COMPUTER-AIDED SELECTION OF THE OPTIMAL LOT SIZING SYSTEM (CALS)

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ABSTRACT

A lot of works have been done by the researchers to solve lot-sizing problems over the past few decades. Many techniques and algorithm have been developed to solve the lot-sizing problems. Basically, most of the algorithms are developed either based on heuristic or mathematical approach. Since Computer-Aided has been given attention by the researchers in many areas including production planning, therefore in this paper we implement Computer-Aided to solve single level lot-sizing problem. Five models are developed based on five well known heuristic techniques, which are Lot-For-Lot (LFL), Economic Order Quantity (EOQ), Periodic Order Quantity (POQ), Part Period Balancing (PPB) and Wagner-Within algorithm (WW). The planning period involves in the model is 5 period where demand in the periods are varies but deterministic. The model was developed using Visual Basic Version 5 with ACCESS database. Results show that when entering the needed inputs through the user interface, which is general inputs and special inputs, the **(CALS)** system selects the suitable lot size technique that gave optimum solution and easy application to the lot-sizing problem.

KEYWORDS: Lot sizing techniques, Material requirements planning.

اختيار حجم الدفعه الإنتاجيه الافضل باستخدام الحاسوب (CALS)

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الموجز

خلال العقود القليلة الماضية ظهرت الكثير من البحوث الخاصة بحل مشاكل حجم الدفعة الإنتاجية التي اتبعت فيها العديد من التقنيات والخوارزميات. هذه الخوارزميات اما تعتمد بشكل اساسي على التقنية البحتية او الرياضية. استقطبت المساعدة الحاسوبية اهتمام الكثير من الباحثين في العديد من المجالات بما فيها تخطيط الإنتاج، لذلك سيتم استخدام الحاسوب لحل مشاكل حجم الدفعة في هذا البحث عن طريق بناء برنامج حاسوبي لخمسة تقنيات مهمة من تقنيات حجم الدفعة الإنتاجية هي (دفعة بدفعة LFL، كمية الطلب الاقتصادية EOQ، كمية الطلب الدورية POQ، موازنة الفترة الجزئية PPB، وخوارزمية واكنر WW).

سنتناول في هذا البحث خمس فترات للتخطيط يكون الطلب فيها متغير لكن محدد. تــم بنــاء هـ ذا النموذج باستخدام برنامج حاسوبي بلغة الفيجوال بيسك الإصــدار الخــامس مــع قاعــدة بيانــات اكــسس ACCESS.

النتائج بينت بانه عند إدخال البيانات المطلوبة من خلال واجهة المستخدم (والبيانات هي بيانات عامة وخاصة) فان نظام CALS سوف يقوم باختيار افضل وانسب تقنية تعطي الحل الامثل والاسهل لحل مشاكل حجم الدفعة الإنتاجية.

NOMENCLATURE

BOM = Bill of Material
C = Carrying Cost Per Item Per Unit Time.
Ci = Duration For Which Inventory is Carried
CALS = Computer aided lot sizing
Co = Ordering Cost
D = Average Demand
EOQ = Economic Order Quantity
EPP = Economic Part Period
LFL = Lot For Lot
LLC = Low Level Code
LS = Lot Size
LT = Lead Time
MPS = Master Production Schedule
MRP = Material Requirements Planning
PP = Cumulative Part-Period for period
PPB = Part period balancing
POQ = Periodic Order Quantity
Q = Economic Order Quantity.
Ri = Requirement for period i.
S = Setup Cost Per Batch
SM = Silver - Meal
T =Ordering Interval
WW = Wagner- Within

1. INTRODUCTION

Lot sizing is an approach used to determine optimum order or production quantity in each period in a planning horizon. It is widely used in Material Requirement Planning System. Many lot-sizing techniques have been developed and established by the researchers. The developments of lot-sizing techniques are basically based on either heuristic approach or mathematical modeling. Order Quantity (EOQ), Periodic order quantity (POQ), Lot-For-Lot (LFL) and Part Period Balancing (PPB) are amongst techniques that adopted heuristic approach. Meanwhile, Wagner-Within (WW) is considered mathematical approach in which it was developed based on dynamic programming. This paper will discuss about implementing computerized model to solve lot-sizing problems. The purpose of developing computerized model is to evaluate the performance of computer in solving lot sizing problems and to overcome the difficulties faced by the user in using either heuristic or mathematical approach.

2. LITERATURE REVIEW

This section gives literature review on lot sizing, computer-Aided and the research that motivates the author to apply computer-Aided in MRP problem of lot sizing. Problem in determining the optimum quantities (lot sizes) to order in discrete time periods of a single item over

N periods to satisfy a certain demand pattern with the objective to minimize the sum of ordering and carrying cost is a common problem in keeping inventory always in stock. Method proposed by **(Radzi, Haron and Johari 2006)** shows neural network to solve single level lot-sizing problem. Three models are developed based on three well known heuristic techniques, which are Periodic Order Quantity (POQ), Lot-For-Lot (LFL) and Silver-Meal (SM). The model was developed using MatLab software. **(Hoesell & Wagelmans 1990)** study sensitivity analysis of the incapacitated single level economic lot-sizing problem, which was introduced by Wagner and Whitin about thirty years ago. **(Cheng 1989)** tested two other well-known non-cost-based heuristics: the lot-for-lot and fixed period requirement rules, and compared with the Wagner-Within(WW)optimization algorithm the lot-for-lot proves to be an effective rule to use when inventory cost is high. **(De Matteis 1968)** developed simpler algorithm that has been such as by PPB. **(Saydam & Evans 1990)** show the relative performances of four popular heuristic against the (WW). **(AL-Juboory 2002)** developed Computer-Aided Monitoring of Production Planning System which was built by means of the relational database technology using Visual Basic Version 5 with ACCESS database. **(Gaafar 2000)** applied neural network model in MRP problem of lot sizing. The performance of the model is analyzed and compared to common heuristic method.

3. REASEARCH METHODOLOGY

3.1. Data Preparation: The necessary information for (CALST) system are shown in **figure (1).** They are:

- Master Production Schedule (MPS): due dates and quantities for all top level items
- Bills of Material (BOM): for all parent items
- Inventory Status: (on hand plus scheduled receipts) for all items
- Planned Lead-times: for all items

3.2. The developed (CALS) system: The (CALS) system is developed specifically to select the suitable lot size technique that give optimal solution, also it is easy to be applied in lot-sizing problems. The developed system can perform several functions as depicted in **figure (1).** Each function interface with the other functions.

3.2.1. User interface: The user interface main module plays a key role in various (CALST) system activities, by providing the possibility of accessing any part of the system. User interface is the communication mechanism between the user and other modules of the system. When the user enters the needed inputs through the user interface, the system selects the suitable techniques relative to the input.

3.2.2. Common Database: the database must contain high level information about the product, because in such system we need common database that supports the user interface. This database consists of:

1. Item Master Database.

The item master database (also called part master database or inventory record database) contains a record for every item in the company's inventory products, assemblies, components, materials, and supplies. A typical list of the data stored for each item is represented in **table (1).** We will describe the elements on the list.

a- Item Number: The item number is a unique number that identifies the item and is the key to record in the file.

b- Projected Inventory on Hand: The projected inventory on hand is the current inventory of the item.

c- Lead times: The lead-time is the time between placing an order and receiving it.

d- Scheduled receipt: Scheduled receipt is the previously released orders, either purchased from the market or manufactured.

e- Ordering Cost: The cost of order release.
f- Holding Cost: the cost of carrying.

2. Bill of Material Database.

The bill of material database specifies what materials, components, assemblies, and subassemblies are used in making the product. We will describe the elements on the list.

a- Low Level Code (LLC): Level refers to where an item fits in the product structure. The final product is at level 0. The components used directly in making the final products are at level 1. Components used in making level 1 items are at level 2, and so forth.

b- Quantity per Assembly: it is the required number of a part in each assembly.

3.2.3. Lot Sizing Module: lot sizing function is the process of determining the quantities in which order are placed. This module consists of several lot sizing techniques. Therefore, depending on the type of inputs that the user enter, the system has been designed and developed to suggest the best lot sizing technique that correspond to these inputs as shown in **figure (2).**

1. **LFL Function:** it is the name given to the method that orders exactly what is required in each period. It should produce units only as needed with no safety stock and no anticipation of future orders. Lot for lot is frequently used for expensive items and high discontinuous demand item. The LFL function is built as shown in **figure (3).**

{Net Requirements}= {Gross Requirements} – {On-hand Inv.} – {Scheduled Receipts}

Gross Requirements: The anticipated future usage of the item (MPS).
Scheduled Receipts: Previously released orders, either purchased or manufactured.
Current: On-hand inventory (end-item, subassembly, or processed parts).
Lot-Sizing (LS) Rule: How the jobs will be sized in order to minimize the cost.
Planned Lead-Time: The time between placing an order and to receiving it.
Planned Order Receipts: Purchase or manufactured items that must be available at the beginning of a timer bucket.
Planned Order Released: Planned orders after offsetting using lead-time.

2. **EOQ Function:** EOQ module assumes that the demand is constant. In the EOQ formula, annual demand is replaced with average demand per period. A weakness of the EOQ technique is that large quantities of units, which are not immediately required, are carried in stock. The order quantity is specified by the economic order formula:

$$Q = \sqrt{2SD/C} \qquad (1)$$

Where:
Q= Economic order quantity.
S= Setup cost per batch.
D= Average demand for item per unit time.
C=Carrying cost per item per unit time.

The EOQ function is built as shown in **figure (4).**

3. **POQ Function:** The periodic order quantity (POQ) technique is based on the same thinking as the EOQ method. For the EOQ technique the order quantity is constant while ordering interval varies. However, for the POQ model the ordering interval is constant while the order quantity various, thus:

$$T=Q/D \qquad (2)$$

Where:
T=Ordering interval.
Q= Economic order quantity.
D= Average demand for item per unit time.

The POQ function is built as shown in **figure (5).**

4. **PPB Function:** PPB is a more dynamic approach to balance setup and holding cost, PPB uses additional information by changing the lot size to reflect requirements of the next lot size in the future. It divides demand requirements into order periods such that ordering and holding cost are balanced. Although the technique does not guarantee an optimum solution, it does produce a very good solution. The procedure for PPB is as follows:
Calculate an economic part period or EPP, for the problem. This value is expressed as a ratio between ordering and holding cost. It is used as a measuring tool to determine when to place an order.

$$EPP = \text{Ordering cost}/\text{Carrying cost} = Co/Cc \quad (3)$$

This technique selects the order quantity at which the part period cost matches the EPP value, most closely

$$PP_i = PP_{i-1} + (R_i * C_i) \quad (4)$$

Where:
PP: Cumulative Part-Period for period i.
Ri: Requirement for period i.
Ci: Duration for which inventory is carried.
The PPB function is built as shown in **figure (6).**

5. **WW function:** The Wagner-Within procedure is a dynamic programming model that adds some complexity to the lot-size computation. Wagner-Within begins with the first period in the planning horizon and evaluates all possible combinations of orders to meet demand in that period. It then proceeds to period two and does the same, and so on, until the optimal method for meeting demand in all periods is determined.
The WW function is built as shown in **figure (7).**

4. RESULTS AND DISCUSSION

To show the validity of our approach and for the purpose of completeness, we applied this system in state company of rubber industries. This company provided us the necessary information such as (production plan, ordering and carrying cost for product, operation time for all the production processes, and the inventory information). The company produces several types of products. Product (X) is being selected which consists of (21) part. Planned order is released at the same time for all the parts. The monthly quantity of product (X) are (1716) for September 2010.

The researcher selected part number (1) of product (X) to test the (CALS) system as follow:

By entering the following data(current year, month, monthly quantity, days per period, and holiday at each period), and by using the bill of material database that consist of(part number, quantity per assembly, and low level code). The cost database provide the system (ordering cost and carrying cost). The inventory database provide the system (scheduled receipts, projected on hand and lead time).the results are master production schedule table from the following equations:

Quantity per day= monthly quantity / number of work days during the month
= 1716 / 26= 66
Quantity per period= Quantity per day ×number of work days per period
Quantity per period_1 = 66 × 2 = 132
Then the system calculate the lot sizing techniques as follow:

1- **Lot-for-lot:**
- { Gross Requirements }= {Quantity per period} × { Quantity per assembly }
{ Gross Requirements for period1}= 132 × 1 =132

- {Net Requirements}= {Gross Requirements} – {On-hand Inventory} – {Scheduled Receipts}
  {Net Requirements for period$_1$}= 132 –0–0=132
- {Planned Order Receipts}={Net Requirements}=132
- Total cost= Ordering cost for all period+ Carrying cost for all period = (8072.4 × 5) + 0 = 40362 $

2- Economic order quantity:

- { Gross Requirements }= {Quantity per period} × { Quantity per assembly }
  { Gross Requirements for period$_1$}= 132 × 1 =132
- Average demand for item per unit time(D)=SUM{ Gross Requirements for all periods}/ number of periods= (132+396+396+396+396)/ 5=343.2
- Economic order quantity (Q)= $\sqrt{\text{2 ×Ordering cost per batch (S)×Average demand for item per unit time(D) / Carrying cost per item per unit time(C)}}$
  Economic order quantity (Q)for period1= (2 ×8072.4×343.2) / 16.1448=586
- {Net Requirements}= {Gross Requirements} – {On-hand Inventory} – {Scheduled Receipts}
  {Net Requirements for period$_1$}= 132 –0–0=132
- {Planned Order Receipts}={ Economic order quantity }=586
- Total cost= Ordering cost for all period+ Carrying cost for all period = (8072.4 × 4) + (7329.7392+ 7329.7392+ 936.3984+0+9202.536)= 57088.0128 $

3- Periodic order quantity:

- { Gross Requirements }= {Quantity per period} × { Quantity per assembly }
  { Gross Requirements for period1}= 132 × 1 =132
- Average demand for item per unit time(D)=SUM{ Gross Requirements for all periods}/ number of periods= (132+396+396+396+396)/ 5=343.2
- Economic order quantity (Q)= $\sqrt{\text{2 ×Ordering cost per batch (S)×Average demand for item per unit time(D) / Carrying cost per item per unit time(C)}}$
  Economic order quantity (Q) for period1= (2 ×8072.4×343.2) / 16.1448=586
- Ordering interval(T)=Economic order quantity(Q)/Average demand for item per unit time(D) =586/343.2=2
- {Net Requirements}= {Gross Requirements} – {On-hand Inventory} – {Scheduled Receipts}
  {Net Requirements for period$_1$}= 132 –0–0=132
- **{**Planned Order Receipts}={ Planned Order Receipts for pereiod$_1$+ Planned Order Receipts for pereiod$_2$ }=132+396= 528
- Total cost= Ordering cost for all period+ Carrying cost for all period = (8072.4 × 3) + (6393.3408 ×2)= 37003.8816 $

4- Part-Period balancing:

- { Gross Requirements }= {Quantity per period} × { Quantity per assembly }
  { Gross Requirements for period$_1$}= 132 × 1 =132
- Economic part period(EPP)=Ordering cost(Co)/Carrying cost(Cc)= 8072.4/16.1448 =500
- Cumulative Part-Period for period $_1$ (PP$_1$)= Cumulative Part-Period for period 0 (PP$_0$) + {Requirement for period $_1$ (R$_1$)* Duration for which inventory is carried (C1)}
  Cumulative Part-Period for period$_1$(PP1)=0-(132×0)=0 (is this closet match to EPP) ? No
- {Prospective lot size for period $_1$ }={Net Requirements for period $_1$ + Net Requirements for period $_0$ }=132-0=132

- Total cost= Ordering cost for all period+ Carrying cost for all period = (8072.4 × 4) + (10655.568+4262.2272+6393.3408)= 53600.736$

5- Wagner-Within:

- { Gross Requirements }= {Quantity per period} × { Quantity per assembly }
  {Gross Requirements for period1}= 132 × 1 =132
- {Net Requirements}= {Gross Requirements} – {On-hand Inventory} – {Scheduled Receipts}
  {Net Requirements for period$_1$}= 132 –0–0=132

period	alternatives	Ordering cost	Carrying cost	Total cost	Optimal policy
1	(1)	8072.4	0	8072.4	(1)

After calculate all period the optimal policy is (1,2,3,4,5)

- {Planned Order Receipts}=SUM{Net requirements}=132+396+396+396+396=1716
- Total cost= Ordering cost for all period+ Carrying cost for all period = (8072.4) + (25573.363+19180.022+12786.6811+6393.3408)= 72005.808$

From the above techniques the system selects the best technique (Periodic order quantity) that have minimum cost

The application of the proposed system is introduced here.

Figure (8) shows the proposed input frame and the result (master production schedule MPS) depend upon database in **figure (9),(10),(11**) to calculate the lot sizing technique for the five techniques as shows in **figures (12),(13),(14),(15),(16).**

Figure (17) shows the output of the system and the selected suitable lot sizing technique depend on minimum cost.

4. CONCLUSIONS

In this paper, we construct a software program that selects the suitable lot sizing technique depend upon scientific bases.

The **(CALS)** system provides with bill of material database, inventory database, and cost database that can be updated at any time.

This model can be applied to solve lot sizing problems faster and easier because it can give optimum solution and posses certain characteristic that make the model more effective to be used.

From the **(CALS)** system we conclude the following:

- Lot-for-lot techniques order just what is required for production based on net requirements and it may not always be feasible. If setup costs are high, costs may be high as well
- EOQ using average demand and expects a known constant demand and MRP systems often deal with unknown and variable demand
- Part-period balancing tries to make the setup costs as close to the carrying costs as possible**.**
- Fixed order quantity method — constant lot sizes
- Wagner-Whitin — “optimal” method

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Table (1): Item Master File

Item No.	Projected on Hand	Lead Time	Scheduled Receipt	Ordering Cost	Holding Cost

Serial No.	Part No.	LLC	Quantity Per Assembly

Table (2): Bill of Material File

Table (3): Lot Sizing Report

Item: LLC: LS: LT:	Current	Period 1	2	3	4	5	6	7	8
Gross Requirements									
Scheduled Receipts									
Projected Inventory Balance									
Net Requirements									
Planned order Receipts									
Planned Order Released									

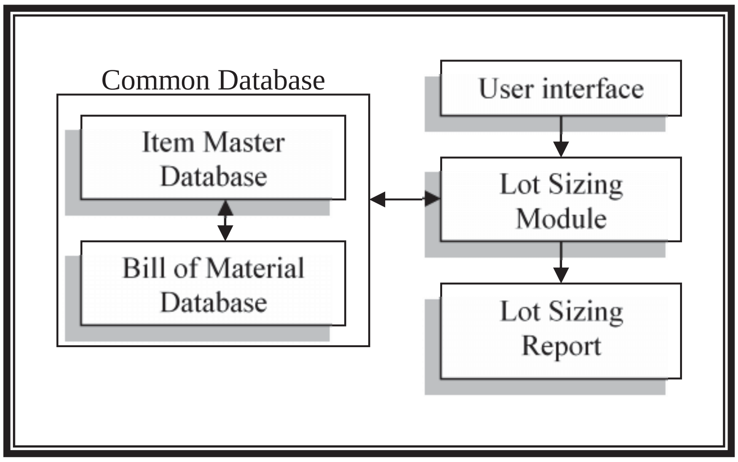


Figure (1): System architecture

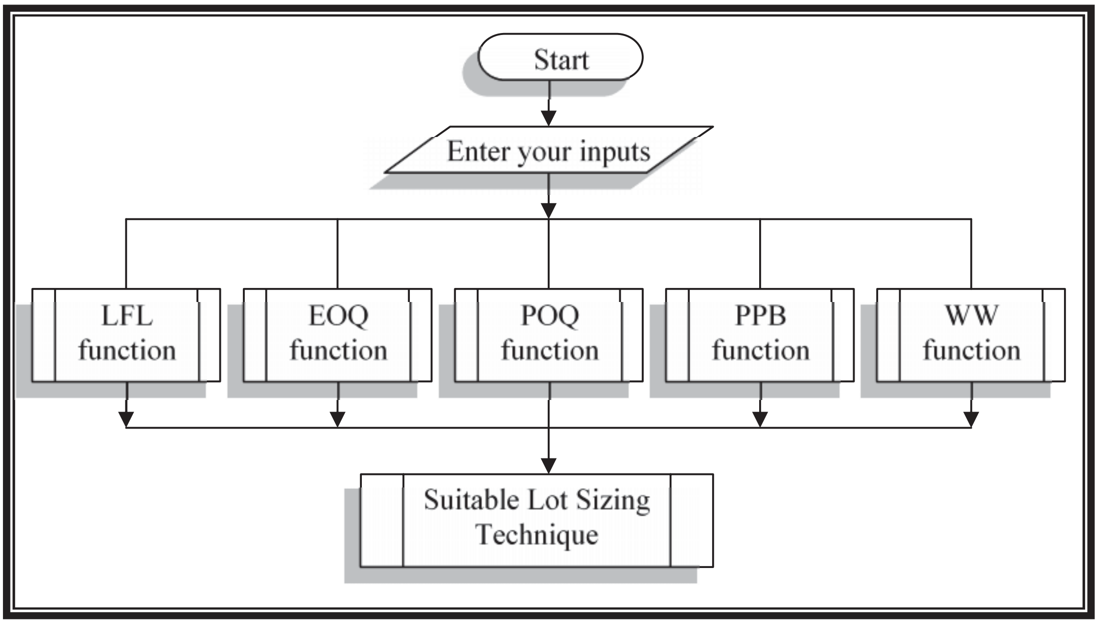


Figure (2): Flowchart of the Lot Sizing Module

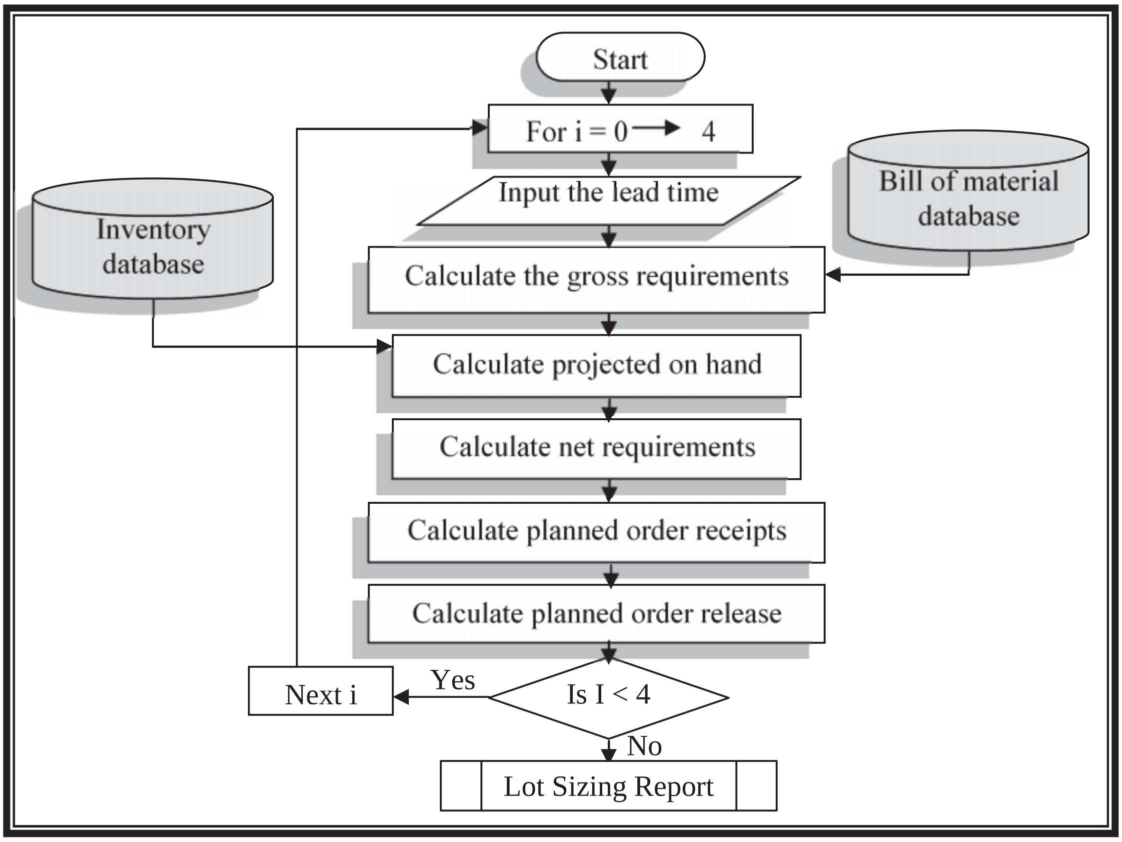
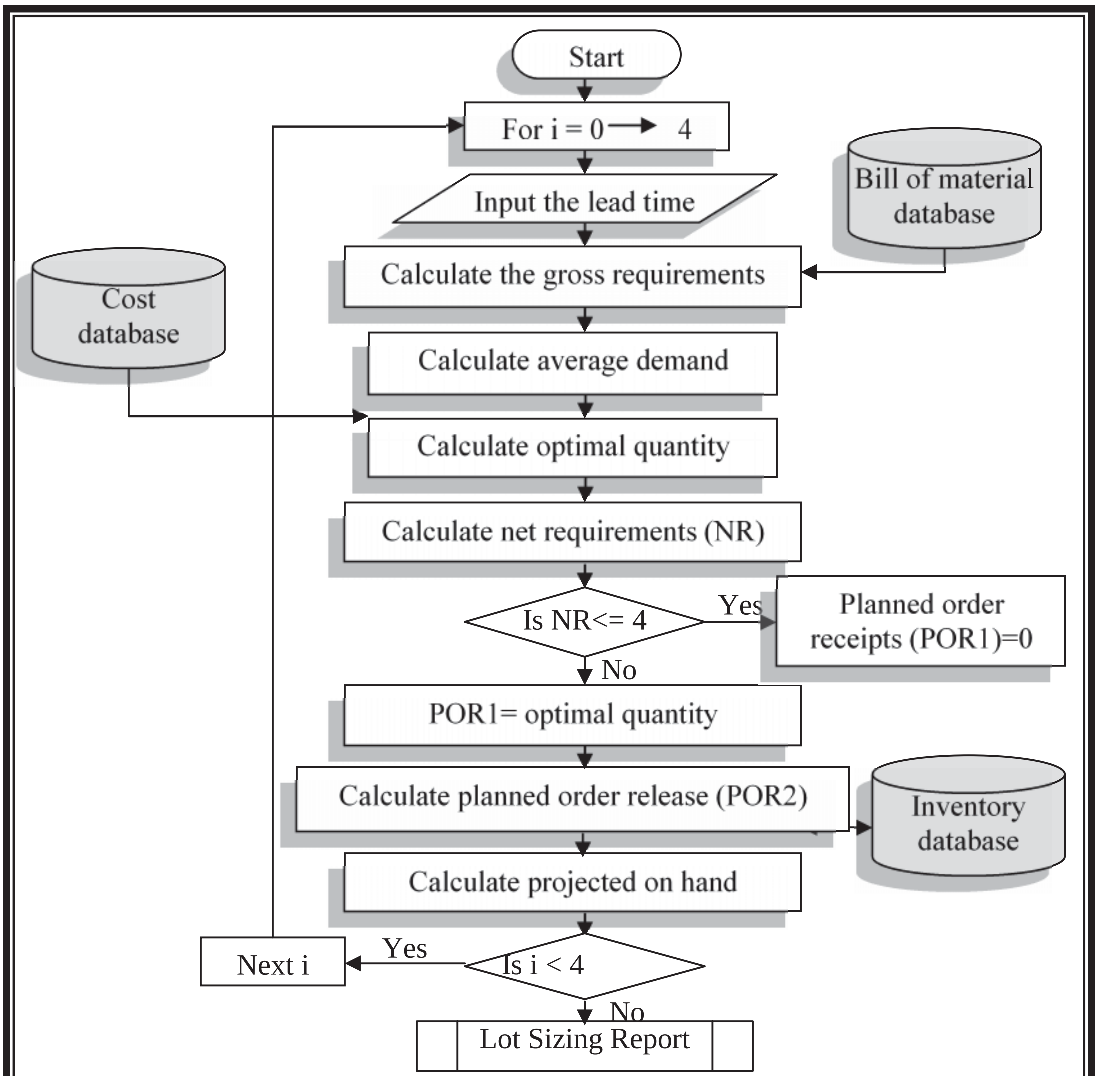


Figure (3): Flowchart of the LFL Function



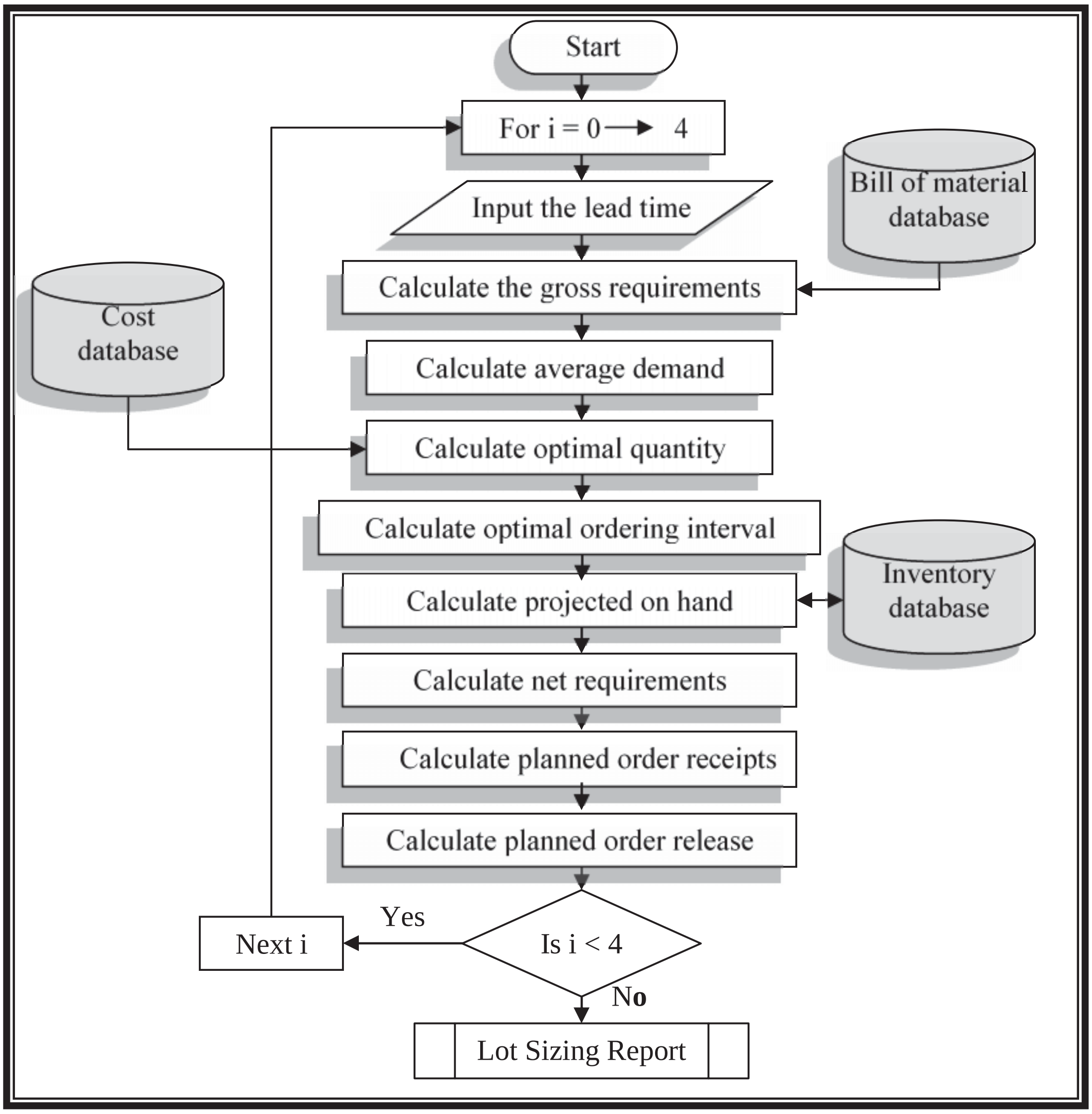


Figure (5): Flowchart of the POQ Function

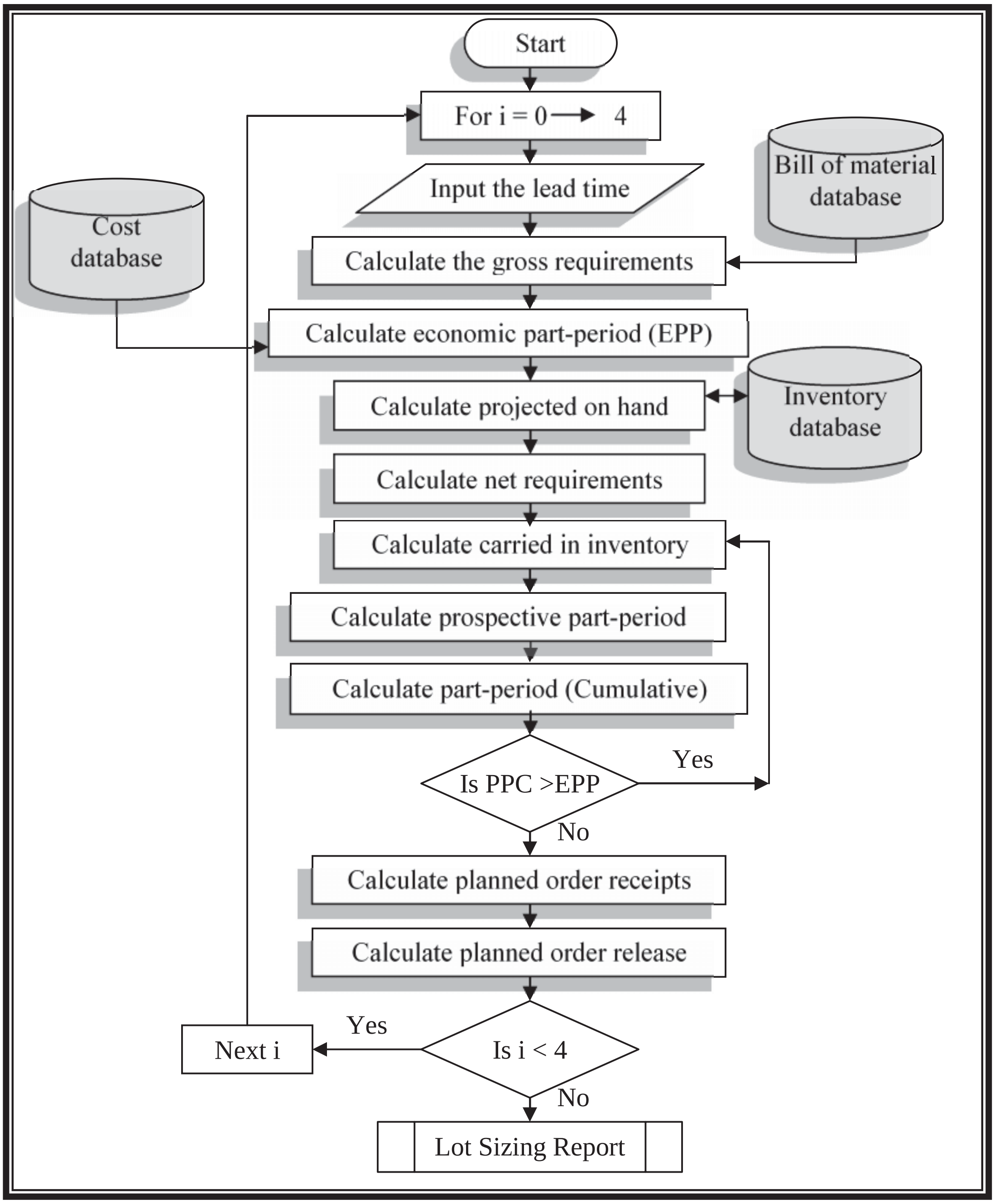


Figure (6): Flowchart of the PPB Function

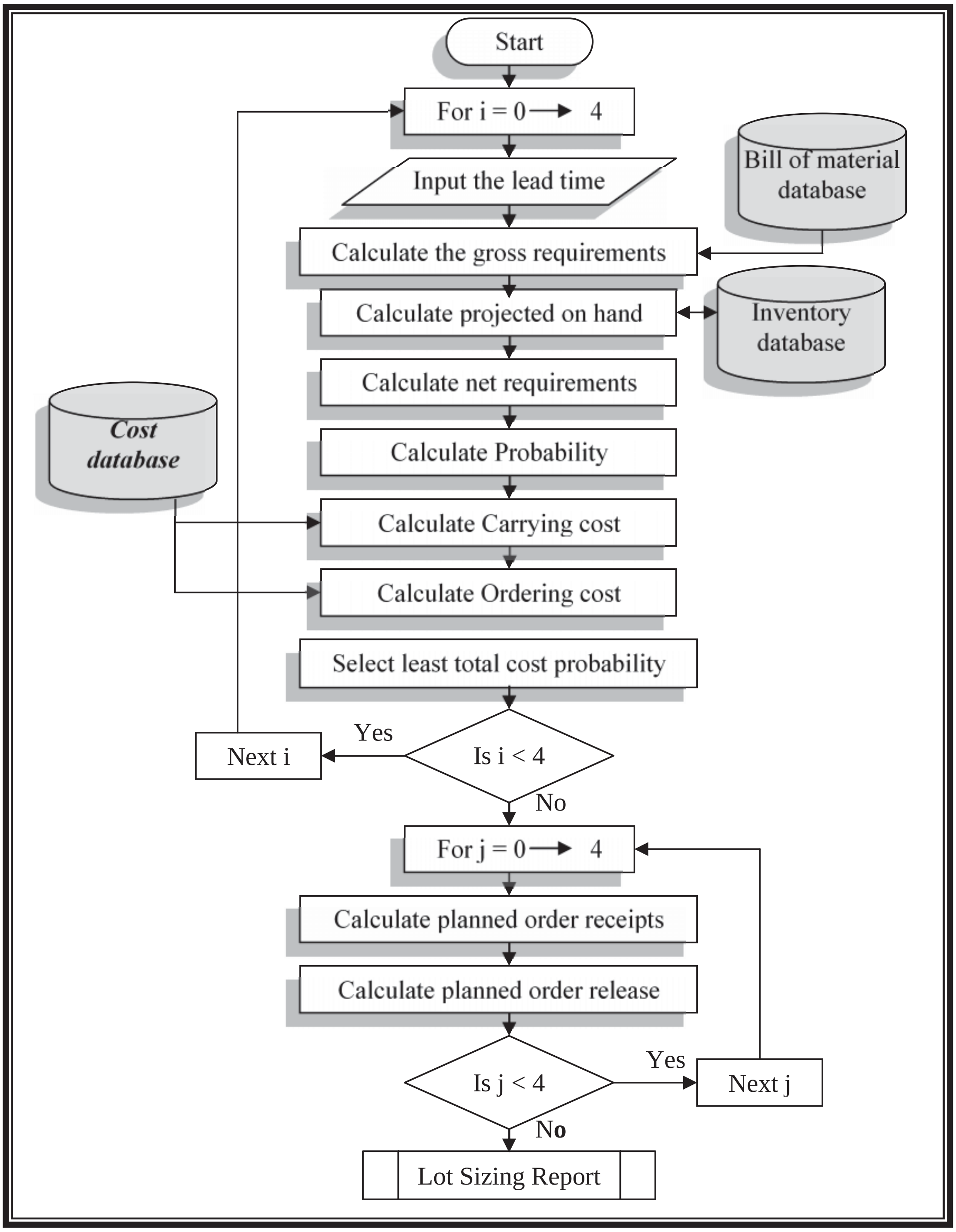


Figure (7): Flowchart of the WW Function

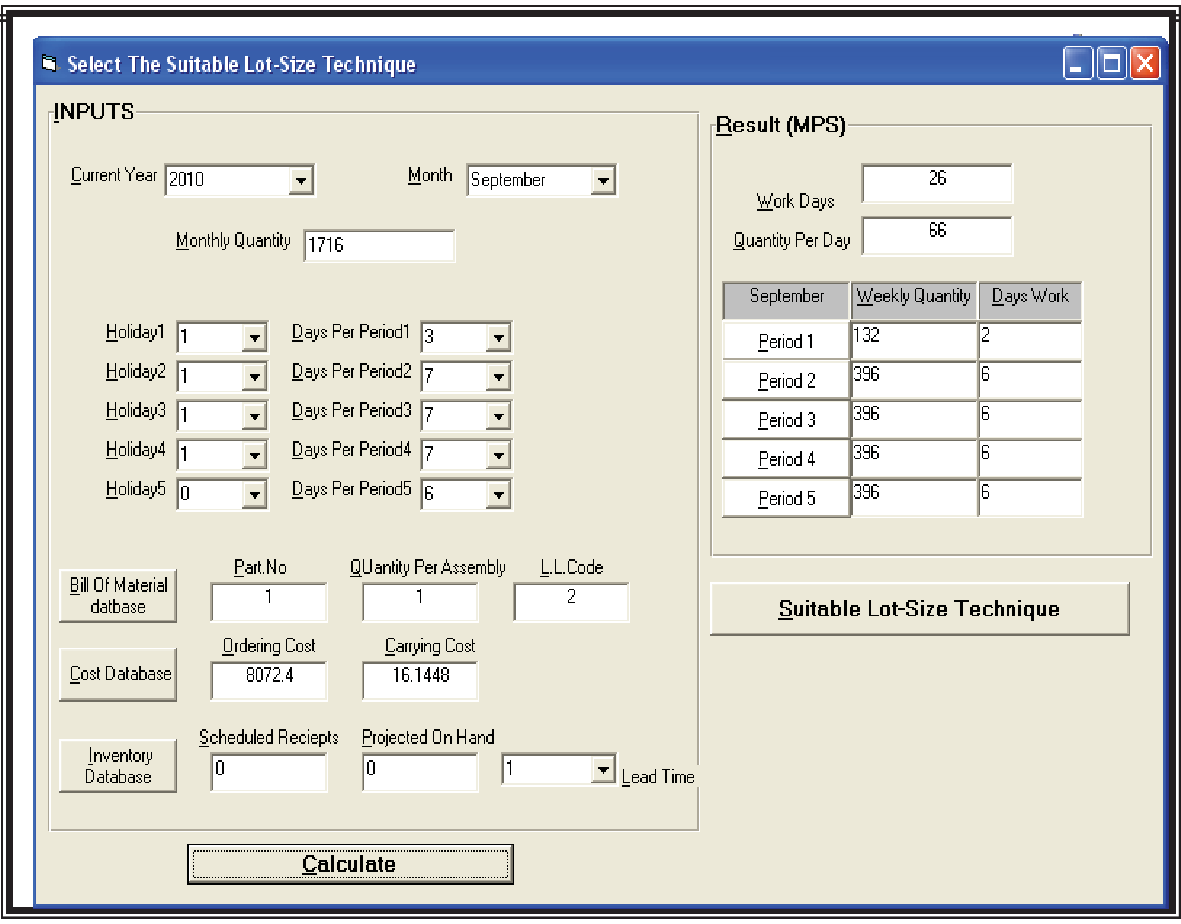


Figure (8): The proposed input frame

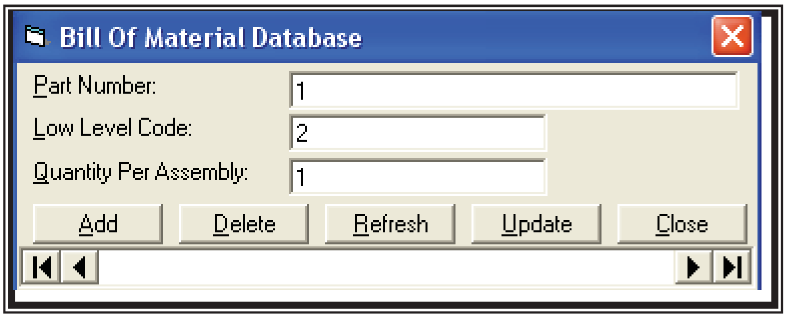


Figure (9): Bill of Material Database frame

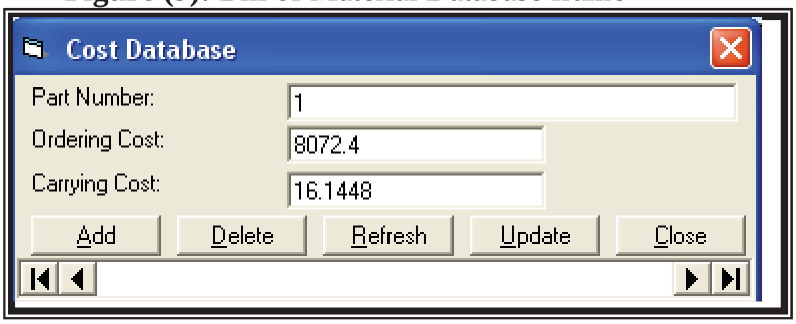


Figure (10): Cost Database frame

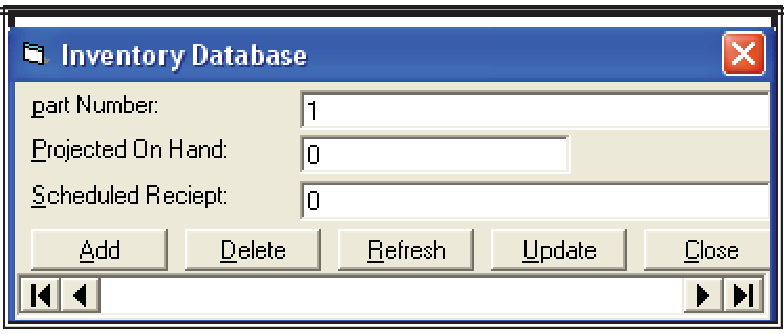


Figure (11): Inventory Database frame

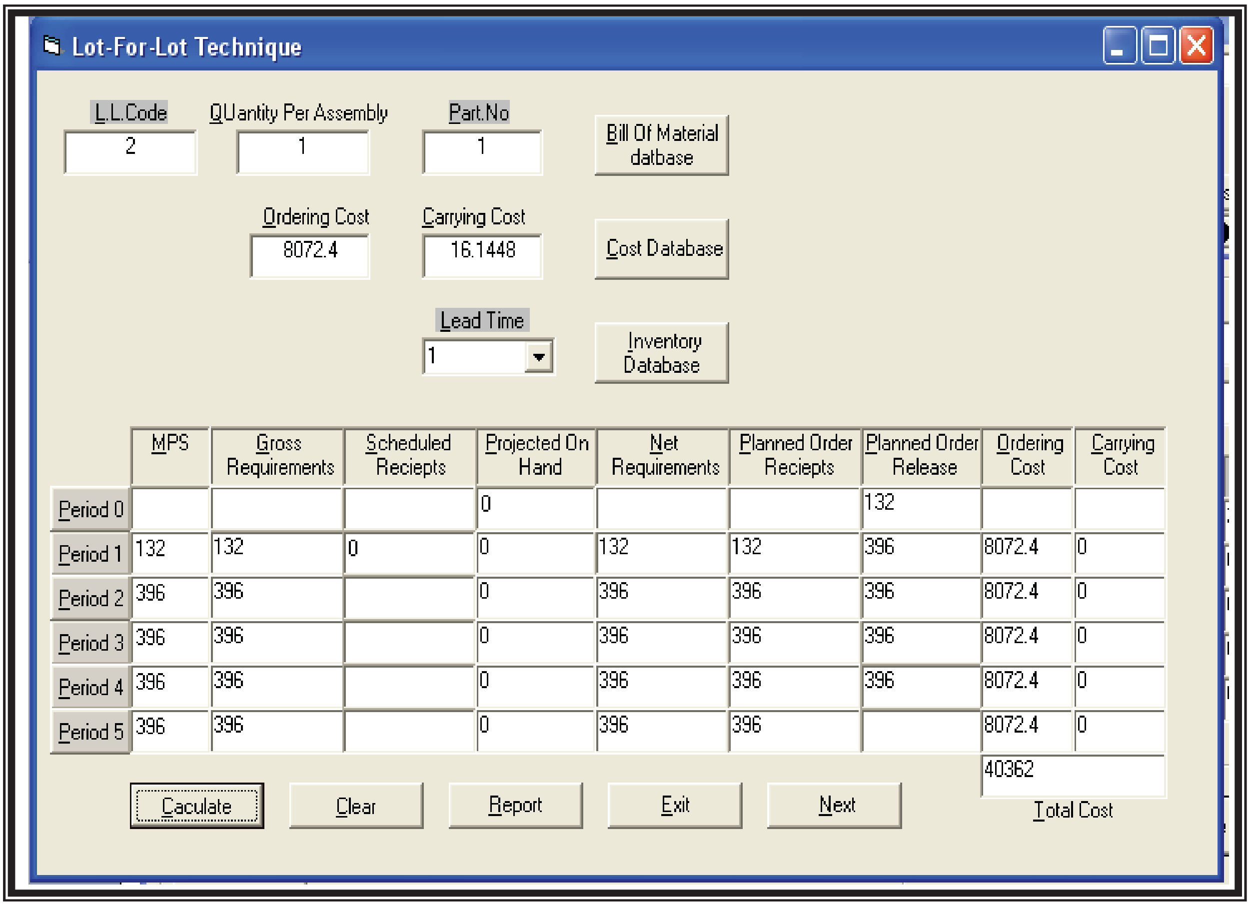
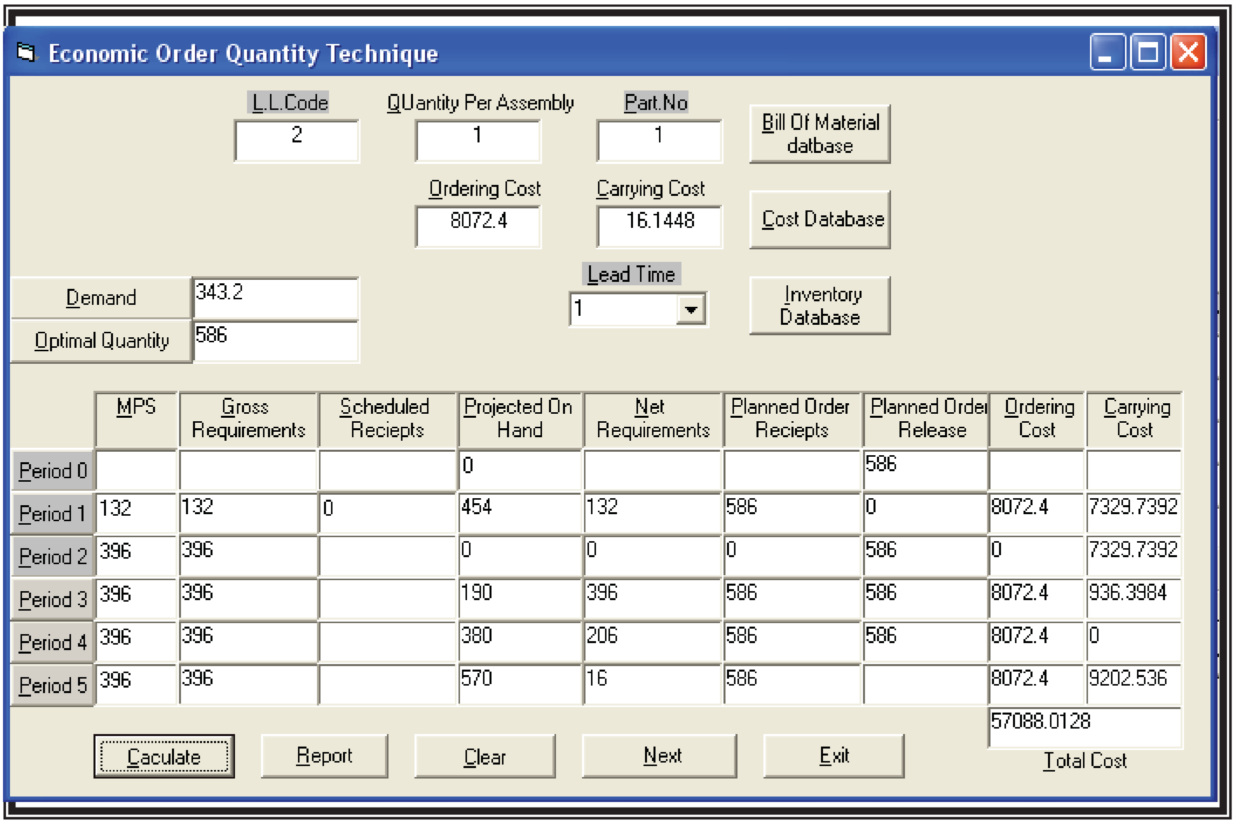


Figure (12): Lot For Lot Technique Frame



Economic Order Quantity Technique

L.L.Code: 2 | QUantity Per Assembly: 1 | Part.No: 1 | Bill Of Material datbase

Ordering Cost: 8072.4 | Carrying Cost: 16.1448 | Cost Database

Lead Time: 1 | Inventory Database

Demand: 343.2

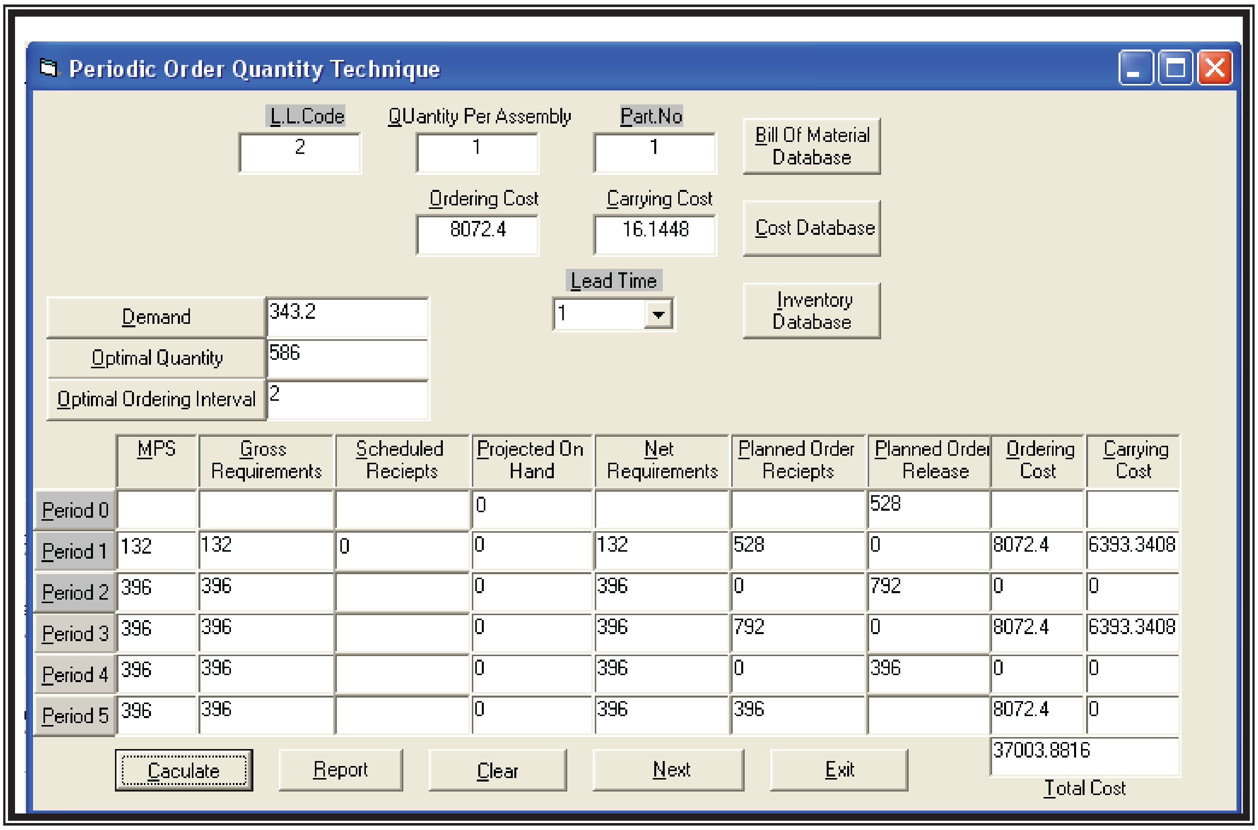
Optimal Quantity: 586

	MPS	Gross Requirements	Scheduled Reciepts	Projected On Hand	Net Requirements	Planned Order Reciepts	Planned Order Release	Ordering Cost	Carrying Cost
Period 0				0			586		
Period 1	132	132	0	454	132	586	0	8072.4	7329.7392
Period 2	396	396		0	0	0	586	0	7329.7392
Period 3	396	396		190	396	586	586	8072.4	936.3984
Period 4	396	396		380	206	586	586	8072.4	0
Period 5	396	396		570	16	586		8072.4	9202.536

Total Cost: 57088.0128

Caculate | Report | Clear | Next | Exit

Figure (13) Economic Order Quantity Technique Frame



Periodic Order Quantity Technique

L.L.Code: 2 | QUantity Per Assembly: 1 | Part.No: 1 | Bill Of Material Database

Ordering Cost: 8072.4 | Carrying Cost: 16.1448 | Cost Database

Lead Time: 1 | Inventory Database

Demand: 343.2

Optimal Quantity: 586

Optimal Ordering Interval: 2

	MPS	Gross Requirements	Scheduled Reciepts	Projected On Hand	Net Requirements	Planned Order Reciepts	Planned Order Release	Ordering Cost	Carrying Cost
Period 0				0			528		
Period 1	132	132	0	0	132	528	0	8072.4	6393.3408
Period 2	396	396		0	396	0	792	0	0
Period 3	396	396		0	396	792	0	8072.4	6393.3408
Period 4	396	396		0	396	0	396	0	0
Period 5	396	396		0	396	396		8072.4	0

Total Cost: 37003.8816

Caculate | Report | Clear | Next | Exit

Figure (14) Periodic Order Quantity Technique Frame

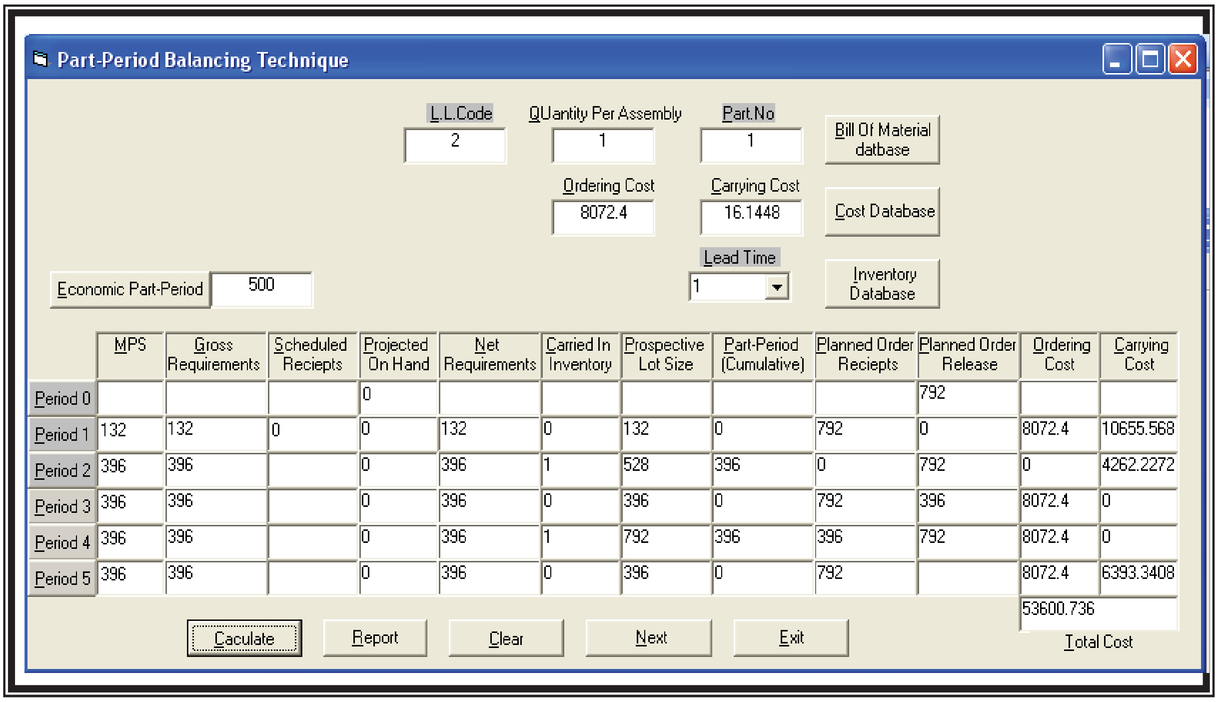


Figure (15) Part Period Balancing Technique Frame

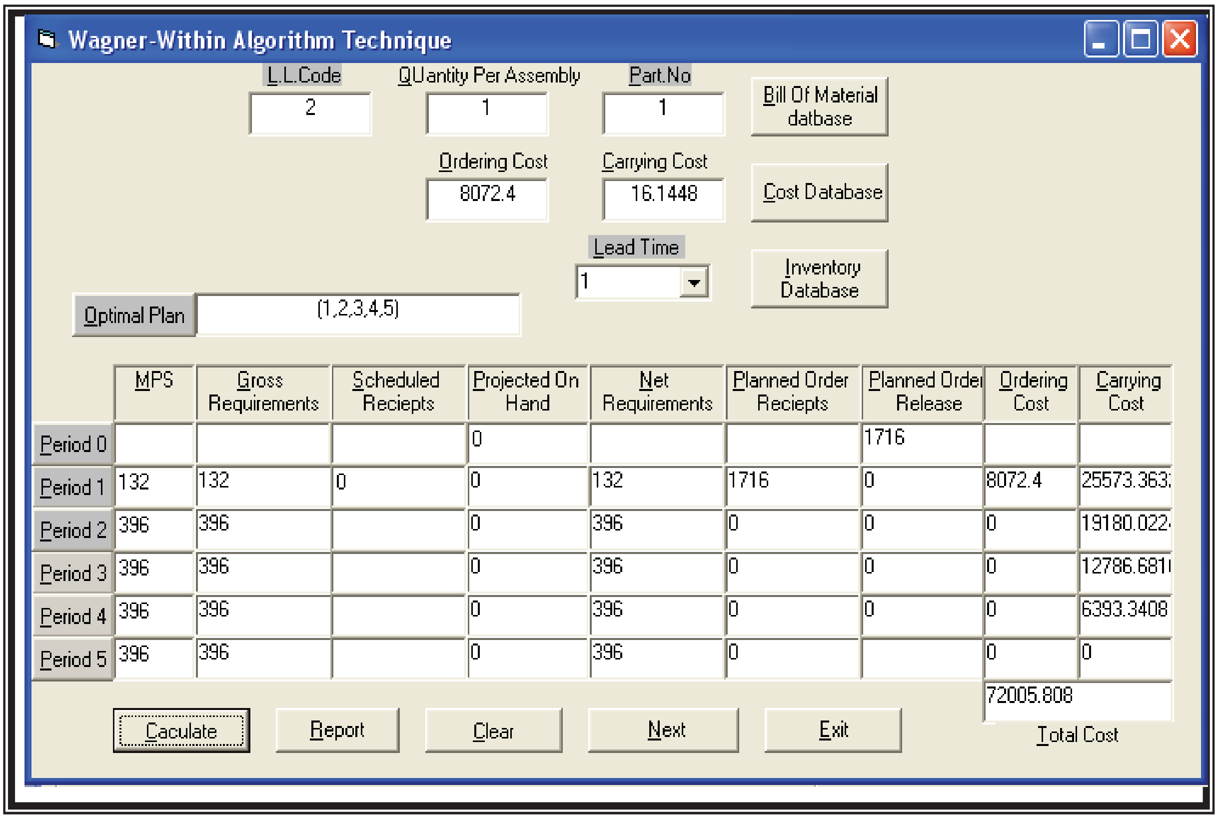


Figure (16) Wagner -Within Algorithm Technique Frame

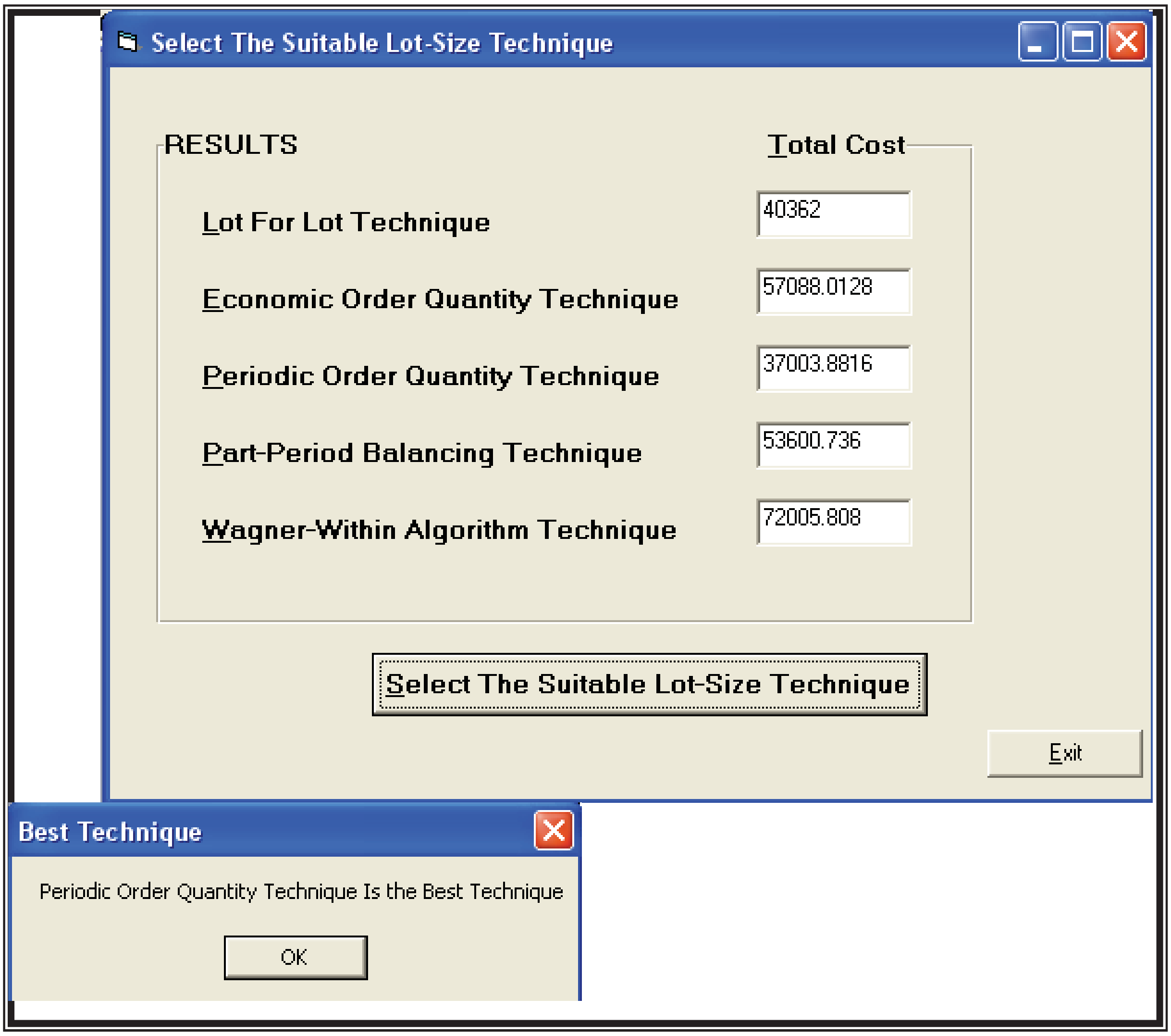


Figure (17) Select The Suitable Lot Size Technique Frame