

Adding MRP/DRP Functionality to Microsoft Navision

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Adding MRP/DRP Functionality to Microsoft Navision

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We recommend acceptance of this manuscript in partial fulfillment of this candidate's requirements for the degree of Master of Software Engineering in Computer Science. The candidate has completed the oral examination requirement of the capstone project for the degree.

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ABSTRACT

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Estimating the correct materials to order for the production of finished goods has been a daunting task for many manufacturing industries. Questions such as ‘*what* materials are needed’, ‘*how much* of each material is needed’, and ‘*when* it is needed’ have been a challenge that each industry has to deal with. This is where Materials Requirements Planning (MRP) can come in handy. MRP is a system developed to handle the ordering and scheduling of inventories, such as raw materials and subcomponents, which will be used in the production of finished goods [1]. A MRP system is intended to simultaneously meet three objectives: (1) to ensure that materials and products are available for production and delivery to customers (*what* is needed), (2) to maintain the lowest possible level of inventory (*how much* is needed), and (3) to plan manufacturing activities, delivery schedules and purchasing activities (*when* is it needed) [1]. For industries that have multiple locations, Distribution Requirements Planning (DRP) is another handy tool. DRP is an extension of MRP. In the calculation of MRP, it takes into consideration unused raw materials and subcomponents from different locations within the industry. Raw materials and/or subcomponents are recommended to be transferred from one location to another to fill a need instead of ordering raw materials from suppliers. ORC Industries uses an Enterprise Resource Planning (ERP) system called Microsoft Navision. An ERP system is an integrated software solution used to manage an industry’s resources (accounting, purchasing, inventory, etc.). Navision comes with stock MRP functionality but needs to be custom-tailored in order to meet the requirements of ORC Industries. It is therefore decided to develop a customized MRP/DRP system for ORC industries. This manuscript describes the development of the

customized MRP/DRP system. It includes a forecasting module that attempts to predict the sales for a specified period, which will be used in the MRP/DRP calculation.

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GLOSSARY

Bell Canoe

A division of ORC Industries that uses the software. Bell Canoe specializes in making canoes, kayaks, and accessories.

Bill of Material

The term used to describe the "parts list" of components (raw materials and subcomponents) needed to complete a finished good [2].

Bin Code

A physical location within a plant.

Distribution Requirements Planning (DRP)

Is an extension of MRP. In the calculation of MRP, it takes into consideration raw material and subcomponents from different locations within an industry. Subcomponents and raw materials are recommended to be transferred from other locations due to overstock or due dates of orders instead of being purchased.

Division

A field used to distinguish between different companies (ORC, RF, and BC).

Enterprise Resource Planning (ERP) System

An ERP system attempts to integrate all data and processes of an organization into a unified system. A typical ERP system will use multiple components of computer software and hardware to achieve the integration. A key ingredient of most ERP systems is the use of a unified database to store data for various system modules [2].

Finished Good

The item that is produced at the end of production.

Location

The plant where production is taking place.

Loc/Bin

A combination of location and bin code

Master Planner

The person who manages the MRP/DRP functionality. This person runs MRP/DRP, makes adjustments to Purchase Orders and Transfer Orders, and then processes the Purchase Orders and the Transfer Orders.

Master Production Schedule (MPS)

A realistic, detailed, manufacturing plan for which all possible demands upon the manufacturing facilities (such as available personnel, working hours, management policy, and goals) have been considered and are visualized. The MPS is a statement of what the industry expects to produce and to purchase; MPS is expressed in selected items, specific quantities and dates [2].

Material Requirements Planning (MRP)

A software based production planning and inventory control system used to manage manufacturing processes. An MRP system is intended to simultaneously meet three objectives: ensure that materials and products are available for production and delivery to customers (*what* is needed), maintain the lowest possible level of inventory (*how much* is needed), and plan manufacturing activities, delivery schedules and purchasing activities [2].

Microsoft Navision

The ERP software package that ORC Industries uses.

ORC Industries

The main company that uses the software. ORC Industries specializes in military outerwear.

Production Order

An order that holds the information on how many units of a finished good item to produce.

Purchase Order

An order that is used to order raw materials.

Raw Material

Items that are purchased from a vendor to use in the production of finished good and subcomponent items.

Redfeather Snowshoes

A division of ORC Industries that uses the software. Redfeather specializes in snowshoes.

Sales Forecast

A prediction of future sales, based mainly on past sales performance. Sales forecasting takes into account the economic climate, current sales trends, company capacity for production, company policy, and market research. A sales forecast can be a good indicator of future sales in stable market conditions, but may be less reliable in terms of rapid market change [3].

Subcomponent

An item that is made and is to be used in the production of another item. For example, a bicycle wheel may be considered as a subcomponent if the frame and the rubber wheel are bought separately and then the bicycle wheel is made.

Transfer Order

An order that is used to transfer raw materials and subcomponents from one location to another.

Unit of Measure (UOM)

The unit of measure is assigned to each item. For example, the most common UOM are inch, yards, and pounds.

1. Introduction

MRP is a system developed to handle the ordering and scheduling of inventories, such as raw materials and subcomponents, which will be used in the production of finished goods [1]. A MRP system is intended to simultaneously meet three objectives: (1) to ensure that materials and products are available for production and delivery to customers, (2) to maintain the lowest possible level of inventory, and (3) to plan manufacturing activities, delivery schedules and purchasing activities [1]. Typically, MRP describes what raw materials need to be ordered and subcomponents to be made in order to produce the finished goods. At the same time, MRP also takes into account that there is no overstock of raw materials and subcomponents. For industries that have multiple locations, Distribution Requirements Planning (DRP) is another handy tool. DRP is an extension of MRP. In the calculation of MRP, it takes into consideration unused raw materials and subcomponents from different locations within the industry. Raw materials and/or subcomponents are recommended to be transferred from one location to another to fill a need instead of ordering raw materials from suppliers.

An ERP system is an integrated software solution used to manage a company's resources. It integrates all business management functions, including planning, inventory/materials management, order processing, manufacturing, purchasing, accounting and finance, human resources, and payroll. ORC Industries uses an Enterprise Resource Planning (ERP) system called Microsoft Navision. Figure 1 shows a data flow architecture of Microsoft Navision.

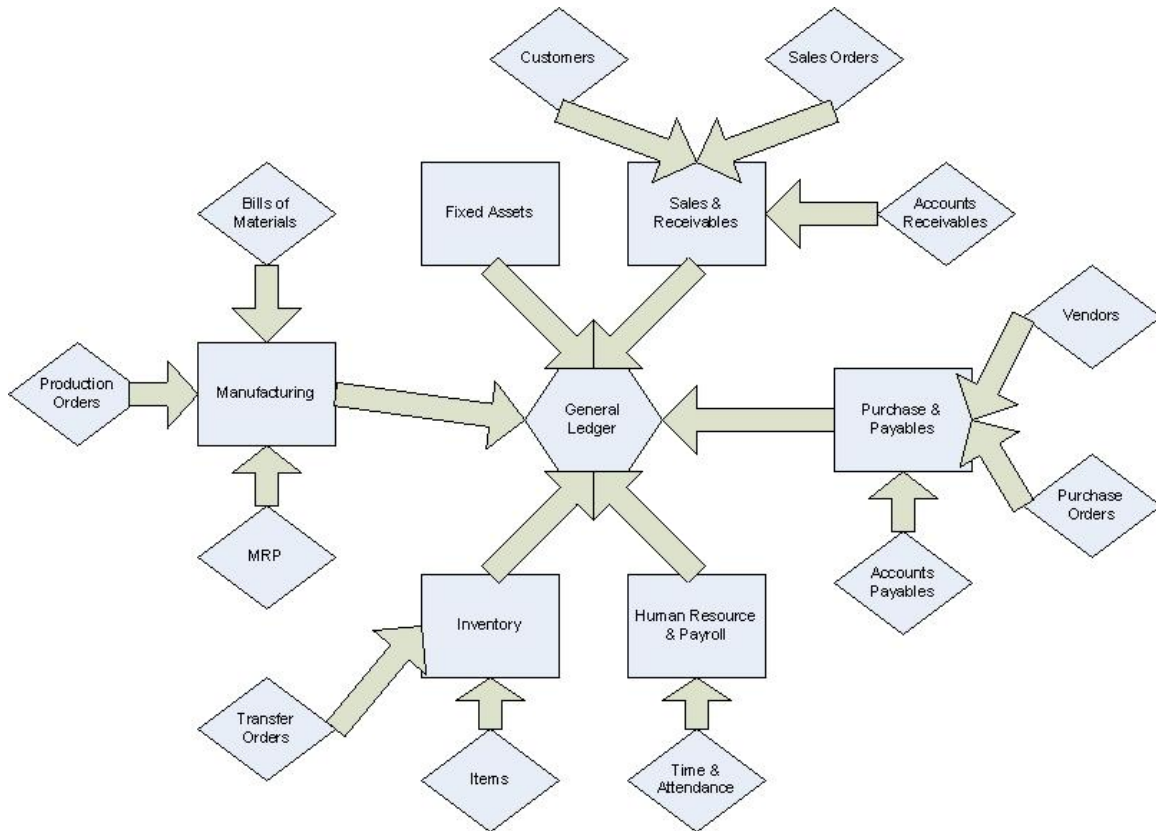


Figure 1. Microsoft Navision Data Flow

Navision comes with stock MRP functionality but needs to be custom-tailored in order to meet with the requirements of ORC Industries. ORC Industries is the parent company and it has two divisions, Redfeather Snowshoes and Bell Canoe. ORC Industries specializes in military outerwear such as parkas, trousers, rain suits, ponchos, sailor hats, and other types of clothing. ORC Industries bids for contracts from the Department of Defense. Once it wins a bid, the total amount of finished goods to produce is known and the shipments dates are predetermined. These contracts are usually good for 1-4 years. So planning for these sales is fairly straightforward. There is no need for a forecast because the total amount needed to be produced is already known. The only complexity involves is the DRP because these contracts may be produced in several plants.

Redfeather and Bell Canoe produce commercial products. Therefore, their requirements are based on sales forecast as well as customer pre-orders. Planning for these sales require more thinking and efforts because ORC Industries does not want a lot

of inventory left over. At the same time, the company does not want to forecast less because there will not be sufficient quantities of stock when they are ordered by the customers. Redfeather makes snow shoes which is a seasonal product. The majority of its products are purchased during the winter months. Bell Canoe makes canoes, kayaks, and accessories which are also seasonal products. The majority of its products are purchased during the summer months.

This section will describe why stock MRP functionality in Navision does not meet the requirements of ORC Industries. When Navision runs MRP, it runs for the whole company which includes all the three divisions - ORC Industries, Redfeather, and Bell Canoe. ORC Industries requires that MRP be run for each division separately. When Navision runs MRP it takes into account every item in a bin; however, some of these bins contain defective items which are not supposed to be considered as quantity on hand because they are defective. In addition, the resulting Purchase Orders are created for each location. ORC Industries only receives purchased ordered items to two locations and MRP would have to account for this. The locations that don't receive purchased items will be directed to be delivered to one of the two locations that except delivery. From these two locations, the items are then transferred to the appropriate locations.

The DRP functionality within Navision also does not meet the requirements of ORC Industries. There are primarily two reasons for this: (1) Stock Navision does not come with DRP. (2) ORC Industries may produce the same item at multiple locations. Instead of always buying items to restock at each location, it may be easier and cheaper to just transfer items that are unused from one location to another. ORC Industries spends a lot of money on shipping items overnight to locations that are running out of items. If ORC Industries can plan for these shortages ahead of time it would save a lot of money on the shipping costs.

The need to develop MRP and DRP functionality to meet the requirements of ORC Industries is the basis of this project. The MRP functionality has been developed from scratch instead of reengineering the previous MRP functionality. DRP will then be developed to work with the MRP functionality. A simple sales forecasting requirement of allowing the user to specify a percentage increase based on the previous year's sales

was given by ORC Industries. However, it was decided that it would enhance this project by including its own forecasting algorithm. Sales forecasting will have the additional functionality of using this algorithm to determine a forecast to use with MRP functionality.

2. Development of MRP/DRP Functionality

Microsoft Navision is an ERP software that can be extendible and customizable. Navision would probably have been able to be modified to add the needed MRP/DRP functionality that ORC Industries required. However, it would have been very costly to have Navision modified by a Navision development company. ORC Industries would also have been able to purchase the fully functional Navision source code and be allowed to these make modifications but this choice would have also been very costly. Therefore, the decision was made to create an external software for MRP/DRP functionality that would interact with the Navision database. This software was built from scratch instead of modifying Navision. The major benefit is that ORC Industries would have control over any modifications and add any new functionality in the future without additional cost from outside sources.

Database Setup was an additional functionality added to aid in testing and future development of the software. The Database Setup functionality was added to allow the user to specify the SQL Server, Navision Database, Navision Company, and MRP Database. This functionality would allow the user to create a copy of the Navision database and run testing on it without affecting live data on the original Navision database. If the software were to be sold or given to another company, that company would have the capability to use the software by changing the information in the Database Setup to match their database information.

The final software was developed using C# in Microsoft Visual Studio .Net and having a Microsoft SQL Server database. Navision uses a Microsoft SQL Server database as well. The Navision database includes information such as bill of materials, item information, vendor information, and customer orders. Navision also had to be modified to work with the MRP/DRP functionality that ORC Industries developed. ORC Industries has the capability to add fields to some tables in Navision. A field called Division was added to some of the tables in Navision to account for the different divisions of ORC Industries. A field called Purchase Location was added to the Location

table to specify which location would be the purchase location for that division. A field called Smoothing Constant was added to the Item table to hold the Smoothing Constant used by the forecasting algorithm.

2.1 MRP/DRP

The calculations a typical MRP system performs dates back to 1915 when Ford Harris published a formula to calculate an economic order quantity to minimize the total of ordering-related and inventory carrying cost. In 1934, R.H. Wilson showed how statistics could be used to plan inventory cushions to reduce the impact of forecast errors, reduce material shortages, and improve customer deliveries with minimum inventories [4]. Current MRP systems are very complex and are used for production schedule. A Master Production Schedule (MPS) is a realistic, detailed, manufacturing plan for which all possible demands upon the manufacturing facilities (such as available personnel, working hours, management policy, and goals) have been considered and are visualized. The MPS is a statement of what the company expects to produce and to purchase; it is expressed in selected items, specific quantities, and dates [2]. Materials Requirements Planning (MRP) driven by MPS was first applied in 1961 by J.A. Orlicky on J.I Case Company farm machinery. The rigorous logic and masses of data to be handled made this task an ideal computer application. The enormous potential benefits over existing ordering techniques generated great interest worldwide [4]. Subsequent paragraphs details the development of the MRP system for ORC industries.

In this software, requirements for MPS include customer orders and/or a sales forecast. MPS will be handled differently for the different divisions. For ORC Industries, MPS will be manually entered into a table. For Bell Canoe and Redfeather, MPS will use Production Orders based on customer orders and sales forecast.

Bill of material (BOM) is the term used to describe the "parts list" of components (raw materials and subcomponents) needed to complete a finished good [2]. An Exploded BOM is a list of all the raw materials from all the BOM levels of the finished good as well as a list of all the subcomponents from all the BOM levels of the finished good. For example, Figure 2 shows a list of BOMs for a mountain bike, training bike, and junior's bike. The raw materials are not bolded and the subcomponents are bolded.

Figure 2 also list the second level BOMs for the subcomponents wheel, seat, and training wheel.

Bill Of Materials

| Mountain Bike | Training Bike | Junior's Bike |
|----------------------|-------------------------|----------------------|
| 8 Bolts - Large | 8 Bolts - Large | 1 Basket |
| 5 Bolts - Small | 6 Bolts - Small | 8 Bolts - Large |
| 2 Brakes | 1 Brakes | 6 Bolts - Small |
| 1 Chain | 1 Chain | 2 Brakes |
| 1 Frame | 1 Frame | 1 Chain |
| 2 Handle Bar | 2 Handle Bar | 1 Frame |
| 1 Kick Stand | 1 Kick Stand | 2 Handle Bar |
| 2 Paddles | 2 Paddles | 1 Kick Stand |
| 1 Seat | 1 Seat | 2 Paddles |
| 1 Speed Changer | 2 Training Wheel | 1 Seat |
| 2 Wheel | 2 Wheel | 2 Wheel |

| Wheel | Seat | Training Wheel |
|---------------|-----------------|-----------------------|
| 1 Rim | 1 Bolts - Small | 1 Training Frame |
| 1 Rubber Tube | 1 Rubber Pad | 1 Training Rim |
| 1 Tire | 1 Seat Frame | 1 Training Tire |
| | | 1 Bolts - Large |

Figure 2. Bill of Materials

Figure 3 lists the exploded BOM for the mountain bike, training bike, and junior's bike. As seen from this figure, the subcomponents have been replaced by the quantity of the subcomponents used to make the finished good multiplied by the amount of the raw material used to make the subcomponent. Figure 4 shows the exploded list of subcomponents that are needed to produce the finished good. The Exploded BOMs for finished goods used by ORC Industries may have up to five levels or more and may comprise of many raw materials and subcomponents.

Exploded BOM - Raw Materials

| Mountain Bike | | Training Bike | | Junior's Bike | |
|----------------------|---------------|----------------------|----------------|----------------------|---------------|
| 8 | Bolts - Large | 10 | Bolts - Large | 1 | Basket |
| 6 | Bolts - Small | 7 | Bolts - Small | 8 | Bolts - Large |
| 2 | Brakes | 1 | Brakes | 7 | Bolts - Small |
| 1 | Chain | 1 | Chain | 2 | Brakes |
| 1 | Frame | 1 | Frame | 1 | Chain |
| 2 | Handle Bar | 2 | Handle Bar | 1 | Frame |
| 1 | Kick Stand | 1 | Kick Stand | 2 | Handle Bar |
| 2 | Paddles | 2 | Paddles | 1 | Kick Stand |
| 1 | Rubber Pad | 1 | Rubber Pad | 2 | Paddles |
| 1 | Seat Frame | 1 | Seat Frame | 1 | Rubber Pad |
| 1 | Speed Changer | 2 | Rim | 1 | Seat Frame |
| 2 | Rim | 2 | Rubber Tube | 2 | Rim |
| 2 | Rubber Tube | 2 | Tire | 2 | Rubber Tube |
| 2 | Tire | 2 | Training Frame | 2 | Tire |
| | | 2 | Training Rim | | |
| | | 2 | Training Tire | | |

Figure 3. Exploded BOM – Raw Materials

Exploded BOM - Subcomponents

| Mountain Bike | | Training Bike | | Junior's Bike | |
|----------------------|-------|----------------------|----------------|----------------------|-------|
| 1 | Seat | 1 | Seat | 1 | Seat |
| 2 | Wheel | 2 | Wheel | 2 | Wheel |
| | | 2 | Training Wheel | | |

Figure 4. Exploded BOM – Subcomponents

The prerequisites to MRP functionality are MPS, BOMs, and on-hand inventory. On-hand inventory includes inventory that is located at each location that is not defective. It also includes raw materials that have already been ordered and are due to arrive within the start and end time that MPR/DRP was calculated. These are the factors that drive MRP.

After analyzing the situation with MPR/DRP, the software will generate a list of Purchase Orders, Transfer Orders, and Production Orders. Purchase orders contain raw materials that are needed to be ordered for the production of finished goods. Transfer

Orders contain raw materials and/or subcomponents are needed to be transferred from one location to another for the production of finished goods. Production Orders contain subcomponents that are needed to be made for the production of finished goods.

Distribution Resource Planning, or DRP, was created by Andre Martin while he worked for Abbott Laboratories in the 1970s. DRP has become the accepted planning process for manufacturing industries with make-to-stock products [12]. DRP is the process for determining inventory requirements in a multiple plant/warehouse environment. DRP is an extension of MRP that recognizes the needs of the distribution system in the planning of production and inventory levels [13]. DRP will create Transfer Orders to move items from locations that have a surplus to locations that need the items. DRP lowers the amount of inventory that is over purchased as well as increases the availability of items. MRP/DRP data flow is represented in Figure 5.

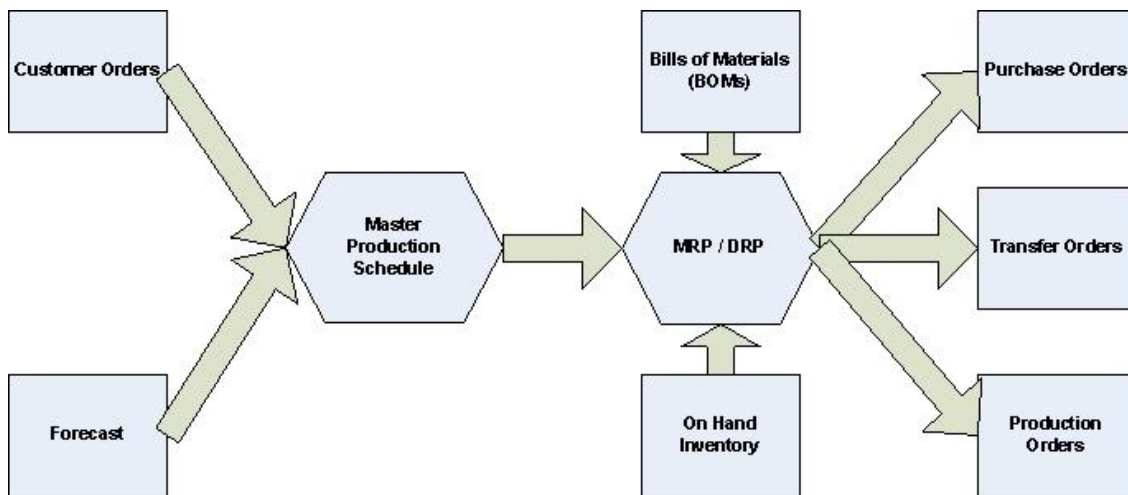


Figure 5. MRP/DRP Data Flow

2.1.1 Functionality Requirements

The following tables will describe the functional requirements of the MRP/DRP module. Table 1 describes the functionalities that are needed to be setup in order to run the Run MRP functionality. Table 2 describes the functionalities used to run MRP/DRP as well as functionalities used after running MRP/DRP.

| Functionality | Description |
|--------------------|---|
| Date Range | Date Range functionality allows the user to specify a date range to run MRP/DRP. MPR/DRP can be run for any specified date range such as a month, a quarter, a year. |
| Division | Division functionality allows the user to select the division for which to run MRP/DRP. |
| Invalid Bins | Invalid Bins functionality allows the user to specify which locations/bins should not be included in MRP/DRP. These locations/bins contain defective items and should not be counted while taking inventory. |
| MRP Mode | MRP Mode functionality allows the user to specify the software to run MRP or MRP/DRP. ORC Industries will most likely not run MRP by itself too often, but there may be a need for it in the future. This software could to be sold or given to another company. In this case, the company might not need to run DRP. Therefore, the user will have the capability to choose which mode to use. |
| MPS Mode | MPS Mode functionality allows the user to specify if MPS is based on Production Orders or manual entries. ORC Industries uses manual entries as the MPS. Redfeather and Bell Canoe use Production Orders as the MPS. |
| Purchase Locations | Purchase Locations functionality allows the user to specify which locations are able to receive purchased items. For ORC Industries, only a couple of the locations are able to receive purchased items. For a location that doesn't receive purchased items, when MRP/DRP is run, a Purchase Order will be created for the purchase location that is assigned to that location. A Transfer Order will also be created, so when the items are received at the purchase location, they are then transferred to the specified location. |
| Scrap Items | Scrap Item functionality allows to the user to assign a scrap percentage to an item. This is used mostly for fabric. For instance, when fabric is used to cut out shapes, not all the fabric is used. The fabric that is not used is most likely thrown away. So it becomes necessary to buy more fabric than what is on the BOM because of scrap. |

| | |
|--------------------|---|
| Transfer Locations | Transfer Locations functionality allows the user to specify which locations are able to transfer items between them. This functionality is needed because ORC only transfers items between certain locations. |
| Transfer Mode | Transfer Mode functionality allows the user to specify which transfer mode (Production Order Date, Greatest Amount to Order, or Production History) to use when running DRP. If set to Production Order Date, then transfers will be based on the production order dates. If set to Greatest Amount to Order, then transfers will be based on the greatest amount that is ordered. If set to Production History, then transfers are based on which location has used the item the most. |

Table 1. MRP/DRP Setup Functionality

| Functionality | Description |
|---------------------------|--|
| Process Orders | Process Orders functionality allows the user to finalize and create the Purchase Orders, Transfer Orders, and Production Orders in Navision. These orders are first created by MRP/DRP in the software and then edited if needed. |
| Run MRP | Run MRP functionality allows the user to run either MRP or MRP/DRP functionality depending on the MRP Mode specified by the user. |
| Update BOM Tables | Update BOM Tables functionality allows the user to update the exploded BOM information of finished goods. This information is stored in the MRP Database and then used when running MPR/DRP. |
| Update Production | Update Production functionality allows the user to update manual entries used in MPS. The user is able to add, delete, or modify these entries. |
| View/Edit Purchase Orders | View/Edit Purchase Orders functionality allows the user to view and edit purchase orders created by MRP/DRP. This functionality allows the user to make any needed changes that they feel is needed. For instance, the user knows that if a certain amount of items was purchased, the vendor would give a discount. In this case, the user can increase the amount to be ordered to save some cost. |

| | |
|-----------------------------|--|
| View/Edit Transfer Orders | View/Edit Transfer Orders functionality allows the user to view and edit Transfer Orders created by MRP/DRP. This functionality for instance, would allow the user to add additional items to the Transfer Order if needed. |
| View/Edit Production Orders | View/Edit Production Orders functionality allows the user to view and edit Production Orders created by MRP/DRP. This functionality for instance, would allow the user to add/decrease quantity to the Production Order if needed. |

Table 2. MRP/DRP Functionality

2.1.2 Design

The incremental prototyping lifecycle model was used in the development of the MRP/DRP. A prototype typically implements only a small subset of the features of the eventual program; this implementation may be completely different from that of the eventual product. The purpose of a prototype is to allow users of the software to evaluate proposals for the design of the eventual product by actually trying them out, rather than having to interpret and evaluate the design based on descriptions. Prototyping has several benefits: The software designer and implementer can obtain feedback from the users early in the project [2]. Incremental prototyping includes several iterations of prototypes before the final product is completed.

A prototype was developed after the requirements document was written and put into production. Before the prototype was developed, users were using Excel spreadsheets to determine MRP/DRP needs. Once the prototype was developed, the users compared the results to the spreadsheets to determine the accuracy. The prototype was changed to account for any discrepancies that were found. With the use of the prototype, additional requirements were also found that were not thought of before. The addition of requirements included bins with defective items, purchased items, conversion of purchased items, in-transit items, and scrap items. Bins with defective items were excluded when running MRP/DRP. Purchased items that were expected to be delivered within the time period specified by MRP/DRP were included with the on hand inventory when running MRP/DRP. The purchased items were converted from unit of measure

used in purchasing to the unit of measure used in inventory. This conversion is needed because, for example, ORC Industries will buy a box of tape, and there are ten tapes in a box. On the Purchase Order, it will show one box ordered, but this truly represents ten tapes. In-transit items were included with the on-hand inventory when running MRP/DRP. In Navision, when an item is on a Transfer Order and it is shipped but not received, it is considered in-transit. The item is taken out of inventory and it is not put back in until it is received. This item should be considered as on-hand inventory for the location that is receiving it because it will be put back into inventory once it is received in. Scrap items are needed to be accounted for. This is needed mostly for fabric because of the fabric that is thrown away once a design has been cut from it. A percentage will be assigned to each scrap item.

Users provided useful input to make the software easier to use. A generic user interface was first developed at first, but ultimately the user interface was modeled to look and function like Navision. The idea was to make it seem like MRP/DRP was part of Navision so users would feel more comfortable using the software. The following UML diagrams were used to help develop the software.

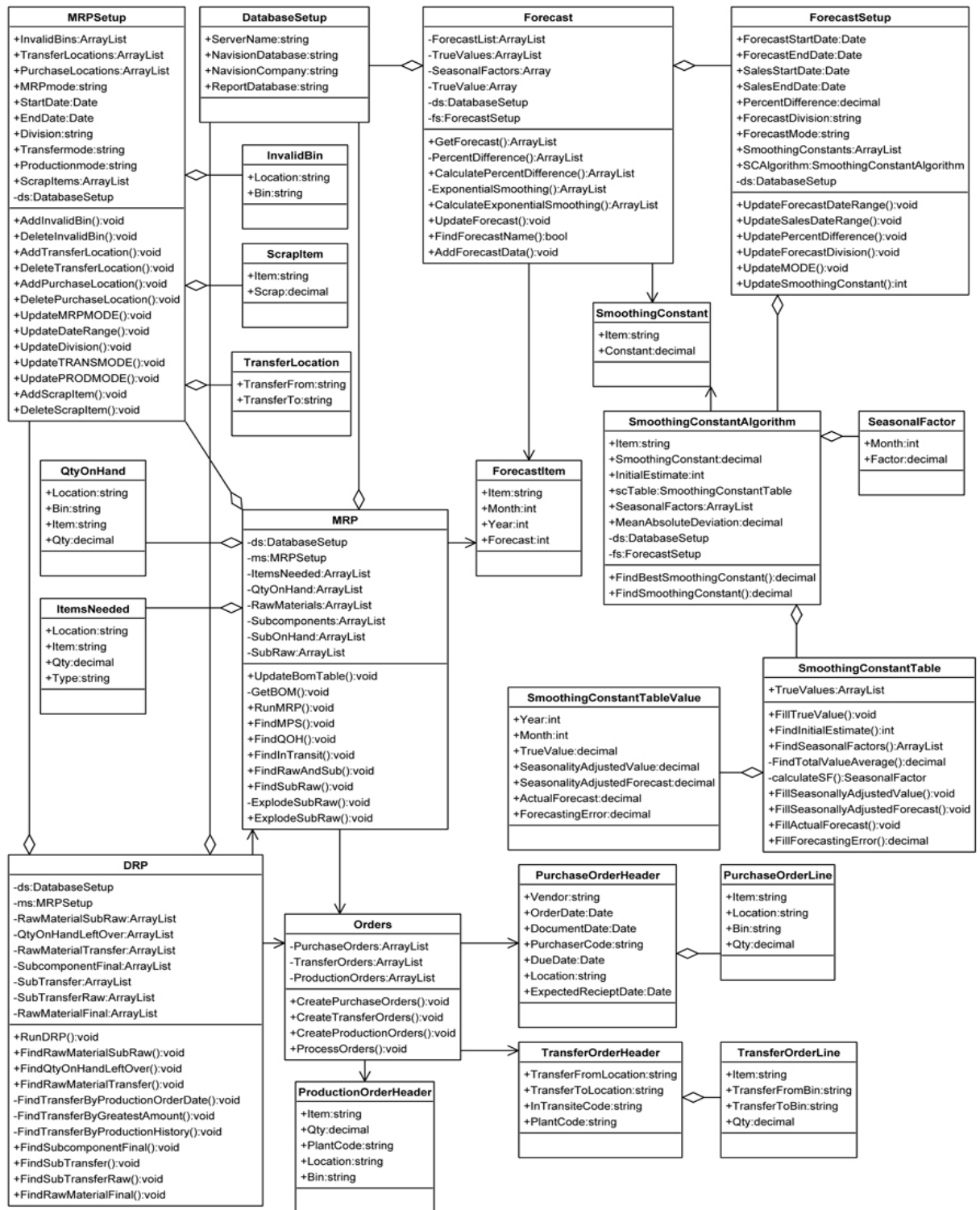


Figure 6. Class Diagram

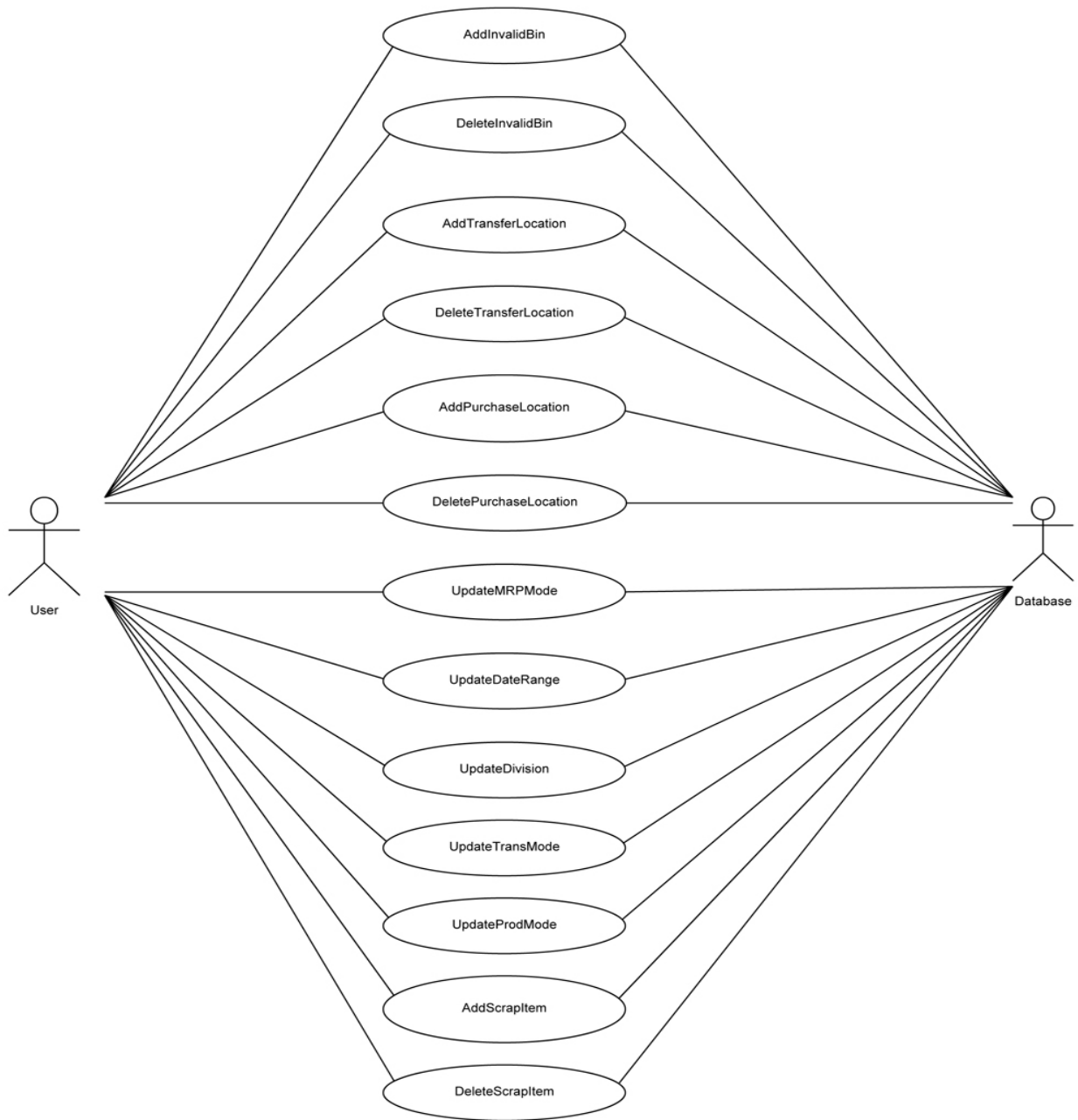


Figure 7. Use Case Diagram for MRP Setup

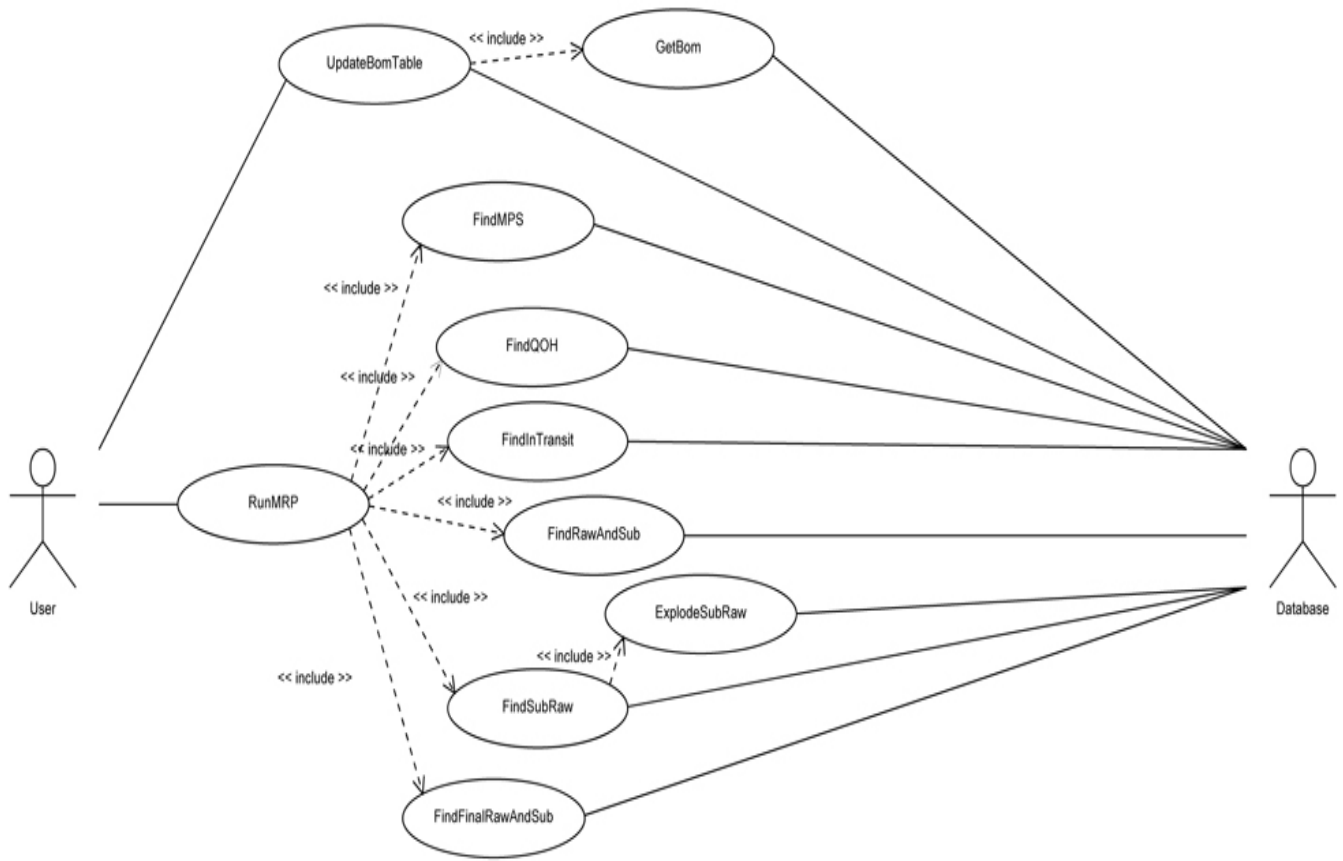


Figure 8. Use Case Diagram for MRP

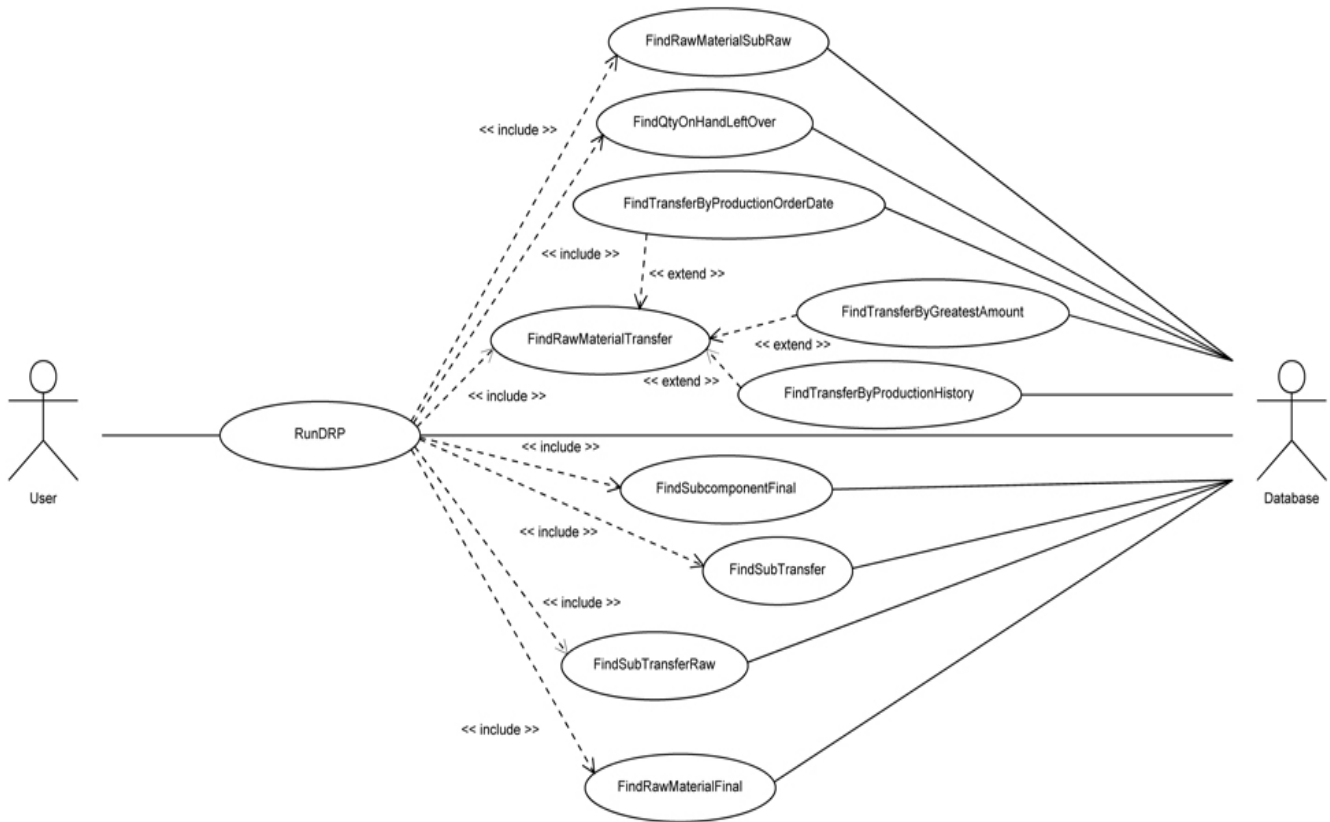


Figure 9. Use Case Diagram for DRP

The first MRP database that was created with the first prototype was generic. The tables were created just to hold the prototype information. Using best practices in designing databases in SQL server, the database name, tables, and columns were renamed to make them easy to understand for the developer. The final MRP database was also normalized to improve accuracy and integrity of the database. Because the software also interacts with the Navision database, it was also designed to exclude any information that was already in the Navision database. Figure 10 represent s the MRP/DRP database.

2.1.3 Implementation

MPS for ORC Industries comes from manual entries that are stored in the MRP database. A table was created in the MRP database to hold these manual entries. MPS for Redfeather and Bellcanoe come from Production Orders in Navision based on customer pre-orders and a sales forecast. When running MRP/DRP, Production Order information is retrieved from the Navision database. The sales forecast information used to create the Production Orders is stored in a table in the MRP database. The sales forecast information comes from running the Forecast module of the software. Exploded BOM information is stored in a table in the MRP database. This information comes from the Update BOM Tables functionality that retrieves BOM information from the Navision database and iterates through all the levels of the BOM of a finish good item. It calculates and records which raw materials and subcomponents that are needed to make the finished good item and it stores the information in the MRP database. When running MRP/DRP, on-hand inventory is retrieved from the Navision database. This inventory includes items that are currently at each location, items that are on a Purchase Order due to arrive during the time period specified by MRP/DRP, and in-transit items.

When MRP/DRP is run, it takes the finished good items from MPS that are needed to be produced and it retrieves the Exploded BOM for each item. It then multiplies the quantity needed to be produced for each finished good item by the quantity of each item of the Exploded BOM. The results of all the calculations are then summed up to create a final list of total raw materials and subcomponents needed by location. This will be called **Items Needed**. On-hand inventory will then be calculated. Items on Purchase Orders due to arrive during the time period specified by MRP/DRP are found and in some cases converted from the unit of measure used in purchasing to the unit of measure used in inventory. Non-defective items are then found from each location and summed with the items on the Purchase Orders. In-transit items are also found and included. This will be called **Qty on Hand**.

We will first look at the equations of the MRP functionality. As an illustration, Figure 11 will show the equations and Table 3 will give the descriptions.

$$\text{Raw Material}_R = \text{Items Needed}_R - \text{Qty on Hand}_R$$

$$\text{Subcomponents}_S = \text{Items Needed}_S - \text{Qty on Hand}_S$$

$$\text{Sub on Hand}_S = \text{Items Needed}_S - \text{Subcomponents}_S$$

$$\text{SubRaw}_R = \text{Sub on Hand}_S * \text{Exploded BOM}$$

$$\text{Raw Material Final}_R = \text{Raw Material}_R - \text{SubRaw}_R$$

where R = raw materials and S = subcomponents

Figure 11. MRP Equations

| Equation Name | Description |
|--------------------|--|
| Raw Material | The raw materials on Items Needed are subtracted by the raw materials on Qty on Hand for each location. |
| Subcomponent | The subcomponents on Items Needed are subtracted by the subcomponents on Qty on Hand for each location. The final subcomponents that are needed to be produced are also represented by Subcomponent . |
| Sub on Hand | The Subcomponents on Items Needed are subtracted by the subcomponents on Subcomponent , meaning they are already in stock and not needed to be produced. |
| SubRaw | The Exploded BOM for each subcomponent on Sub on Hand for each location is found and then each subcomponent is multiplied by the quantity of each raw material of its Exploded BOM. SubRaw is needed because we don't want to purchase raw materials for subcomponents that have already been made and are in inventory. |
| Raw Material Final | Raw Material is then subtracted by SubRaw in order to find the final raw materials needed to be purchased. |

Table 3. MRP Equations

We will now look at the equations of the MRP/DRP functionality. As an illustration Figure 12 will show the equations and Table 4 will give the descriptions.

$Raw\ Material_R = Items\ Needed_R - Qty\ on\ Hand_R$
 $Subcomponent_S = Items\ Needed_S - Qty\ on\ Hand_S$
 $Sub\ on\ Hand_S = Items\ Needed_S - Subcomponent_S$
 $SubRaw_R = Sub\ on\ Hand_S * Exploded\ BOM$
 $Raw\ Material\ SubRaw_R = Raw\ Material_R - SubRaw_R$
 $Qty\ on\ Hand\ Leftover_{RS} = Qty\ on\ Hand_{RS} - Items\ Needed_{RS}$
 $Raw\ Material\ Transfer_R = Raw\ Material\ SubRaw_R - Qty\ on\ Hand\ Leftover_R$
 $Subcomponent\ Final_S = Subcomponent_S - Qty\ on\ Hand\ Leftover_S$
 $SubTransfer_S = Subcomponent_S - Subcomponent\ Final_S$
 $SubTransferRaw_R = SubTransfer_S * Exploded\ BOM$
 $Raw\ Material\ Final_R = Raw\ Material\ Transfer_R - SubTransferRaw_R$
 where R = raw materials and S = subcomponents

Figure 12. MRP/DRP Equations

| Equation Name | Description |
|----------------------|--|
| Raw Material | The raw materials on Items Needed are subtracted by the raw materials on Qty on Hand for each location. |
| Subcomponent | The subcomponents on Items Needed are subtracted by the subcomponents on Qty on Hand for each location. |
| Sub on Hand | The Subcomponents on Items Needed are subtracted by the subcomponents on Subcomponent , meaning they are already in stock and not needed to be produced. |
| SubRaw | The exploded BOM for each subcomponent on Sub on Hand for each location is found and then each subcomponent is multiplied by the quantity of each raw material of its Exploded BOM. |
| Raw Material SubRaw | Raw Material is then subtracted by SubRaw . |
| Qty on Hand Leftover | Raw materials and subcomponents on Qty on Hand will also subtracted by raw materials and subcomponents on Items Needed for each location. This is done to determine if there is leftover inventory that is not needed at each location. This inventory can then be transferred to be used at a different location. |

| | |
|-----------------------|---|
| Raw Material Transfer | Depending on which transfer mode you have set (Production Order Date, Greatest Amount to Order, or Production History), the raw materials on Raw Material SubRaw is subtracted by the raw materials on Qty on Hand Leftover for each location. Raw Material Transfer will contain both raw materials that are needed to be purchased as well as raw materials that are needed to be transferred for each location. |
| Subcomponent Final | Then the subcomponents on Subcomponent are subtracted by the subcomponents on Qty on Hand Leftover for each location. The final subcomponents that are needed to be produced and transferred are represented by Subcomponent Final . |
| SubTransfer | The subcomponents that are going to be transferred are calculated by taking the Subcomponent and subtracting by the Subcomponent Final . |
| SubTransferRaw | The exploded BOM for each subcomponent on Sub Transfer for each location is found and then each subcomponent is multiplied by the quantity of each raw material of its Exploded BOM. |
| Raw Material Final | Raw Material Transfer is then subtracted by SubTransferRaw in order to find the final raw materials needed to be purchased and transferred. |

Table 4. MRP/DRP Equations

2.2 Sales Forecasting

A sales forecast is a prediction of future sales, based mainly on past sales performance. It is a good indicator of future sales in stable market conditions, but may be less reliable in times of rapid market change [3]. Forecasting sales can be considered a projection as well as a prediction. A projection is a calculated figure based on simple examination of past data, and the assumption of all other things being equal in the future. A prediction is a calculated figure based on more complex analyses of relationships between causes and effects in the past, and the use of quantitative measures of these relationships to predict the outcome of future combinations of these causal factors [7]. The most important thing to realize is that sales forecasting is about managing resources and managing risk [10]. Therefore, it is important that sales forecast are accurate so that

all resources are aligned to provide more timely and efficient customer service and to meet the maximum amount of customer demand [9]. Inaccurate sales forecasts may lead to inappropriate inventory levels and increased supply problems. Very often this results in increased costs, and money being spent unnecessarily [11].

Sales forecasting is relatively new for ORC Industries because Redfeather and Bell Canoe have been acquired by ORC for only a few years back. Most of ORC Industries’s business is with government contracts which already have a predefined ordered amount. A standard way to run a sales forecast has not been set. ORC Industries previously used a simple forecasting algorithm that would just multiply the previous year’s sales by a percentage specified by the user. However, as stated in the Introduction, it was decided that it would enhance this project by developing a forecasting algorithm to try to predict future sales as accurately as possible. For this software, the sales forecast will be used to create Production Orders. Production Orders represent MPS which will be a component that drives MRP/DRP.

2.2.1 Functionality Requirements

The following tables will describe the functional requirements of the Forecast module. Table 5 describes the functionalities that are needed to be setup in order to run the Run Forecast functionality. Table 6 describes the functionalities used to run the Forecast as well as functionalities used after running the Forecast.

| Functionality | Description |
|---------------------|---|
| Division | Division functionality allows the user to select which division to run the Forecast. For ORC Industries, the Forecast will only be run for Redfeather and Bell Canoe. |
| Forecast Date Range | Forecast date range functionality allows the user to specify a date range to run the Forecast. The Forecast can be run for a month, a quarter, a year, or another specified date range. |
| Forecast Mode | Forecast Mode functionality allows the user to specify which Forecast Mode (Percent Difference or Exponential Smoothing) to use when running Forecast. Percent Difference Mode calculates the Forecast based on a percentage specified by the user. |

| | |
|---------------------------|--|
| | The percentage is multiplied by the previous year's sales. If set to Exponential Smoothing, then Forecast is based on Exponential Smoothing algorithm. |
| Percent Difference | Percent Difference functionality allows the user to specify the percent difference used in the Percent Difference Forecast Mode. This value is stored in the MRP database and use to run the Forecast. |
| Sales Date Range | Sales Date Range functionality allows the user to set the sales date range of the Forecast. |
| Update Smoothing Constant | Update Smoothing Constant functionality allows the user to update the Smoothing Constant that is used in the Exponential Smoothing algorithm. |

Table 5. Forecast Setup Functionality

| Functionality | Description |
|----------------------|--|
| Process Forecast | Process Forecast functionality allows the user to finalize and create a sales forecast. The user will be able to create multiple sales forecasts for the same time period if needed. These sales forecasts can be used for comparison. |
| Run Forecast | Run Forecast functionality allows the user to calculate the Forecast using the specified forecast setup information. |
| Update Forecast | Update forecast functionality allows the user to modify the Forecast. The user will be able to add, delete, and edit the Forecast. This functionality allows the user to make the necessary changes that they feel are needed. |

Table 6. Forecast Functionality

2.2.2 Research

In order to develop a good forecast algorithm, the developer first chose the following algorithms published in literature: Linear Regression, Exponential Function, Logarithmic Function, Percent Difference, Moving Average, and Exponential Smoothing.

Linear Regression is a simple forecasting method that calculates a straight line. By its nature, the straight line it produces suggests that it is best suited to data that is expected to change by the same absolute amount in each time period. The mathematical equation in Figure 13 shows that the variable y varies by a constant and increasing (or decreasing) over time (denoted by t) by factor of b .

$$y_t = a + bt$$

Figure 13. Linear Regression Algorithm

Exponential Function is a method that uses an increasing or decreasing curve rather than the straight line of the Linear Regression method. An exponential method is useful when it is known that there is, or has been, increasing growth or decline in past periods.

$$y_t = ab^t$$

Figure 14. Exponential Function Algorithm

Logarithmic Function is a method similar to Exponential Function, but uses an alternate logarithmic model.

$$y_t = a + b \log(t)$$

Figure 15. Logarithmic Function Algorithm

Percent Difference smoothes out past data by calculating the difference between one period ago versus a varying number of periods ago.

$$y_t = y_{t-1} * y_{t-1} / y_{t-1-n}$$

where n is a variable number of periods

Figure 16. Percent Difference Algorithm

The Moving Average technique forecasts demand by calculating an average of previous sales from a specified number of previous periods. Each new forecast drops the sales from the oldest period and replaces it with the sales in the most recent period; thus, the data in the calculation “moves” over time.

$$M_t = (Y_{t-L+1} + Y_{t-L+2} + \dots + Y_{t-1} + Y_t) / L$$

L = number of months used in moving average

M = month

t = the period

Y = sales for month

Figure 17. Moving Average Algorithm

Exponential Smoothing is a type of modified moving average. The idea is to correct a prior forecast and use it to make the next forecast. Exponential Smoothing uses a Smoothing Constant and a damping factor to help determine the amount of error in an earlier forecast to use in making the next one. The sum of the Smoothing Constant and damping factor is one. For example, if your last forecast was too low, Exponential Smoothing increases your next forecast and if your last forecast was too high, Exponential Smoothing decreases your next forecast. Exponential smoothing corrects the next forecast in a way that would have made your previous forecast a better one.

$$M_t = uY_t + (1 - u) M_{t-1}$$

M = month

t = the period

u = Smoothing Constant

Y = sales for month

Figure 18. Exponential Smoothing Algorithm

These algorithms were used on a group of selected items from Redfeather. Redfeather was chosen because between Redfeather and Bell Canoe (the two divisions that do forecasting), Redfeather had the most historical information that could be used. Bell Canoe was a more recent acquisition and only had a years worth of historical information. These items included items that had a large number of sales to items that have very little sales. Figures 19-24 represent some of the data that was collected. The algorithms were tested against a wide range of variables and also tested for a three year period from 2004 to 2006. The results of each algorithm included the year, month, forecast quantity, actual quantity, and difference. The ‘forecast quantity’ is calculated for each year and month combination for the item. The ‘actual quantity’ represents what was actually sold for the year and month combination for the item. The ‘difference’ field shows the absolute value of the difference of the forecast quantity subtracted from the actual quantity. The result of the differences for each year and month was put into another spreadsheet and graph. Figure 25 represents a sample graph of this combined data.

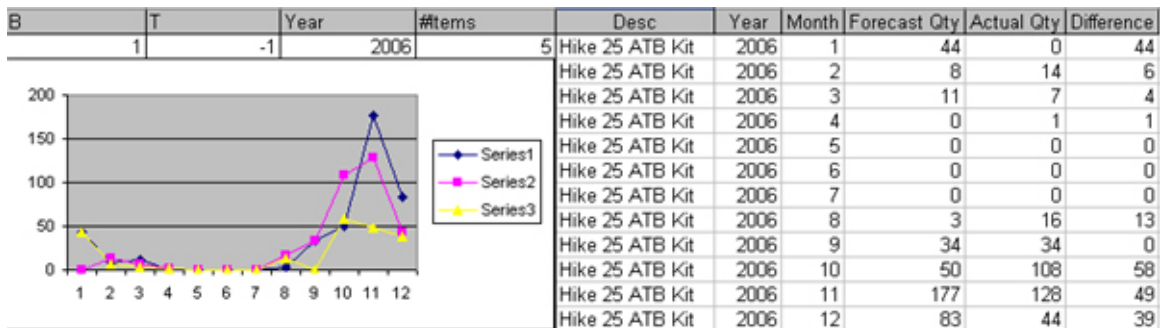


Figure 19. Linear Regression Sample Data

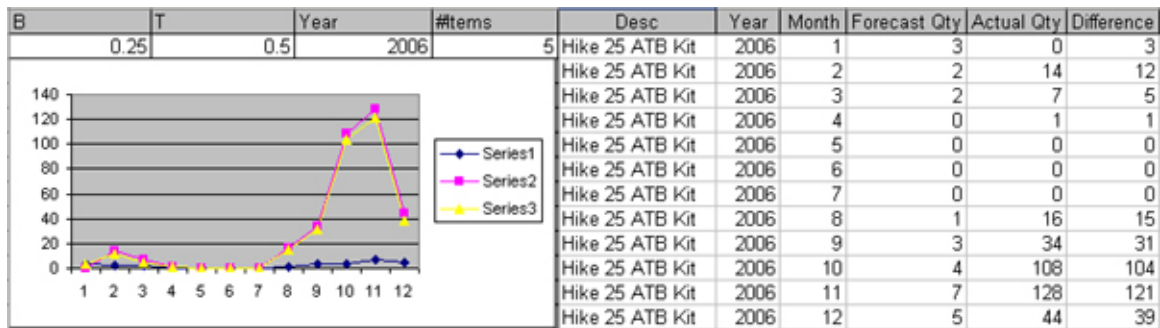


Figure 20. Exponential Function data

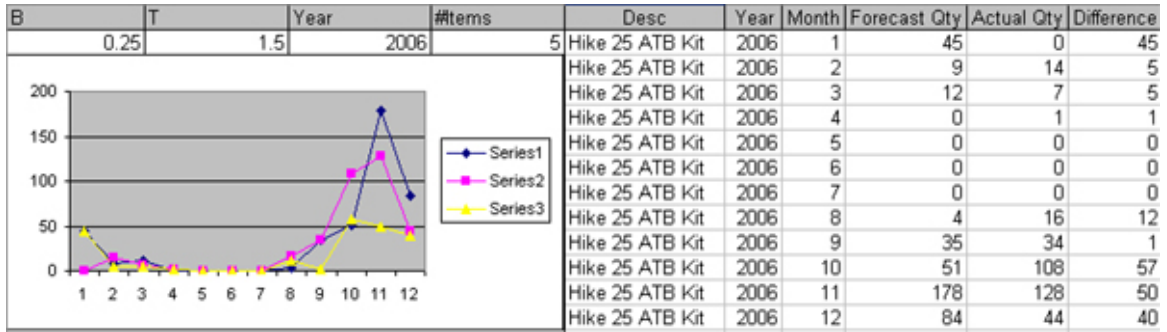


Figure 21. Logarithmic Function Sample Data

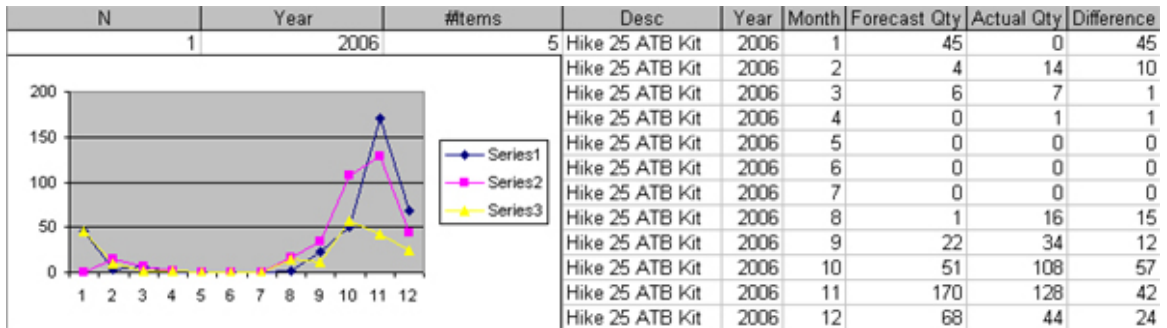


Figure 22. Percent Difference Sample Data

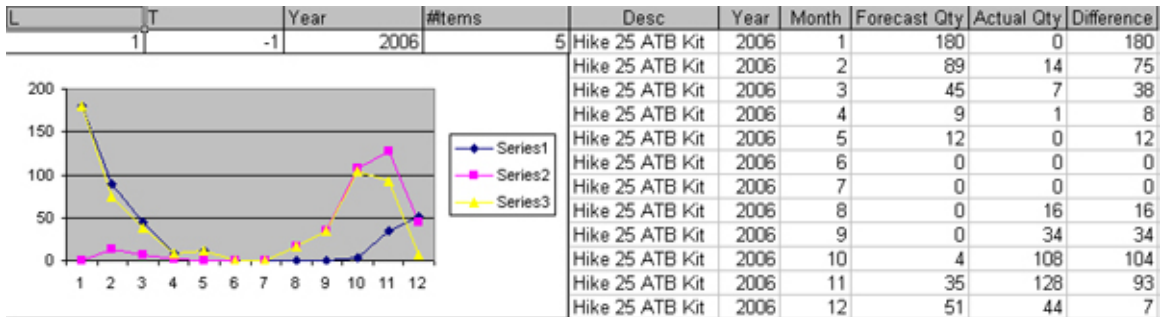


Figure 23. Moving Average Sample Data

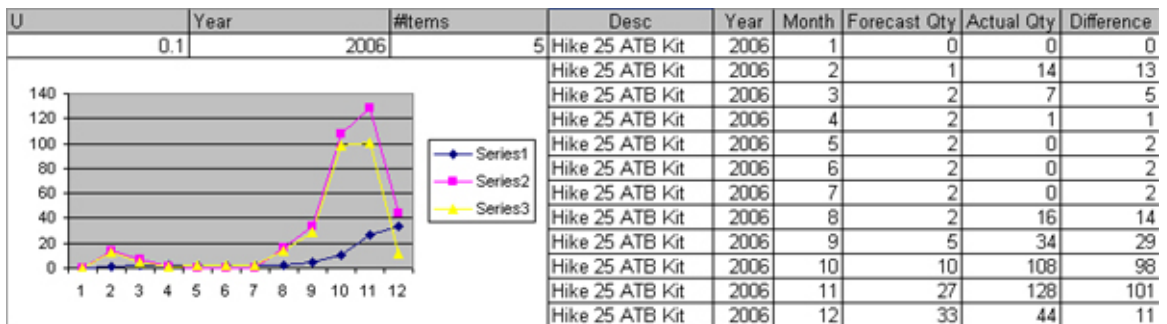


Figure 24. Exponential Smoothing Sample Data

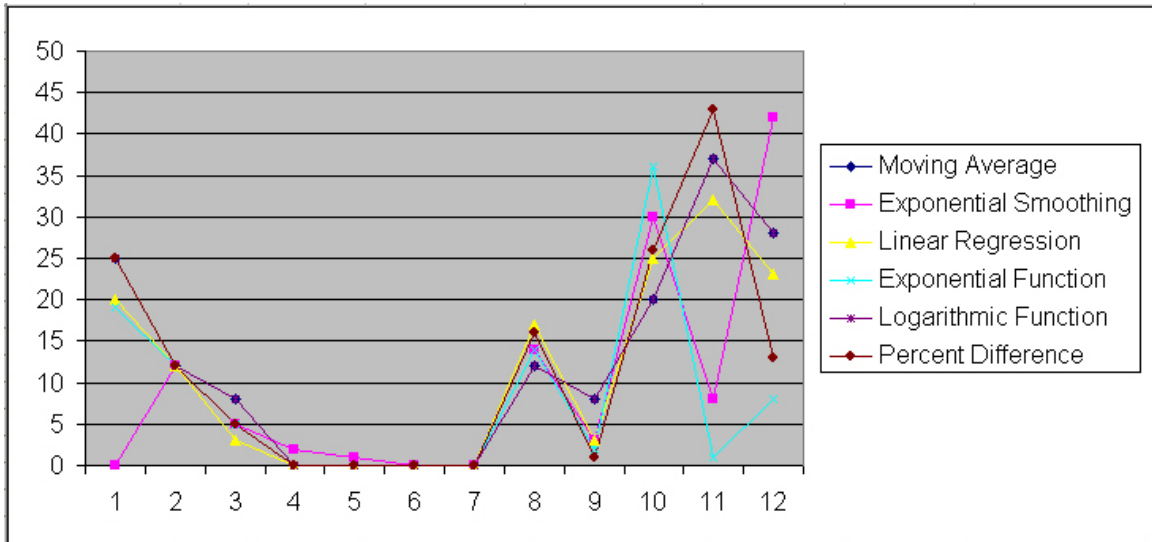


Figure 25. Algorithm Analysis Results

The results were analyzed but a best fit algorithm was not determined. Therefore, the Statistical Consulting Center of the University of Wisconsin – La Crosse was contacted for some guidance. Dr. Abdulaziz Elfessi, who is the head of the Statistical Consulting Center, was asked to look at the data to help determine the best algorithm to use. Dr. Elfessi had experience with forecasting and was able to determine that the Exponential Smoothing Algorithm was the best fit. However, he recommended using an Exponential Smoothing Algorithm that included seasonality. Figure 26 represents the Exponential Smoothing Algorithm that was modified to include seasonality.

$$M_t = (u (Y_t/S) + (1 - u) M_{t-1}) S$$

M = month

t = the period

u = Smoothing Constant

Y = sales for month

S = seasonality

Figure 26. Exponential Smoothing Algorithm with Seasonality

The next step was finding the best Smoothing Constant to use. Dr. Elfessi provided a spreadsheet that contained an Exponential Smoothing algorithm. This spreadsheet would help determine the best Smoothing Constant. The spreadsheet was modified to include seasonality for multiple years. A set of Seasonal Factors were calculated for each year. The first year wouldn't have a set of Seasonal Factors because the only data to compare it against was itself, so the Seasonal Factor would only be 1 for each month. The following years will have a set of Seasonal Factors based on information from the previous year(s) and its own year's information. For example, Figure 27 is an example of the spreadsheet that was used. The date range for Figure 27 is January 2005 to December 2007. The first year will not have a set of Seasonal Factors, the second year will have a set of Seasonal Factors based on information from January 2005 to December 2006, and the third year will have a set of Seasonal Factors based on information from January 2005 to December 2007. By changing the Smoothing Constant and looking at the Overall % Error, the best Smoothing Constant would be the one with the lowest Overall % Error.

The True Value is the actual sales. The Seasonally Adjusted Value is the True Value divided by the Seasonal Factor. The Seasonally Adjusted Forecast is the forecast calculated from the Exponential Smoothing algorithm. The Actual Forecast is the Seasonally Adjusted Forecast multiplied by the Seasonal Factor. The Forecasting Error is the absolute value of the difference of the True Value subtracted from the Actual Forecast. The Forecasting Error % was the percent error. Figure 28 shows the True Value vs. the Actual Forecast of the example. Figure 29 shows the Forecasting Error of the example.

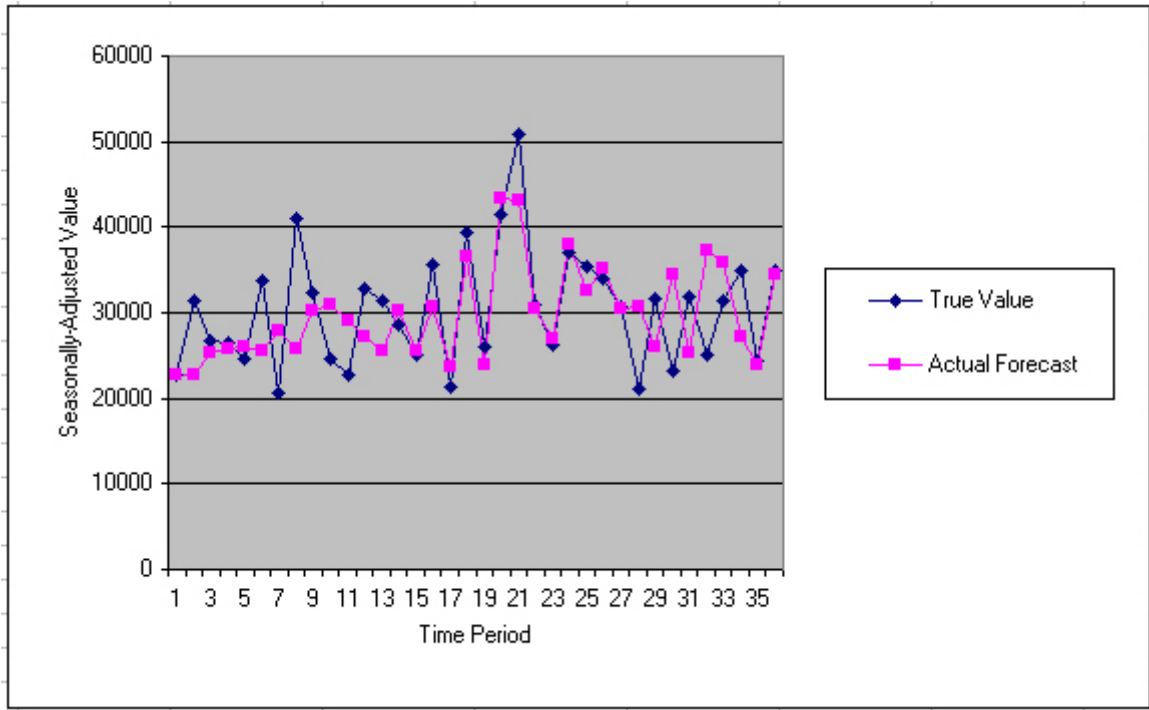


Figure 28. True Value Vs. Actual Forecast

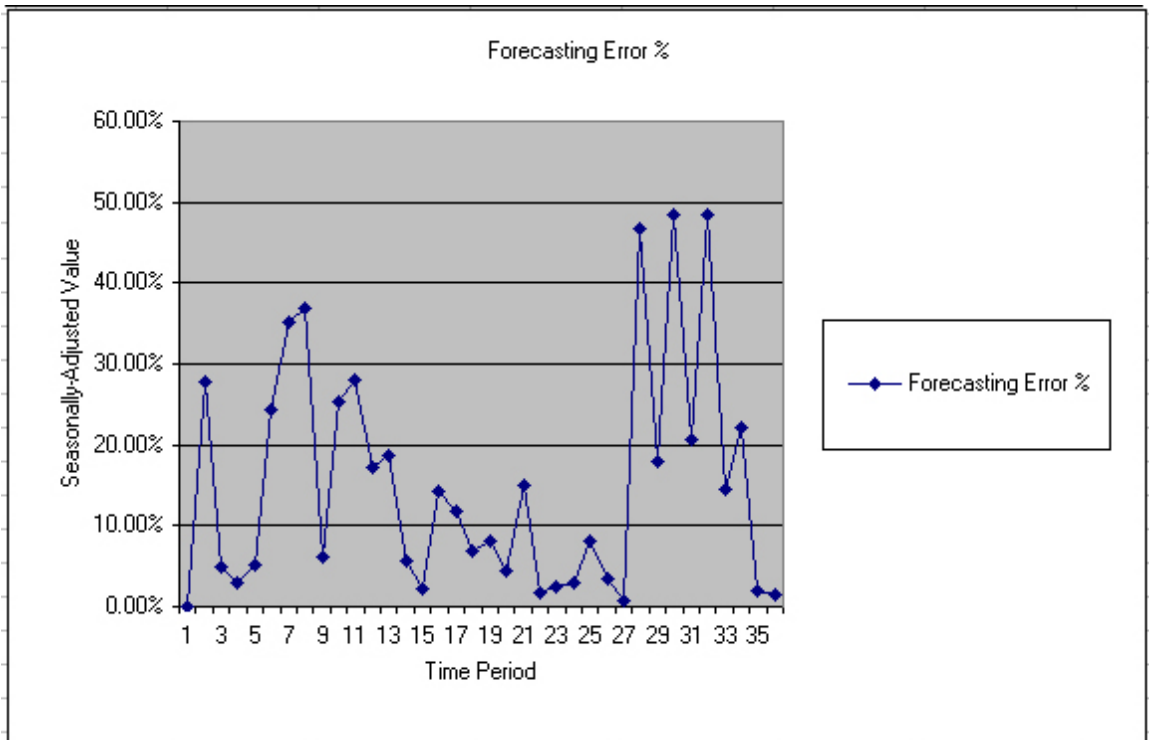


Figure 29. Forecast Error

The spreadsheet was used on the same group of items from the previous algorithms. The results were mixed. Some of the data provided good results while other data didn't. Most of the data was within a 20% error. Therefore, an outside company was asked to supply data to test against to validate the algorithm. The data used was for the period of January 2005 to December 2007. The data for the items of the outside company had more sales than that of the Redfeather items. The spreadsheet was used on this data and the results were the same. Some of the data provided good results while other data didn't. Again most of the data was within a 20% error. The decision was made to use the algorithm but allow the user to make any needed changes to the forecast. This would allow the user to increase or decrease any forecast that wasn't in the expected range.

2.2.3 Design

The developer used incremental prototyping approach to develop the forecasting module. Like the MRP module, the Forecast module's user interface was modeled to look and function like Navision. For the database design, the forecast tables were designed in the MRP database and were also normalized as well. Because the Forecast module also interacts with the Navision database, the forecast tables were also designed not to include any information that was already in the Navision database. The Class Diagram that was used for the Forecast is represented in Figure 6. The Use Case Diagrams are represented by Figures 30-31. The Database Diagram is represented by Figure 32.

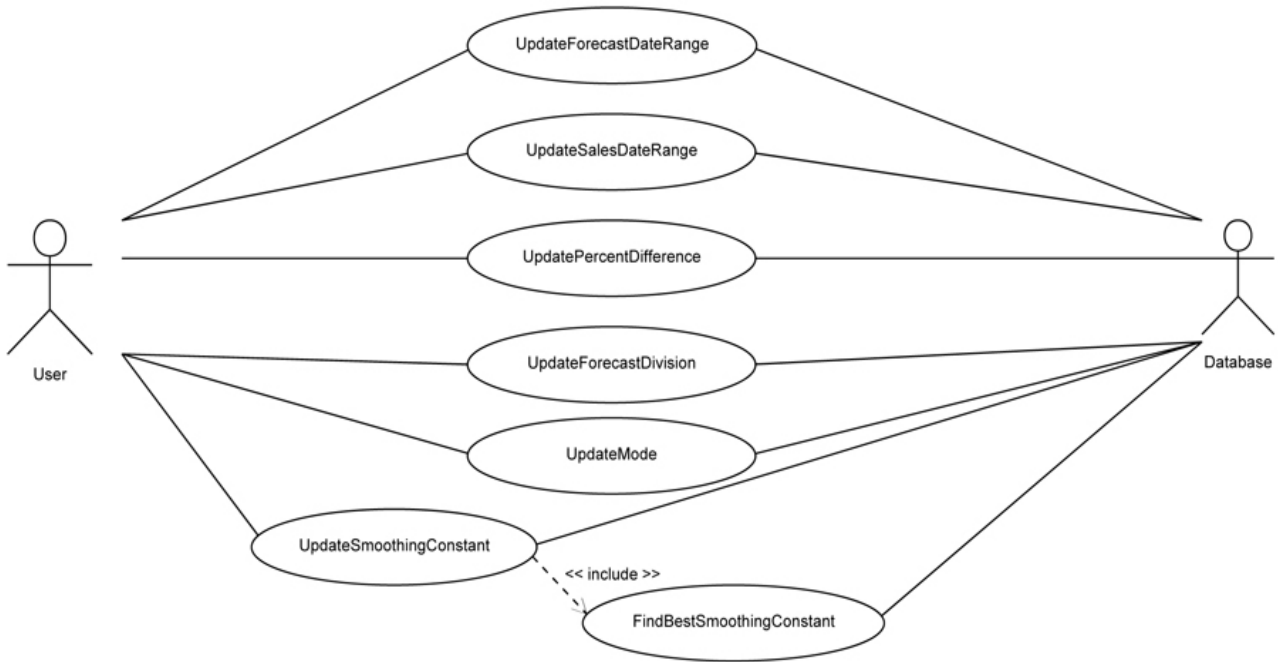


Figure 30. Use Case for Forecast Setup

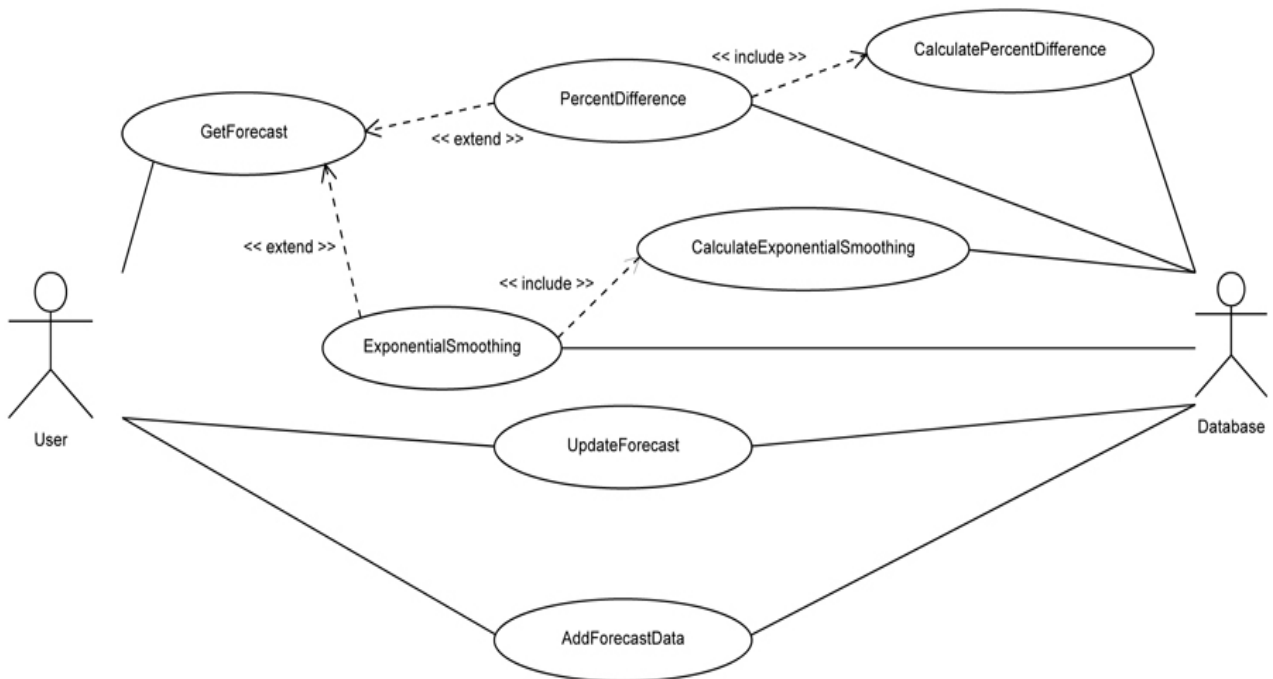


Figure 31. Use Case for Forecast

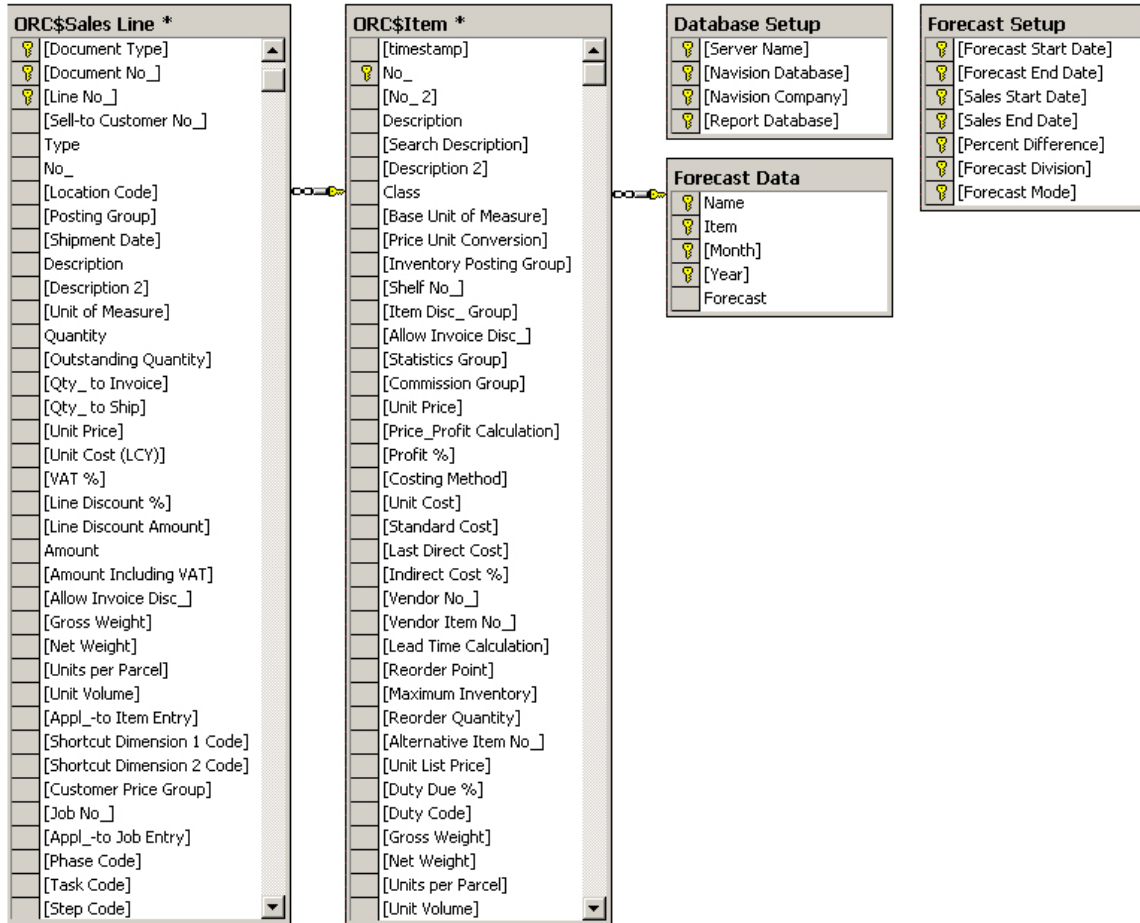


Figure 32. Database Diagram for Forecast

2.2.4 Implementation

When running the Forecast, sales information is retrieved from the Navision database. Depending on the Forecast Mode chosen, the Forecast will be calculated differently. If the Forecast Mode is set to Percent Difference, then the forecast generated will be based on a percent that the user has specified in the Forecast Setup. The previous year's sales will be retrieved from the Navision database and will be multiplied by the percent specified by the user. The result will be the forecast. The user will then have the capability to modify this forecast as needed.

If the Forecast Mode is set to Exponential Smoothing, the forecast will be calculated using the Exponential Smoothing Algorithm. In order to use Exponential Smoothing, each item will have to have a Smoothing Constant assigned to it. Each item will have its own Smoothing Constant instead of using an overall Smoothing Constant because it

would make the forecast more accurate. Therefore, functionality was created to calculate the Smoothing Constant for each item. The Smoothing Constant functionality was based on the Exponential Smoothing Algorithm spreadsheet that was provided by the Statistical Consulting Center. For each item, the True Value for each year and month combination within the Sales Forecast Date Range specified by the user was retrieved from the Navision Database. The set(s) of Seasonal Factors were then found for each year.

For instance, in the following example we will use the data from Figure 27 with the Sales Date Range set for a three year period, January 2005 to December 2007. Two sets of Seasonal Factors will be calculated. The first will be for the first two years and the second will be for the three years. Originally the algorithm that the Statistical Consulting Center provided only had one set of Seasonal Factors for all the calculations. The sets of Seasonal Factors were then re-calculated and used in the algorithm. The results were compared with the results of the algorithm that only had one set of Seasonal Factors. The forecast was more accurate for the algorithm that has the sets of Seasonal Factors. Therefore, it was decided to use the algorithm with the sets of Seasonal Factors in the software.

To find the set Seasonal Factors for each year, the average of the total True Value for all sales was calculated for the period. This will be called **Avg True Value**. Then for the first set of Seasonal Factors, there will be Seasonal Factors for each month, January to December. The Seasonal Factor will be found by taking the January 2005's True Value and adding it with January 2006's True Value. This value is then divided by the number of months and then divided by the **Avg True Value**. As an illustration Figure 33 will show this equation. This algorithm will be calculated for each month. The result is the **2nd Year Seasonal Factor** table found in Figure 27.

$$\text{Seasonal Factor} = \text{Month}_1 + \text{Month}_2 / \text{Number of Months} / \text{Avg True Value}$$

Figure 33. Seasonal Factor Algorithm for Two Year Period

For the second set of Seasonal Factors, there will be Seasonal Factors for each month as well, January to December. The Seasonal Factor will be found by taking the January 2005's True Value, adding it with January 2006's True Value, and adding it with January

2007's True Value. This value is then divided by the number of months and then divided by the **Avg True Value**. As an illustration Figure 34 will show this equation. This algorithm will be calculated for each month. The result is the **3rd Year Seasonal Factor** table found in Figure 27.

$$\text{Seasonal Factor} = \text{Month}_1 + \text{Month}_2 + \text{Month}_3 / \text{Number of Months} / \text{Avg True Value}$$

Figure 34. Seasonal Factor Algorithm for Three Year Period

Now that we have the True Values and the sets of Seasonal Factors we can start the calculation of the **Overall % Error**. As an illustration, Figure 35 will show the equations for all the values needed to find the **Forecasting Error** of the first year and Table 7 will give the descriptions.

$$\text{Seasonally Adjusted Value}_C = \text{True Value}_C$$

$$\text{SCSAV} = \text{Smoothing Constant} * \text{Seasonally Adjusted Value}_P$$

$$\text{SCSAF} = (1 - \text{Smoothing Constant}) \text{Seasonally Adjusted Forecast}_P$$

$$\text{Seasonally Adjusted Forecast}_C = \text{SCSAV} + \text{SCSAF}$$

$$\text{Actual Forecast}_C = \text{Seasonally Adjusted Forecast}_C$$

$$\text{Forecasting Error}_C = \text{AbsoluteValue}(\text{True Value}_C - \text{Actual Forecast}_C)$$

where C = current month and P = previous month

Figure 35. Smoothing Constant Algorithm First Year Equations

| Equation | Description |
|------------------------------|---|
| Seasonally Adjusted Value | For 2005, January through December, the Seasonally Adjusted Value for each month will be the same as its True Value . |
| SCSAV | The Smoothing Constant will be multiplied by the previous month's Seasonally Adjusted Value . |
| SCSAF | The Smoothing Constant will be subtracted from one and then multiplied by the previous month's Seasonally Adjusted Forecast . |
| Seasonally Adjusted Forecast | For 2005, the very first entry for January will have its True Value also serve as its Seasonally Adjusted Forecast . For February through December, the |

| | |
|-------------------|---|
| | Seasonally Adjusted Forecast will use the Exponential Smoothing algorithm. The Seasonally Adjusted Forecast for the current month will be SCSAV + SCSAF . |
| Actual Forecast | For 2005, the very first entry for January will have its True Value also serve as its Actual Forecast . For February through December, the Actual Forecast will be the same as the Seasonally Adjusted Forecast . |
| Forecasting Error | For 2005, the very first entry for January, the Forecasting Error will be zero. For February through December, the Forecasting Error will be the absolute value of the True Value subtracted by the Actual Forecast . |

Table 7. Smoothing Constant Algorithm First Year Equations

For 2006, the set of Seasonal Factors will be represented by the **2nd Seasonal Factor** table in Figure 27. For 2007, the set of **Seasonal Factors** will be represented by the **3rd Seasonal Factor** table in Figure 27. As an illustration, Figure 36 will show the equations for all the values needed to find the **Forecasting Error** of the second year and third year and Table 8 will give the descriptions.

$$\text{Seasonally Adjusted Value}_C = \text{True Value}_C / \text{Seasonal Factor}_C$$

$$\text{SCSAV} = \text{Smoothing Constant} * \text{Seasonally Adjusted Value}_P$$

$$\text{SCSAF} = (1 - \text{Smoothing Constant}) \text{Seasonally Adjusted Forecast}_P$$

$$\text{Seasonally Adjusted Forecast}_C = \text{SCSAV} + \text{SCSAF}$$

$$\text{Actual Forecast}_C = \text{Seasonally Adjusted Forecast}_C * \text{Seasonal Factor}_C$$

$$\text{Forecasting Error}_C = \text{AbsoluteValue}(\text{True Value}_C - \text{Actual Forecast}_C)$$

where C = current month and P = previous month

Figure 36. Smoothing Constant Algorithm Second and Third Year Equations

| Equation | Description |
|---------------------------|---|
| Seasonally Adjusted Value | For January through December, the Seasonally Adjusted Value will be the True Value divided by |

| | |
|------------------------------|---|
| | the Seasonal Factor of the corresponding month. |
| SCSAV | The Smoothing Constant will be multiplied by the previous month's Seasonally Adjusted Value . |
| SCSAF | The Smoothing Constant will be subtracted from one and then multiplied by the previous month's Seasonally Adjusted Forecast . |
| Seasonally Adjusted Forecast | The Seasonally Adjusted Forecast will use the Exponential Smoothing algorithm. The Seasonally Adjusted Forecast for the current month will be SCSAV + SCSAF . |
| Actual Forecast | The Actual Forecast will be the Seasonally Adjusted Forecast multiplied by the Seasonal Factor of the corresponding month. |
| Forecasting Error | Forecasting Error will be the absolute value of the True Value subtracted by the Actual Forecast . |

Table 8. Smoothing Constant Algorithm Second and Third Year Equations

The **Overall % Error** will be calculated by taking the sum of the Forecasting Errors and dividing by the sum of the True Values. In order to find the best Overall % Error, the functionality will calculate a couple of Smoothing Constant Algorithms using a different Smoothing Constant each time. The first Smoothing Constant will be 0.1 and the Smoothing Constant will be incremented by 0.1 each time another algorithm is ran. The Smoothing Constant will be increased up to a value of 0.9. The Overall % Error will be stored for each algorithm. At the end, the Smoothing Constant with the lowest Overall % Error will be used as the Smoothing Constant for the item. This value will be assigned to the item in the Navision database and used during the Exponential Smoothing functionality.

Once the Smoothing Constant has been updated for the items, the Forecast can be calculated using the Forecast Mode of Exponential Smoothing. First the True Values for the specified Sales Forecast Date Range will be retrieved from the Navision database. The Seasonal Factors will be calculated using the True Values. The Seasonal Factors will depend on the specified Sales Forecast Date Range. If the date range is for a two year period, Figure 33 will illustrate the Seasonal Factor Algorithm. If the date range is

for a three year period, Figure 34 will illustrate the algorithm. If it is more than three years, you will need to add the additional month(s) to the beginning of the algorithm. After the True Values and Seasonal Factors are found, the Exponential Smoothing Algorithm with Seasonality in Figure 26 will be used to calculate the Forecast.

3. Limitations

The software was designed as a starting point for a larger project that ORC Industries has planned. The section Continuing Work will detail the enhancements that ORC Industries would like to make to improve this software. The MRP/DRP functionality of the software was designed for the requirements of ORC Industries and may or may not work with other companies. The software will work in ORC Industries' environment but will have to be modified if used in another company's environment. The Database Setup functionality allows the user to specify which databases to use. Although these databases will have to be Microsoft SQL Server databases, companies with Navision will be able to be modified to run this software. Companies with another ERP software package will have to conform to the database tables that are used in this software. In this case, a formal analysis of the company's ERP software will have to be done to determine how best to retrieve information from the ERP software and how to setup the MRP database.

4. Continuing Work

MRP/DRP is just the beginning of ORC Industries' MRP initiative. ORC Industries plans to add time-phased Master Production Scheduling (MPS) as an add-on to MRP/DRP. MPS sets the schedule for production. This will allow ORC Industries to see what exact date an item will be produced and what exact date the raw materials and subcomponents will be needed to produce this item. Once MPS is in place, DRP can also be modified to account for the scheduling of finished goods. For example, item A is produced at plant B and plant C. Plant C doesn't start production on item A until two months down the line. Therefore, if plant C needs any items that are in another plant and production hasn't started, it can be transferred to plant C to save time and then a Purchase Order will be created to restock the other plant.

There are two alternative ways of keeping MRP up-to-date: Schedule Regeneration and Net Change. This means that there has been a change to amount of finished good items needed during the specified time period MRP/DRP is ran for. Therefore, changes to the Purchase Orders, Transfer Orders, and Production Orders will have to be made to account for this change. ORC Industries plans to add both functionalities. The differences between regeneration and net change are the frequency of re-planning and what initiates it. Regeneration is run periodically when all MPS, revised or not, is fed to MRP. Net change is run at more frequent, random intervals when inventory transactions are processed [4].

Another plan is to refine the forecasting algorithm. Either changing the current algorithm or finding a better fit one as more historical information is gathered and ORC Industries gets a better feel for forecasting. These are some of the modifications that ORC Industries has in store, but more may come in the future. With the software developed and maintained at ORC Industries, these future changes will be possible and less costly.

5. Conclusion

This software was designed as a starting point for a larger project that ORC Industries has planned. It was designed to assist a user in the production, purchasing, and transferring of items used in the production of finished good items. It allowed the user to generate Purchase Orders, Transfer Orders, and Production Orders. These generated orders are then able to be edited by the user. It has become a useful tool for the user as it has cut the cost for items being over purchased as well as items being transferred. It has also provided inventory at the time of production.

There were many challenges during the development of the software. The following will describe some of these challenges. The very first challenge was deciding how to develop the software. The software could either be modified to include the needed functionality or it would have to be developed as an external software that would interact with the Navision database. After careful consideration, it was decided to go with the external software. The deciding factors were the cost and the ability by ORC Industries to make adjustments to the software as well as the ability by ORC Industries to add future functionality.

The development of the MRP/DRP algorithm was another challenge. Since ORC did not have the source code to the MRP functionality in Navision, the MRP functionality had to be developed from scratch. Information was gathered from various employees within the organization as well as research from outside sources. After a couple of prototype runs and evaluating the results, the MRP/DRP functionality was finally agreed upon.

Another challenge was deciding what information from the Navision database could be used and what information had to be captured in the MRP database. Information already captured in the Navision database would not need to be captured in the MRP database because it would be redundant. After analyzing the Navision database and consulting with various employees within the organization, the tables that would be

required were found and the tables that were needed to be created to capture the additional information that would be needed were created in the MRP database.

The Forecast functionality was another challenge. ORC did not have a forecasting algorithm that it would be able to use to predict future sales. Therefore, a forecasting algorithm was developed with the help of the Statistical Consulting Center to solve the challenge.

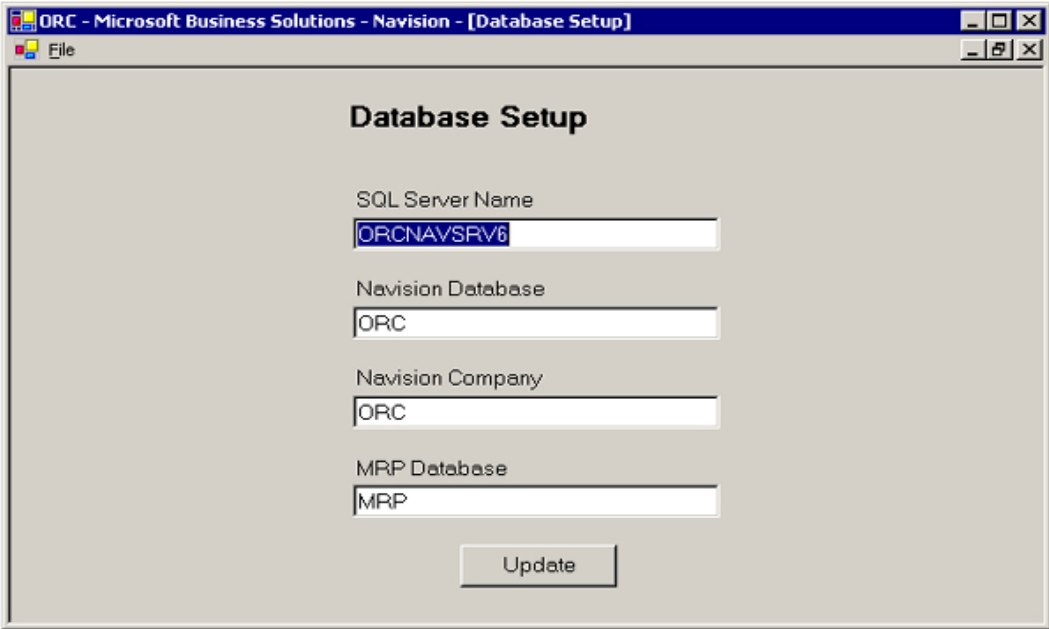
The accuracy of the Forecast functionality is up for debate. For ORC Industries, the Forecast will work because ORC Industries has the capability to adjust the Forecast and will adjust the Forecast as needed. If another company uses the software and is satisfied with the forecast, then the functionality will work. If not, then the company will have the alternative to use a percent difference of the previous year's sales or perhaps design their own algorithm. The algorithm used, Exponential Smoothing with Seasonality, is a simple algorithm. It doesn't factor in trends or other factors that may affect the forecast. Each company is different and in order to find the right algorithm to use, each company will have to do its own research to find the best fit algorithm for them.

The development of this software has helped me gain a better understanding of the process that ORC Industries uses to order, transfer, and make products. This knowledge will help me in the future development of the software.

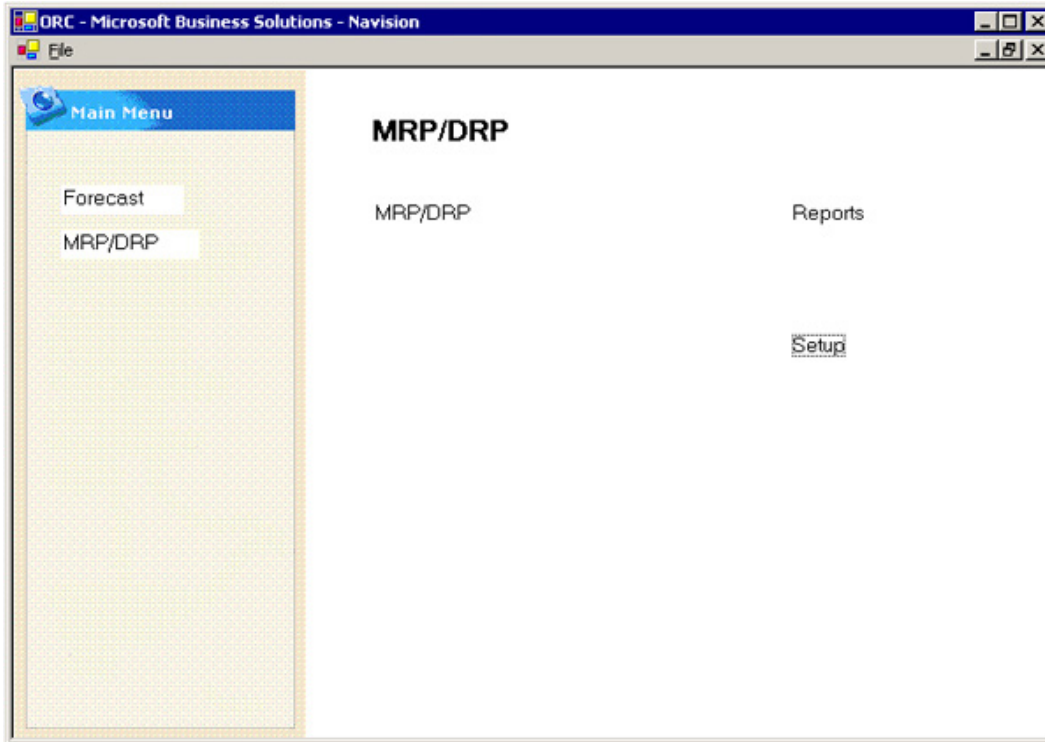
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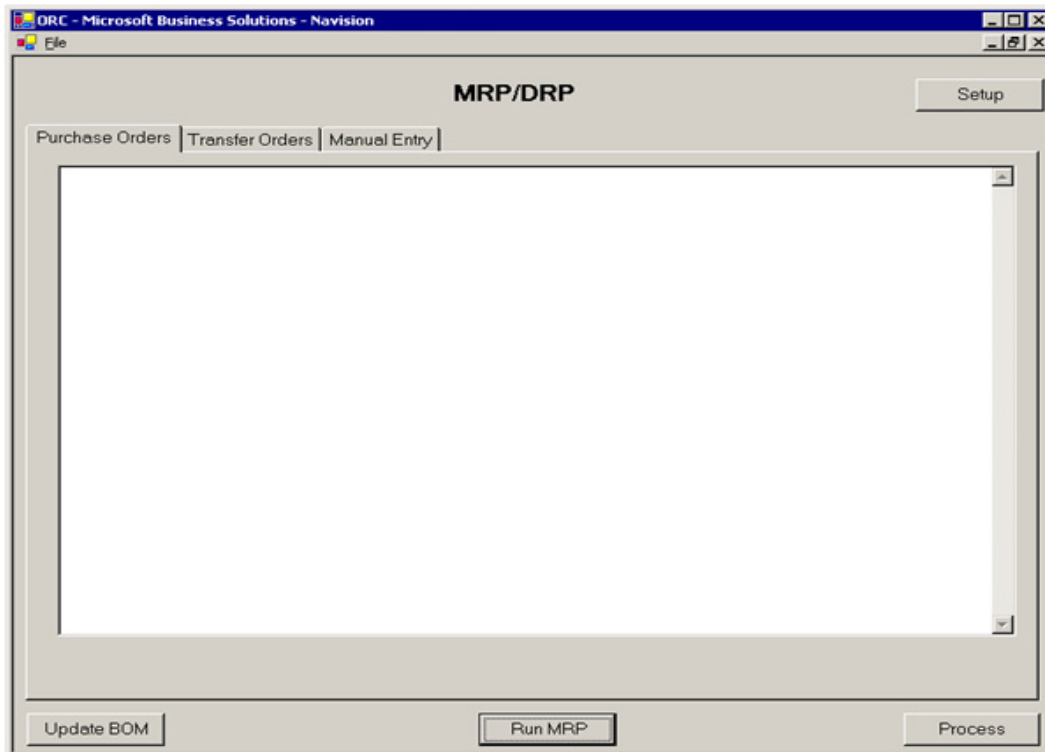
APPENDIX A: Screen Shots



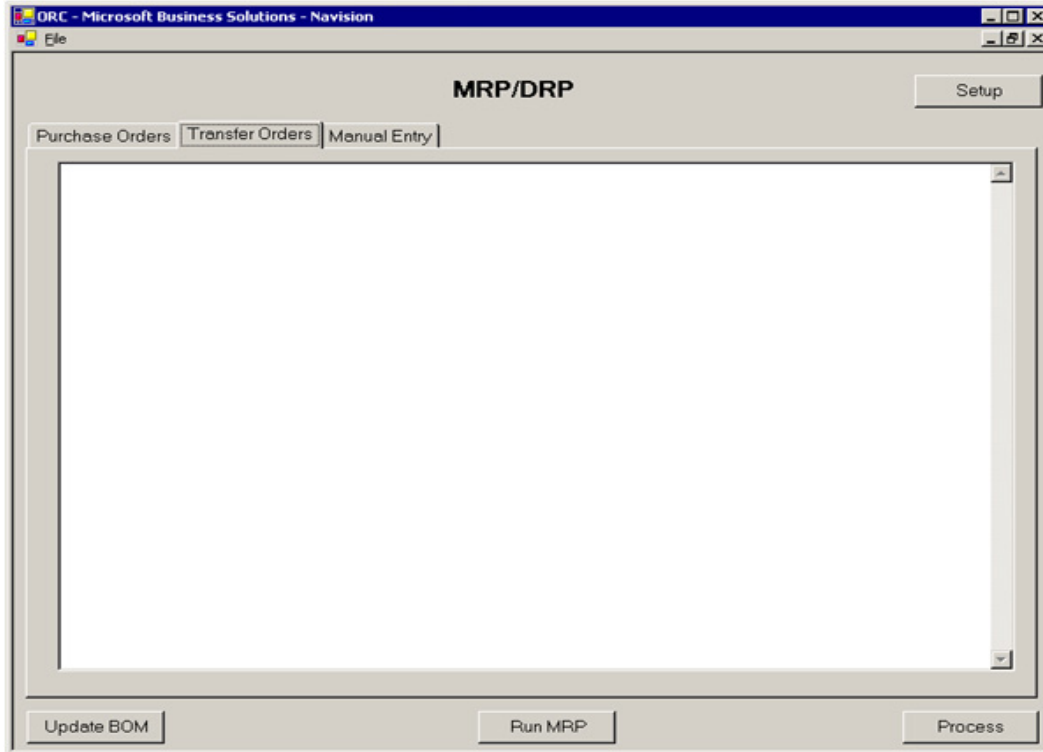
Database Setup Screen



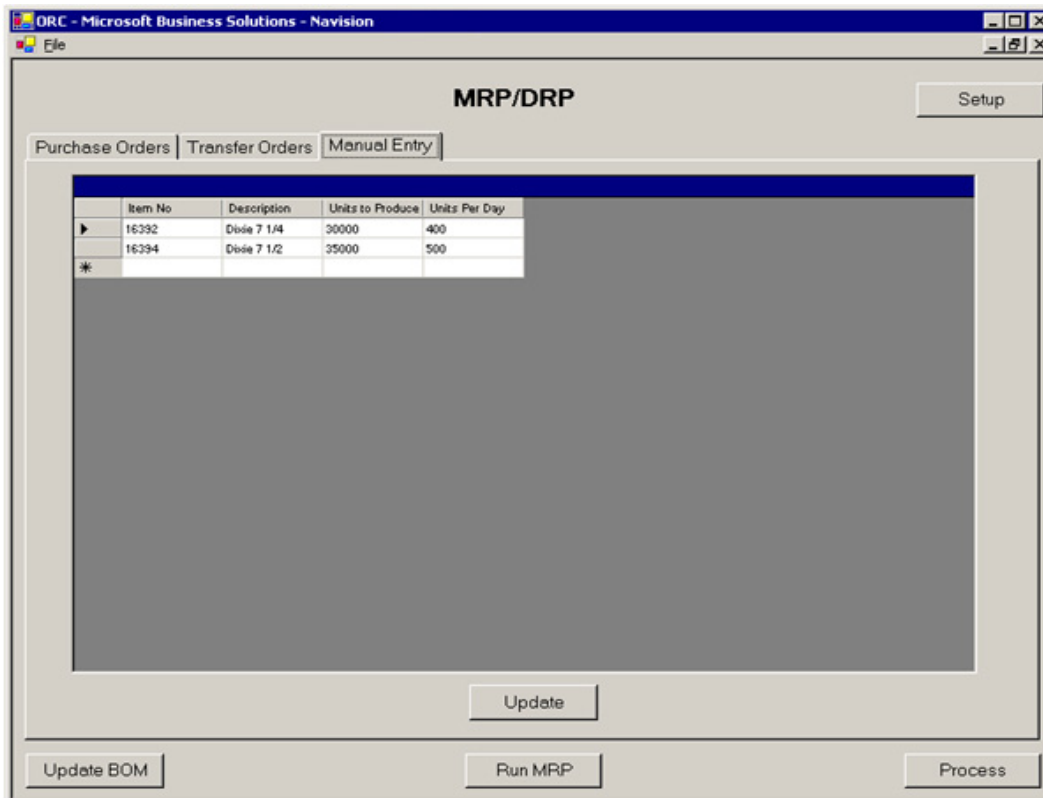
MRP/DRP Main Screen



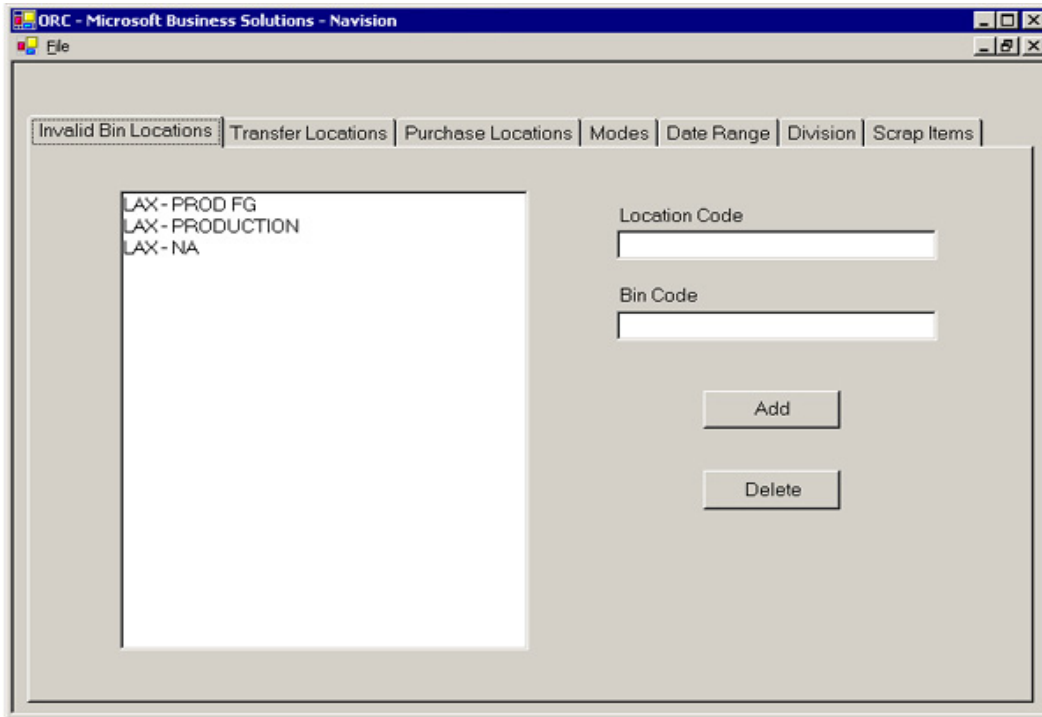
MRP/DRP Screen: Purchase Order Tab



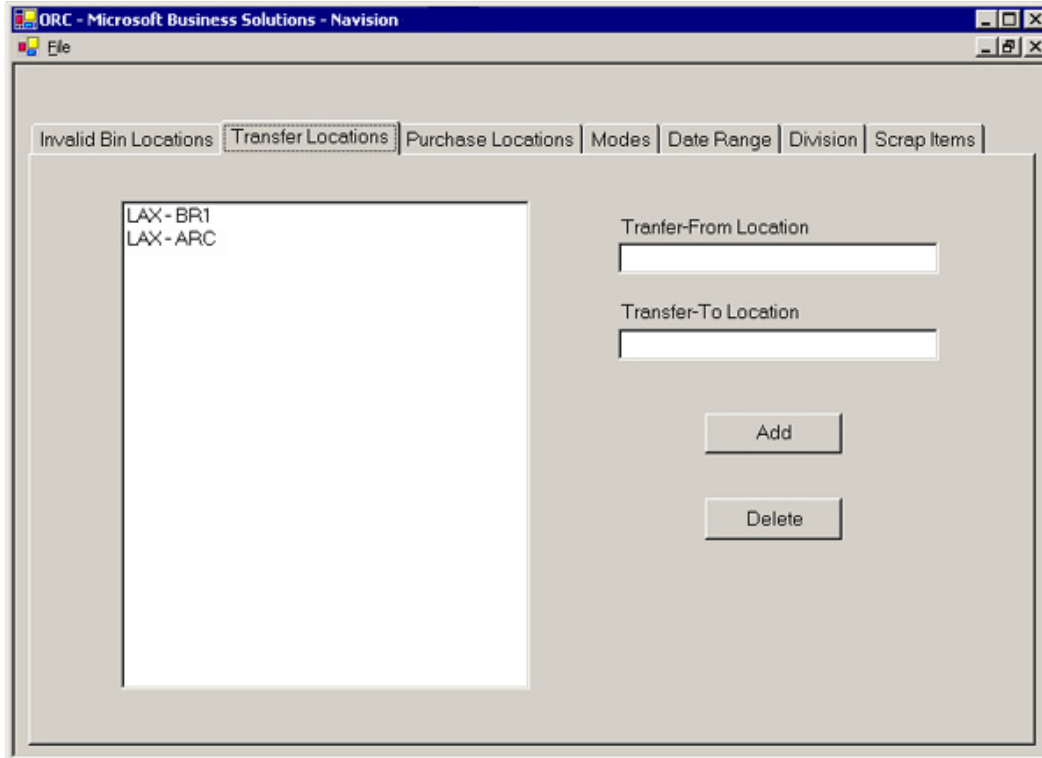
MRP/DRP Screen: Transfer Order Tab



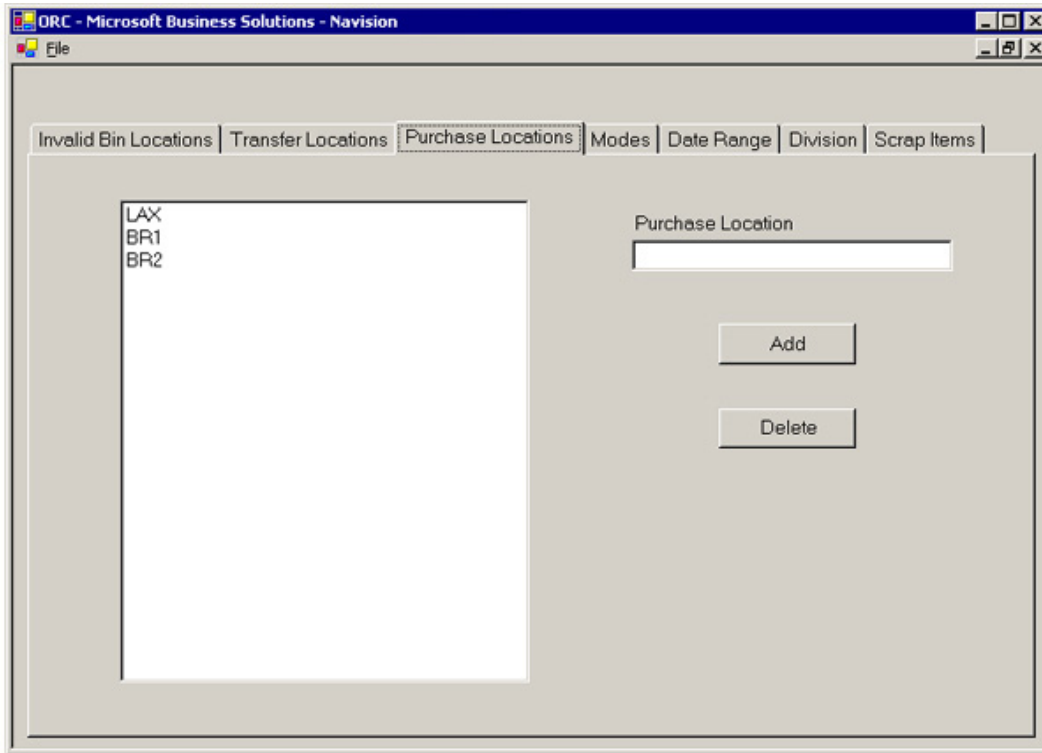
MRP/DRP Screen: Manual Entry Tab



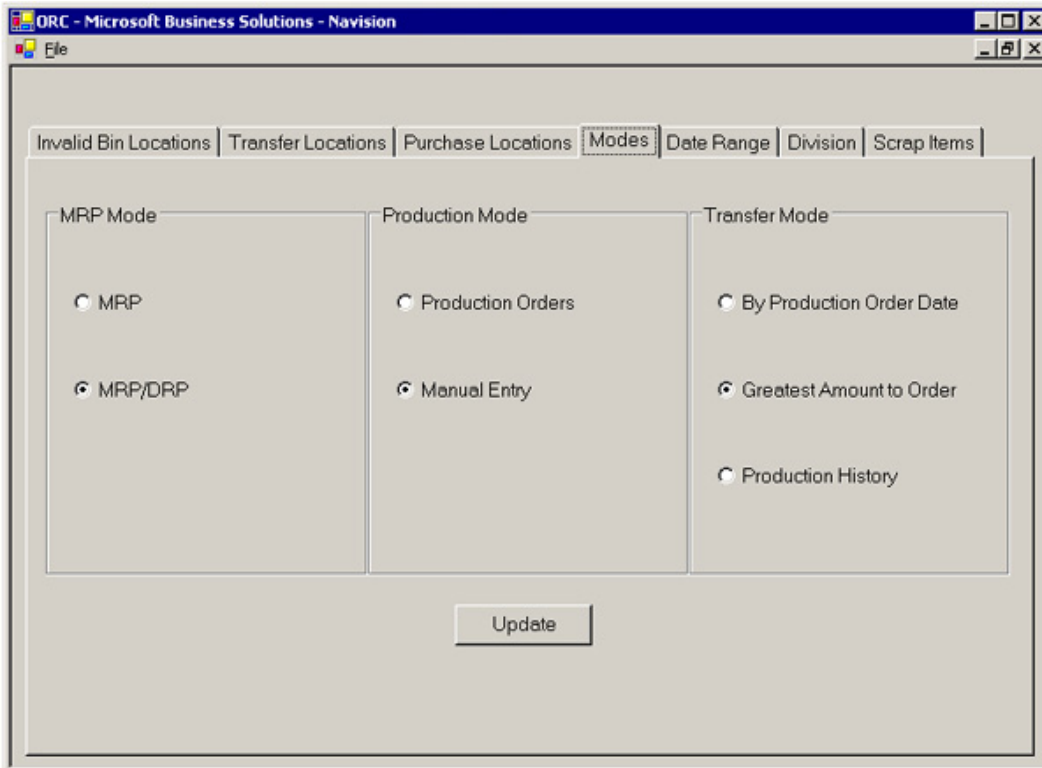
MRP/DRP Setup Screen: Invalid Bin Locations Tab



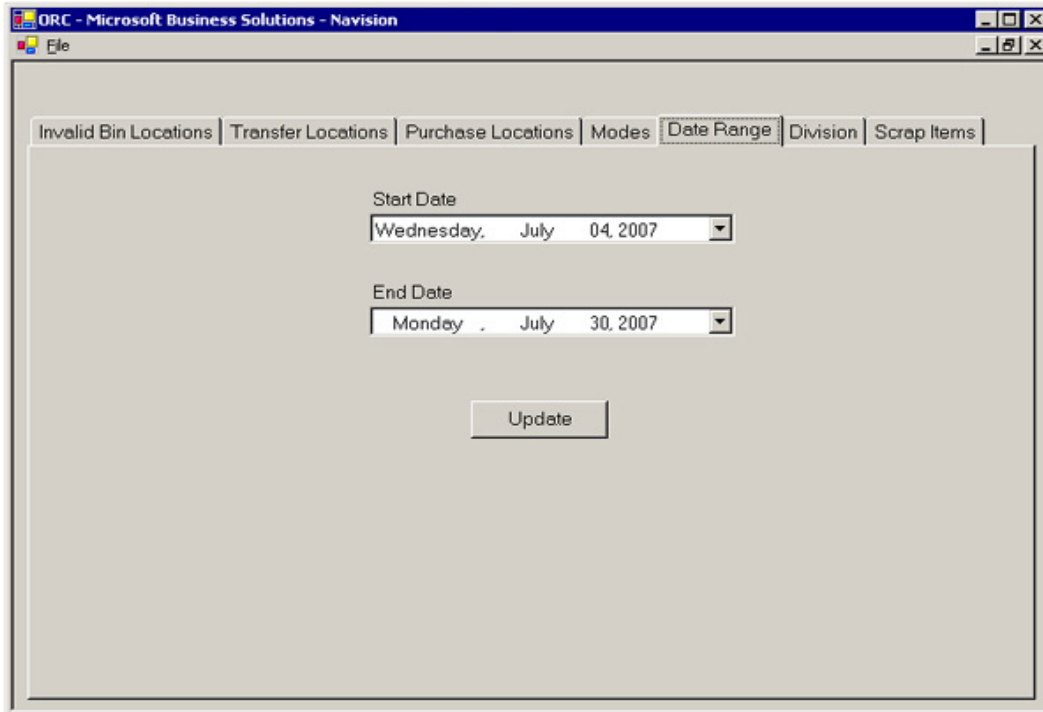
MRP/DRP Setup Screen: Transfer Locations Tab



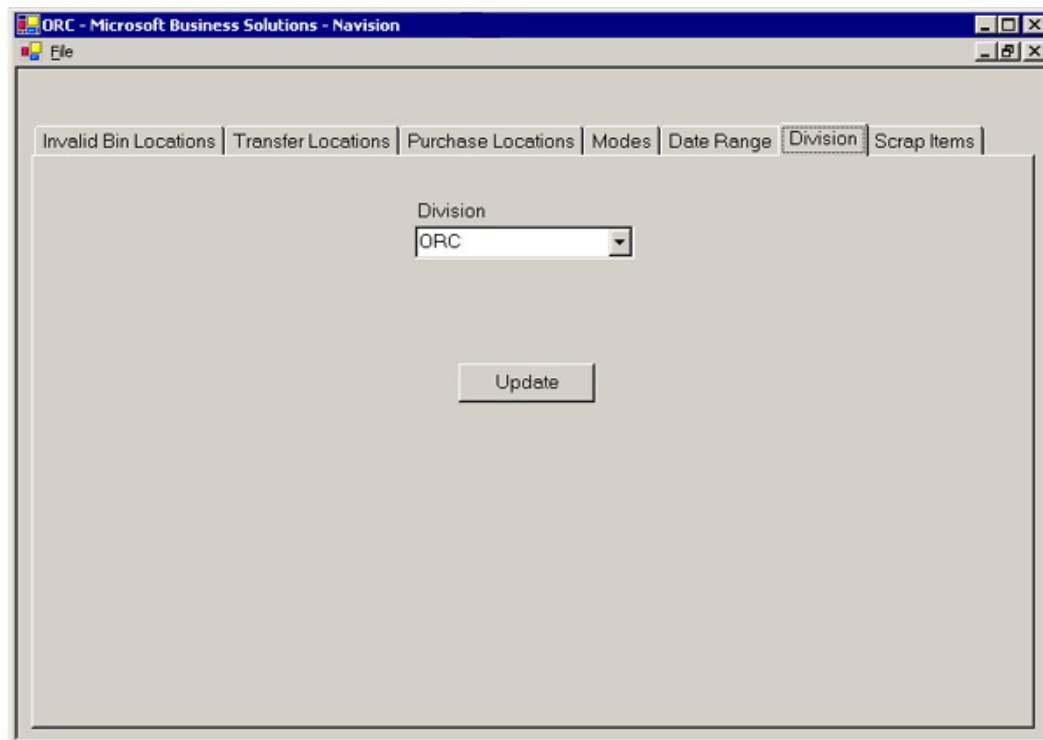
MRP/DRP Setup Screen: Purchase Locations Tab



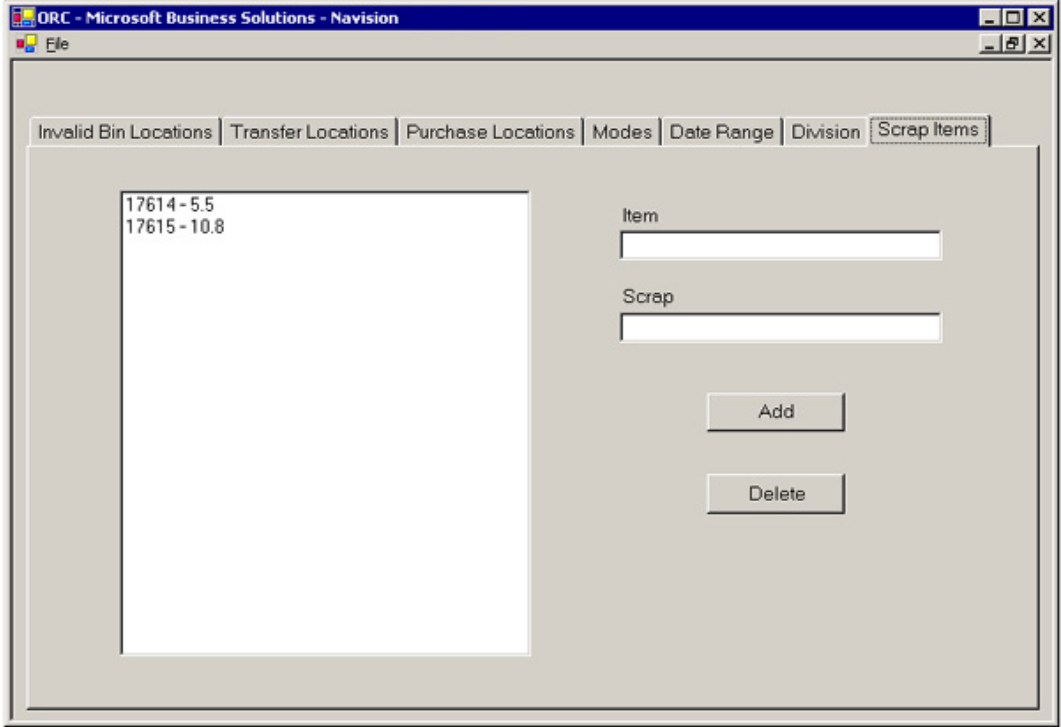
MRP/DRP Setup Screen: Modes Tab



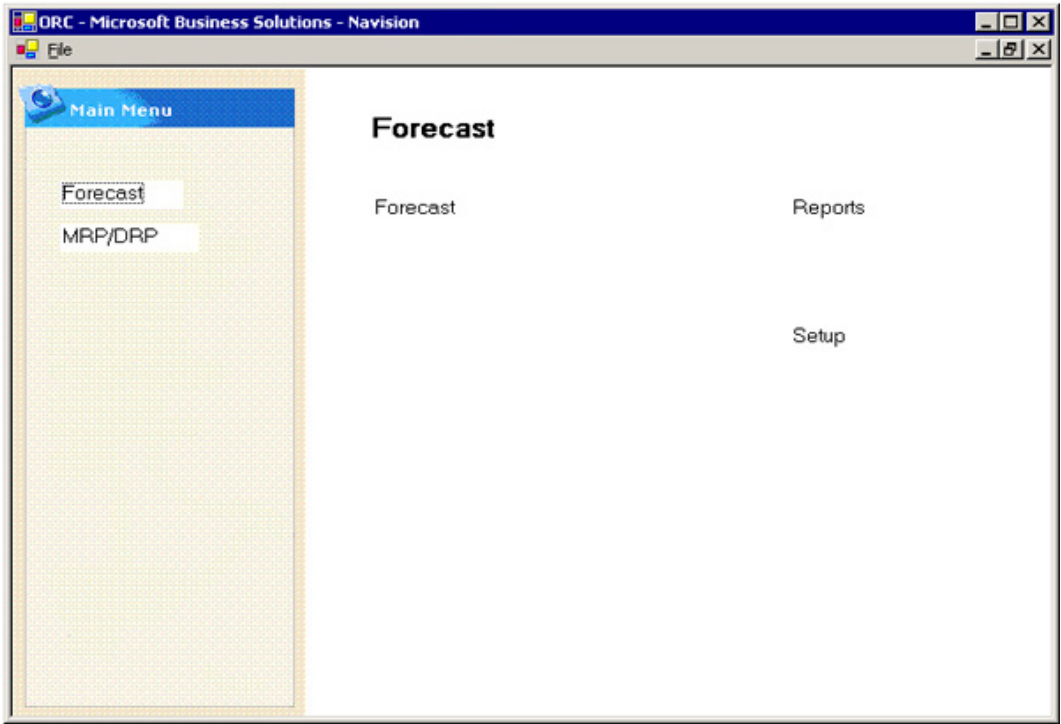
MRP/DRP Setup Screen: Date Range Tab



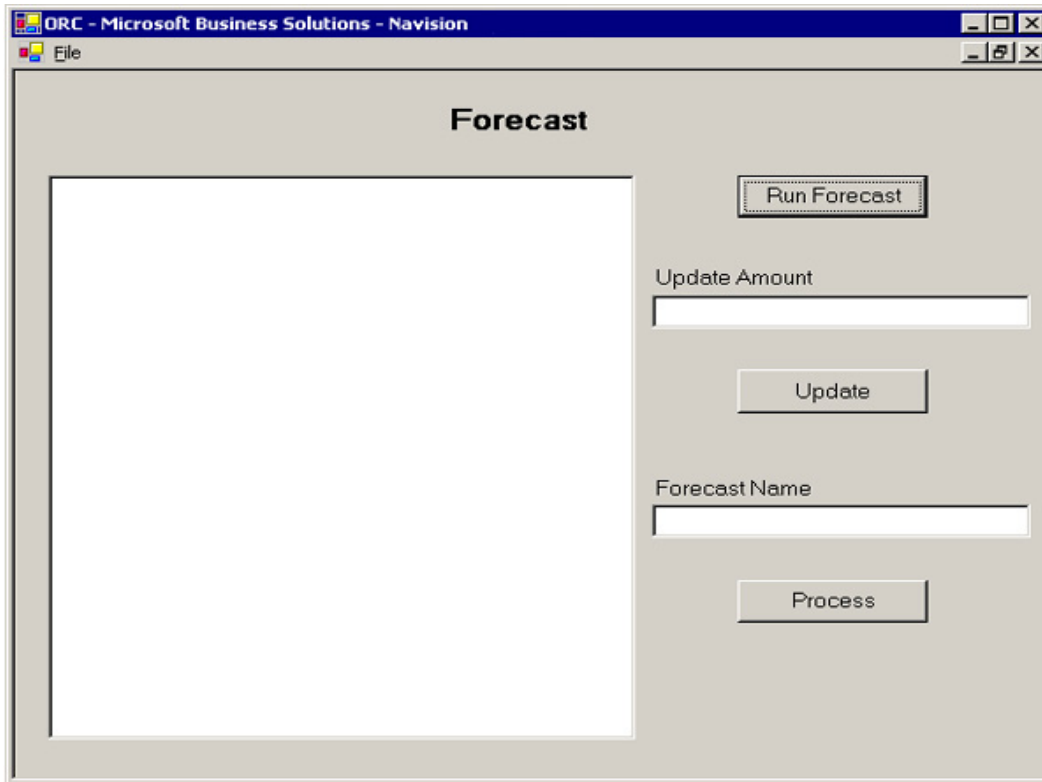
MRP/DRP Setup Screen: Division Tab



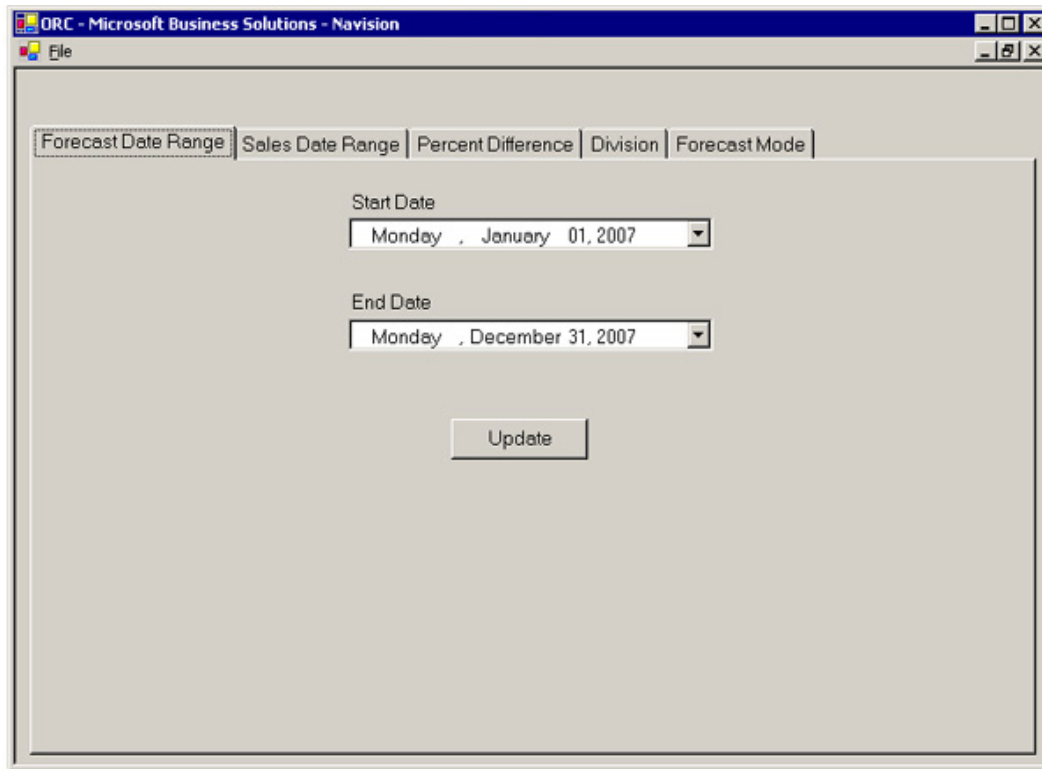
MRP/DRP Setup Screen: Scrap Items Tab



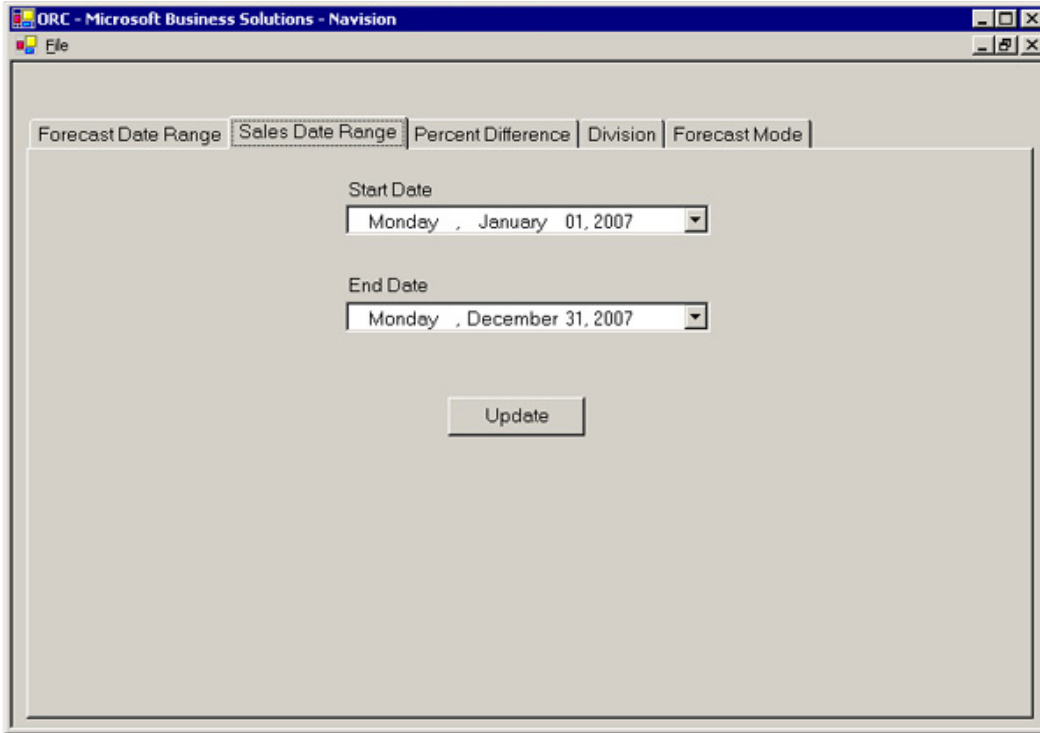
Forecast Main Screen



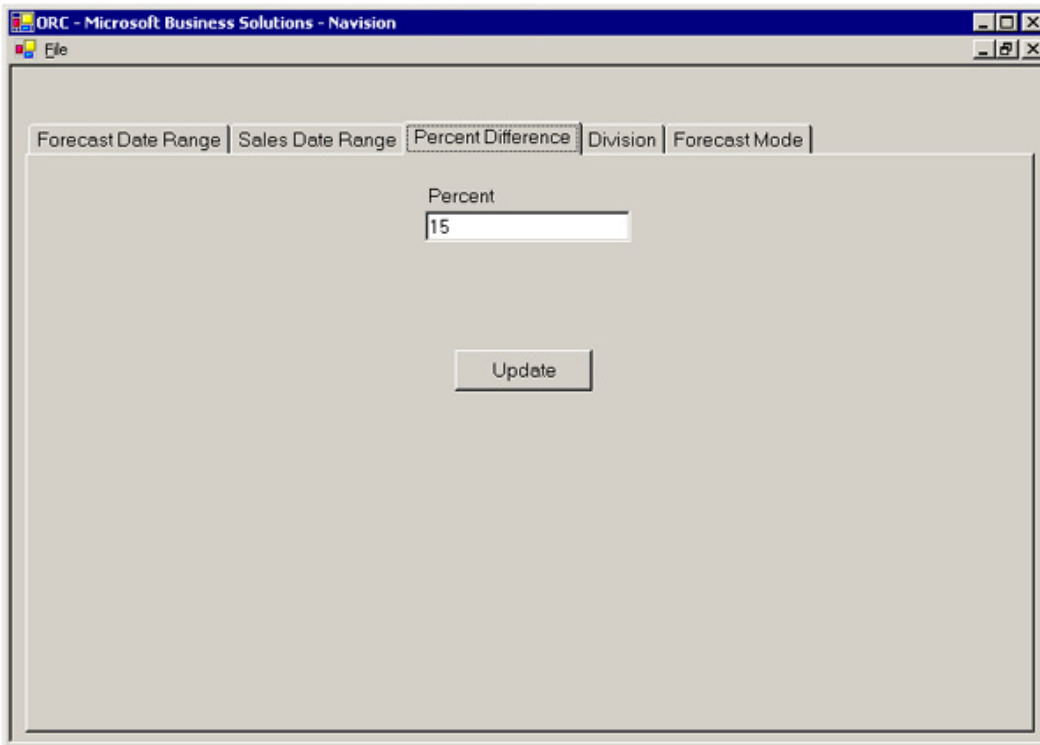
Forecast Screen



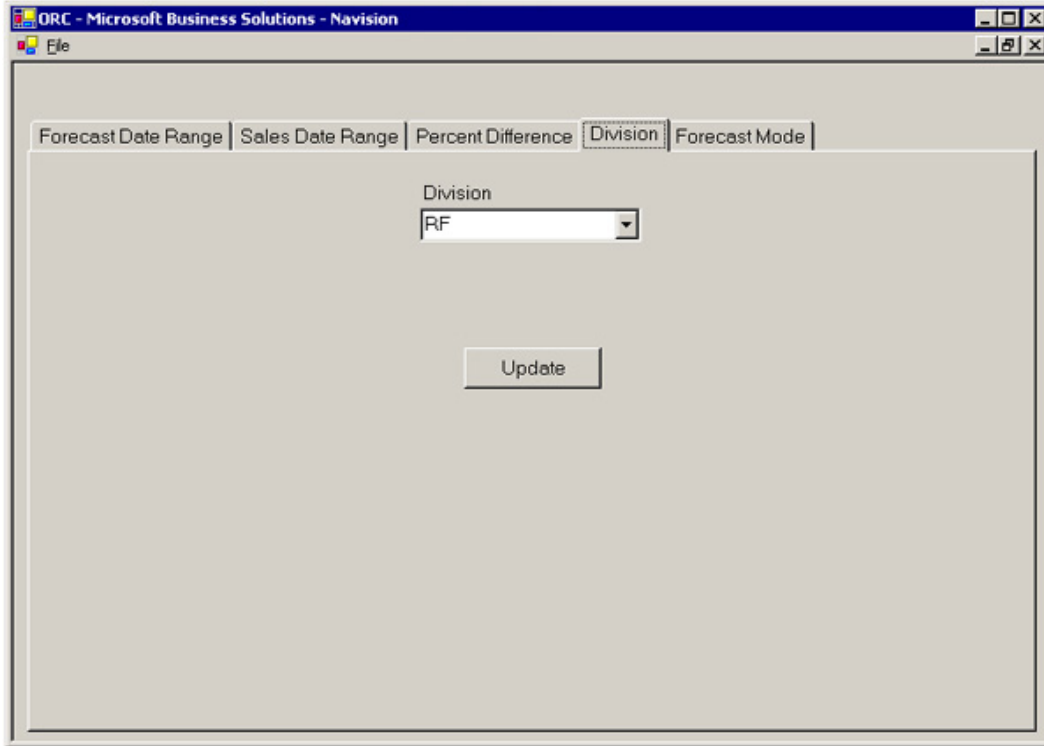
Forecast Setup Screen: Forecast Date Range Tab



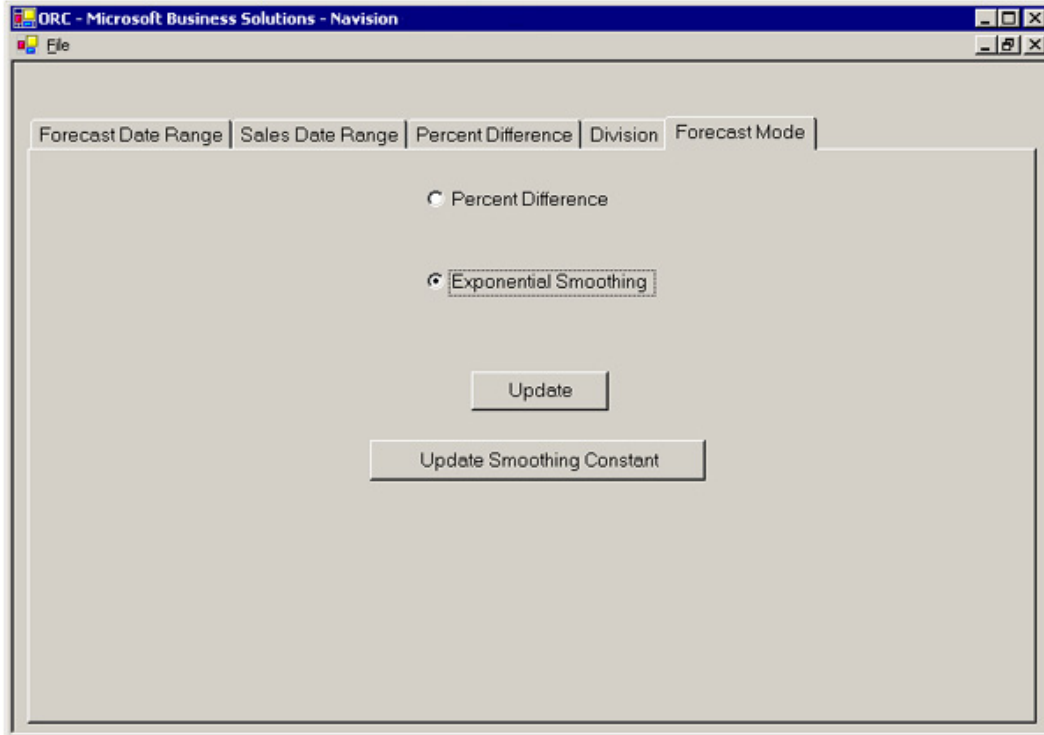
Forecast Setup Screen: Sales Date Range Tab



Forecast Setup Screen: Percent Difference Tab



Forecast Setup Screen: Division Tab



Forecast Setup Screen: Forecast Mode Tab