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基於CSA之分散式生產訂單允諾系統：以TFT-LCD Array製程為例
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基於 CSA 之分散式生產訂單允諾系統：以 TFT-LCD Array 製程為例
Distributed Production Order Promising System based on Conservative Synchronization Algorithm for the Array Process of TFT-LCD Manufacturing

國科會研究計畫報告 NSC 99-2628-E-029-010

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摘要

現今的生產環境由於產業變動快速，產品生命週期短暫，企業紛紛以保留自己核心技術，其餘部分與具有相關技術企業的廠商進行合作，以虛擬企業的模式來完成產品的生產。企業間的合作需要溝通。為了降低溝通所浪費的時間，各種類型的溝通方式紛紛被提出。然後這許多方法僅降低了溝通時間，各企業內部處理時間仍未能有效被降低。

在企業間許多的溝通中，最需要快速完成的就是對於客戶訂單的允諾與否。在產業變動快速的環境中，回應客戶的速度極可能主導客戶訂單的歸屬。

為了確保企業可以對客戶的訂單進行快速的回應，本研究分析企業在接收到客戶詢單後的動作與流程，將之由整體生產環境細分至機台，找出完成生產排程所需要的知識與資訊，並將之分為*可公開*與*不可公開*兩類。最後以 JAVA 之 TCP/IP 架構作為資訊傳輸/接收介面，專家系統語言 CLIPS 儲存排程所需知識與能力，建立一架構。在不取得(帶走)合作廠商生產資訊的前提下，藉由統一格式的訂單資訊輸入、計算與輸出，快速地完成一可行的排程，決定生產路徑，並以之結果回應客戶，達成快速允諾客戶訂單的目的。

關鍵詞：訂單允諾、分散式生產、CLIPS、CSA

ABSTRACT

Highly fluctuated market demand and shortened production life cycle force companies to maintain their core technologies and to outsource other business activities. ‘Virtual enterprise’ is the term that vividly describes the way that companies collaborate. However, companies communicate so they can collaborate. To reduce the time waste in communication, various communication formats (protocols) are proposed. Nevertheless, among the applications of the communication protocols only communication time is reduced, processing time in companies remains unchanged.

Among the company-wide communications, order promising is the most essential business process. A customer order is highly possibly given to a supplier that can promise an order quickly. In order to ensure that a company can quickly respond to the customers under a virtual enterprise environment, this research investigates processes after the order been inquired in detail. The processes are detailed into the machine level. Additionally, process information is divided into two categories: open and closed. Finally, by Java TCP/IP interface and CLIPS for storing the scheduling knowledge rules, this research develops an order promising architecture. In the architecture, companies can easily retrieve the information that other companies are willing to offer for making the order promising decision.

Keywords: Order Promising, Distributed Production, CLIPS, Conservative Synchronization Algorithm

1. 緒論

現今的產業環境下，企業必須與具有各類型核心能力的企業進行合作，才能及時因應市場需求，完成產品生產。

企業合作時，彼此間的溝通是無法避免的。然而

溝通雖然必要，卻未能對產品附加任何價值。因此有許多的研究專注在如何降低溝通時間。

這許多的研究中，爲企業間各種可能的溝通設計了許多架構，以求降低溝通時間。然而各種溝通流程的時間雖然因爲這些架構而降低，但因爲無法掌握各企業內處理各種溝通流程所需的時間，各種溝通流程的整體所需時間仍是無法被確定。

企業間各種溝通中，用來回應客戶詢單的溝通流程是最重視時間與效率的。由於產業環境變動快速，客戶訂單允諾所需時間的長短往往可以決定客戶訂單的歸屬。

然而多階多廠區的跨企業生產模式下，由於牽涉到利潤問題，取得合作企業的生產資訊有相當的難度。如何在不取得合作企業生產資訊的前提下，快速完成排程，取得一可行且較佳的結果回應客戶的訂單，是本研究著重的議題。

2. 文獻探討

2.1 虛擬企業

現在的產業環境中，由於產品生命週期短暫且逐漸走向少量多樣的客製化生產模式，因此企業紛紛由從頭到尾自行生產的傳統生產模式改變爲保留自己核心技術，其餘部份依照產品特性與專業的企業進行合作，進而完成整個產品的生產。這樣的企業合作生產方式，被稱之爲虛擬企業(Virtual Enterprise)。

企業之間存在許多差異，因此在溝通方面若沒有訂定特殊的方式，在名詞轉換或認知上會有許多的問題產生，進而延長了溝通所需要的時間。在虛擬企業產生之初，Davis 等人[8]提出了合約式網路協定(Contract Net Protocol, CNP)的概念，成爲企業間合作溝通時的基本架構。

雖然 CNP 可以解決各類型的企業合作問題，但其所需要的溝通時間較長，而理論上企業間合作企業的類型較爲固定，因此後來有許多研究爲企業間常見的互動一一設計了通訊協定(protocol)，如黃泰翔[2]、陳志銘[3]等人，分別爲企業間的各種互動設定了特定的通訊協定，藉此減少企業間溝通所需要的時間。

然而這許多研究都只是爲企業間溝通進行標準化的格式設計。雖然大幅降低了企業間溝通所需要的時間，卻仍無法確認各個合作企業內部處理該流程所需的時間，進而掌握整個流程所需要的總時間。

2.2 分散式環境

過去有許多的觀點來定義分散環境系統結構的基本單位，如 fractal [12]、holon[11]來減低分散的動態環境對集中式系統所造成的衝擊，增加系統的彈性。

從表 2.1 的歸納與比較來看，以分散式的觀點來看待系統中的問題，較集中式的方式上具有較多的優點，同時較貼近現況系統所處的環境。

表 2.1 集中式系統與分散式系統之比較[4]

	特性	分散式系統	集中式系統
集中式系統較佳	理論上最佳化	否	是
	計算之穩定性	低	高
分散式系統較佳	符合現實情況程度	高	低
	集中式資料的需求	否	是
	對變動的回應能力	強韌	脆弱
	系統重新組態的能力	容易	困難
	排程所需的時間	及時	緩慢

一個分散式製造系統的設計原則應該考量下列四項主要的需求：

1. 區域性資料與決策權力
   個別的元件都必須具有區域性資料與決策權力，並且對於創造與執行計畫或策略有必須具有一定的處理能力。
2. 合作
   個別的元件不應該絕對自主的假設前提下作業。相反地，應該與其他元件合作，並且在系統限制下運作以及它們的行爲必須根據協調資訊來運作。
3. 可調整性
   元件的實體與資訊觀點的結合對這些元件可以簡單地整合至一個系統中而言是必要的。換句話說，分散式製造必須能夠藉著整合必要的元件而被建立，也必須能夠藉著增加、適應、調整與減少元件的行爲簡單而且快速地重新安裝這個系統。
4. 可回朔性
   一個製造系統可能會在不同的層級上將元件組

合，其在不同層級上的元件必須在有意義的整合上從一個層級至另一個層級形成有結構化的架構。

2.3 訂單允諾

許多文獻中，訂單允諾(Order Promising)與交期指定(Due-date Assignment)被視爲相同，最終結果都是爲了取得交期。但在這些文獻中，通常都使用數學方法求得最佳解，與最佳化排程類似。

在這許多關於訂單允諾的文獻中，可查詢到比較符合快速回應的原則的方法只有可允訂購量(Available to Promise, ATP)的概念。

可允訂購量之定義如下[1]：

「根據美國生產及存貨管理學會(America Product and Inventory Control Society, APICS)在 1987 年所出版的 APICS 字典中將傳統可允諾量(ATP)定義爲製造商尙未允諾達交的完成品存貨與預計生產量加總。其數量由主排程(MPS)取得，且可作爲顧客訂單允諾的依據。根據此一定義，可允諾量是作爲製造商未被訂購的生產額度紀錄簿，製造商以此獲得的資料，做爲客戶訂單需求允諾數量與交期的依據。」

可允訂購量的概念相當合理，由於是事前進行生產規劃，對於分散式各階層的排程分配耗時的缺點也一併解決了。但仍有其先天上的限制：

1. ATP 爲未允諾庫存量與預計生產量的加總。而預計生產量必須用 MPS 依靠歷史資料排出。也就是說，這個方法需要參考歷史資料，不可能在一開始就執行。
2. 預測不一定準確。可能會多產造成庫存成本或少產造成機會損失。
3. 各品項其生產的資源，包含原物料及產能可能爲彼此通用。因此爲各種產品設定預計生產量將對其他產品的可生產量產生影響。

除了可允訂購量之外，Huang 等人[9]提出了分散式製造系統之訂單確認機制，已有在不取得合作廠商生產資訊的狀態下完成排程之概念。但其模型較小，生產路徑的選擇較少。

2.4 人工智慧

在 1950 年代初期，電腦之發展主要以數值處理爲主，1970 年代後便大量使用電腦來處理資料，而專家系統隨之開始發展。1972 年，MYCIN（血液感染疾病診斷專家系統）的誕生，突破專家系統應用層次之發展瓶頸，促成專家系統進入商業應用階段。1980 年代學者們開始研究人工智慧（Artificial Intelligence, AI）技術，許多專家系統建構工具相繼問世，歐美日主要國家均投入資金與人力推動人工智慧與專家系統之研究發展。

人工智慧之目的是讓電腦能夠處理認知問題，而不再僅是當作數值計算機。隨著人工智慧之興起，電腦應用層面逐漸超脫數值分析與資料處理之巢臼，亦讓電腦之應用程式逐步具有智慧，強化電腦與使用者間之互動。人工智慧主要之研究課題有：自然語言之溝通、符號處理、經驗法則搜尋和邏輯系統等，而其中發展較成熟並已有具體成就者爲專家系統。

表 2.2 專家系統與一般電腦程式系統之比較

	專家系統	一般電腦系統
功能	解決問題、解釋結果、進行判斷與決策	解決問題
處理能力	處理數字與符號	處理數字
處理問題種類	多屬於準結構性或非結構性之問題，可處理不確定之知識、應用於特定領域	多屬於結構性之問題，處理具確定性之知識

專家系統之基本架構應包括下列幾部份：

1. 知識庫（Knowledge Base）：儲存專家系統所需要之經驗性和一般性知識，包括法則或事實。知識來源主要爲領域專家或相關的研究報告、期刊與領域知識文獻等。
2. 推理機制（Inference Engine）：爲知識庫中法則與程序方法之啓動機制，其包括解譯器（Interpreter）與排程器（Scheduler）。利用解譯器來搜尋與事實關連之知識庫法則，驗證事實之真僞，並以法則推論獲得新的事實，而排程器則

可決定法則執行之順序。

3. 使用者介面（User Interface）：爲專家系統和使用者互動接觸之機制，使用者透過介面和系統溝通，良好之互動介面能夠幫助使用者瞭解系統運作流程，降低使用或學習系統之複雜度與困難度。
4. 工作記憶區（Working Memory）：儲存專家系統在運作過程所需之現有事實或所推論之事實，如解決問題時所需之前提事實資訊，與知識庫法則所推論出之事實。
5. 架構完整且具有後續發展潛力之專家系統，另須具有：
   (1) 解釋機制（Explanation Facility）：將系統運作時所採用推論之法則與所依據之事實，提供使用者透明化之說明管道，使專家系統之推論具有透明化之特性，此亦爲專家系統與傳統程式之主要差異。
   (2) 知識擷取介面（Knowledge Acquisition Facility）：將知識工程師（Knowledge engineer）從領域專家中訪談所獲得之經驗與知識，透過知識擷取介面，進行知識的擷取、維修與擴充知識庫之實體內涵

開發專家系統之應用程式之主要程序爲：

1. 確定問題領域
2. 擷取相關知識
3. 知識表達形式確認
4. 選定建構工具
5. 建立知識庫
6. 測試系統

3. 研究方法

3.1 生產流程分析

現今產品生命週期短暫且高度客製化，MTS (Make-to-Stock)、MTO (Make-to-Order)、ATO (Assemble-to-Order)三種基本生產模式中，MTS 除了生產大量庫存耗費庫存成本外，無法因應客戶客製化需求的缺點使它已明顯地無法適用在許多產業中。而 MTO 與 ATO 這兩種生產模式有一共通點，就是接單後的生產流程，也就是一連串的生產(組裝)活動。

一個採用 MTO 或 ATO 生產模式的廠商在接收到來自客戶的詢單需求時，會進行什麼動作？首先查看庫存，庫存充足則由庫存發貨；庫存不足，則必須規劃生產，並以規劃結果回應客戶，最後客戶同意之後，再把訂單正式排入生產中。

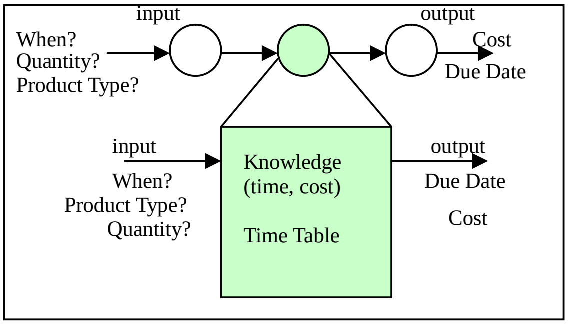

圖 3.1 排程所需資訊與知識示意圖

如圖 2.1，要判斷工作何時可完成及所需成本，必須具有以下的相關資訊：

1. 產品類型
2. 產品數量
3. 進入時間
4. 各種工作的平均工時或方程式
5. 各種工作的單位成本或方程式
6. 時間表

3.2 CLIPS 之應用

CLIPS [10]是一套專家系統的開發軟體。如 2.3 節中所述，專家系統藉由事實(facts)的狀態觸發法則(rules)，來產生新的事實。而新的事實又可能會觸發其他法則，進一步產生新的事實。

本研究利用 CLIPS 來推論工作在機台的工作時間與成本，並以 CLIPS 建立時間表，利用生產系統中最小單位的機台同一時間僅能處理一件工作的原則來規劃排程。CLIPS 中對於事物的定義方式可以分爲 deffacts、deftemplate、defrule 等數種。

本研究中 CLLIPS 之法則主要應用在：

1. 工作排程
2. 工作時間與成本之計算

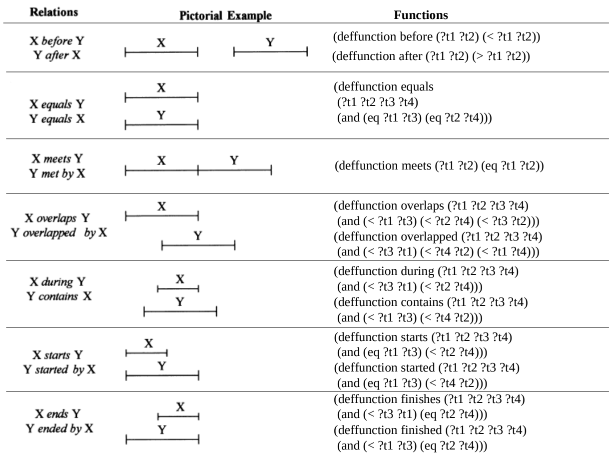

圖 3.2 時序關係之 deffuntion 設計

本研究將 CLIPS 中的事實(facts)分為五類：

1. fact，表已確定並已在排程中的工作。
2. scheduled，表已預排，但未確認的工作。
3. schedule，表將進行排程的工作。
4. new，表新進入的工作。
5. temp_fact 與 temp_scheduled，為重新排程時原有排程資訊的暫存形式。此類事實將視重新排程結果予以消滅，或復原為 fact 與 scheduled。

3.3 CSA 之應用

Conservative Synchronization Algorithm(以下簡稱 CSA)是一個為了確保分散式模擬時，各相關事件順序性的法則。CSA 在每一個機台上都建立了與其有關聯的機台的時間表(time list)。當這些時間表上都不為空白的時候，就依照時間表上的順序一步一步往下進行；當有時間表隨著時間的進行而成為空白時，機台會以兩機台間的運送時間自動產生一個「最快何時會有工作」的空訊息。空訊息除了代表沒有工作之外，同時也代表了該時間點之前不會再有工作進入，因此可以放心進行下一步而不需擔心會違反因果關係。

本研究的程式分為兩部份，第一部分是生產規劃，也就是排程的部份。排程的部份由事前所知之條件進行生產規劃。第二部份則是時間前進的部份。在這部份中，由於實際生產環境的異動(如機台故障等)，有可能導致某些工作無法進行或延遲，進而影響到整體生產的進行。因此本研究運用 CSA，以其確保因果關係的特性，來確保系統中在發生狀況時不同機台中相關工作的先後順序不會被違背。

本研究針對 CSA 的應用部份設計了六個步驟，一一說明如下：

1. 時間前進

接單介面通知各點更新時間。

2. 檢查工作完成時間➔工作結束➔遞至下一站

各點更新時間後，搜尋是否有工作已完成。若有，則設定該工作為已完成並通知生產路徑中之下一站。此時也會將各點中所儲存的錢站工作表已到期的時間點去除。

3. 接收前站工作完成訊息➔該工作下步驟改為可執行

各點接收到前站工作完成訊息，將該工作下一步驟改為改為可執行，表示進行該工作步驟時不會違背工作之間的因果關係。

4. 檢查工作開始時➔工作開始➔遞至下一站

檢查完已完成的工作後，檢查正要開始的工作。若有工作正要開始，則設定該工作進行中。由於本研究中設定各機台之間運送時間幾乎可忽略(亦即沒有運送時間)，因此在工作開始時便通知下一站，更新時間表，以便用 CSA 確保工作間的因果關係。

5. 接收前站開始工作訊➔更新前站時間表

接收到前站的工作開始訊息後變馬上更新前站時間表，將這些工作訊息加入。

6. 檢查是否有前站時間表數量為 0。若有，檢查工作是否即將開始。若是，則回報接單介面：「前站異常」並進行相關訂單重排。

使用 CSA 之設定，當各點所儲存的前站工作表中工作的數量為零時，則必須確認前站狀態並補上新工作訊息或空訊息(null message)，以確保時間可繼續前進而不至於影響工作間的因果關係。

3.4 程式設計

根據前方所歸納之因素與條件，一個結合 CSA 特性的分散式生產訂單快速回應程式應具備以下之功能：

1. 紀錄 Time List
2. 接收訂單資訊
3. 計算產品作業時間與成本
4. 找出滿足作業時間的時段，算出最早交期
5. 傳送訂單資訊

本研究使用 JAVA 撰寫使用者介面，使用 CLIPSJNI 連接 JAVA 與 CLIPS，運用 TCP/IP 架構處理資訊的接收與傳送，以 CLIPS 紀錄 Time List 中的各個時戳，並在收到新工作時計算工作的時間與成本並找出該點的最早交期。

如圖 3.3，接單介面包含了 Order Info.、Waiting、Scheduling、Scheduled、Confirmed、Rescheduled Temp、Information、Points 幾個區域。功能分述如下：

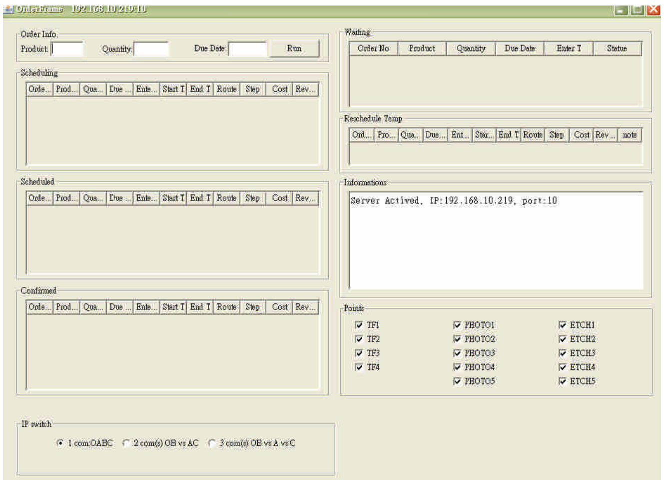

圖 3.3 接單模擬起始狀態

1. Order Info.區：用來輸入訂單資訊，其中包含了產品類型、數量、交期等三個最重要的訂單資訊。
2. Waiting 區：當輸入訂單資訊時，若有排程進行中，則該訂單資訊會先暫存至 waiting 區等候。當現有排程結束後，會從 waiting 區抓取訂單進行下一步的排程。
3. Points 區：此區代表了整個生產系統中的機台，當機台發生故障或意外事件時，會先傳送訊息至接單單位，取消該機台在此處對應的選取。待機台恢復正常後，則會發送訊息至接單單位，恢復該機台在此處對應的選取。
4. Scheduling 區：當訂單開始排程時，會依照 Points 區中可用的機台產生生產路徑，並將之列在 Scheduling 區中。程式依照 Scheduling 區中所列出的生產路徑一一發送訊息給對應的機台，並取得結果，最後再所有路線中取一條最符合條件的列入 Scheduled 區，最後清空 Scheduling 區中所有的路徑，開始下一輪排程。
5. Scheduled 區：存放排程後被選取訂單生產路徑。當某訂單被客戶確認則轉移至 Confirmed 區；反之則清除所有機台中該訂單的排程；若客戶未確認也未取消，則這些訂單的排程會保留，當新訂單進入時也必須考量到這些訂單，不與之重疊。
6. Confirmed 區：本區儲存以被客戶確認的訂單。本研究不考慮訂單取消的狀態，因此進入此處的訂單均已確認會被執行。
7. Reschedule Temp 區：當有重新排程的狀態產生時，以排程但符合重排條件的訂單會被移至此處暫存，直到完成重排被消滅或重排失敗被移回原有區域。
8. Information 區：顯示排程中各種資訊，如各訂單的生產路徑，排程花費的時間等。

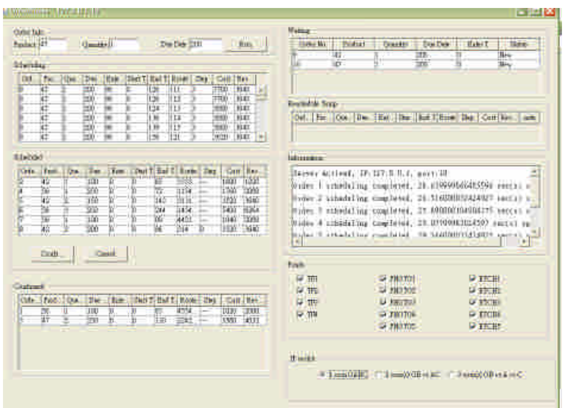

圖 3.4 接單模擬後所有路線與建議路線交期與成本示意圖

2. 各機台介面

各機台之程式之基本功能如下：

1. 接收資訊，轉換為訂單資訊
2. 將訂單資訊轉換為工作時間與成本
3. 在時間表中進行排程
4. 傳送排程結果至生產路徑中之下一站
5. 紀錄前方工作站之時間軸，確保因果關係

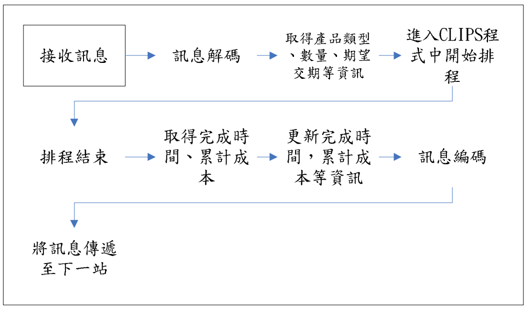

圖 3.5 各點接收訊息並排程之基本流程

其基本流程如圖 3.5，其中生產相關知識僅在 CLIPS 程式排程時使用，輸出資訊並未包含該點之生產相關知識，確保各點的獨立性。

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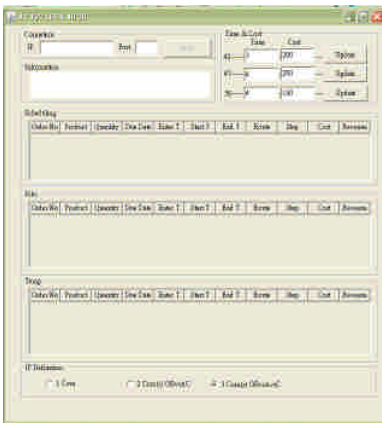

圖 3.6 各點程式介面

各點程式介面如圖 3.6，分別說明如下：

1. Time & Cost 區：存放了各類型工作所需的時間成本。此區域同時也提供了修改各類工作時間成本的功能。但修改後所有訂單將釋出進行重排，以確保生產路徑的可行性。
2. Scheduling 區：收到來自前站的排程訊息後，使用 CLIPS 進行排程，然後將排程結果列於此處，並發送給下一站。
3. Jobs 區：當生產路徑被選取後，該訂單生產路徑會移至此處。
4. Temp 區：若收到重排訊息時，則需重排之訂單均從 Jobs 區移至此處，等重排完成後被消滅或重排失敗後回到原區域。
5. Information 區：排程中的資訊存放處。

各點與接單介面傳送之訊息為同一格式，如圖 3.7 所示。訊息格式制式化可除了易於處理外，也可確保不願分享之資訊不會被輸出之資訊夾帶出去。

圖 3.7 訊息格式示意圖

整體程式如圖 3.8 所示，各點處理完各生產路徑將結果後彙整至接單介面，由接單介面依照設定之條件(如最大利潤、最早交期等)決定生產路徑並回應客戶。

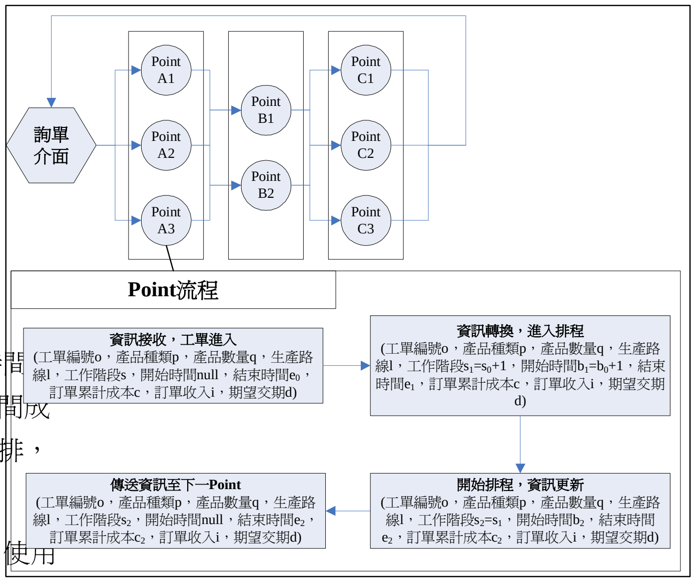

圖 3.8 整體程式示意簡圖

4. 情境模擬

4.1 模擬環境背景

本研究使用面板廠中，Array、Cell、Module 三大步驟中的 Array 部分來做爲情境模擬的環境。

以往在面板廠中由於設備昂貴，不論有無訂單都會盡量排入工單，以 MTS 的方式生產，使產能滿載。各種世代的廠房均有其預設的最佳生產尺寸，MTS 時也以此爲依據生產庫存。

但隨著整體市場環境的快速變動，各種不同類型產品的盛行(如手機、i-pod、mp4、Net Book 等)，廠商也會接到不屬於規劃中尺寸的訂單。如這一兩年上網型筆電(Net Book)與大螢幕手機盛行，小尺寸面版的需求量大增。爲了應付這些突如其來的需求，除了原先就規劃來生產小尺寸面板的舊世代廠房外，新世代的廠房也或多或少必須生產一些小尺寸面板以便即時交貨給客戶。爲了應付客戶各種產品不同的需求，傳統的 MTS 模式已漸漸不適用。

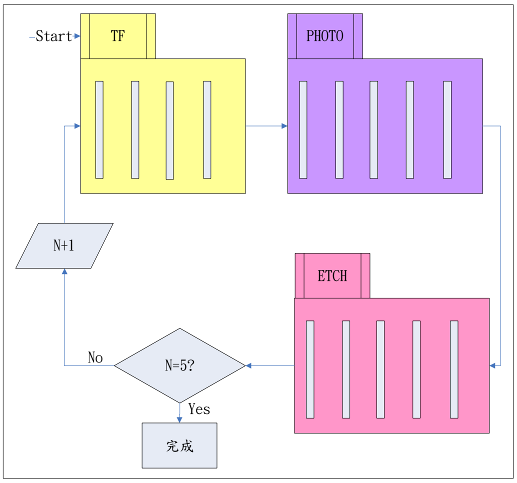

圖 4.1 Array 製程示意簡圖

本研究採用面板廠中的 Array 製程。Array 製程中依照生產方式可以粗分爲三個步驟：環光(TF)、顯影(PHOTO)、蝕刻(ETCH)。每一件產品在 Array 製程中必須經過 Gate、Semiconductor、Data、Protective Layer、ITO 等五個製程，每個製程必須經過前述的三個生產步驟。整體來說，必須經過 15 道生產步驟。

4.2 模擬環境設定

4.2.1 不可插單

許多排程相關的文獻中會將插單視爲一個重要的議題，以「這張訂單很重要」的說法，將之插入排程中。

事實上，很少有訂單的重要性(利益)大到可以彌補這些有形與無形的損失。因此本研究不考慮因滿足新訂單而使現有訂單的完成日期延後至超出交期的情況。

本研究對於訂單的處理爲循序式的。新訂單必須在不影響現有訂單交期的情況下才能排入。也就是說，可以因爲新訂單而進行整體的重新排程，但是不能夠影響到已經對客戶允諾的交期。

4.2.2 各點自主其生產交期、成本設定，且這些資訊無法分享

各機台之生產時間、交期與其時間表爲各機台獨有之生產知識，無法藉由任何方式取得。藉此使各點之不願公開之資訊不外流，達到本研究真正分散式生產的研究目的。各點的成本與生產方程式的設定交由各廠商或廠區自行設定，如此一來便可確保不希望公開的資訊被公開。

現在的產業環境變動快速，爲了確保能順利生產，同樣的元件或生產步驟往往會有兩個以上的合作廠商以便替代。在這樣的情況下，如果廠商設定的成本過高，所經過的生產路徑就不易被選擇而會被同性質的廠商取代；反之成本過低，則該廠商必須自己承擔損失。交期亦然，工作時間設定過長，整體生產路徑的總工作時間就跟著變長，也就不易被選擇；工作時間設定過短雖然經過的生產路徑被選擇的機會大增，相對的也必須負起及時達交的責任。

4.3 情境模擬

本研究設計三個情境，分別爲排程、重排程與機台異動三種情境。分別用來驗證其處裡速度與各種常見意外狀況下之應對能力

4.3.1 排程

表 4.2 二十筆訂單資料

單號	產品	數量	單號	產品	數量
1	56	1	11	56	1
2	42	1	12	47	2
3	47	2	13	56	1
4	56	1	14	47	3
5	42	2	15	56	3
6	56	3	16	56	2
7	56	1	17	47	2
8	42	2	18	42	2
9	42	1	19	56	1
10	47	1	20	47	2

表 4.3 分別以一台、兩台、三台電腦模擬所得之平均運算時間與標準差(秒)

單號	產品	數量	最佳路徑	完成時間	單一電腦	兩電腦	三電腦
					OABC	OB vs AC	OBvsAvsC
1	56	1	455455455455455	65	######	26.116	17.388
2	42	1	333333333333333	65	######	25.677	16.937
3	47	2	224224224224224	130	######	25.469	16.714
4	56	1	115445445445155	72	######	25.656	16.451
5	42	2	313114333333333	143	######	25.000	16.378
6	56	3	145455455455455	244	######	24.809	16.432
7	56	1	442125122215452	89	######	24.866	16.706
8	42	2	314143343333333	204	######	24.858	16.694
9	42	1	314333324343314	117	######	25.070	17.356
10	47	1	254335224234224	137	######	25.070	17.383
11	56	1	145115112115145	157	######	25.264	18.526
12	47	2	254224224224224	247	######	25.033	17.991
13	56	1	152142125412455	175	######	25.400	18.952
14	47	3	244334224224224	349	######	25.228	19.012
15	56	3	115442455455455	356	######	25.481	18.553
16	56	2	133142115145455	290	######	25.555	19.867
17	47	2	214233234333335	343	######	25.611	19.891
18	42	2	353311343141143	338	######	25.847	20.273
19	56	1	115152335124125	227	######	26.057	20.941
20	47	2	234214224244224	381	######	26.053	20.612
				總平均	######	25.406	18.153
				標準差	5.344	0.628	2.688

以表 4.2 中 20 筆訂單進行排程，分別以單電腦、兩電腦與三電腦進行模擬。最後得到之排程時間與標準差如表 4.3 所示。可得結論為：

1. 排程時間短，符合設計之目的。
2. 多電腦模擬時處理時間較短。
3. 三電腦標準差大於兩電腦，為網路環境對處理時間造成影響。

4.3.2 重排程

此情境中設計十筆訂單，第八筆訂單會因超出交期而使訂單重排。重排後會產生兩種情況：重排成功與重排失敗。

當有訂單交期無法滿足時，程式會詢問是否進行重排程，如圖 4.2。若是，則抓取交期大於該訂單且交期大於完成時間的已排程訂單已交期先後進行重排。當其中有任一筆訂單重排後交期無法滿足則重排失敗。

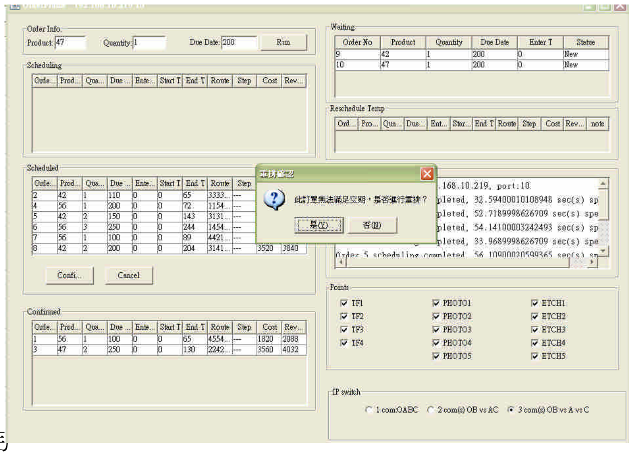

圖 4.2 無法滿足交期時，詢問是否重排示意圖

由於重排失敗時，會將所有訂單狀態回復至重排程前之狀態，其排程結果如結果前一情境第一至第十筆訂單。

表 4.4 重排成功之十筆訂單

單號	產品	數量	期望交期	單號	產品	數量	期望交期
1	56	1	101	6	56	3	400
2	42	1	110	7	56	1	100
3	47	2	250	**8**	**42**	**2**	**200**
4	56	1	200	9	42	1	200
5	42	2	150	10	47	1	200

表 4.5 重排後之生產路徑

	產品	數量	原路徑	最終路徑	期望交期	完成時間
1	56	1	455455455455455	455455455455455	100	65
2	42	1	333333333333333	333333333333333	100	65
3	47	2	224224224224224	224224224224224	250	130
4	56	1	115445445445155	115112122455155	250	72
5	42	2	313114333333333	313114333333333	150	143
6	56	3	145455455455455	115445455455455	400	244
7	56	1	442125122215452	442125122215452	100	89
8	42	2	314143343333333	244241143353353	200	204
9	42	1	314333324343314	423343333324153	200	117
10	47	1	254335224234224	242344234245314	200	137

如表 4.4，調整各訂單交期後，其最終排程與原先排程結果之比較如表 4.5 所示。

4.3.3 機台異動

生產過程難免會遇到各種意外產生，對於生產中發生意外的情形加以應對也是一個重要的議題。本情境為十五張訂單已排程的情況下，當其中一機台發生故障而進行的應對情境。

令 ETCH2 對接單介面發出故障訊息。接單介面收到訊息後先取消 ETCH2 機台之選取，表示其狀態異常，如圖 4.3 所示。

接著在已排程工作中選出生產路徑經過 ETCH2 之工作，如表 4.6 所示。

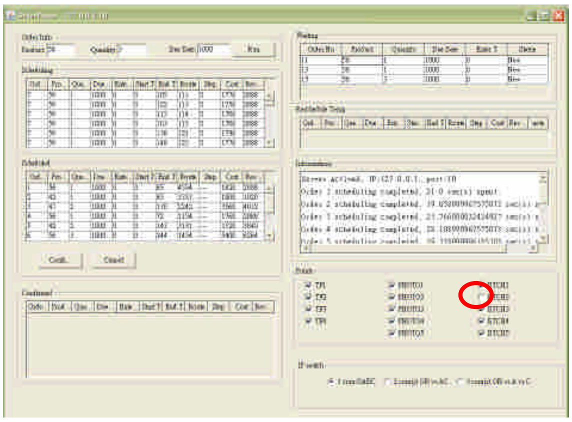

圖 4.3 取消異常機台選取示意圖

表 4.6 ETCH2 原定之生產排程

訂單	產品	數量	交期	進入時間	開始時間	完成時間	生產路徑	步驟	成本
7	56	1	1000	14	14	18	442	3	1840
7	56	1	1000	55	55	59	122	9	1780
7	56	1	1000	85	85	89	452	15	1820
11	56	1	1000	122	122	126	112	9	1760
13	56	1	1000	92	92	96	152	3	1780
13	56	1	1000	126	126	130	142	6	1800
13	56	1	1000	158	158	162	412	12	1800
15	56	3	1000	227	227	239	442	6	5520

表 4.7 重排後訂單資訊

訂單	產品	數量	交期	完成時間	生產路徑	成本	收益
15	56	3	1000	320	115415443455455	5280	6264
13	56	1	1000	90	443425123415451	1830	2088
11	56	1	1000	169	145115145124153	1800	2088
7	56	1	1000	207	153131155143444	1770	2088

原先生產路徑經過 ETCH2 之訂單抽出重排，最後之排程結果如表 4.7 所示。

5. 結論與建議

5.1 本研究之特性與貢獻

將本研究之特點如下：

1. **各節點獨立**

   各節點資料不須共享，一來保留隱私，二來避免非專業人士無法判讀數據變動引起的錯誤決策。所經過之數據流只帶走交期與總成本資訊，不會使產能與成本資訊外洩。

2. **非最佳解，但反應快速**

   目的在於快速回應客戶詢單，因此不須得到最佳解。只需得到可行而較最佳解寬鬆的解即可回應客戶。

5.2 未來發展方向

本研究以架構為主，因此沒有針對排程方法進行更深入的探討。事實上，有許多排程方法可以比本研究所使用的區域窮舉法得到更好的結果與更短的運算時間。未來可以針對此點加以改進，使整個架構更為完整可行。

此外，本研究為簡化問題，省略各步驟之前置時間與庫存相關問題。

此一架構要能被廠商接受，首先程式碼部分自然必須要公開透明，確保不會帶走任何不該有的資訊，才能使廠商有使用的意願。除此之外，訊息格式的一致性也確保輸入與輸出資訊的可靠度。

此架構系統需要能夠與廠商現有系統連結，即時取得各參數的變動，加上與實際排程系統相同設定但較為寬鬆的生產時間設定，系統之間的連結還需要進一步研究。

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出席國際學術會議心得報告

1. 出席 Asia-Pacific Industrial and Management Systems 國際會議與 International Foundation for Production Research-Asia Pacific Region 會議

本次的會議在馬來西亞麻六甲的 Renaissance Melaka Hotel 舉行。時間在 12/7-12/10，2010。計畫主持人的論文主題為 Communication Protocols for Collaborative Production Planning。

<u>**行程：**</u>

前往：由於台灣學者前往者眾，國內班機直飛吉隆坡的機位均客滿，因此計畫主持人搭乘 12/7 上午 9:20 的國泰航空班機經香港於 16:45 抵達馬來西亞。後再搭乘計程車前往會議飯店。

返回：會議結束後的隔天 12/10 即搭乘國泰航空 13:45 經香港於 20:30 返抵國門。

<u>**會議心得：**</u>

參加本次會議最重要的任務在於被選為 IFPR-APR 主席。計畫主持人於 2009 年日本的 IFPR-APR （同 APIEMS 2009 會議時間同時召開）被選為接任主席，於此次會議正式接任主席。

圖一、2011 年馬來西亞 IFPR-APR 會議中計畫主持人（最右一位）被選任為 IFPR-APR 主席。中間為 Ishii 教授（現為 IFPR President）。左二為 Anthony Chiu 教授（現任 APIEMS 主席）。右二為 Voratas Katchitvitchyanukul 教授（Elect APIEMS 主席）。

在本次會議中計劃主持人與 Ishii 教授並 Anthony Chiu 教授有許多意見交換。對於如何促進亞太地區有關生產研究議題的研究有許多建設性的看法。同時在 IFPR-APR 會議中 Prof. Ishii 亦推薦計畫主持人與 Anthony Chiu 教授成為 IFPR 的理事，於 2011 年 7 月底於德國 ICPR 會議中通過。

根據本次 APIEMS 的論文中因國家別所產生的水準差異過大的論文，我們一致的看法是應該透過 APIEMS 讓這些國家的學者持續與會。然後在會議中邀清一些先進國的優秀學者開授一些基本的 seminars 來輔導後進國的學者。IFPR-APR 亦應負責邀請歐美的知名

學者於 APIEMS 擔任 plenary speaker，使生產研究的議題與貢獻能在亞太地區深根。同時，使 APIEMS 成為大師培育的搖籃亦是中間重要的結論。透過廣邀有機會成為未來重要的研究議題的亞太學者給 plenary speech，使這些學者的理論被肯定與重視。

整體而言 APIEMS 的論文水準尚待加強，我國學者在其中應該扮演領頭羊的角色，但不幸只看到席間各自顧各的以華語交談。既然 APIEMS 是我國工業工程相關領域學者可以影響的國際會議，建議對於參加的資深學者應該要有更多的經費禮遇並要求有更具體的貢獻。

本次的論文主要提出協同生產計畫之通信協定。席間也受到許多學者的討論，咸認為通信的規範是協同生產效率的重要一環，對於本人所提的八類通信協定類別也多有討論。

2. 出席 The 21th International Conference on Production Research

本次會議於 7/31/2011-8/4/2011 在德國 Stuttgart 舉行。會議在 Kultur-und Kongresszentrum Liederhalle 會議廳舉行。Stuttgart 是德國重要的汽車與工業城市。賓士與保時捷汽車都在該城有博物館。本次的論文發表主題為 SUPPLY NETWORK PLANNING FOR MEMORY MODULE INDUSTRY BY DISTRIBUTED PARALLEL COMPUTING。

<u>行程：</u>

前往：計畫主持人於 7/29 11:15pm 搭乘華航班機飛往法蘭克福。

於當地 7/30 6:50am 抵達。旋即轉乘德國國鐵 DB 的 ICT 到 Stuttgart。

返回：會議結束的當天 8/4 即搭德國國鐵至法蘭克福。接著於隔天 8/5 搭乘中華航空 11:20am 於 8/6 6:25 返抵國門。

<u>會議心得：</u>

國際生產研究會議是一個歷史超過 40 年的重要國際會議。會議最多人數曾超過 800 人。其背後的支持組織 International Foundation for Production Research (IFPR)亦是二個重要國際期刊 (International Journal of Production Research 與 International Journal of Production Economics) 的支持機構。透過主持人在 IFPR-APR 成為主席的事實，主持人在這一次召開的理事會被推薦成為 IFPR 的理事成員。同時因為主持人身兼 IFPR-APR 主席，亦為 IFPR 之執行委員會之委員。

圖二 主持人與與會之南美洲學者(左二均為 IFPR 理事)

在理事會議中,計畫主持人亦爭取於2015年在台灣舉行ICPR會議。然不幸敗北，輸給菲律賓。

本次會議在德國舉行算是一個回顧多年的會議。德國嚴謹華麗的會議安排隊計畫主持人而言是一項重要的學習。在會議的開幕晚宴，計畫主持人與 IFPR 重要成員如 Dieter Spath, Bopaya Bidanda, Hans-Jörg Bullinger, Rob Dekkers, Sergio E. Gouvea da Costa, Robert W. Grubbstrom, Kazuyoshi Ishii, Shimon Y. Nof, Christopher O`Brien, Jinwoo J. Park, Luis E. Quezada, 與 Agostino Villa 有許多交流的機會。

本次的會議中計劃主持人成為資深的學者在會議中穿梭。以色列，南美洲，與歐洲的學者都亟於透過計畫主持人了解亞太地區與其國家合作的可能。由於和許多學者之間有很多的互動，會議結束

返台即收到 IFPR 邀請成為這次會議於 IJPE special issue 的 co-guest editor 邀請。

本次計畫主持人的論文主要在介紹如何使用分散式平行計算來大幅降低供應網絡最佳化的求解時間。報告獲得許多的迴響。甚至有學者不克參加但閱讀論文後寄 e-mail 給主持人致上其欣賞之意。

計畫主持人亦參加多場論文發表，包括以控制理論詮釋生產與庫存的消長關係，能源分派網路，與中國服務業的需求趨勢。會議中討論熱絡，真為一學術與應用價值極高的會議。

本次會議中亦有機會參訪 Fraunhofer 實驗室。對於其中許多的應用研究能有一個優質的 demo 環境感到敬佩。

圖三 Fraunhofer 實驗室之組裝研究模組

此次會議對個人而言是一個極具收穫之旅。身為台灣唯一的 IFPR

理事成員，有許多的責任與壓力。同時由於 IFPR 亦對計畫主持人拓展亞太地區開發中國家對生產研究的應用有許多期許，亦是一項重要的責任與使命。整體而言，計畫主持人在國科會補助少許之下(多數經費由計畫主持人自行支應)完成了不可能的任務。

INVITATION LETTER

Dear **Dr Chin-Yin Huang,**

Warmest greetings of the day,

The initial review process for your paper has been completed. However, there is another review process to consider the suitability of your paper to be forwarded for publication to associated journals of the conference is still on-going. You will receive a different notification if your paper is accepted for that purpose.

Based on the recommendations of the reviewers and the Program Committee, I am very pleased to inform you that your paper **ID: - 518 ,** with the title **"Communication Protocols for Collaborative Production Planning"** has been accepted for presentation. You are cordially invited to present the mentioned paper at the APIEMS2010 conference to be held on December 7th - 10th, 2010 in Melaka, Malaysia.

The acceptance of your paper is made with the understanding that at least one author will **REGISTER** and **ATTEND** the Conference to present the paper. Failure to do so will result in the paper being expunction from the conference proceeding and database. Further details for registration please visit our website www.apiems2010.um.edu.my.

I would like to take this opportunity to thank you for choosing the APIEMS2010 conference to present your research results and am looking forward to seeing and listening to you in Melaka, Malaysia.

Expecting a great conference!

Regards,

Raja Ariffin Raja Ghazila
Conference Secretary
APIEMS 2010 Conference

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Communication Protocols for Collaborative Production Planning

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Abstract *- In the real world applications, collaborative production planning is usually realized by a sole system. Participants are forced to adopt the system, in addition with their legacy systems for maintaining their daily production. This research intends to define communication protocols for collaborative production planning that do not require participants to adopt any system. What they have to do is to follow the regulations of protocols, rules of communication, to efficiently communicate with their partners for making their plans. Decisions of material availability, resources availability, outsourcing, and changing due dates are the major concerns in the 12 protocol designs presented in this research.*

Keywords: *Collaborative Production, Communication, Production Planning, Protocols*

1. INTRODUCTION

Modern market uncertainties are presented in four perspectives: price, demand quantity, demand specification, and delivery. In addition to the uncertain availability of resources which include labour, capital, equipment, facilities, and materials, today's manufacturers are facing a tremendous pressure in production management.

Collaborative production is considered an effective approach to conquer the above problems. By integrating the resources of cooperative enterprises, participated companies can avert uncertainties while maintaining their core capabilities in grasping transient opportunities (Huang and Wu 2003).

However, the success of collaborative production heavily relies on the information technologies. To integrate the autonomous and distributed resources within the participated companies so the production can operate as in a single company, while respecting the legacy information systems of the participated companies, is a critical research issue (Huang *et al*. 2009). Protocols have been investigated in literature as a tool to efficiently coordinate information of different systems to achieve a common goal (Huang 2002; Huang and Nof 2002; Huang *et al*. 2008) However, it still lacks a systematic approach to deliver a complete communication protocol that can collaborate the production planning for distributed production companies.

Hence, designing communication protocols for collaborative production planning is the objective of this research. Communication protocol is defined as structures of dialogues (Huang and Nof 2000). It regulates the interactive behaviours of messages passing among the participated companies, so a task or problem-solving strategy can be fulfilled (Muller 1997).

2. LITERATURE REVIEW

2.1 Requirements on Collaborative Production Planning

The dynamic structure of a collaborative production network usually results from product specification changes

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of orders or changes of suppliers. For example, replacement of a functional subsystem may imply replacement of a supplier. Besides, an enhancement on a product subsystem may imply recruiting a new subcontractor that has better equipment. The uncertainties in the network results from uncertain demand, process and supply (Lee and Billington 1993). Any uncertainty happening in a partner company may result in a disturbance on plans of other partner companies over a supply network. Additionally, Sauer (2006) points out that performing production planning with distributed processes has the following concerns:

1. Interdependencies between companies
2. Integration of local companies' production plans
3. Necessity to co-ordinate with other companies' production plans
4. Uncertainties happening in each local company.

Jagdev and Thoben (2001) define the requirements for collaborative production as follows:

1. Collaborative partners need to have a clear understanding to what is expected from each partner.
2. It will need to streamline both material and information flow systems.
3. Information exchange among the partners must occur efficiently to operate effectively.
4. Information and decision support systems at each partner must be able to respond dynamically to meet the ever-changing needs and communicate accordingly to the affected partner in the collaborative network.

2.1 Communication Issues

In general, communications between partner companies can be classified into either a blackboard-based or message exchange (Muller 1997; Nof *et al.* 2006). A blackboard-based communication utilizes a centralized public knowledge pool that can accept benevolent information announcements or queries from participant. On the other hand, message exchange communication is employed based on a prior agreement of interactive messages (including data format and interactive sequence) among the participants. Contract Net Protocol is a typical example of message exchange communication in this high level communication. Most communication protocols are designed by sequence diagram today (Fowler and Scott 1999).

3. FUNCTIONAL STRUCTURE OF COLLABORATIVE PRODUCTION PLANNING

3.1 Decision Flow

Collaborative production planning includes various decisions. The decisions include checking material availability, checking capacity availability, and then outsourcing. The final one will be to negotiate with the customer for a later due date if any unavailability on material, capacity, or outsourcing activity occurs. Order will be accepted if material and capacity are available either from the company itself or from the partnered companies. Otherwise, order will be rejected. Such a decision flow has to be followed by each participated company and is shown in Figure 1.

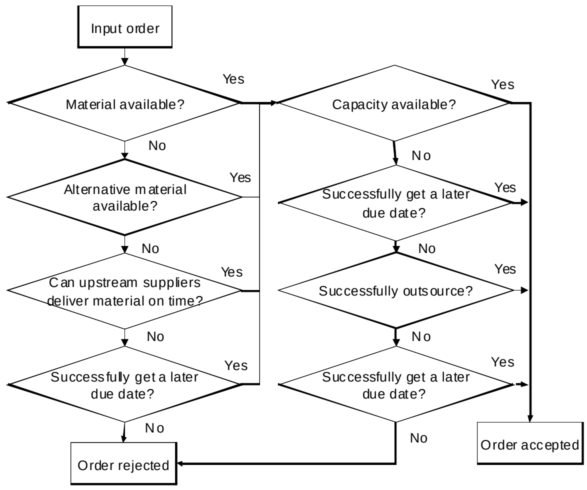

Figure 1: Decision flow of collaborative production planning for each company

3.2 Agents of Collaborative Production

Although this research does not give a rigorous definition for agent, an agent is a unit that is responsible for sending and receiving messages in terms of communication. Agents and their communication functions are designed and listed in Table 1.

Table 1: Communication Functions of Agents

Agent	Communication Functions
Order Agent	1. Take orders 2. Pass orders to Material Agent 3. Pass customer information to Due Date Coordination Agent 4. Reply results to the Customer Agent
Material Agent	1. Check material availability (including current and incoming inventories, materials that are on order, etc.) 2. Search for alternate materials 3. Inform Purchase Agent about the

	unavailability of materials 4. Pass orders to Capacity Agent
Purchase Agent	1. Check the success of delivery with the Supplier 2. Give purchase order to Supplier 3. Pass delayed information to Due Date Coordination Agent 4. Pass order to Capacity Agent
Supplier	1. Acknowledge Material Agent's message 2. Take orders from Material Agent
Capacity Agent	1. Inform Order Agent to accept the order 2. Acknowledge messages from Purchaser and Material Agent 3. Broadcast outsourcing information to Suppliers 4. Take messages of capacity and due date from Suppliers 5. Inform Due Date Coordination Agent an acceptable later due date
Outsourcing	1. Acknowledge Capacity Agent's message 2. Reply Capacity Agent information about due date and capacity
Due Date Coordination Agent	1. Reject order and inform Order Agent 2. Accept order and inform Order Agent 3. Release materials that are under consideration for accepting the order 4. Take message about delayed due date 5. Use anti-bidding to ask Order Agent and Purchase Agent for a new due date
Customer Agent	1. Give order 2. Receive message of order accepted

4. COMMUNICATION PROTOCOLS

Communication protocols that are associated with the decision flows in Figure 1 are classified into four categories. Specific protocols for each category are list in Table 2. Detailed descriptions for each protocol are presented in the following subsections.

Table 2: Communication Protocols for Collaborative Production Planning

Category	ID	Category name	Protocol
I	1	Confirm availability	Simple Confirm Protocol
II	2	Check material availability	Use Alternate Material Protocol
	3		Purchase Material Protocol
	4		Protocol to Change Due Date Due to Material Supply Delayed
	5		Reject Order Protocol (due to material)
III	6	Check capacity availability	Protocol for Outsourcing Capacity
	7		Protocol to Change Due Date (Capacity Outsoucers)
IV	8	Negotiate for changing order due date	Protocol for Outsourcing Capacity with Alternate Material
	9		Protocol for Outsourcing Capacity with Extra Material Supply
	10		Protocol for Outsourcing Capacity When Due Date is Changed According to Material Delivery
	11		Protocol for Changing Due Date with Alternate Material Due to Delayed on Outsourcing Capacity
	12		Protocol for Changing Due Date Due to Delays on Material Supply and Capacity Outsourcing

4.1 Simple Confirm Protocol

Figure 2 shows a scenario occurring when both material and capacity are available to meet customer's order requirements.

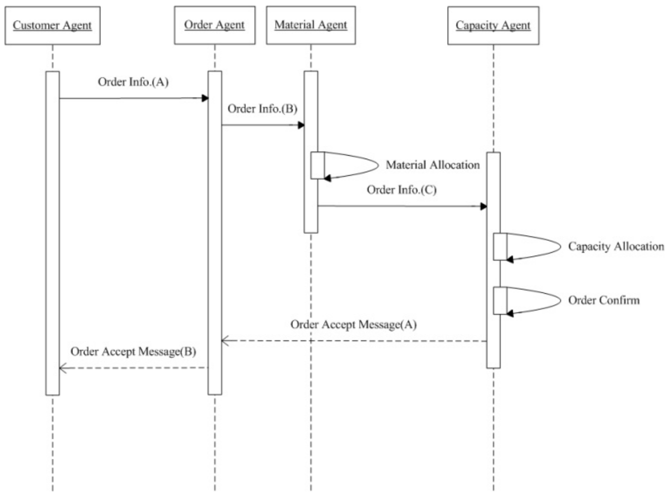

Figure 2: Simple Confirm Protocol

4.2 Use Alternate Material Protocol

Figure 3 shows a scenario occurring when typical material is not available. However, alternate material is available to meet the order requirements.

4.3 Purchase Material Protocol

Figure 4 shows a scenario occurring when both material and alternate material are not available. However, material supplier is capable to deliver material in accordance with customer order's requirements.

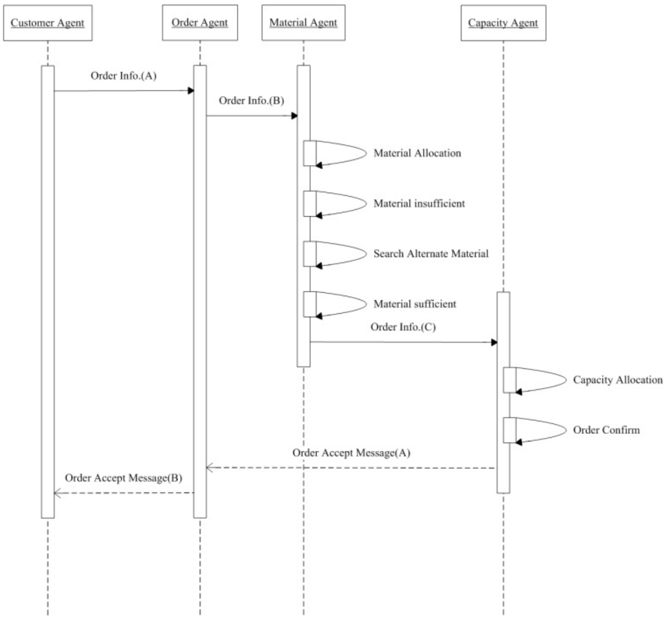

Figure 3: Use Alternate Material Protocol

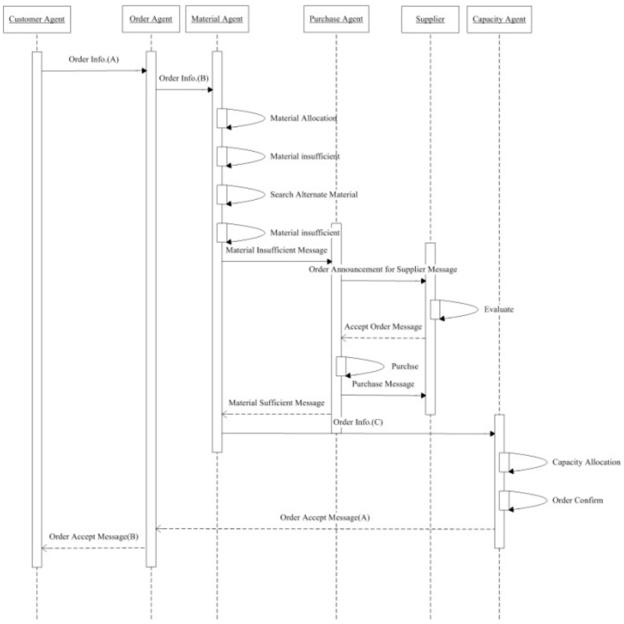

Figure 4: Purchase Material Protocol

4.4 Protocol to Change Due Date Due to Material Supply Delayed

Figure 5 shows a scenario occurring when material supplier propose a material delivery time. However, the delivery time will results an expected delay for the customer order. After negotiating with the customer, a new due date is set and the order is accepted.

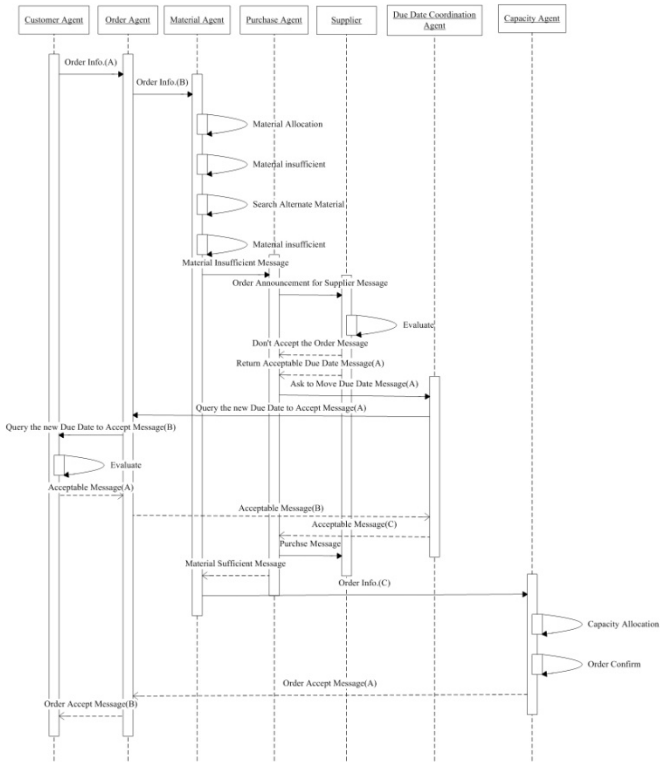

Figure 5: Protocol to Change Due Date Due to Material Supply Delayed

4.5 Protocol for Outsourcing Capacity

Figure 6 shows a scenario for outsourcing capacity. The protocol is performed when a company has enough material, but is short of capacity. By embedding a bidding mechanism in the protocol, the scenario describes that the company can successfully receive a bid from one of its outsourcers to meet the requirements of customer order. There are two similar protocols with outsourcing capacity. One occurs when regular material is not available, but alternate material is available. Such a similar protocol is named Protocol for Outsourcing Capacity with Alternate Material. The other one occurs when extra material has to be ordered. The extra material from supplier however can meet the due date requirements. Additionally, capacity has to be outsourced. The outsourcing capacity can also meet the requirements of customer order. Such a protocol is named Protocol for Outsourcing Capacity with Extra Material Supply.

4.6 Protocol to Change Due Date (Capacity Outsoucers)

Figure 7 shows a scenario occurring when material is available, but the capacity is not. Worse yet, capacity outsourcers are unable to meet the order requirement.

Fortunately, customer can accept the later due date proposed by the capacity outsourcers. Meanwhile, material is no longer required, because the order due date is changed. Therefore, material is released for other customer orders. However, an anti-bidding message passing is performed to choose a material supplier based on the given new due date.

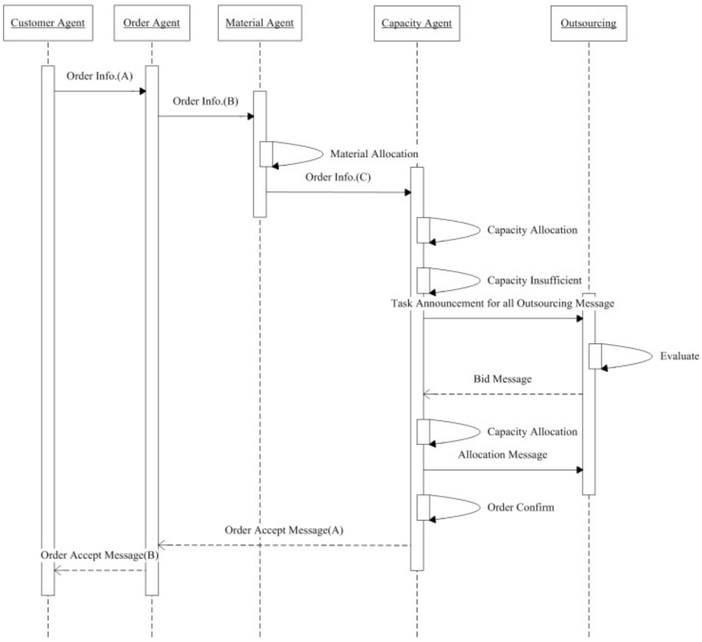

Figure 6: Protocol for Outsourcing Capacity

4.7 Protocol for Outsourcing Capacity When Due Date is Changed According to Material Delivery

Figure 8 is a scenario occurring when material delivery from the supplier cannot meet the due date of customer order. However, the customer agrees to postpone the due date. Further, capacity has successfully outsourced.

4.8 Protocol for Changing Due Date Due to Delays on Material Supply and Capacity Outsourcing

A more complicated scenario (Figure 9) occurs when both material supplier and capacity outsourcer are unable to meet the due date requirements. In this case, the customer will be requested for changing the due date twice, one for material and the other for capacity. Some other similar scenario occurs when alternate material is available but due date is changed according to the delayed capacity outsourcing. Such a scenario applies Protocol for Changing Due Date with Alternate Material Due to Delayed on Outsourcing Capacity.

5. DISCUSSION AND CONCLUSIONS

This research reports a set of communication protocols based on a given decision flow for collaborative production planning. In the flow, planning decisions regarding material, capacity, outsourcing, and negotiation for changing due date are considered. Based on the four decisions, communication protocols are developed. Communication protocols present the interactive message passing among the participants (agents). The development of communication protocols has at least two meanings for collaborative production planning:

(1) The production planning can be delivered by exchanging messages. The execution of protocols is unrelated with how the messages are generated in each agent. That is, collaborative planning can be developed disregarding the information systems behind their associated agents.

(2) Collaborative production planning can be actually done by all of the participants. Participants do not have to invest and use a big system that is mandated by the major player of a collaborative production network. They can participate in the production by keeping using their legacy systems.

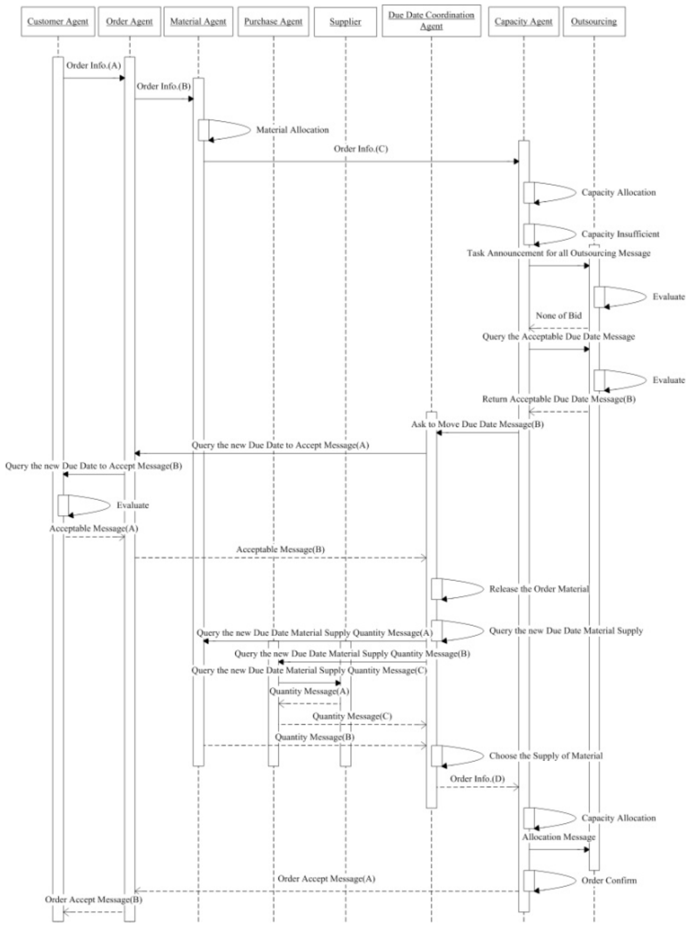

Figure 7: Protocol to Change Due Date (Capacity Outsoucers)

The future work of this research will be to modularize the protocols for better applicability and usability. Additionally, the development can be expanded to other management issues, such as collaborative forecasting and collaborative inventory management.

ACKNOWLEDGMENT

The authors would like to thank the financial support from the research projects NSC 99-2628-E-029-010 and NSC 98-2221-E-029-019, National Science Council, Taiwan.

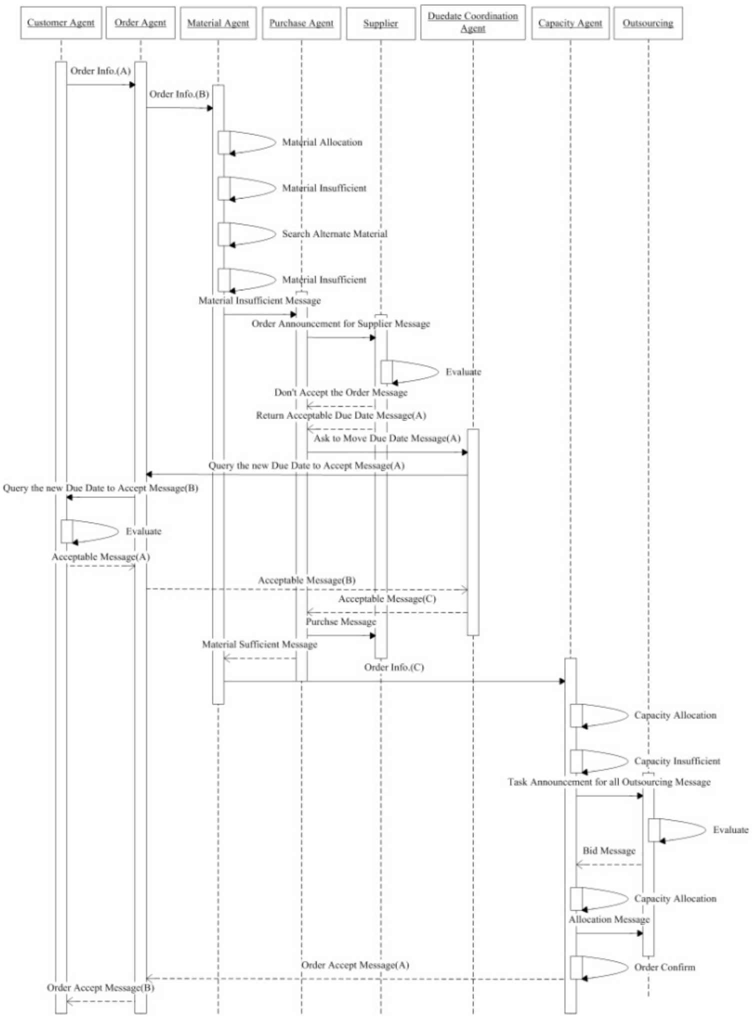

Figure 8: Protocol for Outsourcing Capacity When Due Date is Changed According to Material Delivery

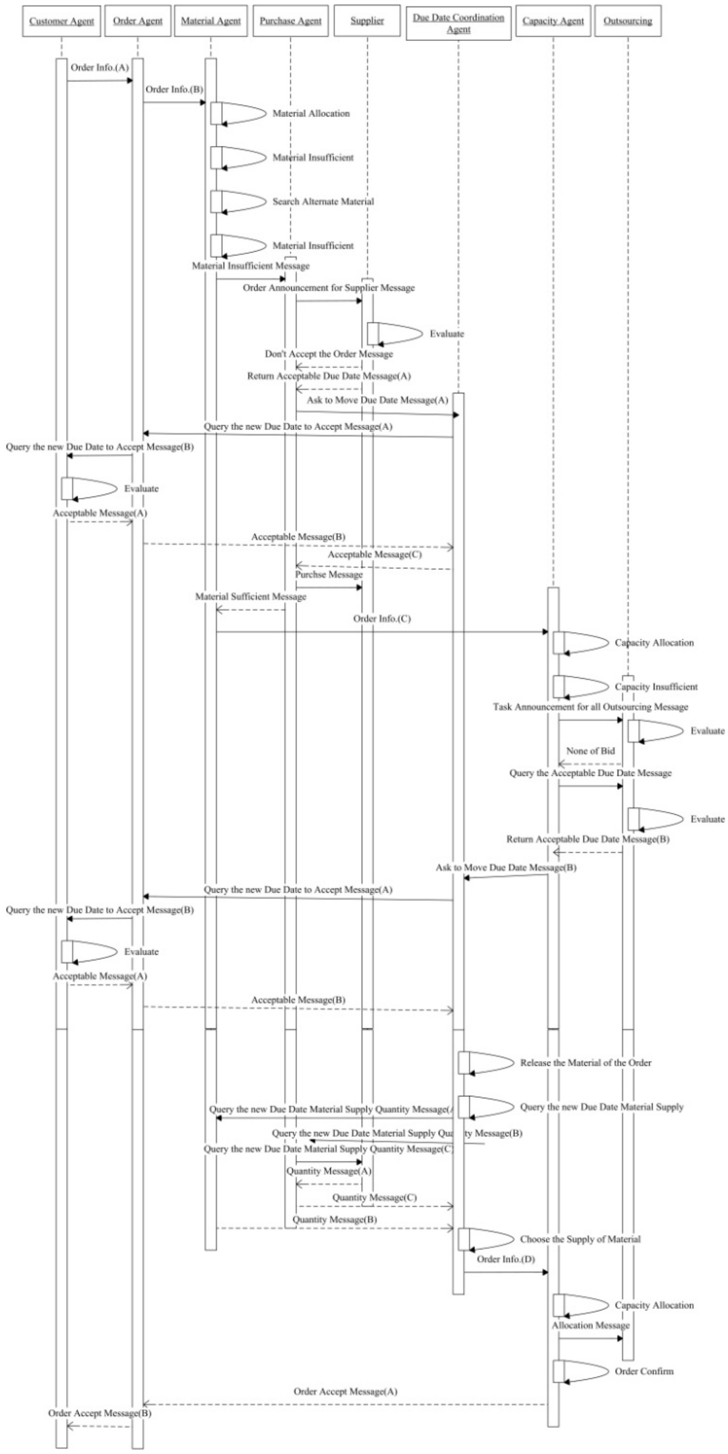

Figure 9: Protocol for Changing Due Date Due to Delays on Material Supply and Capacity Outsourcing

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主旨: ICPR21 - Full Paper Notification
從: "Krause, Tobias" <Tobias.Krause@iao.fraunhofer.de>
日期: Thu, 12 May 2011 16:18:52 +0200
到: "huangcy@ie.thu.edu.tw" <huangcy@ie.thu.edu.tw>

Dear Professor Huang,

We are pleased to inform you that your paper "SUPPLY NETWORK PLANNING FOR MEMORY MODULE INDUSTRY BY DISTRIBUTED PARALLEL COMPUTING" (paper number "304") has been accepted for presentation at ICPR21.

Please be aware that one author must be registered and present the paper at the conference. Sofar we do not have a registration linked to your paper number. If you have already registered without indicating your paper number please respond to this mail including your "Invoice No." (you'll find your "Invoice No." on the top right of the "Confirmation of Registration" you have received after registering. The "Invoice No." is a four digit number followed by "/11".).

If you have not registered yet please **register by Thursday next week (May 19, 2011).**

- You will find the online registration form at www.icpr21.de.
- For each paper at least one of the authors has to register and to present the paper at the conference.
- If you have questions on the registration please contact Ms. Tanja Vartanian and her team at registration@icpr21.de.

If you have not yet booked a hotel please find the details of recommended hotels at http://www.icpr21.de/location-and-venue/accomodation.html. If you have questions on the hotel booking at conference hotel (Maritim Stuttgart) please contact info.stu@maritim.de.

Thank you very much for your contribution. We are looking forward to meeting you in Stuttgart.

Kind regards,
Tobias Krause

黃欽印 **<huangcy6669@gmail.com>**

Invitation to the IFPR Board Meeting at ICPR 21

1 message

Krause, Tobias <Tobias.Krause@iao.fraunhofer.de> **Wed, Mar 23, 2011 at 11:36 PM**
To: "huangcy@thu.edu.tw" <huangcy@thu.edu.tw>

Dear Professor Chin-Yin Huang,

You have been proposed as new board member of IFPR. The board will decide on your election at the board meeting at ICPR 21 in Stuttgart.

As president of IFPR and organizer of ICPR 21 I invite you to attend the board meeting.

You will have the possibility to introduce yourself to the board. If the board elects you as new member you are invited to participate the rest board meeting as well.

As you might have recognized ICPR 21 is taking shape. We are happy to tell you that we have more than 600 abstracts submitted with mostly sufficient quality. So we are expecting a large number of participants and looking forward to an interesting conference.

To organize the Board Meeting we need to know about the number of participants.

Please send an email to Tobias.Krause@iao.fraunhofer.de by March 31, 2011 letting him know if you are planning to participate in the Board Meeting.

The IFPR Board Meeting will as usually be held prior to the conference:

July 31, 2011 9:30 – 12:30 Board Meeting (part I)

July 31, 2011 12:30 – 13:30 Lunch Break (spouse welcome)

If necessary:

July 31, 2011 13:30 – 16:30 Board Meeting (part II)

We'll have the meeting on Sunday morning (July 31, 2011).

The preliminary agenda is as follows. (With an special focus on the bold items)

- Welcome
- Elections/ Nominations (we will start with this topic to permit the newly elected members to participate and vote in the meeting)
- Approval of minutes from ICPR 20
- Report on activities
    - Conferences
        - ICPR 20: report
        - ICPR 21: current information
        - ICPR 22: Status
        - ICPR 23: Presentations and election
    - Regional Conferences
        - Reports
        - Information on the upcoming conferences
    - Regions report
- **Treasurers report**
- **IFPR Registration, Constitution & Bylaws**
- Membership report
- Publications and web

If have additional topics to be discussed please let us know.

You will receive the details on the agenda in advance of the conference.

Looking forward to welcoming you in Stuttgart.

Best regards

Dieter

--

Univ.-Prof. Dr.-Ing. Dr.-Ing. E.h. Dieter Spath

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ICPR 21 - Information on your presentation

1 message

Krause, Tobias <Tobias.Krause@iao.fraunhofer.de> **Wed, Jun 15, 2011 at 11:16 PM**
To: "huangcy@ie.thu.edu.tw" <huangcy@ie.thu.edu.tw>

Dear Professor Huang,

We are pleased to announce the current presentation schedule for your paper presentation. Your paper "SUPPLY NETWORK PLANNING FOR MEMORY MODULE INDUSTRY BY DISTRIBUTED PARALLEL COMPUTING" (paper number "304") is currently scheduled for August 1, 2011, 13:30 - 15:00.

Some details on the presentation:

- Please prepare a presentation of 15 minutes including question and answer time.
- We will provide a computer for the presentation, please do not bring you own computer.
- Supported formats are MS PowerPoint and PDF. Please do always prepare a PDF version for backup purposes.
- To ensure a trouble-free flow of the presentation please be at the presentation room 30 minutes prior to your session so we can copy the presentation to the computer and test it.

To prevent overlapping in the presentations we need to know which of the authors will present your paper. If you do not provide other information we assume you will present the paper personally.

Please find details on the conference program online at www.icpr21.de.

Thank you for your contribution for your registration. We are looking forward to meeting you in Stuttgart.

Kind regards,

Tobias Krause

SUPPLY NETWORK PLANNING FOR MEMORY MODULE INDUSTRY BY DISTRIBUTED PARALLEL COMPUTING

Chin-Yin Huang[1*], Wu-Lin Chen[2], Sz-Chang Yeh[1]

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Abstract

Success of a memory module industry largely relies on the planning efficacy of the supply network. However, supply network planning is a planning problem in a multi-site and multi-site network, which has been proved an NP-complete problem. To solve the NP-complete problem, various algorithms have been developed in literature. However, most of the algorithms are infeasible in the real cases. From a perspective of computing, parallelizing the problem solving is an alternative. However, how to divide a single problem into pieces so the PC cluster can handle the problem in parallel is the most critical issue.

This research parallelizes the supply network planning problems for the memory module industry, so the (near) optimal solution can be obtained. First, the supply network planning problem is formulated as a nonlinear programming problem. Then, the problem is coded by LINGO. By duplicating the LINGO programs, each in a different smaller solution space, and parallelly running the LINGO programs in a PC-clustered computing system, the (near) optimal solution of the supply network planning can be found in a reasonable time.

Keywords:

Java RMI, LINGO API, memory module industry, nonlinear programming, parallel computing, supply network planning

1 INTRODUCTION

DRAM module industry is a globally integrated industry that involves various manufacturers, e.g., DRAM, SRAM, and flash memory manufacturers, chipset manufactures, and connector companies. Due to the highly fluctuating price of memories, the efficacy of supply chain planning determines a DRAM module company's survival in the market.

Besides the characteristics of a multi-tier multi-site network, factors that have to be considered in supply chain planning for a DRAM module industry include costs (purchase costs, production costs, inventory holding costs, transportation costs, and out-of-stock costs) and constraints (supply-demand, materials, manufacturing capacities, transportation paths, etc.). The characteristics of the network and the considered factors increase the complexity and NP-completeness of problem solving.

Traditional approaches to solve the problem timely can be classified into two categories: (1) reducing the problem complexity and then optimally solving the problem by mathematical programming and (2) solving the problem by developing a heuristic algorithm, but the optimization is not guaranteed.

Unlike the above two problem-solving categories, this research applies distributed parallel computing method to plan a supply network without either reducing the problem complexity or reducing the complexity of problem solving by applying a heuristic algorithm.

2 MODEL AND METHODS

2.1 Supply Chain Planning (SCP)

Various techniques (e.g., linear programming, simulation, agent technology, and heuristic algorithms) have been applied in SCP to handle the (optimization) problems of order planning/scheduling in a multi-tier and multi-site production/distribution network. Table 1 shows a summary of the researches in this research area from the perspectives of techniques, planning horizon, and planning concerns.

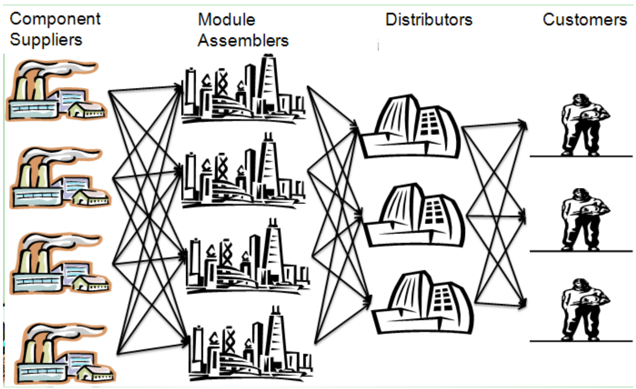

Figure 1: Supply Network for DRAM Module Industry

Wu (2004) proved that the uncapacitated planning for a single item on multiple time periods and multiple facilities is an NP-complete problem. That is, it is not possible to optimize the supply chain planning in a reasonable (polynomial) time as the problem scale is enlarged on time periods, tiers, and sites (facilities). Unfortunately, it is critical for a DRAM module company to plan its supply network timely, because of the market dynamics on price and demand.

2.2 MATHEMATICAL MODEL

The supply chain planning is modeled by a mathematical model with the objective to maximize the total profit of the network. Notations of the model are listed as follows:

- Indices

  i supplier index ($i = 1, 2, \ldots, I$)

  j manufacturer index ($j = 1, 2, \ldots, J$)

  k order index ($k = 1, 2, \ldots, K$)

Table 1: Summary of Typical Supply Chain Planning Research

Research	Planning Techniques	Planning Horizon	Planning Concerns			
			Materials Constraints	**Order Due Date**	**Capacity Constraints**	**Transporation Lead Time**
(Moon, 2002) [1]	Genetic Algorithm	Single Tier, Multiple Sites		✓	✓	✓
(Giglio et al., 2003) [2]	Mixed Integer Programming	Single Tier, Multiple Sites	✓	✓		✓
(Shen et al., 2003) [3]	Agent	Single Tier, Multiple Sites		✓		✓
(Watson & Polito, 2003) [4]	Heuristic Algorithm	Multiple Tier, Multiple Sites		✓	✓	✓
(Wu, 2004) [5]	Mixed Integer Programming	Single Tier, Multiple Sites		✓	✓	
(Chan et al., 2005) [6]	Genetic Algorithm	Single Tier, Multiple Sites			✓	✓
(Gen & Syarif, 2005) [7]	Genetic Algorithm	Multiple Tier, Multiple Sites		✓		
(Yeh, 2005) [8]	Heuristic Algorithm	Multiple Tier, Multiple Sites	✓		✓	
(Altiparmak et al., 2006) [9]	Genetic Algorithm	Multiple Tier, Multiple Sites	✓	✓	✓	
(Lim et al., 2006) [10]	Simulation	Multiple Tier, Multiple Sites	✓	✓	✓	
(Yeh, 2006) [11]	Heuristic Algorithm	Multiple Tier, Multiple Sites	✓		✓	
(Aliev et al., 2007) [12]	Genetic Algorithm	Multiple Tier, Multiple Sites		✓	✓	
(Chern & Hsieh, 2007) [13]	Heuristic Algorithm	Single Tier, Multiple Sites		✓	✓	✓
(Lin & Chen, 2007) [14]	Mixed Integer Programming	Multiple Tier, Multiple Sites		✓	✓	✓
(Nie et al., 2008) [15]	Genetic Algorithm	Single Tier, Multiple Sites		✓	✓	
(Altiparmak et al. ,2009) [16]	Genetic Algorithm	Multiple Tier, Multiple Sites	✓	✓	✓	
(Kanyalkar & Adil, 2010) [17]	Linear Programming	Multiple Tier, Multiple Sites		✓	✓	✓

- Time Variables

  T_i^S Shipping time for supplier i

  T_j^F Shipping time for manufacturer j

  t_k^{SHIP} Due date for order k

  t_{ij}^{SF} Lead time (including manufacturing and transportation) from supplier i to manufacturer j

  t_{jk}^{FD} Lead time (including DRAM assembly and transportation) from manufacturer j for order k

- Cost Variables

  c_i^{SP} Unit purchase cost for supplier i

  c_j^{FP} Unit manufacturing cost for manufacturer j

  c_k^{DP} Unit assembly cost for order k

  c_j^{FI} Unit inventory holding cost for manufacturer j

  c_k^{DI} Unit inventory holding cost for order k

  c_{ij}^{SF} Unit transportation cost from supplier i to manufacturer j

  c_{jk}^{FD} Unit transportation cost from manufacturer j for order k

- Quality Variables

q_i^S Maximal shipping quality that supplier i can provide

q_j^F Full capacity of manufacturer j

q_k^R Required quantity for order k

Q_{ij}^{SF} Shipping quantity from supplier i to manufacturer j

Q_{jk}^{FD} Shipping quantity from manufacturer j for order k

- Other Variables

t_i^{SP} Manufacturing lead time for supplier i

t_i^{SI} Inventory cycle time for supplier i

Q_k^{SH} Out of Stock quantity for order k

e_k Unit price for order k

c_k^{SH} Unit shortage cost for order k

Objective Model: Maximize Gross Profit = Order Revenue – Total Cost

- Order Revenue

Order Revenue= $\sum_{k=1}^{K}(q_k^R \times e_k)$

- Total Costs= Purchase Cost + Production Cost + Inventory Holding Costs + Transportation Cost + Out of Stock Cost, where

(1) Purchase Cost = $\sum_{i=1}^{I}\sum_{j=1}^{J}(Q_{ij}^{SF} \times c_i^{SP})$

(2) Production Costs can be divided into two categories: manufacturing cost in the manufacturer and assembly cost in the distribution center

Manufacturing Cost= $\sum_{i=1}^{I}\sum_{j=1}^{J}(Q_{ij}^{SF} \times c_j^{FP})$

Assembly Cost= $\sum_{j=1}^{J}\sum_{k=1}^{K}(Q_{jk}^{FD} \times c_k^{DP})$

(3) Inventory Holding Costs

for manufacturer

$$= \sum_{i=1}^{I}\sum_{j=1}^{J}\left[Q_{ij}^{SF} \times \left(T_j^F - T_i^S - t_{ij}^{SF}\right) \times c_j^{FI}\right]$$

for distribution center

$$\sum_{j=1}^{J}\sum_{k=1}^{K}\left[Q_{jk}^{FD} \times \left(t_k^{SHIP} - T_j^F - t_{jk}^{FD}\right) \times c_k^{DI}\right]$$

(4) Transportation cost

from suppliers to manufactures

$$\sum_{i=1}^{I}\sum_{j=1}^{J}(Q_{ij}^{SF} \times c_{ij}^{SF})$$

from manufacturers to distribution centers

$$\sum_{j=1}^{J}\sum_{k=1}^{K}(Q_{jk}^{FD} \times c_{jk}^{FD})$$

(5) Out of Stock Cost= $\sum_{k=1}^{K}(Q_k^{SH} \times c_k^{SH})$

Constraints of the models are as follows:

- Balance between supply and demand quantities

$$\sum_{j=1}^{J}Q_{jk}^{FD} + Q_k^{SH} = q_k^R \quad \forall k = 1,2,...,K$$

- Total supply quantity to J manufacturers is less than the maximal shipping quantity a supplier can provide.

$$\sum_{j=1}^{J}Q_{ij}^{SF} \le q_i^S \quad \forall i = 1,2,...,I$$

- Total number of products that can be delivered is less than the full capacity of each manufacturer.

$$\sum_{k=1}^{K}Q_{jk}^{FD} \le q_j^F \quad \forall j = 1,2,...,J$$

- The total supply quantity from the suppliers to the manufacturers is equal to the total shipping quantity from the manufacturers to the distribution centers

$$\sum_{i=1}^{I}Q_{ij}^{SF} = \sum_{k=1}^{K}Q_{jk}^{FD} \quad \forall j = 1,2,...,J$$

- Transportation routes

from suppliers to manufacturers: the route P_{ij}^{SF} is 1, when the shipping quantity is larger than 10. Otherwise, the route does not exist and P_{ij}^{SF} is 0.

$$10 \times P_{ij}^{SF} \le Q_{ij}^{SF}$$
$$Q_{ij}^{SF} \le m \times P_{ij}^{SF}$$
$$\forall i = 1,2,...,I \quad \forall j = 1,2,...,J$$

from manufacturers to distribution centers: the route P_{jk}^{FD} is 1, when the shipping quantity is larger than 10. Otherwise, the route does not exist and P_{jk}^{FD} is 0.

$$10 \times P_{jk}^{FD} \le Q_{jk}^{FD}$$
$$Q_{jk}^{FD} \le m \times P_{jk}^{FD}$$
$$\forall j = 1,2,...,J \quad \forall k = 1,2,...,K$$

- Constraints for suppliers' shipping time

$$P_{ij}^{SF} \times t_i^{SP} \le T_i^S \quad \forall i = 1,2,...,I \quad \forall j = 1,2,...,J$$
$$T_i^S \le t_i^{SP} + t_i^{SI} \quad \forall i = 1,2,...,I$$
$$T_i^S \le m \times \sum_{j=1}^{J}P_{ij}^{SF} \quad \forall i = 1,2,...,I$$

- Constraints for manufacturers' shipping time

$$T_j^F \ge (T_i^S + t_{ij}^{SF}) - m\times(1-P_{ij}^{SF}) \quad \forall i=1,2,...,I \quad \forall j=1,2,...,J$$

$$T_j^F \le m\times\sum_{k=1}^{K} P_{jk}^{FD} \quad \forall j=1,2,...J$$

$$t_k^{SHIP} \ge (T_j^F + t_{jk}^{FD}) - m\times(1-P_{jk}^{FD}) \quad \forall j=1,2,...,J \quad \forall k=1,2,...K$$

2.3 Remote Message Invocation (RMI) for Distributed Parallel Computing

RMI in Java allows an object to call the method of an object running on a distributed computer. In other words, objects on distributed Java Virtual Machines can be executed as they are in a solitary Java Virtual Machine through Java RMI. It largely reduces the overhead in distributed computing, compared with the traditionally socket approach.

3 PARALLELIZING THE MATHEMATICAL MODEL

3.1 Distributed computer network for sub-optimization computation

Since the optimization on the supply chain planning is an NP-complete problem, as the number of companies involved in the planning is smaller, the computation time in finding the optimal time will be much less. Fortunately, the optimal supply plan is usually performed on a subset of suppliers and a subset of manufacturers. Hence, the original global planning with a large number of companies can be equally true as finding the best supply plans on all the sub-optimal plans with subsets of the suppliers and the manufactures.

Take a case of 6 suppliers and 6 manufacturers as an example. If the planner can guarantee that the optimal plan can occur on al most 4 suppliers and 4 manufacturers, the original optimization problem will become finding the best plan on the $C_4^6 \times C_4^6 = 225$ sub-problems. Each of the problem is with 4 suppliers and 4 manufacturers only. We can parallelize the 225 sub-optimization computations on the distributed computers to find the 225 sub-optimal solutions, and then easily pick up the best solutions on the 225 sub-optimal solutions.

The prrallelization is fulfilled by a computer network, as shown in Figure 2. The server first divides the n sub-optimal problems (n domains). Then, the sub-optimization computation is assigned to any available computation node by a switch. When each sub-optimization computation is finished (through LINGO API) in the computation node, the result is transmiteed back to the server. Then, the server assgins a new sub-optimiation computation problem to the free computation node.

3.2 Speeding up the computation

Even though the computation for finding the optimal plan can be reduced by finding the best plan of the 225 sub-optimal plans found in parallel, it still takes a lot of time if the number of computers is not as large as 225. To speed up the computation, the strategy is interrupting each sub-optimization computation when the computation in the midway indicates that the final sub-solution cannot outperform the so-far best solution.

This research finds the sub-optimal solution with few companies (suppliers and manufacturers) is always less than the sub-optimal solution with a large number of companies. As shown in Figure 3, the optimal solution B of (3 suppliers and 2 manufacturers) will be always better than the optimal solution A of (2 suppliers and 2 manufacturers).

Additionally, the optimization process in a mathematical model is to synthesize the upper bound and lower bound values, as shown in the two blue lines in Figure 4. If the upper bound of a subset problem is less than the so-far best solution (yellow line), the computation should be interrupted, because the final optimal solution on the subset problem is definitely smaller than the so-far best solution. Because LINGO API can provide the real-time upper bound status, the idea in Figure 4 can be implemented.

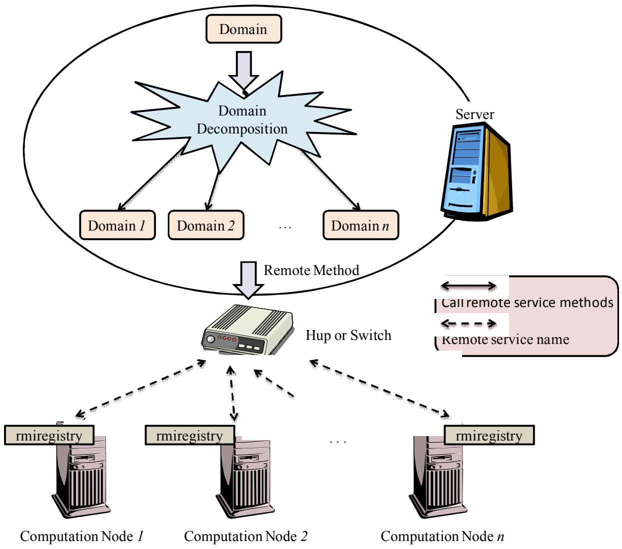

Figure 2: Network structure for the distributed sub-optimization computation

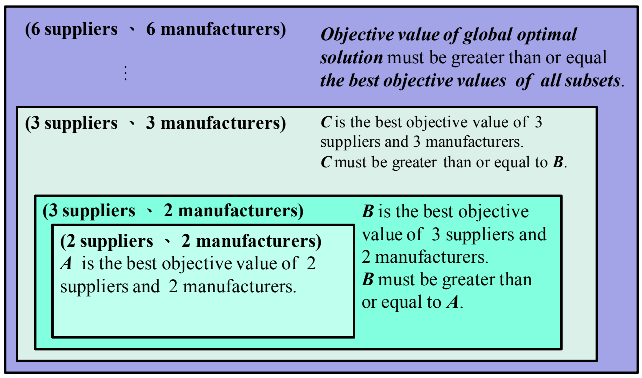

Figure 3: Sub-optimal solution with more companies is always better than the sub-optimal solution with less companies

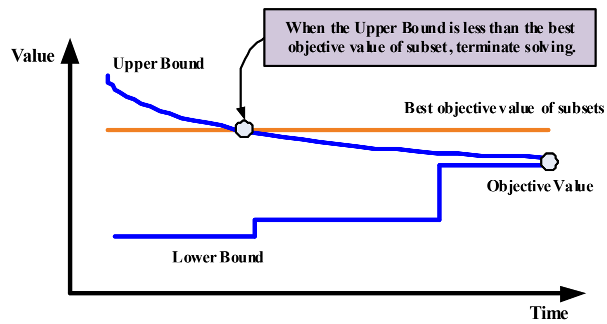

Figure 4: Interrupting the optimization computation on a subset problem, if its upper bound status is less than the so-far best solution

3.3 Terminating the computation

Figure 3 shows that the sub-optimization should start from small numbers of suppliers and manufacturers. It is suggested that the numbers should not be less than the required capacities on the suppliers and manufacturers, but the numbers should not be too large. The optimization should be terminated when the increased numbers on the suppliers or manufacturers cannot significantly increase the gross profit on the sub-optimal problems and the numbers of the suppliers and the manufacturers reaches to a certain numbers defined by the planner.

4 DESIGN OF EXPERIMENTS

4.1 Problem, facilities, and parameters

It is assumed that there are 8 suppliers, 6 manufacturers, and 6 distribution centers in the planning problem. Control factors and levels in the experiments are shown in Table 2. Values of the variables been set in the experiments are shown in Table 3. Each computation node (personal computer) is equipped with Windows XP Professional SP2，Pentium 4 2.8 G CPU, and 512MB RAM. Tool for optimization is LINGO 10 EXTENDED. Due to the space limitation, the termination of the parallel computation is not addressed.

Table 2 Control factors and levels

Factors	Level	Note
Demand	High	80% of the total supply
	Medium	60% of the total supply
	Low	30% of the total supply
Number of computation nodes	High	16
	Medium	12
	Low	8

4.2 Experimental results

Figure 5 shows the runtime with computation nodes in the three levels and with demand of 30% supply. It is found that increased number of computers can effectively reduce the runtime time. Figure 6 shows percentages of reduction in computation times on different levels of demands and numbers of computation nodes. It is found that the reduction on the computation time may not be so significant when the loading on the capacities increases.

Table 4 shows comparisons with the traditional approach (running on a solitary computer) when the demand is at 80% level of supply. It indicates that the three parallelizing cases in this research can find the optimal solutions as good as the traditional approach. However, the needed computation times are less than 50% of the traditional approach. Besides, the optimization computation on the traditional approach is not completed. The gross profit in the traditional case is a lower bound, and is not the optimal gross profit.

Table 3: Variables and values set in the experiments

Variables	Values							
q_i^S	i = 1	i = 2	i =3	i = 4	i = 5	i = 6	i = 7	i = 8
	106	106	117	136	140	143	146	143
c_i^{SP}	i = 1	i = 2	i = 3	i = 4	i = 5	i = 6	i = 7	i = 8
	61	61	68	60	64	70	61	68
t_i^{SP}	i = 1	i = 2	i = 3	i = 4	i = 5	i = 6	i = 7	i = 8
	4	3	9	3	10	7	4	8
t_i^{SI}	i = 1	i = 2	i = 3	i = 4	i = 5	i = 6	i = 7	i = 8
	5	0	4	5	2	0	2	6

Variables	Values					
q_j^F	j = 1	j = 2	j = 3	j = 4	j = 5	j = 6
	281	281	294	285	210	208
c_j^{FP}	j = 1	j = 2	j = 3	j = 4	j = 5	j = 6
	45	49	47	52	45	52
c_j^{FI}	j = 1	j = 2	j = 3	j = 4	j = 5	j = 6
	3	9	3	9	10	1
c_k^{DP}	k = 1	k = 2	k = 3	k = 4	k = 5	k = 6
	48	40	44	49	50	51
c_k^{DI}	k = 1	k = 2	k = 3	k = 4	k = 5	k = 6
	4	7	2	7	8	4

Variables	Degree \ k	1	2	3	4	5	6
q_k^R	30%	85	29	25	31	86	56
	60%	101	82	78	51	203	108
	80%	56	201	84	316	38	135

Variables	Values					
t_k^{SHIP}	k = 1	k = 2	k = 3	k = 4	k = 5	k = 6
	24	23	27	27	23	27
e_k	k = 1	k = 2	k = 3	k = 4	k = 5	k = 6
	388	371	376	369	384	362
c_k^{SH}	k = 1	k = 2	k = 3	k = 4	k = 5	k = 6
	517	494	501	491	511	481

Variables	i \ j	1	2	3	4	5	6
c_{ij}^{SF}	1	26	22	14	25	12	30
	2	24	29	13	21	12	20
	3	15	15	27	10	26	15
	4	15	14	22	28	17	30
	5	11	14	29	13	29	25
	6	28	14	11	17	23	13
	7	11	17	11	23	28	30
	8	12	10	12	14	12	20

Variables	j \ k	1	2	3	4	5	6
c_{jk}^{FD}	1	20	26	21	18	17	20
	2	13	17	27	20	28	16
	3	11	29	15	20	17	10
	4	10	20	17	15	17	19
	5	11	24	12	16	25	29
	6	24	27	23	27	18	30

Variables	i \ j	1	2	3	4	5	6
t_{ij}^{SF}	1	9	10	8	5	15	10
	2	7	10	14	5	12	9
	3	10	6	15	14	12	11
	4	12	7	12	12	11	6
	5	6	14	13	8	13	7
	6	5	11	14	15	14	5
	7	13	15	7	6	8	6
	8	10	14	7	14	15	12

Variables	j \ k	1	2	3	4	5	6
t_{jk}^{FD}	1	12	5	10	5	8	10
	2	13	10	11	11	15	5
	3	10	9	12	14	14	10
	4	15	6	8	10	8	9
	5	13	10	11	12	9	13
	6	13	7	14	13	12	13

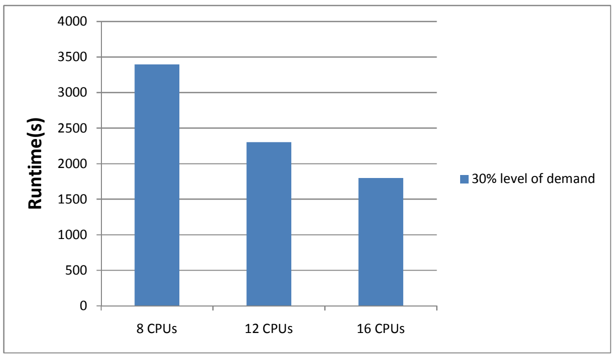

Figure 5: Optimization computation time with computation nodes in three levels and with demand of 30% supply

5 CONCLUSIONS

This research parallelizes the supply network planning problems for the memory module industry, so the (near) optimal plan can be obtained. First, the supply network planning problem is formulated as a mathematical programming problem. Then, the suppliers and manufacturers are divided into subsets. The demands are then optimally planned for the subset companies by the distributed computers in parallel. The results show that the optimization computation times are largely reduced, while the gross profit is as good as the optimization running in a solitary computer. This research indicates a future direction in supply plan optimization.

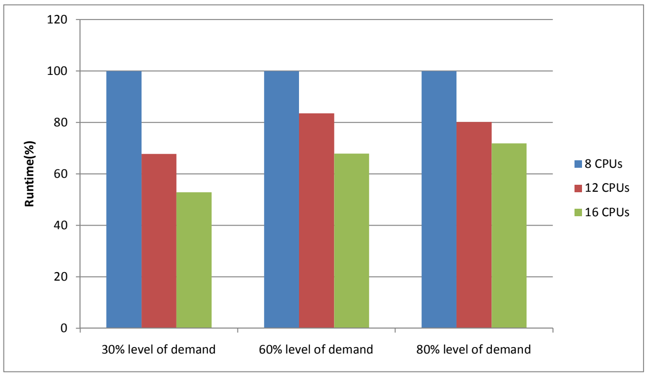

Figure 6: Percentages of reduction in computation times on different levels of demands and numbers of computation nodes

Table 4: Comparison with the traditional approach (single computer) with demand of 80% supply

No. of computation nodes	1	8	12	16
Gross profit ($)	152124*	152124	152124	152124
Runtime (sec)	132250	60431	48462	43458
Completed optimization computation	No	Yes	Yes	Yes
Differences in profits	-	0%	0%	0%
Differences in runtime	-	54.31%	63.36%	67.14%

*lower bound

6 ACKNOWLEDGMENTS

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國科會補助計畫衍生研發成果推廣資料表

日期:2011/10/18

<table>
<tr><td rowspan="3">國科會補助計畫</td><td>計畫名稱: 基於CSA之分散式生產訂單允諾系統：以TFT-LCD Array製程為例</td></tr>
<tr><td>計畫主持人: 黃欽印</td></tr>
<tr><td>計畫編號: 99-2628-E-029-010-　　　學門領域: 生產系統規劃與管制</td></tr>
<tr><td colspan="2">無研發成果推廣資料</td></tr>
</table>

99 年度專題研究計畫研究成果彙整表

計畫主持人：黃欽印	計畫編號：99-2628-E-029-010-
計畫名稱：基於 CSA 之分散式生產訂單允諾系統：以 TFT-LCD Array 製程為例	

成果項目			量化			單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
			實際已達成數（被接受或已發表）	預期總達成數(含實際已達成數)	本計畫實際貢獻百分比		
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	3	3	100%		
		研討會論文	1	1	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	5	5	100%	人次	
		博士生	1	1	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	3	3	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	2	2	100%		
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	在本計畫的支持下，計畫主持人成為 IFPR-APR 主席，與 IFPR 理事，IFPR 執行委員會委員，IJPE Guest Editor.

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估 ■達成目標 □未達成目標（請說明，以 100 字為限） □實驗失敗 □因故實驗中斷 □其他原因 說明：
2. 研究成果在學術期刊發表或申請專利等情形： 論文：■已發表 □未發表之文稿 □撰寫中 □無 專利：□已獲得 □申請中 ■無 技轉：□已技轉 □洽談中 ■無 其他：（以 100 字為限） 在本計畫的經費支持下，已發表三篇論文於 IJPE, IJCCC, 與 Engineering Computations. 同時也發表二篇國際會議論文.
3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限） 多數的生產規劃問題少被放在平行運算的環境執行，計畫主持人在此領域研究多年，將會有更多具體的研究產出. 平行計算能解決過往許多因 NP Hard 而必須倚賴 heuristic algorithm 的現象. 本研究雖然只是一個初探（採用 Java.net 與 CLIPS)確為日後鋪設很多重要的技術. 包括 Java 各類 API 的使用以及如何使用 PC Cluster 等.