2016, http://electionwatch.unimelb.edu.au/articles/an-expensive-hoax-vs-an-urgent-threat.

[6] Essam El-Hinnawi, *Environmental Refugees* (Nairobi, Kenya: United Nations Environment Programme (UNEP, 1985)

[7] Reuveny, "Climate Change-induced," 657.

II. Correlation: Climate Change and Human Migration

In 2008, the United Nations estimated that 20 million people were displaced from their homelands due to climate change, and one person every second has been displaced by a disaster since 2009.[8] Former UK shadow immigration minister Chris Bryant predicted that there will be around 200 million climate refugees,[9] and the Christian Aid Charity also warned that 184 million people might die in Africa because of climate change by the end of the twenty-first century.[10] As Hillary Clinton, during her presidential campaign, classified climate change as a "threat multiplier" to global security,[11] the public bears a strong responsibility to acknowledge the direct correlation between climate change and migration and take appropriate actions to stop this calamity.

Evidences of climate migration could be seen anywhere around the world. For instance, rising sea levels wiped out fertile and cultivated agricultural land in Bangladesh; a 30% drop in wheat price followed this catastrophe,[12] and farmers were forced to migrate to urban areas. As this exodus has been causing political conflicts in Dhaka due to lack of supplies and overpopulation, the current public system and infrastructure are desperately in need of reformation. However, as the World Bank predicted that "half of all Bengalis will live in urban centers"[13] in half a century, immediate response should be taken to prevent further damages. In addition, the Pakistanis are also victims of heat stress and unexpected flood that occurred due to climate change.

In 2010, 14 million fled the Indus River basin since the timing of such heavy monsoon rains was unexpected.[14] Heat stress created much worse damage to Pakistan as abnormally high temperatures made land uneconomical to practice agriculture and forced men to migrate upwards. Thus, the International Food Policy Research Institute claimed that "we are left with an overall picture that heat stress - not high rainfall, flooding, or moisture - is most strongly associated with migration."[15]

Lastly, the tragic trace from climate change could also be seen in Pacific Islands like Kiribati. Kiribati only has an average height above sea level of just two meters, and its 32 atolls are in danger of sinking underwater within the next several decades as the sea level around Kiribati has risen by 4mm per year while the global average was only 2.8-3.6mm per year.[16]

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[8] UNHCR, "Climate Change and Disasters," United Nations Higher Commissioner for Refugees (UNHCR), accessed December 2, 2016, http://www.unhcr.org/en-us/climate-change-and-disasters.html.

[9] Hannah Barnes, "How Many Climate Migrants Will There Be?" BBC News, last modified September 2, 2013, accessed December 3, 2016, http://www.bbc.com/news/magazine-23899195.

[10] Nils Petter Gleditsch and Ragnhild Nordås, "Climate Change and Conflict: A Critical Overview," *Die Friedens-Warte*, 2010, 10, PDF.

[11] Chris Hayes, "Climate: A National Security 'Threat Multiplier'," MSNBC, last modified October 14, 2014, accessed November 12, 2016, http://www.msnbc.com/all-in/watch/climate--a-national-security--threat-multiplier--342601795986.

[12] Abul Kalam Md. Iqbal Faruk, "Climate Change Induced Migration in Bangladesh," International Union for Conservation of Nature (IUCN), last modified October 5, 2015, accessed December 2, 2016, https://www.iucn.org/content/climate-change-induced-migration-bangladesh.

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[14] LEAD Pakistan, "Climate Migration in Pakistan," LEAD Pakistan, last modified February 24, 2016, accessed November 28, 2016, http://www.lead.org.pk/lead/postDetail.aspx?postid=293.

[15] V. Mueller, C. Gray, and K. Kosec, "Heat Stress Increases Long-term Human Migration in Rural Pakistan," *Nature Climate Change* 4 (2014): 3, doi:10.1038/nclimate2103.

[16] Republic of Kiribati, "Changing Climate," Kiribati Climate Change, accessed December 1, 2016, http://www.climate.gov.ki/changing-climate/.

Although fishing and handicrafts are the main industries in Kiribati that are no way close to pollution, people live under constant fear of losing their land and home.

John Kerry once warned the public by saying, "you think migration is a challenge to Europe today because of extremism, wait until you see what happens when there's an absence of water, an absence of food, or one tribe fighting against another for mere survival."[17] Before Kerry publicized this problem, however, scientists have explored climate change and its linkage with migratory patterns since the 1990s.

Although natural phenomena have also contributed to climate change, the primary cause is the excessive emission of carbon dioxide and other pollutants from industrial facilities.[18] The emission of carbon dioxide and the rise of global temperature creates a positive feedback loop, in which the rate of input and output of the system keeps increasing. The amount of carbon dioxide increases as slashing and burning of trees accelerate deforestation, and the burning of fossil fuels and mass production from factories also emit ridiculous amount of the pollutants. As more carbon dioxide stays in the atmosphere, the global temperature rises because of the Greenhouse Effect. Then, the increased global temperature fastens carbon sequestration; a soil microbe respires more actively and emits more carbon dioxide.

This instance also affects the permafrost and glaciers as the ice melts due to increased temperature, so sunlight increases the temperature as well because it has less amount of area on land to reflect itself back to space. The positive feedback loop thus triggers both the temperature and carbon dioxide emission to rise, and this cycle has caused changes in the climate as unexpected and abnormal patterns on Earth led the ecosystem to function improperly. The emission of CFC (Chlorofluorocarbon) is also a contributing factor to climate change because as CFC, also known as Freon gas, goes up to the ozone layer, it destroys the ozone layer that protects ultraviolet rays from entering the planet;[19] this destruction of the ozone layer causes excessive sunlight to enter the Earth and leads to not only climate change but also skin cancer. As the National Oceanic and Atmospheric Administration (NOAA) claims that "the human impact on climate during this era greatly exceeds that due to known changes in natural processes,"[20] climate change that humans have been experiencing in the post-industrial era (after 1750), is a human-induced phenomenon.

The connection between climate change and human migration was first publicized by the Intergovernmental Panel on Climate Change (IPCC) in 2014. Through the Summary for Policymakers of the Working Group II document on Impacts, Adaptation, and Vulnerability, the IPCC pinpointed that there is a "potential for population migration" due to areas affected by drought and tropical cyclone activities.[21] Climate change leads to human migration because it hinders the development of infrastructure and welfare of the country as examples of climate change, such as deforestation, desertification, and permafrost melts, takes away the natural resources that are crucial in building advanced technologies and infrastructure. In addition,

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[17] Bureau of Public Affairs, "Remarks at the Global Leadership in the Arctic: Cooperation, Innovation, Engagement, and Resilience (GLACIER) Conference Opening Plenary," U.S. Department of State, last modified August 31, 2015, accessed December 3, 2016, http://www.state.gov/secretary/remarks/2015/08/246489.htm.

[18] EPA, "Causes of Climate," Environmental Protection Agency.

[19] James W. Elkins, "Chlorofluorocarbons (CFCs)," *The Chapman and Hall Encyclopedia of Environmental Science*, 1999, accessed December 2, 2016, http://www.esrl.noaa.gov/gmd/hats/publictn/elkins/cfcs.html.

[20] IPCC, "IPCC Fourth Assessment Report: Climate Change 2007," Intergovernmental Panel on Climate Change (IPCC), accessed December 1, 2016, https://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-2-1.html.

[21] *Working Group II: Impacts, Adaptation and Vulnerability*, accessed December 2, 2016, http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=450.

LDCs, which primarily rely their welfare on primary industries like agriculture, mining, and fishing, are located in regions that are most affected by climate change, so residents of those countries are forced to leave their motherland as they face scarcity of resources that have brought them money and life necessities.[22] For instance, the United Nations Environment Programme (UNEP) classified climate change as one of three major causes of displacement in Sudan as lack of resources[23] and essentials from climate change placed the starving and dying Sudanese to fight against one another to acquire the resources for survival. Dr. Ruth Haug from Norweigan University of Life Sciences also added to this idea, claiming that the socioeconomic status was significant for the Sudanese to decide whether they were going to migrate as some were forced to stay due to expensive cost of traveling and the domestic animals that are needed to carry the luggage.[24] Thus, as one observes this devastating trend, it might be more accurate for one to argue that the linkage between violence and climate change cannot be fully made without mentioning migration, rather than forming a direct correlation between migration and climate change.

According to Rafael Reuveny from Indiana University, there are four factors that cause climate migrants to get involved in violence: competition, ethnic tension, and distrust.[25] When migrants settle in a new society, the natives can start violent disputes against the migrants because migrants inevitably use scarce resources that the natives were concerned about. In addition, the existence of new residents can expand the economic and political activities of a community, and this situation can be dangerous for a community as the residents have to risk conflicts against neighboring groups in acquiring resources. Ethnic tension is one of the most probable cases where violence can occur since many ethnic groups have built tension among themselves with their conservative and separatist beliefs. In some cases, violence can spark among the natives and the refugees as the migrants might try to reunify their country with the new country that they settled in. Lastly, distrust from climate migration can initiate conflicts because the migrants' origin country might suspect the receiving country for disrupting the ethnic balance, and the receiving country might also accuse the origin country for trying to penetrate migrants to take away resources and destabilize the economy.[26] As a result, climate change, social disputes, and human migration are linked and have posed threat to global security.

III. Limitations of Current Research

Despite the publications that spread the seriousness of climate migration, more efforts are desperately needed to stop the victimization of innocent people in LDCs who do not have money or resources to protect themselves from climate change. First, the global society should reach to a consensus on coining the term "environmental refugee" because different definitions and data on climate migration have caused confusions from scholars and the public in understanding the intensity of this catastrophe. The term "environmental refugee" was first developed by Lester

[22] Reuveny, "Climate Change-induced," 657.
[23] *Population Displacement and the Environment* (Nairobi, Kenya: United Nations Environment Programme, n.d.), 104, accessed November 12, 2016, http://postconflict.unep.ch/publications/sudan/05_displacement.pdf.
[24] Ruth Haug, "What's in a Name? Environmental Refugees in Northern Sudan," *The Maze of Displacement: Migration, Development and Change*, 2003, PDF.
[25] Reuveny, "Climate Change-induced," 658-659.
[26] Reuveny, "Climate Change-induced," 659.

Brown from the Worldwatch Institute in the 1970s,[27] but many scholars have created their own definition. Furthermore, experts had radically different prediction in announcing the number of climate migrants because there are no legal qualifications that classify an individual as a climate refugee or a migrant. For instance, Greenpeace Germany has suggested that there will be 150 to 200 million environmental refugees by 2035,[28] but scholars like Cairns took one step further, claiming that the entire population on Earth will eventually become environmental refugees.[29] Sadly, the international society has not yet approved the existence of an environmental refugee and has defined "refugee" as "an individual who is outside his or her country of nationality or habitual residence who is unable or unwilling to return due to a well-founded fear of persecution based on his or her race, religion, nationality, political opinion, or membership in a particular social group"[30] through the Article I of the 1951 Convention. Moreover, the public has not even agreed on the lurking variables, such as poverty, political conflicts, or natural resources, that are crucial considering factors when one discusses migration and destruction of nature. Therefore, there should be an official definition dedicated to "environmental refugee" so that the international society can both admit the existence of climate change and legally cooperate with the settlement and protection of the victims who have to flee their motherland.

IV. Case Study – The Syrian Civil War

The Syrian civil war is the best example that displays the linkage among climate change, migration, and violence as a tragic exodus has taken place in the Fertile Crescent where was once the most perfect place for agriculture due to its balance in sunlight and precipitation. Statistically, 10.6 million Syrians have chosen to migrate either within the country or outside the border,[31] and the National Oceanic and Atmospheric Administration (NOAA) pinpointed the Syrian drought as the primary reason that forced Syrians to migrate and start an uprising against the dictator.[32] Syrian drought, which lasted from 2006 to 2011, is often described as the worst long-term drought and most severe set of crop failures since civilizations began in the Fertile Crescent many millennia ago. 75% of the Syrian population had to suffer from crop failures, and 85% of the livestock and the Aleppo peppers,[33] which have been one of the most popular exports,

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[27] Fabrice Renaud et al., *Environmental Degradation and Migration* (Berlin, Germany: Berlin-Institut, 2008), 1, accessed December 3, 2016, http://www.berlin-institut.org/fileadmin/user_upload/handbuch_texte/pdf_Renaud_Environmental.pdf.

[28] Andrew, "Climate Change Refugees," Greenpeace, last modified June 7, 2007, accessed December 2, 2016, http://www.greenpeace.org/international/en/news/Blogs/makingwaves/climate-change-refugees/blog/9692/.

[29] John Cairns, Jr., "Environmental Refugees," *The Social Contract*, Fall 2002, 38, accessed November 25, 2016, http://www.thesocialcontract.com/pdf/thirteen-one/xiii-1-34.pdf.

[30] Paul Weis, ed., *The Refugee Convention, 1951*, 6, 1951, accessed December 1, 2016, http://www.unhcr.org/4ca34be29.pdf.

[31] Corey Charlton, "Europe Should Expect 'Millions and Millions' More Refugees from Syria as War Has Created a 'Living Hell', Warns UN Director as Half the Country Has Been Uprooted," Daily Mail, last modified September 11, 2015, accessed November 28, 2016, http://www.dailymail.co.uk/news/article-3230971/Europe-expect-millions-millions-refugees-Syria-war-turned-country-living-hell-warns-UN.html.

[32] Henry Fountain, "Researchers Link Syrian Conflict to a Drought Made Worse by Climate Change," The New York Times, last modified March 2, 2015, accessed December 2, 2016, http://www.nytimes.com/2015/03/03/science/earth/study-links-syria-conflict-to-drought-caused-by-climate-change.html?_r=0

[33] Francesco Femia and Caitlin Werrell, "Syria: Climate Change, Drought and Social Unrest," The Center for Climate and Security, last modified February 29, 2012, accessed November 13, 2016, https://climateandsecurity.org/2012/02/29/syria-climate-change-drought-and-social-unrest/.

mercilessly dried out. In 2009, nearly 800,000 farmers lost their livelihoods,[34] and over a million classified themselves as food "insecure"[35] because water and food could not be found. The NOAA discovered that climate change caused this drought because the precipitation around Syria and the Mediterranean kept on decreasing despite the rise of global temperature due to the Greenhouse effect.[36]

Moreover, experts predict that Syria will confront an economic regression up to 57% by 2020 based on the current rate of carbon emission, and the economic and political systems will collapse if this prediction is accurate because the violent, endless uprising has not been ending since March 2011. As the Syrians could not harvest any crops from rural areas, farmers abandoned their home and started gathering into urban cities like Damascus and Daraa which were suffering from overpopulation before the drought. Over 200,000 farmers who used earn a living from agriculture decided to move to cities in 2011,[37] and this enormous movement into the cities disrupted stability and created social unrest as people had to fight for limited amount of resources for survival. These conflicts forced Syrians to grow hostility against their regime that did not take any action to handle the situation, and the anti-regime uprising has been continuing since 2011 as more people has settled in major cities in Syria from then. Therefore, the relationship between the Syrian drought and the Syrian civil war best explains the linkage among climate change, violence, and migration as all three variables occurred subsequently over the past decade in Syria and in the Middle East.

V. Policy Recommendation

As incidents from various parts of the world have proven the validity and the existence of climate migration, international society should devise appropriate policies for progressive action in solving this global crisis. First, local governments of communities that are submerging soon should cooperate with nonprofits to teach their citizens skills used in various industries so that the future environmental refugees can be attractive immigrants; the developed countries, such as New Zealand, rejected environmental refugees in the past since the migrants had no skill set and were ineligible to become an active member of society due to illiteracy and lack of education. If countries like the Marshall Islands and Kiribati in the Pacific can train their citizens into cultural ambassadors or lifeguards, these talents will serve as advantages for the climate migrants; more importantly, education of major languages is also significant since communication is the most necessary skill when one participates in social activities.

Second, the most important action that should immediately be taken is spreading the struggle that climate migrants have gone through to let the public pay attention to such innocent victims who have not received any spotlight. Currently, there is a prevalent phobia against

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[34] Robert Siegel, "Syrian Civil War Rooted in Drought Years before Fighting Began," NPR, last modified October 31, 2013, accessed December 3, 2016, http://www.npr.org/templates/story/story.php?storyId=242150651.
[35] FAO, "Support for Agriculture in Syria Critical with Massive Food Insecurity Adding to Suffering," Food and Agriculture Organization of the United Nations, last modified February 4, 2016, accessed December 1, 2016, http://www.fao.org/news/story/en/item/382181/icode/.
[36] NOAA, "New Report Finds Human-caused Climate Change Increased the Severity of Many Extreme Events in 2014," National Oceanic and Atmospheric Administration (NOAA), last modified November 5, 2015, accessed November 29, 2016, http://www.noaanews.noaa.gov/stories2015/110515-new-report-human-caused-climate-change-increased-the-severity-of-many-extreme-events-in-2014.html.
[37] Syrian Refugees, "Timeline," Syrian Refugees, last modified April 2011, accessed December 2, 2016, http://syrianrefugees.eu/timeline/.

immigrants or new migrants because a small group of religious extremists committed horrifying terrorist attacks that killed innocent lives; however, the public should learn the fact that most refugees are desperately seeking for help with sincerity. In fact, developed countries have been self-centered in that they were the loudest ones that emphasized the importance of globalization and unity of all nations, but they have manipulated international law and took separatist actions for their own benefit. As climate change is creating more and worse unexpected natural disasters, now is the time for the countries to act as one family and help underdeveloped countries protect themselves from a formidable crisis. The nonprofits also hold significant roles throughout this process since they could help publicize the movement through social media and offline petitions, and they hold no political belief that can hinder financial aid or action. Furthermore, international conference, such as the COP21 and COP22 (Conference of the Parties) in Paris and Marrakesh, respectively, should address climate migration and its threat to global security more frequently since most of the disputes that covered front page of newspapers have been associated with climate anomalies.

VI. Conclusion

Climate change is real, and the correlation between climate change and migration exists. In fact, this correlation has taken a step further and has caused chaos around the world; this threat should be stopped immediately, and the international community should take cooperative actions to deal with climate anomalies and violent conflicts that originated from climate change. The idea of environmental migration has been mentioned numerous times in academia and has been discussed by multiple conferences worldwide; however, over the past several decades, the international society failed to reach a consensus in coining a legal definition for "environmental refugee," and the most developed nations ironically seemed to be the most hesitant ones when it came to creating a sustainable world. Of course, scholars have discovered the linkage among violence, climate change, and migration but the world has a long way to go in ultimately solving the answer to climate migration.

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Developing a GIS-based Tool for the Management of Fats, Oils, and Grease (FOG): A Case Study of Thames Water Wastewater Catchment

Thomas D. Collin, Rachel Cunningham, Bruce Jefferson, Raffaella Villa

***Abstract*—**Fats, oils and grease (FOG) are by-products of food preparation and cooking processes. FOG enters wastewater systems through a variety of sources such as households, food service establishments and industrial food facilities. Over time, if no source control is in place, FOG builds up on pipe walls, leading to blockages, and potentially to sewer overflows which are a major risk to the Environment and Human Health. UK water utilities spend millions of pounds annually trying to control FOG. Despite UK legislation specifying that discharge of such material is against the law, it is often complicated for water companies to identify and prosecute offenders. Hence, it leads to uncertainties regarding the attitude to take in terms of FOG management. Research is needed to seize the full potential of implementing current practices.

The aim of this research was to undertake a comprehensive study to document the extent of FOG problems in sewer lines and reinforce existing knowledge. Data were collected to develop a model estimating quantities of FOG available for recovery within Thames Water wastewater catchments. Geographical Information System (GIS) software was used in conjunction to integrate data with a geographical component.

FOG was responsible for at least 1/3 of sewer blockages in Thames Water waste area. A waste-based approach was developed through an extensive review to estimate the potential for FOG collection and recovery. Three main sources were identified: residential, commercial and industrial. Commercial properties were identified as one of the major FOG producers. The total potential FOG generated was estimated for the 354 wastewater catchments. Additionally, raw and settled sewage were sampled and analysed for FOG (as hexane extractable material) monthly at 20 sewage treatment works (STW) for three years. A good correlation was found with the sampled FOG and population equivalent (PE). On average, a difference of 43.03% was found between the estimated FOG (waste-based approach) and sampled FOG (raw sewage sampling). It was suggested that the approach undertaken could overestimate the FOG available, the sampling could only capture a fraction of FOG arriving at STW, and/or the difference could account for FOG accumulating in sewer lines. Furthermore, it was estimated that on average FOG could contribute up to 12.99% of the primary sludge removed. The model was further used to investigate the relationship between estimated FOG and number of blockages. The higher the FOG potential, the higher the number of FOG-related blockages is. The GIS-based tool was used to identify critical areas (i.e. high FOG potential and high number of FOG blockages).

As reported in the literature, FOG was one of the main causes of sewer blockages. By identifying critical areas (i.e. high FOG potential and high number of FOG blockages) the model further explored the potential for source-control in terms of "sewer relief" and waste recovery. Hence, it helped targeting where benefits from implementation of management strategies could be the highest. However, FOG is still likely to persist throughout the networks, and further research is needed to assess downstream impacts (i.e. at STW).

***Keywords*—**Fat, FOG, GIS, grease, oil, sewer blockages, sewer networks

T. D. Collin is with Cranfield University and Thames Water Utilities, Reading, RG2 0RP, United Kingdom (phone: +44747 647622; e-mail: t.d.collin@cranfield.ac.uk).

R. Cunningham is with Thames Water Utilities, Wastewater Innovation, Reading, RG2 0RP, United Kingdom (e-mail: rachel.cunningham@thameswater.co.uk).

B. Jefferson is with the Cranfield Water Science Institute (CWSI), Cranfield University, MK43 0AL, United Kingdom (e-mail: b.jefferson@cranfield.ac.uk).

R. Villa is with the Cranfield Water Science Institute (CWSI), Cranfield University, MK43 0AL, United Kingdom (e-mail: r.villa@cranfield.ac.uk).

Transport Infrastructure and Economic Growth in South Africa

Abigail Mosetsanagape Mooketsi, Itumeleng Pleasure Mongale, Joel Hinaunye Eita

Abstract—The aim of this study is to analyse the impact of transport infrastructure on economic growth in South Africa through Engle Granger two step approach using the data from 1970 to 2013. GDP is used as a proxy for economic growth whilst rail transport (rail lines, rail goods transported) and air transport(air passengers carried, air freight) are used as proxies for transport infrastructure. The results showed that there is a positive long-run relationship between transport infrastructure and economic growth. The results show that South Africa's economic growth can be boosted by providing transport infrastructure. The estimated models were simulated and the results that the model is a good fit. The findings of this research will be beneficial to policy makers, academics and it will also enhance the ability of the investors to make informed decisions about investing in South Africa.

Keywords—transport, infrastructure, economic growth, South Africa

Corresponding Author
Abigail Mooketsi from North West University, South Africa
e-mail: 22580093@nwu.ac.za

A Preliminary Study on the Embodied Carbon Emission Considering Variable Factors in Building Construction

Chulu Nam, Dongyoun Lee, Goune Kang, Hunhee Cho, Kyung-In Kang

***Abstract*—**While the world appreciates the importance of sustainable environment and severity of climate change in particular, responsibility to reduce carbon emissions of building sectors has been emphasized due to the large amount of carbon from buildings occupies approximately from 30 to 40 percentage of total emissions. In order to reduce the carbon from buildings effectively, precise estimation of carbon and determining practical target value in life cycle of buildings are priority issues to providing reduction plan. Carbon emissions resulting from buildings consists of two components: operational carbon (OC) and embodied carbon (EC). Recent studies have shown the growing significance of EC because much effort has already been invested into reducing OC. So far EC have been estimated using emission factors of buildings materials or energy sources with activity data from case buildings. Amongst EC from several emission sources, carbon from construction activities is especially difficult to capture due to unexpected variable factors in construction site. In accordance with influence of these variability and uncertainty to construction cost or duration, which have been already shown in existing research, it is likely affect EC from construction work. The aim of this study is to display difference between the EC amounts when considering the variable factors in construction site or not. Building construction process is modeled with certain activity and variable factors, and EC estimation is simulated using System Dynamics.

***Keywords*—**building construction, embodied carbon, system dynamics, variable factors

F. Chulu Nam is with the School of Civil, Environmental and Architectural Engineering , Korea University, Seoul, 02841 Republic of Korea (phone: +82-2-921-5920; fax: +82-2-923-4229; e-mail: glock9@korea.ac.kr).

S. Dongyoun Lee is with the School of Civil, Environmental and Architectural Engineering , Korea University, Seoul, 02841 Republic of Korea (phone: +82-2-921-5920; fax: +82-2-923-4229; e-mail: dy_lee@korea.ac.kr).

T. Goune Kang is with the School of Civil, Environmental and Architectural Engineering , Korea University, Seoul, 02841 Republic of Korea (phone: +82-2-921-5920; fax: +82-2-923-4229; e-mail: gkang17@korea.ac.kr).

F. Hunhee Cho is with the School of Civil, Environmental and Architectural Engineering , Korea University, Seoul, 02841 Republic of Korea (phone: +82-2-3290-3328; fax: +82-2-923-4229; e-mail: hhcho@korea.ac.kr).

F. Kyung-In Kang is with the School of Civil, Environmental and Architectural Engineering , Korea University, Seoul, 02841 Republic of Korea (phone: +82-2-3290-4956; fax: +82-2-923-4229; e-mail: kikang@korea.ac.kr).

Development of Energy Benchmarks Using Mandatory Energy and Emissions Reporting Data: Ontario Post-Secondary Residences

C. Xavier Mendieta, J. J McArthur

***Abstract*—**Governments are playing an increasingly active role in reducing carbon emissions, and a key strategy has been the introduction of mandatory energy disclosure policies. These policies have resulted in a significant amount of publicly available data, providing researchers with a unique opportunity to develop location-specific energy and carbon emission benchmarks from this data set, which can then be used to develop building archetypes and used to inform urban energy models. This study presents the development of such a benchmark using the public reporting data. The data from Ontario's Ministry of Energy for Post-Secondary Educational Institutions are being used to develop a series of building archetype dynamic building loads and energy benchmarks to fill a gap in the currently available building database. This paper presents the development of a benchmark for college and university residences within ASHRAE climate zone 6 areas in Ontario using the mandatory disclosure energy and greenhouse gas emissions data. The methodology presented includes data cleaning, statistical analysis, and benchmark development, and lessons learned from this investigation are presented and discussed to inform the development of future energy benchmarks from this larger data set. The key findings from this initial benchmarking study are: (1) the importance of careful data screening and outlier identification to develop a valid dataset; (2) the key features used to develop a model of the data are building age, size, and occupancy schedules and these can be used to estimate energy consumption; and (3) policy changes affecting the primary energy generation significantly affected greenhouse gas emissions, and consideration of these factors was critical to evaluate the validity of the reported data.

***Keywords*—**Building archetypes, data analysis, energy benchmarks, GHG emissions.

I. Introduction

FROM 1990 to 2013, global energy consumption increased by 55% and is predicted to be on the rise in following decades [1]. Governmental actions and policies play a key component in decreasing the degree of acceleration of the globes energy consumption, which is why several countries started to implement mandatory Energy Reporting and Benchmarking (ERB). Energy reporting involves the continuous process of reviewing the energy consumption of a building, while energy benchmarking is used as to compare a building's energy performance with that of other buildings with similar characteristics [2]. The intention of ERB is to provide knowledge and to encourage building owners and managers in order to improve the energy efficiency of their buildings. Research has demonstrated the positive environmental and economic impacts benchmarking can produce for building stakeholders [3], [4] yet the benefits of benchmarking data can extend far beyond this to identify areas of unexploited energy efficiency, define policies more aligned with local needs, quantify environmental impacts from conservation methods [5], and in some cases to develop Urban Building Energy Models that best represent a desired sample area.

UBEMs are gaining popularity due to their ability to simulate energy reduction interventions at larger scales [6]. To create an UBEM it is necessary to define details about the building stock, including, construction assemblies, geometry, and HVAC efficiencies. The collection of this data for large urban areas can be difficult due to the diversity of buildings therefore UBEMs rely on building archetypes to easily represent a building stock. A building archetype is a model of the average building in a given sample. These models are typically defined by climate, period of construction, geometry and use of space. To ensure that the archetype model performs similar to a certain building type it is important to identify benchmark energy use intensity (EUI) that best represents the operation of the building and the climate its within.

Since 2000, the Office of Energy Efficiency in Canada has published several energy benchmark surveys. The Consumption of Energy Survey (CES) was the first survey that covered all provinces and was based on 2003 data. The CES focused only on Canada's universities, colleges, and hospitals. In following years, CES expanded to cover nearly all segments in the Commercial and Institutional sector. Recently, post-secondary buildings have been included in the "other" category, which makes it challenging to determine accurate benchmarks for these buildings.

In 2013, the Ministry of Energy implemented annual mandatory energy reporting for the Broader Public Sector (BPS) to help organizations better understand how energy is being used. This paper presents the results of statistical analysis of this data. The objective of the research is to develop local EUI benchmarks for institutional residence buildings that fall in ASHRAE's climate zone 6 of Ontario. The results will be used for future work to develop archetypes models for post-secondary buildings in Ontario.

C. X. Mendieta is with the Department of Architectural Science at Ryerson University, Toronto, ON, M5B 2K3, Canada.

J. J. McArthur is with the Department of Architectural Science at Ryerson University, Toronto, ON, M5B 2K3, Canada (phone: 416-979-5000x4082, fax: 406-979-5353; e-mail: jjmcarthur@ryerson.ca,).

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II. METHODOLOGY

A. Data Collection

The report used for this paper includes information gathered on 21,369 buildings in the province of Ontario's Broader Public Sector. Organizations required to report consist of municipalities, municipal service boards, school boards, universities, colleges, and hospitals. Each organization is broken into operation types as they normally contain buildings that serve different purposes. For this paper, only post-secondary institution residences are analyzed due to the lack of existing benchmark information for this building type.

94 such buildings have been included in Ontario's latest BPS energy report. Only institutions that are part of ASHRAE's climate zone 6 (Fig. 1) were considered, as the results from this analysis will be used to develop residence archetype models that are representative of this region. While climate zone 6 extends beyond Ontario, data were only available for buildings within the region shown in Fig. 1.

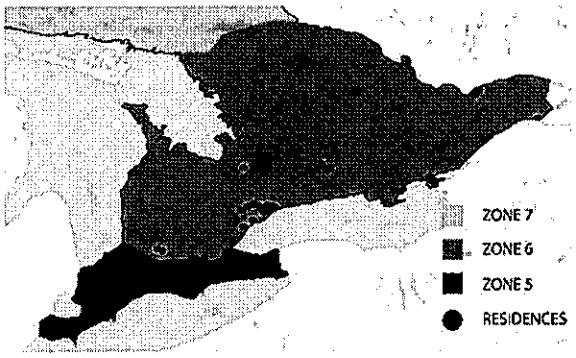

Fig. 1 Post-secondary residence buildings in Ontario's climate zone 6

The BPS energy reports used for this research contain detailed building information such as occupancy schedules, conditioned areas, GHG emissions and normalized EUI's for 2011, 2012 and 2013. Additional building characteristics were added to develop more significant correlations. Building shape was obtained using satellite imagery and geometry calculating tools, while construction periods were determined by means of experience and/or scientific literature.

B. Data Cleaning

Incorrect or inaccurate information complicates data analysis and if left unattended can lead to false conclusions. Since corrupt data is found in all data sources, unless proven otherwise, it is important to carefully review and remove and/or correct any suspicious entries. Before any detailed analysis was performed the data was checked analytically and visually to remove that which had obviously been corrupted. For example, if the EUI of a building varied by less than 50% or more than 200% of the previous and/or following years, the value was deemed erroneous and removed from the analysis dataset.

Box plots were used to identify outliers, as illustrated in Fig. 2. Before outliers were deleted, these plots were created using multiple variables and normalization factors (e.g. calculating emissions on an area basis) to ensure that data consistent with overall trends was not inadvertently deleted from the dataset. Once this verification was complete, these buildings with extremely high or poor performance were removed from the dataset to avoid biasing the benchmark.

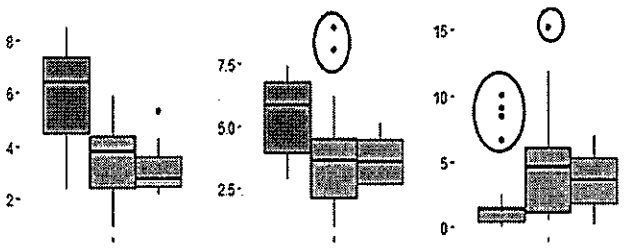

Fig. 2 Identification of outliers using boxplots

Through the climate segmentation and data cleaning process, the data from 38 buildings were determined to be unusable, resulting in a benchmarking sample size of 56 buildings, later broken down by construction period, occupancy schedules, and building geometry as illustrated in Tables I and II, respectively.

TABLE I
VARIABLES AND BUILDINGS INCLUDED IN BENCHMARKING ANALYSIS

Feature	Variables	Total Buildings
Construction Period	Pre-1980	23
	1980-2004	33
Building Geometry	Area	56
	Compactness	52
Weekly Occupancy Schedules	84 hours	4
	128 hours	4
	168 hours	48

TABLE II
AREAS CATEGORIZED BY SIZE RANGE

Category	Area (sf)	Pre 1980	1980-2004
A	Up to 50,000	4	8
B	50,001 – 100,000	10	8
C	100,001-150,000	6	12
D	150,001-200,000	3	3
E	200,001 +	-	3

C. Benchmark Development

In order to develop the benchmark, a forward multi-variable analysis was undertaken to determine which features (building attributes) significantly influenced the building energy consumption and greenhouse gas emissions. As noted in previous studies [7], these typically include climate, period of construction, and building size.

For each feature, the data was sorted using that feature as the differentiator using R – a python-based statistical analysis program with data shaping and regression capability. Box plots were used as a preliminary screening method to identify which features showed significant variation between categories. Once this was completed, the median, lower quartile (Q1), and higher quartile (Q3) values were recorded and have been included in the benchmark to provide end-users

with an indication of how their building compares to the wider population.

III. Results

The results from the analysis are presented in the following subsections.

A. Variation with Period of Construction

In order to have some granularity in the benchmark analysis the period of construction was broken down into two classes. These classes were selected due to the availability of data - majority of construction dates fall into the selected range - and to follow existing methods used by Natural Resources Canada (NRCan) in the development of the Canadian Urban Archetypes library.

The median, lower quartile, higher quartile and Interquartile range values obtained by using period of construction as a variable can be seen in Table III. The analysis shows that buildings that pertain to the Post-1980 category consume almost a third less energy than those built before 1980. These results could be linked to technological improvements in HVAC systems, appliances or operational efficiency measures, however the introduction and constant evolution of building energy codes, as they enforce construction practices that promote energy efficiency in cost effective ways, are likely to be an influential factor in the observed reductions.

TABLE III
EUIs by Period of Construction

Period of Construction	Q1	Median	Q3	IQR	Units
Pre-1980	7.14	9.79	10.79	3.65	eWh/HDD/sf
1980-2004	4.71	6.13	7.72	3.01	eWh/HDD/sf

B. Variation with Building Geometry

The geometry of a building can have significant role on its energy performance.

Conditioned areas, building shape and exposed surfaces all influence the energy demand of a building. As only conditioned areas are part of Ontario's BPS energy reports additional geometric information had to be obtained. Using *Daft Logic* - an advanced distance and area calculator - areas, perimeters, and heights of all buildings were determined. Measured areas were then compared to the BPS reported areas, and if there were a difference greater than 20% the compactness of that building was not considered in the analysis.

A multi-variable regression analysis was performed to evaluate the relationship between energy consumption and building geometry. Building EUI was first plotted against building area and a weak correlation was indicated between decreasing EUI and increasing area. To obtain a stronger correlation, the period of construction and area ranges (summarized in Table II) were used as block variables and EUI was plotted against area, however correlations were still weak, as noted in the first column of R^2 values in Tables IV and V. In both tables, *n* is the number of buildings in the sample while the trend direction is indicated by + (EUI increases with increasing geometry variable) or – (EUI decreases with increasing geometry variable).

TABLE IV
R2 Values for EUI Pre-1980 Buildings

Description	n	EUI vs A; Area only		EUI vs A; Area and shape		EUI vs C; Area and shape	
		R^2	Trend	R^2	Trend	R^2	Trend
A, TH	3	.23	+	.19	+	I	-
B, C-shape	4	.36	-	.009	-	.1	+
B, Tower	4			.29	-	.12	+
C, Tower	5	.16	-	.73	-	.73	+
D,	3	.34	+	-	+	-	

TABLE V
R2 Values for 1980-2004 Buildings

Description	n	EUI vs A; Area only		EUI vs A; Area and shape		EUI vs C; Area and shape	
		R^2	Trend	R^2	Trend	R^2	Trend
A, Cross	6	-		.35	-	-	-
B, L-shape	3	.06	-	.91	-	.93	-
C, C-shape	4	.04	-	.72	-	.24	-
C, Z-shape	4	4		.02	-	.25	-
D,	3	.07	+	-		-	
E,	3	.50	-	-		-	

To develop more meaningful correlations, buildings were next grouped by shape. Eight different building shapes (Fig. 3) were defined based on the assessment of the existing sample. One shape group is omitted from this figure and includes all townhouse style residences less than three stories tall.

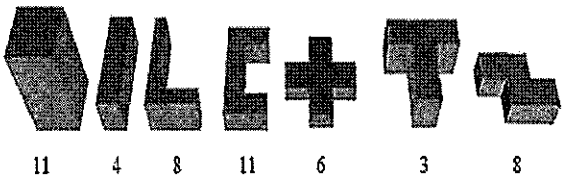

Fig. 3 From left to right: Tower, Beam, L-shape, C-shape, Cross, T-shape, and Z-shape buildings.

When grouped by both area and shape, strong trends began to emerge in the linear regression. Buildings were categorized by either area, or by a combination of area and building shape categories. EUI was then plotted area (A) and the strength of the correlation obtained by linear regression is summarized in the second set of R^2 values in Tables IV and V. These correlations are significantly stronger across both periods of construction. The trends in the data differ, however, suggesting that there may be further confounding factors that need to be incorporated in the model.

The ratio between floor area and enclosure area is often used to determine the compactness (C) of a building form [8]. The area of the enclosure is relevant as surfaces exposed to the environment offer paths for heat transfer to occur; hence a decrease in EUI as building compactness increases is expected. When EUI was plotted against compactness, the R^2 values decreased, implying that for this building type, area has a stronger impact in a building's EUI. Theoretically, two

buildings with identical areas, operation schedules and occupant behavior, and building systems, but having different compactness values would see a significant impact of compactness on EUI, with the more compact building using less energy due to reduced envelope losses and gains. In this real case, however, it is challenging to identify the influence compactness has on its energy consumption given the multitude of unknown variables. To further investigate the impact of compactness, buildings were grouped by shape and both shape and area, (Tables IV and V, 3rd column of R^2 values) and one significant correlation was noted. It is noteworthy that to undertake this latter analysis, the data sets for each group became extremely small, thus limiting this investigation.

When one considers the significant variation in building occupant behavior – an aspect clearly visible in this study where a set of six identical buildings constructed at the same campus at the same time vary by up to 133% in energy consumption – it is not surprising that very strong correlations are not observed. The EPA's Portfolio Manager and Energy Star rating system database have R^2 values higher of only 0.33 [9] and four trends were noted that exceeded this value. Each of these trends noted a decrease in EUI with increasing area and with more compact buildings – findings consistent with building science principles. Should the quality of the reported data improve, a much larger data set will be available to develop better benchmarks and thus better inputs to UBEMs.

C. Variation with Weekly Occupied Hours

The majority (86%) of reporting buildings had scheduled occupancy of 168 hrs/week while the remainder were occupied 84 hrs/week (7%) or 128 hrs/week (7%). Analysis of this data showed a significant increase in energy use with occupancy hours, however there were too few data points for the less-occupied buildings, which prevented more specific analysis from being developed at this time.

IV. Discussion

The energy benchmarking study presented herein identifies key issues with the use of mandatory building energy reporting as a data source for benchmarking. First, the variable data quality resulted in a significantly diminished data set. To an extent, this can be addressed through data cleaning and outlier identification as presented herein. This could be dramatically improved by implementing data verification and periodical energy audits.

The impact of building area, shape, and occupancy hours on energy consumption were investigated in order to provide more detailed benchmark values, however the small data set size limited the conclusions drawn and a larger sample is required to identify statistically significant differences using these categories. The period of construction, however, showed significantly different results. This level of granularity is consistent with the CES published data, thus the study has achieved its first goal of obtaining a benchmark for this building type to fill the existing gap.

It was extremely difficult to identify trends in GHG emissions because of the lack of reporting of primary energy sources, compounded by energy policy changes that influenced such sources [10]. At the macro level, the electrical grid changed substantially from 2011 to 2013 as coal-fired power plants were systematically decommissioned and replaced with wind and solar production, with gas-fired power plants to meet peak loads, however some institutions used cogen plants and did not see the effect of the changing grid. In addition, the institutions were not required to provide the detailed methodology used for GHG emission calculations and thus – particularly given the inconsistency of noted trends – the overall quality of this data set is suspect. Because of this complexity, greenhouse gas emissions have been omitted from this energy benchmarking study.

The results of this study have provided quartile benchmarks for post-secondary residence buildings by period of construction determined using publically available data. As more data is reported - particularly with improved quality control - there is significant potential to use this data to develop archetypal energy models for institutional residence buildings.

Acknowledgment

The authors thank Phylroy Lopez from NRCanada for his insight on current approaches to energy archetype development currently underway.

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Evaluation of Serum Serotonin As A Good Indicator to The Unbalanced of Cellular Oxidants / Antioxidants at Obese Patients Treated by Variant Surgical and Non Surgical Strategies for Loss Weight

***Rasha Hasan Jasim and Ahssan Ali Lefta**

e-mail: dr.rashahussainee@yahoo.com

*Department of Chemistry-Factually of Education for Girls-University of Kufa-Iraq

Abstract

*Biochemically, serotonin or 5- is a vasoconstrictor molecule derived form mono amino acid "Tryptophan", synthesized in the intestine enterochromaffin cells, in addition to central and peripheral neuron cells. Serotonin is a neurotransmitter, it contributes to the feelings well-being and happiness. Firstly it found in the gastrointestinal tract (GIT), especially intestinal mucosa, and platelets, while high concentration of serotonin were recorded in the central nervous system (CNS) and pineal body for animals as well as the human.Serotonin has been associated to a group of different behaviors, such as feeding, social behavioral, aggression, suicide concern, moreover; serotonin had been associated to the motor system functions, sleep-awaken cycle and respiratory stability; finally it found in the body weight organization system. Every day, life requires levels of high of physical activity and food, the tendency genetic prefer to store excess calories in order to help body for staying at the level of alive, so an overweight is mean increase the body weight compared with the level of weight acceptable to the normal. Its belief that obesity is a result for losing of ability to correct habits of eating. Obesity is not a single disease, there are 300 different genes were linked to obesity, in addition to several environmental factors could be associate to obesity happening, while most considerations common indicted to the fact that obesity process is a result of an interaction of environmental factors with the genetic predisposition lead to fat accumulation and increased in the adipose tissues. Under normal conditions ROS and RNS are produced. This production balanced by number of acceptor electron molecules that synthesized cellular. An injured tissues caused by disorders in the balance between the production of reactive species of known as free radicals and antioxidants which is the defensive mechanism, through this status the raise in the oxidation processes will occur in contrast to the reduction in the synthesis of defense molecules.**Subjects:**47patients and 24 healthy individuals were enrolled in the present study. Patients with BMI more than 30 Kg/m^2 haven't diabetes mellitus, they aren't subjected to obesity surgical operation before. Control group might at approximate age range with the patients group, with similar food style. Average BMI of no smoking, no alcohol drinking healthy group was 18.5 Kg/m^2.**Results:** A significant decrease ($p = 0.000$) of serum serotonin levels was noted in obese patients group when compared with those of control individuals group.In contrast to basic comparison between the major study groups, no significant differences in the serotonin levels were observed when males and females subgroups were compared together.Negatively significant correlation ($r = - 0.850$ at $p < 0.05$) was observed for serotonin concentrations in the sera of obese patients group with the BMI levels, as recorded, while no such correlation was observed when serum serotonin levels were correlated to the levels of BMI in the control group.Evaluation of the MDA concentrations revealed a significant increase ($p < 0.05$) in patients of obesity when compared with healthy individuals. From the statistical analysis of the obese patients group, a positive correlation between the serum MDA concentration with BMI raise ($r = 86.925$ % at $p < 0.001$). while highly significant differences ($p < 0.05$) were noticed at the two study's groups were compared together, when both of ceruloplasmin oxidase activity and concentration were examined.It has been monitoring the positive relations between BMI levels and both of the activity and concentration of ceruloplasmin oxidase enzyme in the sera samples of obese patients group, where the activity and concentration of ceruloplasmin oxidase rose in 76.112 % and 68.869 % (at $p < 0.05$) of the total cases of patients.The Person's correlation demonstrated significant positive relationship in those of obese patients ($r = 0.828$ at $p < 0.005$), but not in those of controls group.**Conclusion:**Serotonin andMDA levels are affected during the overweight gain; and they correlated directly to BMI.Ceruloplasmin acts as acute phase protein in response to weight gain, in addition to its an antioxidant role to accommodate the overflow of electrons (free radicals) formed during the process of obesity.*

Key Words: ***Obese, Serotonin, Oxidative Stress, MDA, Ceruloplasmin, Surgical Operation, Bypass, Sleeve and Balloon***

Introduction

Biochemically, **serotonin** or 5-Hydroxytryptamine (5-HT) is a vasoconstrictor molecule derived form mono amino acid "**Tryptophan**", synthesized in the intestine enterochromaffin cells, in addition to central and peripheral neuron cells[1,2]. Serotonin is a neurotransmitter; it contributes to the feelings of well-being and happiness. Firstly, it is found in the gastrointestinal tract (GIT), especially intestinal mucosa, and platelets, while high concentration of serotonin is recorded in the central nervous system (CNS) and pineal body for animals as well as the human[1]. Serotonin has been associated with a group of different behaviors, such as feeding, social behavioral, aggression, suicide concern; moreover, serotonin has been associated with the motor system functions, sleep-awaken cycle and respiratory stability. Finally, it is found in the body weight organization system[3].

Obesity is a disorder in the regulation of body weight, diagnosed by gathering the increase of the body fat. Every day, life requires levels of high physical activity and food, the genetic tendency prefers to store excess calories in order to help body for staying at the level of alive[4]. As such, an overweight means increasing the body weight compared with the level of weight accepted to the normal[5].It is believed that obesity is a result for losing of ability to correct habits of eating[6], and it is not a single disease, there are 300 different genes thatare linked to obesity, in addition to several environmental factors that could be associated with obesity cases[7]. Most considerations are commonly indicted to the fact that obesity process is a result of an interaction of environmental factors with the genetic predisposition that lead to fat accumulation and increase in the adipose tissues[8].

Under normal conditions, reactive oxygen and nitrogen species (ROS and RNS) are produced. This production is balanced by number of acceptor electron molecules that synthesized cellular. An injured tissues are caused by disorders in the balance between the production of reactive species of known as free radicals and antioxidants which is the defensive mechanism. Through this status raise in the oxidation processes will occur in contrast to the reduction in the synthesis of defense molecules[9]. The outcome of this status lead to oxidative stress, and then cellular oxidative damage[10].

Most of oxygen is derived from the free radical related biological cell and is not stable, short-lived and with high degree of the effectiveness. The harmful roles of free radicals in many physiological and pathophysiological phenomena are linked to redox status

cell modification[11]. The external sources of free radicals production include*uv* radiation, ozone, pollution, alcohol intake, cigarettes smoking, excess iron, pesticides, mycotoxins and some medicines[12]. ROS could enhance cellular damage by modifying fats, proteins and DNA characteristics. ROS can influence the health cell and vitality or induce a variety of cellular responses where leading, at last, to cell death by necrosis or apoptosis. Oxidative damage of any biomolecules, if unchecked; probably is responsible of the development to the disease[13]. ROS may be responsible for many pathological cases that include neurodegenerative disease like Alzheimer's and Parkinson's disease, atherosclerosis, inflammatory conditions, certain cancers, diabetes mellitus, pulmonary renal and heart diseases and process of aging[14].

Malondialdehyde (MDA) is a high effective molecule, three carbon dialdehyde produced as a result of peroxidation of polyunsaturated fatty acid, as well as during the arachidonic acid metabolism for the synthesis of prostaglandins. MDA could illustrate its baleful action in the cell through bind to the functional groups in the proteins, lipoproteins, RNA and DNA molecules[15,16].

Ceruloplasmin (Cp) is plentiful blue α_2-glycoprotein that contains more than 95% of copper found in the plasma of all types of vertebrates[17,18], it is synthesized mainly in the liver as single chain of polypeptide of 1046 amino acids, and is excreted in the plasma with six or seven atoms of copper binding in the one molecule[19]. Cp is a molecule association between iron and copper metabolism, also known as serum multicopper protein and exhibition ferroxidase activity, superoxidase activity and amino oxidase activity[18,19]. However, the physiological role of Cp is not known but it may include activity of the extracellular antioxidant by encouraging iron mobilization and then to prevent metal catalysts free radicals tissue damage[20]. Recent studies confirm the absorb food copper which is the transfer by plasma protein carriers like transcuprein, albumin and Cp from the intestine to kidney and liver. The decrease in the concentration of serum Cp is considered as diagnosis indicator of Wilson's disease, while the increase of it concentrations has been reported in patients with macular degenerations and in a variety of tumors and inflammatory conditions such as cancer, leukemia, Hodgkin's lymphoma, primary biliary cirrhosis, systemic lupus erythematous and rheumatoid arthritis[18,21].

Subjects and Methods

Forty seven patients and 24 healthy individuals were enrolled in the present study.Patients with BMI more than 30 Kg/m^2 haven't diabetes mellitus, they aren't subjected to obesity surgical operation before. In order to treat an excess of their body weight or health problems, the present study patients were underwent to the neumours treatment kinds (surgically or non surgical operations). The patients' group is classified into 3 subgroups **according to the type of treatment; firstly 3** patients were treated with bypass surgery, **the second subgroup**that included **22** patients, is underwent to sleeve surgery, while **the last subgroup**that included **22** patients is treated by balloon strategic opinion.Selection of healthy individuals as a control group is based upon several criteria included: an absence of major medical or surgical illness in the previous 5 years, no hospital admissions, no current medication, and a subjective perception of good health as determined by health questionnaire. More than, control group might at approximate age range with the patients group, with similar food style. Average BMI of no smoking, no alcohol drinking healthy group was 18.5 Kg/m^2. Information of study groups data was summarized in the **Table 1.**

Table 1: Age and BMI Details In The Patients and Controls Groups

Groups	*Age (year)*			*BMI (Kg/m^2)*		
(n)	*Mean ± S.D.*	*Min. – Max.*	*Range*	*Mean ± S.D.*	*Min. – Max.*	*Range*
Patients 47	*33.28 ±7.424*	*14 – 48*	*34*	*45.179 ± 9.09*	*30 – 68.7*	*38.7*
Healthy 24	*25.96 ± 3.983*	*22 – 35*	*13*	*22.829 ± 0.752*	*21.5 – 24.4*	*2.9*

Bypass surgical operation patients group included 3 female only, while sleeve surgical operation patients group were included 15 females and 7 males, finally the group of patients who treated with balloon strategic consisted of 14 females and 8 males. Five ml of venous blood samples were collected from the study groups' individuals after fasting period more than eight hours.Sera of patient samples were collected from many private hospitals in the Najaf City, Iraq. Selection of the study cases was based on the clinical diagnosis and the opinion of specialist doctors who identified the best type of treatment for the study cases. The levels of serum Serotonin was determined by Competitive-ELISA method, levels of serum MDA was measured by the TBARS assay[22], while the activity of ceruloplasmin oxidase was determined in the study sera samples using the modified Rice method[23].The statistical analysis was done using the Statistical Package for the Social Science (SPSS) software for windows, Version 19.0. Results were expressed as mean ± standard deviation (**Mean ± S.D.**), maximum, minimum and range. The two study groups data were analyzed with **Student's independent *t*-test.** One way analysis of variance (**ANOVA**) was used to compare parameters in different studied subgroups. **Pearson's correlation** was applied to determined the relations among the laboratory parameters of the present study, significance was determined regression. *p-values* less than 5% ($p < 0.05$) were considered as statistically significant.

Results and Discussion

Serotonin is organized by two independent systems, the first in the central nervous system and the other in the periphery, the blood-brain barrier hinders the passage of peripheral serotonin into central nervous system. Only 2% of the body's serotonin is central nervous system stored. Neural serotonin is supposed to modulate numerous sensory, motor and behavioral processes; moreover, it is involved in the control of feeding behavior and obesity, Previously, it has reported that neural serotonin has a suppressive effect on food intake and tends to decrease body weight gain[24]. On the other hand, peripheral serotonin has not been the subject of such intense object, particularly with respect to body fat and lipid metabolism, even though approximately 98% of the body's serotonin exists in the periphery.

Levels of serum serotonin concentration were measured in the two study groups; obese patients as well as healthy individuals. **Table 2** shows a significant decrease (**$p = 0.000$**) of serum serotonin levels in obese patients group when compared with those of control individuals group.

Table 2: Levels of Serotonin Concentration (ng / ml) In Sera of Obese Patients and Controls Subjects (Mean ± S.D.)

Subjects (n)	Serotonin Concentration (ng / ml) Mean ± S.D.	Min.-Max.	Range	p
Obese 47	0.615 ± 0.196	0.333 - 1.387	1.054	0.000
Control 24	0.876 ± 0.171	0.581 - 1.224	0.643	

This result agreed with numerous researches focused on evaluation of serotonin and / or its mediators levels in the samples of obese subjects comparison to normal weight individuals[25,26].Decreasing of serotonin levels in serum of obese humans may be explain through a several assumptions, and they are probable combined together in serotonin decreasing : **supplementation and conversion of tryptophan[27], reduced of the serotonin transporter (SERT)[25,28],inflammatory, adipokines, cytokines, and hormones network[19,29].**

In contrast to basic comparison between the major study groups, no significant differences in the serotonin levels were observed when males and females subgroups were compared together. **Table 3** recorded similar results when the two healthy subgroups (males and females) were compared.The present study results agreed with several studies[26,30,31].

Table 3: Comparison of Serotonin Levels in Male and Female of Patients and Controls Individuals

Subjects (n)	Gender (n)	Serotonin Concentration (ng / ml) Mean± S.D.	Min.-Max.	Range	p
Obese 47	Female 31	0.597 ±0.174	0.333-1.218	0.885	0.317 For 1vs2
	Male 16	0.650 ± 0.234	0.381-1.387	1.006	0.159 For 3vs4
Control 24	Female 8	0.952 ± 0.199	0.693-1.224	0.531	0.000 For 1vs3
	Male 16	0.837 ± 0.146	0.581-1.104	0.523	0.007 For 2vs4

1: Female Patients, 2:Male Patients, 3: Healthy Females, and 4:Healthy Males. The Mean Difference is Significant at 0.05 Level

In the purpose of study the effect of the BMI in changes of serum serotonin concentrations, linear regression analysis (Pearson's correlation) was used to analyze the results. **Negatively** significantcorrelation **($r = -0.850$ at $p < 0.05$)** was observed for serotonin concentrations in the sera of obese patients group with the BMI levels, as recorded in **Figure 1(A)**, while no such correlation was observed when serum serotonin levels were correlated to the levels of BMI in the control group (**Figure 1(B)**). These findings agreed with many studies[24,31,32], on the side, the results of current study appear contradictory to findings of Wurtmanstudy[33].

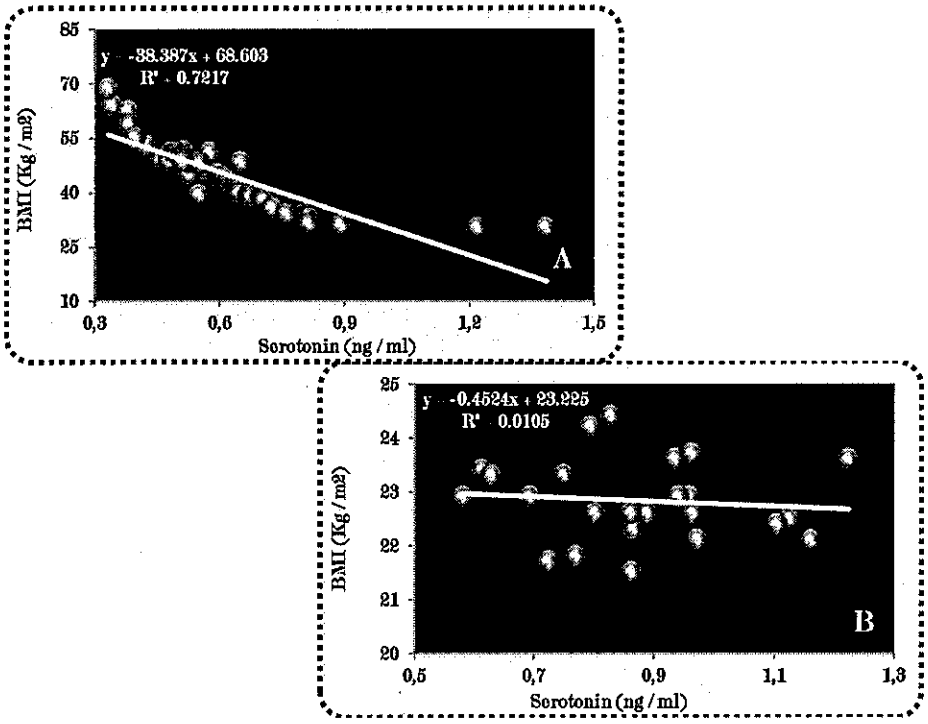

Fig. 1:Correlation of BMIand Serum Serotonin Concentrations in (A):Obese Individuals and (B): Controls

According to the type of medical treatment to reduce the weight, obese patients were classified into **three subgroups**, including: treatment throughgastric **bypass** and **sleeve operations (they were done surgically or laparoscopy)**, and finally treatment by **balloon (this strategy was done by laparoscopy).**

Novelty of the current work backs to the detailed comparison of the serotonin levels and corresponding BMI at different subgroups in the various techniques used to reduce weight.

Figure 3-2 (A)demonstrates the distribution of sera serotonin levels in the female study cases (female patients with numerous strategies to reduce of weight in addition to healthy females). Generally, serum serotonin of healthy females is found to be higher than their corresponding females in the patients subgroup ($p < 0.005$), when; except five female patients (3 of them bowed to sleeve treatment "with BMI ranged between **31.4-39 Kg/m²**" and 2 of them bowed to balloon treatment "with **30 Kg/m²** BMI"), the 5 females were younger than other patients. The lowest serotonin concentration in sera of healthy females was noted in the **29** years old and **23.6 Kg/m²** BMI. In the present work, serotonin levels in the male patient cases were variant to those of healthy individuals **but** with less significant ($p < 0.05$) than these results which recorded in the females subgroup. **Figure 2 (B)**illustrates the relative closeness in the serotonin levels in the different male obese patients and healthy individuals, especially, male patients who underwent to sleeve of stomach strategy. High BMI male patients who suffered from Cardio Vascular Diseases (CVD) complications and bowed to balloon strategy in order to reduce them over weight; they illustrate the lowest serotonin levels. Isolated case was monitored in the youngest male patient (25 years old), with **33Kg/m²**as BMI, he illustrate high serotonin level, as shown in the **Figure 2 (B)**.

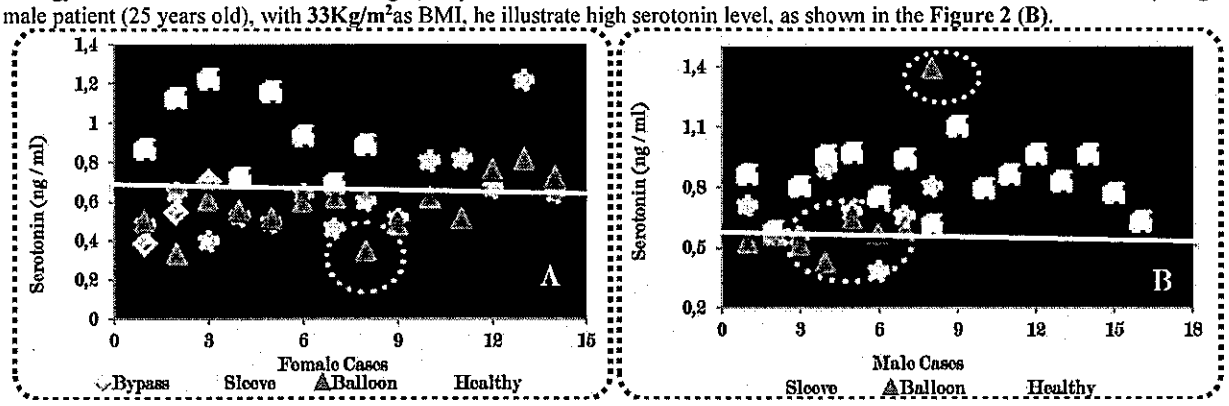

Fig. 2:Gender Differences of Serum Serotonin Levels in obese Patients According to the Type of Treatment Strategies.

While, MDA presented as a decent marker in assessment of oxidative stress occurs during many pathological and non pathological conditions[34][35-38].***Student's t-test*** was applied to test the results of serum malondialdehyde (MDA) levels' changes between obese patients and control groups. Evaluation of the MDA concentrations revealed a significant increase ($p < 0.05$) in patients of obesity when compared with healthy individuals,as shown in **Table 4.**

Table 4 :Levels of MDA Concentration In Sera of Obese Patients and Controls Subjects (Mean ± S.D.)

Subjects (n)	MDA Concentration (mM) Mean ± S.D.	Min.-Max.	Range	p
Obese 47	0.388 ± 0.090	0.166 - 0.514	0.348	0.000
Control 24	0.090 ± 0.058	0.016 - 0.252	0.236	

These results agreed with the several studies which were evaluated MDA levels in different diseases[34,39], on the other hand the current work results were disagreed with other clinical studies[36].Gender was found to have no effect on serum MDA concentrations in patients and control groups, when **ANOVAtest** failed to exhibit significant changes among male and female within same subgroups (**Table 5**). Nemours studies agreed with the finding of the present work in the fact of gender type had no effect in the levels of MDA, neither in patients nor in healthy subjects[40].

Table 5: Comparison of MDA Levels in Male and Female of Patients and Controls Individuals

Obese 47	Female 31	0.384 ± 0.088	0.166 - 0.514	0.348	0.418 For 1vs2
	Male 16	0.362 ± 0.084	0.217 - 0.491	0.274	0.497 For 3vs4
Control 24	Female 8	0.074 ± 0.029	0.048 - 0.143	0.095	0.000 For 1vs3
	Male 16	0.097 ± 0.068	0.016 - 0.252	0.236	0.000 For 2vs4

1: Female Patients, 2:Male Patients, 3: Healthy Females, and 4:Healthy Males. The Mean Difference is Significant at 0.05 Level

In order to verify the changes of the MDA concentrations with the BMI levels, linear regression analysis was applied to study the relationship of serum MDA to BMI in both of patients and control groups.From the statistical analysis of the obese patients group, a positive correlation between the serum MDA concentration with BMI raise ($r = 86.925$ % at $p < 0.001$) was observed (**Figure 3(A)**).No

such results were noted when the serum MDA concentration of the control group were correlated to their BMI levels, as shown in **Figure 3 (B).**

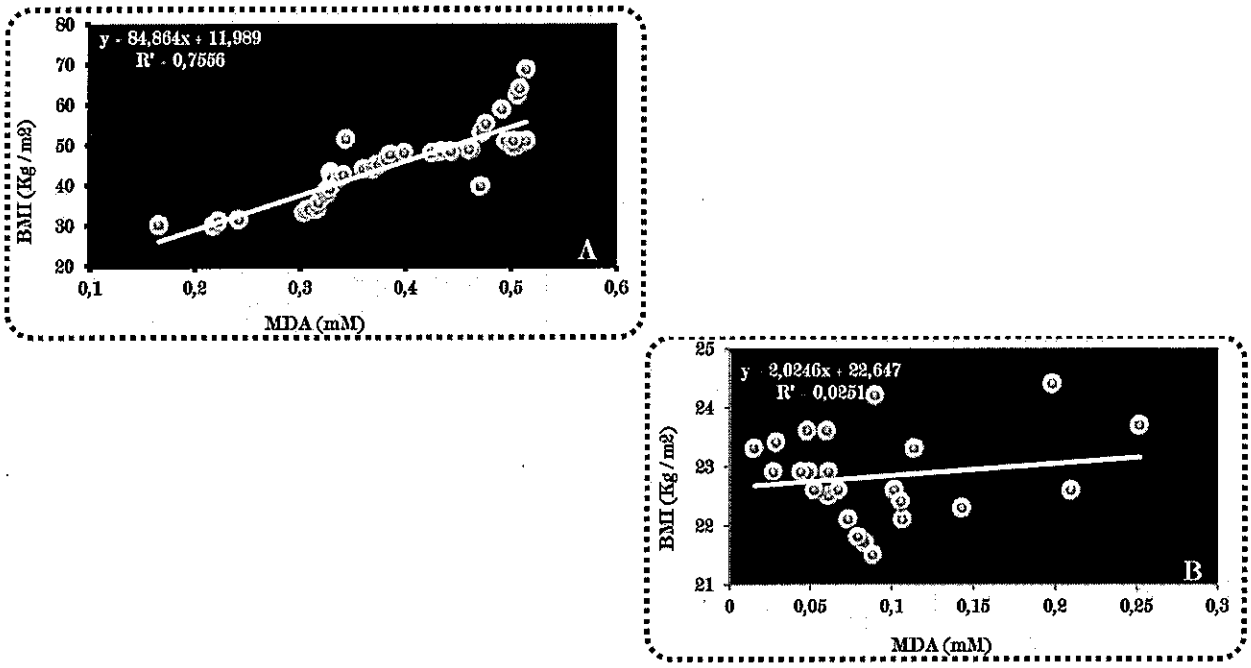

Fig. 3:Correlation of BMI and Serum MDA in (A):Obese Individuals and (B): Normal Controls

This result coincided with Pihl[41] and Codoner-Franch[42] studies, which recorded a positive correlation of excess in the BMI to the elevation in the levels of MDA.

Because of the lack of researches addressing the fact MDA levels and linked to the weight applicants patients for a weight-loss operations, the current study represents the first step in the tracking the cellular stress concurrent with different BMI levels to provide a full concept of what happens in the body of person applying for a weight-loss operations, and what will happen then.

Regardless of the type of techniques followed to treat the increase in the BMI, all the female patient cases illustrated high levels of MDA at compared to healthy females ($p < 0.005$), as observed in **Table 3** and **Figure 4 (A)**. Two young male patients only were illustrated levels of MDA adjacent to cutoff MDA value, this note enhanced the previous observation about the elevations in the sera MDA of obese patients comparison to healthy persons.

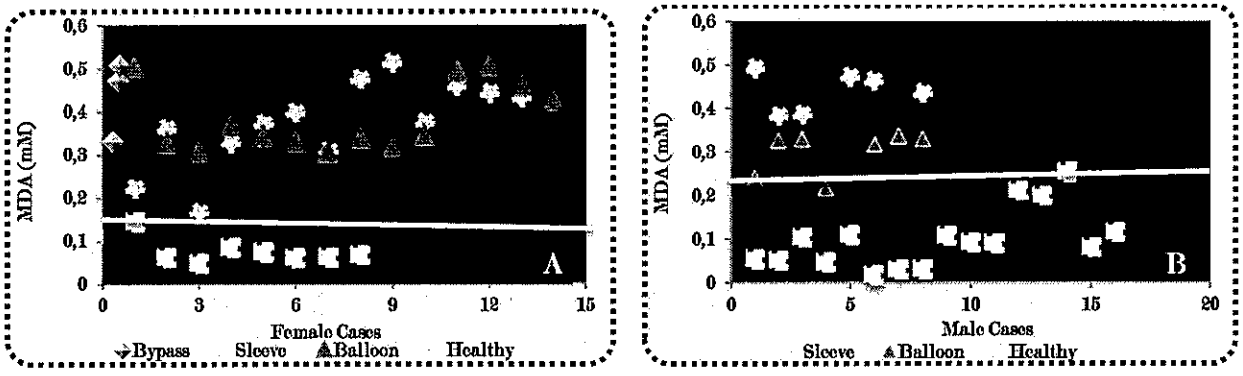

Fig. 4:Gender Differences of Serum Malondialdehyde Levels in obese Patients According to the Type of Treatment Strategies.

Ceruloplasmin as one of the most important blood proteins was evaluated in many researches according to its functionally diverse. These functions ranged from its role in the blood coagulation, ceruloplasmin binding copper transporting as well iron homeostasis[43], furthermore its involved in protection of angiogenesis from tissue injury[43]. One of the acute phase proteins and antioxidant were the major published roles ceruloplasmin [34,44].

According to ***Student's t-test analysis,*** highly significant differences ($p < 0.05$) were noticed at the two study's groups were compared together, when both of ceruloplasmin oxidase activity and concentration were examined, as shown in **Tables 6** and **7**; respectively. This result agreed with the study of Giner[45]; on the other hand, it violated the results of Bharatkumar and Nobilistudies[46,47].

Table 6 : Levels of Ceruloplasmin activity In Sera of Obese Patients and Controls Subjects (Mean ± S.D.)

Subjects (n)	Ceruloplasmin Activity (U/L) Mean ± S.D.	Min.-Max.	Range	p
Obese 47	65.085 ± 27.476	25.479 - 130.890	105.411	0.000
Control 24	40.110 ± 19.581	12.565 - 92.844	80.279	

Table 7 :Levels of Ceruloplasmin Concentration In Sera of Obese Patients and Controls Subjects (Mean ± S.D.)

Subjects (n)	Ceruloplasmin Concentration (g / L) Mean ± S.D.	Min.-Max.	Range	p
Obese 47	13.258 ± 6.107	5.162 - 28.175	23.013	0.000
Control 24	7.594 ± 4.422	1.750 - 19.512	17.762	

The rise of the ceruloplasmin levels in sera of obese patients samples could explain according to the fact, obesity is considered a disease of chronic low-grade inflammation[48], and an inflammation status enhances the acute phase proteins synthesis in the liver. Moreover, ceruloplasmin catalyzed the oxidation of Fe^{2+} to Fe^{3+}; this catalytic effect involving 4 of the 6 copper atoms associated with ceruloplasmin that employ 2 oxygen atoms as the terminal electron acceptor without the intermediacy of a partially reduced oxygen species, normally, this oxidase activity behavior increases during cellular injury, infection, and inflammation[44]. Thus, in the current study ceruloplasmin may act as acute phase protein in response to weight gain, in addition to its an antioxidant role to accommodate the overflow of electrons (free radicals) formed during the process of obesity.

It has been monitored that the positive relations between **BMI** levels and both of the **activity** and **concentration of ceruloplasmin oxidase enzyme** in the sera samples of obese patients group, where the activity and concentration of ceruloplasmin oxidase rose in **76.112%** and **68.869 %** (at $p < 0.05$) of the total cases of patients, as shown in **Figures 5 (A)** and **6 (A)**; respectively.

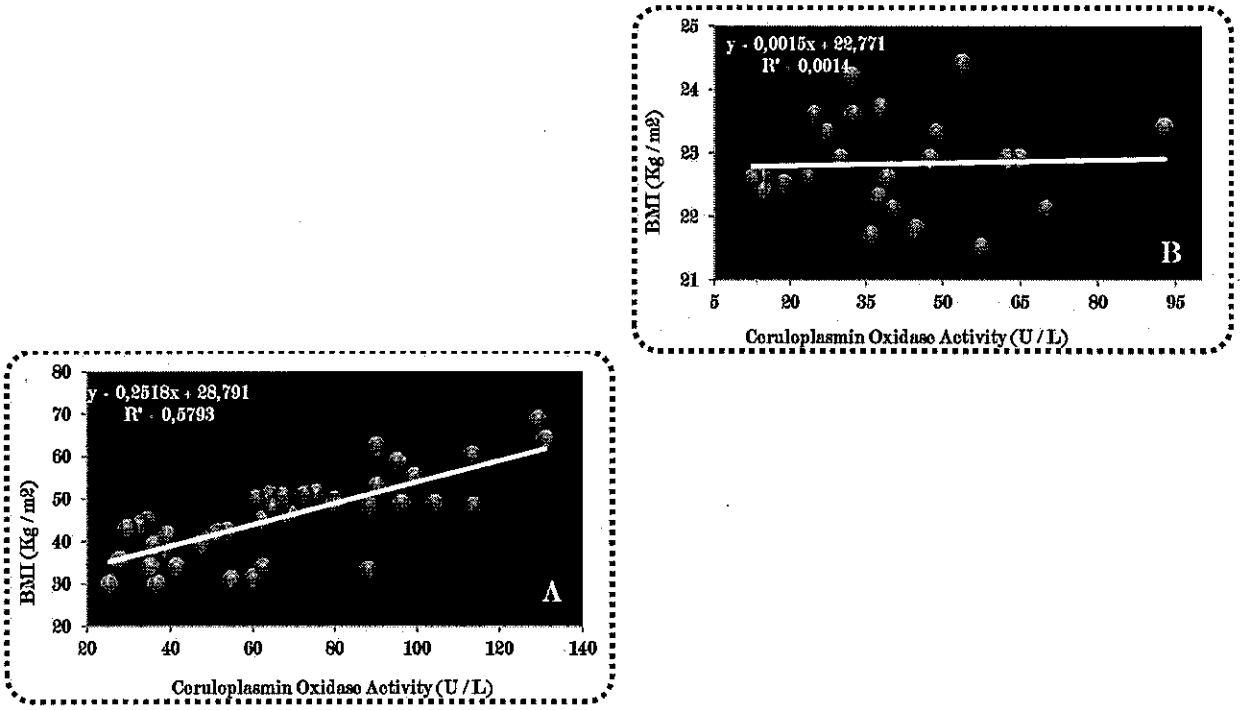

Fig. 5:Correlation of BMI and Serum Ceruloplasmin Oxidase Activity in (A):Obese Individuals and (B): Normal Controls

Serum ceruloplasmin oxidase activity and concentration of the healthy individuals group did not show such correlations with the levels of BMI (**Figures 5 (B)** and **6 (B)**; respectively).

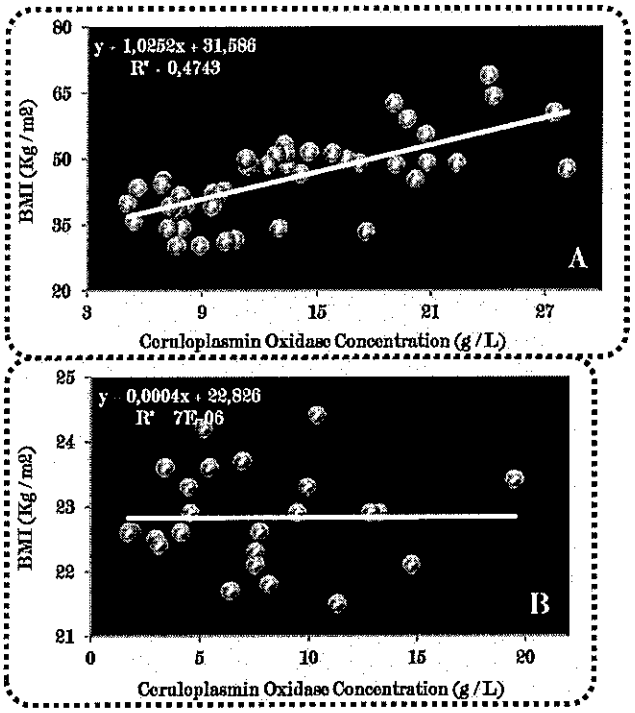

Fig. 6:Correlation of BMIand Serum Ceruloplasmin Oxidase Concentration in (A):Obese Individuals and (B): Normal Controls

This result agreed with the studies of Tajik[49] and Marazziti[50]. Gender was observed to have no effect on serum ceruloplasmin oxidase activity in patients and control groups (**Table8**).

Table 8: Comparison of Ceruloplasmin Oxidase activity in Male and Female of Patients and Controls Individuals

Subjects (n)	Gender (n)	Cp activity (U/L) Mean ± S.D.	Min.-Max.	Range	p
Obese 47	Female 31	68.513 ± 29.248	32.809 - 130.890	98.081	0.191 For 1vs2
	Male 16	58.442 ± 23.085	25.479 - 96.335	70.856	0.134 For 3vs4
Control 24	Female 8	29.275 ±9.110	14.659 - 40.139	25.480	0.000 For 1vs3
	Male 16	45.527 ± 21.337	12.565 - 92.844	80.279	0.047 For 2vs4

1: Female Patients, 2:Male Patients, 3: Healthy Females, and 4:Healthy Males. The Mean Difference is Significant at 0.05 Level

As shown in **Table 9,** the statistical evaluation failed to exhibit significant variation for serum ceruloplasmin oxidase concentration when female patients of obesity were compared with those of male patients, as well as; female and male of healthy individuals group.

Table 9: Comparison of Cp Levels in Male and Female of Patients and Controls Individuals

Subjects (n)	Gender (n)	Cp Concentration (g / L) Mean ± S.D.	Min.-Max.	Range	p
Obese 47	Female 31	14.222 ± 6.509	6.912 - 28.175	21.263	0.095 For 1vs2
	Male 16	11.391 ± 4.897	5.162 - 20.212	15.050	0.100 For 3vs4
Control 24	Female 8	4.965 ± 2.109	1.925 - 7.525	5.600	0.000 For 1vs3
	Male 16	8.908 ± 4.730	1.750 - 19.512	17.762	0.307 For 2vs4

1: Female Patients, 2:Male Patients, 3: Healthy Females, and 4:Healthy Males. The Mean Difference is Significant at 0.05 Level

This result agreed with the study of Viorica[51].For the purpose of monitoring the effectiveness of the gender of the patients and its relationship to the type of technologies used in the treatment of the increase in the BMI, levels of serum ceruloplasmin oxidase activity

and ceruloplasmin oxidase concentration were distributed in each of the two female and male subgroups according to the therapeutic taken in weight loss.

Figures 7 (A) shows the levels of serum ceruloplasmin oxidase activity in the female patients subgroup were higher than cutoff value in regardless type of technique that is followed to reduce weight, **except**; three women **(with the lost BMI among the female patients subgroup)** underwent to stomach sleeve strategy to lose weight, in addition to the youngest female who treated by balloon technique to reduce BMI.

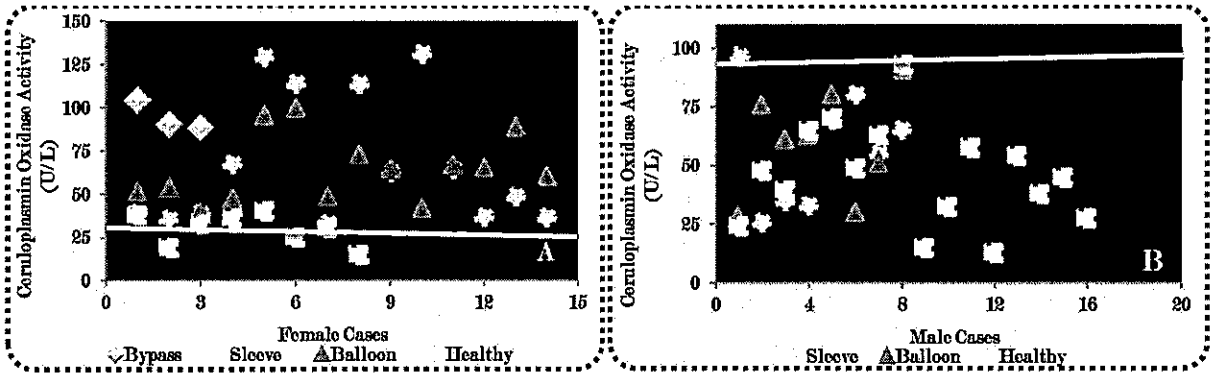

Fig. 7:Gender Differences of Serum Ceruloplasmin Oxidase Activity Levels in obese Patients According to the Type of Treatment Strategies

Figures 8 (A) illustrate the levels of serum ceruloplasmin oxidase concentrations of the obese women were higher those in the healthy female cases. In contract to female subgroup, male patients group failed to exhibit a significant differences between patients and healthy males in the levels of serum ceruloplasmin oxidase activity, where ceruloplasmin oxidase activity results of obese male were interfered with the results of healthy men subgroup **(Figures 7 (B))**.With the same opinions, the levels of serum ceruloplasmin oxidase concentrations of the obese men were asymptotical to the levels of the same parameter in serum of control men subgroup, as demonstrated in **Figures 8 (B)**.The current work findings came compatible with the scientific facts that indicated estrogens mainly responsible for the increased level of serum ceruloplasmin, when they act as an inducer for synthesis of ceruloplasmin RNA templates causing subsequent increase in synthesis of the protein; while progesterone causes a less drastic rise[52].

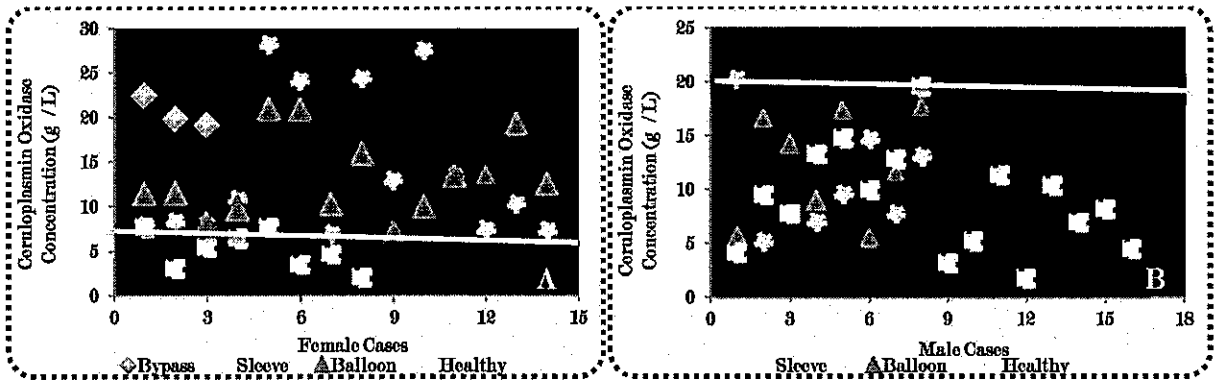

Fig. 8:Gender Differences of Serum Ceruloplasmin Oxidase Concentration Levels in obese Patients According to the Type of Treatment Strategies

Yet, no study has been published on the relationship of ceruloplasmin oxidase with BMI of the two gender patients undergoing techniques for losing of the excess weight, except the present work.

In the present work, **Serotonin** levels were correlated to the levels of **MDA** (as a long stay stable product and easily evaluate able parameter to lipid peroxidation)for the purpose of monitoring cellular changes concurrent with the rise in the BMI and evaluate the oxidative injury caused by the obesity. In several studies evaluated levels of serotonin and malondialdehyde together as marker in progression of numerals dysfunction[53] or as indicators response after treatment by herbs[54], and the current results agreed with the outcomes of these researches.

As shown in **Figure9 (A)**, negative significant correlations were observed when serotonin concentrations **($r = -0.857$ at $p < 0.005$)** was correlated to MDA levels **in sera specimens of patients.**In the controls group, the linear regression analysis failed to find significant statistical correlations for the serotonin levels at linked to the MDA levels, as illustrated in **Figure9 (B)**.

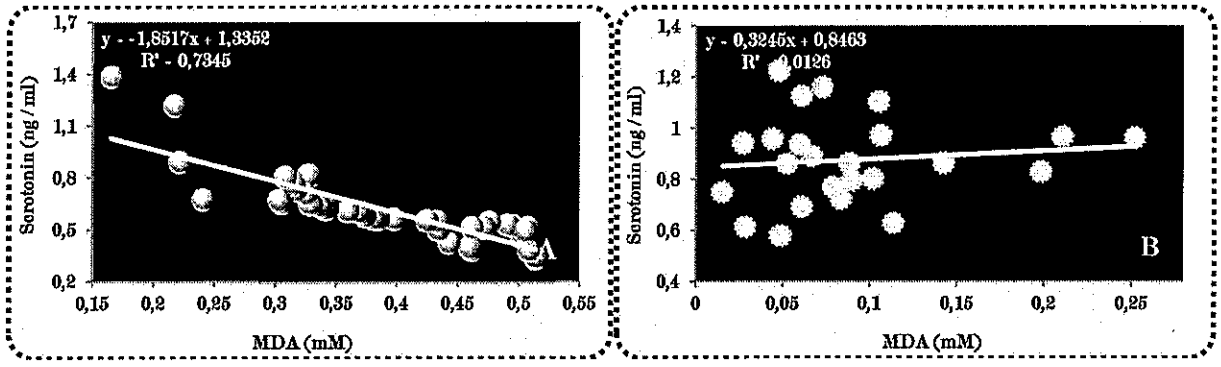

Fig. 9:Correlation Of Serotonin to MDA Concentrations in Sera Samples of (A):Obese Individuals and (B): Normal Controls

In the pharmacological study it is evaluated that the effect of **dexfenfluramine** as one of the anorectic drugs that suppresses food intake on the serotonin levels, when it acts via inhibition of reuptake of serotonin into brain terminal. Results of this study revealed: a notable decrease in the mice body weights and ileal contractile response of acetylcholine increased significantly by dexfenfluramine treatment, meanwhile, ileum glutathione levels decreased and malondialdehyde levels increased in dexfenfluramine treated group, finally; Immunohistochemical detection showed that ideal serotonin levels are increased by dexfenfluramine treatments[55]. At the institute of sleeping disorders in Taiwan has assessed the levels of serotonin and malondialdehyde before and after subjecting a group of depressed patients with insomnia to programmatically far-infrared (FIR) rays. This experiment revealed the increased of serotonin in contrast to the decreased in malondialdehyde levels after the introduction of FIR. These observations indicate that the serotonin pathway is involved in the pathophysiological mechanism responsible for the damaging effects of malondialdehyde[56].These researches absolutely agreed with the present study results and, additionally, they emphasized the authenticity of the primary assumption for the explanation of the results of present study which are illustrated **sections respectively**.

Based on the changes in the levels of serotonin, assess the correlation between the levels of hormone and cellular defenses, using levels of Ceruloplasmin Oxidase, has become an important. Negatively significant correlations were recorded at the relationships were evaluated for serotonin to ceruloplasmin oxidase activity (**r = - 0.720 at p < 0.005**) and ceruloplasmin oxidase concentrations (**r = 0.648 at p < 0.005**) in the obese patients group ((**Figures 10 (A)and 11 (A)**), respectively.

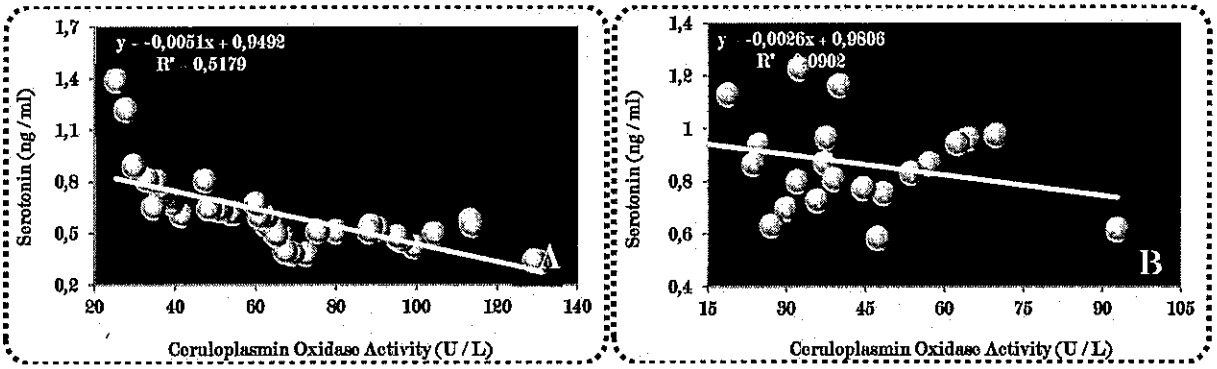

Fig. 10: Correlation of Serotonin Concentrations to Ceruloplasmin Oxidase Activity in Sera Samples of (A):Obese Individuals and (B): Normal Controls

Since the sixties of the past century for today, many researchers studied the relationship of serotonin to ceruloplasmin (or their intermediates and their action products) in numerous non morbidity to pathogenical conditions. During pregnancy, Sean and his colleagues observed the increase of serum serotonin, urinary output of 5-hydroxyindoles (metabolite of serotonin) and ceruloplasmin. They were attributed the increase of ceruloplasmin in sera of pregnant women to the interaction between serotonin metabolism and biochemistry of ceruloplasmin[57].Pathologically, Voiculescu tem found an gradual increases in the values of ceruloplasmin and 5-hydroxyindoleacetic acid in multiple sclerosis patients with the number of repeat strokes and the time elapsed since onset, while serotonin revealed adverse results to those in other evaluated parameters[58].The recent study results agreed fully with Voiculescu findings.

Contrary to the current study, Bassiouni and Rafei study referred to the lower values for both plasma copper and ceruloplasmin and higher values for plasma 5-hydroxytryptamine as more effective cause in the spontaneous abortion occurrence rather than common other causes[59].

The correlations of serotonin levels to the activity and concentration of ceruloplasmin oxidase were not statistically clear when the comparison was carried out at the group of the control persons, as illustrated in **Figures 10 (B)and 11 (B).**

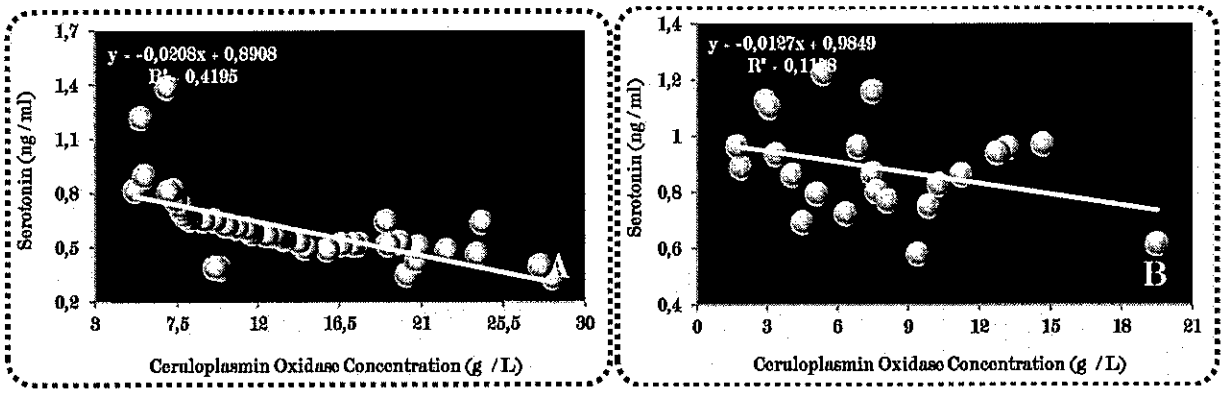

Fig. 11:Correlation of Serotonin Concentrations to Ceruloplasmin Oxidase Concentration in Sera Samples of (A):Obese Individuals and (B): Normal Controls

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Identification of Environmental Damage Due to Mining Area Bangka Islands in Indonesia

Aroma Elmina Martha

Abstract—Environment affects the continuity of life and human well-being and the bodies of other living. Environmental quality is very closely related to the quality of life. Sustainability must be protected from damage due to the use of natural resources, such as tin mining in Bangka island. This research is a descriptive study, which identifies the environmental damage caused by mining land and sea in Bangka district. The approach used is juridical, social and economic. The study uses primary legal materials, secondary, and tertiary, equipped with field research. The analysis technique used is qualitative analysis. The impacts of mining on land among other physical and chemical damage, erosion and widening the depth of the river, a pool of micro-climate, the quality and feasibility, vegetation, wildlife and biodiversity, land values, social and economic. This mining causes damage to the soil structure, and puddles in the former digs which were not backfilled again. The impact of mining on the ocean such as changes in current surge, erosion and abrasion basic coastal waters, shoreline change, marine water quality changes, and changes in marine communities. The findings of the research show that tin mining in the sea also potentially have a significant impact on the life of the reef, populations of marine organisms. However, mining on land needs to consider the impact of the damage, so that the damage can be minimized. In the recovery process needs to be pursued by exploiting the rest of the pile of tin. Thus, mining activities should take into account the distance of beach sediment size, wave height, wave length, wave period, and the acceleration of gravity. The process of the tin washing should be done in a fairly safe area, thus avoiding damage to the coral reefs that will eventually reduce the population of marine life.

Keywords—abration, environmental damage, mining, shoreline

Corresponding Author
Aroma Elmina Martha from Islamic University of Indonesia, Indonesia
e-mail: aroma@uii.ac.id

Multidimensional Approach to Analyse the Environmental Impacts of Mobility

András Győrfi, András Torma, Adrienn Buruzs

***Abstract*—**Mobility has been evolved to a most determining fields of science. The continuously developing segment involves a variety of affected issues such as public and economic sectors. Beside the changes in mobility the state of environment had a significant change in the last period. Alternative mobility as a separate category and the idea of its widespread appliance is such a new field that need to be studied deeper. The research field of alternative mobility implies finding new types of propulsion, using innovative kinds of power and energy resources, revolutionizing the approach to vehicular control. Including new resources and excluding others has such a complex effect which cannot be unequivocally confirmed by today's scientific achievements. Changes in specific parameters will most likely reduce the environmental impacts, however, the production of new substances or even their subtraction of the system will cause probably energy deficit as well. The aim of this novel research is to elaborate the environmental impact matrix of alternative mobility and cognize the factors that are yet unknown, analyze them, look for alternative solutions and conclude all the above in a coherent system. In order to this, the authors of this paper analyze it with a quite novel method called 'the system of systems (SoS) method' to model the effects and the dynamics of the system. A part of the research process is to examine its impacts on the environment, and to decide whether the newly developed versions of alternative mobility are affecting the environmental state. As a final result, a complex approach will be used which is a novel one compering to current scientific studies.
By using the system of systems approach we create a framework of reference containing elements in which we examine the interactions as well. The assessment basis, which can be chosen flexibly and modularly, makes determining the priority of effects possible, also, the deeper analysis in the future on a multidimensional map.

***Keywords*—**environment, alternative mobility, complex model, element analysis

I. Scientific Background

BEFORE the multidimensional assessment method was born, the authors had made extensive literature research in the topic of the environmental effects of alternative mobility. Until now, the main directions of research can be divided into two groups. In the first group there are investigations which are connected mainly with examination of environmental load of vehicles in testing phase so the conclusions could be made only in general or only in a partly complex way. [1] In the second version, the research is very detailed however, a strong emphasis is put on only one or another aspect, for instance the lifetime of batteries or the analysissdsdc of economic indicators. [2], [3] Full studies on alternative mobility's impact on environment are not commonly publicated. The purpose of our research is to fill in the gap in this field, so explore evident connections between environmental and economic models, furthermore using these to create an innovative and universal model. The complex multidimensional inspection method is a novel approachsince it connects several working areas which work as individually as well as related to each other. The aim of the targeted system development is the establishment of an appropriate base model, and for this, the inspected model's development. [4] Every single development or method connected to mobility changes the previously developed solutions' effect on environment basically. Before making decisions about developments it is essential to analyse the predicted consequences on the environment-political and financial situation. In order to realize in the planning phase whether the given alternative has any effects on the environment, it is necessary to model the caused loads. The correct environmental analysis is only possible by assessment of the whole life-cycle.

II. Aims and Methodology

The main aim of there search started at present is on to create a comprehensive, complex and multidimensional assessment method. With the help of this the environmental effects of the developments under planning in connection with the new types of mobility can be accurately measured. The first step of our research was setting up the framework of the model of which we provide further information in this article. This system model defines which future dimensions and what causal circumstances can be investigated during the analysis. To fill up the system mentioned above with comprehensive data the data collection of the full life cycle of developed/planned new solutions is needed and according to this collection the full inspection of the effects. In the later phases of the research our goal is to adopt and run the model in simulation furthermore to refine the parameters used in the model until they add up in relevant and usable result. Accordingly to this, on the top of the priority list there is the establishment of a fully detailed model. The second most important task is to create a so called map, where the elements and their casual effects can be simulated. On the third place the self-supervision of the system can be found, additionally a live test. The fourth deduces straight recommendations and conclusions about the effects on the sustainability of alternative mobility.
In order to develop a base model we used the system of systems approach, so our aim was to dissect the important factors and

András Győrfi, András Torma, and Adrienn Buruzs are with the Dept. of Environmental Engineering, Széchenyi István University, Győr, Hungary (e-mail: gyorfia@sze.hu, torma@sze.hu, buruzs@sze.hu).

establish a detailed system-. For that topic we gathered a professional group consisting of engineers, researchers, sociologists and economic analytics. While choosing the members of the group we tried to avoid being one-sided, or even overvaluing an aspect. The development of the proposals went down with the help of well-constructed workshops.

III. The System of Systems Approach

In order to create the proper model first we have to investigate which theory exists already that could be used for our research purposes. Considering the possibilities discovered by previous studies we selected the SoS (system of systems) adaptation model [5].

With this approach we aimed to make a coordinate system and a model-topology in which we can examine the interactions. The basis of the analysis can be changed easily and modularly, thus making it able to prioritize data and running more complex tests on a multidimensional map.

By constructing the model, the most important thing is the communication between the elements and the real-time self-supervising process, so by involving some new features or economic indicators an immediate reaction is received, which can also be portrayed with the needed loads and calculations. In most systems the connection depends on the border and the value of the limits but using this linear system would be a mistake and would only amplify the subjective judgement, so we aimed a much more sensitive thematic method.

IV. Fuzzy Cognitive Map Method to Picture the Logical Connections

From the size and complexity of linear correlations we cannot longer insist on speaking "ordinary" languages. Adopting and applying Fuzzy Cognitive Map (FCM) theory, which is a suitable method to analyse the interactions in complex systems, the loads and factors that work between the models can be easily simulated. To create a proper environmental analysis which consists all possible conditions of the environmental elements a comprehensive analysis is needed. This cannot be described by one or even more value, because some elements can increase or, in the other case, decrease, even cancel out each other's value. By following the Fuzzy logic researchers can better understand and then map a perfect system. FCM is a directed, signed fuzzy graph structure [6], and is a unique combination of fuzzy logic and neural networks, which is able to model the causal interactions of the system elements and to simulate the general system dynamics.

Using the SoS approach the topology of the complex multidimensional analyzing method can be established; with its own traits, also, causal consequences between individual elements come to surface making it possible to depict them. The FCM, as a simulation method allows to model and weigh these causal relations, and to define the equilibrium state of the complex system which describes reality the most accurately. This information can be used for analyzing the environmental characterization of the alternative mobility solutions and concrete pre-decision proposals can be conducted.

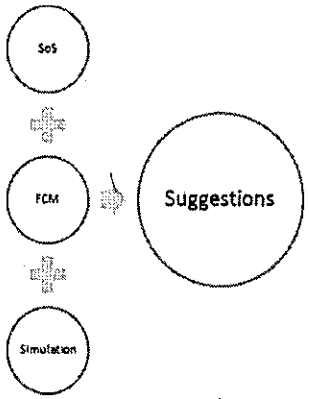

Fig.1 The general model of the research

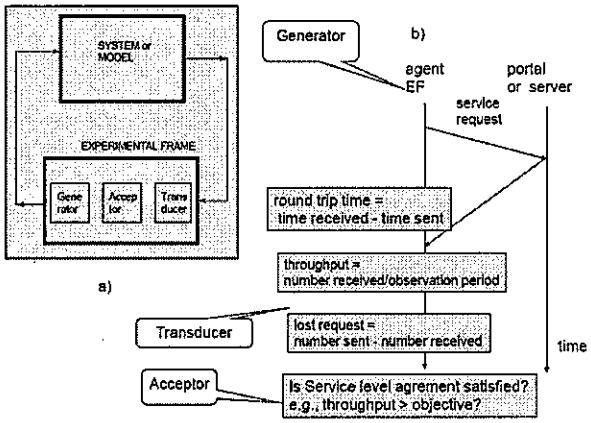

Fig. 2 Experimental Frame and Components [5]

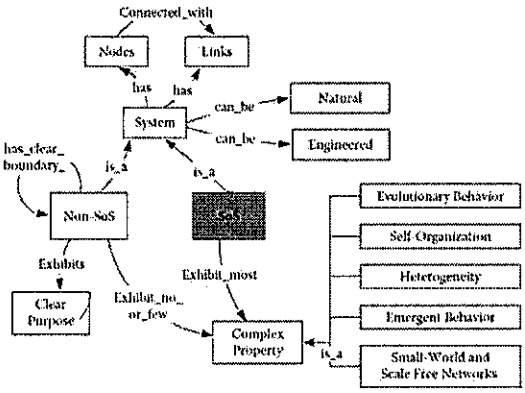

Fig. 3 Concept model of SoS [6]

V. The Structure of the Developed System

For the basis of the system we choosed the so called 'core' element, which, with the attempt of being exhaustive, try to cover all factors that are presently known or are predictably upcoming. The complex multidimensional analysing model (CMAM system) has seven 'core' element: sustainability,

infrastructure, roles, technology, energy, costs and environmental impacts. To determine the elements, we apply the previously mentioned workshop methodology, where every segment of the topic were covered by professionals. We tried to identify only those fields which, either directly or indirectly, has an effect on environmental features. The logical system created that way contains all technological, economical and sociological aspects. These draw up one of the most important questions: is alternative mobility working on a long run?

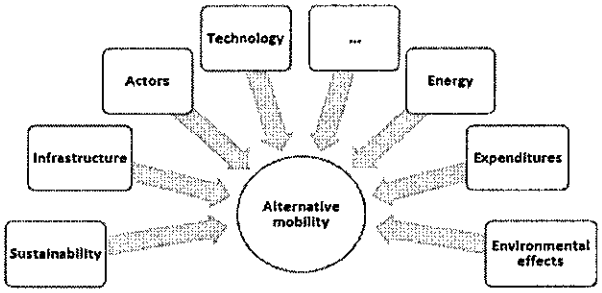

Fig. 4 The core elements of the system

The micro- and macro **actors** in alternative mobility are equally significant and play necessary roles in the market. Between the two macro-elements there are citizens representing the micro level. Inside of them a question is forming: do they want to take advantage of any of the new services? Their decision fundamentally determines the spread of innovative solution and the resulting environmental changes. The government of a country provides the bases of the marketand coordinates it. What it means is that they have control on the products and services of industry, and can also create competition among them. Industry's creating-role is not directly proportional to the appearance of new technologies since openness towards unacquainted newly developed and immature system is, in every cases, uncertain. [7] Based on it, a sudden change in the engagement of industry can cause a huge difference in a certain areas along with the possibilities and needs of citizens.

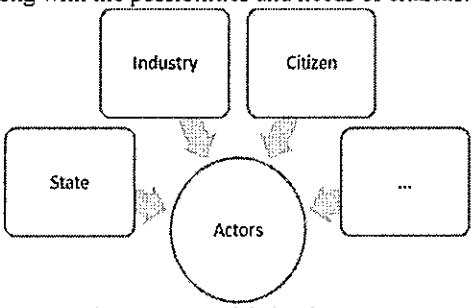

Fig. 5 Actors and their subsystems

Acquiring the best **technology** possible has always been a part of the evolution of technology itself. In the last 30 years more and more alternative systems have emerged from the development phase. The BAT (best available technology) list takes the type of hybrid, electric, petrol-based, energy-cell drived propulsion into account. [8] Alternative mobility's smaller, but existing segments, among many others, are liquified gas and water-powered vehicles. These latter do not reach the limit of todays' standards, but, on the other hand, they appeared in practice alongside the fully electric vehicles. [9] The effect on environmental burdens caused by the chosen technology has an absolutely essential importance.

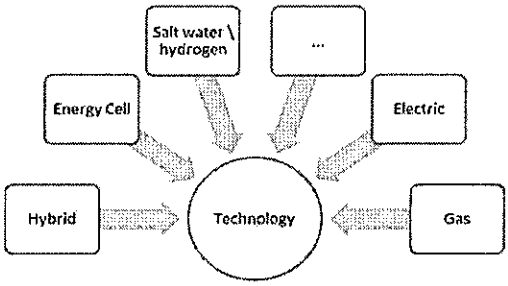

Fig. 6. The technology element and their subsystems

To use and widespread alternative mobility there is an inevitable need of proper **infrastructure.** The fluency of everyday usage should be made possible. Electric vehicles' emphasized logistical problem is the energy source, namely, the rarity and positions of charging stations and other supply points. With the spread of these vehicles the load on the electrical network increases because many people would choose the option of charging at home to provide the energy for the daily commuting. [10] The new and also widened variety of vehicles with alternative propulsion requires new repair workshop tools and IT equipment. Public investments bring means of alternative mobility into traffic, for example electric buses, e-taxi and electric bicycles. These fields operate with roughly the same features mentioned above, they are in need of adequate infrastructure. Every infrastructural development like that, either by the development itself or the influence on the user habits, have an impact on the state of the environment.

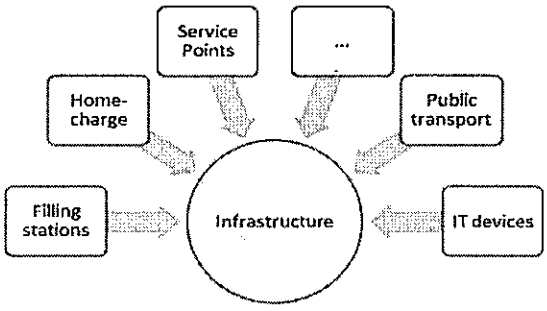

Fig. 7 The Infrastructure element and their subsystems

Providing enough **energy** for the alternative mobility, is unambiguously an environmental question, too. If the development of technology assures the possibility to change, then strategies to fulfil the long term demand of energy are necessary. [11] Taking the environmental effects into consideration, the purpose is using the energy of the renewable sources such as water, wind and the sun. [12] However, the

question is whether the energy deficit, that we will come into sunlight from the technological change will arise or not. [13] Another emerging issue is the difficulties of storing energy. Temporarily, the upkeep of a system like this does not make the on/off energy maintenance possible, but it continuously demands a much higher energy level.

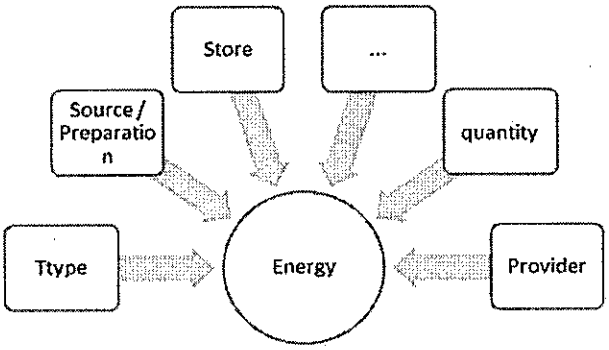

Fig. 8 The Energy element and their subsystems

The key of assuring the renewable **energy** is whether the technology connects to existing finances or not. Involving economic incinerators in a long term shows that besides the current technology, the prices of energy and the operating expenses will be increasing. The question is that who and how will provide this increased price. At the end of electric vehicles' lifetime, some important tasks will appear, for example how to treat these new type of wastes, which is a heavy title on the side of energy-using and expenses as well. The electric vehicles are available on a higher price, but the investment under lifetime, for instance the change of battery or other components, not definitely ensure the cheaper or free energy filled kilometres. [13], [14], [15]

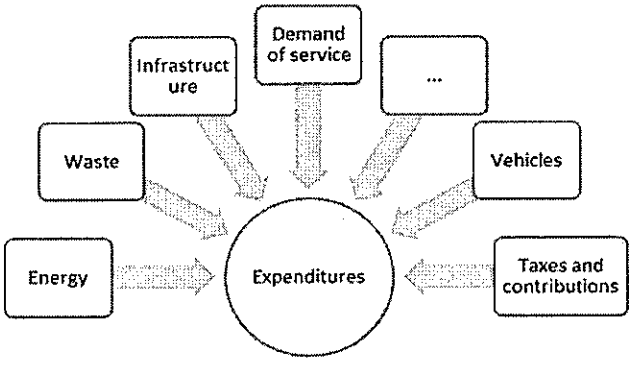

Fig. 9 The Expenditures element and their subsystems

The focal point of alternative mobility firstly aims the to decrease the environmental burdens, besides, to reduce the emissions. The most important system element of the model is to analyzing the **environmental effects.** The emissions such as air and other physical phenomenon can be underpinned by measuring numbers. [16], [17] Among the short term purposes, like the cleansing of the air of cities and reducing noises can also be underpinned. All the same, the effect on global environmental load is not unequivocal. The newly applied resources and the process to avoid the connected new type of wastes to stay in a harmful way could cause an unknown load too. [18] The used sources of energy are mainly renewable but there is a constant debate on the upkeep because of its economic and environmental loading. The goal of the model is not to find universal solutions to global environmental problems, but to find out whether the environmental loads could be reduced and in the following decades making their upkeep possible with current economical investments.

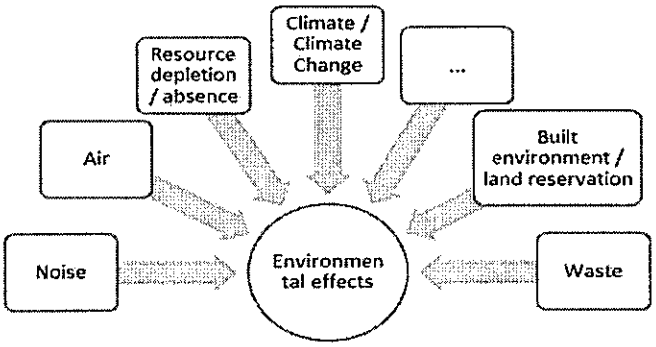

Fig. 10 The Environmental effects element and their subsystems

The cohesion among the previously negotiated cores could be strengthen or weaken by the phenomenon of **sustainability**. The classic model which has 3 pillars, namely the economical, the environmental and the social bases, is not completely suitable for the new dimensions. As for intellectual capital, with the research results mentioned above taken into consideration, it can be concluded, that plays an important role in the life of business organizations and sustainable capitalism. It is verifiable that the upkeep has also a competition-advantage role. [19] In the case of capital and all the environmental-social dimension it is true that they are rare, worthy and cannot be replaced and can be imperfectly copied. In the centre of environmental evaulation there is a continuous development of achievements, and the results can most accurately be given with the help of indicators, however we have to use the most relevant and organisation-orientated ones. [20] The wide pallet of environmental indicators and an already existing and used indicator sets may be applied in the same way. Evaluating the dimension of social sustainability, we can conclude that not only the performance test in the sustainability dimension, but also organizational management and ethical practices have to be considered. [21] [22]

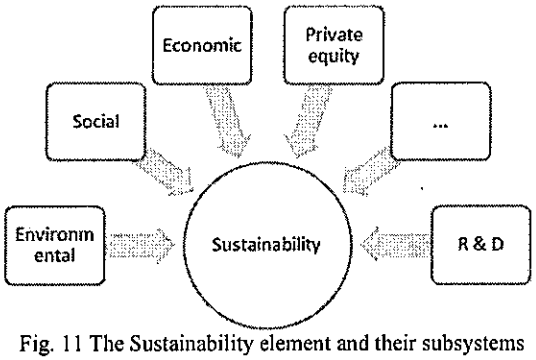

Fig. 11 The Sustainability element and their subsystems

When we established the CMAM system, our goal was to have a look on the new type of mobility, and on the environmental issues that concerning the influent factors, in addition to this, we wanted to systematize them into a clear, logical way with the help of SoS approach. It was important to us that the system during the research should be flexibly and modularly expandable.

VI. Consequences & Further Researching Task

After establishing the base model, we are planning to bring it to perfection with the help of experts. The next step of the research is going to be finding out the connections among the discovered system elements as well as their characterisation. In order to do this, we are intending to use the already mentioned FCM method, which is ideal for the finding the model balance, what is more, it is the most important for drawing the logical coherences. With the help of combining the FCM and SoS methods, the very first simulations can be running on the model, for which we need practical measures and available data. The results of the simulations make it possible to develop the background model in a mathematical way, and to fine-tuning it, although the beta versions should also be tested. We believe in a process, in which the model is not only equipped with theoretical issues but with realized solutions, that help us to validate it properly. We made a partnership with an automobile firm, that is determining in the industry of not just in the region but all over the world. While researching, innovative resources and devices can be born, that will have not even existed before. The aim of the studies is not just analyzing the „up to date" phenomenon, but it must also be appropriate to integrate dynamic changes and for a sustainability widespread examination. To word the connections and come up with suggestions or even to increase the efficiency of the model it is needful to collaborate with an organization of that profession. The further goal is to unite the IT systems (SoS and FCM), evaluate the environmental condition and analyze, then measure economic indicators in real time.

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Mathematical Competence As It Is Defined Through Learners' Errors In Arithmetic And Algebra

Michael Lousis (B.Sc., M.Ed., Ph.D.)

***Abstract*—**Mathematical competence is the great aim of every mathematical teaching and learning endeavour. This can be defined as an idealised conceptualisation of the quality of cognition and the ability of implementation in practice of the mathematical subject matter, which is included in the curriculum, and is displayed only through performance of doing mathematics. The present study gives a clear definition of mathematical competence in the domains of Arithmetic and Algebra that stems from the explanation of the learners' errors in these domains. The learners, whose errors are explained, were Greek and English participants of a large, international, longitudinal, comparative research program entitled the *Kassel Project*. The participants' errors emerged as results of their work in dealing with mathematical questions and problems of the tests, which were presented to them. The construction of the tests was such as only the outcomes of the participants' work was to be encompassed and not their course of thinking, which resulted in these outcomes. The intention was that the tests had to provide undeviating comparable results and simultaneously avoid any probable bias. Any bias could stem from obtaining results by involving so many markers from different countries and cultures, with so many different belief systems concerning the assessment of learners' course of thinking. In this way the validity of the research was protected. This fact forced the implementation of specific research methods and theoretical prospects to take place in order the participants' erroneous way of thinking to be disclosed. These were *Methodological Pragmatism*, *Symbolic Interactionism*, *Philosophy of Mind* and the ideas of Computationalism, which were used for deciding and establishing the grounds of the adequacy and legitimacy of the obtained kinds of knowledge through the explanations given by the error analysis. The employment of this methodology and of these theoretical prospects resulted in the definition of the learners' mathematical competence, which is the thesis of the present study. Thus, learners' mathematical competence is depending upon three key elements that should be developed in their minds: *appropriate representations*, *appropriate meaning*, and *appropriate developed schemata*. This definition then determined the development of appropriate teaching practices and interventions conducive to the achievement and finally the entailment of mathematical competence.

***Keywords*—**appropriate representations, appropriate meaning, appropriate developed schemata, Computationalism, error analysis, explanations for the probable causes of the errors, Kassel Project, mathematical competence.

I. Introduction

MATHEMATICAL error analysis has been generally considered the foundation for the determination of students' mathematical competence. This kind of analysis obtained its great momentum through the advent of computer technology as indispensably contributed towards the development of appropriate software that could provide this competence. Researchers' dominant perception that this technology had the potential to revolutionise the educational process fostered its development ([1], [2], [3]). Mathematics has been deemed an important and useful domain for research into the development of computer-assisted instructional (CAI) applications in Knowledge Engineering Technology in particular and in Artificial Intelligence in general.

Furthermore, mathematical error analysis was deemed to be of triple importance: i) *Diagnostic*: as a means of diagnosing individual learning difficulties and thus raising awareness of them. ii) *Scientific*: as a remarkable scientific research strategy able to apply specific theories to identify the probable causes of the emergence of learner's misconceptions and to give explanations. iii) *Prescriptive*: as a source of prescriptions concerning the effectiveness of the transfer of mathematical knowledge, based on the deterministic character of the outcomes of this particular research strategy.

Finally, the outcomes of errors analysis contributed to re-conceiving mathematical cognition, developing better schemes of assessment, the development of criteria for differentiating mathematics education and policies, developing better schemes of teachers' preparation, constructing better instructional methods and materials.

II. Explanation Of Errors

The fundamental and key assumption in cognitive science is that cognition, being an information process, is purposeful and goal-oriented. Hence, an important part of understanding an information process is to make sense of its significance or the purpose it serves. This, in turn, allows a learner to make systematic responses and decisions as to how to accommodate accordingly his/her behaviour to the contextual conditions, since by their very nature the responses and the behaviour are typically adaptive and goal oriented. Accordingly, any intentional agent, that is, an agent who acts adaptively and purposefully in response to the information taken in from the environment creates a model of this environment. This agent's model of knowledge is vital, since it contributes to the development of understanding and beliefs about that environment. The value of the available information and thus the value of learning depend on how this information contributes to achieving the agent's goals. An understanding of an information process will thus include an account of the content of the information he/she deals with as well as an

M. G. Lousis is with the Greek Ministry of Education, School Advisor of Mathematics Educators in Prefecture of Serres, 62100, GREECE (corresponding author' phone: 00302321038371; mobile: 00306988979197; e-mail: michael.lousis@ gmail.com).

account of his/her competence to employ that information in the service of certain goals. In other words the teaching and learning process should be guided by reasoning about the information and the processes that are needed to serve those goals. Ram and Leake point out that

> "The effectiveness of goal-driven learning depends on being able to make good decisions about when and what to learn, on selecting appropriate strategies for achieving the desired learning, and on guiding the application of the chosen strategies" [6, p. 1]

Furthermore, the ideas of Anderson, et al., [7] are conducive to a better realisation of the role of the decomposition and decontextualisation of cognitive performances into components of knowledge. The postulate of the information processing approach is that the individual's rules or knowledge components do not map in one-to-one correspondence with the individual's bits of behaviour because there is a continual interaction among components of knowledge and behaviour. The aim of that approach is dual. First it intends to create a clear-cut understanding of the components. Second to identify the relations of these components with their environments. In addition, the decomposition of these components gives rise to understanding learning and consequently to developing appropriate learning methods of intervention. Accordingly, Anderson, et al., (2003) point out the principle concerning this decomposition:

> "Assessing learning and improving learning methods requires careful task analysis at the level of component skills, intimately combined with study of the interaction of these skills in the context of broader tasks and environments" [7, p. 3].

At the same time, the decomposition and the study of the components might be impossible to take place outside certain contexts, since these interact and determine each other. For example the context of a problem that employs large enough numbers will make identifiable the required processes for carrying out the long-multiplication, since these cannot be evoked in the multiplication of e.g. 4×7. However, the complexity of that context can be controllable in order to render the assessment of a component of knowledge. Ample research makes clear that only the context of an appropriate subtask is needed to study the components of a larger task, since each task is composed of nearly independent subtasks ([8, Chapter 7], [9]). Nevertheless, each subtask is accomplished by the achievement of sub-goals through the execution of these components. The behaviour in achieving those sub-goals can be independent and assessable. Thus, the way each component works can be independently understood, that is, without simultaneous awareness of the details of all the other components. Anderson, et al. determine the correct principle with respect to the decontextualization as being:

> "Assessing learning and improving learning methods requires research and instruction in contexts that are consistent with the scopes of the skills currently under investigation. Component skills can be viewed within narrower contexts than broad skills. Relating context to task is essential in order to meet the limits of human attention and short-term memory capacity" [7, p. 3].

Consequently, the identification and the appropriate diagnosis of the students' errors have a tripartite character. First, it is a process by which we can come to know the way the students make sense of the mathematical knowledge, as this is described and prescribed by the implementation of the specified curriculum through the execution of specific mathematical tasks. The curriculum sets the goals and regulates the indispensable knowledge that the students must master and be able to apply in real life problem situations. These goals are itemized in specific tasks and are particularized in obtaining specific skills for the accomplishment of these tasks. Second, it contributes to finding out ways of intervening to help them make sense, appropriately represent and conceptualise the mathematical content (reconstruct the curriculum), and to eliminate their probable inconsistencies. Finally, it will guide us to make sense of the mathematical competence they develop and the particular (correct or incorrect) strategies they use, in order to invent and teach them appropriate new strategies that can follow to problem solve efficiently.

According to this spirit, an analysis of the English and Greek students' errors, as these emerged in the tree-year testing project, has been set out in the domains of arithmetic and algebra. This scientific analysis hinges on the ideas of cognitive science in general and on those of computationalism in particular. The analysis also takes into account, as much as possible, the learning context and the curriculum idiosyncrasies of the countries of both samples. Thus, by knowing the information that the students have at their disposal and the goals that they can and must satisfy through the deployment of that information, it is possible to account for their competence.

ARITHMETIC

III. Errors In The Test Of "Number"

Children do not consider the arithmetical computations to be habitual, common and easily done as most adults do. The adults' near-automatic performance leads them to form strong beliefs about the nature of arithmetic and inhibits them from conceptualising the arithmetic computations as problem-solving in natural situations. In contrast, children experience arithmetic computations as being real problem-solving situations. However, the effective mastery of symbols, concepts and procedures in a highly flexible way is not enough for children's mathematical competence. At the very same level, they must be able to create appropriate problem representations, which, in turn, will guide them to a proper selection and employment of suitable algorithms in a number of varied situations.

It is a truism to say that the procedural knowledge starts as conceptual understanding and knowledge. Moreover the effective employment of appropriate procedures depends on the development of appropriate schemata and strategic knowledge. Thus, in essence, any deficiency in developed skills and in practising mathematical procedures should be ascribed to deficiently developed concepts and representations that led to

inappropriate developed schemata that account in turn for incorrect actions. Let us see how this finding stems from the analysis of the specific data.

A. Whole Numbers

When the students are presented with a computation concerning whole numbers, at first the students try to represent it internally. The input percept is stored in their ocular sensory register and is detected through the process of attention, but it is not necessarily understood. Then it is translated from a physical stimulus to a symbolic mental representation through the process of *pattern recognition*, which enables students to form perceptual information into a recognizable pattern. The input is processed in their working memory.

The pupils' mind, as a computational system, understands a mathematical expression by performing two concurrent activities: *symbol recognition* and *symbol-arrangement analysis* [10, p.3]. According to the former a percept (phonemic or typeset) is converted into a set of symbols, whereas according to the latter the spatial arrangement of this set of symbols is analysed to retrieve the information content. These two activities are due to the use of the complex symbols of a two-dimension mathematical notation that consist of different characters and symbol sizes.

The mind, in order to make sense of a mathematical expression, to disclose the meaning and the information content that figures in the computation, that is, the *semantics* of this layout, dissects the mathematical expression. While the mind dissects this expression, it takes into account the given notational conventions that hold for the *syntax*, that is, the spatial arrangement of the symbols. These conventions define the two-dimensional language. This language gives rise to the representation of the information through the patterns that stand for this information. Knowledge of these conventions is prerequisite in order to bring about several other sub-processes that constitute the two main activities of symbol recognition and symbol-arrangement analysis. In this way, the mind engenders the recognition of mathematics.

According to Blostein and Grbavec the process of *symbol recognition* consists of the sub-processes of:

- Early processing
- Segmentation, to isolate symbols
- Recognition of symbols.

Whereas the process of *symbol-arrangement analysis* is composed of:

- Identification of spatial relationships among symbols
- Identification of logical relationships among symbols
- Construction of meaning. [10, p. 3].

The implementation of these sub-processes do not follow a strict order, but rather they can be performed in parallel or in series, in a way that the later processes could provide contextual feedback for the earlier processes during their implementation.

According to Marr ([11], [12]) the assignment of meaning to an incoming stimulus depends on three conditions:

i) the nature of the stimulus
ii) the individual's background knowledge
iii) the context in which the person encounters the stimulus.

Perception hinges on both the capture of the stimulus and the background knowledge that is available, in order for the stimulus to be recognised.

As has been mentioned above, one's understanding of a computation between whole numbers requires an understanding of the way the information is represented in that computation. This is further specified as distinguishing between the ten digit symbols that are the Arabic numerals and the numbers that are represented by them. For example, this can be intelligible by presenting the Arabic and the Roman symbols that stand for the number five. These are 5 and V respectively. Thus the first ten numbers from zero to nine are nowadays represented by the use of the ten Arabic numerals $\underline{0}$, $\underline{1}$, ..., $\underline{9}$. The symbols are underlined in order to be distinguishable by the represented numbers. Numbers that are larger than nine are represented by putting numerals into linear strings. For example, the number that is represented by the three digits in a linear string such as $\underline{407}$ is of length 3 with $\underline{4}$ being in the first position, $\underline{0}$ in the second and $\underline{7}$ in the third, counting from left to right.

According to Lakoff and Núñez the conceptualisation of numbers as wholes made out of parts is accomplished via the idea that "Arithmetic Is Object Construction" [13, p. 82]. For example, every natural number can be uniquely represented and conceptualised as a product of prime numbers. Due to this fact, every natural number can be conceptualised as a polynomial, that is, as a sum of products of the basic digits multiplied with powers of some number b. The number b is then called the *base* of the number system. The place-value function of the decimal number system is grounded on this principle. The number of the fingers of our hands made easier the use of, and contributed to, the establishment of the number *ten* as being the base of the decimal number system.

The assignment of a specific number to its correspondent linear digit string is done systematically by the use of the decimal place-value function. Each number is represented by a linear digit string arrangement, which consists of the use of both the basic assignment of each digit symbol to its specific number, and its position in the string. For example, the string $\underline{407}$ is ascribed to the number four hundred and seven by the use of both the basic assignments of the digits $\underline{4}$, $\underline{0}$, and $\underline{7}$ to the numbers four, zero and seven respectively, and by the use of the place-value function, i.e. $4\cdot10^2+0\cdot10^1+7\cdot10^0$, which equals $400+0+7\cdot1$, or 407. This particular function is a one-to-one correspondence or mapping between linear digit strings and numbers. This is an inherent property of the decimal numerical system and can be seen more clearly in contrast to the Roman system. Although the Roman system also used strings of digit symbols to stand for numbers, the mapping between strings and numbers cannot be defined by a particular place-value function.

Lakoff and Núñez ascribe the establishment of this notational system to our bodily constraints. They point out:

> "Our linear, positional, polynomial-based notational system is an optimal solution to the constraints placed on us by our bodies (our arms and our gaze), our cognitive limitations (visual perception and attention, memory, parsing ability), and possibilities given by conceptual metaphor" [13, p. 86].

They also stress the fact that it would be cognitively important to make a tripartite distinction concerning numbers. They distinguished among:

- "*The number* (e.g., thirteen)
- *The conceptual representation of the number*: the sum of products of powers adding up to that number (e.g., one times ten to the first power plus three times ten to the zeroth power)
- *The numeral that symbolizes the number* by, in turn, symbolizing the sum of products of powers (e.g., 13)" [13, p.84].

In this way, from a small set of basic, discrete digit symbols, new complex symbols are built by the use of only one rule of construction, that of the concatenation of the linear strings of digits specified by the place-value function. This set of digits, and the rule of construction of the complex symbols, constitutes the *syntax* of the whole numbers.

Thus, the all-embracing meaning of the complex symbol consists of the separate meaning of each numeral, and the position in the order of the arrangement that this numeral occupies in the complex symbol, that is, from the syntax of the complex symbol. Similarly, the complex symbol is interpreted by the fixed meaning that each basic digit symbol has, and by the semantic rule that is associated with each syntactic rule, which in this case is the place-value function. For example, the whole numbers from zero to nine constitute the fixed meaning of the ten Arabic numerals respectively. Furthermore, the syntactic rule of concatenation of the ten digits in linear strings is associated with the place-value rule of interpretation.

There are specific information processes that transform the symbolic input structures into symbolic output structures, by operating on the syntactical structure of the inputs. These processes are called *algorithms*. The algorithms are processes that maintain the meanings of the symbolic structures, which they operate on, because the meanings of the symbolic structures are a function of their syntax. Moreover, the algorithms produce meaningful results, and represent meaningful operations in the domain that is represented (here the set of the whole numbers), because they are information processes that operate on the syntax of symbolic structures.

Thus, the product of the multiplication of 60×450 is asked for in question 20. This product of the multiplication will be another whole number that is determined by a function that maps pairs of numbers onto single numbers. This function is the multiplication function that is defined as '×': $\mathbb{N}\rightarrow\mathbb{N}$: $(x, y)\rightarrow x\times y$, for all numbers $x, y\in\mathbb{N}$ that satisfy the properties: $x\times 0 = 0$, $x\times 1 = x$, $x\times y = y\times x$, $x\times(y\times z) = (x\times y)\times z$, $z\in\mathbb{N}$, and $x\times(y+z) = x\times y+x\times z$.

The students must possess representations that stand for numbers and to be able to accept and produce these symbolic structures. The students must be able to transform these symbolic structures in a way that faithfully represents the multiplication function as it was previously defined. This means that the students must always produce the symbol that represents the product of these two numbers, when two symbolic structures are presented. This constitutes the students' mastery of the skill and is the goal that the students must consistently achieve.

A process has been defined that operates syntactically on the decimal place-value representation in such a way that the process succeeds in representing the multiplication function '×'. This process is the multiplication algorithm that is conducted with paper and pencil. This algorithm always represents the multiplication function since the representational mapping between symbols and numbers is always maintained. This means that the application of the algorithm on the linear digit strings 60 and 450, which are mapped to the two numbers, sixty and four hundred and fifty, produces another string of digits that is mapped onto another number, which is the product of the input numbers sixty and four hundred and fifty. This process is completely defined in terms of processes that operate on representations, that is, on the symbolic structures of the numbers and not on the numbers per se. The algorithm is always defined by the formal structure of these representations and not from its meaning.

Thus this process is always a manipulation of linear digit strings according to certain rules. One can use the algorithm successfully by carrying out the rules correctly, without knowing that the strings stand for numbers or why the execution of these rules lead to correct results. The process becomes meaningful by referring to the place-value mapping that determines the meaning of the decimal notation.

The same holds for question 13, where the quotient of the division 900÷30 is asked for. This quotient will be another whole number that is determined by a function that maps pairs of numbers onto single numbers. This function is the division function that is defined as

'÷': $\mathbb{N}\rightarrow\mathbb{N}$: $(x,y)\rightarrow x\div y$, $y\neq 0$, for all numbers $x, y\in\mathbb{N}$.

Again the students must possess representations that stand for numbers and be able to identify and produce these symbolic structures. The students must be able to transform these symbolic structures in a way that faithfully represents the division function as it was previously defined. This means that, when two symbolic structures are presented, the students must produce the symbol that represents the quotient of these two numbers. This is the goal that the students must steadfastly achieve and that constitutes the students' mastery of the skill.

A process has been defined that operates syntactically on decimal place-value representations in such a way that the process succeeds in representing the division function '÷'. That process is the long division algorithm conducted with paper and pencil. One can succeed in obtaining the quotient by correctly applying the set of the rules that constitute this process, without knowing that the strings stand for numbers and why the execution of these rules leads to correct results.

The causal properties that contribute to the emergence of these functions are grounded on our everyday experiences in manipulating objects in the world. These relationships are developed in the "container" and "source-path-goal" schemata, and through the metaphors "Arithmetic as Object Collection", "Arithmetic Is Object Construction", "Measuring Stick Metaphor" and "Arithmetic Is Motion Along a Path" as these established by Lakoff and Núñez [13]. These causal properties

impose the specific formal properties that are syntactical transformations in order to ascribe the semantic commitments. Thus the inter-linkage of these concepts in the mind, when it processes mathematical information, is in the order: causal properties - formal properties - semantic properties of the complex symbols. This entails that the causal properties reflect the formal properties and these, in turn, reflect the semantic properties. This sequence enables the mind to perform computations by performing causal operations.

Thus, the structure of reasoning (the form of the transitions between the consecutive trains of thought in Mentalese) preserves and ensures the conveyance of the stated truth and the semantic properties through this syntactical form of the component parts. This structure is reflected in the development of the particular algorithm, which is a strict process of operations on symbols according to specific rigorous rules. This structure permits the linkage between the causal and the semantic properties of the representations in the mind, through their syntactic or formal properties. This train of thought proceeds when the IF conditions of specific rules (productions) are linked in the pupils' working memory with the THEN content of these rules -- (the appropriate information that has the form of declarative knowledge well-entrenched in schemas stored in the long-term memory) -- that is drawn from the long-term memory. The set of productions constitutes the skill of the algorithm, of multiplication or division between two linear digit strings, that the students must achieve, is ready to retrieve easily and perform automatically. This has not happened.

Some errors ensue from an omission of the application of correct rules. This is the case in problems 20 and 13. The error analysis of question 20 generally indicates a problematic retrieval and, in particular, the omission of the application of a particular production constituting the algorithm of multiplication between whole numbers. Thus:

(i) One plausible case might be that the pupils wrote the number $60 = 10\times6$ and performed the long multiplication $450\times60 = 450\times(10\times6)$ only by the digit 6. They omitted to multiply with the number ten as well.

(ii) Another explanation might be as follows. First, the pupils analysed the number 450 into two components 400 and 50. Then, they multiplied these two numbers only with the digit 6 in consecutive stages:

$400\times6 = 2400$, $50\times6 = 300$. Finally they added the two products, that is, $2400+300 = 2700$.

(iii) A third explanation might be one described by the execution of the following algorithms:

450		450	
×60	or	×60	
000		300	←60×5
2700		2400	←40×60
2700		2700	

The numeral 0 that indicates the units in the number 450 is ignored.

It follows from the above analysis ensues that, when the students multiply a whole number by a multiple of 10, in this case with 60, they usually first multiply only by the digit indicating the multiple of ten. Afterwards, they usually put the nought at the end of the product for reasons of simplicity and automaticity. This particular action causes problems because they are usually unable to keep track of the order of the process and forget to add the nought at the end of the product. For example, because of

$60 = 6\times10$ and $450\times60 = 450\times(6\times10) = (450\times6)\times10$.

Thus they perform the multiplication $450\times6 = 2700$ and instead of then multiplying the product 2700 by 10, as they should do, they add the nought to the end of 2700, since $2700\times10 = 27000$. In this case the students did not perform the last action.

Problematic retrieval from long-term memory is always responsible for the incorrect application of a particular production of the algorithm for division between whole numbers. This is evident in question 13 as well.

Thus, the pupils incorrectly assumed that

$900\div30 = 900\div(3\times10) = (900\div3)\times10 = 30\times10 = 300$.

The other explanation is that they divided $9\div3 = 3$ and then they added to the quotient the two noughts of the number 900.

In both cases, the students have incorrectly applied the particular productions that constitute the algorithm of the division. It seems that multiplication and division by multiples of 10 puzzled the English students. Since the number $30 = 10\times3$, the students are prompted by many English books to divide the dividend first by 10 and then by 3. Thus, they are prompted to practice:

$900\div30 = 900\div(10\times3) = (900\div10)\div3 = 90\div3 = 30$ or

$900\div30 = 900\div(3\times10) = (900\div3)\div10 = 300\div10 = 30$.

In that case the English students did not perform the last production, that is, the division of $300\div10$. They probably did not do that because they did not follow the correct order of the implementation of the strategy.

In addition, errors usually emerge because of failure to recognise specific operators that are implicitly denoted. Symbolism in mathematics has a special plasticity and flexibility that permit the creation of many other symbols that can be ascribed to, and associated with, specific concepts. The creation of more complex symbols is usually made up by the appropriate placement of one close to the other, to form spatial relationships. Blostein and Grbavec [10, p.6] identified ten of them: left, right, above, below, above right, above left, below right, below left. Such kinds of relationships account for much of the meaning in mathematical notation. These relationships are responsible for the determination of the logical relationships between symbols as well.

As a consequence, the interpretation of the complex mathematical symbols should be considered complicated enough and one that is not always successfully developed. The location of the simple symbols, one adjacent to the other, to form complex ones, potentially affects the meaning and, presumably, the resulting inferences. That is, the identification of the spatial relationships among symbols heavily affects the identification of the logical relationships among them. It therefore gives rise to the development of the meaning, that is, the semantics of the formal structure.

In relation to this is the fact that there are many mathematical operators that are indirectly determined by the spatial arrangements of the operands, in this case the operator of exponentiation. These spatial relationships are critical for their accurate recognition. The identification of these relationships might be difficult if a great deal of specific knowledge concerning the conventions that specify them was not adequately encoded, established and available. Moreover, Fraure and Wang [14] provide evidence that the recognition of a particular structure of a mathematical expression by an individual takes place prior to the recognition of its complete symbol-constituents.

This recognition did not occur for the English students in question 40. The pupils failed to recognise the spatial arrangement of these operands, to identify the critical spatial and logical relationships, or to create the correct meaning of the operator as an instance of exponentiation. Moreover, the students failed to retrieve the appropriate set of productions that account for the operations determined by this operator because of their failure in recognition. Instead, they incorrectly recognised the operator of this structure as denoting a multiplication and retrieved the appropriate set of productions that induces the set of actions that are defined by this operator. The set of productions they incorrectly retrieved was:

"IF this $(125)^{\frac{1}{3}}$ is a mathematical expression, THEN classify it as multiplication" (incorrect)

"IF $(125)^{\frac{1}{3}}$ denotes a multiplication THEN multiply 125 with the nominator of the fraction $\frac{1}{3}$."

"IF $\frac{125}{3}$ is a fraction THEN it denotes the division 125÷3."

"IF the expression 125÷3 denotes division THEN find the quotient".

This incorrectly retrieved set of productions led the students to actions that are expressed formally as:

$$(125)^{\frac{1}{3}} = 125 \times \frac{1}{3} = \frac{125}{3} = 125 \div 3 = 41.6,$$

which is the response that was provided.

B. Fractions

When the student is presented with an operation concerning fractions, at first the input percept is detected and translated from a physical stimulus to a symbolic mental representation through the processes of attention and *pattern recognition.* This enables the student to form perceptual information into a recognizable pattern. The input is processed automatically in the working memory. These patterns have been encountered, in instruction and in problem-solving situations, a multitude of times in the past.

The need to express the concept of the quantity of a specific part of a whole, when it is *equally* divided, gives rise to the concept of the fraction. The content and the meaning of this concept are denoted by the use of a complex symbolic structure. This logical convention, the meaning, or the semantics, of this relation is expressed by a particular symbol-arrangement, a notational convention, that is, syntax. Two slots, one below the other, both divided by a horizontal line, compose this structure. The slots are usually filled in by numerals. The numeral that fills the upper slot expresses the quantity of equal parts of the *equally* divided whole that are being taken out, whereas the numeral that fills the lower slot expresses the quantity of equal parts which the whole has been divided into.

Thus, the all-embracing meaning of the complex symbol consists of the separate meaning of each numeral and the position in the order of the arrangement that this numeral occupies in the complex symbol, that is, from the syntax of the complex symbol. This arrangement is a convention established by this logical rule. From this new complex symbol emerges new attributes, all its own, that are greater than those of its constituent parts. These attributes and properties are due to the fact that new relations are created by clumping together the different constituent elements, which constitute a quite new qualitative entity. Consequently, the syntax and semantics are necessary and sufficient conditions for representations in mathematical form to be conveyed and realised. This fact is called '*semantic compositionality*'.

The numerals that are used are the ten digits 0,1…9, to form first linear digit strings that are ascribed to numbers according to the place-value function and then to be put in the slots. There is an important exception according to which the digit 0 cannot be used in the lower slot. This convention expresses the logical restriction that it does not make sense to divide a whole in parts of size 0. This should mean, according to the object-collection metaphor [13, , p. 54], that it does not make sense to split up the whole into a number of equal parts of size zero, that is, into a unique and determinate number of non-existent parts that exhaust the whole part. Certainly, it cannot be such a unique determinate number. The whole can be divided at least into one part, that is, the same whole.

In this way, knowledge of the meaning of a limited number of symbols and their mode of arrangement gives rise to the meaning of the complex symbol. This in turn comes about specific representations that develop and apply semantic relations with things in the world. Moreover, it denotes how these symbols develop semantic interrelations with each other.

Another logical condition or rule that is imposed by reality is that two parts cannot be added or subtracted, except in the case that they express equal parts of the same or identical wholes. This is the principle of uniformity that expresses this particular causation in the real world. This causal property imposes a specific formal property, that is, a syntactical transformation in order to ascribe the semantic commitment. Two complex symbols that are fractions can be added or subtracted when they have the same numeral as a denominator. This leads to the fact that the inter-linkage of these concepts in the mind when it processes mathematical information is in the order: causal properties - formal properties - semantic properties of complex symbols. This entails that the causal properties reflect the formal properties and these, in turn, reflect the semantic

properties, and this sequence enables the mind to perform computations by performing causal operations.

In contrast, the logical principle that maps causal relationships in the world and leads to the establishment of multiplication between two fractions, is the necessity to express what part of the quantity that is expressed by the second fraction constitutes the first fraction. For example, the multiplication $\frac{1}{3} \times \frac{6}{7}$ denotes the $\frac{1}{3}$ part of the quantity that is expressed by the fraction $\frac{6}{7}$, which is $\frac{2}{7}$. This logical relationship is expressed formally with the symbolic representation i.e. $\frac{1}{3} \times \frac{6}{7} = \frac{2}{7}$ which in turn gives rise to the semantic properties of this sequence of symbols.

Thus, the structure of reasoning (the form of the transitions between the consecutive trains of thought in Mentalese), preserves and ensures the conveyance of the stated truth and the semantic properties through this syntactical form of the component parts. This structure is reflected in the development of the particular algorithm, which is a strict process of operations on symbols according to specific rigorous rules. Moreover, this structure permits linkage between the causal and the semantic properties of the representations in the mind through their syntactic or formal properties. This train of thought occurs when the IF-conditions of specific rules (productions) are linked in the pupils' working memory with the THEN content of these rules -- (the appropriate information that has the form of declarative knowledge well-entrenched in schemas stored in the long-term memory) -- that is drawn from the long-term memory.

Thus the reasoning that is an algorithm, i.e. in addition or subtraction, simultaneously has the form:

"IF the addition of the two objects has the form $\frac{a}{b} \pm \frac{c}{d} =$, THEN classify this as an addition (or subtraction) of two fractions.

IF the two denominators of the two fractions are the same THEN add (or subtract) the two numerators.

IF the two denominators of the two fractions are different THEN find their least common multiple (the process of finding the least common multiple presupposes another available and, most importantly, retrievable set of productions available in the long-term memory).

IF the least common multiple is available THEN divide it by the denominator of the first fraction.

IF the quotient of this division is available THEN multiply the numerator and the denominator of the first fraction with this.

IF the least common multiple is available THEN divide it by the denominator of the second fraction.

IF the quotient of this division is available THEN multiply the numerator and the denominator of the second fraction with this".

This set of productions constitutes the skill of the algorithm of the addition or subtraction of two fractions that the students must have achieved, to acquire and be ready to retrieve it easily and to perform it automatically. Other sets of productions constitute the skill of the algorithm of the multiplication and the division of two fractions, which must be performed automatically. This has not happened in most of the questions where the errors under consideration arose.

Retrieval, which is the process that is employed for accessing and focusing on information drawn from long-term memory to consciousness, through attention, is a fallible process. Two are the main reasons for an inadequate - or not at all - retrieval. The first is that information was insufficiently elaborated and inadequately encoded in the long-term memory. The second is that its reconstruction during the process of retrieval was improper. This is due to the fact that the encoding and the retrieval of information are closely linked.

The basic sub-processes of retrieval are *recall* and *recognition*. Usually the processes of recall and recognition are not deemed to be the same by the theoreticians. A symbolic representation can be recognised as such but it cannot be interpreted by ascribing a meaning to it, that is, it cannot be recalled. Recall demands more cognitive resources and more extensive memory search to be allotted than in recognition, and this is not always successful.

According to Tulving's [15] *encoding specificity principle,* the memory performance is regulated from the conditions that hold during the process of encoding and retrieval. Thus, the memory performance is enhanced when the conditions that are present at the process of retrieval are similar or overlap those at encoding. Thus pupils' ability to recall information hinges on their ability to encode as much information as possible in a reasonable, meaningful way with that previously acquired. Moreover, the conditions that hold at the time the information is encoded, such as mood and offered cues, determine the ability to remember it. Whereas the process of encoding is a constructive one, the process of retrieval is reconstructive one. This is due to the fact that the *cost-efficient* mind does not reflect reality as such, but instead it abstracts it and stores the most important elements of it for reasons of economy.

Some reconstructive errors ensue from the desire to modify and distort information to make it fit with already existing knowledge. This is due to the process of accommodation and assimilation in the case of the failure of a successful and proper retrieval. This was the case with the particular errors $\frac{2}{6}$ in question 11, $\frac{1}{5}$ in question 21, 4 in question 29, $\frac{1}{3}$ or $\frac{3}{9}$ in question 33 (i), (ii), (iii) [4].

The pupils could recognise these patterns as fractions and the associated symbols as being the symbols of addition, subtraction, multiplication or division respectively, since they

had been extensively taught previously at primary school. Furthermore, the context in which the stimulus was encountered was conducive to this process, since it was the natural context where this knowledge was acquired. The background knowledge was available for the pattern recognition process, through the activation of a particular schema stored in long-term memory. However, it was inadequate for the retrieval of the set of productions responsible for the performance of the specific algorithm.

One plausible explanation is that the pupils failed to identify the logical relations among the symbols, that is, the syntactical rules. They also failed to construct the specific meaning of the subtraction (case 21(B))[4], or the multiplication (case 29(b), 43) [4], respectively, of the two fractions on those questions that entailed the performance of this set of the particular productions that constitute the respective algorithm.

The other explanation might be that they probably identified these operations but failed to retrieve the appropriate production set (cases 21(A)(ii), case 29(A)(i), (ii), case 33(i), (iii)) [4] that is, to perform the structural analysis. This means that the available schema concerning the subtraction, multiplication or division of the two fractions respectively in all these cases is not rich and well structured. It does not contain strongly interconnected pieces of information of declarative knowledge and productions that are easily activated and retrieved by provided cues. This did not contribute to the decision made concerning the nature of the visual stimulus. Thus, the students, in order to cope with the presented problem, had recourse to the available stored knowledge and the mechanisms of distortion and modification.

One of those apt, causal mechanisms is the brain's innate ability to organize percept according to the Gestaltists' theory[3], which brings about the reconstructive processes of the retrieval. Responses that were due to the Gestaltists' perceptual organization were the error $\frac{2}{6}$ in question 11 and the error $\frac{1}{5}$ made in question 21.

According to the Gestaltists' development of the set of principles of perceptual organisation, students are apt to organise and perceive the percept as a whole, rather than the sum of particular parts of it. Thus, the students tried to organise the sum of the parts $\frac{1}{2}+\frac{1}{4}=$ in question 11, according to these Gestaltists' principles[3] (see Appendix I). Therefore, according to the first principle of the *Law of Prägnanz*, the students tried to reconstruct the percept in order to have a good form. They failed to identify the logical relations among those symbols that could trigger the appropriate production set responsible for the performance of the algorithm of addition.

According to the Gestaltists' *proximity principle,* the elements such as the two numerators and denominators in the array, which are close together, are taken as belonging together. Moreover, because these elements are similar, tend to be grouped together according to the *similarity principle.* Additionally, according to the *principle of closure*, an incomplete figure will tend to be seen as a complete one, as this happens with the two fraction lines are unified to form a continuous one. Finally according to the *continuity principle,* the sum of the numerators and the sum of the denominators are seen as unified, forming a new entity. Thus the sum $\frac{1}{2}+\frac{1}{4}=$ becomes $\frac{1+1}{2+4}=\frac{2}{6}$, which was the final students' answer.

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Furthermore, when the students encountered the expression $\frac{1}{2}-\frac{1}{3}=$ in question 21(A)(i), they grouped the operands according to the Gestalt principles as they did in the previous case. However, in this case, they left the number 1 as a numerator. This particular grouping among the mathematical symbols resulted from the students' interpretation of the notation conventions in the subtraction. These symbols formed the appearance of the complex symbol. These were also responsible for the success of the retrieval process. Thus, the students did it because they were probably puzzled by the operator (-). This operator requires finding the difference of the two numerators. However, in this case, that produces the number 0. This fact contradicted the students' general conceptualisation of the fraction as a complex symbol with operands that are different from zero, which, in turn, led them to leave the number 1 as a numerator.

The students failed to activate the particular schema responsible for the performance of the algorithm of addition or

subtraction. Thus, in this way, they transformed the pattern of addition or subtraction of two fractions into another one that could be assimilated according to their available knowledge, that is, to an addition of two integers.

Nevertheless, in question 21(A) case (ii), as they also did in other cases, the students' thinking did not have recourse to the Gestalt principle. Their recall was based on an improperly developed schema concerning the addition of the two fractions, that is:

$$\frac{a}{b}+\frac{c}{b}=\frac{(a+c)}{b}$$

So, for equal denominators, the numbers are added.

Here, they have equal numerators, so the pupils transferred the method for equal denominators to equal numerators and they ignored the different operator. They reconstructed their poor recall in order to fit in with the case. Thus, this is a reconstructive error that ensued from the students' desire to modify and distort information to make it fit with their already existing knowledge, as a process of assimilation in the case of the failure of successful and proper retrieval.

In other cases, the fallible process of retrieval took other forms. In question 29 (A), the retrieval process concerning the multiplication of two fractions was influenced, either from previously stored knowledge of the algorithm of the addition, or from multiplication among improper fractions, and it was applied in conjunction with that of multiplication. This may be due to the fact that the section concerning instruction in improper fractions and mixed numbers follows immediately after the introduction of multiplication between two fractions in the English curriculum and in many English textbooks.

The operations of multiplication and addition take place in the numerator of a fraction when multiplying mixed numbers and transforming them into improper fractions. That fact may lead to the development of the students' misconception. Thus, in the textbook of Banks et al. (1999, p. 69), in example (1), the following multiplication is referred to:

$$1\frac{1}{2}\times 1\frac{3}{5}=\frac{2\times 1+1}{2}\times\frac{5\times 1+3}{5}=\frac{3}{2}\times\frac{8}{5}=\frac{3\times 8}{2\times 5}=\frac{24}{10},$$

whereas the students may have performed, $\frac{1}{2}\times\frac{4}{5}=\frac{1\cdot 5\times 4\cdot 2}{2\times 5}=\frac{40}{10}=4$. The analogy is clear.

In this instance, when the reconstructive process of the retrieval draws a production whose content has changed, it leads to the misapplication of a correct rule. This happened in question 33 (i). In this case, the students might have incorrectly interchanged the operands of the first fraction instead of the second one. Then, they correctly performed the operation of multiplication.

This is due to the modification of a particular production of the set that comprises the algorithm of division. The students used the production:

"IF the expression $\frac{1}{3}\div\frac{1}{9}$ means division between two fractions THEN interchange the two operands of the <u>first</u> fraction and perform multiplication",
instead of the correct one:

"IF the expression $\frac{1}{3}\div\frac{1}{9}$ means division between two fractions THEN interchange the two operands of the second fraction and perform multiplication".

In the same way, there is an instance where the reconstructive nature of the retrieval used a particular set of productions that constituted an algorithm for the performance of a specific operation in another operation. This happened in question 33 (iii). The students might have converted the first fraction into an equivalent one that had the same denominator as the second fraction, and then they performed the division. In this particular case, their recall of the particular algorithm concerning the division between fractions was too weak. Apparently, the strong schema that influenced their recall was that of the subtraction between fractions. This fact was evidently due to the similarity between the two operators '÷'and '-', since they failed to identify the syntactical analysis (recognition) of the mathematical expression. The fact that the Greek students, among whom this error was prevalent, were not familiar with the use of this kind of symbolism for the division should be stressed. The symbol ':' was used to stand for the operation of division in their textbooks.

Finally, the improper recall of a production concerning the simplification of a 'top heavy' or improper fraction may have led to the emergence of the error in question 33 (ii). The students, in that case, wrote $\frac{9}{3}=\frac{1}{3}$ instead of the correct one $\frac{9}{3}=3$.

Except for the cases where the failure of recall has been shown, there were other instances where the emergence of the errors was due to the failure of appropriate recognition of particular symbols. That failure led to misunderstanding and to improper identification of logical relationships among symbols. This may have been especially the case with the Greek students in questions 21 (B), 29 (B) and 43.

In the case of 21 (B), the Greek students ignored the operator of subtraction or developed a misunderstanding by assuming this as being the operator of addition instead. Since the same algorithm is applied to both addition and subtraction between fractions, -- except for one production that specifies the operation, -- the students proceeded taking for granted the operator (+) instead that of (-). In this case the error is an action slip.

The emergence of the error in question 29 (B) was due to the failure of appropriate recognition of the particular symbol '×', which, in turn, led to a misunderstanding and to an improper identification of logical relationships among symbols. It can be assumed that the Greek students' misinterpreted the sign '×'.

They may have assumed this symbol to be the addition '+' sign, since they rarely use this symbol to represent the multiplication operation, especially in a succession of operations among numerals. The Greek students were used to representing the operator of the multiplication with the symbol '·', both in arithmetic and algebra. Thus, a particular grouping among mathematical symbols, resulting from the students' interpretation of the notation conventions in mathematics and forming the appearance of a particular mathematical expression, accounts for the success of the recognition process. The elimination of the misunderstanding at the third round supports this assertion.

Finally, the emergence of the particular error in question 43 was due to the failure of pattern recognition and especially of the symbol-arrangement analysis. The students failed to identify the spatial and logical relationship among symbols and to construct meaning. The students' misconception concerned the syntactical rule that determines the complex symbol $1\frac{1}{4}$. The students incorrectly took the complex symbol to imply the logical relationship $1\frac{1}{4}=\frac{1\times1}{4}$.

C. Percentages

Finding a percentage of a quantity is similar to finding a fraction of a quantity. This can be done either by transforming the percentage to a fraction or to a decimal. Thus the percentage, the fraction and the decimal are representations of the same number, that is, they are co-referring[1] terms. The substitution of one of these terms by another can take place without changing the truth or falsehood of the sentence in which they are used.

Thus, three key constituents form the students' mathematical competence of the use of the percentages. The first constituent is the students' ability to create the appropriate representation when they encounter its symbol. This means that the students have identified and understood the use of percentage as a symbol useful for communication and for computation too, but with the caveat that when this is used in a computation it must first be transformed into another representation. The second constituent is that the students are able to correctly transform this symbol into other co-referring[1] symbols. This fact indicates that the students have developed appropriate meaning concerning the concept and the symbol through which it is represented. Finally, the students are able to perform computations with this and with other symbols; these operations constituting the students' procedural knowledge, that is, the pupils' appropriately developed schemata.

In fact, it is not sufficient for the students to classify the percentage in a particular category or concept, but rather they have to know how to use this classification. This means that the students know how to regulate their behaviour according to this classification. In general, the belief sentence, as is it expressed by the pupils, depends not on the object represented but on the way that the object is represented. Thus, a concept becomes intensional according to its use, expressing a particular belief that the students have developed regarding the conceptualisation and the use of the concept. Since all of these three types, that is, the fraction, the percentage and the decimal, are complex symbolic structures, their recognition as mathematical expressions is induced through their syntactical analysis. This means, through the identification of the syntactic rules that regulate their conversion from one type of the representation to the other. Because the students' grouping among mathematical symbols results from the interpretation of the notation conventions in mathematics, it forms the appearance of a particular mathematical expression and accounts for the success of the recognition process.

The English pupils, in problem 15, incorrectly assumed 20% $= \frac{1}{20}$. These students grouped the symbols, 1 and 20, to form the complex symbol $\frac{1}{20}$ as being identical to the complex symbol 20%. They used it instead of the correct one, $\frac{20}{100}$. In this way, they showed a misinterpretation of the notational convention and a wrongly developed belief. The pupils recognised this entity as being a percentage, that is, they knew to classify it in this particular category of fractions, but they were not able to correctly express its exact meaning. This was due to their weakly developed schema, which formed part of their declarative knowledge concerning this particular notational convention. Thus, they had recourse to a reconstructive retrieval of grouping the available symbols, 1 and 20, in similar way, to make them fit with previously existing knowledge through the process of accommodation and assimilation because of the failure of a successful and proper recall.

Finding the percentage of a given fraction is exactly the reverse process from these that were examined in the previous question. The students had to develop the concept of percentage and its symbolic representation as declarative knowledge incorporated in a particular schema in order to be able to apply any strategy to find out the percentage corresponding to that fraction. Moreover, they had to develop a particular schema containing sets of productions that constitute specific procedures, that is, strategies. These strategies had to be used to convert the fraction into another one, equivalent with the first, which would have as a denominator the number 100 and would be identical with the symbolic representation of the percentage. This did not happen, in problem 25, since the pupils incorrectly assumed either that $\frac{1}{8}$ = 80% (Error 25(A)) or that $\frac{1}{8}$ = 8% (Error 25(B)) [4].

This particular error shows again that the students did not understand the syntactic rules that define the correct grouping of mathematical symbols and the meaning of the resultant grouping. They failed to convert the identification of the spatial and logical relationships among the symbols into the appropriate procedure.

D. Decimals

The students' mathematical competence to deal with decimal numbers is constituted by three basic components. The first constituent is its representation. A decimal can be represented both as a polynomial --i.e. a finite or infinite sum of products of numerals with powers of ten, where the indices of the powers of ten can also be negative numbers -- and as a fraction. The second constituent is the construction of meaning of the concept of a decimal number with its conceptual representation of the number. Both of them are accomplished through the use of the polynomial expression, which, in turn, is based on the place-value function. Finally, the third constituent is the development of the particular schemata that constitute the students' procedural knowledge of the use of the decimal in computations with other numbers. This presupposes flexibility and fluency in the use of all three representations of the number according to the encountered situation.

The problems concerning decimals were used in the test in order to check whether the students were able to create correct conceptualisation and representation of the multiple forms of these numbers. Concurrently, they were tested on whether they used them effectively in operations with other numbers. The error analysis indicated that the students did not create appropriate representations of the multiple forms of these numbers. Thus, because of this fact, the students incorrectly used sets of productions that determined the transformations of these representations that were used in the particular arithmetic operations.

Fractions and decimals are two different representations of the same number. Since both of them are complex symbolic structures, their recognition as mathematical expressions is induced through their syntactical analysis, that is, the identification of the syntactic rules that regulate their conversion from one type of representation to the other. Because grouping among mathematical symbols results from the interpretation of the notation conventions in mathematics, it forms the appearance of a particular mathematical expression, and accounts for the success of the recognition process.

The students were called to answer question 30 by transforming the fractional representation of a number to a decimal one. The students failed to convert the fraction to a decimal and they created several errors in important percentages. This was due to a weakly developed, poorly structured schema that regulated the flow of information concerning the conversion of fractions to decimals and vice versa.

Thus, the students failed to recall the correct definition of a fraction as a division: $\frac{1}{8}=1\div 8$. Consequently, they reconstructed this retrieval in order to fit and assimilate it into their existent schematic declarative knowledge. They probably based this on their vague recollection of decimal fractions. Hence, they gave as an answer $\frac{1}{8}=\frac{8}{10}=0.8$ (Error 30(A)) [4]. In another case, the students' reconstructive retrieval took the form $\frac{1}{8}=1.8$ (Error 30(B)) [4]. They incorrectly assumed that by simply putting the numerator as the digit of the units and the denominator as the digit of tenths it would form the decimal. Their lack of development of the appropriate concept of decimal number and its symbolic representation is apparent. Moreover they lacked any conceptualisation of the determination of a fraction as a division and vice versa. Finally, the students' reconstructive retrieval took the form $\frac{1}{8}=8\%=\frac{8}{100}=0.08$ (Error 30(C)) [4]. They incorrectly assumed that the fraction was equivalent to the percentage 8%. The students' confusion in regard to the percentage, the fraction and the decimal is obvious.

The students' conceptualisation of decimal numbers and their skill in comparing them was tested in problem 18. The students' incorrect responses were 15.758 (Error(A)) and 15.759(Error(B)) [4]. These are decimal numbers that contain three decimal digits, whereas the students were asked to provide a decimal with two decimal places that lies between the 15.755 and 15.762. This indicates the students' incorrect conceptualisation and representation of decimal numbers, which was due to in an inaccurately developed declarative knowledge mostly concerning the place-value function.

This knowledge also concerns the different representations of decimals as polynomials of powers of ten or as fractions. That is, the students had to put the number in the form:

$a_1a_0.a_{-1}a_{-2} = a_1\cdot 10^1+a_0\cdot 10^0+a_{-1}\cdot 10^{-1}+a_{-2}\cdot 10^{-2}$

or in the form: $\frac{a_1a_0a_{-1}a_{-2}}{100}$, taking into account that this number had to be between the other two, given decimal numbers with three decimal places, 15.755 and 15.762. In this case, the students had to develop particular procedural knowledge made up of an appropriate set of productions. This knowledge should account for how to compare decimal numbers either by use of a number line or by putting them one on top of the other, keeping the decimal points in the same vertical column. Apparently this knowledge was lacking as well.

Thus, the students, in order to accommodate their uneasiness and provide an answer, tried to assimilate the input into their already existent declarative knowledge. So, they invented a decimal number with three decimal places in direct contradiction to the specified conditions of the problem, which was the average of the given decimal numbers, that is, either 15.758 or 15.759.

The inappropriately developed representations of decimal numbers were responsible for the incorrect execution of the particular set of productions used in the performance of the operations between decimal numbers or between decimal and whole numbers. Thus, in problems 22, 31 and 41, the students showed misconceptions that were due to the place-value function. These misconceptions became apparent through the

omission of the execution of particular productions during the application of a particular strategy, as is the case in Error 22(A), (B), Error 31(A)(ii) and Error 41 [4].

Consequently, the pupils assumed 7×3 = 21 and then incorrectly put the decimal point of the product one position to the left (Error 22(A)). They took into account only the number of decimal places of the decimal number 0.3 and not the 10s in 70.

The strategy that is common in both English and Greek textbooks consists of the following productions:

"IF you encounter an operation 70×0.3 = ? THEN classify it as a multiplication".

"IF there is a dot at the bottom among the digits of a number THEN classify it as a decimal number"

"IF one of these numbers or both are decimal numbers THEN count the total number of the decimal places in the numbers being multiplied together".

"IF the operation is a multiplication THEN ignore the decimal points and multiply the numbers using long multiplication".

"IF you find the product of the multiplication THEN place the decimal point so that the answer has the same total number of decimal places you counted".

Apparently, the error in this question was due to the misapplication of the fourth production, since the students multiplied the number 7×3 = 21 instead that of 70×3 = 210. This might be due to the automaticity of the strategy, since the students usually perform the multiplication with the digits. They usually do not include the zeroes at the end of the numbers. The students usually cancel as many zeroes as the number of decimal places in the decimal number, for reasons of simplicity. This did not happen here, with the result that they moved the decimal point one place to the left in the product of the multiplication 7 × 3 = 21, so the error emerged.

Similarly, the pupils assumed 70×3 = 210 and then they did not move the decimal point of the product one position to the left. The pupils correctly performed this strategy except for the last production and so the error emerged (Error 22(B)). In the same way, the students multiplied the divisor 0.7 by 10 in order to convert it to an integer but they did not do the same to the dividend. Then they performed the division 490÷7 taking as a result the number 70 (Error 31(A)(ii)) [4]. Apparently, the students retrieved the appropriate set of productions that constitute the specific algorithm concerning division between decimals but they did not apply these productions appropriately. This was due to a weakly developed schema, to memorisation without understanding, and to an improper elaboration of this set of productions.

Finally, the pupils incorrectly assumed that

$(2.1\times10^2)\times(3\times10^4) = 21\times30000 = 630000$ (Error 41).

Thus the pupils applied a correct production in a wrong way, since they were puzzled when they multiplied a decimal by a power of ten. This was due to an incorrectly developed schema concerning the concept of place value. The correct productions that had to be applied were:

"IF there is multiplication of a decimal with a n power of ten THEN move the decimal point n number of places to the right to get the product"

"IF the number m of the decimal places in the decimal are smaller than n THEN move the decimal point n number of places to the right and supplement with n-m noughts the remained places".

In this case a nought has been omitted and the value of other figures changed.

Other reconstructive errors ensued from the students' desire to modify and distort information or productions to make them fit with their already existing knowledge. This was due to the process of accommodation in the case of the failure of a successful and proper retrieval. This was especially the case in Error 31(A)(i), where the pupils multiplied both the divisor and the dividend by 10. Then, they performed the division 4900÷7 = 700. Finally, they moved the decimal point and put it one place to the left of the quotient, as they usually did in multiplication. This shows that the set of appropriate productions that constitute the particular algorithm was memorised without making sense of it, with the result being heavily influenced by the concept of decimal number.

In the same way, the pupils misapplied a correct and appropriate set of productions in a wrong situation that should have been done another way. This led to the emergence of Error 31(B). They simply performed the division, 49÷7 = 7, assuming that the decimal point of the 0.7 is nullified by the 0 in the number 490. That is, they performed the division between the whole numbers, as they did in multiplication 490÷7 = 70. They found the quotient 70. Then they moved the decimal point one place to the left, as they did in the product of the multiplication because of the existence of the decimal 0.7.

E. Integers

There was only one problem (14) included in the test to check the students' skills on the conceptualisation of integers and their manipulation in computations. The emergence of errors can be imputed again to the inappropriately developed schemata that account for the poorly developed declarative and procedural knowledge concerning integers.

The conceptualisation of integers is usually promoted in school-mathematics by the manipulation of scales that indicate temperatures or depths and heights, below or above sea level, rather than with deposits and withdrawals of money from a bank account. This conceptualisation hinges on the use of a number line, of which the scales form a part.

The introduction of the number line, in turn, is the aftermath of the "Arithmetic Is Motion Along a Path" metaphor. This metaphor permits the path to be extended indefinitely from both sides of the origin. Thus, this metaphor is conducive to the conceptualisation of the zero and the negative numbers as point-locations on the path (line). Therefore, they can be realised as numbers just like any other numbers that express quantities. In this way, the transition from Arithmetic to the ideas of Algebra is achieved without getting involved in obscure theoretical accounts. Nevertheless, as Lakoff and Núñez [13, p. 89] have pointed out, this metaphor is not sufficient to ground arithmetic

for zero, negative numbers and fractions. Thus, they extend this metaphor by the introduction of the concepts of rotation, orientation and symmetry to account for the establishment of the four operations among integers. In fact, they define multiplication among integers by the rule: "Rotation by 180° Is Multiplication by –1" [13, p. 90]. This account is very useful in instruction, since it naturally extends the metaphor "Arithmetic Is Motion Along a Path", which, in turn, is easily realised through experience.

Both the English and the Greek curricula make use of the number line to introduce integers, but in different ways. Both of them make use of the number line to represent numbers as locations, but in an arbitrary manner without making clear why this happens.

The English curriculum defines the four operations with integers through the use of movements on the number line. Thus the right-hand or upward movement indicates positive movements, whereas movement in the opposite direction indicates negative ones. This conceptualisation -- covert in the English curriculum -- of the integers and especially the negative numbers has its roots in the conceptualisation of Algebra as being the generalisation of Arithmetic. This issue is discussed below.

In contrast, the Greek curriculum introduces integers by the use of the absolute value of a number to denote the distance of an integer from the origin in the number line. Then, a positive number r is defined through the distance of its representation (location) on the number line in the right-hand direction from the origin. Whereas, its opposite negative number $-r$ is defined through exactly the same distance from the origin of its representation (location) on the number line, but in the left-hand (opposite) direction. The representations of two opposite integers are symmetrical to the origin of the number line, that is, they have the same distance from it. The introduction of the four operations with integers follows this conceptualisation. This realisation -- covert in the Greek curriculum -- of the integers and especially of the negative numbers has its roots in the conceptualisation of Algebra as being a purely abstract, coherent, symbolic system.

Consequently the students' mathematical competence must be considered in relation to both curricula separately.

It seems that the emergence of the response 12 (Error 14(A)) [4] ensued from the students' incorrect use of the number line in order to give an answer concerning increase of temperature. Thus, the students started counting up to 8 from that point on the number line, where the number –5 is located. Whereas they counted up every other number, they omitted to count the number zero (0). They incorrectly assumed it to be a neutral number that had to be left off the numeration. Hence, they reached the answer 12 instead of the correct 13. By counting up from the left to the right or from down to up, they implicitly assumed that the distance that is moved in this way is positive.

Apparently, the error emerged as the result of the application of an incorrect production concerning the number 0 (zero). This particularly used production contains false information constituted as declarative knowledge in the THEN part of it. This production might have had the form:

"IF you start counting up from a point to the left or down from zero and to the direction of a point that is at the right or up to the zero THEN count up the numbers that correspond to the equal intervals except the zero that is a neutral number in the addition".

In this way, the error emerged as an application of an incorrect rule.

The fact that the Greek students were not familiar with using the strategy of making movements along a number line to find out sums should be pointed out. They might have been prompted in the use of this strategy by the representation of a thermometer that is contained as an example in their textbook.

The emergence of the other error 3 (Error 14(B)) might have had a quite different cause. The students correctly represented the problem and recognised it as one that could be coped with by the operation of addition. Nevertheless, they were not properly primed by cues to appropriately retrieve a particular correct set of productions in order to perform the addition (-5) + (+8). These sets of productions accounted for the execution of computations among integers by the English students' use of appropriate movements on the number line. Those sets of productions constituted the English students' skills and mathematical competence to manipulate integers. These sets of productions accounted for the execution of computations with integers by the Greek students' use of the absolute values of the integers as well. These sets of productions responsible for practising operations with integers by the use of their absolute values constituted the Greek students' skills and their mathematical competence to manipulate integers as well.

The students of both samples failed to retrieve the correct set of productions in order to cope with this problem and they had recourse to their already existing knowledge. They deemed these numbers as denoting subtraction between whole numbers. Thus, they performed subtraction instead of practising the set of productions relevant to addition of integers i.e. (-5)+(+8) = 8-5 = 3. Finally, they gave this result as an answer.

F. Problem Solving

It is not enough for students to carry out basic mathematical procedures when they cope with problems that are presented in symbolic form. Although these skills for practising arithmetic computations are sine qua non for their mathematical competence, they are deemed to be low-level skills. The students' mathematical competence requires them to be able to effectively apply these procedures to solve problems that are presented in words. A definition of what word problems are is given by Verschaffel, Greer, and de Corte:

> "word problems are verbal descriptions of problem situations wherein one or more questions are raised the answer to which can be obtained by the application of mathematical operations to numerical data available in the problem statement" [17, p. ix].

These problems are usually *well-defined problems*, where the initially given state, the goal state one has to reach, and the employed set of operators are clearly specified. Students' basic high-level skills of effective problem solving constitute their required mathematical competence. These high-level skills

consist of conceptual understandings, multiple representations and connections, and mathematical problem solving. These are described below.

Problem solving is the term used to describe the cognitive processes or thinking one always develops in order to achieve the transition from the given initial state to the goal state. A problem is categorised as a *mathematical problem* whenever a mathematical operator, that is, an arithmetical or algebraic procedure, is needed to solve it. Problem solving takes place in a mathematical problem when one is not already aware how to find the way to reach the goal state. Mayer (2003) points out that

> "*Problem solving* occurs when a problem solver determines how to solve a problem, that is, how to accomplish the goal" [18, p. 71]([italics in the initial)

Moreover he distinguishes three constituent features:

> "(a) cognitive-problem solving occurs internally in one's cognitive system (but must be inferred indirectly through behaviour), (b) process- problem solving involves mental computation in which a mental operation is applied to a mental representation, and (c) directed- problem solving is based on one's goal and results in activity intended to solve a problem" [18, p. 71].

Problem solving is an indispensable attribute of the mathematical problems that is grounded on the rules of the arithmetic and algebraic theory. Finally, this is distinguished into two components: *mental representations* and the *process of the solution*. Representations are created when one tries to figure out the wording of the problem, whereas the process of the solution comprises the actions that are carried out to achieve the solution.

Mayer ([19], [20]) distinguishes four interdependent cognitive processes as constituent parts of effective mathematical problem solving: *translating*, *integrating*, *planning*, and *executing*. Translating and integrating are constituent processes of the problem representation, whereas planning and executing are constituent processes of the solution process.

Translating is the process of creating a mental representation from each sentence in the wording of the problem. The effective process of translating one develops hinges on his/her semantic and linguistic knowledge. Translating is not always given the importance it needs since many consider it as a simple process that takes place automatically. Nevertheless, many research findings ([21], [22], [23], [24]) stress the fact that many students show serious difficulties in translating, understanding and then internally representing a problem. Mayer and Hegarty [25] set forth two procedures for translating the wording of a mathematical problem. Those are: *direct translation strategy* and *problem model strategy*.

According to the first, the problem solver just picks up numbers from the problem and performs consecutive computations on them, providing a numerical answer by developing simple quantitative reasoning. The computations that are usually carried out are those, which are most strongly primed from the wording of the problem.

According to the second, the problem solver first tries to figure out the situation described in the wording of the problem. Then, he/she tries to create a mental representation of it based on the internal representations that were created from the sentences. Finally he/she tries to devise a solution plan based on that representation. The problem model strategy presupposes an understanding of the relations among the variables in the problem. This is the phase of *integrating*, where the problem solver creates a mental situation model or problem model from the description of the problem. The process absolutely hinges on one's schematic knowledge concerning the problem situations.

The phase of *planning* follows, when the problem solver contrives a solution plan based on the mental situation model that believes it will bring him/her to the goal state. This phase requires strategic knowledge, that is, the way to compartmentalise the solution plan in consecutive steps of action. Conjoint to the planning process are two other sub-processes: *monitoring* and *reflecting* [18, p. 74]. *Monitoring* occurs when the problem solver pays attention and follows the course, the development, and the effectiveness of the solution plan. *Reflecting* is the process of checking over the course of the developed syllogisms that entailed the complete problem solution.

Finally, the phase of *executing* takes place when the problem solver carries out mathematical computations that are constituents of his/her solution plan. This process pivots on one's developed mathematical procedural knowledge.

Consequently, the students' mathematical competence on problem solving requires the mastery of all those four cognitive stages. The students must be able to appropriately represent the problem through translation and integration based on their well-developed semantic, linguistic and schematic knowledge, that is, knowledge of problem situations. Moreover, they must be able to appropriately contrive and implement solution plans that permit them to select appropriate operators. These operators must be correctly applied and practised through the development of the prerequisite strategic and procedural knowledge.

Seven such problems were presented to the students in the test of arithmetic with the intention of checking the students' skills in arithmetic problem solving and to find out any inconsistencies. The errors that emerged on the tests can be imputed to two key causes.

The first is that the errors emerged when the students applied specific operators in order to reach the goal state. The errors resulted from the incorrect execution of the selected operators, although the students were able to correctly represent the problem internally through a correct translation, and the creation of a specific mental model and a solution plan. This can be ascribed to the students' deficiently developed procedural knowledge. The errors that emerged in problems 16, 17, 19 and 23 can be ascribed to that particular case.

The second cause of the emergence of errors can be imputed to the students' incorrect development of the representation of the problems. The students resorted to the direct translation strategy by picking up numbers and executing computations

with them that were most strongly primed by specific words in the problem. They failed to understand and identify the relations among the variables in the problem. They failed to integrate the translation and to create a mental situation model and a solution plan. The direct translation strategy is the method of choice, and a characteristic of less successful problem solvers that frequently leads to incorrect answers. The errors that emerged in the problems 16, 26, 27 and 36 (i) can be ascribed to that particular case.

The errors resulting from the incorrect execution of the selected operators, that were identified in problem 17, were 12 (Error (A)) and 20 (Error (B) (i)) [4]. The operators selected by some students, in that particular problem, were recursive multiplication or recursive addition. Thus, they performed 2×15 = 30, 4×15 = 60, ..., 10×15 = 150, 12×15 = 180, or (15+15) = 30, 30+30+30 = 90, and 30+30+30 = 90 and finally 90+90 = 180. Then, they subtracted 180 from 200 and received 200-180 = 20p without taking into account that 20>15 and 20÷15 = 1 with remainder 5. Others might have performed a long division taking 12 or 13 as a quotient and, as a remainder, the number 20, which they assumed satisfied the conditions of the problem without taking into account the abovementioned constraints. Thus the emergence of the error can be imputed to the incorrect practice of particular sets of productions.

As they did in the previous case, the students might have selected different strategies as operators in order to reach the goal state. One of them might be long division. They incorrectly assumed that the quotient of the division of the 200p by 15p is either 12 or 14 and the remainder is 10 (Error (B) (ii)). Thus, the emergence of the error was due to the incorrect practice of a particular set of productions concerning long division.

In the same way, the errors 2.75 or 3.15 (Error (A)) in problem 19 might be due to the incorrect execution of specific mathematical procedure. Thus, the students may have made a slip in adding the numbers, 1m+2m 40cm+3m 75cm = 7m 25cm, which in turn, by subtracting it from the number 10m, resulted in 2.75. Similarly, the errors 3.85 or 5.15 (Error (B)) in the same problem may be imputed to the same cause. Thus, the slip in this case may have been made in the addition of the numbers, 1m + 2m 40cm + 3m 75cm = 6m 15cm, which in turn, by subtracting it from the number 10 m, resulted in 3.85. The other case may be that the slip was made, when subtracting the correct result of the abovementioned addition, 7m 15cm, from the number 10 m giving as a result 3.85.

The emergence of the error $\frac{40}{100}$ in the problem 16(ii) may be due to the incorrect execution of a particular production. The students represented and correctly solved the problem by use of the proper operators. Nevertheless, they failed to express the answer in centimetres. They symbolised it by the fraction $\frac{40}{100}$ instead of the correct use of the symbol *cm* that denotes centimetres. This might be due to the fact that the translation of the word 'centimetre' in Greek is given by the word 'εκατοστό' that has the same meaning as the fraction $\frac{1}{100}$. Thus, instead of writing 40cm, they represented it symbolically by $\frac{40}{100}$. This might be due to the fact that the students had not been re-taught this section, as this usually happens at the outset of the school year.

The incorrect execution of the selected operator may be the cause of the emergence of error 100 in problem 23 as well. Thus, the students may have recognised that the solution would stem from the multiplication of the number 20 with the reciprocal of the fraction $\frac{2}{5}$. Nevertheless, they did not perform the procedure in a logical sequence, but rather they tried to perform the multiplication with the denominator first. Then, they omitted to divide the product by 2. They failed to represent the problem symbolically and algebraically, that is, $\frac{2}{5}x = 20$, and, in turn, to solve the equation, $x = \frac{5}{2} \times 20 = \frac{100}{2}$ = 50g.

The emergence of other forms of the students' errors might be imputed to their incorrect representation of the problem or to their development of the direct translation strategy that frequently leads to incorrect answers.

This is the case with the emergence of the error $\frac{4}{10}$ in problem 16. Thus, the students identified the first operator, that is, the multiplication of the fraction $\frac{1}{10}$ by the given value 4m. The number 4m expresses magnitude of length, when it is measured by a specific unit (metre). Nevertheless, they did not make the necessary transformation of the form of this magnitude from metres to centimetres, as was asked by the wording of the problem. One probable explanation is that this specific background declarative and procedural knowledge was not available to them. The other is that their representation of the problem was poor, since they failed to keep the goal state in their working memory. Finally, they did not monitor their problem solving process to identify and to rethink carefully whether the strategies they followed had guided them to the goal state. It should be stressed that problem solving as a particular domain of mathematics is not being taught in Greek secondary schools.

The same happened in problem 26, where the emergence of error 34.65 was due to the students' selection of the direct translation strategy. The students just picked up the numbers 3.15 and 11 from the wording of the problem and they performed computations on them, providing a numerical answer by only developing simple quantitative reasoning. The computation that was carried out was the multiplication 3.15×11 = 34.65, which was most strongly primed from the wording of the problem. This was especially cued by the

reference of the 'cost of 11 tickets' in the demanding question in the problem.

In the same way, the students had recourse to the direct translation strategy in problem 27. They just picked up the numbers 50 and 8 from the wording of the problem and performed computations on them providing a numerical answer by only developing simple quantitative reasoning. The computation that was carried out was division between these two selected numbers: 50÷8 = 6.25 or 200÷7 = 28.57. The lack of the development of any appropriate representation of the problem, and the contrivance of a particular plan based on that representation is obvious.

Similarly, the students selected the direct translation strategy when they coped with problem 36. They simply picked up the given numerals, 20 and 120, and performed a computation on them to provide an answer, based on a poorly developed representation of the problem through sentence translation. Thus, they added this value to the price of the TV that resulted after the reduction and provided the answer that ensued from this addition, £120+£20 = £140 (Error (A)). The Greek students made the same calculations in drachmas, that is, 120000+20000=140000 (Error (B)), incorrectly assuming that 20% = 20000 drachmas.

The emergence of the error, £144 or 144000 drachmas, (Error (B)), in the same problem can be imputed to the students' resort to the direct translation strategy as well. The students did not correctly identify the problem situation and failed to properly and symbolically represent it, especially the goal state. They did not make sense of the conditions of the problem situation through translation of the wording of the problem. Thus, they failed to map the relationships expressed in the problem in a written form into mathematical concepts, symbols and procedures. Their failure was due to the selection of inappropriate operators based on an incorrectly developed plan of the solution, which, in turn, was founded on an inappropriately developed situation model of the problem. They incorrectly assumed that the initial price of the TV set was 100% + 20% = 120% = 1.2 of the price after the reduction, that is, £120 × 1.2 = £144 or 120000 × 1.2 = 144000 drachmas.

G.Substituting Values Of Variables

Substituting values of variables in a formula, and finding out the value of a specific variable from that formula, constitute a students' basic skill. This particular skill is based both on making sense of the concepts of the *variable* and of a *formula*, and on the procedural knowledge of conducting substitutions and computations as these are prescribed by the formula. Thus, the students' competence for the skill is determined by the effective performance of this skill in problems that use specific formulas and their transformations into arithmetical expressions. This is a key skill that the students have to develop in order to be introduced to the ideas of Algebra. Moreover, the acquisition of the skill would enable them to cope effectively with problems in science.

The students' competence for the skill was tested through the use of problems 24, 37 and 47. The error analysis indicated that the students did not experience any problem in realising the concepts of the variable, of the formula, or in making correct substitutions of the variables with their specified values. The analysis indicated that the students' errors could be imputed to their incorrectly developed procedural knowledge on executing particular computations with numerals as these were prescribed by the formula. This was the case for the emergence of the errors in problems 37 (Error (A)), 47 and 24 (Error (B)) [4]. In contrast, Error (A) and Error (B) in the problems 24 and 37 respectively were due to another cause, that of the improper identification of an operator that was implicitly denoted.

Thus, when the students were presented with a formula and the specific values of the variables that were included in it, the students at first tried to represent it internally. The input percept was stored in their ocular sensory register and was detected under the process of attention but it was not necessarily understood. Then it was translated from a physical stimulus to a symbolic mental representation through the process of *pattern recognition*, which enabled the students to form perceptual information into the recognizable pattern. The input was processed in the working memory.

The students made sense of that particular mathematical expression by recognising the specific symbols and by making the symbol-arrangement analysis in each of the presented problems 24, 37 and 47. Thus, according to the first process, they converted the input into a set of symbols as these denoted by the specific letters. The students' mind dissected the mathematical expression taking into account the given notational conventions. Then the students' mind disclosed the meaning and the information content and, as a consequence, it replaced the recognised letters with their given values. Thus, the segmentation, the isolation, and the recognition processes of the particular symbols were successful.

The students retrieved the appropriate set of productions in order to perform the specified operations in problem 24 after having recognised the particular symbols and having made the appropriate replacements. Thus they performed: $v = u + ft = 5 + (-2)\times4 = 5+8 = 13$ (Error (B)). Apparently, their retrieval of the appropriate production responsible for the multiplication (-2)×4 was false, and it was reconstructed into +8, instead of the correct –8. Thus, an appropriate operator was misapplied and the error emerged.

In the same way, the students' mind was also successful in the process of symbol-arrangement analysis in problem 37. It identified and made sense of the logical arrangement of the operator that was implicitly denoted by the relative symbol placement as being the exponentiation 0.3^2 and 0.4^2. The students retrieved the correct production accountable for the correct application of the particular operator. Nevertheless, the performance of the square power of 0.3^2 and 0.4^2 led to important errors.

In this case, the students incorrectly assumed that $0.3^2 = 0.9$ and they performed:

$$s = ut + \frac{1}{2}at^2 = 10\times0.3 + \frac{1}{2}\times20\times0.9 = 3+10\times0.9 = 3+9 = 12$$

(Error (A)) and the error emerged. Certainly, the students did not recall the appropriate set of productions in order to correctly

perform the multiplication between decimals. Similarly, the English students coped with a slightly different problem in the second round of testing, since the values of the variables had been changed. For u = 20, t = 0.4, a = 10 they incorrectly assumed $0.4^2 = 1.6$ and they performed:

$S = ut + \frac{1}{2}at^2 = 20\times0.4 + \frac{1}{2}\times10\times1.6 = 8+5\times1.6 = 8+8 = 16$

(Error (A)). The error 37(A) was again due to the incorrect performance of the algorithm of multiplication between decimals.

Similarly, the pupils succeeded in correctly performing the placement of the values of the given variables a=2 and b= -1 in problem 47, but afterwards incorrectly added the two denominators and left the same number 1 as a numerator. The explanation is exactly the same as that one concerning the addition of the two fractions in question 11. In this case, the students' thinking did not have recourse to the Gestalt principle, but rather their recall was based on an improperly developed schema concerning the addition of two fractions, that is:

$$\frac{a}{b}+\frac{c}{b}=\frac{(a+c)}{b}$$

So, for equal denominators, the numbers were added. Here they have equal numerators, so the pupils have transferred the method for equal denominators to equal numerators and they also have ignored the different operator. They have reconstructed their poor recall in order to fit the case. Thus, this was a reconstructive error that ensued from the students' desire to modify and distort information to make it fit with their already existing knowledge, through a process of accommodation, because of the failure of a successful and proper retrieval.

The cause of the emergence of some errors in problems 24 and 37 was quite different. Although the students' mind was successful in the process of recognition, it failed to be successful in the process of symbol-arrangement analysis. It failed to identify and make sense of the operator that was implicitly denoted in the expression *ft* by the relative symbol placement in problem 24. Hence, the students' mind failed to identify the spatial and logical relationship between these two symbols. Identification of these relationships is difficult for many students and presupposes a great deal of knowledge of the conventions that specify them.

Thus, the pupils misunderstood the lack of a multiplication sign in the *ft* expression in problem 24, which is implicitly denoted by this relative symbol placement. They incorrectly assumed it as denoting addition. Accordingly, they practised:

$ft = -2+4 = 2$ and $v = u + ft = 5+2 = 7$ (Error (A)).

The emergence of the particular errors in problem 37 was due to the students' incorrect application of a wrong set of productions in order to calculate the square power of 0.3^2 and 0.4^2. Thus, the students may have incorrectly assumed that $0.3^2 = 2\times0.9$ and $0.4^2 = 2\times0.4$. In this case, the pupils incorrectly assumed the exponentiation as being a multiplication, that is, $0.4^2 = 2\times0.4$. Thus they performed:

$S = ut + \frac{1}{2}at^2 = 10\times0.3 + \frac{1}{2}\times20\times0.3^2 = 3 + \frac{1}{2}\times20\times2\times0.9 = 3+18 = 21$ and

$S = ut + \frac{1}{2}at^2 = 20\times0.4 + \frac{1}{2}\times10\times0.4^2 = 8+\frac{1}{2}\times10\times2\times0.4 = 8+4 = 12$ (Error (B)).

This kind of error has been shown to be very common in many studies, especially among English and Australian students ([26], [27], [28], [29], [30], [31]). Stacey and McGregor [31] it '*conjoining error*'. Many explanations have been provided concerning the '*conjoining error*' in these studies. These researchers have ascribed the emergence of this particular error to many causes. One that has not been provided and seems to be plausible enough ascribes the emergence of this error to the following factors. The emergence of this error is due to both the use of the specific symbolism for multiplication in English textbooks, and to an incorrect encoding during the process of instruction.

The symbol '×' is in common use in English textbooks and denotes multiplication especially between numerals. The convention that holds concerning multiplication between letters and numerals is implicitly denoted by a simple conjoining relative symbol placement. This is specified by a simple statement, i.e. $n + n = 2\times n = 2n$. Whereas, the symbolism $n\times n$ denotes repetitive multiplication and thus exponentiation, that is, an operator implicitly denoted by the particular relative symbol placement n^2. Thus, the symbolism $n + n = 2\times n = 2n$ denotes addition whereas the symbolism $n\times n = n^2$ denotes multiplication. The incorrect encoding of these particular representations defined by the two symbols '+' and '×', because of their visual similarity, leads to confusion over their use. Moreover, they lead to the emergence of the error coined as '*conjoining*', or to the misconception that $2n = n + n = n \times n = n^2$, which is found in many research studies.

The other reason concerning the emergence of that particular error might be the students' familiarity with the conceptualisation of the place-value convention. This particular convention is denoted by a function that is one-to-one correspondence or mapping between digit linear strings and numbers. Each number is represented by a linear digit string arrangement, which is constituted by the joint use of both the basic assignment of each digit symbol to its specific number and its position in the string. The operation of addition is used to denote the value of each digit in the relative linear concatenation of those symbols in a number. For example, the students are familiar with the conceptualisation that the particular relative placement of the three digits i.e. $\underline{407}$ in a linear concatenation implicitly denotes an addition. They have learnt that the digit $\underline{4}$ represents four hundreds, the digit $\underline{0}$ represents zero tens, and the digit $\underline{7}$ represents 7 units, and finally the number 407 is composed of, and represents the sum of, those magnitudes.

The students are called to radically alter this conceptualisation and their well-developed schema since their first schooling years, when they are introduced to the

symbolism of multiplication between numerals and variables. This alteration is forced to induce by the introduction i.e. of the symbolism 2xy, based only on a simple reference of the convention denoting the multiplication among these three symbols. This is impossible, as many research studies indicated, for a significant number of students. Whereas, it would be detrimental for the students to believe that for example, the linear digit string 243 could denote a multiplication among the numerals $2\times4\times3 = 2\cdot4\cdot3$, in fact, they are forced to accept that this convention can hold among numerals and variables. Moreover, the students are forced to come to realise for reasons of simplicity and abstraction, -- by a simple reference of the convention, -- that the symbolism of multiplication among numerals and variables i.e. $2\times x\times y$ or $2\cdot x\cdot y$ (in Greek textbooks) can be denoted by the simple concatenation of the symbols without the intervention of any specific symbol. Furthermore, the students are called to conceptualise this particular convention at an age where the conceptualisation of the variable, and its use as a general number, is yet frail.

This well-established and entrenched schema, concerning the conceptualisation of the place-value convention for a number from the relative placement of its digits into a linear string concatenation, is resistant to change. Thus, the assimilation of the new convention must gradually take place by the introduction of convenient and appropriate symbolism and by the use of as many cues as possible during the instruction. This fact must be taken into account in the design of instruction, textbook writing, and in the development of other instructional materials.

ALGEBRA

IV. Errors In The Test Of "Algebra"

An ability to perform rudimentary arithmetic computations such as subitizing, estimating numbers, and executing simple operations of addition and subtraction, has been found in many species and in babies [13, p.21]. Nevertheless, among all species only humans can develop the ability to reason at a high-level of abstraction by creating mathematical representations and operating on them. This ability is gradually developed through an organised and systematic intervention by education and human experience, which, in turn, are developed by evolution, culture and history. Thus, the educational system in almost every country demands from every child that he/she develops appropriate mathematical representations and masters arithmetic operations during a period of seven to eight years, so as to be able to implement them in problem-solving.

The problems in students' competence in school mathematics start emerging with the introduction of the concepts of Algebra almost at the age of thirteen. The roots of these problems might be detected by studying the conceptualisation of what exactly the nature of Algebra is, covert in the curricula.

The nature of Algebra is an epistemological problem that arose through the debate among British mathematicians in the first half of the 19th century ([32], [33]). The emergence of this issue divided the mathematicians into two groups. One group asserted that Algebra is *universal arithmetic*. They conceptualised Algebra as being a natural, coherent aftermath of Arithmetic. This conceptualisation of Algebra as being the domain of the study of quantities and the operations that are permitted to be applied to these quantities was denoted by this term. Piaget also considered algebra as ensuing from reflective abstraction from arithmetic and as the aftermath of operation on operations. He states that reflecting abstraction

> "is the general constructive process of mathematics: it has served, for example, to construct algebra out of arithmetic, as a set of operations on operations" [34, p. 125].

Moreover, the key conceptualisation was that the rules of Algebra were prescribed authoritatively by the properties of these operations developed in quantitative Arithmetic. This belief brought Algebra into direct contradiction with the legitimacy of the use of negative integers, irrational and imaginary numbers in that domain. This happened because these numbers cannot be deemed to be measures of quantity. The other group of mathematicians embraced the belief that Algebra is a purely abstract, coherent, symbolic system founded on arbitrarily established symbols, postulates and rules.

Wheeler [33] alleged that Algebra is usually presented in school curricula as stemming naturally from Arithmetic as a *generalisation* of it. The consequence of this conceptualisation is that the pedagogy of this school Algebra is not consistent because it is not always apparent to the students that its rules are deducible from the rules of Arithmetic. So it permits students to create confusion and to call into question the grounds of the justification of particular algebraic transformations. The main question that was raised by Kieran is:

> "Is such-and-such a transformation legitimate because it is implied by the behaviour of quantities or does it depend on some apparently arbitrary rule?" [35, p. 98].

The consequences of this kind of confusion over the grounds of Algebra have been identified and pointed out in a number of studies (see Kieran, 1990, p.98). A theoretical account is given below based on an analysis conducted by Lakoff and Núñez, [13, p. 107].

The fact that the English curriculum has been founded on this belief should be stressed. Piaget's conceptualisation of Algebra was the bedrock of its development as well. The Greek curriculum was developed on the basis of revisions of by-products of the curricula that were established during the New Maths Era. This curriculum is based on the ideas of the N. Bourbaki group, founded on the belief that Algebra is a purely abstract, coherent, symbolic system. It was grounded on arbitrarily established symbols, postulates and rules and should be taught as such.

These two different conceptualisations concerning the domain of Algebra created different kinds of problems for students. The aftermath of the influence of these curricula in the students' conceptualisation of algebraic ideas became apparent in the following error analysis.

A. Number Patterns

A *sequence* is a particular category of numbers, in which numbers form a particular pattern. Specific numbers are deemed to be included in that category, if they conform to a particular set of attributes and characteristics that are singly necessary and jointly sufficient for their categorisation as such. Sequences are deemed to be the appropriate introductory means by which the structures of Algebra can be conceptualised.

Mathematical cognition, and especially algebra, use as means for development not only conceptual schemata, but other more complicated conceptual structures or cognitive mechanisms, in order to express abstractness and generality. One of these conceptual structures is *metaphor*. Conceptual metaphor is a particular cognitive mechanism that permits reasoning about a specific entity, as if it were another one. Lakoff and Núñez, determined the *conceptual metaphor* as:

> "a *grounded, inference-preserving cross-domain mapping*-a neural mechanism that allows us to use the inferential structure of one conceptual domain (say, geometry) to reason about another (say, arithmetic). Such conceptual metaphors allows us to apply what we know about one branch of mathematics in order to reason about another branch" [13, p.6], italics in the original).

A distinct common metaphor widely used in mathematics is the metaphor "*Categories are Containers*" [13, p.43]. This particular metaphor allows us to think of a category of objects as being a bounded region in space and the objects as points inside that region. This particular metaphor, in conjunction with the "Container Schema", the "Aspect Schema", and the "Into" and "Out-of Schema", are accountable for our ability to make sense of numbers, to categorise them, and to perform operations such as addition and subtraction.

Lakoff and Núñez [13, p.51] assert that these schemas and the "Categories are Containers" metaphor are not enough for doing arithmetic, but rather that other simpler capacities have to be developed in order for one to develop such ability. Thus one should develop capacities of "grouping", "ordering", "pairing", "memory", "exhaustion-detection", "cardinal-number assignment", "independent-order", "combinatorial-grouping", "symbolizing" and "metaphorizing".

The English curriculum employs the concept of *number patterns* or *sequences of numbers* in order to achieve the transition from the concepts and procedures of Arithmetic to those of Algebra. The employment of number patterns in this curriculum was purposefully established following the belief that Algebra naturally stems from Arithmetic as a *generalisation* of that. Furthermore, its main aim is to find out critical principles and relationships that hold among numbers. These principles and relations in turn permit us to categorise numbers accordingly and to generalise their behaviour in order to use them in practice by making predictions.

Also, sequences introduce induction as a way of thinking. An introduction to the conceptualisation of the processes of algebra, that allows the realisation of such categorisation among numbers, is the presentation of lists of numbers that constitute a particular sequence. These lists of numbers permit one to realise how the terms of a sequence are related and, in turn, to recognise number patterns that are regulated by a specific formula or rule. Accordingly, one comes to realise the general attributes and principles that constitute a particular category of numbers and describe its members, without it being necessary to work out or refer to all the members of the category. According to this mode of organization, abstraction is achieved, and the abundance and complexity of the information are restricted. Furthermore, the information per se is characterised by coherence, cohesiveness and economy.

Consequently, the students' mathematical competence is characterised by their ability to identify the specific relation among the numbers in a list and to describe it by a specific formula or rule. They must be able to employ appropriate and specific mathematical reasoning (inductive) and operators for this purpose.

Thus, question 2 was presented to students in order to check their conceptualisation of these procedures as being critical for their mental transition from Arithmetic to Algebra. This particular topic is not included in the Greek curriculum. This fact should be stressed in order to make sense the reasons of the failure of a high percentage of the Greek students to provide a correct answer at that question.

The students' errors on that particular topic can be classified into two key categories. The first category contains these errors that were due to a mistakenly performed operation, whereas the students seem to have identified the number pattern and the general rule or formula that the numbers follow. Error 71 (Error (A)) that was made by the Greek students belongs to that category. The second category contains these errors that were due to the students' failure to conceptualise and to identify the general rule and the formula that the list of presented numbers followed. Errors $\frac{1}{6}$ (Error (B) (i)) and $\frac{1}{3}$ (Error (B) (ii)) [5] belong to this category.

Thus, the students recognised the symbols of the first sequence in question 2 as numbers. They identified the spatial and logical relationships among symbols. Furthermore, they realised that they form the terms of a sequence and, in this way they constructed the specific meaning. Hence, the students discerned that the logical relation among the numbers of the list is that they form equal ratios: $3=\frac{9}{3}=\frac{27}{9}=\ldots$, or that each term of the sequence ensues from the previous one by multiplying it by three i.e. $9 = 3\times3$, $27 = 9\times3$,.... When they came to find the next term they incorrectly performed $27\times3 = 71$ (Error (A)). Consequently, the students did not perform correctly the particular set of productions that constitute the algorithm of multiplication.

The two errors that emerged in the second sequence of question 2 might be due to the students' failure to identify the logical relationships among these numbers in the list. So, they failed to realise that the terms of the sequence formed a constant ratio: $\frac{1}{2}=\frac{\frac{1}{2}}{1}=\frac{\frac{1}{4}}{\frac{1}{2}}=\ldots$, or that each term of the sequence ensued

from the previous one by its multiplication by $\frac{1}{2}$. Instead, the students incorrectly assumed that the denominator would be decreasing by 2 each time. In this way, a wrong recognition induced the retrieval and application of an inappropriate set of productions and the emergence of the $\frac{1}{6}$ (Error (B) (i)) [5] occurred.

In the same way, the students failed to identify the logical relationships among the numbers in the presented list of the second sequence in question 2. Hence, the students retrieved a particular set of productions that accommodated it according to their existent knowledge in order to cope with the specific problem. In particular, they started by finding the difference between the first and second term, i.e. $1-\frac{1}{2}=\frac{1}{2}$, and then they added this difference to the following term of the sequence, $\frac{1}{4}$, in order to find the next one. But by doing so, they assumed the sequence to be linear, that is, each term increases or decreases from the next one by the same amount. In fact, they did not find the difference between the second and third terms, $\frac{1}{2}$ and, $\frac{1}{4}$ in order to ascertain that the difference is the same, and consequently that the sequence really is a linear one. Finally, they added the difference, $\frac{1}{2}$, to the last provided term, $\frac{1}{4}$, in order to obtain the next term albeit mistakenly: $\frac{1}{2}+\frac{1}{4}=\frac{2}{6}=\frac{1}{3}$ (Error (B) (ii)). In this way, they mistakenly represented the problem and applied an acceptable procedure however, in a situation that needed to be worked out in a different manner.

B. Problem Solving

Four problems were used in the test in order to check the students' competence to solve algebraic problems. Two of them, problems 4 and 15, referred to the topic of number patterns. The other two, problems 9 and 3, tested the students' ability to effectively use the concept of a variable to appropriately represent the wording of a problem.

Both problems, 4 and 15, are well-defined problems with an initial state and two goal states. Although the first problem, 4, provides clear-cut cues that the topic of the mathematics that is referred to is that of sequences of numbers, this does not happen to the second one, 15. It is not possible to cope with this particular kind of problem by the employment of a particular algorithm, whose application would lead to a certain solution. In particular, the students needed to develop their own representation, solution plan and strategies in order to reach a solution.

Consequently, the students' mathematical knowledge consists of two components: the creation of appropriate *mental representations* and the implementation of an appropriate *process of solution,* through the four stages as identified by Mayer [18]. Representations are created when one tries to figure out the wording of the problem, whereas the process of solution comprises the actions that are carried out to achieve the solution.

Especially in problem 15, first the students should have internally represented and understood the problem statements. Then, they should have identified the nature of the problem by constructing a problem model transforming the representation from a proposition-based one to the problem situation representation. This might have happened by analysing the component parts of the problem and jotting down the different stages that the ball reached after bouncing on the ground, taking into account the original height from where the ball was dropped. This activity should have guided the students to identify the different stages of the problem and the respective problem space. Accordingly, the students would have been able to construct a solution plan, based on their strategic knowledge, and in turn to identify the operators and their constraints involved in the problem. This did not happen. Consequently, the errors that emerged in these two problems can be divided into two main categories.

The first category contains these errors that were due to the incorrect representation of the problem and thus to the selection and execution of inappropriate operators. Errors 1000 or 400 (Error (A) (i)), and 1500 or 600 (Error (A) (ii)) of problem 4, and errors 8 (Error (A)), 27 (Error (B) (ii)) of problem 15 belong to this category [5].

The second category contains these errors that were due, not to the incorrect representation of the problem, but either to the mistaken application of a correct operator, as was the case in error 0.4 (Error (B) (i)) of problem 4, or to the selection and execution of inappropriate operators although a correct representation had been achieved. Error 3 (Error (B) (i)) of problem 15 belongs to the latter category.

The emergence of the errors that belong to the first category was due to the fact that the students failed to appropriately represent the problems internally. They failed to appropriately translate and integrate the problem in order to reach a problem model. They created a representation that contained less information than that contained in the initial wording of the problem. They failed to make sense of the problems with their particular different stages, in order to create a solution plan and to select appropriate operators. They made a direct translation of the problem by picking up what is given in the problem (numbers). The students developed their own strategies and attempted to give answers dependant on their own existing knowledge in order to reduce their discomfort.

Thus, in problem 4, both the Greek and English pupils might have incorrectly assumed that the differences of the sizes were increasing by 200 ml each time. The transition from the difference 200 to the difference 400 contributed to this misconception. In fact, they added this assumed difference to

the last bottle before that with the super giant size, in order to obtain the size of the super giant bottle.

The success one has when implementing a specific strategy greatly depends on the way one identifies and represents the problem and the type of strategy one applies. It became clear that, although the selection of that strategy was correct, its application was faulty. This was due to a wrong decision, made based on assumption and intuition, rather than on ascertained facts through the calculation of the differences between the values of the sizes of the bottles. Thus the students' decision was based on the difference between the sizes of the bottles of 400 ml and 200 ml, rather than on a systematic identification of the constancy of the difference between their sizes. Hence, if the students had applied the strategy they had learnt, they should have tried to find out whether these differences were equal (i.e. 200-100 = 100, 400-200 = 200, 800-400 = 400). As a consequence, they should have recognised this sequence as being a non-linear one. So, they should not have added the assumed constant difference of 200 to the size of the last bottle 800 ml, that is, 200+800 = 1000 ml (Error (A) (i)), in order to obtain the size of the giant bottle. As a result, the misapplication of the first production led to the application of the second one:
"IF the numbers of the ordered list 100, 200, 400, 800, have equal differences THEN classify it as a linear one".
"IF this ordered list of numbers 100, 200, 400, 800 is a linear one, THEN add the standard difference of them in the last number in the list in order to find the next one".

The same explanation holds for the English students, who made the same error in the second round of testing, although the wording of the problem had been changed. They assumed that the differences between the numbers were equal (80-40 = 40, 160-80 = 80, 320-160 = 160) based only on the difference between 160 and 80, i.e. 160 – 80 = 80, and then the pupils added this number to the next one, 80+320 = 400 (Error (A) (i)), in order to provide the subsequent one.

Similarly, the emergence of the error, 1500 or 600 (Error (A)(ii)), in problem 4 was again prevalent among the Greek students, especially in the first and the second rounds of testing. In this particular case, the students failed to identify and represent the problem as being one of sequences. The students' failure to recognise the problem as being one concerning sequences, led them to employ the direct translation strategy. They just picked up the numbers and applied another one, consistent with the students' existent knowledge that could preclude them from the discomfort of not giving an answer. Thus, they invented a strategy that could bring them from the initial state to the goal state. So, this strategy was the addition of all the numbers given in the ordered list, 100+200+400+800 = 1500 (Error (A)(ii)). Nevertheless, the fact that should be emphasised is that Greek students receive neither specific instruction for the development of problem solving skills, nor instruction concerning the concepts of sequence and number pattern.

In the same way, about 1.5% of the English students gave the number 600, in error, when tested with the same problem 4 at the second round. The fact that should be emphasised was that the wording of the problem had been altered. Consequently, the students' conceptualisation of the problem radically changed as well. Nevertheless, these students, as did their Greek counterparts in the previous case, added the numbers in the ordered list, 40+80+160+320 = 600, and the error 600 (Error (A)(ii)) emerged.

Similarly, the students were not able to represent the problem 15 internally. They did not identify its nature by inferring that this was a problem that involved the concept and procedures of sequences. Thus, the students incorrectly assumed that the height the ball would reach after one bounce would ensue from the division of the original height by the sum of the only given numbers, $\frac{3}{4}+\frac{3}{4}=\frac{6}{4}$, that is, $12\div\frac{6}{4}=12\times\frac{4}{6}=\frac{48}{6}=8$ (Error (A)).

In another case of understanding, they correctly computed the first question, $12\times\frac{3}{4}=9$, and then they incorrectly assumed that the height the ball would reach after three bounces would be the result of the multiplication three times of 9m, that is, 9×3 = 27m (Error (B)(ii)). In this way, they failed to realise that the height the ball reached each time faded out as a result of its multiplication by $\frac{3}{4}<1$. The students, by following the direct translation strategy, just picked up the numbers and created their own idiosyncratic strategies in order to cope with it. They failed to appropriately represent and identify the conditions of the problem. They just engaged in quantitative reasoning, without understanding the problem, and they provided an answer based on these computations to avoid discomfort.

Except for these errors, students showed an error, 0.4 (Error (B) (i)), in problem 4, which was due to the mistaken application of a correct operator. Thus, they correctly identified what was the demanded state. They applied the value of the 400 ml bottle into the given formula, cost = 0.1×contents (ml), in order to find the cost of this bottle. This particular error emerged as a misapplication of the correct set of productions in order to perform the algorithm of multiplication. The pupils performed the multiplication, 4×0.1 = 0.4, where 4 is the number of hundreds and they did not multiply afterwards by the 100, as they should have done. The multiplication of multiples of 10 by decimals seems to have puzzled the Greek students a lot.

On the other hand the error, 3 (Error (B) (i)), of problem 15 can be ascribed to the selection and execution of inappropriate operators, although a correct representation had been achieved. The students correctly answered the first question by assuming that the height of the ball after its first bounce on the ground should have been obtained by computing $12\times\frac{3}{4}=9$ m. Then, these students were unable to apply appropriate operators and strategies in order to identify the nature of the particular sequence that was involved, from the conditions and constraints of the wording of the problem. They failed to apply specific strategies in order to recognise and make decisions concerning

the particular kind of sequence, as being linear, quadratic or one of another kind.

Hence, some of them assumed that the sequence would be a linear one. Consequently, they computed its second term 9m, as being the height of the ball after its first bounce on the ground. Then they assumed that the next terms would differ from each other by 3 units i.e. 12, 9, 6, 3. Since the height after the first bounce was 9m they assumed that the height after the second bounce would be 6m and the height after the third bound would be 3m. Thus, they gave this value as an answer.

Other students assumed that the sequence would be a linear one but its terms would differ from each other by $\frac{1}{4}$. Thus they incorrectly assumed that, since the ball reached $\frac{3}{4}$ of the original height after one bounce, the ball should have reached $\frac{2}{4}$ of the height the second time and it should have reached $\frac{1}{4}$ of the height the third time. Consequently, they computed $12\times\frac{1}{4}=3$ m (Error (B)(i)) and gave this value as an answer.

Quite different was the way the students dealt with the other two problems, 9 and 3. These two problems are also well-defined ones. Problem 9 was presented in the testing programme to assess the pupils' capability to express the wording of the problem algebraically. In fact, the students' mathematical knowledge was tested concerning their ability to make sense of the relationships that were verbally expressed in the problem and to map them onto mathematical concepts and symbols by the use of variables. This is a mathematical problem, which requires mathematical reasoning depending on the rules of the number system. Accordingly, the students first had to make an internal representation of the problem through the reading of the wording of the problem. Then, they had to express it by a formula -- which is the goal of the problem -- after having identified the internal relationships from the wording of the problem. The error $n = 20n$ or $n = 30n$ (Error (A)) was due to an incorrect understanding of the concept of a formula. The mind's Gestalt property of closure contributed to the formation of this particular error. In direct contrast, was the emergence of the error $n = 20$ or $n = 30$ (Error (B)). This ensued from the students' implementation of the direct translation strategy.

Thus, in the problem under study in the first case, the students failed to integrate the information presented in the problem with their schematic knowledge. For example, the mental representation of this particular problem hinges on knowledge of buying something from a shop and the computation of the cost of the goods from the equation, "total cost = unit cost × number of units". Thus, the problem solver needs to know how to organise this schematic knowledge with the information incorporated in a particular problem and to adapt it to the requirements of the problem situation in order to make sense of it.

A review of many related research studies, which was made by Verschaffel et al. [17], indicated that this process is difficult for students and liable to result in errors. Students are not always able to use their prior knowledge to make sense of the problem under study. They are prone to fail when they try to integrate a mental model of the problem. According to the "*suspension of sense-making hypothesis*" [18, p. 79], many errors in mathematical problem solving are imputed to this failure.

The students identified and comprehended the symbol n as being a general number, and the cost of the n cakes as being the product of the multiplication $20n$. Then they tried to organise this information with their existent schema concerning the cost of the goods, from the equation "total cost = unit cost × number of units". This organisation was primed by the word 'formula' contained in the problem.

The students always apprehend a formula as being an algebraic combination of symbols and numbers containing the 'equal' symbol that triggers off the execution of operations that ascribes a particular value to a specific variable. Moreover, they connected the unknown number with an equal sign in order to declare correspondence or association. This imposes the execution of an operation rather than stating equality. This fact stems from their developed schema concerning arithmetic.

Pupils are used to identities (tautologies), equalities that hold true for every element of the set of natural numbers. In arithmetic, the equal sign joins co-referring[1] (see Appendix I) terms, that is, different representations of the same entity. Moreover, the equal sign always triggers the transformation of the current representation to its consecutive co-referring one. These terms express transformations on the representations without changing the truth or falsehood of the sentence or the train of thought in which they are used. Furthermore, it is used jointly as a representation of a problem with the result of the execution of the consecutive transformations on that representation or mental model of the problem. In this case, n was used to denote the association of the cost of the cakes with the numerical result of the computation.

Finally, the organisation of the information incorporated in the problem, and the existent one contained in the students' organised schemata, might have resulted from the Gestalt principle of '*closure*'. The term 'closure' is used to explain our tendency to supply missing information to close a figure or structure and to separate it from or connect it to its background. Thus, the pupils considered the expression $n\times20$ as incomplete and as one that needed an evaluation. Consequently, they used the equality to complete the structure and to link it with the context of the problem. This 'lack of closure' explains pupils' psychological tendency to connect the answer with the concept of cost and to 'complete' it with equality.

Thus, the pupils felt the necessity to connect the cost of the cakes with the expression $n\times20$ that represents its numerical result. But, in this case, the pupils' conceptual structure concerning the concept of the variable did not permit them to use another letter as a variable that should have represented the cost of the cakes. Therefore, they used the same letter n instead.

The development of such a misconception may also have been due to the way several of their textbooks were written. For example, the Banks et al. textbook "Mathematics for SEG GCSE" states: "A formula is an algebraic rule. It always has an equal sign" [15, p. 133]. The same textbook writers give the definition: " an expression is just an answer using letters and numbers" (p. 133). The dictionary of mathematics of Borowski and Borwein defines the formula as being:

> "1. any sequence of symbols of a FORMAL CALCULUS, whether or not complying with the FORMATION RULES of that theory...
> 2. such a sequence that is syntactically correct; a sentence or WELL-FORMED FORMULA of any formal theory" [36, p.227].

According to this definition, a monomial is a formula. There is not any stipulation that the equality symbol has to be contained.

Thus, the students tried to use a variable to represent the concept of the 'total cost of cakes'. The students failed to invent one because their developed schema concerning the concept of a variable did not permit it. Consequently, they had recourse to the existent one that was activated by the wording of the problem, that is, by the number of the cakes n. As a result, they equated the product $20n$ or $30n$ of the multiplication "unit cost × number of units" with the letter n and the error was shown, i.e. $n = 20n$ or $n = 30n$ (Error (A)).

Other students failed to integrate the relevant information in the problem, and in their existent knowledge, into a coherent structure and to create a mental model of the problem situation. A major distinction has been made and shown by Mayer (1981) concerning the nature of a word problem. He asserted that the components of each problem are the *assignment statement* and the *relational statement*. When a numerical value is ascribed to a variable, then the process is referred to as assignment, whereas when there is a specification of the quantitative relation between two variables in a problem, then this process is called relational. For example, in that particular problem, the statement "one cake costs 20p." is an assignment statement, whereas a specific number of cakes and their cost is the relational statement. Mayer and Hegarty [25] have shown that students make more errors in remembering and identifying relational statements that in remembering assignment statements.

The students used the *direct translation strategy*, in which they selected the relevant numbers, 20 or 30, and n, giving the numbers 20 or 30 as values of the variable n. Consequently they wrote $n = 20$ or $n = 30$ (Error (B)). They failed to develop a relational statement between the variables. Again the use of the equal sign might be due to the lack of closure, resulting from their psychological need to organise the selected information.

Finally, error 16 in problem 3 arose from the students' incorrect problem representation. The students followed a direct translation strategy. Accordingly, they selected the key numbers and performed arithmetic operations that were mostly strongly primed by the key words in the problem. They did not develop a particular problem model that would lead them to the expression of the relation between the variables of the problem and to the creation of an appropriate equation. Then the solution plan they created was executed according to the priming of these specific words.

Thus, the words 'take away' primed a subtraction of the available number, 1, from the other given number, 33. The students performed this operation and they took 33-1 = 32. Then the word 'doubles' primed the reverse operation, that is, the division, since they recognised it as an inconsistent language problem. Thus, they divided the number ensuing from the subtraction, that is, 32÷2 = 16. They took the number 16 and gave it as their answer. In this way, they created an impoverished representation of the problem. They failed to create the relation between the variables and to take into account all the information that was contained in the wording of the problem.

C. Algebraic Procedures

> "Algebra is the study of mathematical form or 'structure'. Since form (as the Greek philosophers assumed) is taken to be abstract, algebra is about abstract structure" [13, p. 110].

According to that conceptualisation, the variable that is represented by a letter becomes a representative of each member of a set of elements. This set is formed by the specific properties that hold among its constituent members, that is, it is a 'structure'. Simultaneously, this letter becomes an independent object that is amenable to transformations through the operations that hold and determine the 'structure' and the essential properties of these operations. Moreover, each of these operations that is described and absolutely determined by the properties of the elements of the particular set under study, are self-existent and independent, with their own symbolism. Nevertheless, the terms that are still held for these operations and the respective symbolism are these of 'addition' and 'multiplication', since the domain of mathematics from which Algebra originally came is Arithmetic. This does not become clear especially in the development of the English curriculum, where the conceptualisation of Algebra is deemed to be a generalised Arithmetic.

Then, students' mathematical competence will consist of their mastery of the properties of these operations and their ability to use them effectively in transformations. The properties of these operations are different and are dependant on the set under consideration. Since the sets of numbers that are studied in school mathematics are these of whole numbers, integers, rational and real numbers, students should be aware of the properties of these operations in each of these sets. Since algebraic transformations are grounded on the concept of the variable and on the properties of these operations, students must be fluent in these conceptualisations.

The students' ability to perform operations with algebraic expressions and to simplify those expressions was tested in the project by the inclusion in the test of problems 8, 10, 11, 22, and 30. The errors that arose from these can be allocated to three main causes.

The first cause is the '*conjoining error*', as this was explained and clarified in Arithmetic, and concerned mostly the English students' competence. The errors $7x^2$ or $8x^2$ (Error 8(A) (i)) and

$2x^2$ or $1x^3$ (Error 8(B) (i)) in problem 8, the error 6xy in the problem 10, the error 4a or 9a (Error 11(A) (i)), $4a^2$, 4aa, $2(2a^2)$, $(2\times2)a^2$, or $15a^2$, $3(5a^2)$, $(3\times5)a^2$ (Error 11(A) (iii)), 30a or 40a (Error 11(B) (i)), 10a or 11a (Error 11(B) (ii)) in problem 11, and 2x-1 (Error 22(A) (i)) and 2x (Error 22(B) (ii)) [5] in problem 22 were due to this cause.

The second cause of the emergence of the errors was due to many students' omission failure to finish simplifying the algebraic expressions, leaving them incomplete. This particular case concerns mostly the Greek students who were more prone to the emergence of this particular error. The errors (2+5)x (Error 8(A) (ii)), (1+4-2)x (Error 8(B) (ii)) in problem 8, 2a+4a or 6a+9a (Error 11(A) (ii)) in problem 11, and x^2-2x+x-2 (Error 22(A) (ii)) in problem 22, were induced by this particular cause.

Finally the third cause of the emergence of errors was the incorrect execution of a particular operator or operation by the students of both samples. The errors 4a or 9a (Error 11(A) (i)), 30a or 40a (Error 11(B) (i)), (2×3×5)a (Error 11(B) (iii)), $3a^3$ (Error 11(C) (i)) in problem 11, the errors x^2-a (Error 22(B) (i)), $3a^2$-$2b^2$ or $2x^2$-$9y^2$ (Error 22(C) (i)), $9a^2$-$4b^2$ or $4x^2$-$9y^2$ (Error 22(C) (ii)), 9a-4b or 4x-9y (Error 22(C) (iii)) in problem 22, and finally the errors $\frac{1}{x}$ (Error 30(A)), $\frac{2}{x}$ (Error 30(B)), $\frac{1}{(2x)}$ (Error 30(C)) in problem 30, emerged because of this cause.

The errors that were due to the first cause emerged in the following way: the algebraic expression was detected by the proper sensor, which, in turn, was stored in the working memory. The phase of recognition started in the working memory by ascribing meaning to it according to the stored information that was drawn from the long-term memory.

The recognition of the percept was incorrect, since the students failed to identify the spatial and logical relationships among the symbols. Thus, the failure of recognition triggered an inappropriate set of productions in order to cope with this percept that led to an incorrect execution of particular actions.

The appropriate execution of the operations specified in a particular algebraic expression should be primed by a well-established set of productions. In this case, the appropriate schema concerning the distributive law had to have been developed for a successful grasp and execution of the set of productions. This particular set of productions accounted for the correct order and priority of execution of the operations. This did not happen in this case.

The students understood the addition between the monomials as a multiplication and, although they added the coefficients, they took the two x's as being exponential, which in turn led to the emergence of the error $7x^2$ or $8x^2$ (Error 8(A) (i)).

Similarly, the pupils performed the subtraction first and then assumed the addition to be a multiplication. They multiplied the two coefficients and maintained the same like terms. Accordingly: $x^2+4x^2-2x^2 = x^2+2x^2 = 2x^2$ (Error 8(B) (i)). The English students coped with the respective problem in the second test in the same way: $x^3+7x^3-6x^3 = x^3+x^3 = 1x^3$ (Error 8(B)(i)).

The students simply added the two coefficients and they just multiplied the two variables incorrectly, by identifying the addition as a multiplication, in problem 10. Thus, the emergence of the error 6xy (Error 10) took place. The students simply put the letters into a succession.

Another possible explanation, among others, in problem 11 (a), was that the emergence of this particular error should be imputed to the incorrectly developed conceptualisation of the symbolism of multiplication and addition among monomials. Thus the students might have thought 2(a+2a)=2a2a=4a (Error 11 (A) (i)), confusing addition with multiplication. The same cause may explain the emergence of all these cases $4a^2$, 4aa, $2(2a^2)$, $(2\times2)a^2$ or $15a^2$, $3(5a^2)$, $(3\times5)a^2$ (Error 11(A) (iii)) that emerged as errors in problem 11(a).

In the same way, the English students might have multiplied only the coefficients and not the variables in problem 11(b) and the error 30a or 40a (Error 11 (B) (i)) emerged.

In contrast, other students failed to properly recognise the operation sign. Thus, they created the error, 10a or 11a (Error 11(B) (ii)). The same happened when the students encountered the product (x+1)(x-2). The students performed (x+1)(x-2) = x+1+x-2 = 2x-1 (Error 22 (A) (i)). Similarly in the same problem the students executed an addition instead a multiplication when they encountered (x+a)(x-a) = x+a+x-a = 2x (Error 22 (B) (ii)). All the abovementioned errors are instances of the hackneyed error in the literature, coined by Stacey and MacGregor [31] as '*conjoining error*'.

The following errors comprise the second group of errors that were due to the incomplete simplification of the algebraic expressions. These arose mainly among students of the Greek sample. The Greek students left the expressions (2+5)x (Error 8(A)(ii)), $(1+4-2)x^2$ (Error 8(B)(ii)), 2a+4a or 6a+9a (Error 11(A) (ii)), and x^2-2x+x-2 (Error 22 (A) (ii)) incomplete. They did not exhaustively simplify the expressions, although they correctly performed the operations.

Finally, there were errors that could be imputed to the incorrect execution of a particular operator or operation. The emergence of the error in problem 11(a) can also be allotted to that category by providing a different explanation of it. When the pupils performed the operation of multiplication, they expanded the bracket and incorrectly concluded that: 2(a + 2a) = 2a +2a = 4a (Error (A)(i)). In this way, they showed a deficient conceptualisation of how to multiply and add like terms of monomials. A perfectly developed schema concerning the distributive law was probably lacking. They multiplied only the first addend of the sum in the bracket and ignored the second.

The reason for this might be the presentation of the subject matter in students' textbooks. Teachers base their instruction on the textbooks and students study the subject matter from the same resource. So, the belief that the textbooks are strongly influential on how students' conceptualise the subject matter should be seriously considered. An investigation into how the subject matter is presented in a few textbooks took place in order to find out the roots of these inconsistencies that were developed among the students.

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sample. The Greek students left the expressions (2+5)x (Error 8(A)(ii)), (1+4-2)x^2 (Error 8(B)(ii)), 2a+4a or 6a+9a (Error 11(A) (ii)), and x^2-2x+x-2 (Error 22 (A) (ii)) incomplete. They did not exhaustively simplify the expressions, although they correctly performed the operations.

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The aftermath of this investigation was that the expansion of a bracket as following the distributive law was never mentioned in the English textbooks. The procedure of the expansion of a bracket, and the concept of a formula or an equation, were concurrently introduced to the pupils. They were being called to learn the procedure by rote without any specific explanations given about the truth of this procedure. The subject matter was not presented to them in a way conducive to making connections with other relevant concepts. This is apparent in Graham's [38, p.45] textbook.

Similarly, in Banks et al's [16, p.135] textbook, the presentation of this procedure follows the introduction of the concept of a formula (presenting brackets and factorisation again on p. 196, without any regard to the distributive law). Specifically, the development of a particular method is presented by the use of a geometrical diagram i.e. that of two rectangles with a common side, in order for pupils to conceptualise how the procedure works. The conceptualisation of this procedure is based on the pupils' previous development of the concepts of the addition of two segments in a straight line and the concept of the calculation of an area.

This diagrammatic method promotes a better conceptualisation of the distributive law. Moreover, it greatly contributes to the inscription of that law on the students' working memory, based on its visual perception. Nevertheless, it does not help in the development of a particular set of productions conducive to the development of skill in manipulation of such kind of algebraic procedures. It contributes little to the pupils' development of particular conceptual connections of the arithmetical operations with their respective algebraic ones.

Pupils cannot realise the concept of the monomial as an independent and basic entity for the development of Algebra, because this concept is not introduced to them as such. They are given guidelines, neither on how to simplify monomials based on the concept of like terms, nor on how to multiply or divide monomials. Pupils are called to learn the order and priority of the execution of arithmetical operations by rote and through practice without constructing meaning. Thus, they learn the rule that it is necessary to perform, first of all, operations inside the brackets and then all the others. The algebraic expressions constitute an exception to this rule, since they probably contain summands with different variables that cannot be added. In this way, the necessity the distributive law arises to help in coping with such kind of mathematical expressions.

The pupils find it difficult to consider different conventions in algebra. A change of that particular schema must take place. Consequently, the pupils need to learn the value of the distributive law very early, in order to make an appropriate and smooth transition from the arithmetical schema to a more abstract algebraic one. If the distributive law had been taught and learnt by the pupils in arithmetic, this would also have helped them to realise the factorisation procedure more easily in algebra.

In addition, the fact must also be underlined that the English pupils were not able to realise that the addition of the two addends also held in this particular case. Thus, they could add the two like terms, i.e. 2(a+2a) = 2(1a+2a) = 2(1+2)a = 2(3a) = 6a. The existent brackets cued them to think of the two addends as being concrete and of different magnitudes that could not be added.

Similarly, the emergence of the errors 30a or 40a (Error 11(B)(i)), and (2×3×5)a (Error 11(B)(iii)) in problem 11 (b) [5] may be due to the performance of an incorrect operator. Thus, the Greek students may have failed to properly recognise the multiplication sign '×' as such. They may have assumed it to be an addition sign and thus they activated the set of productions accountable for the factorisation procedure, instead of that of multiplication, which is the correct one. Consequently they performed: (2a)×(3a)×(5a) = (2×3×5)a = 30a.

In the same way, the students simply divided the two coefficients but they did not do the same for the two variables. Thus, they incorrectly performed: $(12a^3)\div(4a) = (12\div4)a^3 = 3a^3$. The retrieval of the appropriate information in the above cases was poor. Consequently, their encoding of the information concerning the simplification between monomials was very poor as well.

Similarly, in problem 22(b), the replacement of an appropriate production by a false one led to the emergence of the error. Thus, the students performed: (x+a)(x-a) = x(x-a)+a(x-a) = x^2-ax+ax-a = x^2-a (Error (B)(i)). They omitted to multiply a×a = a^2.

Accordingly, the following errors were due to students' failure to activate and apply a correct set of productions in order to perform the multiplication that is denoted implicitly in question 22 (c). The recognition of the percept was incorrect since the students failed to identify the spatial and logical

relationships among the symbols. Specifically, the students failed to recognise that the expression $(3a-2b)^2$ means 'the square of (3a-2b)', which is (3a-2b)(3a-2b), and then to perform the expansion by multiplying the two algebraic expressions. The percept failed to trigger the appropriate set of productions required for the execution of the expansion. That means that the process of encoding of this particular set of productions in appropriate schemata in the long-term memory was very poor and weak. For a very poor and weak encoding we received a very poor and weak retrieval of information.

Thus, the students gave as an output, $(3a-2b)^2 = 3a^2-2b^2$ (Error 22(C) (i)), raising into the square power only each variable of the two monomials. The English students reconstructed the input and gave as an output, $(3a-2b)^2 = (3a)^2-(2b)^2 = 9a^2-4b^2$ (Error 22(C) (ii)), as did those in the previous case, by raising the two monomials to the square power. Whereas, in another case, they reconstructed the input and gave as an output, $(3a-2b)^2 = (3)^2a-(2)^2b = 9a-4b$ (Error (C) (iii)), this time by raising the two coefficients of the two monomials to the square power. This simplistic activity indicates that the mastery of the declarative knowledge concerning indices and the procedural knowledge regarding operations with indices is lacking.

The emergence of the error, $9a^2-4b^2$ (Error 22(C)(ii)), which was common among the Greek students, may be imputed to a quite different cause. This may be due to the instruction that they received concerning the expansion of the bracket. That instruction was quite different in conceptualisation from the English one.

The Greek students are taught the expressions

$(A-B)^2 = A^2-2AB+B^2$,

$(A+B)^2 = A^2+2AB+B^2$ and

$(A^2-B^2) = (A-B)(A+B)$.

Each of them is identity (tautology), that is, holds for every monomial in the position of the A and B. First, the students are taught the truth of these expressions, by performing the expansion of the first part of each expression. Then, they become able to find the square power of every sum or difference between two monomials according to these expressions. They also become able to find the difference of two squares of two monomials. These expressions are used in order for students to learn the process of factorisation between monomials as well.

Thus, the students should have replaced the A and B with the monomials 3a and 2b respectively, in the expression, $(A-B)^2 = A^2-2AB+B^2$, and then performed the operations by applying the properties of indices. This particular set of productions, used in the execution of these operations, was not activated. This led to a poor encoding of information and a weakly structured schema for the use of this procedural knowledge. Consequently, the students, having recourse to their already existent knowledge, reconstructed the retrieval and transformed the input into $(3a-2b)^2 = (3a)^2-(2b)^2$. Finally they gave $9a^2-4b^2$ as an output by executing the appropriate productions concerning the properties of indices.

The emergence of the errors in problem 30 can be imputed to the same cause. The students failed to recognise the spatial and logical arrangement of the symbols in that algebraic expression. Thus, the students' mind failed to trigger the appropriate set of productions accountable for the execution of the addition between two algebraic fractions. The cognitive mechanism to which that students' mind had recourse was that of the Gestalt. Thus the students added the two numerators and denominators and gave:

$$\frac{1}{x-2}+\frac{1}{x+2}=\frac{1+1}{x-2+x+2}=\frac{2}{2x}=\frac{1}{x}$$ (Error 30 (A)).

In another case, the students' developed schemata took the form:

$$\frac{1}{x-2}+\frac{1}{x+2}=\frac{1+1}{x-2+x+2}=\frac{2}{x}$$ (Error 30 (B)) [5].

Besides, the students thinking might also have been influenced by the way fractions with equal denominators are added, namely $\frac{a}{b}+\frac{c}{b}=\frac{(a+c)}{b}$. Thus, they reconstructed the input according to this way of thinking, in order to accommodate and assimilate it. Consequently they performed:

$$\frac{1}{x-2}+\frac{1}{x+2}=\frac{1}{x-2+x+2}=\frac{1}{(2x)}$$ (Error 30 (C)) [5].

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All the above cases have their roots in an incorrect application and performance of a particular operator and comprise the third group of errors in the specified problems. All the above cases have their roots in an incorrect application and performance of a particular operator and comprise the third group of errors in the specified problems

D. Factorisation

Although factorisation is an algebraic procedure that could be included with the others previously examined, it is studied separately because of the importance of its mastery. Factorisation is a key procedure that is used in transformations of the sums of algebraic expressions into the multiplication of such expressions in calculus. Its profound mastery is usually neglected, since the students' and teachers' endeavour is focused mostly on the fluency of practising the algebraic operation of multiplication that leads to algebraic sums, and not on the inverse process.

The students' mathematical competence for the use of factorisation demands an ability to transform an algebraic sum that has common factors into a product. Its mastery presupposes a profound knowledge of the concept and use of the monomials. The profound mastery of this process is prerequisite in order for other mathematical processes to be deployed in algebra and calculus such as solving equations, integrals etc.

Two main problems, 14 and 20, were employed in the test in order to check the students' ability to use factorisation. The students' failure to effectively cope with these problems, and the emergence of errors, were due to the confusion students had in distinguishing between the multiplication and the addition of algebraic procedures, as the following analysis indicates. This is the hackneyed '*conjoining error*'.

When the students encountered the algebraic expressions in problems 14 and 20, they apprehended the algebraic expressions as a percept. The percept, in turn, was detected by the proper sensor and was stored in the working memory. The phase of recognition started there by ascribing meaning to the percept according to the stored information that was drawn from long-term memory. The recognition of the percept was incorrect since the students failed to identify the spatial and logical relationships among the symbols. They incorrectly transformed the x^2 into 2x, that is, they incorrectly assumed $x^2 = 2x$ in problem 14. Thus, failure of recognition triggered an inappropriate set of productions in order to cope with this percept that led to an incorrect execution of particular actions. Consequently, they performed $x^2-3x = 2x-3x = -1x = -x$ (Error 14). Similarly, the students assumed the addition to be a multiplication and they used exponentials to represent the succession of operations. Thus they wrote $2p^2q+pq^2 = 2p^3q^3$ (or $6a^4b^4$ when the problem was modified in the second round) (Error 20). This is a dominant and hackneyed error in the English samples, named '*conjoining error*'.

The students doing this transformation reconstructed the input in order to fit it into their already existent knowledge, that is, into the addition of monomials with like terms, and they performed addition. They had no appropriate set of productions to be cued by the word 'factorise', thus factorisation was not induced.

E. Indices

One of the basic algebraic skills that the students must develop is the mastery of the concept of index form, as this is defined by repetitive multiplication, and its use in algebraic expressions and equations. Thus, the students' mathematical competence on the conceptualisation of the index form and its use consisted of the students' ability to effectively use the definition, and the properties of the indices, in different algebraic expressions and in equations. This ability was tested through problems 13, 23, 25 and 27.

The errors that arose in these problems were due to the improper execution of particular productions, which in turn can be imputed to incorrectly developed declarative and procedural knowledge.

When the students encountered the particular algebraic expression, they realised it as a percept. The percept had the form of an input and it was stored in the working memory in order for the process of recognition to take place. This did not happen successfully, since the students failed to appropriately recognise the spatial and the logical relations between the symbols and the operators they stand for. Hence, a particular set of productions was primed from those existing in the long-term memory schemata, in order to process the input. In no way were all the productions appropriate that constituted reconstructive retrieval for successful problem-solving. The wrong production that was executed in problem 13 was:

"IF the expression $x^2 \times x^4$ is a product of indices, THEN keep the same base x and multiply the indices, i.e. $x^{2\times4}$".

This was due to the inscription of an incorrect fact in a particular schema in long-term memory. The incorrect fact determined that, when multiplying two numbers with common bases, the indices are multiplied, instead of the correct fact that they are added. Thus, the students incorrectly applied $x^2 \times x^4 = x^a$ and $x^{2\times4} = x^a$ and $x^8 = x^a$ and finally a=8 (Error 13).

Similarly, the incorrect production that was executed in problem 23 (a) was:

"IF the expression $(x^2)^n$ is a power powered in another index n, THEN keep the same base x and add the indices, i.e. x^{2+n}",

accordingly the students incorrectly applied:

$x^6 = (x^2)^n \Leftrightarrow x^6 = x^{2+n} \Leftrightarrow 6 = 2+n \Leftrightarrow 6-2 = n \Leftrightarrow n=4$ (Error 23 (a)).

In the same way, this reasoning in case (b) of the same problem took the form:

$x^{100} = (x^2)^n \Leftrightarrow x^{100} = x^{2+n} \Leftrightarrow 100 = 2+n \Leftrightarrow n = 100-2 \Leftrightarrow n = 98$ (Error 23 (b)).

Whereas, the production, in case (c) in the same problem, became:

"IF the expression, $\frac{1}{x^2} = x^{2n}$, is an equality between powers THEN equate the indices"

so the students, following this incorrect production, equated the index of the power in the denominator of the first fraction with the index of the power after the equal sign: $2 = 2n \Leftrightarrow n = 1$. That is, they started as:

$\frac{1}{x^2} = (x^2)^n \Leftrightarrow \frac{1}{x^2} = x^{2n} \Leftrightarrow 2 = 2n \Leftrightarrow n = 1$ (Error 23(c)(i)).

In another case, the students performed the production:

"IF the expression $\frac{1}{x^2} = x^{2n}$ is an equality between powers, THEN equate the indices".

Nevertheless, the students, in this case, equated the number $\frac{1}{2}$, which was assumed to be the index of the x in the first part of the equality, with the index *n* in the second part of the equality and finally received $n = \frac{1}{2}$ (Error 23(c)(ii)).

In addition, the particular production that was executed in problem 25 was:
"IF the expression $(t^3)^2$ is a power powered in another index 2, THEN keep the same base t and add the two indices, i.e. t^{3+2}",
which, in turn, led to the incorrect train of thought:
$(t^3)^2t^{-2} = t^p \Leftrightarrow t^{3+2}\, t^{-2} = t^p \Leftrightarrow t^{3+2-2} = t^p \Leftrightarrow 3+2-2 = p \Leftrightarrow p = 3$ (Error 25(A)).

In another case in the same problem, the students failed to recognise the spatial and the logical relations between the symbols. They incorrectly recognised the symbols t^{-2} as being t^2. The failure of an appropriate recognition led to the emergence of the error. Thus, the students incorrectly assumed that:
$(t^3)^2 \cdot t^2 = t^p \Leftrightarrow t^{3+2+2} = t^p \Leftrightarrow t^7 = t^p \Leftrightarrow p = 7$ (Error 25(B)).
Whereas, in a third one, the students executed the production:
"IF the expression $(t^3)^2 \cdot t^{-2}$ is a product of a power powered in another index 2 with another power with the same base, THEN keep the same base t and multiply all the existing indices, i.e. $t^{3 \cdot 2 \cdot (-2)}$",
which, in turn, led to the reasoning:
$(t^3)^2 \cdot t^{-2} = t^p \Leftrightarrow t^{3 \cdot 2} \cdot t^{-2} = t^p \Leftrightarrow t^{6 \cdot (-2)} = t^p \Leftrightarrow t^{-12} = t^p \Leftrightarrow -12 = p$ (Error 25 (C)).

In a same way, the students executed, in problem 27, the incorrect production:
"IF the algebraic expression x^{16} is an exponential THEN square the x powered to 4, i.e. x^{4^2}",

which is translated in reasoning: $x^{16} = x^{4^2} = (x^4)^2$, instead of the correct $x^{16} = (x^8)^2$. Thus they performed: $\sqrt{25x^{16}} = \sqrt{5^2 x^{4^2}} = \sqrt{(5x^4)^2} = 5x^4$.

F. Equations

Solving an equation constitutes a problem-solving situation, which is equivalent to identifying the numerical value of a variable that makes the equality true. Equations are mathematical problems, since they involve mathematical content such as numbers, algebraic relations and mathematical reasoning based on specific rules of numbers or algebra. Thus, equations are well-defined problems (caveat: at least these that are included in the curriculum). These always contain a specific current stage, which is constituted by the form in which the equation is presented, and a goal state with the form $x = n$ that is always clear, where *n* is a number. How individuals can reach that goal depends on the operators they use.

Therefore, the transition from the current state to the goal state in equations is achieved by the employment of a means-ends analysis strategy or a directed problem solving strategy and appropriate operators. The selection of those operators depends on the presented problem, that is, the kind of equation. Hence, it is a cognitive process, since it occurs internally in individual's cognitive system and the operators the individual used can be inferred indirectly through behaviour. Equations encompass a process, that is, mental computations, which are operations that are applied to mental representations.

Solving an equation involves procedural knowledge, that is, the application of appropriate knowledge in action through the selection of appropriate operators. These operators are expressed in productions that render specific actions. These actions follow a specifically referred order that permit the transition from the current state to the goal state. The action is always sparked by the execution of a set of productions when their conditional part, IF-information, is satisfied.

The conditional part of the productions is determined by individuals' declarative knowledge of *knowing that*. Persons' declarative knowledge that is employed in the procedure can come to be known by a variety of forms e.g. recognition, application associated with other forms of knowledge. Declarative knowledge is mainly constituted by facts that are stored in individuals' long-term memory and is acquired by a single exposure to instruction or other means of providing information e.g. textbooks, computer software packages etc. By its very nature, declarative knowledge is constituted by propositions that are characterised as either true or false. In contrast, procedural knowledge is neither true nor false. It always starts as declarative knowledge, that is, as one's verbal expression of the succession of the different steps of the procedure. It is always acquired through repetitive practice.

Thus, the students' mathematical competence is composed of a skill specifically and appropriately developed for each kind of equation linear or quadratic. This particular skill consists of a particular set of productions that must be executed in a specific order. The appropriate execution of this particular set of productions presupposes the appropriately developed declarative and procedural knowledge upon which this set hinges. These kinds of knowledge include one's skills in adding or subtracting the same numbers from both sides of an equation. They include skills in multiplying or dividing both sides by the same number. Finally, they include skills in simplifying by combining like terms. Moreover, solving quadratic equations requires the mastery of the skills of the technique *completing the square* and in factorising algebraic expressions or implementing the respective formula.

There are several strategies one can apply in solving an equation. Thus, it is difficult to identify a person's way of reasoning from only a number given as the result of reaching the goal state, without recording person's way of thinking in written or verbal protocols. Consequently, then the factor of uncertainty arises when one tries to identify students' way of thinking only by guessing.

Two linear equations were used in problem 16 and two quadratic equations in problems 17 and 31, respectively, in the test. The students' skills in solving equations were tested through these problems. The errors that emerged in the process of solving an equation were due to an inappropriate selection and execution of operators that were expressed through productions. Another probable cause might be that responsible for the emergence of '*conjoining error*' especially among the English students.

So, the process of pattern recognition took place through the activation of an appropriate production, before the conditions of other productions were met that fired particular action. The pattern recognition was induced through the process of symbol recognition and symbol-arrangement analysis. Thus, the processes of isolation, recognition, and identification of the spatial and logical relations of symbols took place.

The production that was accountable for the recognition of the algebraic expression as being an equation was:
"IF the algebraic expression has the form x+1 = 3-x THEN classify it as a linear equation",
for the first case in problem 16, whereas for the second case that was:
"IF the algebraic expression has the form 4-2x = 7-x THEN classify it as a linear equation".

Then a particular set of productions was fired that was accountable for the execution of particular actions, which might have led to the emergence of the error.

The first set of productions that constituted a particular strategy, which might have taken place, is translated into the train of thinking:
x+1 = 3-x and x+1 = 3 and x = 3-1 and x = 2(Error 16(A)).

Another set of productions might have led to the syllogism:
x+1 = 3-x and 3+1 = x+x and 4 = 2x and x = 2 (Error 16(A)).

Another set might be accountable for the reasoning x+1 = 3-x and x = 3-1-x and x = 2-x and x = 2 (Error 16(A)).

Similarly, a particular set of productions might have been accountable for the train of thought

4-2x = 7-x and 4-7 = -x-2x and –3 = -3x and $\frac{-3}{-3} = \frac{-3x}{-3}$ and x = 1 (Error (B)(i)).

A different train of thought might have been
3x = 7-4 and 3x = 3 and x = 1(Error (B)(i)).

In the same way, productions that were accountable for the emergence of this error might have been
4-2x = 7-x and x-2x = 7-4 and x = 3 (Error (B)(ii)).

Finally, the emergence of the particular errors, 2 in the first equation and 3 in the second equation of problem 16, might be due to the hackneyed '*conjoining error*' common in the English samples. Thus, in the first equation, the developed strategy might have been x+1= 3-x and x = 2 where the students performed multiplication instead of addition and the subtraction of the monomial from the number. Whereas, in the second equation, this might have been 4-2x = 7-x and 2x = 6 and x=3, where the students subtracted the monomials from the numbers.

For the quadratic equations, the productions that took place and were accountable for the recognition of the algebraic expressions as being equations were:
"IF the algebraic expression has the form $x^2+13 = 49$ THEN classify it as a quadratic equation"
for the equation in problem 17. Whereas, for that in problem 31, it was:
"IF the algebraic expression has the form $x^2+5x-7 = 0$, THEN classify it as a quadratic equation".

Then a particular set of productions was fired that was responsible for the execution of particular actions that might have led to the emergence of the error. The students failed to retrieve one of the appropriate sets of productions that they had been taught in order to process the input. This was due to weak connections of the particular schema that contained these sets of productions. The strategies that the English students had been taught, but which were not executed were: by factorising, graphically, and by trial and improvement. Whereas, the strategies the Greek students have been taught and were not executed were: by factorising, by application of the particular formula and graphically.

Thus, the students might have executed the set of productions that was accountable for the following trains of thought:
$x^2+13 = 49$ and $x^2 = 49-13$ and $x^2 = 36$ and $x = 36$ (Error 17(A))
or
$x^2+13 = 49$ and $2x+13 = 49$ and $2x = 49-13$ and $2x = 36$ and finally $x = 18$ (Error 17(B)).
$x^2+5x-7 = 0$ and $2x+5x-7 = 0$ and $2x+5x=0+7$ and $7x = 7$ and $x = 1$ (Error 31). In this particular case, the students failed to fire the action that was specified by the production:
"IF the equation $x^2+5x-7 = 0$ is quadratic and the goal is to find out the value of the unknown x, THEN apply the formula of x $= \frac{-b\pm\sqrt{b^2-4ac}}{2a}$, for a = 1, b = 5, c = -7".
The pupils incorrectly assumed that $x^2 = 2x$ in both cases (Error 17 (B)) and (Error 31) [5]. By doing so they degraded the equation into a linear one, which they could cope with. This is another form of the hackneyed '*conjoining error*' dominant in the English groups. Consequently, they found resort to their existent and available knowledge concerning the linear equations in order to provide an answer and prevent discomfort.

G.Simultaneous Equations

Solving simultaneous equations constitutes a problem-solving situation, which is equivalent to identifying the numerical value of each of the two variables that make the two incorporated equalities true. Simultaneous equations constitute a well-defined mathematical problem. These always contain a specific current stage, which is constituted by the form in which the two equations are presented, and a goal state with the form $x = m$ and $y = n$ that is always clear, where m, n are numbers. How individuals can reach that goal depends on the operators they use. Particular sets of operators constitute different strategies that lead to the solution of the simultaneous equations. Therefore, the transition from the current state to the goal state in a problem with simultaneous equations is achieved

by the employment of the means-ends analysis strategy, or a directed problem solving strategy, and the application of particular operators, which are constituents of the particular strategies.

The selection and the effective application of these strategies constitute students' mathematical competence for solving such kind of problems. These strategies that are taught to the students include: the use of the graphs of the two equations, the elimination strategy and the substitution strategy. The students' mathematical competence for solving linear and quadratic equations is prerequisite for the development of their competence for coping with problems with simultaneous equations.

The problems that tested the students' skills in solving problems with simultaneous equations were these with numbers12 and 19. Before solving a problem with simultaneous equations, the recognition of the two algebraic expressions as being simultaneous equations takes place by the application of the productions:

"IF the two algebraic expressions have the form x-y = 2 and x+y = 4 of linear equations, THEN classify those as being simultaneous equations".

"IF the two algebraic expressions have the form x+2y = 3 and 2x-y = -4 of linear equations, THEN classify those as being simultaneous equations".

Then the students failed to develop the appropriate strategies that lead to a guaranteed solution and they performed their own that led to the emergence of the particular errors. Thus, the students might have substituted the values of the variables x = 4, y = 2 in the first equation using the trial and error method in problem 12. Then they might have omitted the substitution in the second equation. In this way, the error 4, arose (Error 12(A)). The emergence of error 2 (Error 12(B)) might have been due to the development of the following strategy:

x-y =2 (-1)x→ (x-y = 2 -x+y =-2
x+y =4 and (1) x→ (x+y =4) and x+y = 4 Then they added the two equations and they got x+y-x+y = 4-2, and they (incorrectly) took y = 2. Finally, by substitution of this value in the first equation, they took x-2 = 2 and x = 4. In this case, the students have mastered the skill but their declarative knowledge concerning the addition of the monomials might have been fickle.

Similarly, the emergence of the error 1 (Error 19(A)) might be due to the following strategies followed by the students:

x+2y = 3 x = 3-2y x = 3-2y x = 3-2y
2x-y = -4 and 2x-y = -4 and 2(3-2y) = -4 and 2y-y = -4
x = 3 – 2y x = 1
y = -4 and y = -4.

Another wrong computation might be that:

x = 3-2y x = 3-2y x = 3-2y x = 3-2y
2(3-2y)-y = -4 and 5-2y-y = -4 and -3y = -4-5 and -3y = -9
x = 3 – 2 x = 1
y = 3 and y = 3.

There is one more case where the error is the '*conjoining error*'. The pupils incorrectly assumed that x+2y = 3 and 3x = 3 and x = 1.

Whereas, the emergence of the error 6 (Error 19(B)) in the same problem is probably due to the fact that, having found the incorrect value x = 1 for the variable x, the students substituted it in the second equation. It became: 2-y = -4 and –y = -4-2 and –y = -6 and y = 6.

The other case might be the '*conjoining error*'. The students incorrectly assumed that 2x –y = -4 and y = 2x+4 and y = 6.

H.Inequalities

Finally, inequalities constitute problem-solving situations, which are equivalent to identifying the numerical values of a variable that make the inequality true. The way one copes with inequalities is very similar to that coping with equations. Inequalities are well-defined problems. They always contain a specific current stage, which is consists of the form in which the inequality is presented, and a goal state with the form either $x < n$ and $x \le n$ or $x > n$ and $x \ge n$, that is always clear, where n is a number. How individuals can reach that goal depends on the operators they use. They are the same with these that are employed in solving equations, except the following, which concerns the division of both parts of the inequality with a positive or negative number. These become:

"IF $a \ge b$ and m is positive,THEN (i) $ma \ge mb$ and (ii) $\frac{a}{m} \ge \frac{b}{m}$"

and

"IF $a \ge b$ and n is negative number, THEN (i) $na \le nb$ (ii) $\frac{a}{n} \le \frac{b}{n}$".

The students' mathematical competence concerns the mastery of the particular skill that is composed of a particular set of productions that must be executed in a specifically referred order. This set of productions is the same as the one that is employed in solving equations and includes the two productions given above.

The students' skill in solving inequalities was tested by problem 24. The production accountable for the recognition of the inequality was:

"IF the algebraic expression has the form 3x+4<13, THEN classify this as being an inequality".

Then the students developed their own strategies that led to the emergence of the particular error x < 2 (Error 24). These were:

3x+4<13 and 3x<13-7 and 3x<6 and $\frac{3x}{3} < \frac{6}{3}$ and x<2, and the error emerged.

The execution of another set of productions might have given rise to the following train of thought: 3x+4<13 and 7x+4<13 and x+4<13-7 and x+4<6 and x<6-4 and x<2. Or 7x<13-4 and 7x<9 and x<9-7 and x<2.

The students incorrectly assumed that 3x+4 = 7x in both cases, which in turn was subtracted from the 13 in the right hand side. This is the hackneyed '*conjoining error*'.

V.CONCLUSIONS

Mathematical competence can be defined as an idealized conceptualisation of the mathematical subject matter that is

included in the curriculum. It can be experienced and shown only through the accuracy of performance in doing mathematics.

To know exactly how individuals' mind works, thinks and learns is very difficult, since it constitutes a serious epistemological problem. This epistemological problem is the aftermath of the Gödel's theorem [39]. Its implication in cognitive science has been taken to be that "entirely understanding one's own mind is impossible, since like any other closed system, it can only be sure of what it knows about itself by relying on what it knows about itself" [40]. Our ability to completely mirror our mental structures into symbols that carry them out has been called into question. Moreover, just as we cannot see our faces with our own eyes, but only indirectly through mirroring in a polished glossy surface, the impossibility of capturing our own mental states by symbolic representations is latently implied. Consequently, it begs the question of what exactly sanity is and how it can be achieved.

However, we deliberately and purposefully disregard these theoretical accounts, since they do not completely determine the educational enterprise in everyday life. The fact that we can come to have some real or conjectured access to persons' covert mental functioning that lies behind their actions, through the errors they develop in well-defined problems, where the specific reasoning is unique and predictable, is taken for granted. The accuracy of performance provides only *indirect* information about the way the mind processes the symbolic structures of internal mental states. This is of central interest in mathematics education.

One would easily wonder about, and cast doubt on the validity and the reliability of such kind of analysis, based on conjectures rather, than on 'real facts', and finally to dispute and reject the inferences. The arguments raised may be that we cannot be quite sure about the students' real thinking processes because those are hidden and not accessible. For these reasons, the analysis and the inferences that stem from such conjectures may be plausible but not real or verifiable. This kind of dispute is understandable.

The final accuracy of the aforementioned analysis can be verified by conducting case studies, by the use of interviews, or by providing protocols of the students' work on the same problems in distinguishable educational settings. Moreover, teachers can test these explanations in real practice in their classroom. This shall definitely constitute the value of this research. Because the strength of this research lies in its elaborated data that was gathered in natural settings, where people behave naturally in their everyday life, and the resulting explanations are addressed to people who are becoming involved in the educational enterprise.

Nevertheless, an argumentation could be established concerning the validity of the aforementioned analysis and on the provided explanations. This argumentation would be based on an account of what constitutes the real nature of mathematics and on the basic criteria of the validity of the mathematical thinking and statements in one's own mind.

Accordingly, the accuracy of an agent's performance derives its strength from the form of the transitions in Mentalese between mental states. This accuracy is conducive to be truth-preserving (as this was discussed in philosophy of mind) following the order in the information process of the inter-linkage of the causal properties -- formal properties -- semantic properties of complex symbols. This means that the causal properties reflect the formal properties and these in turn reflect the semantic properties. An agent's ability to perform computations by performing causal operations hinges on this concatenation. The link between the causal properties and the semantic properties of the representations by an agent is provided through their syntactic or formal properties of them. Specific rigorous rules regulate the concatenation of the symbols that stand for representations and give rise to the development of meaning. The whole process is then interpreted as computation.

This relationship among the causal properties that reflect reality into the semantic properties, which, in turn, contribute to the agent's creation of meaning through the formal syntactical structure of the symbols, is strong and uniform among all humans. Thus, an agent's accuracy of performance is indirectly predictable if the agent shares the same formal symbolic structures with the person who guesses his/her train of thought. Differentiation and deviation in the train of thought usually takes place through the employment, or involvement, of different strategies to those that have been officially presented. These, albeit enriching the ways one can think, might be predictable but less certain than those that are taught to them and which the learners usually incorporate. Apart from these arguments concerning the way the mind processes mathematical thinking, there are also others concerning the nature of mathematics and the relation between teacher and students based on Skemp's [41] ideas.

Historically, mathematics developed concurrently with the natural sciences and technology. Their relationship was interdependent. Mathematics was developed based on humans' need to understand, explain, harness, and control the facts and their physical or social consequences and then to make predictions. This need led to the development of measurement, computation and reasoning. Thus, mathematics has more in common with natural sciences than with the disciplines in the humanities. Nonetheless, there is a basic trait that sharply differentiates it from natural sciences.

Experiment is the essential criterion of the validity of any statement or theory in natural sciences. Other criteria would be the prediction of natural facts if certain conditions are set up and the applications of those predictions to real life and human experience.

Students develop their personal knowledge about nature not by witnessing all those experiments but by developing their own schemas based on the knowledge provided by different sources, and testing this knowledge all the time by their own experience. Finally, their knowledge is developed from interpersonal situations and on real facts from their own experience and not on the authority of the teacher [41, p.84].

In contrast, the basic criterion of validity in mathematics, which makes it sharply distinguishable from the natural sciences and humanities, is its coherence, and consistency. This

is despite the fact that Gödel has recently cast doubt on the internal logical consistency concerning a closed formal logical mathematical system by proving that there are true statements that cannot be derived from a given set of consistent axioms. Coherence and consistency in mathematics are present based on an essential agreement on basic tenets, axioms and reasoning between mathematicians and others, and between teacher and learner [41, p.84]. Mathematical coherence and consistency, in turn, are established in humans' bodily experiences in everyday life, in the human brains' inner workings, and in cognitive mechanisms such as metaphor and analogy, as Lakoff and Núñez [13] have emphasised.

A mathematical statement is true if and only if a proof has been provided. This proof has to be based on the truth of other statements and axioms previously accepted. Moreover, proof is amenable to the accepted processes of reasoning such as *modus ponens* and *tollens*, which are the results of the inner workings of the brain and by their very nature are truth preserving. Thus, proof plays the role of experiment in the discipline of mathematics. Statements must not contradict each other and must compose a logical system that is consistent, coherent and complete (although the completeness has been disproved by the Gödel's theorem). This system is necessary to give answers to questions that arise from real facts. When this happens, the agreement is certainly provided among individuals and it is strong. Then the consistency is tight.

This criterion holds because there is an implicit and inherent agreement between teachers and students as well. This agreement concerns the mathematical processes that were followed and established in the logical structure of the mathematical content, on teachers' and students' pure reasoning based on their uniform cognitive apparatuses and on their shared schemas that were formed by common experiences. This fact is explained through the homogeneous answers that are given by different people to the same mathematical problems that they have never encountered before and that are both correct and/or incorrect.

For example, teachers' and students' identification and correction of the errors that emerge when they practice mathematical problems or procedures, take place after having shown them to each other and being admitted as such by them. This agreement is based on neither teachers' authority nor student's pusillanimity, but rather on the aforementioned reasons. The same situation holds for the learners as well. Skemp states:

> "Teachers are subject to the same rules as learners, and these are not rules of an authoritarian hierarchy but of shared structures of concepts. In mathematics perhaps more than any other subject the learning process depends on agreement, and this agreement rests on pure reason". [41, p. 85].

As cognitive science has shown, people learn by interpreting and processing information ([42], [43]). Thus, by analysing and interpreting students' errors at their formal level of the information process, we can get a conception of their mathematical competence. Students' errors are the results of their learning and as such represent the final criterion for the effectiveness of our instruction on how these results match the desired effects of the learning process. In the aforementioned way, pupils' errors are explicable, predictable and can be described precisely.

By establishing the clarity and soundness of the error analysis in the preceding argumentation, the classification of the probable causes that contributed to the emergence of those errors among the students can take place. This classification is less detailed than others, which prescribe the types of mathematical learning outcomes as being: (i) conventions (ii) facts (iii) concepts (iv) conceptual structures (schemata) (v) skills (vi) general strategies (vii) appreciation, made by other researchers such as Bell, Küchemann, and Costello [44]. The key reason rests on the fact that although the main cause may be identified as being the misunderstanding of a convention or a concept, the final result is due to a whole procedure that was developed because of the reconstructive nature of the recollection. Thus, although the root of a misconception might be a convention or a fact, this cannot be absolutely imputed to that convention or fact. This happens because of the development of a particular procedure that reflects a particular incorrect representation or declarative and procedural knowledge structured in schemata.

Consequently, the key categories that arose from the causes contributing to the emergence of errors are three. The fact that the bounds of these categories are not firmly determined should be emphasised. The reason is that an inappropriately developed representation always leads to an incorrect construction of meaning. This, in turn, may fire an incorrect set of productions that is constituted by particular procedural knowledge based on declarative knowledge. Thus, these three categories are interconnected and interdependent following a circular cyclic course. These categories arose because of:

(i) or statements incorrect recognition -- inappropriate representation of the mathematical symbolism
(ii) incorrect recognition of symbols -- incorrect recall -- incorrect construction of meaning
(iii) incorrect recall -- incorrect declarative knowledge (incorrect conventions, facts, concepts) or/and inappropriate procedural knowledge (incorrect procedures, skills, general strategies) -- inappropriately developed schemata.

Accordingly the errors in the specific problems can be grouped in those categories in the following way:

TABLE 1
ALLOCATION OF PROBLEMS IN CATEGORIES ACCORDING TO THE CAUSES CONTRIBUTING TO THE EMERGENCE OF ERRORS

	INAPPROPRIATE REPRESENTATION		INCORRECT MEANING		INAPPROPRIATELY DEVELOPED SCHEMATA	
	PROBLEM	ERROR	PROBLEM	ERROR	PROBLEM	ERROR

ARITHMETIC	16	$\frac{4}{10}$	40	41.6	20	2700
	26	34.65	21	$\frac{5}{6}$	13	300
	27	6.25	43	0.6	11	$\frac{2}{6}$
	36	140, 140000 or 144, 144000	24	7	21	$\frac{1}{5}$
			37	21	29	4, $\frac{40}{10}$
					33	$\frac{1}{3}, or \frac{3}{9}$
					15	$\frac{1}{20}$
					25	80%, 8%
			30	1.8	30	0.8, 1.8, 0.08
	18	15.758, 15.759	18	15.758, 15.759	18	15.758, 15.759
					22	2.1, 210
					31	7, 70
					41	630000
					14	3, 12
					16	$\frac{40}{100}$
					17	12, 20, 10
					19	2.75, 3.85
					23	100
					24	13
					37	12
					47	1
ALGEBRA	4	1000 or 400, 1500 or 600	8	$7x^2$ or $8x^2$	2	71, $\frac{1}{6}$, $\frac{1}{3}$
	15	8, 27	10	6xy	15	3
	3	16	11	A(i) 4a or 9a A(iii) 4a2, 4aa, 2(2a2) or 15a2, 3(5a2), (3×5)a2 B(i) 30a or 40a B(ii) 10a or 11a	4	0.4
	9	n=20, or n=30	22	A(i) 2a-1 B(ii) 2x	9	n=20n, n=30n
			14	-1x or –x	8	A(ii) (2-5)x B(ii) (1+4-2)x
			20	$2p^3q^3$	11	A(ii) 2a+4 or 6a+9a
			16	A x = 2 B x = 1	22	A(ii) x^2-2x+x-2
			17	B x = 18	11	A(i) 4a or 9a B(i) 30a or 40a B(iii) (2×3×5)a C(i) $3a^3$
			31	x = 1	22	B(i) x^2-a C(i) $3a^2$-$2b^2$ or $2x^2$-$9y^2$ C(ii) $9a^2$-$4b^2$ or $4x^2$-$9y^2$ C(iii) 9a-4b or 4x-9y
			19	A 1 B 6	27	A $\frac{1}{x}$ B $\frac{2}{x}$ C $\frac{1}{(2x)}$
			24	x<2	13	8 or x8
					23	A 4 or 6 B 98 or 48 C 1
					25	(i) 3 (ii) 7, -12
					27	$5x^4$
					16	A x = 2

						B x = 1
					17	x = 36
					12	A 4 B 2
					19	A 1 B 6
					24	x<2

The aforementioned analysis shows that mathematical competence -- as it was determined by the curriculum -- hinges on three key constituents that have to be developed in students' minds:

- *Appropriate representations* (knowledge about symbolism and syntactical rules)
- *Appropriate meaning* (the development of semantics-construction of meaning through the use of symbolic structures)
- *Appropriately developed schemata* (the development of correct declarative and appropriate procedural knowledge).

This inference constitutes the thesis of the present research as well. This is pictorially presented in the following way:

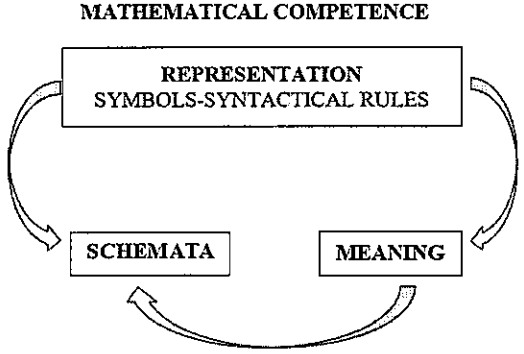

Fig. 1 The development of Mathematical Competence in a learner's mind

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Number Sense Proficiency and Problem Solving Performance of Grade Seven Students

Laissa Mae Francisco, John Rolex Ingreso, Anna Krizel Menguito, Criselda Robrigado, Rej Maegan Tuazon

Abstract—This study aims to determine and describe the existing relationship between number sense proficiency and problem-solving performance of grade seven students from Victorino Mapa High School, Manila. A paper pencil exam containing of 50-item number sense test and 5-item problem-solving test which measures their number sense proficiency and problem-solving performance adapted from McIntosh, Reys, and Bana were used as the research instruments. The data obtained from this study were interpreted and analyzed using the Pearson - Product Moment Coefficient of Correlation to determine the relationship between the two variables. It was found out that students who were low in number sense proficiency tend to be the students with poor problem-solving performance and students with medium number sense proficiency are most likely to have an average problem-solving performance. Likewise, students with high number sense proficiency are those who do excellently in problem-solving performance.

Keywords—number sense, performance, problem solving, proficiency

Corresponding Author
Ingreso John Rolex from Philippine Normal University, Philippines
e-mail: ingreso.jrc@pnu.edu.ph

Land Use Sensitivity Map for the Extreme Flood Events in the Kelantan River Basin

Nader Saadatkhah, Jafar Rahnamarad, Shattri Mansor, Zailani Khuzaimah, Arnis Asmat, Nor Aizam Adnan, Siti Noradzah Adam

***Abstract*—**Kelantan river basin as a flood prone area at the east coast of the peninsular Malaysia has suffered several flood and mudflow events in the recent years. The current research attempted to assess the land cover changes impact in the Kelantan river basin focusing on the runoff contributions from different land cover classes and the potential impact of land cover changes on runoff generation. In this regard, the hydrological regional modeling of rainfall induced runoff event as the improved transient rainfall infiltration and grid based regional model (Improved-TRIGRS) was employed to compute rate of infiltration, and subsequently changes in the discharge volume in this study. The effects of land use changes on peak flow and runoff volume was investigated using storm rainfall events during the last three decades.

***Keywords*—**Kelantan river basin, Improved-TRIGRS model, flood event, land cover changes.

I. Introduction

LAND cover changes triggered by population increase and economic growth in recent decades is considered as the dominant cause of increased flood occurrence [1], [2]. Malaysia was affected by uncontrolled deforestation in the last decades. The massive deforestation raised the runoff coefficients and reduced the infiltration and retention, so a higher volume of rainfall becomes runoff, which concentrates as flash floods.

A research note on the estimated of flood event showed that 9% of Malaysia's land area, which amounts to 29000 km^2, is under flood disaster. The Kelantan river basin at the east coast of the peninsular Malaysia is one of flood prone areas, which is affected with the north-east monsoon season during November and December. Meteorological factors (i.e. climate change), rapid changes in land use, urbanization, and weaknesses in development planning and monitoring are affected on the increasing of flood events at Kelantan river basin in recent decades.

The land cover changes lead to higher peak flow and large volumes of runoff flow. Therefore, this study tried to quantify the effects of land cover/land use (LULC) changes (e.g. urbanization, deforestation) on increased rate of flood at the Kelantan river basin. In this regard, the hydrological regional modeling of rainfall induced runoff event were employed to compute rate of infiltration, and subsequently changes in the discharge volume in this paper. The effects of land use changes on peak discharge and flood volume are investigated using a storm rainfall events during December 2014. Attention was given to differences in peak flood and discharge volume resulting from the land cover changes during 30 decades.

II. Models and Materials

A. Improved-TRIGRS Model

In the process of simulation of flood events, knowledge of canopy characteristics and geotechnical properties of the study area are imperative steps. Fig. 1 shows the overall research flow of this study. The first part of the research methodology focused on the preparing raster data to simulate runoff event at the Kelantan river basin. Having an information assigned to each cell, the input data were converted into a grid-based framework (e.g. terrain data, slope geometry data, soil hydrological and mechanical properties, rainfall information, interception loss water data, drainage basin areas and plant cover map). All input layers were acquired by the GIS database system (ArcGIS 10.3). A map was generated at the same Grid based (10 m×10 m) and raster format for each of the parameters used in the model.

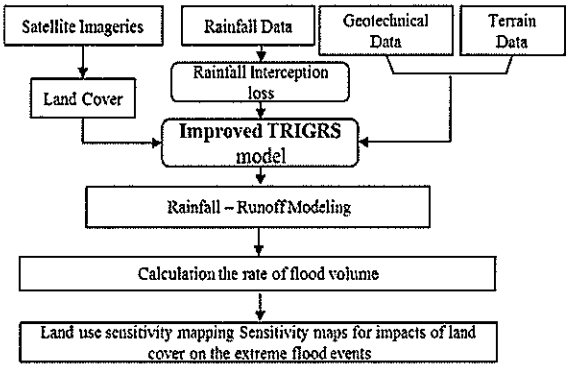


Fig. 1 Rainfall Runoff modeling

The second part of research methodology is dedicated to analyze the impact of land cover changes on the flood volume in terms of sensitivity maps. In this regard, the assessment of

Nader Saadatkhah is with the The Academic Center for Education, Culture and Research (ACECR), Kerman, Iran (Corresponding Author, e-mail: n_saadat_khah@hotmail.com).

Jafar Rahnamarad is with the Department of Geology, Zahedan Branch, Islamic Azad University, Zahedan, Iran.

Shattri Mansor, Zailani Khuzaimah, Siti Noradzah Adam are with the Geospatial Information Science Research Center (GISRC), Department of Civil Engineering, Faculty of Engineering, University Putra Malaysia (UPM), Serdang, Selangor, Malaysia.

Arnis Asmat is with the School of Chemistry and Environmental Studies, Faculty of Applied Sciences, Universiti Teknologi MARA (UiTM), Shah Alam. Selangor, Malaysia.

Nor Aizam Adnan is with the Centre of Studies Surveying Science and Geomatics, UiTM, Shah Alam. Selangor, Malaysia.

the effect of land cover changes as a main factor in the rate of infiltration/ loss water, consequently the runoff volume is conducted based on the modified TRIGRS [3] model in this study. The canopy interception method and the water infiltration/ loss model based on Lawrence and Chase [4] and Richard equation, respectively, is employed for calculating the rate of precipitation arriving at the vegetation, top, ground surface, and infiltrated on the ground over broad areas of the Kelantan river basin. Subsequently, the flood simulation is obtained based on interception loss of water estimated from leaf area index (LAI), which is the net amount of precipitation that reaches ground surface and plant cover characteristics as an input.

The Improved TRIGRS model uses a routing method of surface runoff from cells that have excess surface water to adjacent downslope cells where it can either infiltrate or flow farther down slope. So, this model is used for storage and movement of water vertically within the soil layer. It is assumed that runoff occurs when the precipitation and runoff supplied to a cell exceed its infiltrability [5]. It is computed the infiltration, I, at each cell as the sum of the precipitation, P, plus any runoff from upslope cells, Ru, with the limitation that infiltration cannot exceed the saturated hydraulic conductivity, Ks.

B. *Hydrological and mechanical characteristics of Kelantan soil*

The Kelantan river basin is generally underlain by extrusive and intrusive igneous rocks. Weathering and the erosion of the igneous rocks have led to the concentration of the residual soils in the study area on the granitic masses and produced Grade V and Grade VI residual soils with a thickness of approximately 1 m to 30 m in the Kelantan area. The top layer of soil was classified under the eight different types of soil classes, i.e. Clay (CL Prang), clayey sands (SC Rengam), clay (CL Langkawi), fat clay (CH STP), clayey sands (SC Munchong), clayey sands (SC Batu Hitam), silty sands (SM Batang/ Durian Munchong), and lean clay (CL ULD) using 1:100,000 scale Kelantan soil map (Department of Irrigation and Drainage, Malaysia), as shown in Fig. 2.

The mechanical and hydraulic characteristics of soil are collected from the ministry of agriculture and agro-based industry of Malaysia (MOA) and the slope-engineering branch of public works department Malaysia (PWD), as well as, the data compiled from the previous reported studies and geotechnical boreholes. Each cell in a grid map was assigned to one of the properties of the soil, through a creation of the ASCI grid files. It contains respective information about soil cohesion, soil residual water content θr, and total unit weight of soil, soil saturated water content θs, friction angle, vertical saturation hydraulic conductivity, unit weight of water, and residual hydraulic conductivity of soil Ks, Kr, as listed in Table I. Based on van Genuchten equation, matric suction versus volumetric water content was assigned to each of the zones as shown in Table I. The leaf area index (LAI) of the study area was defined as ranging from 1.49 to 3.99 based on LAI-2000 [6] and linear regression equation from NDVI [7], as shown in Fig. 3.

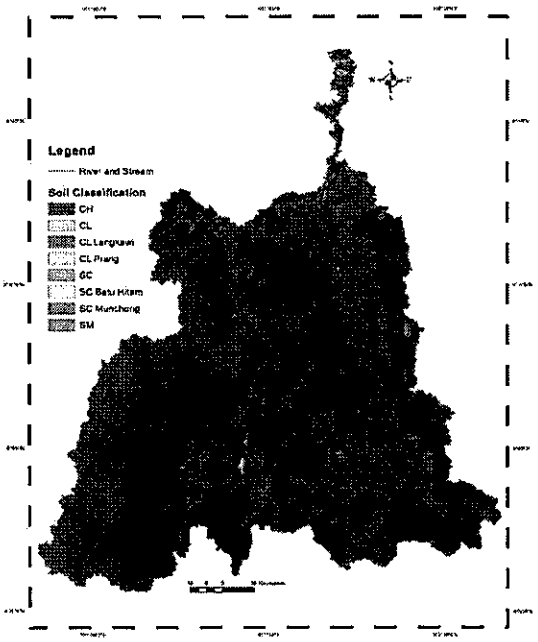


Figure 2. Soil classification of Kelantan river basin

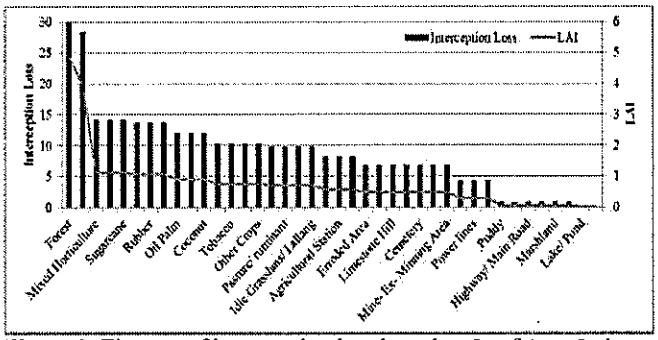


Figure 3. The rate of interception loss based on Leaf Area Index (LAI)

TABLE I. Characteristics of soils at Kelantanbasin

Soil Name	Group Sym.	γ_t	C'	φ'	K_s	θ_r	θ_s
Batu Hitam	SC	15.7	5	32	1.61E-07	0.049	0.263
Munchong	SC	16.8	4	33	1.49E-07	0.05	0.275
Rengam	SC	16.3	11	31	9.61E-07	0.055	0.278
STP	CH	13.7	26	23	3.12E-09	0.166	0.873
Prang	CL	14.1	23	31.5	2.10E-08	0.181	0.842
ULD	CL	14.8	22	28	1.84E-08	0.189	0.793
Langkawi	CL	15.4	21	29	1.64E-08	0.28	0.754
Batang/ Durian Munchong	SM	18.7	2	35	1.52E-06	0.294	0.339

C. *The December 2014 Flood Event*

At the end of December 2014, Kelantan river basin in the northeast of Peninsular Malaysia has faced the extreme floods in recent decades. Heavy rainfall events since 17th December to 3rd January has forced Kelantan people at river basin to flee their homes while Kelantan basin recorded monthly total rainfall amount exceeded 1200 mm during December 2014. Apparently, the flood occurrences showed good agreements with the rate of rainfall events in Kelantan river basin. These observations signified the importance of correlating the

initiations of flood occurrences in Kelantan river basin with rainfall runoff. In this paper, 10 days of hourly rainfall data at the end of December 2014 are considered for analyzing rainfall-induced runoff based on 15 rainfall measurement stations at Kelantan river basin.

III. Results and Discussion

A. *Land Use Sensitivity Map*

The covered area of Kelantan land has been defined by forest reserves, which is 956,139.9 ha (63.66% of Kelantan's total land area). It is mainly located in the upstream of Kelantan river basin and is followed by agriculture, which covers an area of 395,156.8 ha (26.32%), i.e. rubber and oil palm cover 349,365.4 ha (23.27%), while urban area and development area covers only 14,616.5 ha (0.92%). The remaining area is covered by scrub, grassland, pasture, secondary forest and other crops. Due to an urban development, the way, the land is used has been changed. Whereas, the conversion of forests into agricultural areas has been changing progressively with a higher pace during 1984 to 2002, which became slower in 2002 until 2013.

The land cover distribution for this study area was classified based thirty two types of land covers, i.e. lake/ pond, highway/ main road, railway, power lines, recreational area, mine and ex-mining area, urban/ residential etc., quarry and ex-quarry, cemetery, agriculture station, floriculture, mixed horticulture (village), vegetables, herbs and spices, cocoa, coconut, rubber, oil palm, orchard, banana, paddy, tobacco, other crops, aquaculture, poultry and others, pasture/ ruminant, idle grassland/ lallang, scrub, forest, secondary forest, swamp forest/ mangrove swamp, marshland, beach sand/ river sand, cleared land, eroded area, a limestone hill and reclaimed areas (Fig. 4).

The initial run of the models are made for the end of December 2014 with land use/ land cover values obtained from site. The land use parameter was chosen to further evaluate rainfall runoff models sensitivity at Kelantan river basin. Land use changes in any catchment areas affect many processes like interception loss, resistance to surface runoff, and evapotranspiration. The input values were initially set based on the best fit of outputs and expected ranges.

Figure 5 showed the total amounts of precipitation along with the total infiltration losses that resulted in the presented with the extreme rainfall intensities of more than 44 mm/hour in the most intense 1 hour of the 10 day storm. The absolute loss of a certain event is only a function of the land cover, soil characteristics, and the absolute rainfall depth regardless of the intensity distribution. According to apply Improved TRIGRS model, after the beginning of the rainfall event, no runoff begins until the accumulated precipitation P equals the initial hydraulic conductivity of soil K. After the accumulated rainfall exceeds the initial K, runoff is calculated by subtracting R (water retained in the watershed) from the accumulated rainfall.

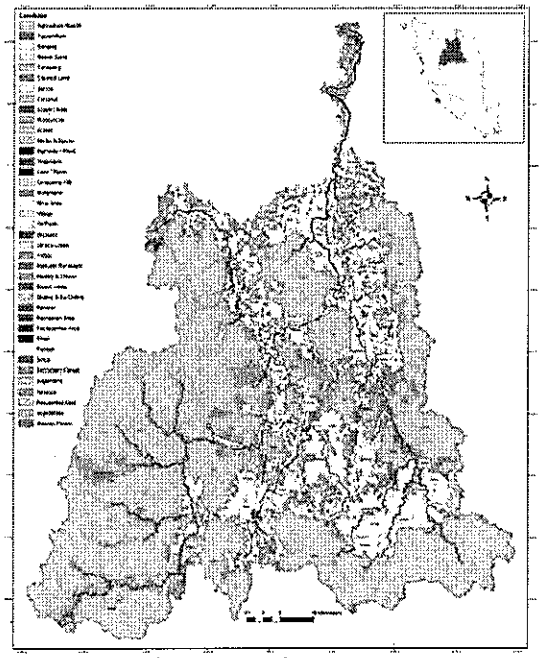


Figure 4. Land cover map

According to the Improved model, the resulting land use changes effects on the flood flows as the land use sensitivity evaluations are illustrated in the study area (Fig. 6). The critical runoff events were mainly scattered on the cleared areas and the areas under development (i.e., urban areas). Forest conversion to the less canopy coverage (i.e.,. oil palm, rubber, and mixed horticulture areas) is responsible for a very high to high level of runoff events in the study area (Figs. 7). In this regards, the fatal debris flows and runoff were caused by a combination of extreme rainfall, destruction of natural forest cover (human-caused), and conversion to agricultural plantations in thin, granitic soils.

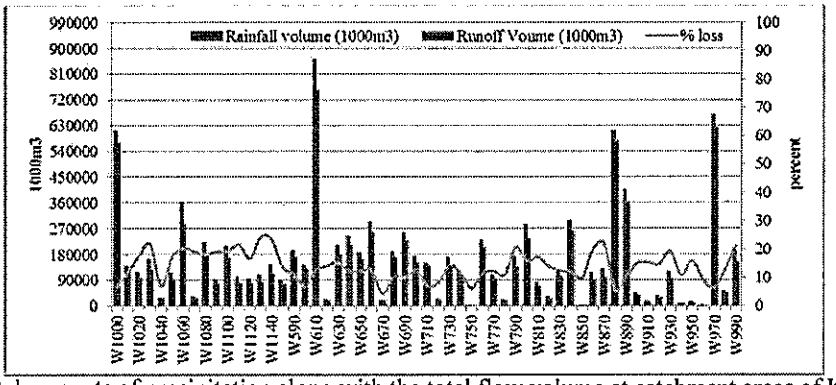


Figure 5. The total amounts of precipitation along with the total flow volume at catchment areas of Kelantan river basin

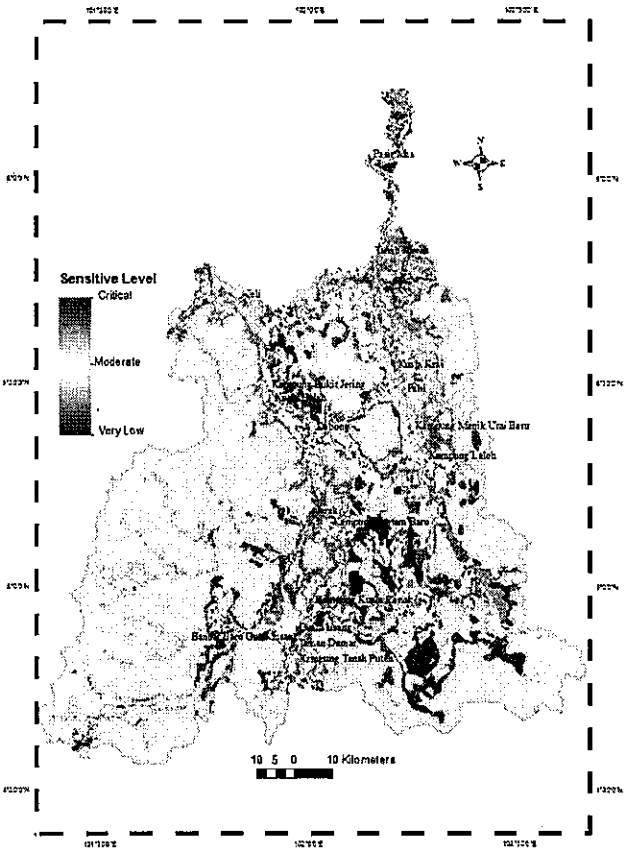
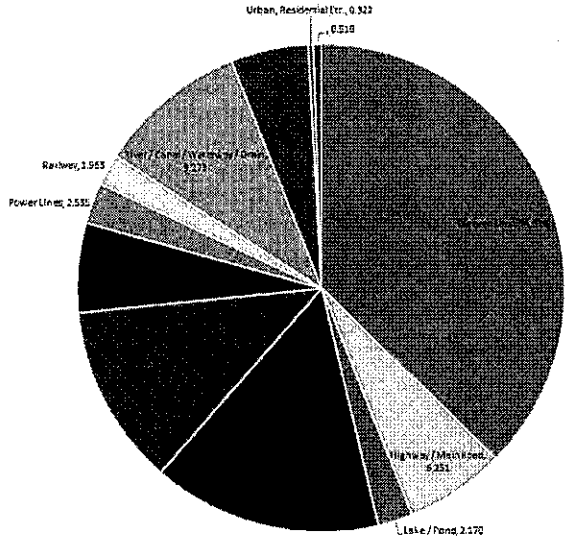


Figure 6. Land use sensitivity map

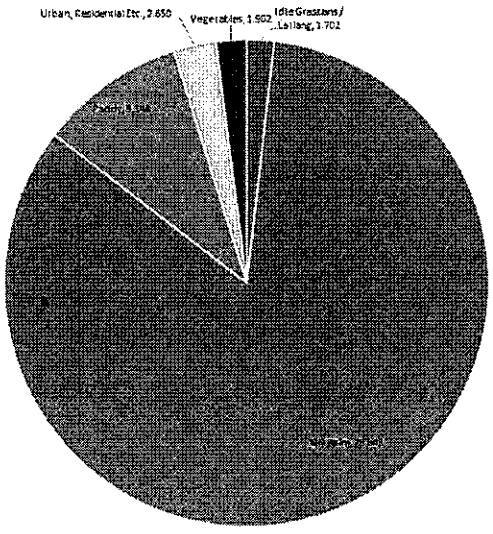
B. *Models Assessment and Calibration*

Model calibration is a systemic approach for adjusting model parameters values to derive an acceptable match between the simulated and observed hydrographs. The discharge volume and peak of discharge were employed to measure quantitatively the degree of difference between simulated and observed flood [8]. The process tries to find the optimum values for parameters, which cannot be estimated through observation of catchment characteristics or measurement. The assessment and calibration of model are carried out to evaluate whether the Improved-TRIGRS model, using the land cover parameter set obtained by optimization can produce outputs with reasonable accuracy. Subsequently, the output data is set based on observed ranges and best fit of outputs.

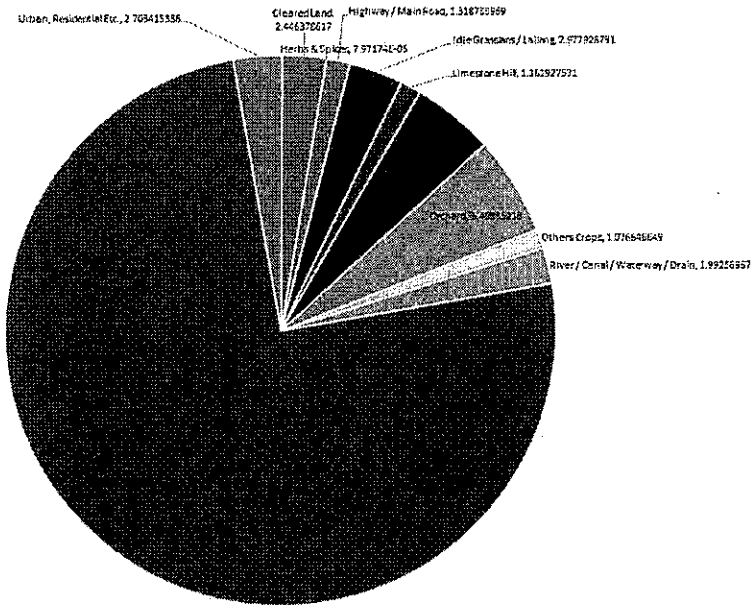
Two hydrological measurement stations close to Jeli and Tanah Merah catchment areas at Kelantan river basin is selected for assessment and calibration simulated results. The rate of increasing discharge volume for two observed sites and the usage model are collected and compared together. The comparison is carried out numerically (comparison of observed and simulated values) or graphically (visual comparison) using performance measures. From the assessment results, an acceptable shape of hydrograph was achieved (Figs. 8a, b). The rising and decreasing chart line showed acceptable agreement between the flood observed sites and simulated hydrographs based on Improved-TRIGRS model while the simulated result using TRIGRS model is shown a suitable fit with observation data.



(a)

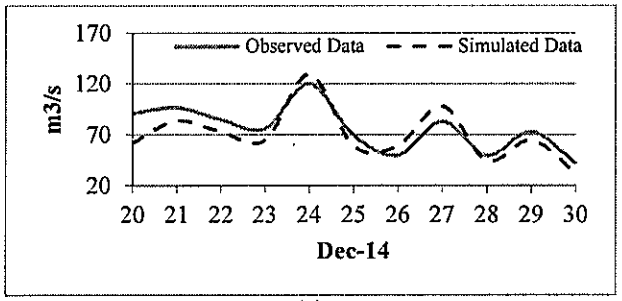


(b)

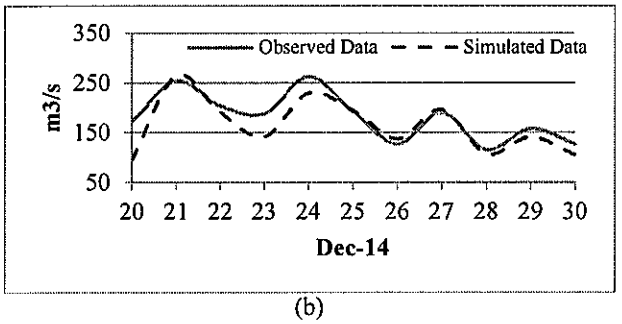


(c)

Figure 7. a) Critical; b) very high; and c) high Land use sensitive level based on sensitivity map



(a)



(b)

Figure 8a, b. Calibration and assessment Improved TRIGRS model on the a) Jeli and b) Tanah Merah

IV. CONCLUSION

This paper provides the assessment of land cover impact on the runoff processing using the Improved-TRIGRS modeling under rain stream events during last three decades at Kelantan river basin. The following conclusions and key findings can be summarized:

- The usage Improved-TRIGRS model showed that land cover changes caused significant differences in hydrological response to surface water. The increasing of runoff volume at Kelantan river basin is as a function of deforestation and urbanization, especially conversion the forest area to agricultural land (i.e. rubber and mixed- agriculture).
- Deforestation and conversion to agricultural area caused increases in peak of discharge and flood volume due to lower interception loss, evapotranspiration capacity. In contrast, urban development area lead to a greater impervious ground surface and excess to runoff volume when less infiltration occurred.
- The main findings of this paper demonstrated that forest area plays an important role in controlling water flow and subsequently minimizing the runoff volume in the study area. If jungle area were replaced by different land cover types such as development area and agricultural land, less loss/ infiltration would be incurred and hence a higher flood magnitude would be predicted.
- After the calibration and verification process for the improved model, it is clearly demonstration by the evaluation results that the model was capable of generating reliable water level forecasting at Kelantan river basin.
- The current analysis showed that the reliable framework to detect the impact of land cover changes in understanding the behavior of the hydrological and mechanical system in catchment areas.

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Learners' Conspicuous and Significant Errors in Arithmetic

Michael Lousis

Abstract—The systematic identification of the most conspicuous and significant errors made by learners during three-years of testing of their progress in learning Arithmetic are presented in this article. How much retentive these errors are over three-years in the officially provided school instruction of Arithmetic is also shown. The learners' errors in Arithmetic stem from a sample, which is comprised of two hundred (200) English students and one hundred and fifty (150) Greek students. The sample was purposefully selected according to the students' participation in each testing session in the development of the three-year *Kassel Project* in England and Greece, in both domains simultaneously in Arithmetic and Algebra. This means that a student was immediately excluded from the sample if a script for whatever reason was missing in one of these testing sessions. Thus the data sample included six test-scripts, for each student, corresponding to three testing sessions in both Arithmetic and Algebra respectively.

Keywords—Arithmetic, errors, Kassel Project, progress of learning, retentiveness of errors in the officially provided instruction.

I. Introduction

Two key objectives are set for accomplishment by the researchers in mathematics education. Firstly, they aim to develop a functional conceptual framework that contributes to a better understanding and explanation of how mathematical knowledge, as a process of mind and as a psychological entity, occurs in reality. Secondly, they try to promote a better understanding of how knowledge is recorded through different means and is represented in context. The improvement of these means and the transmission of such knowledge in specific contexts, natural (classroom) or artificial (textbooks, computerised materials) is their final goal [1].

Because of the inter-subjective nature and social construction of knowledge, these two perspectives are interconnected. Both perspectives have used error analysis as an effective means to advance their understanding of human cognition. The determination of students' mathematical competence has heavily been based on mathematical error analysis [2] – [4]. This was the motivation behind my study. Students' mathematical error analysis was considered to be of triple importance: i) *Diagnostic*: identifying individual difficulties and thus raising awareness ii) *Scientific*: as a research strategy applying to specific theories which identify the probable causes of the emergence of learner's misconceptions and to provide explanations. iii) *Prescriptive*: as a source of prescriptions concerning the effectiveness of the transfer of mathematical knowledge, based on the deterministic character of the outcomes of this particular research strategy.

The *diagnostic* [5], [6] character of a study concerning basic units of Arithmetic stands out in this paper.

II. The Selection Of The Sample

The present study started as a part and supplement of a larger, international, longitudinal, comparative research program with the title *Kassel Project* [7], [8]. The study was closely interrelated with the broad topic that this wide program aimed to cover. This aspired to contribute to the solution of the overall research problem that was posed by that particular research program, that is, "to carry out research into teaching and learning of mathematics in different countries (18 countries), and ultimately to make recommendations about good practice in helping pupils achieve their mathematical potential" [8, p. 135] with the objective of finding "the *key factors* that give rise to successful progress in *mathematics*" [8, p. 135] (italics in the original). The present study was an error analysis. This study aimed to investigate the English and Greek students' errors, as these were developed in the tests of Number (arithmetic) and Algebra that were issued to the students who participated in the Kassel Project. A large, random, quantitative sample was used for the development of this program in these countries. Nonetheless, for the purposes of this particular study, a separate purposeful qualitative sample was selected from the available data of this research program, which was collected in both countries England and Greece. However, this article focuses on the learners' outcomes in Arithmetic in both countries Greece and England.

Thus, the sample of the present study included two hundred (200) English students, who were purposefully selected according to their participation in each phase of testing in the domains of Arithmetic and Algebra during the three-year development of the project in England. Consequently, six test-scripts were available for each of these English students, which corresponded to the three testing sessions in Arithmetic and Algebra respectively. The selection of each student was based on his/her participation in both domains at once, since this was deemed to be important for tracking down the study of the learners' probable progress in learning through specific errors they made in each domain during the three-years of testing. A

M. G. Lousis is with the Greek Ministry of Education, serving as School Advisor in Prefecture of Serres, 62100, GREECE (mobile tel: 00306988979197; e-mail: michael.lousis@ gmail.com).

student's inclusion in the sample was rejected, if the specific student did not participate in a particular time of testing in one of the two domains for whatever reason, or when a particular student's test-script in one of the six occasions of testing was missing. According to this procedure of selection, one thousand two hundred scripts (1200) were collected from the students of specific schools across England. These schools were private or state-funded, comprehensive or grammar schools, and belonged to working-class and middle-class, rural, suburban and urban areas of England. Consequently, one could not easily cast doubt concerning the findings of this research, as being common to all schools in the sample, and that these findings apply to the general population of English students, although these schools were not randomly selected.

Similarly, one hundred and fifty (150) Greek students were selected and included in the sample. They fulfilled the same conditions of selection as their English counterparts. Nine hundred (900) test-scripts were provided by the Greek Coordinator, which were resulted from testing students of specific schools in Greece. The procedure that was followed was the same with that one for the English students. These schools were selected from working-class and middle-class, rural, suburban and urban areas of Greece. These schools are of the classical type of state schools in Greece called Gymnasiums. Thus, although these schools were not randomly selected, the findings of this research could be applied to the general population of Greek students, without any doubt, because of two reasons: i) the uniformity that characterizes these schools in Greece and ii) that almost the same teaching practices are commonly performed in these schools, and one textbook is in use, which is provided by the state.

III. The Use Of Descriptive Statistics

After the collection of the purposeful sample and the registration of the data into the computer, the calculation of the *frequencies* of each of the specific errors the students made in each problem and in each of the testing times, took place. The number of times that a specific error is shown in each of the English and the Greek samples in a testing time, that is, the rate of emergence of each error in the sample for each testing session is defined as the *frequency of an error*. The two samples were elaborated separately and the frequency of each error in each time of testing was found by using the software of Excel.

Then the *relative frequency* of each error in each Greek and English sample was calculated. The *relative frequency* of an error is defined as the number of times this specific error occurs compared to the total number of elements in the sample (Greek or English) under consideration. Since the frequency of an error is a natural number smaller or equal to the total number of the elements of the sample, the number of each relative frequency is a decimal smaller than the number one. This decimal then is transformed into a percentage for reasons of an easier comparison. The bigger this percentage is, the more important and significant this error becomes. In this way the identification of the significant errors became easier. Moreover, this transformation enabled the comparison between the different percentages of the same error in both samples to take place. Those errors that showed the higher frequency were deemed significant for calculating their relative frequencies. By applying this procedure, the identification of the course of each specific error in the sample, during the three times of testing became possible. That is, the resistance to subversion of each error in the officially provided instruction was tracked down during the period of the development of the project.

Because of the vast number and diversity of these errors, the study of all of them was deemed to be impossible under the present circumstances and the time restrictions. Thus, not all of them were arbitrarily considered important for further investigation or for giving explanations except for these errors, which had a relative frequency of over 5% at the first time of testing. However, this data reduction sacrifices some details, but the remaining data serves to transmit the main picture. These specific significant errors were presented in tables with their respective relative frequencies, and the course of their appearance and retentiveness was commended.

The selection of that particular research method was imperative because of the *diagnostic* purpose of the study. Moreover, it was dictated by a necessity for providing an answer to the first research question, which was to identify and finally to find out *what* kind of unexpected and unanticipated errors the English and the Greek students made in the three- or two-years of testing, when participating in the project.

The frequencies and relative frequencies of the conspicuous and significant errors that have been made in particular questions or problems of specific topics of Arithmetic are presented in tables. Each table comprises an indicator, i.e. Q4, which stands for the number of the question under examination in the administered test. The expression "Key Trends" refers to commends made concerning the course of resistance to remedy of these errors during the three years of testing, or to the comparison between the two samples concerning these errors.

IV. Questions

A. Whole Numbers

TABLE I
INFORMATION CONCERNING QUESTION No 20 OF THE TEST

				Age 13+	14+	15+
Q20	60×450 = ?	% correct	ENGLAND	42.5	51.5	54
			GREECE	78	80	81.3
	Significant error	2700 or 1950	ENGLAND	16.5	18	18.5
			GREECE	9.3	10	9.3

Key Trends

- Steady improvement for both samples
- Significantly better performance by GREECE than ENGLAND
- Error 2700 dominant for ENGLAND becomes more significant in time. Error 2700 persists over time for GREECE.

TABLE II
INFORMATION CONCDERNING QUESTION No 13 OF THE TEST

				Age 13+	14+	15+
Q13	900÷30 = ?	% correct	ENGLAND	71.5	77	79.5
			GREECE	92	88	88.6
	Significant error	300	ENGLAND	9	8.5	6.5
			GREECE	Not significant		

Key Trends

- Steady improvement for both samples
- Better performance for GREECE than ENGLAND
- Dip for GREECE at 14+ that continued by 15+
- Error 300 for ENGLAND becomes less significant with time.

TABLE III
INFORMATION CONCERNING QUESTION No 40 OF THE TEST

				Age 13+	14+	15+
Q40	$(125)^{1/3} = ?$	% correct	ENGLAND	0	0.5	18
			GREECE	0	1.3	2.5
	Significant error	41.6	ENGLAND	7	9.5	2.5
			GREECE	Not significant		

Key Trends

- Important improvement for ENGLAND at 15+
- Steady unobtrusive improvement for GREECE. Very poor performance over time
- Error 41.6 significant with a slight increase at 14+ but then considerable improvement.

B. Fractions

TABLE IV
INFORMATION CONCERNING QUESTION No 11 OF THE TEST

				Age 13+	14+	15+
Q11	$\frac{1}{2}+\frac{1}{4}=?$	%correct	ENGLAND	72.5	80.5	84
			GREECE	76.6	70.6	80.6
	Significant Errors	$\frac{2}{6}$	ENGLAND	9	7	3.5
			GREECE	6	6	5.3
		$\frac{1}{6}$	ENGLAND	4.5	3.5	5.5
			GREECE	1.3	6.6	1.3

Key Trends

- Steady improvement for ENGLAND
- Dip for GREECE at 14+, but then improvement
- Error $\frac{2}{6}$ less significant in time for ENGLAND
- No real improvement for error $\frac{2}{6}$ in GREECE over time
- Error $\frac{1}{6}$ persists over time for ENGLAND.

TABLE V
INFORMATION CONCERNING QUESTION No 21 OF THE TEST

				Age 13+	14+	15+
Q21	$\frac{1}{2}-\frac{1}{3}=?$	% correct	ENGLAND	39.5	48	53
			GREECE	66.6	70	73.3
	Significant errors	$\frac{1}{5}$	ENGLAND	4	6	5.5
			GREECE	Not significant		
		$\frac{5}{6}$	ENGLAND	Not significant		
			GREECE	5.3	1.3	1.3

Key Trends

- Significantly better performance by GREECE than ENGLAND
- Error $\frac{1}{5}$ persists for ENGLAND with time
- Error $\frac{5}{6}$ for GREECE becomes less significant with time.

TABLE VI
INFORMATION CONCERNING QUESTION No 29 OF THE TEST

				Age 13+	14+	15+
Q29	$\frac{1}{2}\times\frac{4}{5}=?$	% correct	ENGLAND	49	44.5	51.5
			GREECE	65.3	72.6	74.6
	Significant errors	4	ENGLAND	8.5	3.5	4
			GREECE	Not significant		
		$\frac{40}{10}$	ENGLAND	Not significant		
			GREECE	6.6	5.3	0.6

Key Trends

- Significantly better performance by GREECE than ENGLAND
- Error 4 significant, but with some improvement over time, for ENGLAND

- Error $\frac{40}{10}$ for GREECE eradicated by age 15.

TABLE VII
INFORMATION CONCERNING QUESTION No 33 OF THE TEST

				Age 13+	14+	15+
Q33	$\frac{1}{3} \div \frac{1}{9} = ?$	% correct	ENGLAND	31	31	33
			GREECE	12.6 (40.6) *	31.3 (60.6) *	32 (60) *
	Significant error	$\frac{1}{3}$ or $\frac{3}{9}$	ENGLAND	21	24	17.5
			GREECE	14	12	8

Key Trends

- The performance is almost the same for both samples. (*)Significantly better performance by GREECE than ENGLAND if one takes into account the Greek students' answer $\frac{9}{3}$ as a correct answer
- $\frac{1}{3}$ error is prevalent for England. The error persists with time for both samples. A slight improvement for both samples in the third round.

TABLE VIII
INFORMATION CONCERNING QUESTION No 43 OF THE TEST

				Age 13+	14+	15+
Q43	$2.4 \times 1\frac{1}{4} = ?$	% correct	ENGLAND	10.5	20.5	23.5
			GREECE	10	4	7.3
	Significant error	0.6	ENGLAND	Not significant		
			GREECE	0	2.6	7.3

Key Trends

- Steady improvement for ENGLAND
- Better performance by ENGLAND than GREECE
- Dip for GREECE at 14+, but then slight improvement albeit less than that in the first round Error 0.6 becomes significant over time for GREECE.

C. Percentages

TABLE IX
INFORMATION CONCERNING QUESTION No 15 OF THE TEST

				Age 13+	14+	15+
Q15	Express 20% as a fraction	% correct	ENGLAND	65	66.5	75
			GREECE	93.3	90.6	90.6
	Significant error	$\frac{1}{20}$	ENGLAND	6.5	7.5	7.5
			GREECE	Not significant		

Key Trends

- Significantly better performance by GREECE than ENGLAND
- Dip for GREECE at 14+ but then steady performance
- Error $\frac{1}{20}$ dominates and persists for ENGLAND over time.

TABLE X
INFORMATION CONCERNING QUESTION No 25 OF THE TEST

				Age 13+	14+	15+
Q25	Express $\frac{1}{8}$ as a percentage	% correct	ENGLAND	29	40.5	39
			GREECE	15.3	29.3	31.3
	Significant errors	80%	ENGLAND	9	8.5	6
			GREECE	Not significant		
		8%	ENGLAND	9	7.5	9.5
			GREECE	7.3	17.3	6

Key Trends

- Significantly better performance by ENGLAND than GREECE
- An unobtrusive dip for ENGLAND at 15+
- Error 80% is significant for ENGLAND over time. A slight improvement at 15+
- Error 8% is significant both for England and Greece over time.
- A steep increase of the error 8% for GREECE at 14+ but then a slight improvement in contrast with the percentage at 13+.

D. Decimals

TABLE XI
INFORMATION CONCERNING QUESTION No 30 OF THE TEST

				Age 13+	14+	15+
Q30	Express $\frac{1}{8}$ as a decimal	% correct	ENGLAND	20.5	25.5	27.5
			GREECE	17.3	22	23.3
	Significant errors	0.8	ENGLAND	23.5	24.5	25
			GREECE	8	18.6	10
		1.8	ENGLAND	7.5	7.5	6.5
			GREECE	15.3	14	5.3
		0.08	ENGLAND	3.5	8	6
			GREECE	Not significant		

Key Trends

- Better performance by ENGLAND than GREECE
- Steady improvement for both samples

- Error 0.8 dominant for ENGLAND becomes more significant in time. No improvement over time
- Error 0.8 becomes more significant for GREECE in time. A steep increase at 14+. No improvement over time.
- No real improvement for error 1.8 in ENGLAND over time
- Error 1.8 becomes less significant for GREECE over time
- Error 0.08 becomes more significant for ENGLAND in time. A steep increase of the error at 14+ but then a slight dip at 15+. No improvement over time.

TABLE XII
INFORMATION CONCERNING QUESTION No 41 OF THE TEST

				Age 13+	14+	15+
Q41	Calculate $(2.1\times10^2)\times(3\times10^4)$	% correct	ENGLAND	11	14	23.5
			GREECE	16	14	14
	Significant error	630000	ENGLAND	7	7.5	8
			GREECE	Not significant		
			GREECE	Not significant		

Key Trends

- Steady improvement for ENGLAND
- Dip for GREECE at 14+ that continued by 15+
- Better performance by GREECE than ENGLAND at 13+ but then significantly better performance by ENGLAND at 15+
- Error 630000 persists over time for ENGLAND.

TABLE XIII
INFORMATION CONCERNING QUESTION No 22 OF THE TEST

				Age 13+	14+	15+
Q22	70×0.3 = ?	% correct	ENGLAND	27	44.5	51.5
			GREECE	60	64	70.6
	Significant errors	2.1	ENGLAND	11.5	5	7.5
			GREECE	6.6	11.3	5.3
		210	ENGLAND	11	5	5
			GREECE	10.6	2.6	4.6

Key Trends

- Steady improvement for both samples in time
- Significantly better performance by GREECE than ENGLAND
- Error 2.1 becomes less significant for ENGLAND with time. A dip at 14+ but then a slight increase again
- No real improvement for error 2.1 in GREECE over time. A steep increase at 14+
- Error 210 becomes less significant for ENGLAND with time.
- Error 210 becomes less significant for GREECE with time. A dip at 14+ but then a slight increase at 15+.

TABLE XIV
INFORMATION CONCERNING QUESTION No 31 OF THE TEST

				Age 13+	14+	15+
Q31	490÷0.7 = ?	% correct	ENGLAND	9.5	16.5	19
			GREECE	46.6	49.3	38
	Significant errors	70	ENGLAND	13	13.5	15.5
			GREECE	12.6	2	2
		7	ENGLAND	10.5	9	12
			GREECE	0.6	8.6	9.3

Key Trends

- Steady improvement for ENGLAND
- Steady improvement for GREECE as well but then a dip at 15+
- Impressively better performance by GREECE than ENGLAND
- Error 70 dominant for ENGLAND becomes more significant in time
- Error 70 for GREECE much less significant at 14+ and thereafter
- Error 7 persists over time for ENGLAND Error 7 becomes much more significant in time for GREECE.

TABLE XV
INFORMATION CONCERNING QUESTION No 18 OF THE TEST

				Age 13+	14+	15+
Q18	Give a number to two decimal places, which lies between 15.755 and 15.762	% correct	ENGLAND	42	48.5	54
			GREECE	30	54.6	53.3
	Significant errors	15.758	ENGLAND	5	7.5	8
			GREECE	12	2	2
		15.759	ENGLAND	5	6.5	7
			GREECE	3.3	2.6	3.3

Key Trends

- Steady improvement for ENGLAND
- Impressive improvement for GREECE at 14+ but then a slight dip.
- Almost the same performance for both samples at 15+

- Error 15.758 becomes more significant for ENGLAND in time. No improvement over time
- Error 15.758 for GREECE almost eradicated by age 15+
- Error 15.759 becomes more significant for ENGLAND in time. No improvement over time
- No real improvement for error 15.759 in GREECE over time. A slight dip in 14+.

E. Integers

TABLE XVI
INFORMATION CONCERNING QUESTION No 14 OF THE TEST

				Age 13+	Age 14+	Age 15+
Q14	The temperature changes from -5°C to +8°C. What is the increase in temperature?	% correct	ENGLAND	79	87.5	89
			GREECE	62	70.6	82
	Significant errors	12	ENGLAND	7.5	3	5
			GREECE	6.6	6	4
		3	ENGLAND	6	5	2.5
			GREECE	17.3	13.3	4

Key Trends

- Steady improvement for both samples in time
- Better performance by ENGLAND than GREECE
- Error 12 significant, but with some improvement over time, for ENGLAND
- Error 12 persists over time for GREECE. A slight improvement by 15+
- The emergence of the error 3 significantly diminished at 15+ for ENGLAND
- Error 3 important for GREECE, but with some improvement at the second round, which became significant in the third round.

F. Problem Solving

TABLE XVII
INFORMATION CONCERNING QUESTION No 16 OF THE TEST

				Age 13+	Age 14+	Age 15+
Q16	Calculate $\frac{1}{10}$ of 4m and express the answer in cm.	% correct	ENGLAND	60	66	70
			GREECE	26	43	45.3
	Significant error		ENGLAND	Not significant		
	$\frac{4}{10}$ =0.4		GREECE	14	8	14.6

Key Trends

- Significantly better performance by ENGLAND than GREECE
- Steady improvement for both samples
- Error 0.4 was persistent over time for GREECE except a dip at 14+.

TABLE XVIII
INFORMATION CONCERNING QUESTION No 17 OF THE PROBLEM

				Age 13+	Age 14+	Age 15+
Q17	Pencils cost 15p each. (a) How many can be bought for £2?	% correct 17(a)	ENGLAND	69	69	77.5
			GREECE	80.6	79.3	79.3
	(b) How much change will there be?	% correct 17(b)	ENGLAND	71	73.5	83.5
			GREECE	80.6	83.3	78.6
	Significant errors	(a) 12	ENGLAND	14	15	9.5
			GREECE	5.3	6.6	4.6
		(b) (i) 20	ENGLAND	11	15	9
			GREECE	6	5.3	4.6
		(b)(ii) 10	ENGLAND	9	7	3
			GREECE	5.3	4.6	5.3

Key Trends

- Steady performance in the second and third round of testing for ENGLAND in the first question but then improvement
- Almost steady performance for GREECE throughout testing in the first question
- Steady improvement in the second question for ENGLAND in time
- Steady improvement in the second question for GREECE, but then a dip at 15+
- Error 12 significant for ENGLAND, but some improvement in 15+
- No real improvement for error 12 in GREECE over time
- Error 20 was significant for ENGLAND with an increase in its emergence at 14+ but then a slight decrease. No real improvement throughout testing.
- Error became less significant in time for ENGLAND
- Error 10 was almost steady in emergence for GREECE over time.

TABLE XIX
INFORMATION CONCENRING QUESTION No 23 OF THE TEST

				Age 13+	14+	15+
Q23	$\frac{2}{5}$ of a mass is 20g. What is the mass?	% correct	ENGLAND	57.5	57.5	61
			GREECE	46.6	57.3	63.3
	Significant error	100	ENGLAND	Not significant		
			GREECE	8	4.6	4

Key Trends

- Steady improvement for GREECE
- Better performance for ENGLAND at 13+ but then almost the same for both samples.
- Error 100 for GREECE becomes less significant with time.

TABLE XX
INFORMATION CONCERNING QUESTION No 19 OF THE TEST

				Age 13+	14+	15+
Q19	Three lengths of wood, 1m, 2m 40cm, 3m and 75cm are cut from a piece of length 10m. What length of wood is left?	% correct	ENGLAND	56	57	71.5
			GREECE	38.6	50	52.6
	Significant errors	2.75 or 3.15	ENGLAND	8	6	4.5
			GREECE	Not significant		
		3.85 or 5.15	ENGLAND	6.5	5.5	7
			GREECE	4.6	4	0

Key Trends

- Almost steady performance for the first and second round of testing for ENGLAND, but then improvement
- Steady improvement for GREECE in time
- Error 2.75 less significant in time for ENGLAND
- Error 3.85 persists over time for ENGLAND, whereas this has been eradicated for GREECE by 15+.

TABLE XXI
INFORMATION CONCERNING QUESTION No 27 OF THE TEST

				Age 13+	14+	15+
Q27	£50 is invested in an account, which pays 8% interest per year. How much interest is paid after one year?	% correct	ENGLAND	22.5	38.5	42
			GREECE	10	22	27.3
	Significant error	6.25 or 28.57	ENGLAND	11.5	2	5.5
			GREECE	Not existent		

Key Trends

- Steady improvement for both samples.
- Significantly better performance by ENGLAND than GREECE
- Error 6.25 for ENGLAND becomes less significant with time. Dip for ENGLAND at 14+ but then an increase.

TABLE XXII
INFORMATION CONCERNING QUESTION No 26 OF THE TEST

				Age 13+	14+	15+
Q26	7 tickets cost £3.15. What is the cost of 11 tickets?	% correct	ENGLAND	41.5	52	51
			GREECE	28.6	40.6	37.3
	Significant error	34.65 or 27.3	ENGLAND	5.5	2	2.5
			GREECE	7.3	4.6	2.6

Key Trends

- Improvement for ENGLAND at 14+ but then almost steady performance.
- Improvement for GREECE at 14+ but then a dip.
- Error 34.65 less significant in time for GREECE and for ENGLAND.

TABLE XXIII
INFORMATION CONCERNING QUESTION No 36 OF THE TEST

				Age 13+	14+	15+
Q36	In a sale, the price of a TV set, after a reduction of 20% is £120. Calculate the price before the reduction.	% correct	ENGLAND	25	30	32.5
			GREECE	4.6	3.3	8.6
	Significant errors	140	ENGLAND	9.5	3	4.5
			GREECE	3.3	8.6	2
		144	ENGLAND	10	8	8.5
			GREECE	4.6	6	0.6

Key Trends

- Impressively better performance by ENGLAND than GREECE
- Dip for GREECE at 14+ but then improvement. The performance of GREECE is very poor
- Error 140 becomes less significant in time for ENGLAND. A dip at 14+ but then a slight increase again.
- A steep increase of the error 140 for GREECE at 14+ but then considerable improvement slightly better than 13+
- No real improvement for error 144 in ENGLAND over time
- Error 144 for GREECE almost eradicated at 15+. A slight increase at 14+ in contrast of the percentage at 13+.

G.Substituting Values of Variables

TABLE XXIV
INFORMATION CONCERNING QUESTION No 24 OF THE TEST

				Age 13+	14+	15+
Q24	Let v = u +ft. Find the value of v when u = 5, f = -2, and t = 4.	% correct	ENGLAND	29.5	48.5	59
			GREECE	26	54	68
	Significant errors	7 or 3	ENGLAND	12.5	17.5	10
			GREECE	18	2.6	0
		13 or 10	ENGLAND	6	6	5.5
			GREECE	2.6	4.6	4

Key Trends

- Steady improvement for both samples
- Better results for GREECE at 14+ and after that than ENGLAND
- No real improvement for error 7 in ENGLAND over time. A considerable increase at 14+
- Error 7 for GREECE eradicated by age 15+
- Error 13 persists over time for ENGLAND
- Error 13 becomes more significant in time for GREECE

TABLE XXV
INFORMATION CONCERNING QUESTION No 37 OF THE TEST

				Age 13+	14+	15+
Q37	The formula for s is given by $s = ut + \frac{1}{2}at^2$. Find a value of s when u = 10, t = 0.3 and a = 20.	% correct	ENGLAND	3	3	6.5
			GREECE	0.6	6	18
	Significant errors	12 or 16	ENGLAND	8.5	16.5	14.5
			GREECE	1.3	3.3	7.3
		21 or 12	ENGLAND	6	8.5	10
			GREECE	Not significant		

Key Trends

- Very low performance but some improvement at 15+ for ENGLAND
- Very low performance but steady improvement that became significant at 15+ for GREECE
- Error 12 becomes more significant for ENGLAND in time. A steep increase at 14+ but then a dip
- Error 12 becomes more significant for GREECE over time
- Error 21 becomes more significant for ENGLAND over time.

TABLE XXVI
INFORMATION CONCERNING QUESTION No 47 OF THE TEST

				Age 13+	14+	15+
Q47	H=? $\frac{1}{H}=\frac{1}{a}+\frac{1}{b}$, a = 2, b = -1	% correct	ENGLAND	1.5	6.5	6.5
			GREECE	0	1.3	8.6
	Significant error	1	ENGLAND	15	9	11.5
			GREECE	Not significant		

Key Trends

- Considerable improvement for ENGLAND at 14+ and steady thereafter

- Steady improvement for GREECE. The performance of both samples is very poor
- Error 1 remains significant over time for ENGLAND. Dip at 14+ but then an increase at 15+.

V. Conclusion

By using the method of the Descriptive Statistics the significant and important learners' errors, when they study Arithmetic, became conspicuous and were presented in the recorded tables. Moreover, these outcomes of this analysis give an answer to the first research question of the study, which was: "What are the most conspicuous and important errors the learners' made during the three-years of testing of their progress in Arithmetic? How did these learners' errors change over three-years of school Arithmetic learning?" Furthermore, these errors were submitted under categories, which specify particular domains of Arithmetic, such as whole numbers, fractions, decimals etc., so a qualitative answer to the question of *what* kind of errors the English and the Greek students made when participating in the project to be provided, serving the *diagnostic* purpose of the investigation as well. Additionally the recorded numbers of percentages give a quantitative answer concerning the retentiveness or the resistance to subversion of these errors in the officially provided instruction in schools. Concurrently, the influences and impacts that the independent variable of the Kassel Project, "*the level of the national school mathematical education of each country*" had on the dependent variable "*the student' school-level mathematical attainment*" generally and for subversion and remedy of these errors in three-years course was also tested. In other words, an explanation of the influence that the officially provided teaching practices of the two countries had on the subversion of these errors during the three -years of testing has been clarified. This fact was taken for granted for formulating and providing the definition of the learners' *mathematical competence.* Furthermore, this analysis helped the identification of the probable causes that result in the emergence of such kind of errors, and explanations were given concerning these causes, grounded on the information-processing and Computationalism theory of learning, which will be presented in a proceeding paper. Besides, this analysis, in accordance with the identification of the probable causes for the creation of such kind of errors in Arithmetic, guided the invention and development of appropriate intervening teaching practices for subverting and remedying these specific errors. The ways that these errors should be coped with these remedial prescriptive teaching methods will be displayed in proceeding papers as well.

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