行政院國家科學委員會專題研究計畫 成果報告

應用粒子族群最佳化演算法於物流中心揀貨路徑整合分區儲存、訂單批量之研究(I)

研究成果報告(精簡版)

計 畫 類 別 ：個別型
計 畫 編 號 ：NSC 95-2221-E-216-026-
執 行 期 間 ：95 年 08 月 01 日至 96 年 07 月 31 日
執 行 單 位 ：中華大學科技管理學系(所)

計 畫 主 持 人：謝玲芬

計畫參與人員：博士班研究生-兼任助理：林立弘
碩士班研究生-兼任助理：黃建霖、劉淑梅

報 告 附 件 ：出席國際會議研究心得報告及發表論文

處 理 方 式 ：本計畫涉及專利或其他智慧財產權，1 年後可公開查詢

中 華 民 國 96 年 10 月 15 日

行政院國家科學委員會補助專題研究計畫 ☑ 成 果 報 告
□期中進度報告

應用粒子群最佳化演算法於物流中心揀貨路徑整合分區儲存、訂單批量之研究(I)

計畫類別：☑ 個別型計畫　　□ 整合型計畫
計畫編號：NSC 95－2221－ E －216－026－
執行期間：　95 年　8 月　1 日至　96 年　7 月　31 日

計畫主持人：謝玲芬
共同主持人：
計畫參與人員：林立弘、黃建霖、劉淑梅

成果報告類型(依經費核定清單規定繳交)：☑精簡報告　□完整報告

本成果報告包括以下應繳交之附件：
□赴國外出差或研習心得報告一份
□赴大陸地區出差或研習心得報告一份
☑出席國際學術會議心得報告及發表之論文各乙份
□國際合作研究計畫國外研究報告書一份

處理方式：除產學合作研究計畫、提升產業技術及人才培育研究計畫、列管計畫及下列情形者外，得立即公開查詢
□涉及專利或其他智慧財產權，☑一年□二年後可公開查詢

執行單位：中華大學科技管理學系

中　華　民　國　96 年　10　月　15　日

中文摘要

物流目前已廣泛被視為創造顧客價值之重要途徑，而在全球化競爭的時代，唯有透過系統化與效率化之物流系統，才能降低生產與流通成本使公司獲利，並提升企業之競爭力以永續經營。而文獻許多學者已針對物流中心效率化提出許多研究，影響之因素可歸納為數個因子，包括倉儲佈置、儲位規劃、訂單揀取法、揀貨路徑規劃…等影響因子，如何針對各因子對物流中心做一整合性規劃，以降低揀貨作業成本，提昇物流中心營運績效，將為本研究之重點。

本研究針對物流中心儲位規劃問題，考慮分區與不分區兩種方式，並藉由關聯法則進一步改善儲位指派，在訂單揀取法中比較單一訂單別、最適封包批量與關聯訂單批量，在揀貨路徑規劃部分，本研究將運用近幾年才提出之粒子群最佳化演算法求解最佳路徑，並建構一啟發式演算法作為粒子群最佳化演算法之起始解，以提昇求解效率，並與文獻中有較佳表現之螞蟻理論與最短旅行迴圈啟發式一同比較。透過模擬實驗驗證並以九項績效指標評估各因子水準組合，利用統計分析手法找出各因子之最佳水準組合，並將本研究之成果提供給物流業者用於物流規劃與績效提昇之參考。

關鍵詞：物流中心、揀貨系統、最大迴圈插入法、粒子群最佳化演算法、螞蟻理論

Abstract

The logistics has now been an important path to create customer value. In the global competition of trend, to solve the problem of cost down and profit advance of business through the efficient and systematic operation of logistics system. Beside, there are many researches have proposed on the efficient of the distribution center, which the influence of situation can induce to several factors, including storage design, storage planning, route planning…etc. The objective of this project is to show how to combine and plan each factor for cost down of the order picking and promotion of performance of the distribution center.

This research will consider two strategies of storage planning (i.e the zoning storage and non-zoning storage), then to improve the storage assignment by association rule. In addition, single order, First Fit-Envelope Based Batching (FF-EBB), and association based batching are compared for order batching. The Particle Swarm Optimization algorithm(PSO) are implemented in order picking system to find optimal route. In order to speed up the solving process, a heuristic algorithm is developed to generate an initial solution for the PSO algorithm, and the effect is also verified by comparing with the Ant System and MTLI algorithm. According to the concept of viewing the situation as a whole, all combinations of different storage assignment strategies, other batching policies and order picking routing are compared by simulation. The simulation result are analysed by SPSS 10.0 to find the optimal combination for order picking system. Consequently, the result of this project will enhance the whole performance of order picking systems in distribution centers and provide the industry as a reference in the warehouse design.

Keywords: Distribution center, Order picking systems, Maximum Loop Insertion, Particle Swarm Optimization, Ant System

1. 前言

物流中心隨著物流服務競爭多樣化與經營戰略的要求，導致物流成本不斷向上攀升，學者【8、27】於研究中皆提到揀貨作業約佔倉儲營運成本 65%，而揀貨作業時間佔整個作業時間的 30%，因此，揀貨作業效率化將可有效降低營運成本，本研究將針對影響揀貨作業之因子做一同步規劃，期望在多重改善下能更進一步提昇揀貨作業效率。

本研究針對物流中心儲位規劃問題，考慮分區與不分區兩種方式，並藉由關聯法則進一步改善儲位指派，在訂單揀取法中比較單一訂單別、關聯訂單批量與最適封包批量，在揀貨路徑規劃部分，本研究將用運粒子群最佳化演算法尋找最佳路徑，並提出一啟發式演算法作為粒子群最佳化演算法之起始解，冀望可有效提昇求解效率，並與文獻中有較佳表現之螞蟻理論與最短旅行迴圈啟發式一同比較。本研究期望達到以下目的：

一、提出利用粒子群最佳化演算法之特性，應用於揀貨路徑規劃，並找尋在揀貨系統中之最佳參數設定。

二、為加速粒子群最佳化演算法之求解效率，本研究提出一啟發式演算法先求得較佳之起始解，再運用於粒子群最佳化演算法中，以期可更快速求得全域最佳解。

三、將粒子群最佳化演算法與已成功導入揀貨路經規劃之螞蟻理論做一比較。

四、對於影響物流中心中之分區儲存、訂單揀取法與揀貨路徑策略之各種不同組合進行比較分析，以得到最佳之分區儲存、訂單揀取法與揀貨路徑方法組合。

2. 文獻探討

2.1. 倉儲佈置

倉儲佈置規劃之良窳，對於揀貨作業有很深之影響，況且一旦決定佈置的型態後，要再變更其型態，成本耗費必十分龐大。因此，如何在有限空間下，發揮最大效益將是倉儲佈置之重點。一般倉儲設計主要探討為矩形型態，Caron et al.【6】將倉儲分成三種類型，第一種為垂直走道，進出口位於中央；第二種為垂直走道，而進出口位於左下方；第三種為平行走道，進出口位於中央。Ben-Mahmud【5】曾比較有一條交叉走道(Cross Aisle)與沒有交叉走道之倉儲佈置，經實驗證明在有一條交叉走道之環境下，能有效提昇揀貨效率。Vaoughan and Pertersen【28】就此更進一步探討在傳統倉儲中加入交叉走道後，對揀貨距離的影響，實驗結果顯示加入交叉走道將可提昇揀貨路徑行走之彈性，能有效縮短揀貨距離，但加入過多的交叉走道時，將使倉儲面積過度增加致使揀貨距離上昇，且倉儲系統之空間利用率也隨之下降。

2.2. 儲位規劃

儲位規劃主要可分為儲存策略與儲位指派兩個部份，儲存策略為儲位規劃的大原則，儲存策略的決定將影響儲位指派之方式，兩者相互搭配才能充分利用儲存空間，並提升物品移動效率以縮短出入庫移動距離。孫海皎、董福慶【2】曾針對儲存策略提出下述類型，定位儲放(Dedicated Storage)、隨機儲放(Random Storage)、分類儲放(Class Storage)、分類隨機儲放(Random Within Class Storage)及共用儲放，各儲存策略各有其優缺點，應視環境與情況加以應用。兩位學者於儲位指派法曾提出十五種不同方法，文獻中主要探討的儲位指派法則有三種分別為週轉率、產品關連性與存取頻率。

最早使用週轉率方法的學者為 Heskett【14】，他提出之每類體積指標(Cube-per-order Index;

COI)，主要利用貨品的週轉率與所須的儲存空間來決定儲存位置，計算方式為貨品之儲存空間除以貨品週期內之訂購次數，因此 COI 值越小的貨品，擺放位置越靠近 I/O 點。Hausman et al.【13】在自動倉儲系統中，比較 ABC 週轉率(ABC Turnover Based)搭配定位儲存、隨機儲存與分類儲存，探討此三種方案，結果顯示定位儲存較隨機儲存好。林嘉慶【1】運用資料探勘中關聯法則的 Apriori 演算法以分析貨品之間的關聯強度，將相關性較高的貨品擺放至相同走道上，以縮短揀貨距離。Petersen and Schmenner【18】提出依需求量分配的四種儲位指派法則，分別為對角法 (Diagonal) 、通道間法 (Within-Aisle) 、橫越法 (Across-Aisle) 與週緣法 (Perimeter)並與六種揀貨法則搭配，研究結果顯示通道間法較其他的儲存法節省約 10~20%的揀貨路徑。

2.3. 產品關連法則

關聯法則最早由 IBM 研究員 Agrawal et al.在 1993 年提出【3】，主要目的是從龐大銷售交易記錄資料庫中，尋找銷售項目間令人感到有興趣的關聯或相互關係，最典型的應用為市場購物籃分析(Market Basket Analysis)【11、25】，從原始銷售記錄當中，分析每筆交易記錄，從中瞭解顧客購買行為，以找出令人感興趣之關聯法則，因此店家可根據找出的關聯法則決定相關產品之行銷策略。Han and Kamber【11】認為最小支持度與最小信賴度的門檻值(Threshold)設定，需依據使用者的需求而定。Megiddo and Srikant【17】亦指出此兩個值之設定十分重要，當最小支持度設太低時，將會包含重要性較低之項目，而設定太高時，又可能失去某些重要規則。最小信賴度設定太低時，則該關聯規則較不具意義。

2.4. 訂單揀取法

Tompkins and Sminth【26】曾將訂單揀取法分成四類，個別揀取、分區揀取、批次揀取、波浪揀取。一般常採用的方式大多為訂單別揀取與批次揀取，學者 Choe and Sharp【7】針對批次揀取提出批次化的準則主要可分為相似性(Proximity)與時窗限制(Time Windows)。De Koster et al.【9】更將過去相似性批次方法分成種子法 (Seed Algorithm) 與節省法 (Saving Algorithm) 兩大類型。Ruben and Jacobs【19】比較五種訂單批次法，分別為隨機批量 (Random Batching; RAN)、最少批量(First-Fit- Decreasing; FF-D)、連續最小距離(Sequential Minimal Distance; SMD)、最適封包批量(First Fit-Envelope Based Batching; FF-EBB)、最適分級批量(First Fit-Class Based Batching; FF-CBB)，研究中指出最適封包批量在大多環境中有較佳的績效。

2.5. 揀貨路徑規劃

Tompkins et al.【27】提及旅途時間(Travel Time)約佔揀貨活動 50%。因此透過良好的揀貨路徑規劃，將可縮短揀貨時間並提昇揀貨績效。亦有 Ratliff and Rosenthal【19】兩位學者探討加入交叉走道與否，對揀貨路徑的影響，結果顯示在有交叉走道的倉儲中，揀貨路徑規劃將變的十分困難。Ho and Su【15】提出兩種啟發式演算法，分別為最接近矩形中心啟發式(Nearest Center of Rectangular Insertion; NCRI)與最短旅行迴圈插入啟發式(Minimum Traveling Loop Insertion; MTLI)。並與先前學者方法如最大間隙策略(Largest Gap Strategy)、最接近幾何中心啟發式(Nearest Center of Geometry Insertion Heuristic)比較，結果顯示作者所提出兩啟發式演算法皆有較佳績效。

2.6. 螞蟻理論

螞蟻系統(Ant System; AS)最早是由 Dorigo 於 1992 年【10】所提出來，其理論為觀察自然界螞蟻搜尋食物的過程，所發展出來的。螞蟻在搜尋食物時，會在所走過的路上留下揮發性的化學物質，稱為費洛蒙(Pheromone)，而幾乎全盲的螞蟻便是藉由費洛蒙來傳遞訊息，以進行溝通。

Dorigo最早提出來應用於銷售員旅行問題的AS公式如下：

$$p_{ij}^{k}(t)=\begin{cases}\dfrac{[\tau_{ij}(t)]^{\alpha}\times[\eta_{ij}]^{\beta}}{\sum_{k\in allowed_k}[\tau_{ik}(t)]^{\alpha}\times[\eta_{ik}]^{\beta}} & \text{if} \quad j\in allowed_k, \\ 0 & \text{otherwise}\end{cases} \tag{2.1}$$

$P_{ij}^{k}(t)$表示第 k 隻螞蟻在第 t 次迭代中，從城市 i 選擇下一個城市 j 的機率；$\tau_{ij}(t)$表示世代 t 時，由城市 i 到城市 j 之費落蒙素濃度；η_{ij} 表示世代 t 時，由城市 i 到城市 j 的視覺能力，公式(2.1)主要依據螞蟻行走時所遺留的費洛蒙與其視覺能力，兩者所構建而成。

$$\tau_{ij}(t+n)=\rho\cdot\tau_{ij}(t)+\Delta\tau_{ij} \tag{2.2}$$

$$\Delta\tau_{ij}=\sum_{k=1}^{m}\Delta\tau_{ij}^{k} \tag{2.3}$$

公式(2.2)為費洛蒙更新機制，隨著時間的經過費洛蒙將會逐漸的蒸發，所以藉由ρ表示此蒸發機制，而費洛蒙亦會因螞蟻行走於相同的路徑上而逐漸累積，由公式(2.3)計算所有 m 隻螞蟻，於城市 i 到城市 j 所遺留的費洛蒙總和。

針對費洛蒙累積($\Delta\tau_{ij}$)之更新方式著手，所以有許多學者針對此更新方式提出許多研究，而主要可將分為兩類：

一、局部更新法(Local Update)

每當螞蟻經過一路徑，不等到建構出完整路徑，即立刻更新路徑上的費洛蒙，主要是降低該隻螞蟻所建構路徑的費洛蒙濃度，避免吸引其他的螞蟻走上相同路徑，使其他螞蟻有機會收尋其他路徑。

二、全域更新法(Global Update)

於每世代中螞蟻建構出完整路徑(tour)後，才進行費洛蒙更新，能促使最佳解之路徑有較高的費洛蒙濃度，引導其餘螞蟻往此路徑探索(Explore)或開發(Exploit)。

2.7. 粒子群最佳化演算法

1995 由 Kennedy and Eberhart 【16】共同提出粒子群最佳化演算法(Particle Swarm Optimization, PSO)，其主要概念源自於鳥類或魚群覓食的社會行為。PSO 為具有群體智能(Swarm Intelligence)的演算法，透過群體智能來求解問題，主要依據三個因子，分別為自己目前前進的方向、自己先前的最佳經驗與群體的最佳經驗，依此三者不斷修正自己的速度與位置，逐漸往食物的所在位置移動。

Shi 和 Eberhart 於 1998 所提出慣性權重(Inertia Weight, w)【23】底下為慣性權重公式：

$$v_{id}^{new}=w*v_{id}^{old}+c_1*rand()*(p_{id}-x_{id}^{old})+c_2*Rand()*(p_{gd}-x_{id}^{old}) \tag{2.4}$$

$$x_{id}^{new}=x_{id}^{old}+v_{id}^{new} \tag{2.5}$$

x_{id}表示第 i 個粒子於第 d 個空間維度的位置，v_{id}表示第 i 個粒子於第 d 個空間維度的速度。x_{id}^{old}代表目前這個世代所在位置，x_{id}^{new}則代表下一個世代新的位置，v_{id}^{old}代表目前這個世代移動速度，v_{id}^{new}則代表下一個世代新的移動速度。公式中 rand( ),Rand( )為兩個介於[0,1]的隨機變數。c_1及 c_2為正數的學習係數。w 為慣性權重，可使求解的過程中更快找到全域的最佳解，後續兩位學者更針對慣性權重提出較好的經驗設定【22、24】。從公式(2.4)中可看出粒子主要依據三個因子不斷更新搜尋方向，有了新的搜尋方向，粒子便可透過公式(2.5)從目前位置移動到新的位置，如此經過數次迭代後，粒子即可搜尋到最佳解。

3. 模式構建

3.1. 儲存策略

於此小節中，本研究主要考慮兩種不同儲存策略環境，分別為不分區儲存與分區儲存，不分區儲存即為採用隨機儲存方式，隨機指定物品擺放於任一儲位中；分區儲存亦可稱為分類儲存，本研究依據貨品存取頻率，將存取頻率高於 70%的貨品歸為 A 類，存取頻率低於 10%的貨品歸為 C 類，存取頻率介於前兩者之間的貨品歸為 B 類。A 類貨品存放空間佔整個倉儲空間的 10%，B 類貨品存放空間佔整個倉儲空間的 20%，C 類貨品存放空間佔整個倉儲空間的 70%。依據 Petersen and Schmenner【15】之研究結果，並考量本研究倉儲環境的設定下，將採取通道間法把倉儲劃分三區，如圖 3.1。

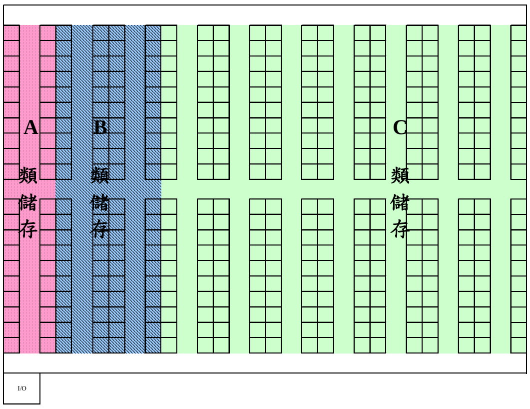

圖3.1 分區儲存佈置圖

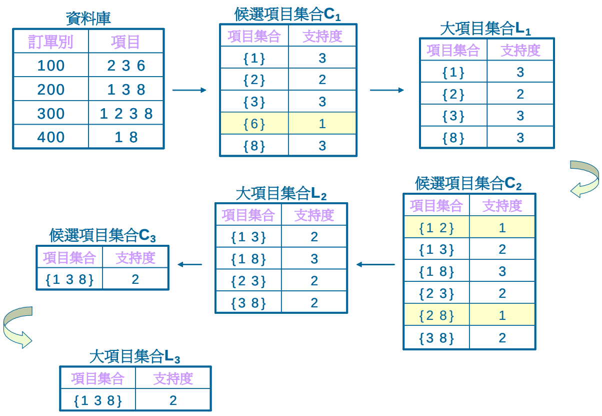

圖3.2 Apriori演算法之範例說明

3.2. 應用關聯法則於儲位指3.3.派

貨品依不同儲存策略規劃完畢後，本研究將應用關聯法則改善儲位指派，以提昇揀貨效率。運用關聯法則中的 Aprori 演算法，進行歷史訂單的分析，找出貨品之間的關聯性，依找出之關聯規則，將具有高度關聯性的貨品擺放於相同走道。Aprori 演算法說明如下，流程如圖 3.2。

步驟一：起先須掃描整個資料庫，找出所有的候選項目集合(C1)的支持度，依據最小支持度將支持度小於 2 的項目刪除，以產生大項目集合(L1) 。

步驟二：利用先前產生的大項目集合(L1)，合併(Join)以產生新的候選項目集合(C2)，接著重新掃描資料庫以進行修剪(Prune)動作，將未滿足最小支持度的候選項目集合刪除，產生新的大項目集合(L2) 。

步驟三：重複步驟 2，直到無法產生新的候選項目集合，即可找出所有高關聯度之品項集合。

3.4. 訂單批量

本研究於訂單批量策略方面，主要考量三種不同訂單批量方法，分別為單一訂單、最適封包批量及關聯訂單批量。各方法說明如下所示。(1)單一訂單：每位揀貨員每趟揀取作業只負責一張訂單，能節省分類時間且錯誤率較批次揀取低。(2)最適封包批量：依據訂單內所有貨品擺放的走道，將訂單劃分成不同訂單封包(Order Envelope)，依據最小增加橫跨走道距離(Cross Aisle Distance)合併訂單。(3)關聯訂單批量：藉由關聯法則應用於儲位指派而找出之高度關聯性貨品，將具有高度關聯性貨品之訂單進行訂單合併，在沒有高度關聯性貨品之訂單，則依據訂單品項數

量，將品項數量愈高的訂單愈優先選出以進行批次。

3.5. 揀貨路徑規劃

揀貨路徑規劃將探討五種不同方法，首先是最短旅行迴圈啟發式與螞蟻理論，為文獻中有較佳表現之演算法，隨後將介紹本研究所提出之最大迴圈插入法與文獻中尚未有學者應用於物流中心之粒子群最佳化演算法，最後一種方法為結合最大迴圈插入法與粒子群最佳化演算法，即為以最大迴圈插入法所得之解作為粒子群最佳化演算法之初始解。

3.5.1. 最短旅行迴圈啟發式

本研究於此小節將蘇騰昇【3】所提出之最短旅行迴圈啟發式(Minimum Traveling Loop Insertion; MTLI)作一說明，MTLI演算法流程如下：

步驟一：一開始將I/O與最接近的揀取點u'連接起來，以實際行走路徑經由走道圍成一個旅行迴圈L(Loop)，如圖3.3 (a)，點a。

步驟二：從剩餘每一個揀取點j中，尋找插入旅行迴圈L之任一邊$\overline{u'u''}$，可使得加入後所增加的旅行距離TDu'j + TDju'' - TDu'u''為最小。

步驟三：以剩餘揀取點j加入後有最小增加旅行距離為插入點k，加入迴圈L。若有兩個以上的點皆為最小增加旅行距離，則選擇其中任一點加入。

步驟四：以$\overline{u'k}$及取$\overline{ku''}$代$\overline{u'u''}$，構成一個新的迴圈L。

步驟五：如果迴圈L已包含所有揀取點，即算出揀貨路徑距離，則停止。否則回至步驟2。

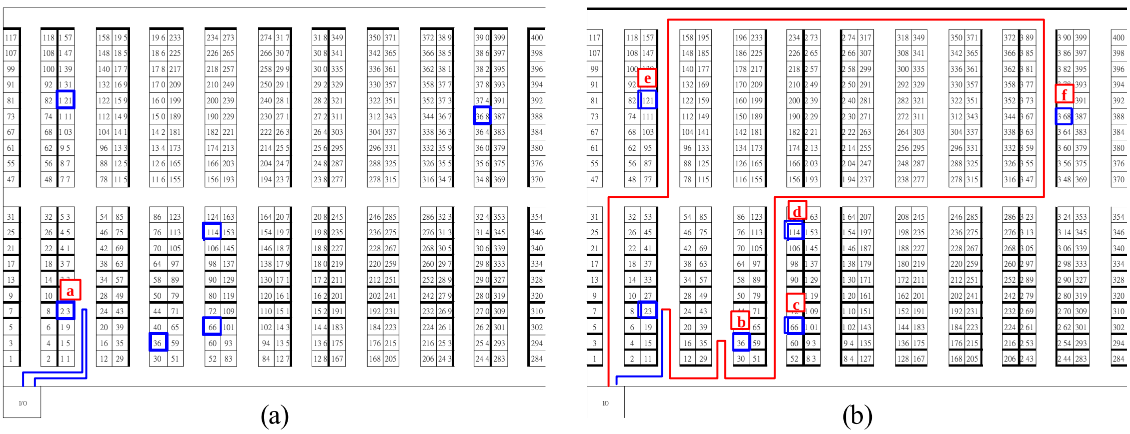

圖3.3 MTLI揀貨路徑

3.5.2. 應用螞蟻理論

由於本研究將螞蟻理論應用於揀貨路徑規劃，其中η_{ij}視覺能力以儲位i到儲位j距離之倒數代表，因此$\eta_{ij} = \frac{1}{d_{ij}}$，表示越接近的儲位越容易看見。Dorigo et al.【11】曾建議重要關係程度參數α與β之設定方式，如圖3.4，結果指出(0.5, 5)、(1, 1)、(1, 2)、(1, 5) ，四種之組合可找到最好的解。費洛蒙殘留係數ρ值之設定主要介於0到1之間，螞蟻數與迭代數則視使用者與問題特性而設定。螞蟻理論流程如圖3.5所示。

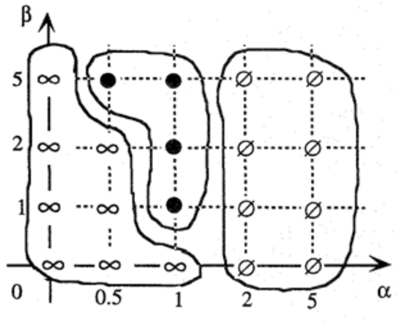

圖3.4 α與β之參數設定組合

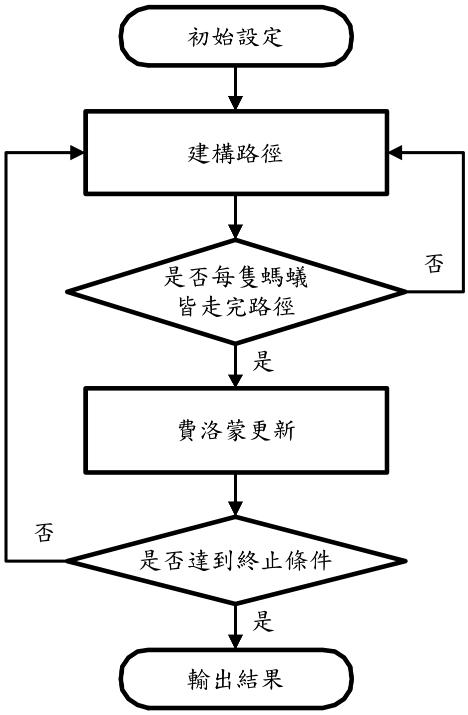

圖3.5 螞蟻理論流程圖

費洛蒙更新機制的不同，將影響費洛蒙濃度促使螞蟻選擇不同的路徑，因全域更新方法較能參考到全域性的資訊，故本研究以全域性更新的方式作為費洛蒙之更新機制。Q為費洛蒙素值累積量，L_k 表示由第k隻螞蟻所行走之路徑長度。

$$\tau_{ij}(t+n) = \rho \cdot \tau_{ij}(t) + \Delta\tau_{ij} \tag{3.6}$$

$$\Delta\tau_{ij} = \sum_{k=1}^{m} \Delta\tau_{ij}^{k} \tag{3.7}$$

$$\Delta\tau^{k}{}_{ij} = \begin{cases} \dfrac{Q}{L_k} & \text{if kth ant uses edge}(i, j) \text{ in its tour (between time } t \text{ and } t+n), \\ 0 & \text{otherwise,} \end{cases} \tag{3.8}$$

3.5.3. 最大迴圈插入法

以往學者所提出之揀貨法則，大多一味地以最短距離建構揀貨路徑，如此難以對所有揀取

儲位有整體之概念，將容易陷入區域解，因此本研究針對此問題提出最大迴圈插入法(Maximum Loop Insertion; MLI)，使得建構揀貨路徑時，能對全部揀取點有整體概念，以改善演算法求解績效。本啟發式演算法將從全部揀取點中，找出三個揀取點並與I/O點以最短路徑形成最大迴圈(Maximum Loop)，此路徑之行走距離為完成揀貨路徑規劃時，揀取最外圍儲位必定行走之距離，而剩餘尚未揀取之揀貨點，即位於最大迴圈所形成的路徑周圍，所以能對必須揀取的儲位有整體的概念。MLI演算流程如下：

步驟一：先找出最左邊且有揀取點之走道，再找出該走道上距離I/O點最近之揀取點，如圖3.6 (a)，點a。

步驟二：先找出距離I/O點深度最遠之揀取點，若有相同深度之揀取點，則選擇走道距I/O最近之揀取點，如圖3.6 (a)，點b。

步驟三：先找出最右邊且有揀取點之走道，再找出該走道上距離I/O點最近之揀取點，如圖3.6 (a)，點c。

步驟四：檢查前三個步驟找出的三點是否有重複，若有重複則刪除重點，將剩餘之點及I/O點以最短行走距離，建構最大迴圈途程。

步驟五：以最短插入距離為依據，從尚未選取的揀取點中尋找插入目前途程所增加距離最小之揀取點k。

步驟六：將此揀取點k入迴圈，形成新的迴圈，若有相同最短插入距離之揀取點，則擇一加入。

步驟七：檢查目前所建構迴圈是否包含所有揀取點，若已包含所有揀取點跳到步驟8，否則回到步驟5。

步驟八：計算所建構迴圈之行走距離，完成揀貨路徑規劃。

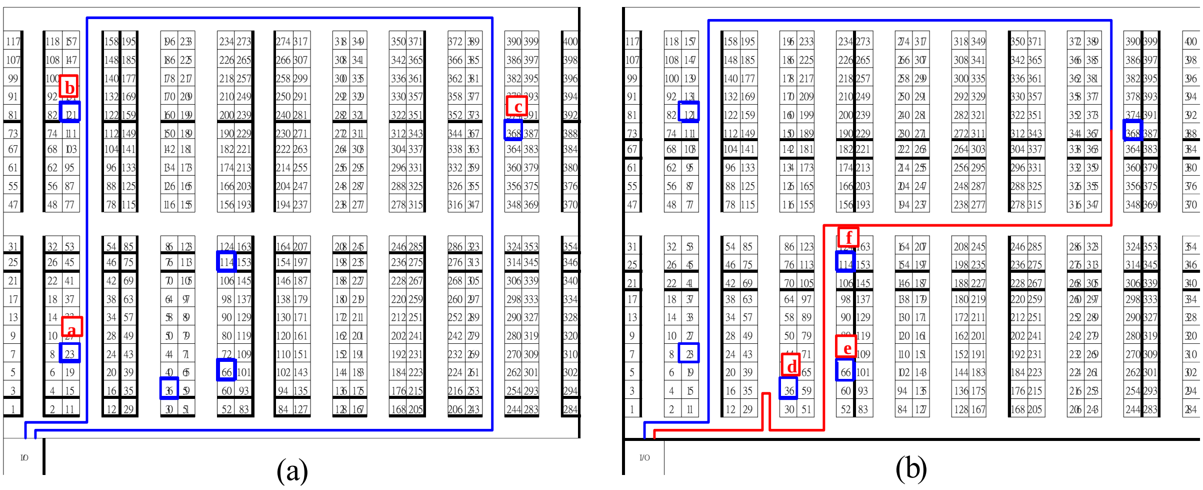

圖3.6 MLI揀貨路徑

3.5.4. 應用粒子群最佳化演算法

本研究將粒子群最佳化演算法應用於揀貨路徑規劃，而每一個粒子即為一組可行解，即代表一組揀貨路徑。假設揀貨員由I/O點出發依序揀取儲位341, 87, 99, 11，揀完所有貨品後回到I/O點，以編號0代表I/O點編號，可得到一揀貨順序(0, 341, 87, 99, 11)，為簡化粒子編碼形式，因此本研究將揀取儲位之編號重新編列，由小到大重新給予編號。

$$(0, 341, 87, 99, 11) \xrightarrow{\text{重新編號}} (1, 5, 3, 4, 2)$$

因此第i個粒子為$X_i=(x_{i1}, x_{i2}, \ldots, x_{iD})$，其中$x_{iD}$代表某個儲位編號，此粒子表示揀貨員依序揀取儲位$x_{i1}, x_{i2}, \ldots, x_{iD}$。$X_i= (x_{i1}, x_{i2}, x_{i3}, x_{i4}, x_{i5}) = (1, 5, 3, 4, 2)$。

粒子速度於本研究中表示儲位編號改變量，假設第i個粒子之速度為$V_i=(v_{i1}, v_{i2}, v_{i3}, v_{i4}, v_{i5}) = (0, -3, +2, -1, -3)$，因此第i個粒子依速度更新其位置，(1, 5, 3, 4, 2) + (0, -3, +2, -1, -3) = (1, 2, 5, 3, -1)，當粒子經過速度更新後，產生非整數之編號或編號超出原始範圍，因此將儲位編號依大小重新編列

$$(1, 2, 5, 3, -1) \xrightarrow{\text{重新編號}} (2, 3, 5, 4, 1)$$

最大速度之設定將決定粒子移動範圍，而每張訂單品項數皆不同，因此粒子空間維度也不相同，本研究將採用比例之方式設定最大速度。假設比例值η_{ij}，若粒子空間維度為5，則$0.2*5=1$，表示粒子最大所能移動範圍於± 1之間。

適應函數之功能在於評估PSO中的粒子是否找到理想位置，在本研究中以最小化揀貨距離作為適應函數。相關參數設定包括，粒子數、最大速度、學習因子、慣性權重及終止條件。根據以往學者的研究結果【23、24、29】，各參數可依據以下設定：粒子數：一般粒子數設在20到30之間；學習因子：學習因子c_1、c_2之和小於4；慣性權重：慣性權重(w)設定介於0.9 到1.2；最大速度、終止條件通常依使用者與問題特性而定。PSO演算法流程如圖3.7。

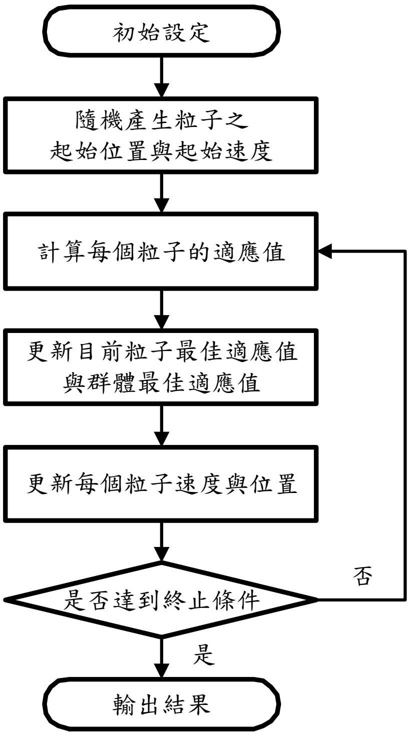

圖3.7 PSO演算流程圖

4. 模擬驗證分析

4.1. 模擬環境與

本模擬實驗所採一矩形物流中心，共有 10 條主走道，走道兩側各有 20 個儲位，共計 400 個儲位，儲位寬為 1 公尺、深度為 1 公尺，倉儲前後方分別有前走道與後走道，中央有 1 條交叉走道(Cross Aisle)，寬度皆為 2.5 公尺，領單點與集貨點(I/O) 皆於左下角，佈置如圖 4.1 所示。揀貨車容積上限值為 50 單位。揀貨車速度為每分鐘 90 公尺。

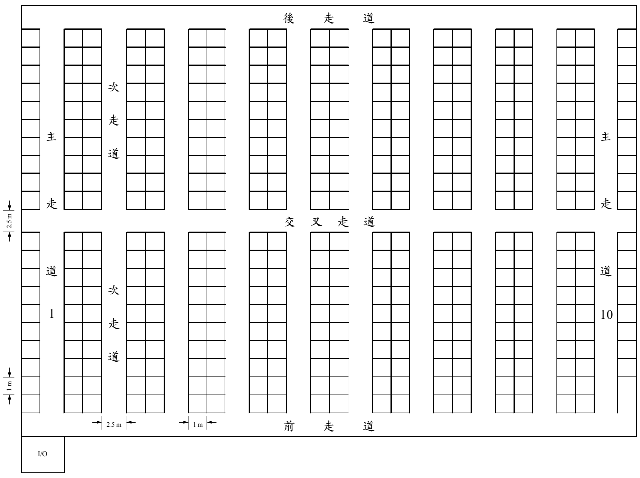

圖4.1 倉儲佈置圖

表4.1 各實驗組合表

實驗編號	實驗因子組合	實驗編號	實驗因子組合
1	分區儲存*單一訂單*MLI	16	不分區儲存*單一訂單*MLI
2	分區儲存*單一訂單*MTLI	17	不分區儲存*單一訂單*MTLI
3	分區儲存*單一訂單*AS	18	不分區儲存*單一訂單*AS
4	分區儲存*單一訂單*PSO	19	不分區儲存*單一訂單*PSO
5	分區儲存*單一訂單*MLI結合PSO	20	不分區儲存*單一訂單*MLI結合PSO
6	分區儲存*最適封包批量*MLI	21	不分區儲存*最適封包批量*MLI
7	分區儲存*最適封包批量*MTLI	22	不分區儲存*最適封包批量*MTLI
8	分區儲存*最適封包批量*AS	23	不分區儲存*最適封包批量*AS
9	分區儲存*最適封包批量*PSO	24	不分區儲存*最適封包批量*PSO
10	分區儲存*最適封包批量*MLI結合PSO	25	不分區儲存*最適封包批量*MLI結合PSO
11	分區儲存*關聯訂單批量*MLI	26	不分區儲存*關聯訂單批量*MLI
12	分區儲存*關聯訂單批量*MTLI	27	不分區儲存*關聯訂單批量*MTLI
13	分區儲存*關聯訂單批量*AS	28	不分區儲存*關聯訂單批量*AS
14	分區儲存*關聯訂單批量*PSO	29	不分區儲存*關聯訂單批量*PSO
15	分區儲存*關聯訂單批量*MLI結合PSO	30	不分區儲存*關聯訂單批量*MLI結合PSO

針對螞蟻理論與粒子群最佳化演算法參數設定，本研究將使用田口方法(Taguchi Method)進行實驗設計，以找出穩健適宜之參數水準組合。實驗結果指出螞蟻理論最佳參數組合為，(α, β)設定為(1, 1)，ρ 設定為 0.9，母體數設定為 15，迭代數設定為 100。粒子群最佳化演算法最佳參數組合為，w 設定為 0.9，(c1, c2)設定為(2, 1)，V_{max} 設定為 0.2，母體數設定為 25，迭代數設定為 250。

本研究實驗考慮兩種儲存策略、一種產品關聯性、三種訂單批量、五種揀貨路徑規劃，共有 30 種排列組合，實驗因子水準如表 4.1 所示。以 eM-Plant 7.0 模擬軟體建構物流中心，由電腦產生 10,000 筆歷史訂單，每次實驗隨機從中抽取 300 張訂單，重複 30 次模擬實驗。以九項績效指標評估績效，分別為(1)不同訂單批量電腦運算時間、(2)不同揀貨路徑規劃電腦運算時間、(3)總電腦運算時間，為(1)與(2)之和、(4)總揀貨距離、(5)總揀貨旅行次數、(6)車輛滿載率、(7)揀貨時間、(8)分流時間、(9)總作業時間，為(7)與(8)之和，並將模擬結果利用 SPSS 10.0 統計軟體進行

資料分析，期望能找出最佳實驗組合。揀貨時間與分流時間的計算方式主要參考學者 Petersen 之研究【19】，敘述如下：

一、揀貨時間計算方式：尋找與揀取每一個不同儲位貨品之所需時間為 0.2 分鐘，若揀取相同儲位第二件以上之貨品每件所需時間為 0.1 分鐘。

二、分流時間包含了三個部份，分別為卸貨時間、分類時間及檢查時間，計算方式分述如下

1. 卸貨時間計算方式：從揀貨車中將2. 貨品取出，3. 第一件貨品需0.1分鐘，4. 其餘每一件需時0.5分鐘。
2. 分類時間計算方式：將6. 批次化後之貨品分類到每一張訂單之貨物箱中，7. 每一張訂單需時0.24分鐘，8. 分類到最後一張訂單則無須分類時間。
3. 檢查時間計算方式：檢查訂單貨品是否正確，10. 每一個貨品需時0.08分鐘。

表4.2 各因子水準於九項績效指標之平均數

	來源	不同訂單批量電腦運算時間	不同揀貨路徑規劃電腦運算時間	總電腦運算時間	總揀貨距離	總揀貨旅行次數	車輛滿載率	揀貨時間	分流時間	總作業時間
儲存策略	分區儲存	0.089	1092.981	1093.070	19306.157	193.400	0.705	1296.551	3432.671	4729.221
	不分區儲存	**0.096**	**1352.574**	**1352.670**	**45890.651**	193.378	0.706	**1600.620**	3432.685	**5033.304**
訂單批量	單一訂單	**0(1)**	**1343.473(3)**	**1343.473(3)**	**43509.348(3)**	**300(3)**	**0.401(3)**	**1684.971(3)**	**3364.447(1)**	**5049.417(3)**
	最適封包批量	**0.212(3)**	**1187.336(2)**	**1187.548(2)**	**27281.462(2)**	**142.167(2)**	**0.845(2)**	**1338.717(2)**	**3465.460(2)**	**4804.177(2)**
	關聯訂單批量	**0.066(2)**	**1137.524(1)**	**1137.589(1)**	**27004.402(1)**	**138(1)**	**0.871(1)**	**1322.067(1)**	**3468.127(2)**	**4790.194(1)**
揀貨路徑規劃	MLI	0.093	**14.879(1)**	**14.972(1)**	**28008.331(1)**	193.389	0.706	**1397.584(1)**	3432.677	**4830.262(1)**
	MTLI	0.093	**15.248(1)**	**15.341(1)**	**30392.103(3)**	193.389	0.706	**1424.071(3)**	3432.677	**4856.748(1)**
	AS	0.093	**3210.775(4)**	**3210.868(4)**	**28495.569(2)**	193.389	0.706	**1402.998(2)**	3432.677	**4835.676(1)**
	PSO	0.093	**1446.076(3)**	**1446.169(3)**	**48170.678(4)**	193.389	0.706	**1621.610(4)**	3432.677	**5054.288(3)**
	MLI 結合 PSO	0.093	**1426.908(2)**	**1427.001(2)**	**27925.339(1)**	193.389	0.706	**1396.662(1)**	3432.677	**4829.340(1)**

註：粗體表示有顯著差異

( )內數字表示Duncan分群結果

網底表示為最佳績效

4.2. 實驗結果分析

本研究將探討各因子之不同水準於不同績效指標下是否具有顯著差異，並以 95%信賴水準進行變異數分析，分析是否達顯著差異，若有顯著差異將再以 Duncan 分群作事後多重比較檢定，以瞭解各因子水準間差異型態為何。

從表 4.2 中可知儲存策略在不同訂單批量電腦運算時間、不同揀貨路徑規劃電腦運算時間、總電腦運算時間、總揀貨距離、揀貨時間與總作業時間有顯著差異，且結果顯示若能採取分區儲存，將在眾多績效指標下達到較佳績效表現。從表 4.2 中可知訂單批量於九項績效指標下皆有顯著差異，於不同訂單批量電腦運算時間與分流時間之績效指標下，以單一訂單有最佳表現，而於其他七項績效指標中，是以關聯訂單批量表現最佳，其次為最適封包批量，最差為單一訂單，因此在消費需求多樣少量下，採用訂單批次化方法相較使用單一訂單批量更為適合。從表 4.2 中可知揀貨路徑規劃於五項績效指標有顯著差異，本研究所提出之最大迴圈插入法於各績效指標皆有優異之表現，於不同揀貨路徑規劃電腦運算時間、總電腦運算時間中有最佳表現並與最短旅行迴圈啟發式於第一子集。且當最大迴圈插入法結合粒子群最佳化演算法時，於總揀貨距離、揀貨時

間與總作業時間有最佳績效表現，證實適當的加入初始解可有效提昇粒子群最佳化演算法之求解品質與效率。

於表 4.3 中可知，在儲存策略、訂單批量與揀貨路徑規劃三因子交互作用下，於不同揀貨路徑規劃電腦運算時間與總電腦運算時間下，以分區儲存搭配單一訂單搭配最大迴圈插入法，有最佳績效表現，而以實驗編號 23 即為不分區儲存搭配最適封包批量搭配螞蟻理論，有最差績效表現，且可結果中發現使用啟發式演算法皆優於巨集啟發式演算法。總揀貨距離、揀貨時間與總作業時間績效指標下，以實驗編號 10 即為分區儲存搭配最適封包批量搭配最大迴圈插入法結合粒子群最佳化演算法，有最佳績效表現，而以實驗編號 19 即為不分區儲存搭配單一訂單搭配 PSO，有最差績效表現。

5. 結論

本研究之目的在於提昇物流中心揀貨績效，因此本研究嘗試應用粒子群最佳化演算法於揀貨路徑規劃中，並有鑑於粒子群最佳化演算法初始之母體乃採用隨機產生，本研究遂提出一啟發式演算法--最大迴圈插入法，冀以提昇其求解品質與效率。並針對影響物流中心之各因子，如儲存策略、訂單批量與揀貨路徑規劃，作一整合設計規劃，經實驗模擬比較，本研究所提出之最大迴圈插入法與最大迴圈插入法結合最大迴圈插入法皆有不錯之表現。綜合本研究之成果，將分述如下：

一、文獻中尚未有學者將粒子群最佳化演算法應用於物流中心裡揀貨路徑規劃上，而本研究 成功地將粒子群最佳化演算法應用於此，並透過實驗分析找出最適參數設定，可供後續學者作一參考。

二、本研究針對過往揀貨法則，大多一味地以最短距離建構揀貨路徑，如此難以對所有揀取儲位有整體之概念，致使揀貨法則容易陷入區域解，因此本研究針對此問題提出一啟發式演算法--最大迴圈插入法，且本研究所提出之最大迴圈插入法，經實驗證實的確實能有不錯之績效且優於文獻之方法。

三、由於粒子群最佳化演算法初始母體皆由隨機方式產生，針對此問題本研究將最大迴圈插入法所找出之解，作為粒子群最佳化演算法之初始解，而最大迴圈插入法結合粒子群最佳化演算法經實驗證明，有最佳績效表現，能有效提昇粒子群最佳化演算法之求解品質與速度。

四、本研究在儲存策略、訂單批量與揀貨路徑規劃三因子綜合評估下，結果以分區儲存搭配最適封包批量搭配最大迴圈插入法結合粒子群最佳化演算法於眾多績效指標中有最佳績效表現，惟在不同揀貨路徑規劃電腦運算時間與總電腦運算時間下，是以分區儲存搭配單一訂單搭配最大迴圈插入法有最佳績效表現。

五、在訂單批量因子下，於大多績效指標下採用關聯訂單批量與最適封包批量，績效皆較單一訂單批量為佳，惟在不同訂單批量電腦運算時間與分流時間之績效則相反，但綜觀總作業時間亦為關聯訂單批量與最適封包批量績效較佳，因此在多樣少量下，採用訂單批次化方法相較使用單一訂單批量更為適合。而採用訂單批次化所需擔心之錯誤率與分類之問題，可藉由現今之電腦輔助設備加以改善，以降低問題之發生。

六、本研究為符合實務上物流中心實際情況，於倉儲環境佈置中加入交叉走道，考慮之設定囊括儲存策略、儲位指派、訂單揀取法與揀貨路徑規劃，使整體環境更符合實際狀況，並考慮九項績效指標，經模擬實驗驗證各實驗組合之績效，冀望本研究之結果可提供物流中心業者於倉儲規劃設計與績效改善時參考。

表4.3 各實驗組合於各績效指標之Duncan Test

實驗編號	不同揀貨路徑規劃電腦運算時間		實驗編號	總電腦運算時間		實驗編號	總揀貨距離		實驗編號	揀貨時間		實驗編號	總作業時間	
	平均數	子集		平均數	子集		平均數	子集		平均數	子集		平均數	子集
1	9.494	1	1	9.494	1	10	13225.900	1	10	1170.178	1	10	4638.326	1
2	9.766	1	2	9.766	1	6	13241.800	1	6	1170.335	1	6	4638.483	1
16	12.479	1	16	12.479	1	8	13854.900	2	8	1175.534	1,2	8	4640.952	1
17	13.055	1	17	13.055	1	7	13855.883	2	7	1175.711	1,2	7	4641.128	1
11	13.821	1	11	13.821	1	15	13875.983	2	15	1177.484	1,2	15	4645.632	1
12	13.917	1	12	13.917	1	11	13890.183	2	11	1177.506	1,2	11	4645.654	1
6	14.145	1	6	14.145	1	12	14533.533	3	12	1182.523	2	12	4647.941	1
7	14.371	1	7	14.371	1	13	14535.583	3	13	1182.534	2	13	4647.952	1
26	19.309	1	26	19.309	1	5	23937.450	4	9	1298.677	3	9	4766.825	2
27	19.751	1	27	19.751	1	1	23991.717	4	14	1305.356	3	14	4770.774	2
21	20.027	1	21	20.027	1	3	24136.583	4	30	1364.507	4	5	4831.952	3
22	20.628	1	22	20.628	1	2	24901.450	5	26	1364.947	4	1	4832.555	3,4
15	1173.481	2	15	1173.481	2	9	24909.883	5	28	1375.480	5	3	4832.612	3,4
14	1180.659	2	14	1180.659	2	14	25440.950	6	25	1388.969	6	30	4833.052	3,4
10	1223.444	3	10	1223.444	3	30	30282.317	7	21	1389.389	6	26	4834.164	3,4,5
9	1236.801	3	9	1236.801	3	26	30321.933	7	23	1398.223	7	2	4842.663	3,4,5
30	1285.158	4	30	1285.158	4	25	31173.233	8	27	1400.812	7	28	4843.585	3,4,5
29	1293.151	4	29	1293.151	4	21	31211.050	8	22	1423.769	8	25	4854.472	4,5,6
25	1345.306	5	25	1345.306	5	4	31260.550	8	5	1467.505	9	21	4854.892	5,6
24	1358.773	5	24	1358.773	5	28	31269.867	8	1	1468.108	9	23	4866.315	6
5	1692.851	6	5	1692.851	6	23	32239.117	9	3	1469.718	9	27	4866.328	6
4	1716.550	7	4	1716.550	7	27	33316.783	10	2	1478.216	10	22	4889.271	7
20	1841.211	8	20	1841.211	8	22	34305.183	11	4	1548.873	11	4	4913.319	8
19	1890.523	9	19	1890.523	9	18	54937.367	12	29	1723.335	12	18	5176.395	9
3	2658.140	10	3	2658.140	10	20	55057.150	12	24	1762.574	13	20	5177.726	9
13	2668.819	10	13	2668.819	10	16	55393.300	13	18	1811.949	14	16	5181.461	9
8	2768.449	11	8	2768.449	11	17	61439.783	14	20	1813.279	14	29	5191.441	9
18	3590.657	12	18	3590.657	12	29	62576.883	15	16	1817.014	14	24	5229.077	10
28	3707.169	13	28	3707.169	13	24	64797.667	16	17	1884.198	15	17	5248.644	11
23	3871.418	14	23	3871.418	14	19	80038.133	17	19	2090.846	16	19	5455.293	12

6. 參考文獻

1. 林嘉慶(2004)，「運用關聯法則技術於倉儲系統儲位指派與揀貨策略配置模型之研究」，中華大學科技管理研究所碩士論文。

2. 孫海皎、董福慶(1995)，「物流中心儲位管理」，經濟部商業自動化系列叢書。

3. 蘇騰昇(2002)，「物流中心之最佳化揀貨策略」，國立中央大學工業管理研究所碩士論文。

4. Agrawal, R., T. Imielinski, and Swami, A. (1993), "Mining Association Rules between Sets of Items in Large Data Bases," In Proceedings of the ACM SIGMOD Conference in Management of Data, Washington, DC, USA, pp. 207-216.

5. Ben-Mahmud, Y. (1987), "The Effect of Warehouse Layout on Order Picking efficiency," Unpublished M.S. thesis, Oregon State University, Corvallis, OR.

6. Caron, F., G. Marchet, and Perego, A. (2000), "Layout Design in Manual Picking Systems: a Simulation Approach," Integrated Manufacturing Systems, Vol. 11, No. 2, pp. 94-104.

7. Choe, K. and Sharp, G. P. (1991), "Small Parts Order Picking: Design and Operation," Vailable on-line at: http://www.isye.gatech.edu/logisticstutorial/order/article.htm (accessed May 2005).

8. Coyle, J. J., E. J. Bardi, and Langley, C. J. (1996), "The Management of Business Logistics," St Paul, MN: West.

9. De Koster, R., T. Le-Duc, and Roodbergen, K. J. (2007), "Design and Control of Warehouse Order Picking: a Literature Review," European Journal of Operational Research Vol. 182, No. 2, pp.

481-501.

10. Dorigo, M. (1992), “Optimization, Learning and Natural Algorithms,” Ph.D. Thesis. Politecnico di Milano, Italy, EU.

11. Dorigo, M., V. Maniezzo, and Colorni, A. (1996), “Ant System: Optimization by a Colony of Cooperating Agents,” IEEE Transactions on System, Man, and Cybernetics-Part B, Vol. 26, No. 1. pp. 29-41.

12. Han, J. and Kamber, M. (2000), “Data Mining: Concepts and Techniques,” Morgan Kaufmann Publishers, San Franscisco.

13. Hausman, W. H., L. B. Schwarz, and Graves, S. C. (1976), “Optimal Storage Assignment in Automatic Warehousing Systems,” Management Science, Vol. 22, No. 6, pp. 629-638.

14. Heskett, J. L. (1963), “Cube-Per-Order Index a Key to Warehouse Stock Location,” Transport and Distribution Management, Vol. 3, pp. 27-31.

15. Ho, Y. C. and Su, T. S. (2002), “A Study on Optimizing Order-Picking Operations in Distribution Centers,” The Fourth Asia-Pacific Conference on Industrial Engineering and Management Systems, Taipei Taiwan, pp. 18-20.

16. Kennedy, J. and Eberhart, R.C. (1995), “Particle Swarm Optimization,” Proceedings IEEE International Conference on Neural Networks, Vol. 4, pp.1942-1948.

17. Megiddo, N. and Srikant, R. (1998), “Discovering Predictive Association Rules,” American Association for Artificial Intelligence.

18. Petersen II, C. G. and Schmenner, R. W. (1999), “An Evaluation of Routing and Volume-Based Storage Policies in an Order Picking Operation,” Decision Sciences, Vol. 30, No. 2, pp.481-501.

19. Petersen II, C. G. (2000), “An Evaluation of Order Picking Policies for Mail Order Companies,” Production and Operations Management, Vol. 9, No. 4, pp. 319-35.

20. Ratliff, H. D. and Rosenthal, S. (1983), “Order-Picking in a Rectangular Warehouse: A Solvable Case of the Traveling Salesman Problem,” Operations Research, Vol. 31, No. 3, pp.507-521.

21. Ruben, R. A. and Jacobs, I. R. (1999), “Batch Construction Heuristics and Storage Assignment Strategies for Walk/Ride and Pick Systems,” Management Science, Vol. 45, No. 4, pp.575-594.

22. Shi, Y. and Eberhart, R., (1999), “Empirical Study of Particle Swarm Optimization,” Proceedings of the 1999 Congress on Evolutionary Computation, Washington, DC, USA, Vol. 3, pp. 1945-1950.

23. Shi, Y. H. and Eberhart, R. C. (1998), “A Modified Particle Swarm Optimizer,” Proceedings of IEEE International Conference on Evolutionary Computation, Anchorage, Alaska, pp. 69-73.

24. Shi, Y. H. and Eberhart, R. C. (1998), “Parameter Selection in Particle Swarm Optimization,” The 7th Annual Conference on Evolutionary Programming, San Diego, pp. 591-600.

25. Simoudis, E. (1996), “Reality Check for Data Mining,” Institute of Electrical and Electronic Engineers Expert, Vol. 11, No. 5, pp.26-33.

26. Tompkins, J. A. and Smith, J. D. (1988), “The Warehouse Management Handbook,” McGraw-Hill.

27. Tompkins, J. A., J. A. White, Y. A. Bozer, E. H. Fraz elle, J. M. A. Tanchoco, and Trevino, J. (1996),

"Facilities Planning," Wiley New York.

28. Vaughan, T. S. and Petersen, C. G. (1999), "The Effect of Warehouse Cross Aisles on Order Picking Efficiency," International Journal of Production Research, Vol. 37, No. 4, pp. 881-897

29. http://www.swarmintelligence.org/papers/cPSOTutorial.pdf

計畫成果自評

本研究主要針對物流中心儲位規劃問題，考慮分區與不分區兩種方式，並藉由關聯法則進一步改善儲位指派，在訂單揀取法中比較單一訂單別、最適封包批量與關聯訂單批量，在揀貨路徑規劃部分，本研究將運用近幾年才提出之粒子群最佳化演算法求解最佳路徑，並建構一啟發式演算法作為粒子群最佳化演算法之起始解，以提昇求解效率，並與文獻中有較佳表現之螞蟻理論與最短旅行迴圈啟發式一同比較。以總揀貨成本最小化為目標，進而達到單位時間內揀貨績效提昇，透過模擬實驗驗證並以九項績效指標評估各因子水準組合，利用統計分析手法找出各因子之最佳水準組合，並將本研究之成果提供給物流業者用於物流規劃與績效提昇之參考。完全依照計畫書的想法進行，研究結果與原預期之計畫目標相符合，計畫執行過程中已發表一篇研討會論文及一篇期刊論文，詳細資料如下：

1. 謝玲芬、黃建霖，"物流中心之粒子群最佳化演算法應用效率之提昇"， 中國工業工程學會九十五年度年會暨學術研討會，東海大學，台中。**(NSC-95-2221-E-216-026-)**

2. Ling-Feng Hsieh, Chao-Jung Huang and Chien-Lin Huang, "Applying Particle Swarm Optimization to Schedule Order Picking Routes in a Distribution Center," Asian Journal of Management and Humanity Sciences, Vol. 1, No. 4, **(NSC-95-2221-E-216-026-)**

因本人另一研究領域為績效評估之探討與應用，隨著產業變遷與轉移，臺灣政府已將觀光產業列為國家重要策略性產業。而觀光產業對內不僅成為維繫地方經濟與提供就業機會的重要產業；在對外方面除可賺取外匯，更能提升台灣在國際能見度、競爭力。所以本研究在其相關觀光產業中，選擇旅館業來探討其營運狀況。並且以資料包絡分析法(Data Envelopment Analysis；DEA)投入與產出觀念來評估14間國際觀光旅館的相對效能與效率，評估指標包括：相對效率之投入項為客房數、員工人數、設備與管理成本，產出項是顧客滿意度；相對效能之投入項為顧客滿意度，產出項為實際客房住用率、總營運收入。而其中重要之關鍵指標為顧客滿意度，其原因是服務業較傳統製造業更強調與顧客之互動與維持。因此以顧客滿意度當作是效率、效能中間的投入與產出項。因此藉由本研究效能與效率兩段的評估，可以發現國際觀光旅館是哪個環節出了問題，究竟是內部效率所投入資源所得到產出比率不夠好，還是所產出的價值沒達到效能。另外由DEA模式中的差額變數分析更可以細微從指標中來給予未達到效率或效能之旅館改善的方向與建議。研究成果也已發表於國際研討會 BAI 2007 中，而且已根據與會學者之寶貴建議整理完手稿，將投稿國際期刊中。國際會議心得報告及發表之論文詳見附錄。

附錄：出席BAI 2007 國際會議心得報告及發表之論文

附錄：出席 BAI 2007 國際會議心得報告及發表之論文

International Conference on Business and Information

InterContinental Hotel Tokyo Bay

Tokyo, Japan

九十六年七月十一日至七月十三日

謝玲芬

中華大學科技管理學系

一、會議經過

International Conference on Business and Information (BAI 2007) 每年舉辦一次，會期由十二月十一日至十三日共三天，地點選在日本的東京。2006年是在新加坡舉辦。BAI國際研討會算是管理與資訊相關領域的學者齊聚一堂、交換彼此研究心得的時刻，每年台灣出席及發表論文的人數都相當多，今年亦同。研討會收錄的論文相當多，約五百餘篇，大會共分為六十個場次發表論文，每個場次約八至十篇論文，讓與會者能充份挑選自己有興趣的主題之場次參與討論。研討會第一天，來自各各國家的學者相當多，踴躍出席的情況似乎超出主辦單位的預期，更由於日本消費昂貴，大會主辦單位在開幕餐會上雖然供應精緻的餐點，但卻發生供不應求的現象！儘管如此，但與會人士仍熱情參與全程活動。大會主辦單位致辭感謝大家的熱情參與，並邀請大家明年再聚會一同研討學習，典禮中並頒發最佳論文獎，整個國際研討會到此在一片歡樂中圓滿閉幕。

參加研討會期間，在各個發表論文的場次內均熱烈討論，這次參加研討會的論文是我首次嘗試將績效評估理論應用於國內觀光飯店效能評估，在該論文發表場次內，也結識了日本、韓國、馬來西亞等東南亞國家一樣對觀光產業發展與策略管理有濃厚興趣的學者，相談甚歡，也吸收了許多寶貴的意見，已根據與會學者之寶貴建議將該研討會論文重新整理完手稿，將投稿國際期刊。

由於日本物價昂貴，研討會會場的InterContinental Hotel Tokyo Bay，住宿費用相當高，來自台灣之大部分與會學者也都選擇較偏郊區的飯店住宿，剛開始時覺得日本的電車系統錯綜複雜，第一天深怕自己迷路在電車系統內，而錯過論文宣讀的時間；幸好飯店人員協助我找了一條轉車次數最少的方式，出了電車站後再根據飯店提供的地圖，我在東京街頭走了近十五分鐘，終於順利準時抵達研討會會場，但也因此讓我深可瞭解日本的電車系統的便利性。趁著研討會的空檔，親身搭乘日本的電車，逛逛當地的商場，順道體驗當地的民俗風情。相片中左圖為由研討會會場往外可看到的彩虹大橋；右為東京都淺草寺。

二、研討會發表之論文

AN EFFICIENCY AND EFFECTIVENESS MODEL FOR INTERNATIONAL TOURIST HOTELS IN TAIWAN

Ling-Feng Hsieh[*] *Yi-Chen Huang* *Angel Chen*
Department of Technology Management Chung Hua University
No.707 Wu Fu Road Sec. 2 Hsinchu, Taiwan ROC
[*]*lfhsieh@chu.edu.tw*

ABSTRUCT

According to the social change and industry transfer, the tourism industry can be the important strategy industry for the government in Taiwan. The tourism industry is not only maintaining local economic but also offering the chance of employment. Therefore, this paper evaluates how international tourist hotels operate, using Data Envelopment Analysis (DEA) to measure the operational efficiency and effectiveness, and then adopted VIKOR method, to rank the hotels which is either efficiency or effectiveness, out of the 14 international tourist hotel in Taiwan. Based on the evaluating criteria, the tourism industry has more emphasis in customer's loyalty and interactions. It is expected to attract, keep loyalty, and get the visible and invisible feedbacks from customers. This paper proposes an evaluation model to evaluate international tourist hotels in two aspects: efficiency and effectiveness. Proprietor can discover the problems either do not have efficiency value at input internal resources or the output operation revenue does not reach operation effectiveness for the tourism industry. Furthermore, the DEA model can give the directions and suggestions for hotel improvement by slack variable analysis, and last adopted VIKOR method, to rank the hotels which are either efficiency or effectiveness to come up with our last result.

Keywords: Efficiency, Effectiveness, Data Envelope Analysis, VIKOR

1. INTRODUCTION

The development of Taiwan's economy, increased qualities of people's living and internationalization trend, etc. cause Taiwan's tourism industry, the star industry in the 21st century, to grow vigorously. "Tourism" is not only an industry that can link Taiwan with the world but also an indicator that shows a country, city or district's image. According to statistics collected by the Tourism Bureau, R.O.C, revenues in foreign exchange from tourism reached 4.977 billion US dollars in 2005, showing an increase of 22.80% compared with 2004. The average duration of tourists' each stay reached 7.1 nights and 85% of tourists would choose international tourist hotels, showing the important role that the hotel industry plays in the tourism industry. Considering the importance of the hotel industry, we decided to make an assessment of international tourist hotels in Taiwan with the aim of improving their operation performance.

Efficiency and effectiveness are two common assessment points in management. According to Hit(1986)et al., efficiency refers to the ability of an organization to make full use of resources in the short run, and effectiveness means whether the organization's objectives have been achieved over a period of time. According to Gronroos and Ojasafo (2004), efficiency means whether resources are fully utilized within the organization under the influences of costs, and effectiveness refers to actual operating receipts, namely performance of its businesses with the outside world. Documents exploring relative efficiency by means of DEA method have been widely applied in all fields. In addition, view points exploring inputs and outputs with DEA have been used to analyze relative efficiency. For example, Rousseau(1998)analyzed whether R&D of European countries was effective and Kavlaftis(2004)studied public transportation means. According to literature, the difference between effectiveness and efficiency lies in that efficiency is the standard hour of internal operation and effectiveness is related to external customer services. Hean(2006) et al. once adopted DEA method to develop a triangular model (effectiveness, efficiency and production power) so as to assess the operation performance of 49 hotels in pacific rim countries. In this study, on the basis of international tourist hotels' internal and external objectives, we established models for relative efficiency and effectiveness so as to assess the efficiency of international tourist hotels. Then, we substituted cases in the two models and next used DEA Solver to work out values for each hotel's efficiency and effectiveness, and provide hotels having no efficiency and effectiveness with corrective directions. Finally, we adopted VIKOR method to rank hotels by it's efficiency and effectiveness.

2. MODEL CONSTRUCTION

2.1 Data envelopment analysis (DEA)

The estimation of production functions plays an important role in efficiency assessment. It generates from the view point of Farrell(1957) that production frontier is the basis of assessing production efficiency. In other words, the ratio of actual output to production function output is the efficiency value. And therefore, as long as a point falls to production function, it will be regarded as "having efficiency". In the process of establishing production functions, all data are enveloped in production functions. And therefore, scholars named this method as "data envelopment analysis (DEA)(1984)". This term was first proposed by Charnes, Cooper and Rhodes, when they adopted Plato Best Situation to assess the relative efficiency of a decision making unit (DMU). And therefore, it is called as CCR. This is constant returns to scale. Later, Banker, Charnes and Cooper(1978)developed the method for calculating efficiency when returns to scale are variable, which is called as BBC(1984). DEA method can deal with not only quantitative factors such as satisfaction but also inputs and outputs of several different units. The weight given by DEA method to the unit assessed is best for efficiency. In addition, analysis of slack and surplus variables in DEA method can demonstrate whether the unit assessed has invested too much or gained too little, which is shown by Equations (1) and (2). Xik represents DMU i input value of DMU k that is assessed. Xik* represents the best DMU i input value of DMU k that is assessed. θ* is the efficiency value. And therefore, θ*Xik minus excess input ((Si-) is the optimum input value (Xik*). In the respect of output, Yrk represents the original DMU r actual output of DMU k that is assessed. Yrk* represents the optimum DMU r output of DMU k that is assessed. And therefore, the original Yrk plus output differential (Sr+) is the optimum output (Yrk*). Depending on the two equations, we can know how inefficient international tourist hotels improve their efficiency and effectiveness.

$$X_{ik}^{*} = \theta^{*} X_{ik} - s_{i}^{-*},\ i = 1,...m \tag{1}$$

$$Y_{rk}^{*} = Y_{rk} + s_{r}^{+*},\ r = 1,...s \tag{2}$$

2.2 VIKOR

VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) was proposed by Opricovic(1998)and is a compromise to multi-criteria sequencing method. When the decision maker cannot achieve several goals at the same time, he may make a compromise and choose a plan that is closest to the ideal solution. For example from Fig.1, F1* (the ideal value of the first assessment criterion) and F2*(the ideal value of the second criterion) cannot reach F*(ideal solution) at the same time. And the compromised solution is a point on the curve. Fc is closest to the ideal solution (F*) among all non-inferior solutions. And therefore, the optimum compromised solution is: Fc=F1c,F2c. The steps of applying VIKOR are shown as follows:

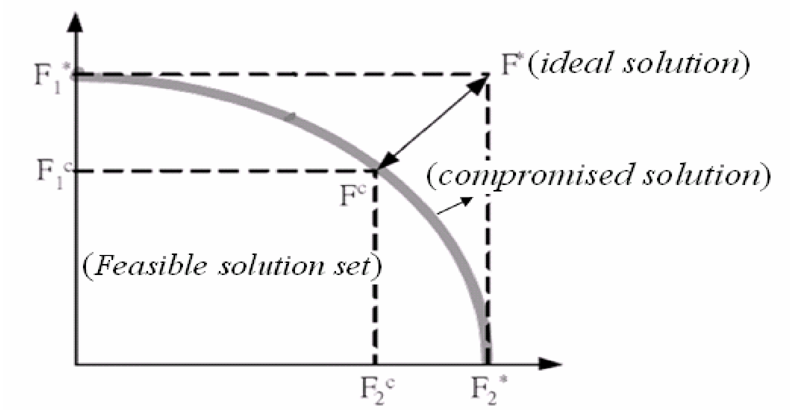

Fig.1: Ideal solution and compromised solution

Step one: Determine the ideal solution (f^*) and the negative ideal solution (f^-) for all assessment criteria. I_1 in equations (3) and (4) is the benefit criteria set. The larger it value is, the better. I_2 is the cost criteria set. The smaller the value is, the better.

$$f_i^* = [(\max_j f_{ij} | i \in I_1), (\min_j f_{ij} | i \in I_2)], \forall_i \quad (3)$$

$$f_i^- = [(\min_j f_{ij} | i \in I_1), (\max_j f_{ij} | i \in I_2)], \forall_i \quad (4)$$

Step two: Calculation of S_j and R_j

$(f_i^*-f_{ij})/(f_i^*-f_i^-)$ in Equations (5) and (6) is the distance ratio of the i criterion of j to the ideal solution. w_i is the weight obtained by using the i criterion. By adding all criteria in j together, we can get the maximum "collective" benefit (S_j). R_j is the ratio criterion selected from j and is farthest from the ideal solution. The smaller S_j and R_j are, the better j will be.

$$S_j = \sum_{i=1}^{n} w_i (f_i^* - f_{ij})/(f_i^* - f_i^-) \quad (5)$$

$$R_j = \max_i \left[w_i (f_i^* - f_{ij})/(f_i^* - f_i^-) \right], \ j = 1,2,\ldots.J \quad (6)$$

Step three: Calculation of Q value

Q_j is the benefit value of j combining collective (S_j) and individual (R_j). Its calculation is shown in Equation (7). The parameter v is the coefficient for decision-making mechanism. When it is larger than 0.5, v will represent the decision of the majority of the people. When it is equal to 0.5, v represents the decision that is passed reluctantly. When it is smaller than 0.5, v means that the decision is not approved.

$$Q_j = v(S_j - S^*)/(S^- - S^*) + (1-v)(R_j - R^*)/(R^- - R^*) \quad (7)$$

where $S^* = \min_j S_j$, $S^- = \max_j S_j$, $R^* = \min_j R_j$, $R^- \max_j R_j$

Step four: On the basis of S, R and Q, we can sort projects by efficiency.

Step five: Check whether the optimum compromised solution (Q (a′)) meets the following requirements:

1. Acceptable advantage: "Q(a″)-Q(a′)≧DQ". The alternative a″ is the second optimum one in Q order and a′ is the optimum solution. "DQ = 1/ n-1". DMU n is the number of cases. The difference between the optimum and the second optimum cases shall not be smaller than the ratio between cases. DMU (n-1) in DQ is the distance between cases.
2. Acceptable decision reliability: S or R value of the optimum case a′ must be an optimum value.

If either one of the above two requirements fails to be satisfied, we can work out a compromised solution by the following means: (1) If the first requirement fails to be satisfied, a′ and a″ shall be taken as the compromised solution. (2) If the second requirement fails to be satisfied, a′, a″, …,a(M) shall be taken as the compromised solution.

2.3 Establishment of models

To adopt DEA method to assess efficiency, we must screen input and output items. Input items refer to factors that are helpful to output items. Output items refer to detailed demonstration of the organization's operating objectives. On the basis of this DEA characteristic and definitions of efficiency and effectiveness in relevant literature, we will establish models of relative efficiency and effectiveness. The establishment of standards is based on the hotel evaluation standards issued by the Tourism Bureau of the Ministry of Transportation and Communications, which include seven standards for the evaluation of hotels' buildings and facilities and twelve standards for the evaluation of services.

2.3.1 Relative efficiency

Standards for the efficiency model are established on the basis of internal objectives of international tourist hotels. International tourist hotels input various resources with the aim of reaching a better customer satisfaction, building up a good reputation and attracting more customers. And therefore, customer satisfaction is taken as the internal objective. Input resources that are helpful to achieving this objective (output) are number of employees, management costs and objects (including number of guest rooms and costs of facilities). So, we can conclude the relative efficiency model (8).

$$Max \quad E_k = \frac{u_1 \cdot CS_k}{v_1 \cdot NR_k + v_2 NE_k + v_3 FE_k + v_4 ME_k}$$

$$\text{Subject to:} \quad \frac{u_1 \cdot CS_k}{v_1 NR_k + v_2 NE_k + v_3 FE_k + v_4 ME_k} \le 1 \quad \text{for} \quad k = 1, \ldots n \tag{8}$$

$$u_1 \ge \varepsilon > 0 \quad v_1, v_2, v_3, v_4 \ge \varepsilon > 0$$

The parameter u1 is the weight of the first output. v1、v2、v3、v4 are weighted values of items one to four. ε is a minimum value. CSk is the customer satisfaction of hotel k. NRk represents the number of rooms of hotel k. NEk represents the number of employees of hotel k. FEk represents facilities expense of hotel k, including costs of decoration, maintenance, cleaning and purchasing facilities. MEk is the management expense of hotel k, including expenses of personnel training, salaries and wages and advertising. From this equation, we can obtain the optimum weight of hotel k and the optimum solution to the objective function Ek. In addition, constraints show that efficiency values of units assessed shall be less than or equal to one. When the efficiency value is equal to one, the international tourist hotel is relatively efficient. And when the efficiency value is smaller than one, the international tourist hotel is relatively inefficient.

2.3.2 Relative effectiveness

According to Gronroos and Ojasafo (2004), effectiveness refers to the actual production revenues of an organization. And therefore, we used actual operating revenues of hotels to study relative effectiveness. In other words, we took the total operating revenue as the output and set inputs contributing to outputs as the customer satisfaction. In other words, the larger the customer satisfaction (input) is, the larger the occupied room rate (output 1) and the total operating revenue (output 2) will be. We get model (9), as shown in the following:

$$
\begin{aligned}
& Max\ \ F_k = \frac{u_1 ORR_k + u_2 TR_k}{v_1 CS_k} \\
& \text{Subject to:}\ \ \frac{u_1 ORR_k + u_2 TR_k}{v_1 CS_k} \le 1 \quad \text{for} \quad k = 1,...n \qquad (9) \\
& \qquad u_1, u_2 \ge \varepsilon > 0 \quad v_1 \ge \varepsilon > 0
\end{aligned}
$$

The parameter u1 and u2 are weights of output 1 and 2. v1 is the weight of input 1. ε is a minimum value. ORRk represents the occupied room rate of hotel k. TRk represents the total revenue of hotel k. CRk represents the customer satisfaction of hotel k. From this model, we can obtain the weighing of inputs and outputs. On the basis of objective function Ek, we can obtain the best solution. When the efficiency value is equal to one, the international tourist hotel is relatively efficient. And when the efficiency value is smaller than one, the international tourist hotel is relatively inefficient. Table 1 shows definitions of input and output indicators. Their relationship is shown in Fig.2.

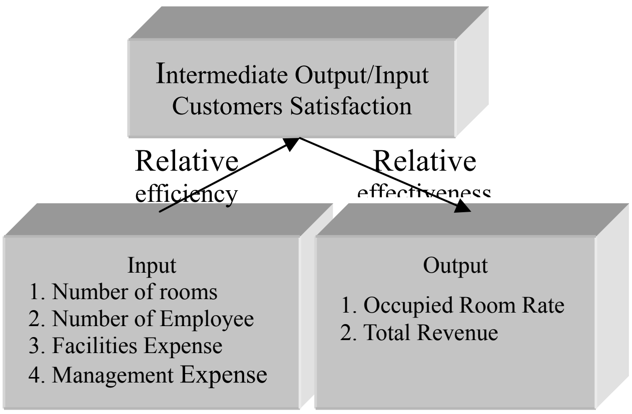

Fig.2：Indicator relationship

2.4 Data source

We obtained data on number of rooms and employees, occupied room rate and total revenues, etc from statistics concerning the hotel industry in 2005 that were collected by the Tourism Bureau of the Ministry of Transportation and Communications. Values of management and equipments costs were determined according to the number of managing departments and room rates. As for the customer satisfaction, we conducted a questionnaire survey. The questionnaire included 16 survey items. Each item included six choices, namely vary satisfactory, satisfactory, fair, unsatisfactory, very unsatisfactory, which were scored on the scale of 8, 6, 4, 2, and 0, with 128 as full marks. Finally, total marks were averaged and the result was the final customer satisfaction. Input and output data are shown in Table 1. Our questionnaires were sent to seniors majoring in tourism that once worked at hotels as interns. We asked them to complete questionnaires by taking the side of customers. The recovery rate was 55%. Fourteen international tourist hotels were included in returned questionnaires. And therefore, we took the fourteen hotels as objects, which were numbered from A to N.

Table 1: Input and output of relative efficiency and relative effectiveness

Hotel	Relative Efficiency					Relative Effectiveness		
	input				output	input	output	
	NR_k (rooms)	NE_k (persons)	FE_k (NT $100,000)	ME_k (NT $100,000)	CS_k (marks)	CS_k (marks)	ORR_k (percentage)	TR_k (NT$)
A	5832	8163	3,390	1,915	79.5	79.5	70.56	1,184,858,098
B	4536	3088	2,950	266	104	104	80.21	631,135,679
C	2508	3628	3,790	651	92	92	76.14	538,397,733
D	2916	1882	2,810	85	68	68	62.91	229,700,295
E	6162	9837	3,980	143	84	84	67.25	1,513,991,224
F	10272	11038	4,300	934	96.5	96.5	77.84	2,729,950,426
G	6460	8495	2,570	460	90	93	83.94	2,423,298,061
H	3456	5222	4,500	1,030	86.4	86.4	79.57	1,234,060,706
I	3582	2869	1,820	223	72	72	81.63	433,445,762
J	4248	3249	2,710	702	92.3	92.3	84.73	710,543,609
K	3084	3943	3,200	467	85	85	71.58	796,631,413
L	2496	2788	3,310	366	85.6	85.6	66.54	334,745,104
M	7272	10186	3,630	1,583	80	80	75.88	1,678,509,000
N	2664	5532	2,640	1,004	76	76	80.13	690,786,728

3. PERFORMANCE ASSESSMENT

We used DEA Solver to process the data in Table 1 and obtained values of relative efficiency, relative effectiveness, slack and surplus variables, which are shown in Table 2. We can find that hotels whose efficiency values (θ) are equal to one include B, C, D, I, and L. Efficiency values of other nine hotels are smaller than one, and therefore, they are regarded as relatively inefficient. We can conduct a slack variables analysis so as to offer data on improvement measures to hotels with improper inputs and outputs. Take hotel A for example. In order to improve its efficiency, its number of employees shall reduce by 2436.3249 and its management costs shall reduce by 9.8832172 million NT dollars. And there is no need to change its number of rooms, facilities costs, and output items. Assessment of relative effectiveness shows that hotels F, G and I are relatively efficient and other 11 hotels are relatively inefficient. Slack variable analysis shows that if revenues of hotel D and L increase by 104,344,454 and 18,574,521 NT dollars respectively, the two hotels will become relatively efficient. For hotels A, B, C, E, H, J, K, M and N, we cannot make judgments on how much inputs shall reduce and how much outputs shall increase from Table 2. It is because their slack variables are equal to zero. In order to make these hotels become effective, we shall analyze the value of relative effectiveness (θ). Take hotel A for example. Both its S+ (occupied room rate and total revenue) and S- (customer satisfaction) are zero. According to the formula Xik*=θ*Xik-Si-*, optimum input value (Xik*) is equal to the value of relative effectiveness(θ*=0.865) times customer satisfaction (79.5). The optimum value obtained is 68.7675. Through comparison with the original customer satisfaction (79.5), we can see that hotel A shall reduce inputs by 10.73%.

Table 2: Values of relative efficiency and effectiveness and variable analysis

Hotel	Relative Efficiency							Relative Effectiveness				
	θ	rank	Slack and Surplus					θ	rank	Slack and Surplus		
			input				Output			input	output	
			NR_k	NE_k	FE_k	ME_k	CS_k			CS_k	RR_k	TR_k
A	0.632	12	0	2436.32	0	988.32	0	0.865	7	0	0	0
B	1	1	0	0	0	0	0	0.696	13	0	0	0
C	1	1	0	0	0	0	0	0.742	12	0	0	0
D	1	1	0	0	0	0	0	0.816	10	0	0	104344454
E	0.835	10	1540.86	5876.01	0	0	0	0.817	9	0	0	0
F	0.567	13	1026.22	2416.38	0	230.95	0	1	1	0	0	0
G	0.885	9	1240.98	3933.64	0	128.44	0	1	1	0	0	0
H	0.737	11	0	1044.03	0	393.95	0	0.888	6	0	0	0
I	1	1	0	0	0	0	0	1	1	0	0	0
J	0.957	7	0	299.40	0	432.57	0	0.832	8	0	0	0
K	0.936	8	0	1004.05	0	122.29	0	0.782	11	0	0	0
L	1	1	0	0	0	0	0	0.686	14	0	0	18574521
M	0.557	14	71.12	2486.70	0	634.08	0	0.965	4	0	0	0
N	0.995	6	0	3118.53	0	726.33	0	0.958	5	0	0	0

From Table 2, we can find that although DEA method can demonstrate directions of improving efficiency and effectiveness, it cannot sort hotels with efficiency and effectiveness by their performance. And therefore, we adopted VIKOR method. Through DEA analysis, we know that hotels with internal efficiency are B, C, D, I and L and hotels with external effectiveness are F, G and I. So we take a step further to sort these hotels. First, classify various input and output items into cost and benefit criteria. NR, CS, TR and ORR fall into the category of benefit criterion, and NE, FE and ME fall into the category of cost criterion. Then, select out the ideal solution fi* and the negative ideal solution fi- from each hotel's individual criteria. Detailed results are shown in Table 3.

Table3: Ideal solution and negative ideal solution of various criteria under relative efficiency and effectiveness

Relative Efficiency						Relative Effectiveness			
	NR	NE	FE	ME	CS		CS	ORR	TR
$f_i^* = \{$	4536	1882	1820	85	104 $\}$	$f_i^* = \{$	96.5	0.8394	2,729,950,426 $\}$
$f_i^- = \{$	2496	3628	3790	651	68 $\}$	$f_i^- = \{$	72	0.7784	433,445,762 $\}$

On the basis of Table 3, we can work out Sj, Rj and Qj, which are shown in Table 4. In the respect of relative efficiency, we applied the two VIKOR test conditions. From acceptable advantage, we can work out the threshold value is 0.25 (DQ=1 / 5-1). The difference between the Q value of hotel B ranking last and that of hotels ranking second, third, fourth, and fifth is larger than 0.25. And therefore, B can be regarded as the best tourist hotel. In addition, hotel B has the smallest R or S value and conforms to decision-making reliability. Undoubtedly, hotel B ranks first in the respect of relative efficiency. As the first condition is concerned, the difference between hotel C ranking second and hotels I, L and D that rank third, fourth and fifth respectively is smaller than 0.25. As the second condition is concerned, Q and R values of hotel C are superior to those of hotels L, I and D. And therefore, C just meets the second condition (decision-making reliability). And therefore, the order of hotels in the respect of relative efficiency is: B$\succ$C$\approx$I $\approx$L$\approx$D.

Table 4: Values of Sj, Rj and Qj of efficiency and effectiveness

Relative Efficiency				Relative Effectiveness			
Hotel	S_j	R_j	Q_j	Hotel	S_j	R_j	Q_j
B	0.21872	0.18085	0	F	0.117915	0.117915	0.554234
C	0.664613	0.34707	0.711516	G	0.085939	0.071429	0
D	0.673315	0.5	0.959901	I	0.70444	0.5	10.17144
I	0.539208	0.44444	0.737192				
L	0.712951	0.37343	0.801717				

From Table 4, we can find that the value of QG is the smallest one. By applying the two test conditions of VIKOR method, we can find that the threshold value for acceptable advantage is 0. 5(DQ = 1 / 3-1). The difference of the Q value of hotel G and that of hotels F and G that rank second and third is larger than 0.5. And therefore, both the 1st and the 2nd conditions (Q, S or R value is the optimum one) are satisfied. The difference between hotel F ranking second and hotel I ranking third is 9.617, much larger than the threshold value. In addition, Q, S or R value of hotel F is superior to that of hotel I. So both conditions are satisfied. In the respect of relative effectiveness, the right order is G$\succ$F$\succ$I. On the basis of the above-mentioned sequences and values of DEA relative efficiency and effectiveness, we can sort the fourteen international tourist hotels by relative efficiency and effectiveness, as shown in Table 5.

Table 5: Ranking of relative efficiency and effectiveness of international tourist hotels

Rank of Relative Efficiency						Rank of Relative Effectiveness					
Hotel	Rank	θ	Hotel	Rank	θ	Hotel	Rank	θ	Hotel	Rank	θ
B	1	1	K	8	0.936	G	1	1	J	8	0.832
C	2	1	G	9	0.885	F	2	1	E	9	0.817
I	2	1	E	10	0.835	I	3	1	D	10	0.816
L	2	1	H	11	0.737	M	4	0.965	K	11	0.782
D	2	1	A	12	0.632	N	5	0.958	C	12	0.742
N	6	0.995	F	13	0.567	H	6	0.888	B	13	0.696
J	7	0.957	M	14	0.557	A	7	0.865	L	14	0.686

In this study, integrated performance of efficiency and effectiveness is also analyzed, and the results are shown in Fig.3. We can find that the hotel with the best performance is I, which is located at the point where relative effectiveness and relative efficiency axes cross each other. It demonstrates that hotel I performs best in the management and control of inputs and outputs. As relative efficiency is concerned, we can find that hotels B, C, L and D have internal efficiency but no external effectiveness, demonstrating that the four hotels have achieved relatively high customer satisfaction, but their operating revenues or occupied room rates fail to increase significantly. The possible reason may be that their prices are too low or they have to reduce prices in response to external competitions. Hotels G and F have no internal efficiency and have external effectiveness, demonstrating that the amounts of their inputs are too small to achieve customer satisfaction or are not helpful in improving customer satisfaction. The other seven hotels have neither internal efficiency nor external effectiveness. We can conduct the above-mentioned slack variable analysis to find improvement measures.

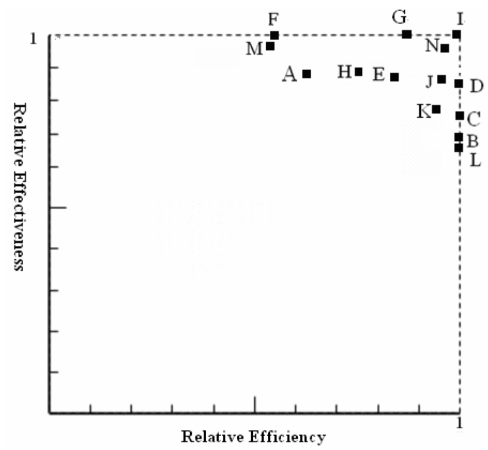

Fig.3: Correlation between relative efficiency and relative effectiveness

4. CONCLUSION

Case analysis shows that by adopting DEA method, we can judge whether international tourist hotels have relative efficiency and effectiveness, and provide hotels having no relative efficiency or effectiveness with improving suggestions by means of slack variable analysis. And therefore, our division of DEA into internal efficiency and external effectiveness is feasible and our setting of efficiency and effectiveness is reasonable. Efficiency refers to various inputs and costs (the number of rooms, the number of employees and management costs, etc), which are aimed at making customers feel satisfied. Effectiveness refers to total revenues and occupied room rate of international tourist hotels under a high or low customer satisfaction. By adopting VIKOR method, we sorted international tourist hotels with relative efficiency and effectiveness (θ =1) by performance. After testing against two conditions, the final sequence is more acceptable and reliable. From Fig.3, we can see which hotel has both efficiency and effectiveness, which hotel has either efficiency or effectiveness, and which hotel both has no efficiency and effectiveness. Fig.3 clearly demonstrates the overall operating status of hotels and whether there is difference between relative efficiency and relative effectiveness of a hotel. In addition, depending on models of relative efficiency and effectiveness, we can find out reasons why some hotels have no relative efficiency and effectiveness. We can also conduct slack variable analysis to find suggestions on making improvements.

ACKNOWLEDGEMENT

The author would like to thank The National Science Council, Republic of China, for financially supporting this research under the grant number of **NSC-95-2221-E-216-026-.**

REFRENCES

Banker, R.D.,Charnes, A. and Cooper,W.W.,1984 Some models for estimating technical and scale efficiencies in data envelopment analysis, *Management Science* Vol.39,No.10,1261-1264。

Charnes, A.,Cooper W.W., and Rhodes E. 1978 Measuring the efficiency of decision making units, *European Journal of Operation Research* Vol .2,.429-444.

Farrell,M.J.1957 The Measurement of Productive Efficiency, *Journal of Royal Statistical SocietyA,*Vol.120,No.3, 253-281.

Gronroos, C., Ojasalo, K., 2004 Service productivity: Towards a conceptualization of the transformation of inputs into economic results in services. *Journal of Business Research 57,* 414–423.

Hean, Tat Keh. Singfat Chu and Jiye Xu 2006 Efficiency, effectiveness and productivity of marketing in services , *European Journal of Operational Research* vol.170, 265–276.

Hit, Middlemist., & Mathis, R. L.1986 Management：Concepts and effective practice. Saint Paul: *West Publishing Company.*

Karlaftis, Matthew G. 2004 A DEA approach for evaluating the efficiency and effectiveness of urban transit systems, *European Journal of Operational Research* vol.152 , 354–364.

Opricovic,S.1998 Multicriteria Optimization in Civil Engineering. *Faculty of Civil Engineering Belgrade.*

Rousseau, Sandra. 1998 The Scientific Wealth of European Nation Taking Effectiveness Into Account, *Scientometrics* . Vol .42 .No.19 .75-87.