Demand Forecast Planner

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Demand Forecast Planner

By Peter J. Landerud

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

LANDERUD, PETER, J., "Demand Forecast Planner", Master of Software Engineering, December 2009, (Dr. Kenny Hunt).

Hy Cite Corporation, a small company by many standards, has over 1,900 currently active and sellable products. Those active products account for 1.19 million physical items totaling $37.9 million dollars in total inventory. Roughly $40 million dollars in working capital is a lot of money to have tied up, and upper management has been putting a lot of pressure on the purchasing department to reduce inventory costs. The threat of running out of inventory to fulfill orders is the greatest risk of trying to reduce inventory. More accurate reporting of sales and inventory is needed to reduce this risk. A tool is needed to judge the demand for these products and forecast future inventory purchases. This document describes the software lifecycle used to create such a tool, Demand Forecast Planner, which assists the purchasing department in planning inventory needs.

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I would like to first thank my fiancée, Marki, for all of her support. As I have struggled with this project and the MSE program she has always been there to support me. Having struggled with reading and writing all my life, I would also like to thank her for the countless hours she spent proof reading this thesis, correcting numerous spelling and grammatical errors.

Secondly, I would like to thank my parents Dave and Jacqui. Growing up with the love and support of two great parents has made more of a difference in life than I ever could have imagined. Instilling a good set of moral values, a can do attitude and a good work ethic has done more to make me successful in life than anything else. Additionally growing up with a learning disability it would have been easy for me to forgo advanced academics, but my parents, as well as exceptional teachers, ensured I never felt like there was anything I could not do.

Finally I would of course like to the Computer Science Department, and specifically Dr. Kenny Hunt and Dr. David Riley for all their help with my thesis and being overall excellent professors who I have learned a great deal from. The Computer Science Department at the University of Wisconsin La Crosse has a truly great program that has more than adequately prepared me for a career in the field of software engineering.

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GLOSSARY

Article (Article ID)

The alphanumeric value used internally to identify a product. Also called Product Code.

Avg Cost (Average Value)

The average cost of all products in inventory. For any one item, the landed cost can fluctuate based on shipping method, country of origin, 1st cost changes, etc.

Avg Inventory (Average Inventory)

Average Inventory that is in stock for a specific period of time.

Avg Sls Units (Average Sales Units)

The average predicted units to be sold per period based on the future year of predicted sales.

BOH Qty (Beginning On Hand Quantity)

Beginning On Hand Quantity - units available at the beginning of the current period.

Cost (Purchase Price)

1st cost of an item. This is the actual cost that we pay for the product, it does not include domestic or international freight, duties, customs fees, etc.

Lead (Lead Time)

Required timeframe between purchase order (PO) placement and PO delivery. This includes production and shipping timeframes.

Product Group

The group that a given product belongs to. For example CO6301 (9 Ply 5 piece Cookware set) belongs to the Cookware product group.

PPY Sls (Prior Prior Year Sales)

The number of units sold in the prior prior year for a given period or sales from two years ago.

PY BOP (Prior Year Beginning of Period)

The number of units that were on hand at the beginning of the period in the prior year.

PY EOP (Prior Year End of Period)

The number of units that were on hand at the end of the period in the prior year.

PY Plan Sls (Prior Year Planned Sales)

The planned number of units that were predicted to be sold for one year prior to a given period.

PY Plan Sls As % PY Sls (Prior Year Planned Sales as percent of Prior Year Sales)

Prior year plan sales expressed as a percent of prior year sales.

PY Received (Prior Year Received)

The number of units received the prior year for a given period.

PY RTS (Prior Year Return To Stock)

The number of units returned to stock the prior year for a given period.

PY Sls (Prior Year Sales)

The number of units sold the prior year for a given period.

PY Sls As % PPY Sls (Prior Year Sales as a percent of Prior Prior Year Sales)

Prior year's sales expressed as a percent of prior prior year sales.

PY Sls As % PY Plan Sls (Prior Year Sales as percent of Prior Year Planned Sales)

Prior year's sales expressed as a percent of prior year's planned sales.

PY Tot Sales (Prior Year Total Sales)

Total units that were sold over the past one year.

PY Turn (Prior Year Turn)

Prior year turn for the current period.

Total Units On Order

Total units for a particular item that are on existing, approved purchase orders.

Turn

Number of times inventory is replenished; generally calculated by dividing the average inventory level (or current inventory level) into the inventory usage.

TY Act/Plan BOP (This Year Actual/Planned Beginning of Period Units on Hand)

This year actual units that are on hand at the beginning of the current period or the planned beginning of period units for any future period.

TY Plan EOP (This Year Plan End Of Period)

This year's planned end of period units on hand.

TY Plan Sls (This Year Planned Sales)

Total units planned to sell this year.

TY Plan Sls As % PY Sls (This Year Planned Sales as a percent of Prior Year Sales)

This year's planned sales expressed as a percent of prior year's sales.

TY Plan Turn (This Year Planned Turn)

The planned turn for this year for a given period.

TY Project Sales (This Year Projected Sales)

Total units that are projected to be sold over the next one year.

Vendor

The name of the company or merchant we purchase a given product or set of products from.

Vendor Item (Vendor Product ID)

The alphanumeric value our vendor uses to identify a product.

1. Introduction

The direct sales industry, much like the retail industry, depends on a large inventory to be successful. Avon and Tupperware are two commonly known players in the direct sales industry. These two companies, like the company requesting this project, illustrate the importance inventory plays in this type of business. Tupperware, for example, does not manufacture much of its inventory in the same country in which it is sold. A great deal of manufacturing is done in places like China, where turn-around time between when the product is ordered to when it is actually received can be months.

The distributor network that is in charge of selling products for a company like Tupperware has very little insight, if any, into the inventory levels of products they are selling. The distributors are independent of the company itself and by design only need to concern themselves with making sales. Everything else is the responsibility of the company employing the distributor. This makes work easier for the distributor, but puts a great deal more responsibility on the company supporting them to have inventory available when it is needed.

In order to support sales, a large supply of inventory is needed to prevent units from going on back-order and customers having to wait for months before getting their products. The best way to predict future inventory requirements is to look at past sales and inventory levels along with consumer trends. When these figures are thought to be less reliable, greater inventory is typically kept on hand to ensure there is enough to meet sales demand.

The amount of money tied up in inventory is something every company wants to minimize, and because of this, the issues stated above cannot be simply solved by ordering an excess supply of inventory. While there is no easy way to minimize working inventory costs and still maintain sufficient inventory to meet demand, one universal truth is that precise, current, and easily accessible data on past sales, inventory and consumer trends is essential to accurately predict future inventory needs.

1.1 Commercial Software Downfalls

Critical to the success of the company requesting this project are two major commercial software packages. The first is Agresso, and it is used to track accounting related data. This software system tracks sales orders when a product is sold and purchase orders for products purchased from vendors. Agresso also tracks how much inventory is on hand, as well as managing a number of other data sets related to both sales and inventory.

The second software system is Highjump; it is used to track the location and quantity of inventory within the warehouse. Highjump is supplied sales orders from the Agresso system and it manages the physical storage locations for all items in inventory. This information is used to direct warehouse employees to the locations of specific items when filling orders. Highjump tracks data from two warehouses – one in Madison, WI, and one in Guadalajara, Mexico.

Both of these software systems are excellent at what they were designed to do and they collect considerable raw data regarding past sales and consumer trends. However, the data within these systems is scattered across fifteen to twenty different locations. Furthermore, these systems lack any type of historical inventory data. They adequately identify current stock, but do not maintain information regarding past stocking levels.

The Purchasing Department tracks the data needed to make purchasing related decisions. Data aggregated from the above systems is compiled into a set of Excel spreadsheets which are used for inventory management. This process is extremely time consuming and often yields inaccurate information for predicting future sales and inventory needs.

1.2 Project Goals

The goals of this project are to create a GUI tool, named Demand Forecast Planner, which can be used by the Purchasing Department to place orders for future inventory needs. This tool should aggregate data from several systems into one centralized application previously scattered across multiple locations. This data can then be analyzed and manipulated to predict inventory needs. The above goals, along with the amount of manual time that was being spent to complete this process, were the reasons for moving forward with this project.

Additional goals internal to the IT Department were to create understandable classes that would abstract the raw data being used by the Purchasing Department from the database. Too often, applications are built directly on top of databases without first abstracting the data into something more easily understood. This causes issues in both understandability as well as maintainability. Knowing this project will be expanded over the years, it was critical to design the project with expansion in mind.

1.3 Project Personnel

Two teams were involved in the creation of the Demand Forecast Planner - the Development Team which consisted of software engineer, Peter Landerud, and the customer which consisted of the purchasing manager, Kara Moorhouse. Both groups are employed by Hy Cite Corporation, and work out of the Madison, WI office. Peter Landerud has been a software engineer for five years with a background in thick client and web application development using Microsoft .Net technologies. Kara Moorhouse has over fifteen years of purchasing experience, and has worked for retail companies such as ShopKo as well as direct sales for Hy Cite.

2. Software Life Cycle Models

A number of different software life cycle models exist, each with its own set of advantages and disadvantages. The one chosen for this project was the iterative prototype model. The main reason for using a prototyping model was because of the effective feedback that can be generated by having an actual program in front of the customer. This, in conjunction with the fact that the customer of this project worked in the same building as the Development Team, made prototypes easy to release and made it convenient to receive feedback from the customer.

An additional reason for using a prototyping model was the lack of leverage the Development Team has on its customers to provide adequate requirements. The job of IT is to support the business functions of departments within a company. This is a vastly different role than that of a commercial software company. If a traditional waterfall model would have been used, more responsibility would have been placed on the customer to come up with complete requirements. As the Development Team for this project had little recourse to ensure the customer provided complete requirements, a prototyping model was used to collect more complete requirements.

Internal departments are generally willing to provide requirements to a moderate degree of detail, but usually it is the Development Team's job to clarify those requirements into what the customer actually wants. In the past experience of the Development Team, it was found that the easiest and most effective way to accomplish this was to get what requirements one could from the customer without pushing too hard and then develop a prototype to clarify the requirements. The feedback received from the prototype paired with the upfront requirements generally would deliver a successful application that would meet the customer's needs.

With all software life cycle models there are trade-offs, and the iterative prototype model is no exception. While direct customer feedback from a prototype is extremely useful to the Development Team, it can also lead to a great

deal of throw-away work. Gathering clear, unambiguous requirements is a difficult task to master, and one that the Development Team for this project is still working to improve. Trying to build a prototype around less than complete requirements can lead to incorrect or unwanted functionality. Additionally, the time spent implementing this functionality into a prototype is ultimately thrown away and may have been avoidable with more complete upfront requirements. Even with the potential for a fair amount of throw-away work, an iterative prototyping model was determined to be the best choice for this project. It provided a way of clarifying initial requirements defined by the customer and also helped the Development Team to identify better ways to clarify requirements up front.

3. Requirements

The first, and many times most, important phase of software development is requirements gathering. IEEE has the following definition for a requirement: [6]

“

1. A condition or capability needed by a user to solve a problem or achieve an objective.
2. A condition or capability that must be met or possessed by a system or system component to satisfy a contract, standard, specification, or other formally imposed documents.
3. A documented representation of a condition or capability as in (1) or (2).

”

This definition suggests that a set of requirements is a document, or set of documents, that define(s) the behavior of a software system. Gathering correct requirements is critical because it defines what the software being built is required to do and is the foundation on which all other software life cycle phases will be built upon. IEEE states “poorly defined system requirements” as one of the leading causes of why software systems fail [10].

3.1 Requirements Gathering Methodology

For the reasons given in section 2, the model shown in figure 3.1 was used to define the requirements for the Demand Forecast Planner.

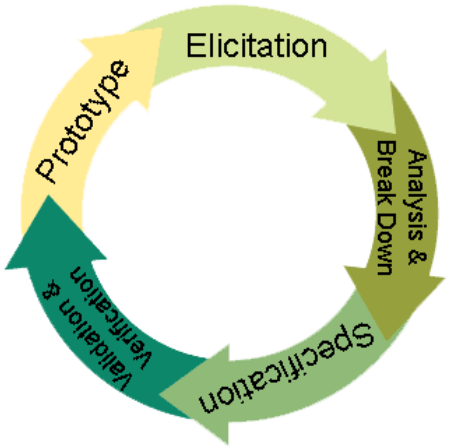


Figure 3.1. Requirements Gathering Model

Under this requirements model, elicitation is the first step in gathering requirements. During the elicitation phase, the Development Team asks the customer questions about what the software system will do. These questions, and the customer's responses, are informally written down and become the purest, most unrefined version of the requirements. Additionally the elicitation phase allows for the customer and the Development Team to come to a common understanding of terms and the definition of any non-functional requirements.

Following the elicitation phase, informal questions and answers are analyzed, and clarified with the customer, if needed, to remove ambiguities. While analyzing the data from the elicitation phase, it can be helpful to talk over the data with a third party independent from the software system. A third party sometimes assists by giving unbiased input regarding issues that may have been overlooked by both the Development Team and the customer. Sometimes complex requirements are broken into smaller requirements during elicitation. Lastly, multiple questions from the elicitation phase may have resulted in the same requirement being defined multiply; such requirements should be consolidated.

The system requirements that result from elicitation need to be transformed into a specification. The choice was made to develop a specification that adheres to the

IEEE 830-1998 standard [7]. During this phase, the analyzed data is formed into functional system requirements and non-functional system requirements.

The formal requirements defined in the specification phase need to be validated against the original elicitation information, with the customer and possibly with an additional third party. The first step after formal requirements have been specified is to validate that requirements meet the data defined in the elicitation phase. The requirements must ensure the elicitation information is fully captured, and must also ensure additional requirements are not added, because development team prejudice might result in items that the customer did not specifically define. Additionally, during this phase the Development Team needs to verify the defined requirements with the customer. Often elicitation information is lost in translation and should be verified before any prototyping or design work begins. It can also be beneficial to verify the requirements with a third party. A third party should be able to understand the requirements defined, and if not, additional work is needed to clarify the requirements.

The last step in this requirements model is to create a prototype that implements most or all of the functional requirements defined. The goal of this prototype is to help further refine the requirements of the software system. For this reason, it is not essential to implement all the requirements into the prototype. Additionally, this prototype is throw-away code and the amount of design put into how it is created should be greatly limited; this is only a tool to help gather more complete requirements.

Once the prototype is complete, the process starts again with the elicitation phase, but the questions asked during this phase should be driven by the prototype developed in the previous iteration. The customer, while using the prototype, can explain how the final software system should be similar to or different from the prototype. This elicitation information will be used to again start the requirements gathering phase. The process of creating iterations of prototypes is one with

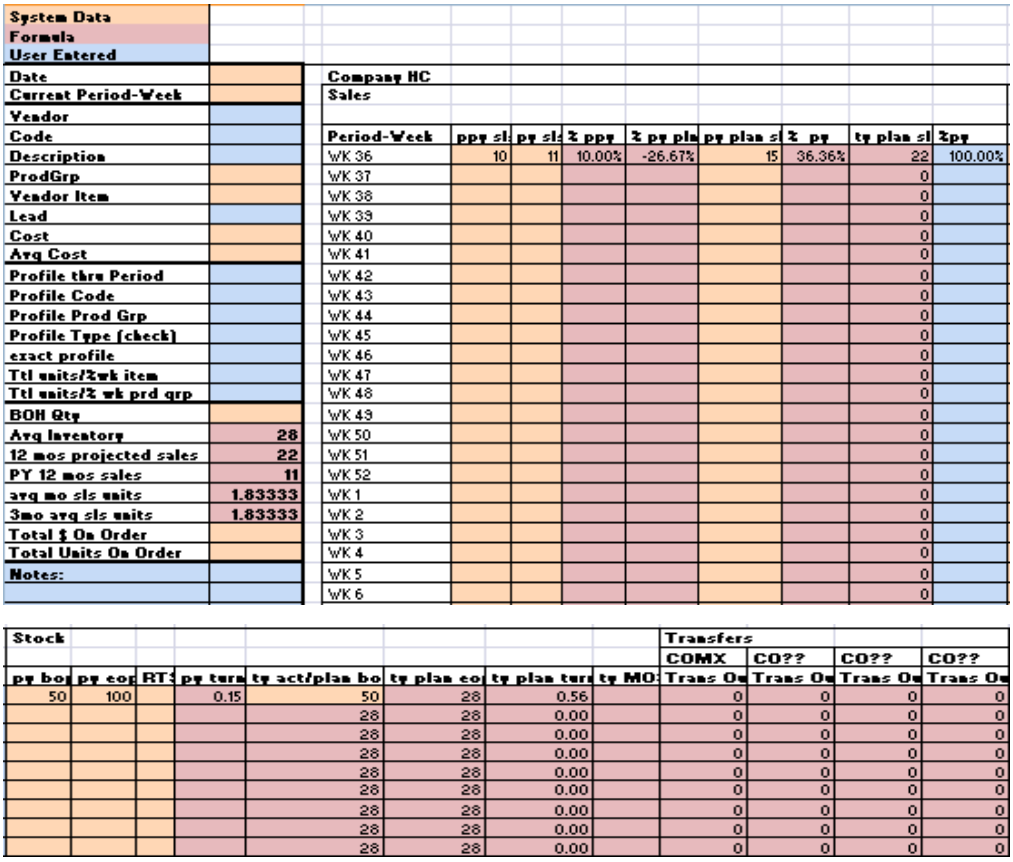
greatly diminishing returns and the number of prototypes created before moving onto the design phase should be limited as these prototypes are throw-away work.

3.2 Requirement Gathering - Demand Forecast Planner

During the elicitation phase for the Demand Forecast Planner, the customer and the Development Team had several face-to-face meetings where the requirements of the software system were discussed. Purchasing, much like software engineering, has its own set of terms and acronyms. The initial few meetings were spent getting the Development Team up to speed on the ins-and-outs of purchasing. Software engineers and developers are often asked to create applications within domains that are unfamiliar to them. In order for adequate requirements to be defined, both the customer and the Development Team must have some common level of understanding about the application domain. In the case of this application the establishment of that common ground took several meetings for the Development Team to understand.

After common terms and the initial requirements were discussed, this information was analyzed and a formal requirements document was created that adhered to the IEEE 830-1998 standard [7]. A separate document was created to hold the non-functional requirements. These documents were reviewed by the Development Team as well as a third party member of the IT department before they were delivered to the customer for verification. During the verification process with the customer, a few requirements changed and several new requirements were added. The resulting requirements document was reviewed, and it was determined an adequate prototype could be created using Excel. While the final system would not be implemented in Excel, it was determined that a simple Excel prototype could be created that would save a great deal of time. As this prototype would be thrown away after the requirements phase, it made sense to develop something quickly even if it would be different from the final system.

This prototype was then reviewed by the customer and the above process was repeated. The prototype was updated with new and changed requirements. After the second iteration of the prototype, it was determined the requirements were sufficient to move on to the design phase. The resulting requirements document consisted of 51 terms and 16 functional requirements. No formal GUI requirements where defined, but the Excel prototype (Figure 3.2) was used to define initial GUI requirements. The prototype could have been translated into formal GUI requirements, but the benefit of such an action was seen as wasteful, as GUI requirements were a small part of this application and functionality was its major concern.



System Data	
Formula	
User Entered	
Date	
Current Period-Week	
Vendor	
Code	
Description	
ProdGrp	
Vendor Item	
Lead	
Cost	
Avg Cost	
Profile thru Period	
Profile Code	
Profile Prod Grp	
Profile Type (check)	
exact profile	
Ttl units/%wk item	
Ttl units/% wk prd grp	
BOH Qty	
Avg Inventory	28
12 mos projected sales	22
PY 12 mos sales	11
avg mo sls units	1.83333
3mo avg sls units	1.83333
Total $ On Order	
Total Units On Order	
Notes:	

Company HC

Sales

Period-Week	ppy sl	py sls	% ppy	% py pla	py plan s	% py	ty plan sl	%py
WK 36	10	11	10.00%	-26.67%	15	36.36%	22	100.00%
WK 37							0	
WK 38							0	
WK 39							0	
WK 40							0	
WK 41							0	
WK 42							0	
WK 43							0	
WK 44							0	
WK 45							0	
WK 46							0	
WK 47							0	
WK 48							0	
WK 49							0	
WK 50							0	
WK 51							0	
WK 52							0	
WK 1							0	
WK 2							0	
WK 3							0	
WK 4							0	
WK 5							0	
WK 6							0	

Stock								Transfers			
								COMX	CO??	CO??	CO??
py bo	py eo	RT	py turn	ty act/plan bo	ty plan eo	ty plan turn	ty MO	Trans Ou	Trans Ou	Trans Ou	Trans Ou
50	100		0.15	50	28	0.56		0	0	0	0
				28	28	0.00		0	0	0	0
				28	28	0.00		0	0	0	0
				28	28	0.00		0	0	0	0
				28	28	0.00		0	0	0	0
				28	28	0.00		0	0	0	0
				28	28	0.00		0	0	0	0
				28	28	0.00		0	0	0	0
				28	28	0.00		0	0	0	0

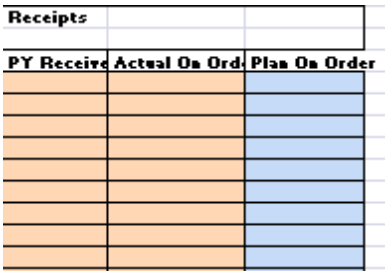


Figure 3.2 Excel Based Prototype

(The images shown above would span one row, but are broken apart for visibility)

3.3 Functional Requirements Overview

This section will give a high level overview of the functional requirements and terms defined in the initial requirements phase of the Demand Forecast Planner. The information shown here is in no way the complete set of requirements defined for the Demand Forecast Planner, and for such information the formal software requirement specification [2] should be referenced.

3.3.1 Terms Supporting Functional Requirements

These were the terms defined within the first several days of requirements gathering. These terms helped establish a common understanding of the application domain that could be built upon to establish functional requirements.

Global Purchasing Terms		
Term	**Definition**	**Calculation/Reference**
Current Period-Week	The current week number and the date the current week started on (i.e. 200838 – 9/17/08)	None
Vendor	The vendor we purchase a given product from.	Agresso.ASUHEADER.APAR_NAME
Product Code (Article/Article ID)	The article and article ID we use to identify a product.	Agresso.ALGARTICLE.ARTICLE

Product Description	The description of the product.	Agresso.ALGARTICLE .ART_DESCR
Product Group	The product group of the product.	Agresso.ALGARTICLE GR.DESCRIPTION
Vendor Item (vendor product ID)	The code the vendor uses internally to identify the item. This will default to our internal article until purchasing manually updates this value within Agresso.	Agresso. APOPRICE.ARTICLE
Lead (Lead Time)	Required timeframe between PO placement and PO delivery - includes production and shipping timeframes.	None
Cost (Purchase Price)	1st cost of an item - this is the actual cost that we pay for the product, it does not include domestic or international freight, duties, customs fees, etc.	Agresso. ASTARTVALUE.UNIT _PRICE
Avg Cost (Average Value)	The average cost of all products in inventory. For any one item, the landed cost can fluctuate based on shipping method, country of origin, 1st cost changes, etc.	ALGARTICLE.UNIT_ VALUE
Profile Type	The type of profile that will be used to predict future sales.	None
Profile thru Period	If a profile is used this date would indicate when the profile would cease and the items own history would start. I.E. use the profile product to gets PY Sls until this date is reached.	None
Profile Code	An active code (article/article ID) with 12mos+ selling history that could be used to model history for a new code.	

BOH Qty (Beginning On Hand Quantity)	Beginning On Hand Quantity - units available at the beginning of the current period. This information should be pulled out of Agresso.	Sum all FIFO layers within WeeklyStockLevels for the current period/article.
Avg Inventory	Average Inventory that is in stock for a specific period of time - for this application it would be the future 52 weeks.	BOH Qty for the future 52 weeks / 52.
52 Week Projected Sales (TY Projected Sales)	Total units that are projected to be sold as of the current date for the next 52 weeks.	Sum of this year's planned sales (TY PLAN SLS) for the next 52 weeks.
PY 52 Week Sales	Total units that were sold for the previous 52 weeks.	Sum of last year's sales (PY SLS) 52 weeks.
Avg Weekly Sls Units (Average Units Sold Per Period)	Average weekly sales units based on the 52 weeks future.	Sum of this year's planned sales (TY PLAN SLS) for the next 52 weeks divided by 52.
12 Week Avg Sls Units (Average Units Sold Over Next 90 Days)	Average Weekly sales units based on the 12 week future.	Sum of this year's planned sales (TY PLAN SLS) for the next 12 weeks divided by 12.
Total Units On Order	Total units for a particular item that are on existing, approved purchase orders.	PO's where the Rev Delivery Date is in the future
Notes	Area where the user can make notes that pertain to the product, demand planning process that can be saved and will appear when the code is brought up again.	None

Table 3.3 Global Purchasing Terms

The following terms define shorthand used by the Purchasing Department to represent sales data during a given period of time. All terms are defined based on a week timeframe in the past, present or future. For example, PY Sls (prior year

sales) defines how many of a given item was sold during a week timeframe last year.

Period Based Purchasing Terms For Sales		
Term	**Definition**	**Calculation/Reference**
PPY Sls	Prior prior year sales for a specific period.	None
PY Sls	Prior year sales for a specific period.	None
PY Sls As % PPY Sls	Prior year's sales expressed as a % +/- prior prior years sales.	(PY Sales/PPY Sales) – 1
PY Sls As % PY Plan Sls	Prior year's sales expressed as a % +/- prior years planned sales.	(PY Sales/PY Plan Sls) – 1
PY Plan Sls	Prior year planned sales.	None
PY Plan Sls As % PY Sls	Prior year plan sales expressed as a % +/- prior year sales.	(PY Plan Sls/PY Sales) - 1
TY Plan Sls	Total units planned to sell this year.	(PY Sls) * ((TY Plan Sls As % PY Sls) + 1)
TY Plan Sls As % PY Sls (% PY)	This year's plan sales expressed as a % +/- prior year's sales.	PY Sales/PPY Sales – 1

Table 3.4 Period Based Purchasing Terms for Sales

The following terms define shorthand used by the Purchasing Department to represent inventory data during a given period of time. All terms are defined based on a week timeframe in the past, present or future. For example, PY BOP (prior year beginning of period on hand units) defines how many of a given item was on hand during the beginning of the weekly period last year.

Period Based Purchasing Terms For Inventory

Term	Definition	Calculation/Reference
PY BOP	Prior year beginning of period on hand units.	None
PY EOP	Prior year end of period on hand units.	None
Turn	Number of times inventory is replenished; generally calculated by dividing the average inventory level (or current inventory level) into the inventory usage.	None
PY Turn	Prior year turn for the current period. (See Turn)	(PY SLS) / (((PY BOP) + (PY EOP))/2)
TY Act/Plan BOP	This year actual units that are on hand at the beginning of this period for the current period or the planned beginning of period units for any future period. This info should be pulled from Highjump.	For current period no calculations just get current BOP units. For future periods retrieve the previous periods TY Plan EOP
TY Plan EOP	This year's planned end of period units on hand for the current period.	(TY Act/Plan BOP) + (Actual On Order) + (Plan On Order) – (TY PLAN SLS) – (Trans Out)
TY Plan Turn	The planned turn for this year for the current period. (See Turn)	(TY PLAN SLS) / (((TY Act/Plan BOP) + (TY Plan EOP)) / 2)
TY Weeks	This year weeks of supply that the planned end of period units can support based on future 12 weeks average sales units.	(TY Plan EOP) / (Sum Next 12 Periods TY PLAN SLS / 12)
Trans Out	Units that are planned to transfer out of a given warehouse into a different warehouse.	None

Trans In	Units that are planned to transfer into this warehouse from a different warehouse.	None
PY Received	Prior year units received during the current period last year.	None
Actual On Order	Actual units currently on an approved purchase order for that period.	None
Plan On Order	Additional units needed - or order planned to be placed for that period.	None

Table 3.5 Period Based Purchasing Terms for Inventory

The terms from Table 3.5 define the data metrics of interest to the Purchasing Department for properly predicting future inventory needs. Several of these terms were defined directly from an existing system, and some were calculated based on data from existing systems. Other terms are independent of prior systems and defined only with reference to the Demand Forecast Planner. A number of calculations were known by the Purchasing Department, and listed where available, but some terms needed to be calculated by the Demand Forecast Planner and those calculations were defined in the design phase.

The intent of defining the terms was to establish what the customer wanted, not how to actually implement these items. This line became somewhat blurred during this process; for example, what the customer wanted was a data metric called "Prior Year Turn". The calculation of the value could be viewed as design detail that should be defined within the design phase, but Prior Year Turn is better understood when the context is provided. During this process the development team worked hard to keep what the customer wanted separate from how it would actually be implemented, but like the example given above some overlapping occurred.

3.3.2 Functional Requirements for Warehouse

During the process of defining the requirements, the concept of being able to represent a warehouse arose. Previously, the Excel documents used to predict sales had no concept of a warehouse. Units sold for a given item were simply aggregated, even though some of the units were from different warehouses. This was acceptable since the sales from the Mexico warehouse were relatively small. As the Mexico warehouse increased in sales growth, this lack of warehouse distinction became more of an issue and was on the top of the list for requirements.

Requirement Name	**Requirement Description**
Create Warehouse	Create a virtual location, referred to as a warehouse, which represents a physical location where stock is shipped to and/or sold from. When showing/predicting sales and inventory for a product a warehouse will further break down the sales and inventory for that product by a location. This location, referred to as warehouse, represents the current operations in the US and Mexico.
Modify Warehouse	Modify an existing warehouse.
Remove Warehouse	Remove an existing warehouse.

Table 3.6 Functional Requirements for a Warehouse

3.3.3 Functional Requirements for Product

A product is a physical item that is sold by or used for replacement parts at the company. The data elements that represent these items are already tracked within systems in the company, but the concept of being able to use the Demand Forecast Planner to predict future sales and inventory is one that does not apply to every product. For this reason a product in the context of the Demand Forecast Planner is an existing product the Demand Forecast Planner is allowed to predict sales and inventory needs for.

Requirement Name	Requirement Description
Create Product	Creates a new product that can be used by the demand forecast planner.
Remove Product	Remove an existing product.

Table 3.7 Functional Requirements for a Product

3.3.4 Functional Requirements for Warehouse Product

A warehouse product is a specific physical item sold or stored at a specific physical location over a given amount of time. For example, how many of product code 1234 were sold out of the Madison warehouse during the sixth week of 2008 would be the kind of data a Warehouse Product would contain. The idea of breaking out sales and inventory for a specific item by location was a function the previous system did not have. The primary focus of the Demand Forecast Planner is to view sales and inventory data based on a weekly period, but the ability to view this information on a monthly period is also needed. For this reason a warehouse product also represents a specific amount of time or time period, be it weekly or monthly.

Requirement Name	Requirement Description
Create Warehouse Product	To create the relationship between warehouse and product. A warehouse product represents a specific product being stored, shipped and sold from a given warehouse. It further breaks down those sales based on Period Type. The main focus of this application is to see sales and inventory on a weekly basis, but the option to view them on a monthly basis is also needed.
Retrieve Warehouse Product Details	Based on the product and warehouse retrieve product info.
Get Past Sales	To get the past 2 years (104 weeks, or 24 months) of sales for this warehouse product. The past 2 years of sale are retrieved from the database for this warehouse product. If there are not 2 years of sales present retrieve whatever history is available.

	If there is a profile in place for this product, get past sales based on the profile details.
Calculate Past Sales Metrics	To calculate a set of metrics based on past sales.
Get Past Inventory Levels	To get the past 1 year (52 weeks or 12 months) of inventory levels for this warehouse product. The past 1 year of inventory for this warehouse product is retrieved from the database. If there is not 1 year of inventory present, retrieve whatever history is available. If there is a profile in place for this product, get past inventory based on the profile details.
Calculate Past Inventory Metrics	To calculate a set of metrics based on past inventory levels.
Get Planned Incoming Inventory	To retrieve purchase orders (PO's) that have already been placed for this warehouse product. For the future 52 weeks or 12 months retrieve any PO's for this warehouse product.
Calculate Future Warehouse Product Sales and Inventory Levels	To calculate the future sales and inventory levels based on user input and past history.

Table 3.8 Functional Requirements for a Warehouse Product

3.3.5 Functional Requirements for Profile

A profile is substituting the past sales and inventory levels of one product for another. New products have no past sales or inventory data and thus no data to base future inventory needs on. A profile can then be used until there is enough history for the new product to use its own sales and inventory data to predict future inventory needs.

Requirement Name	**Requirement Description**
Create Profile	Create a profile that will be used to predict future sales. All profiles must be defined to pull sales and inventory for a specific warehouse.

Modify Profile	To modify an existing profile.
Delete Profile	To delete an existing profile.

Table 3.9 Functional Requirements for a Profile

3.4 Lessons Learned During Requirements Gathering

This section will detail some of the major areas that could have been improved during the requirements gathering phase. Starting implementation with incomplete requirements or no requirements at all is a common problem the Development Team has seen. Many managers in charge of software engineers were once, or are still, programmers themselves and have a mentality of creating software without first defining requirements. The Development Team struggled to gain acceptance on why software engineering principles needed to be used for this project, but eventually gained agreement from management.

An additional issue that needed to be resolved by the Development Team was the format for expressing requirements. A template within Word was used to define the formal software requirements, and while the number of requirements was fairly small for this system, it could have benefited from proper tool support. One of the major areas where tool support would have been helpful was in the tracking of questions and answers between the Development Team and the customer regarding requirements. To keep the Word document concise and uncluttered, this data was not added as part of the formal software requirements document. The Development Team could have benefited from a separate section that is common in most software requirements management packages used for collaboration between two parties.

Additionally, a way of sorting or filtering the requirements based on the phase or date they were added, as well as some kind of logical grouping, would have been beneficial. Even with the small number of requirements, it became difficult for the Development Team to navigate the requirements document. The ability to

track changes or versions of the requirements document would have been helpful. History tracking facilities would be beneficial in order to keep the requirements document dynamic. Section 7 details how the completed system was maintained and history was tracked without built-in tool support.

The last major lesson learned by the Development Team was the value of face-to-face contact with the customer. Too often questions with the requirements would result in an email or phone call to the customer. The quality of requirements defined using these methods normally turned out to yield a less accurate requirement than one discussed face-to-face with the customer. While this was not always possible, it was learned that if the Development Team and customer could meet it almost always resulted in a more accurate requirement.

4. Design

The second phase of software development is the design phase. IEEE has the following definition for design [6].

“

1. The process of defining the architecture, components, interfaces, and other characteristics of a system or component.
2. A document that describes the design of a system or component. Typical contents include system or component architecture, control logic, data structures, input/ output formats, interface descriptions, and algorithms.

”

In other words, a system design is a document, or set of documents, that defines how the software system will work and be implemented. Like requirements, a well thought-out design will lay a solid foundation on which the rest of the software system can be built. Taking the time to create a good design often pays large dividends later in the software life cycle.

4.1 Design Methodology

The design for the Demand Forecast Planner was a part of the iterative software life cycle model. A traditional waterfall model would expect all customer interaction to be complete by the time the design phase started, but often in the design phase the Development Team will need to clarify areas with the customer. Additionally during the design phase it is important to review and enhance the design over multiple iterations.

For the reasons given above, the model shown in figure 4.1 was used to design the Demand Forecast Planner.

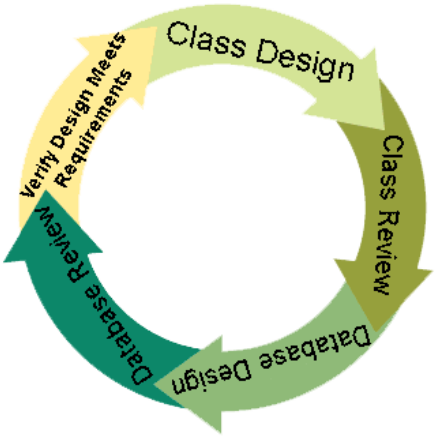


Figure 4.1. Design Model

The first step in the design model is Class Design. While there are many schools of thought on how to design a software system, class design is done first in this model because it breaks down the system into small easily understandable units. Once the classes that make up the software system are identified, the rest of the system logically falls into place to support these classes. In addition to breaking down the system into easily understandable units, class design also helps to abstract the system from the raw data elements that makeup the system. Too many software systems try and manipulate raw data directly and become lost in the overwhelming amount of data. One of the main focuses of the Demand Forecast Planner was to aggregate large amounts of data, and for this reason abstracting that data from the database into easily understandable classes was an important first step in designing the system. During this phase, class design is expressed as a class diagram and then specified in a document that supports the IEEE 1016-1998 standard [8].

After a first pass is made to design the classes, a class review phase is next in the design model. During this phase the classes are reviewed by the Development Team for conceptual and logic flaws. Classes are reviewed to ensure that they correctly describe all the playing pieces needed to support the software system

and that the interplay between those pieces is also correctly described. In addition, classes are also reviewed for maintainability, reusability and expandability. Designing classes that simply support the current requirements of the software system is not enough. No software remains constant once it is released, and ensuring the core classes that make up the software system are able to grow and change easily over the life of the system is an important part of the class design and review phase. Additionally, a third party can review the class design. An outside perspective on the classes can help the Development Team to look at the class design in a new way. A third party can easily raise maintainability concerns about the classes, as a class design should be able to be supported by a third party with little or no understanding of the system. If a third party cannot easily see how a class could be maintained or reused from the class design, it needs to be further defined and explained within the design.

The logical next step after designing the classes is to create the database structure that will support these classes. Software systems dealing with existing systems may want to break the database design into two parts, first to design how the classes would pull data from existing systems, and second how any data independent to the new system would be stored. Database design is first modeled as an entity relationship (ER) diagram and then specified in a document that supports the IEEE 1016-1998 standard [8].

Next, the database design must be reviewed. During this step, the Development Team will review the database design with relation to the class design to ensure that any data elements within the class design that require storage are represented in the database design. Additionally, any data that is pulled from existing systems into classes must also be represented within the database design. The database design should describe how this existing data will be retrieved. A concern that should also be looked at during the database design and review phases is that if data is pulled from existing systems how will the database design ensure it does not adversely affect the existing system. Similar to the class review phase, having

a third party review the database design can be beneficial and increase the quality of the design.

Lastly, after the classes and database structure have been designed and reviewed, they need to be verified against the requirements to ensure the design meets all the requirements specified. During this phase, the Development Team may also go back to the customer if needed to get clarification on requirements to help support the design. If changes to the requirements are found during this step, they should be updated in the formal system requirements specified during the requirements phase. It is also important to ensure the design is within the scope of the system originally described by the customer. The Development Team needs to stay on track and not start to over-design the system into something the customer did not request. Designing the system for maintainability, reusability and expandability is important, but avoiding scope creep and designing to the requirements is equally important.

Based on the results of this iteration of the design phase, the Development Team can choose to move onto the implementation phase or repeat the design phase again to further refine the design. Completing more than one iteration of the design phase will yield a better, more complete design and is recommended, but similar to iterations in the requirements phase, each iteration should have demising returns and the value of repeating the design phase should be weighed before repeating. When considering whether to repeat the design phase, it is important to remember that the later an error is found in the software life cycle the more time-consuming it is to fix. Identifying errors early may increase the length of the requirements and design phases, but in the long run it is a safe bet this was time well spent.

4.2 Designing the Demand Forecast Planner

This section gives an overview of the design phase for the Demand Forecast Planner. During this phase, the Development Team used the requirements

produced in the requirements phase to create a set of classes, database tables and stored procedures that would fulfill the requirements. To accomplish this, the Development Team first created a class diagram using Visual Studio to model the classes. This class diagram was then translated into a document that specified technical details about the classes that is not expressed in the class diagram. The class design for the Demand Forecast Planner was reviewed by the Development Team as well as a third party within the IT department.

The reviewed class design was then used to specify a database design that would support the defined classes. The database design was first modeled as an entity relationship diagram using Microsoft SQL Server and then translated into a document that specified technical details about the database structure that could not be described in the entity relationship diagram. The database design was then reviewed by the Development Team as well as the database administrator of the company to ensure that performance and load on the existing systems would be acceptable.

Finally, the reviewed class and database designs were verified against the requirements to ensure that the design implemented these requirements correctly. A few short meetings were then held between the Development Team and the customer to clarify some areas of the requirements. The requirements document was updated to reflect these meetings and then the design phase was repeated to incorporate these changes as well as review and refine the design that had been created during the first iteration of the design phase.

4.2.1 Class Design Overview

The following section gives an overview of the class design for the Demand Forecast Planner. This section in no way is meant to describe the full class design for this system; for such information the formal software class design [3] should be referenced. The class diagram shown in figure 4.2, 4.3, 4.4 and 4.5 gives a high-level overview of the classes design.

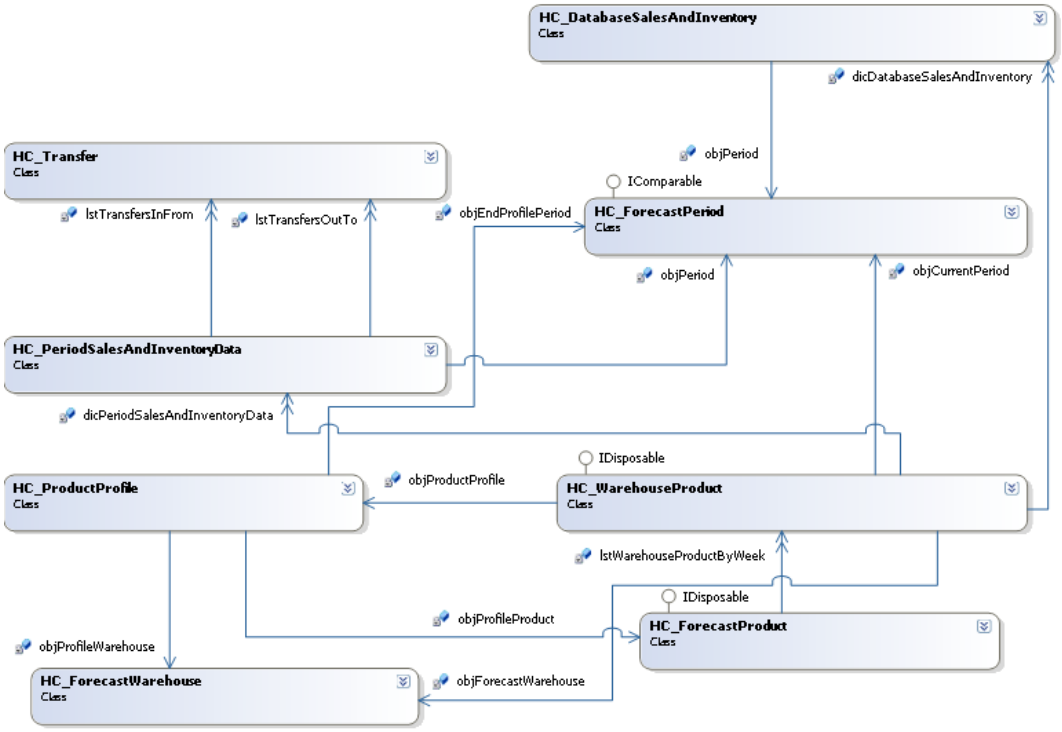


Figure 4.2 Class Diagram

The first class in Figure 4.2 is the ForecastProduct. This class is designed to represent a product that can be sold or ordered by the company; ForecastProducts include data elements such as the purchase price of the product as well as the ID used to identify the product and its description. Additionally, the ForecastProduct class has two collections that define WarehouseProducts that represent sales and inventory data for this product at a specific warehouse. One collection is defined to hold WarehouseProducts with sales and inventory broken out monthly and the other stores sales and inventory broken out weekly. Each collection holds one WarehouseProduct object for each warehouse defined for the system. This class is designed to be the parent class for the Demand Forecast Planner system, using this class to query data about sales and inventory for specific products.

The next class shown in Figure 4.2 is the ForecastPeriod. This class is designed to represent a given period of time as well as perform calculations about the

relationship between two periods. Periods can be defined as weekly or monthly and are used to define sales and inventory data during a specific length of time. For example, the month of May 2008 or the 32nd week of the year 2008 are examples of data that could be represented by the ForecastPeriod class. This class is designed to implement the IComparable interface to support easily comparing multiple periods that would be used by language specific collections to sort periods correctly.

The ForecastWarehouse class shown in Figure 4.2 is designed to represent a specific physical warehouse for storing inventory. This class really provides a way to logically group a set of data from existing systems by defining how to aggregate data within those systems into this logical grouping called a ForecastWarehouse. It also provides constraints on how inventory can be transferred from one warehouse to another. This class is used to model the physical warehouses in the U.S. and Mexico and the transfer rules between them.

The WarehouseProduct class shown in Figure 4.2 specifies the behavior and relationship between the ForecastProduct, ForecastWarehouse and ForecastPeriod classes and represents a specific product being sold, ordered, shipped or transferred at a specific warehouse during a specific period of time. For example, if someone wants to know the number of widgets defined by product code 1234 that were sold during the 32nd week of the year 2008 from the U.S. warehouse, the WarehouseProduct class would hold a PeriodSalesAndInventoryData object that defines this information. While the PeriodSalesAndInventoryData class actually holds the sales and inventory data, the WarehouseProduct class defines the context for that data.

The DatabaseSalesAndInventory class shown in Figure 4.2 represents sales and inventory data specific to a single period and is created within the context of the WarehouseProduct class. This class aggregates data from the database for one period as specified by the ForecastPeriod within this class. This class uses its

parent class, WarehouseProduct, to represent the ForecastProduct and ForecastWarehouse it needs to pull data for.

The PeriodSalesAndInventoryData class shown in Figure 4.2 is very similar to the DatabaseSalesAndInventory class with one key difference - DatabaseSalesAndInventory aggregates data from multiple periods. For example, the PeriodSalesAndInventoryData class has data elements such as "PriorYearSales" and "PriorPriorYearSales". Rather than building specific logic into this class about how to go to the database and pull data for multiple periods, it simply uses the DatabaseSalesAndInventory class to retrieve the data from the database and then pulls data from multiple periods to get the needed data elements. All this work could have been done within this class, but it would have made it unnecessarily complex and thus it was broken out into a separate class.

The Transfer class shown in Figure 4.2 is a simple class created within the context of the PeriodSalesAndInventoryData class to represent transfers from one ForecastWarehouse to another during a specific period of time. This class simply specifies how many units are being transferred and what the source and destination ForecastWarehouse of the transfer is. The parent objects of this class are used to specify the product and period data for the transfer.

Lastly the ProductProfile class shown in Figure 4.2 is a class used to represent sales and inventory for one product based on another product. New products are commonly added that have no past sales or inventory data, but are similar to a specific product or product line that is already sold. This class provides a way of specify how to substitute past sales and inventory data for a specific product based on a different product or product line.

The above classes specify the building blocks of a software system that supports the requirements for the Demand Forecast Planner. The design is in no way perfect and could be enhanced in many ways, but the Development Team did the best it could, given its level of experience and understanding of software engineering principles.

4.2.2 Database Design Overview

The following section gives an overview of the database design for the Demand Forecast Planner. This section is in no way meant to describe the full database design for this system; for such information the formal database design [4] should be referenced. The entity relationship diagram shown in figure 4.6 and 4.7 gives a high-level overview of the database design.

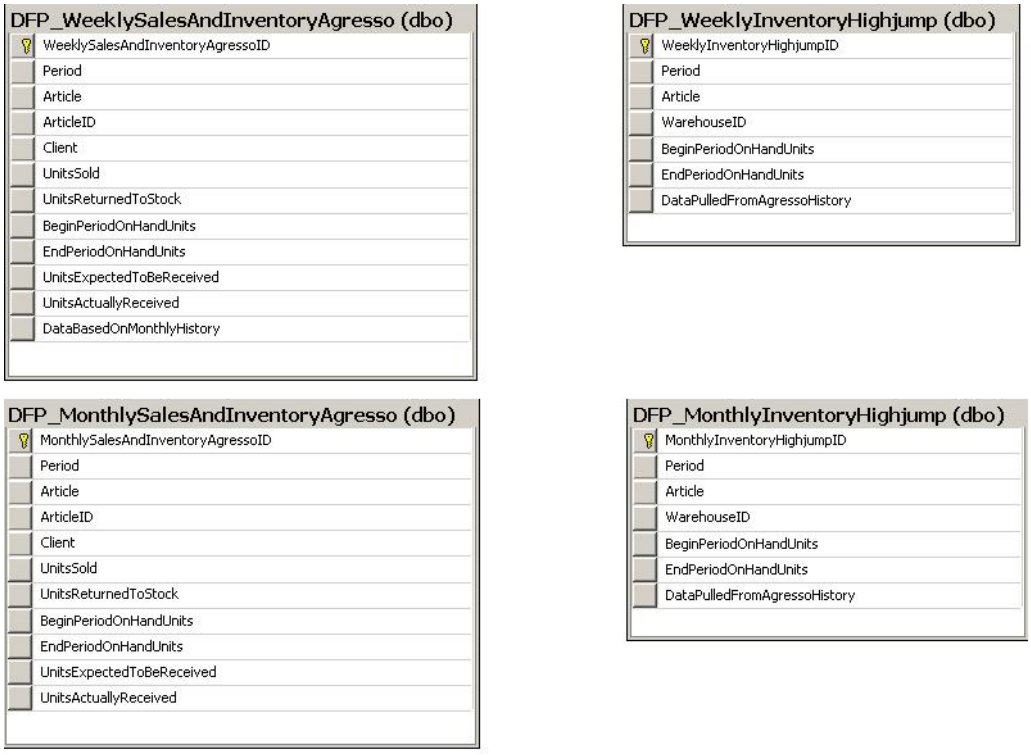


Figure 4.3 Entity Relationship Diagram 1

The tables shown in Figure 4.3 are summary or aggregate tables designed to hold sales and inventory data from existing systems. There are two major reasons for creating these tables. First, because the sheer volume of data within the existing systems is so great, user response time to query the data directly would have been unacceptable. Second, because running large, CPU intensive queries

throughout the day would have adversely affected the performance of the existing systems. For these reasons, a set of views and stored procedures were created and scheduled to be ran during off peak hours to load these summary tables that the Demand Forecast Planner would then use in place of running queries directly against the existing systems. Data could potentially become as much as one day out of sync with the existing systems, but this is considered an acceptable tradeoff for increased performance.

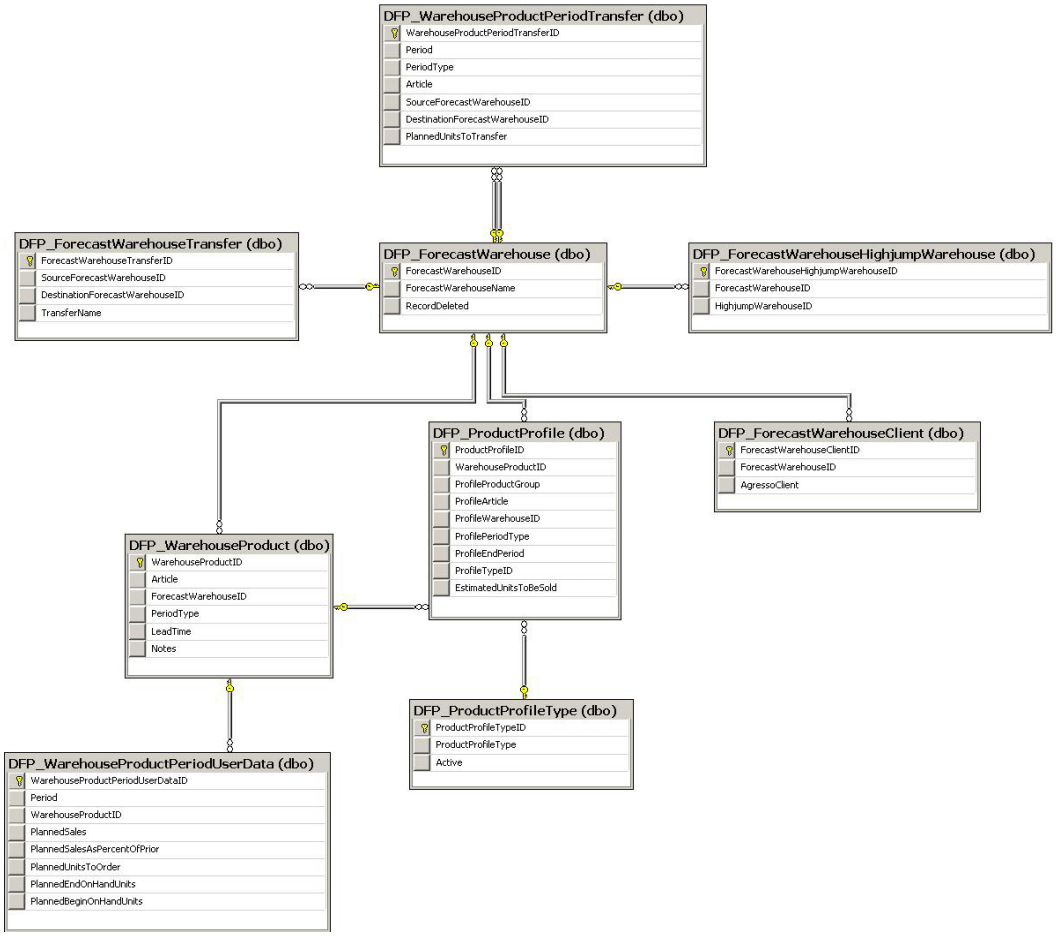


Figure 4.4 Entity Relationship Diagram 2

The DFP_ForecastWarehouse table in Figure 4.4 is designed to support the ForecastWarehouse class from the class design. This table includes a name and ID

that represent a physical warehouse. Using a primary/foreign key relation with DFP_ForecastWarehouseHighjumpWarehouse and DFP_ForecastWarehouseClient tables these tables show the particular data in existing systems that should be combined to define a ForecastWarehouse entity. The DFP_ForecastWarehouseTransfer table represents the acceptable types of inter-warehouse transfers. For example, this table specifies if inventory can be transferred from the U.S. warehouse to the Mexico warehouse and vice versa. The last table that represents data associated with the ForecastWarehouse class is the DFP_WarehouseProdutPeriodTransfer table. This table represents an actual transfer from one warehouse to another. It specifies the product being transferred, the source and destination warehouse, the number of units being transferred and the period of time when the units are transferred.

The DFP_WarehouseProduct table shown in Figure 4.4 was designed to support the WarehouseProduct class required in the class design. This table represents a relationship between a warehouse and a product, using a primary/foreign key relation with DFP_WarehouseProductPeriodUserData, projected future sales, and inventory levels for a given WarehouseProduct can be represented.

Lastly the table DFP_ProductProfile defined in Figure 4.4 is designed to support the ProductProfile class from the class design. This table represents a relationship between two WarehouseProduct entities or a single WarehouseProduct entity and a product line. This data is used to substitute historical sales and inventory data from one WarehouseProduct, or product line, to another WarehouseProduct that does not have enough historical data to predict future inventory needs.

4.3 Lessons Learned During Design

This section will detail some of the major areas that the Development Team believes could be improved or that played an especially important role in the

design phase. A problem that arose both in the requirements phase and the design phase was a lack of tool support. While tools are available to model both the class and database design, Microsoft Word was again used to specify the detailed class and database designs. The increased amount of data tracked in the design phase, as compared to the requirements phase, made the design documents cluttered and hard to navigate. With the class and database design each extending beyond fifty pages, finding key design decisions became cumbersome.

A tool that allows both modeling capabilities and additional detailed design support would have been helpful to the Development Team. A way to track collaboration on design decisions would help outside parties understand the thought process that went into the design. The collaboration that went into design decisions for the Demand Forecast Planner was omitted by the Development Team from the detailed design documents in many cases to keep these documents a manageable size. Along with this concept, a way of tracking versions of design documents could have been useful.

Tool support to help navigate the detailed design documents would also have been beneficial. A way of sorting and filtering a design specification based on phase or a user defined logical category could increase the efficiency in the Development Team's ability to access key design information. Because class and database design are closely related, tools linking the two areas of design were needed. Overall tool support rather than free form text could greatly increase the effectiveness of the Development Team during the design phase.

Another important lesson learned during the design phase was how important a well defined class design is for understanding and further designing a system. Refining requirements into small, easily understandable units greatly helped the Development Team's understanding of the problem. Additionally, abstracting the data into classes made the database design a straight forward task of supporting the underlying classes; this simplified design. The upfront time invested in

properly creating the classes for the Demand Forecast Planner was the key to the Development Team's success.

5. Implementation

The third phase of software development is the implementation or coding phase. IEEE has the following definition for coding [6].

“

1. In software engineering, the process of expressing a computer program in a programming language.
2. (IEEE Std 1002-1987) The transforming of logic and data from design specifications (design descriptions) into a programming language.

”

Unlike the requirements gathering and design phases, the implementation phase should not require a great deal of upfront time. Most of the consideration on how the system will be created was done in the design phase and actually implementing the system at this point should be a mechanical translation from design to code. If excessive time is required during implementation, then it is likely the design is inadequate and needs further work. The reason so much time was spent in the requirements gathering and design phases was to make the implementation phase simple and straight forward.

5.1 Implementing the Demand Forecast Planner

While no official methodology was followed during the implementation of the Demand Forecast Planner, a number of guidelines were followed by the Development Team that applied to this phase. This section will give a brief overview of the implementation guidelines followed, but little detail will be given to the actual code itself as this is outside the scope of this document. Table 5.1 lists several of the most important guidelines and best practices related to variables used during this phase.

Coding Guideline	**Guideline Description**

Use Meaningful Variable Names	When defining a variable the name should express the use or meaning from this variable.
Variable Type Prefix	When defining a variable a standard prefix should be used so the type of the variable can be determined from the variable name.
Proper Variable Capitalization	Ensure proper capitalization is used when naming variables.
Class Variables Declared Private	Class variables should always be declared private. If public access is needed to a variable read only and/or write only, properties to get and set this variable should be defined.
Limit Access To Class Variables	If a class variable only needs to be read by an external application, ensure a read only property is defined for this variable. Never allow external code to update a value that should only be updated internally. i.e. use write access sparsely.

Table 5.1 Variable Guidelines and Best Practices

A standard variable prefix was used by the Development Team in order to specify the type of a variable outside the location it is declared. For the Demand Forecast Planner, the Microsoft Naming Conventions for Visual Basic [11] were used as a standard set of variable prefixes. For example, a string variable that stores a customer's first name might be defined as 'strCustomerFirstName', to both identify the meaning and type of the variable regardless of where in the code the variable is used. It is also important to use proper capitalization when creating variables. The variable name 'strCustomerFirstName' is easily understood because proper capitalization breaks the words apart.

The scope of a variable will likely be specified within the design specification of a system, but if it is not, class level variables were declared private or protected by the Development Team. If there is a need for a class level variable to be accessed, read or written, the Development Team included get and set properties. Using properties in this way is a better practice than declaring variables as public and should be used by the coder whenever possible. Additionally, access to class level variables is tightly restricted.

Another important area that needs to be focused on during the implementation phase is readability, complexity and understandability of code. Table 5.2 defines several of the most important guidelines and best practices related to these areas that were used by the Development Team while implementing the Demand Forecast Planner.

Coding Guideline	**Guideline Description**
Commenting and Standard Comment Blocks	Commenting code is an important part of coding and should be done consistently, using a standard comment style or built in language specific comment block if supported.
Regions and Logical Groupings	Logically grouping like segments of code should be done to increase readability and understandability. Regions should be used if supported by the language being used.
Complex Functions Broken Apart if Possible.	Whenever possible, large and complex functions should be broken out into smaller and easer to understand functions. This will help readability, complexity and understandability of the code.

Table 5.2 Readability, Complexity and Understandability Guidelines

Commenting code is an elementary concept in software engineering and properly writing code, but one that is often overlooked. To help with the task of commenting code the Development Team used Microsoft Visual Studio's standard comment block. The use of these standard comment blocks (illustrated in figure 5.3) can help to clearly define the code. Additionally third party tool support is available for converting these standard comment blocks into auto generated help files or online documentation. While this topic is interesting, this document will not discuss the use of such auto generating help file tools, but more information on this topic can be obtained from [12].

```
''' <summary>
'''   Creates a new instance of WarehouseProduct
''' </summary>
''' <param name="InForecastWarehouse">
'''   The ForecastWarehouse this WarehouseProduct will represent.
''' </param>
''' <param name="InPeriodType">
'''   The Period Type this WarehouseProduct is defined for.
''' </param>
''' <param name="InParentProduct">
'''   The parent ForecastProduct this WarehouseProduct will represent.
''' </param>
''' <remarks>
'''   This class defines the relationship between a ForecastProduct and ForecastWarehouse
'''   for a specific period type
''' </remarks>
Public Sub New(ByRef InForecastWarehouse As HC_ForecastWarehouse, _
               ByVal InPeriodType As HC_ForecastPeriod.enumPeriodType, _
               ByRef InParentProduct As HC_ForecastProduct)
```

Figure 5.3 Standard Comment Block

Another guideline that can help the readability and understandability of code is that of logically grouping similar areas of code together. Figure 5.4 shows how Regions, a language specific element of VB.Net and C#, were used to logically group data within the WarehouseProduct class. In conjunction with making the code easy to navigate, it also helps the coder to easily define where new code should be written within a class. While this process is in no way ground breaking, the Development Team found its use extremely helpful during the implementation phase.

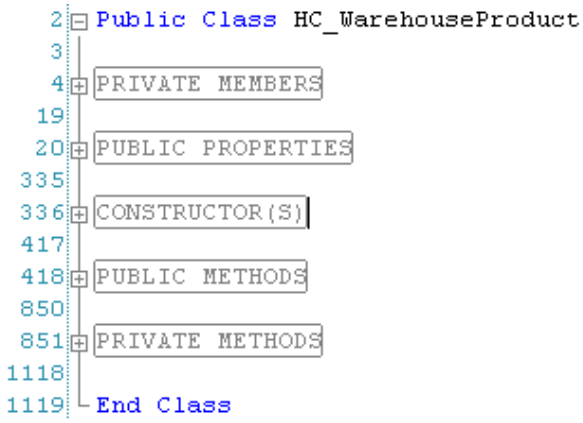


Figure 5.4 Regions and Logically Grouping Code Elements

The complexity of functions should be reviewed and specified within the design phase, but sometimes what seems simple during the design may become more complex when coding begins. If this happens during the implementation phase, the design should be updated and reviewed to ensure the change will not affect the rest of the software system.

The last set of guidelines used by the Demand Forecast Planner that will be discussed is that of error handling and using built-in libraries. Table 5.6 defines two important guidelines and best practices related to these areas.

Coding Guideline	**Guideline Description**
All Code Within A Try Catch Block	Any code that has the potential to cause an error should be defined with a Try Catch block to handle potential exceptions.
Do not Reinvent the Wheel – Use Libraries	The libraries of frameworks of commercial software packages today are extensive and likely have already solved a majority of the problems that will be encountered while coding.

Table 5.6 Error Handling and Library Usage Guidelines

Proper error handling can help to pinpoint errors and quickly identify how to correct them. For this reason, the Development Team placed the majority of code written within try catch blocks. The Development Team also strove to attend to software reuse whenever possible. For example the design for the Demand Forecast Planner required that the ICompariable interface be implemented to sort sales and inventory data by period. The use of this interface allowed the Development Team to take advantage of library specific data structures to store and sort custom objects.

5.2 Code Metrics for the Demand Forecast Planner

At the time of its initial release the Demand Forecast Planner consists of eight classes. These eight classes include a total of forty-two public methods for an average of approximately five public methods per class. The total lines of code

contained within these eight classes is 4,954, and the total lines for code for the complete application, classes and GUI, is 6,279. While these numbers might seem small for an application of this size, the database objects needed to support the Demand Forecast Planner were complex and offloaded a large amount of work to the database.

The supporting database contains twenty-one tables. Additionally, thirty-two stored procedures and eight views were created to support the retrieval of data for the application. Lastly, two scheduled SQL jobs were created to aggregate data from existing systems to ensure adequate performance for the Demand Forecast Planner. The total lines of code for the above database objects totals 1,863.

6. Testing

The fourth phase of software development is the testing phase. IEEE has the following definition for testing [6].

“

1. An activity in which a system or component is executed under specified conditions, the results are observed or recorded, and an evaluation is made of some aspect of the system or component.
2. To conduct an activity as in (1).

”

In the context of the Demand Forecast Planner this definition refers to executing a specific area of the application with an expected output, and then comparing the actual output to what was expected. A specific test, or test case, should be derived from the requirements, as the purpose of every test should be to verify the system or component is doing what it is required to do. Creating test cases before the design and implementation phases begin will often lead to a more complete design and less errors within the code.

6.1 Testing Methodology

To test the Demand Forecast Planner, a methodology loosely based on the IEEE 829-1998 standard [9] for software testing documentation was used. This standard was mainly used by the Development Team to specify a set of test cases to verify the Demand Forecast Planner adhered to the requirements specified for the system. These test cases were used to conduct system testing before the application was turned over to end users for user acceptance testing.

User acceptance testing was used to validate that the Demand Forecast Planner met the requirements of its end users. While the Development Team learned a great deal about the purchasing and manufacturing areas of the business during the development of the Demand Forecast Planner, in the end the Development

Team members are not purchasing professionals and were unable to determine if the application would be adequate to meet the purchasing needs of its end users.

6.2 Testing the Demand Forecast Planner

The following section gives an overview of the testing phase for the Demand Forecast Planner. During this phase, the Development Team first produced a set of generic test cases based on the requirements created in the first step of the software life cycle. These test cases did not use application domain specific data, but rather generic sample data used to illustrate how the final system should function. These generic test cases were translated into application domain specific test cases when the application was complete and testing began. Table 6.1 is the set generic test data and test cases that were defined for the Demand Forecast Planner; for additional information the formal test plan [5] should be referenced.

Sample Data for Fictional Product TST01 – US Warehouse										
Period	**TY Plan Sls**	**PY Sls**	**PY Plan Sls**	**PPY Sls**	**TY BoH**	**TY EoH**	**PY BoH**	**PY EoH**	**Plan On Order**	**Actual On Order**
200801	300	150	135	20	2222	1922	2000	1850	0	0
200802	303	153	138	23	1922	1619	1850	1697	0	0
200803	306	156	140	26	1619	1313	1697	1541	0	0
200804	309	159	143	29	1313	1004	1541	1882	0	0
200805	312	162	146	32	1004	692	1882	1720	0	0
200806	315	165	149	35	692	377	1720	1555	0	0
200807	318	168	151	38	377	2059	1555	1387	0	2000
200808	321	171	154	41	2059	1738	1387	1216	0	0
200809	324	174	157	44	1738	1414	1216	1042	0	0
200810	327	177	159	47	1414	1087	1042	865	0	0
200811	330	180	162	50	1087	757	865	685	0	0
200812	333	183	165	53	757	2424	685	502	0	2000
200813	336	186	167	56	2424	2088	502	316	0	0
200814	339	189	170	59	2088	1749	316	127	0	0
200815	342	192	173	62	1749	1407	127	935	0	0
200816	345	195	176	65	1407	1062	935	740	0	0

200817	348	198	178	68	1062	714	740	542	0	0
200818	351	201	181	71	714	363	542	341	0	0
200819	354	204	184	74	363	9	341	137	0	0
200820	357	207	186	77	9	1652	137	930	2000	0
200821	360	210	189	80	1652	1292	930	720	0	0
200822	363	213	192	83	1292	929	720	507	0	0
200823	366	216	194	86	929	563	507	291	0	0
200824	369	219	197	89	563	194	291	72	0	0
200825	372	222	200	92	194	2822	72	-150	3000	0
200826	375	225	203	95	2822	2447	-150	1125	0	0
200827	378	228	205	98	2447	2069	1125	897	0	0
200828	381	231	208	101	2069	1688	897	666	0	0
200829	384	234	211	104	1688	1304	666	432	0	0
200830	387	237	213	107	1304	917	432	195	0	0
200831	390	240	216	110	917	527	195	1955	0	0
200832	393	243	219	113	527	134	1955	1712	0	0
200833	396	246	221	116	134	3238	1712	1466	3500	0
200834	399	249	224	119	3238	2839	1466	1217	0	0
200835	402	252	227	122	2839	2437	1217	965	0	0
200836	405	255	230	125	2437	2032	965	710	0	0
200837	408	258	232	128	2032	1624	710	452	0	0
200838	411	261	235	131	1624	1213	452	191	0	0
200839	414	264	238	134	1213	799	191	2927	0	0
200840	417	267	240	137	799	382	2927	2660	0	0
200841	420	270	243	140	382	3462	2660	2390	3500	0
200842	423	273	246	143	3462	3039	2390	2117	0	0
200843	426	276	248	146	3039	2613	2117	1841	0	0
200844	429	279	251	149	2613	2184	1841	1562	0	0
200845	432	282	254	152	2184	1752	1562	1280	0	0
200846	435	285	257	155	1752	1317	1280	995	0	0
200847	438	288	259	158	1317	879	995	707	0	0
200848	441	291	262	161	879	438	707	416	0	0
200849	444	294	265	164	438	3494	416	122	3500	0
200850	447	297	267	167	3494	3047	122	2825	0	0
200851	450	300	270	170	3047	2597	2825	2525	0	0
200852	453	303	273	173	2597	2144	2525	2222	0	0

Table 6.1 Fictional Product Test Data

Test Case	**Test Element**	**Test Value(s)**	**Valid Response**	**Calculation**

1	Avg Inventory	TST01	1575	BOH Qty for the future 52 weeks / 52.
2	52 Week Projected Sales	TST01	19578	Sum of this year's planned sales (TY PLAN SLS) for the next 52 weeks.
3	PY 52 Week Sales	TST01	11778	Sum of last year's sales (PY SLS) 52 weeks.
4	Avg Weekly Sls Units	TST01	377	Sum of this year's planned sales (TY PLAN SLS) for the next 52 weeks divided by 52.
5	12 Week Avg Sls Units	TST01	317	Sum of this year's planned sales (TY PLAN SLS) for the next 12 weeks divided by 12.
6	Total Units On Order	TST01	4000	Total units for a particular item that are on existing, approved purchase orders.
7	PPY Sls	TST01 200805	32	None
8	PY Sls	TST01 200805	162	None
9	PY Sls As % PPY Sls	TST01 200805	406.25%	(PY Sales/PPY Sales) – 1
10	PY Sls As % PY Plan Sls	TST01 200805	10.95%	(PY Sales/PY Plan Sls) – 1
11	PY Plan Sls	TST01 200805	146	None
12	PY Plan Sls As % PY Sls	TST01 200805	-9.87%	(PY Plan Sls/PY Sales) – 1
13	TY Plan Sls	TST01 200805	312	None
14	TY Plan Sls As % PY Sls	TST01 200805	92.59%	(TY Sales/PY Sales) – 1 (USER INPUT)

15	PY BOP	TST01 200805	1882	None
16	PY EOP	TST01 200805	1720	None
17	PY Turn	TST01 200805	8.99%	(PY SLS) / (((PY BOP) + (PY EOP))/2)
18	TY Act/Plan BOP	TST01 200805	1004	For current period no calculations just get current BOP units. For future periods retrieve the previous periods TY Plan EOP.
19	TY Plan EOP	TST01 200805	692	(TY Act/Plan BOP) + (Actual On Order) + (Plan On Order) – (TY PLAN SLS)
20	TY Plan Turn	TST01 200805	36.79%	(TY PLAN SLS) / (((TY Act/Plan BOP) + (TY Plan EOP)) / 2)
21	TY Periods	TST01 200805	2.09	(TY Plan EOP) / (Sum Next 12 Periods TY PLAN SLS / 12)
22	PY Received	TST01 200805	0	None
23	Plan On Order	TST01 200805	0	None
24	Actual On Order	TST01 200805	0	None

Table 6.2 Test Cases for Fictional Product TST01

The data in Tables 6.1 and 6.2 does not completely cover all requirements for the Demand Forecast Planner, but the Development Team believes these test cases encompass the major functionality. While all the data used for the above test cases is fictional, it clearly illustrates how the final system should function. The above test cases were created by the Development Team, but signed off by the customer to ensure both sides were in agreement as to what needed to be

delivered in the end product. This open dialog was helpful to the Development Team and led to a few updates to the initial requirements.

Although these test cases did not test data for an actual product, they defined what would be tested in the final system. After the design and implementation phases were complete, these generic test cases were translated into specific test cases for the final system. This decreased the amount of time needed to test the system once it was complete, as well as made the testing process a fairly mechanical process of plugging in numbers and looking for an expected result. The following is the set of specific test cases defined after the implementation phase was complete.

Actual Data for Product CO6323 (9 Ply, 10 Piece Set) – US Warehouse										
Period	**TY Sls**	**PY Sls**	**PY Pln Sls**	**PPY Sls**	**TY BoH**	**TY EoH**	**PY BoH**	**PY EoH**	**Plan On Order**	**Actual On Order**
200838	93	155	0	228	218	125	4468	4337	0	0
200839	62	103	0	217	125	63	4315	4185	0	0
200840	97	162	0	199	63	-34	4163	4032	0	0
200841	98	164	0	267	-34	-132	4010	3880	0	0
200842	73	122	0	157	-132	-205	3858	3747	0	0
200843	79	132	0	186	-205	-284	3728	3618	0	0
200844	72	120	0	264	-284	-356	3599	3488	0	0
200845	86	144	0	382	-356	-442	3470	3358	0	0
200846	95	158	0	193	-442	-537	3358	3185	0	0
200847	66	110	0	200	-537	-603	3185	3078	0	0
200848	74	124	0	228	-603	-677	3078	2961	0	0
200849	74	124	0	243	-677	249	2961	2844	1000	0
200850	116	194	0	198	249	133	2844	2661	0	0
200851	50	84	0	219	133	83	2661	2563	0	0
200852	76	126	0	209	83	7	2563	2440	0	0
200901	97	162	0	157	7	-90	2440	2307	0	0
200902	52	86	0	351	-90	-142	2307	2210	0	0
200903	107	178	0	183	-142	-249	2210	2041	0	0
200904	113	188	0	197	-249	-362	2041	1901	0	0
200905	86	143	0	211	-362	-448	1901	1688	0	0
200906	70	117	0	123	-448	-518	1688	1634	0	0

200907	6	6	0	130	-518	-524	1564	0	0	0
200908	57	57	0	120	-524	-581	0	1504	0	0
200909	98	98	0	211	-581	-279	1504	670	400	0
200910	111	111	0	204	-279	-390	670	561	0	0
200911	113	113	0	226	-390	-503	561	449	0	0
200912	89	89	0	206	-503	-592	449	1016	0	0
200913	126	126	0	228	-592	-718	1016	928	0	0
200914	109	109	0	211	-718	-827	928	847	0	0
200915	131	131	0	220	-827	-958	847	752	0	0
200916	145	145	0	233	-958	-1103	752	599	0	0
200917	105	105	0	204	-1103	-1208	599	512	0	0
200918	96	96	0	227	-1208	-1304	512	401	0	0
200919	90	90	0	207	-1304	-1394	401	316	0	0
200920	130	130	0	199	-1394	-1524	316	185	0	0
200921	92	92	0	206	-1524	-1116	185	87	500	0
200922	82	82	0	197	-1116	-1198	87	0	0	0
200923	122	122	0	179	-1198	-1320	120	0	0	0
200924	113	113	0	204	-1320	-1433	0	101	0	0
200925	163	163	0	166	-1433	-596	101	92	1000	0
200926	108	108	0	169	-596	-704	92	388	0	0
200927	83	83	0	158	-704	-787	388	517	0	0
200928	95	95	0	176	-787	-882	517	558	0	0
200929	105	105	0	139	-882	-987	558	476	0	0
200930	81	81	0	172	-987	-1068	476	397	0	0
200931	110	110	0	111	-1068	-1178	397	300	0	0
200932	82	82	0	197	-1178	-1260	300	216	0	0
200933	61	61	0	155	-1260	-1321	216	141	0	0
200934	62	62	0	120	-1321	-1383	141	144	0	0
200935	75	75	0	124	-1383	-1458	144	214	0	0
200936	81	81	0	165	-1458	-1539	214	199	0	0
200937	90	90	0	225	-1539	-1629	199	233	0	0

Table 6.3 Product Data for CO6323 (9 Ply, 10 Piece Cookware Set)

Test Case	**Test Element**	**Test Value(s)**	**Valid Response**	**Calculation**	**Test Case**
1	Avg Inventory	CO6323	-660	-660	Pass
2	52 Week Projected Sales	CO6323	4747	4747	Pass

3	PY 52 Week Sales	CO6323	5907	5907	Pass
4	Avg Weekly Sls Units	CO6323	91	91	Pass
5	12 Week Avg Sls Units	CO6323	80	80	Pass
6	Total Units On Order	CO6323	0	2900	Fail Don't Include Planned On Order
7	PPY Sls	CO6323 200850	198	198	Pass
8	PY Sls	CO6323 200850	194	194	Pass
9	PY Sls As % PPY Sls	CO6323 200850	-2%	-2%	Pass
10	PY Sls As % PY Plan Sls	CO6323 200850	0%	0%	Pass
11	PY Plan Sls	CO6323 200850	0	0	Pass
12	PY Plan Sls As % PY Sls	CO6323 200850	0	0	Pass
13	TY Plan Sls	CO6323 200850	116	116	Pass
14	TY Plan Sls As % PY Sls	CO6323 200850	-40%	-40%	User Input
15	PY BOP	CO6323 200850	2844	2844	Pass

16	PY EOP	CO6323 200850	2661	2661	Pass
17	PY Turn	CO6323 200850	7%	7%	Pass
18	TY Act/Plan BOP	CO6323 200850	249	249	Pass
19	TY Plan EOP	CO6323 200850	133	133	Pass
20	TY Plan Turn	CO6323 200850	60.7%	60.7%	Pass
21	TY Periods	CO6323 200850	1.72	1.72	Pass
22	PY Received	CO6323 200850	0	0	Pass
23	Plan On Order	CO6323 200850	0	0	Pass
24	Actual On Order	CO6323 200850	0	0	Pass

Table 6.4 Test Cases for CO6323 (9 Ply, 10 Piece Set)

The data in tables 6.3 and 6.4 are the test cases executed by the Development Team upon the completion of the implementation phase for the Demand Forecast Planner. Similar test cases were executed during the implementation phase to ensure the system was calculating metrics correctly, but testing values were not formally recorded at that time. The only error found during the formal testing phase was test case 6, related to including “planned on order” units within the “total units on order” metric. Several more errors were uncovered by the Development Team during the implementation phase, but having the Development Team both test and implement the application blurred the lines between these two phases. A separation of responsibilities for implementation and

testing the Demand Forecast Planner would have likely resulted in a higher quality and more error-free initial release. The reality of the situation, and that of many in-house applications, was that the Development Team was required to both implement and test the application. The Development Team would have preferred the help of a separate testing team, but as none was available, initial testing was conducted by the Development Team and user acceptance testing was heavily used to find any additional errors.

Lastly, user acceptance testing was conducted to ensure the Demand Forecast Planner met the initially defined requirements of the system and to uncover any errors not detected within the formal testing phase. During this phase the Development Team met with the customer and recorded feedback about the system. While the customer used the application, a few errors were uncovered as well as a few enhancement requests for functionality not initially defined within the requirements. Errors were recorded and corrected by the Development Team while enhancement requests were incorporated into the requirements and design and added to the system. After a few iterations of this process, the system was officially released based on the acceptance of the customer.

6.3 Lessons Learned During Testing

This section will detail some of the major areas that the Development Team feels could have been improved or played an especially important roll during the testing phase. One of the major struggles during the testing phase was that the same personnel served as coding and testing groups. While having the same group both code and test the system does not mean a quality system can not be delivered, it is generally better to have these tasks preformed by separate groups. Generally, the coding group is unlikely to give the same level of detailed testing as an independent testing group. This was true in the testing of the Demand Forecast Planner and lead to a few faults being identified during user acceptance testing rather than during system test.

Another issue that was not specific to the testing phase, but affected the testing phase more than any other, was the high demand for the system to be available as quickly as possible. Given a limited amount of time to develop the system, a great deal of formal testing was delayed until user acceptance testing. Had the testing phase been given more time, more of these issues could have been found prior to user acceptance testing.

The close proximity of the Development Team and customer proved to be helpful for testing the Demand Forecast Planner. This made it easy to get feedback quickly and facilitated user acceptance testing. The Development Team could correct an issue and then walk over to the customer and see the effects of that change, getting quick feedback from the customer. This efficient dialog helped to ensure the system was functioning as required and pinpoint any errors quickly.

7. Maintenance

The fifth, and normally final phase of software development, is the maintenance phase. IEEE has the following definition for maintenance [6].

“

1. Software maintenance is the process of modifying a software system or component after delivery to correct faults, improve performances or other attributes, or adapt to a changed environment.
2. The process of retaining a hardware system or component in, or restoring it to, a state in which it can perform its required functions.

”

In the context of the Demand Forecast Planner the maintenance phase started before the system was delivered. While the official definition states maintenance is a task that occurs after delivery, the Development Team started putting a maintenance framework in place throughout the software life cycle. This maintenance framework helped facilitate the task of maintaining the Demand Forecast Planner after its initial release.

7.1 Maintenance Methodology

No formal methodology was followed to support the maintenance activities of the Demand Forecast Planner. The activity of maintaining a software system is really just repeating the requirements, design, coding and testing phases of the software life cycle for an existing system. For this reason, the Development Team’s major goal was to incorporate maintenance elements into these phases to help support any future changes. In the requirements phase these maintenance elements would help to define when a specific requirement was defined for the system as well as if a requirement was changed from one release to another, and how the requirement was changed. This tracking of requirements to a specific release gives a road map of system change from release to release. The tracking

also assists in maintaining the same strict software development practices when developing future requirements.

Design element introduction was also tracked. This gave a clear understanding of how the design changed over time. The goal of this approach was to keep maintenance changes from bypassing the requirements and design phases. While this might be acceptable for correcting coding issues, most changes to an existing system should update the corresponding requirements and design of the system so an accurate representation of the working system can be identified from the requirements and design.

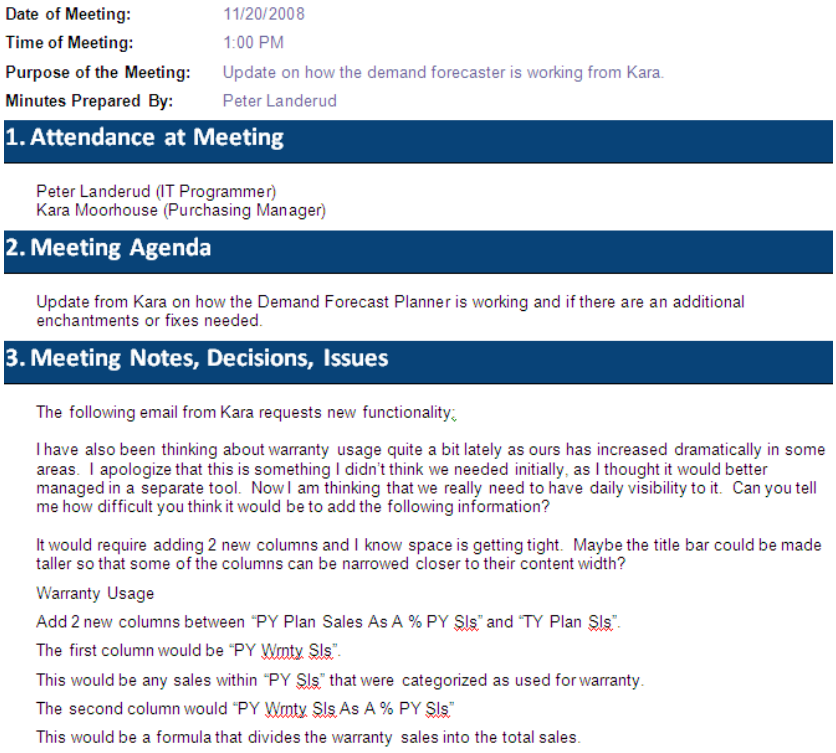
Adequate commenting, including date and reason a change was made, is the first major maintenance element the Development Team used within the implementation phase. Additionally, a number of different programmers will be working on the system over its lifetime, and including who made a specific change was added to comments while maintaining the code. While source code control is not exactly an element that would be added to the code to facilitate maintenance, it was also used during the coding and maintenance phases. For the Development Team knowing exactly what was changed and when was helpful in identifying newly introduced bugs that were the result of a maintenance task.

7.2 Maintaining the Demand Forecast Planner

There has not yet been sufficient time to perform much maintenance on the Demand Forecast Planner. To illustrate how maintenance is planned to be performed, this section will follow the first change request from initial request through implementation and testing. It is expected that this process will be continued for future enhancements and/or error fixes.

The first step in the maintenance phase was for the Development Team to document enhancements and/or errors. Figure 6.1 is an excerpt of the meeting minutes between the Development Team and the customer requesting new functionality. This request provides a description of the change request as given

by the customer and will be referenced when updating the requirements, design, code and test plan of the Demand Forecast Planner.



Date of Meeting: 11/20/2008
Time of Meeting: 1:00 PM
Purpose of the Meeting: Update on how the demand forecaster is working from Kara.
Minutes Prepared By: Peter Landerud

1. Attendance at Meeting

Peter Landerud (IT Programmer)
Kara Moorhouse (Purchasing Manager)

2. Meeting Agenda

Update from Kara on how the Demand Forecast Planner is working and if there are an additional enchantments or fixes needed.

3. Meeting Notes, Decisions, Issues

The following email from Kara requests new functionality:

I have also been thinking about warranty usage quite a bit lately as ours has increased dramatically in some areas. I apologize that this is something I didn't think we needed initially, as I thought it would better managed in a separate tool. Now I am thinking that we really need to have daily visibility to it. Can you tell me how difficult you think it would be to add the following information?

It would require adding 2 new columns and I know space is getting tight. Maybe the title bar could be made taller so that some of the columns can be narrowed closer to their content width?

Warranty Usage

Add 2 new columns between "PY Plan Sales As A % PY Sls" and "TY Plan Sls".

The first column would be "PY Wrnty Sls".

This would be any sales within "PY Sls" that were categorized as used for warranty.

The second column would "PY Wrnty Sls As A % PY Sls"

This would be a formula that divides the warranty sales into the total sales.

Figure 7.1 First Enhancement Request

With the change request documented, the next step was for the Development Team to update the requirements to include the newly requested functionality. In order to assist the Development Team in tracking a change request back to the requirements the date of the change request was used as a reference. While this reference is not the best solution, for small single-person projects it works fairly effectively. A better solution would have been to track the change request within a help desk style of software and then use the ID from this system as a reference. Table 7.2 and figure 7.3 show the updates made to the software requirement specification [2] for the change request. The "Date/Phase Added" element captures what and when this change was applied, and the date can be used to reference the original change request to explain why the change was made.

Period Based Purchasing Terms For Sales			
Term	**Definition**	**Calculation/Reference**	**Date/Phase**
PY Wrnty Sls	Prior year warranty sales.	None	11/20/2008 – User Testing Round 1
PY Wrnty Sls As % PY Sls	Prior year's warranty sales expressed as a % +/- prior year's sales.	PY Wrnty Sls/PY Sales	11/20/2008 – User Testing Round 1

Table 7.2 Updated Terms for Change Request

Index:	WarehouseProduct.4
Name:	Calculate Past Sales Metrics
Purpose:	To calculate a set of metrics based on past sales.
Input parameters:	None
Action:	Using the values returned by WarehouseProduct.3 (Get Past Sales) calculate a set of metrics.
Output parameters:	PY Sls As % PPY Sls (See Terms), PY Sls As % PY Plan Sls (See Terms), PY Plan Sls As % PY Sls (See Terms), PY 52 Week Sales(See Terms) PY Wrnty Sls As % PY Sls (Added 11/20/2008 – User Testing Round 1)(See Terms)
Exceptions:	There are no past sales for this warehouse product.
Remarks:	None
Cross-references:	None
Date/Phase Added:	9/15/2008 – Initial Requirements Phase UPDATED 11/20/2008 – User Testing Round 1

Figure 7.3 Updated Requirements for Change Request

The next step completed by the Development Team to implement this change request was to update the design. The process of reviewing the design, along with an initial design that was laid out with expansion in mind, helped the Development Team easily pinpoint the location the proposed change would fit best. Thinking of how best to incorporate this change into the design, rather than jumping directly to the code, not only made the change fit better into the overall application, but also kept the software development life cycle documentation up-to-date with the system. Figure 7.4 shows the sections of the class design [3] updated for this change request. The Development Team again used the date of the change request to indicate when and what was changed. The database design

was also updated, but because of the complex SQL involved, the changes are not shown here; please refer to [4] for more information.

Class Member:	Field – intPriorYearWarrantySales
Data Type:	Integer
Data Pulled From:	DFP_WeeklySalesAndInventoryAgresso.UnitsUsedForHyciteP aidReturns Or objParentWarehouseProduct.objProfileProduct
Additional Info:	The number of units used for warranty's during this period one year ago.
Date/Phase Added:	11/20/2008 – User Testing Round 1

Class Member:	Property – PriorYearWarrantySales
Data Type:	Integer
Data Pulled From:	Field – intPriorYearWarrantySales
Read Only:	True
Date/Phase Added:	11/20/2008 – User Testing Round 1

Class Member:	Property – PriorYearWarrantySalesAsPercentOfPriorYearSales
Data Type:	Integer
Data Pulled From:	Calculated – See [4] Terms
Read Only:	True
Date/Phase Added:	11/20/2008 – User Testing Round 1

Figure 7.4 Updated Class Design for Change Request

With a good design and supporting requirements in place, the next step for the Development Team was to actually change the source code. Given the careful requirements and design efforts, making changes to the code became a fairly mechanical process of translating the design into code. To track the changes, the Development Team added comments to specify who was making the change, when the change was made and why the change was made. Figure 7.5 shows one of the source code changes made and the commenting that accompanied the change..

```
''' <summary>
''' Gets the prior year warranty sales as percent of prior year sales.
''' </summary>
''' <value>The prior year warranty sales as percent of prior year sales.</value>
''' <returns>((PriorYearWarrantySales / PriorYearSales))</returns>
''' <remarks>
''' PY Wrnty Sls As % PY Sls
'''
''' PJL 11/20/2008 - Additional data element added at Kara's request
''' </remarks>
Public ReadOnly Property PriorYearWarrantySalesAsPercentOfPriorYearSales() As Decimal
    Get
        If PriorYearSales = 0 Or PriorYearWarrantySales = 0 Then
            Return 0
        Else
            Return ((PriorYearWarrantySales / PriorYearSales))
        End If
    End Get
End Property
```

Figure 7.5 Updated Source Code for Change Request

A source code control application called Vault was used by the Development Team to keep track of any changes made to the source code. Source code control will track every change made to the source code as well as who made it and when it was made. Source code control will version each committed change to the source code and these versions can easily be rolled back or promoted if needed. Built-in tools also make comparing two different versions of source code easy. Figure 7.6 shows one area of the source code before and after the change request was implemented. With this change request, the code did not exist at all in the previous version of the system, but had the request been to change a calculation within an existing class element, source code control can be extremely helpful in identifying what was change from one version to the next.

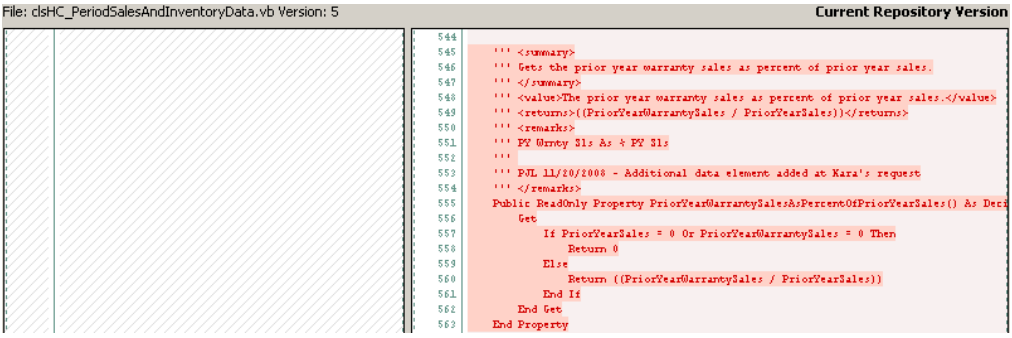


Figure 7.6 Source Code Control Comparison

The last maintenance task completed by the Development Team was to update the test plan to include a test case to test the requested change. This test plan was then executed to ensure the new change worked correctly, as well as to perform regression testing to ensure none of the previously working areas of the application stopped working. For more information on the test cases executed for the change request discussed in this section, see the formal test plan [5].

7.3 Lessons Learned During Maintenance

The maintenance phase of the Demand Forecast Planner is just beginning, but the Development Team has already learned a number of lessons during the initial maintenance request. This section will detail a few of the areas important to the maintenance of this system, as well as some areas important to the general maintenance phase of software that will be used going forward. One of the most useful steps taken by the Development Team to support the Demand Forecast Planner was to have the supporting documentation, such as requirements, design and testing grow with the application. On past projects, the Development Team has seen these documents initially created, but only the source code modified as the application required changes or enhancements. This reactionary maintenance, rather than planned maintenance, led to applications being disjoint from their initial design and difficult to maintain over time.

Additionally, having the ability to track a maintenance request from the initial request through implementation and testing of that request is was found to be useful by the Development Team. Knowing when and why the system changed was many times as important as the change itself. The use of maintenance elements within the software life cycle documents and code worked well for the Development Team to track this information. Moving forward with the maintenance process, it might become necessary to create separate versions of the software life cycle documents if a major change is introduced to the system. As

noted in the requirements and design phases, proper tool support would likely also ease the process of maintaining software life cycle documents.

8. The Demand Forecast Planner Application

This section will give an overview of the Demand Forecast Planner application that was created as a result of the software development processes described in this document. This section will not detail every feature of the Demand Forecast Planner, but will detail the most important areas of the application.

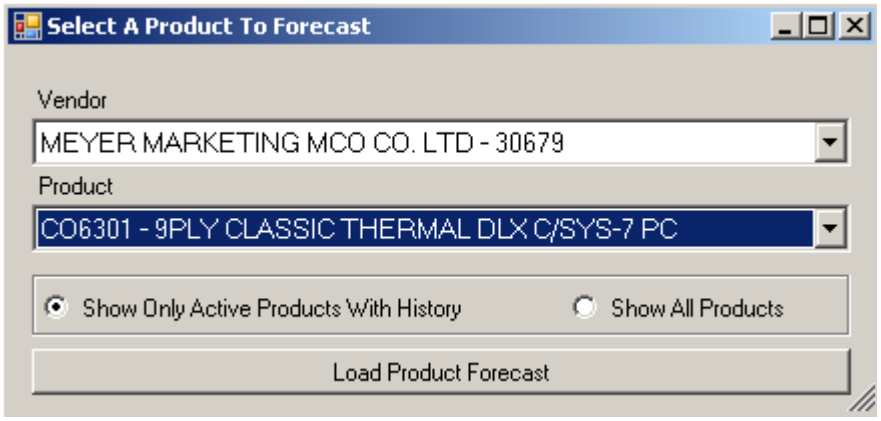
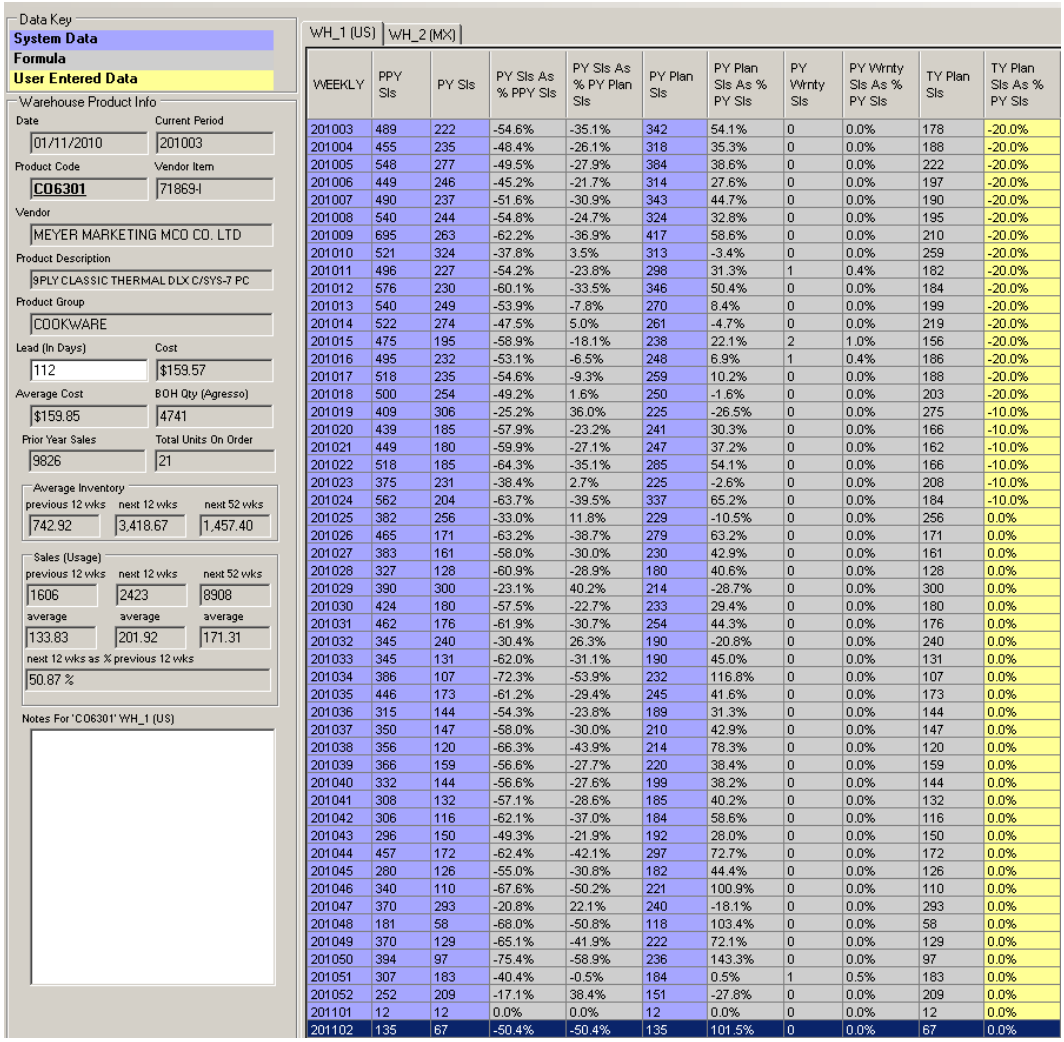


Figure 8.1 Product Selection Form

The Product Selection Form, shown in figure 8.1, is a form that allows the user to select a product to forecast. A vendor drop down was added to assist the user by narrowing the product search down to products supplied by a specific vendor. Additionally, two radio buttons were added to assist the user in filtering out active products that are currently for sales from products that are no longer sold.



WEEKLY	PPY Sls	PY Sls	PY Sls As % PPY Sls	PY Sls As % PY Plan Sls	PY Plan Sls	PY Plan Sls As % PY Sls	PY Wrnty Sls	PY Wrnty Sls As % PY Sls	TY Plan Sls	TY Plan Sls As % PY Sls
201003	489	222	-54.6%	-35.1%	342	54.1%	0	0.0%	178	-20.0%
201004	455	235	-48.4%	-26.1%	318	35.3%	0	0.0%	188	-20.0%
201005	548	277	-49.5%	-27.9%	384	38.6%	0	0.0%	222	-20.0%
201006	449	246	-45.2%	-21.7%	314	27.6%	0	0.0%	197	-20.0%
201007	490	237	-51.6%	-30.9%	343	44.7%	0	0.0%	190	-20.0%
201008	540	244	-54.8%	-24.7%	324	32.8%	0	0.0%	195	-20.0%
201009	695	263	-62.2%	-36.9%	417	58.6%	0	0.0%	210	-20.0%
201010	521	324	-37.8%	3.5%	313	-3.4%	0	0.0%	259	-20.0%
201011	496	227	-54.2%	-23.8%	298	31.3%	1	0.4%	182	-20.0%
201012	576	230	-60.1%	-33.5%	346	50.4%	0	0.0%	184	-20.0%
201013	540	249	-53.9%	-7.8%	270	8.4%	0	0.0%	199	-20.0%
201014	522	274	-47.5%	5.0%	261	-4.7%	0	0.0%	219	-20.0%
201015	475	195	-58.9%	-18.1%	238	22.1%	2	1.0%	156	-20.0%
201016	495	232	-53.1%	-6.5%	248	6.9%	1	0.4%	186	-20.0%
201017	518	235	-54.6%	-9.3%	259	10.2%	0	0.0%	188	-20.0%
201018	500	254	-49.2%	1.6%	250	-1.6%	0	0.0%	203	-20.0%
201019	409	306	-25.2%	36.0%	225	-26.5%	0	0.0%	275	-10.0%
201020	439	185	-57.9%	-23.2%	241	30.3%	0	0.0%	166	-10.0%
201021	449	180	-59.9%	-27.1%	247	37.2%	0	0.0%	162	-10.0%
201022	518	185	-64.3%	-35.1%	285	54.1%	0	0.0%	166	-10.0%
201023	375	231	-38.4%	2.7%	225	-2.6%	0	0.0%	208	-10.0%
201024	562	204	-63.7%	-39.5%	337	65.2%	0	0.0%	184	-10.0%
201025	382	256	-33.0%	11.8%	229	-10.5%	0	0.0%	256	0.0%
201026	465	171	-63.2%	-38.7%	279	63.2%	0	0.0%	171	0.0%
201027	383	161	-58.0%	-30.0%	230	42.9%	0	0.0%	161	0.0%
201028	327	128	-60.9%	-28.9%	180	40.6%	0	0.0%	128	0.0%
201029	390	300	-23.1%	40.2%	214	-28.7%	0	0.0%	300	0.0%
201030	424	180	-57.5%	-22.7%	233	29.4%	0	0.0%	180	0.0%
201031	462	176	-61.9%	-30.7%	254	44.3%	0	0.0%	176	0.0%
201032	345	240	-30.4%	26.3%	190	-20.8%	0	0.0%	240	0.0%
201033	345	131	-62.0%	-31.1%	190	45.0%	0	0.0%	131	0.0%
201034	386	107	-72.3%	-53.9%	232	116.8%	0	0.0%	107	0.0%
201035	446	173	-61.2%	-29.4%	245	41.6%	0	0.0%	173	0.0%
201036	315	144	-54.3%	-23.8%	189	31.3%	0	0.0%	144	0.0%
201037	350	147	-58.0%	-30.0%	210	42.9%	0	0.0%	147	0.0%
201038	356	120	-66.3%	-43.9%	214	78.3%	0	0.0%	120	0.0%
201039	366	159	-56.6%	-27.7%	220	38.4%	0	0.0%	159	0.0%
201040	332	144	-56.6%	-27.6%	199	38.2%	0	0.0%	144	0.0%
201041	308	132	-57.1%	-28.6%	185	40.2%	0	0.0%	132	0.0%
201042	306	116	-62.1%	-37.0%	184	58.6%	0	0.0%	116	0.0%
201043	296	150	-49.3%	-21.9%	192	28.0%	0	0.0%	150	0.0%
201044	457	172	-62.4%	-42.1%	297	72.7%	0	0.0%	172	0.0%
201045	280	126	-55.0%	-30.8%	182	44.4%	0	0.0%	126	0.0%
201046	340	110	-67.6%	-50.2%	221	100.9%	0	0.0%	110	0.0%
201047	370	293	-20.8%	22.1%	240	-18.1%	0	0.0%	293	0.0%
201048	181	58	-68.0%	-50.8%	118	103.4%	0	0.0%	58	0.0%
201049	370	129	-65.1%	-41.9%	222	72.1%	0	0.0%	129	0.0%
201050	394	97	-75.4%	-58.9%	236	143.3%	0	0.0%	97	0.0%
201051	307	183	-40.4%	-0.5%	184	0.5%	1	0.5%	183	0.0%
201052	252	209	-17.1%	38.4%	151	-27.8%	0	0.0%	209	0.0%
201101	12	12	0.0%	0.0%	12	0.0%	0	0.0%	12	0.0%
201102	135	67	-50.4%	-50.4%	135	101.5%	0	0.0%	67	0.0%

Figure 8.2 Demand Forecast Planner Form (Summary and Sales Information)

PY BOP	PY EOP	PY RTS	PY Turn	TY Act/Plan BOP	TY Plan EOP	TY Plan Turn	TY Periods	PY Received	Actual On Order	Plan On Order	Transfers Out To WH_2 (MX)
2013	1824	2	11.6%	4717	4560	3.8%	22.58	0	21	0	0
1824	1574	1	13.8%	4560	4372	4.2%	21.85	0	0	0	0
1574	435	3	27.6%	4372	3850	5.4%	19.26	0	0	0	300
435	180	3	80.0%	3850	3653	5.3%	18.54	0	0	0	0
180	2011	7	21.6%	3653	3463	5.3%	17.53	720	0	0	0
2011	1757	2	13.0%	3463	3268	5.8%	15.97	580	0	0	0
1757	1513	2	16.1%	3268	3058	6.6%	15.12	0	0	0	0
1513	1166	3	24.2%	3058	2799	8.8%	14.12	551	0	0	0
1166	959	0	21.4%	2799	2617	6.7%	13.74	0	0	0	0
959	721	2	27.4%	2617	2433	7.3%	12.63	449	0	0	0
721	482	2	41.4%	2433	**2234**	8.5%	11.60	0	0	0	0
482	208	2	79.4%	2234	**2015**	10.3%	10.21	0	0	0	0
208	162	5	105.4%	2015	**1859**	8.1%	9.61	83	0	0	0
162	776	1	49.5%	1859	**1673**	10.5%	8.63	617	0	0	0
776	0	1	60.6%	1673	**1485**	11.9%	7.86	0	0	0	0
0	374	3	135.8%	1485	**1282**	14.7%	6.46	0	0	0	0
374	212	3	104.4%	1282	**1007**	24.0%	5.13	0	0	0	0
212	569	1	47.4%	1007	**841**	18.0%	4.47	1500	0	0	0
569	771	3	26.9%	841	**679**	21.3%	3.49	0	0	0	0
771	1089	2	19.9%	679	**513**	27.9%	2.68	0	0	0	0
1089	850	3	23.8%	513	**1305**	22.9%	6.98	0	0	1000	0
850	645	4	27.3%	1305	**1121**	15.2%	6.10	0	0	0	0
645	438	1	47.3%	1121	**865**	25.8%	4.79	0	0	0	0
438	232	3	51.0%	865	**694**	21.9%	4.05	1000	0	0	0
232	89	2	100.3%	694	**1533**	14.5%	9.17	0	0	1000	0
89	259	2	73.6%	1533	**1405**	8.7%	8.41	0	0	0	0
259	159	1	143.5%	1405	**1105**	23.9%	6.56	0	0	0	0
159	109	4	134.3%	1105	**925**	17.7%	5.99	1000	0	0	0
109	782	5	39.5%	925	**749**	21.0%	5.02	0	0	0	0
782	885	5	28.8%	749	**1009**	27.3%	6.87	0	0	500	0
885	1386	2	11.5%	1009	**878**	13.9%	6.22	0	0	0	0
1386	1242	1	8.1%	878	**771**	13.0%	5.47	1000	0	0	0
1242	1099	0	14.8%	771	**598**	25.3%	4.24	0	0	0	0
1099	1568	0	10.8%	598	**954**	18.6%	6.31	0	0	500	0
1568	2233	1	7.7%	954	**807**	16.7%	5.61	0	0	0	0
2233	2101	3	5.5%	807	**687**	16.1%	4.82	0	0	0	0
2101	1946	4	7.9%	687	**528**	26.2%	3.76	500	0	0	0
1946	1801	0	7.7%	528	**884**	20.4%	6.20	0	0	500	0
1801	1686	0	7.6%	884	**752**	16.1%	5.08	0	0	0	0
1686	1554	2	7.2%	752	**636**	16.7%	4.61	0	0	0	0
1554	1406	1	10.1%	636	**486**	26.7%	3.63	1000	0	0	0
1406	1244	0	13.0%	486	**814**	26.5%	6.71	0	0	500	0
1244	1110	1	10.7%	814	**688**	16.8%	6.43	0	0	0	0
1110	998	2	10.4%	688	**578**	17.4%	5.99	0	0	0	0
998	710	1	34.3%	578	**285**	67.9%	3.26	0	0	0	0
710	656	2	8.5%	285	**227**	22.7%	3.61	0	0	0	0
656	528	0	21.8%	227	**598**	31.3%	10.30	479	0	500	0
528	420	1	20.5%	598	**501**	17.7%	10.58	0	0	0	0
420	271	0	53.0%	501	**318**	44.7%	8.10	0	0	0	0
271	148	0	99.8%	318	**109**	97.9%	4.54	0	0	0	0
18	0	0	133.3%	109	597	3.4%	90.68	0	0	500	0
0	4725	2	2.8%	597	530	11.9%	94.93	500	0	0	0

Figure 8.3 Demand Forecast Planner Form (Inventory Information)

Figure 8.2 shows the half of the Demand Forecast Planner Form that displays summary and sales information. Figure 8.3 shows the half of the Demand Forecast Planner Form that displays inventory information. Figures 8.2 and 8.3 would normally span one row, but are broken apart for visibility. The upper left

corner of figure 8.2 displays a color key that indicates if the data in a specific column is pulled from the system database, calculated based on a formula or a user entered value. Directly under this color key is summary information about the specific WarehouseProduct that is being viewed. The WarehouseProduct can be changed by selecting a different warehouse tab. The two warehouses “WH_1 (US)” and “WH_2 (MX)” can be seen as tabs across the top of Figure 8.2.

The grid shown in Figures 8.2 and 8.3 shows a set of past, present and future sales and inventory information for the selected WarehouseProduct. The first column in Figure 8.2 displays the weekly period from the current week to one year in the future where the first row is the current week and the last row is one year from the current week. The columns to the right of the weekly period column show the sales and inventory information during that period of time. Each row is bound to a PeriodSalesAndInventoryData object as described in the class design section 4.2.1 that holds the specific sales and inventory information for that period of time.

When the yellow, user input, column values are changed the system updates the underlying PeriodSalesAndInventoryData object corresponding to that row and the forecasted future sales and inventory levels are adjusted throughout the grid. By adjusting these user input values end users are able to forecast future demand for a specific product at a specific location and ensure proper measures are taken to order the needed amount of inventory to meet this demand.

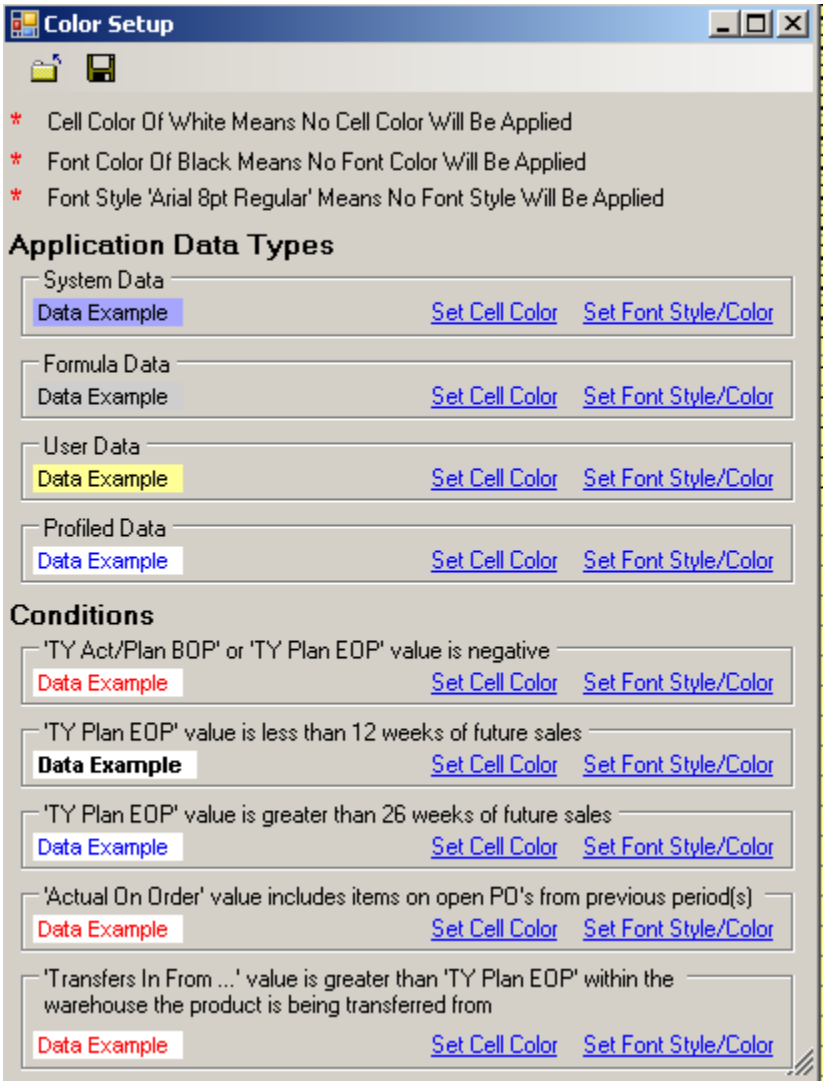
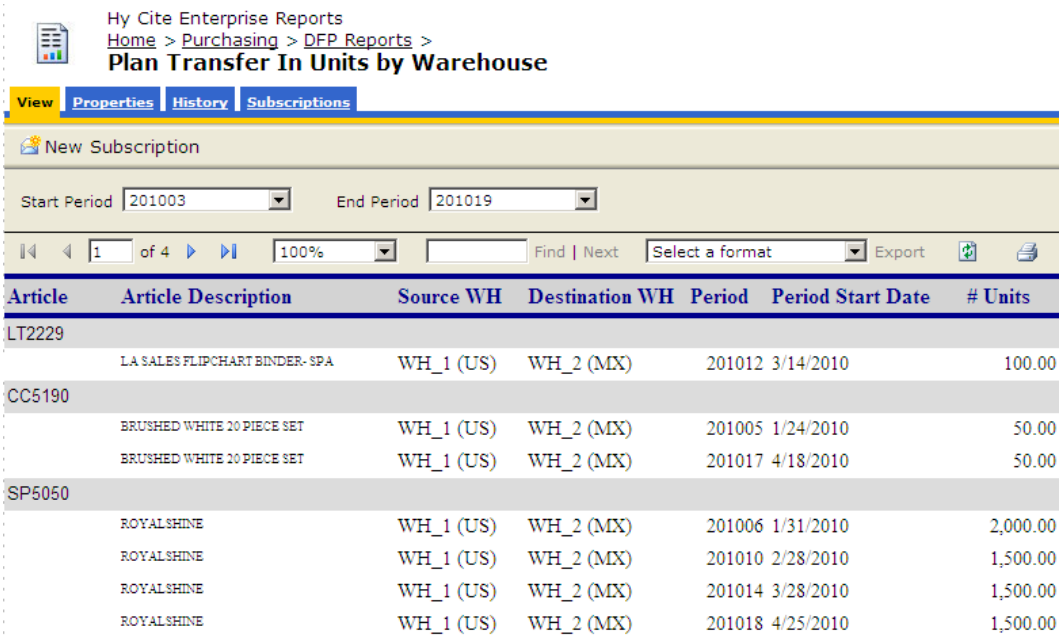


Figure 8.4 Color Setup Form

The Color Setup Form, shown in figure 8.4, is a form that allows the user to assign specific colors or font styles to data that meets specific criteria. For example a cell color of light blue is assigned to data elements that are pulled from system databases, while a font color of red is assigned to any data elements in the This Year Planned End of Period Inventory (‘TY Plan EOP’) column that hold a negative value. These conditional colors help end users to easily identify key data elements.



Article	Article Description	Source WH	Destination WH	Period	Period Start Date	# Units
LT2229						
	LA SALES FLIPCHART BINDER- SPA	WH_1 (US)	WH_2 (MX)	201012	3/14/2010	100.00
CC5190						
	BRUSHED WHITE 20 PIECE SET	WH_1 (US)	WH_2 (MX)	201005	1/24/2010	50.00
	BRUSHED WHITE 20 PIECE SET	WH_1 (US)	WH_2 (MX)	201017	4/18/2010	50.00
SP5050						
	ROYALSHINE	WH_1 (US)	WH_2 (MX)	201006	1/31/2010	2,000.00
	ROYALSHINE	WH_1 (US)	WH_2 (MX)	201010	2/28/2010	1,500.00
	ROYALSHINE	WH_1 (US)	WH_2 (MX)	201014	3/28/2010	1,500.00
	ROYALSHINE	WH_1 (US)	WH_2 (MX)	201018	4/25/2010	1,500.00

Figure 8.5 Plan Transfer In Units By Warehouse Report

The Plan Transfer In Units By Warehouse Report, shown in figure 8.5, is a report that shows the planned number of units for all products that are planned to transfer from one warehouse to another between two periods of time. This report is used by end user to give an overview of all products that will be transferred between warehouses.

9. Continuing Work

As the Demand Forecast Planner continues to be used, it will undoubtedly require additional alterations to meet the changing needs of its end users. While all of these changes are not yet known, one such change that is expected in the future is the forecasting of future monetary liabilities based off data within the Demand Forecast Planner. Currently, the system deals with inventory units that are required to meet future sales, but gives little insight into the projected cost of these units. The customer has expressed interest in such a change, but wants to ensure the system is satisfactory at providing unit projections before dollars and budgeting are associated with the system.

Another expected change is the automated creation of purchase orders. As the system works today, it only predicts future inventory needs and does nothing to interface with the system that actually places orders for those inventory needs. This process is done manually by a user of the system and can be time-consuming and prone to data entry errors. Automating this process will save time, as well as ensure inventory needs are not overlooked or incorrectly entered.

The last anticipated enhancement is some form of automated notification about future inventory levels. The Demand Forecast Planner today is completely driven by an end user analyzing data for future inventory needs. A set of automated rules and email alerts will likely be created to make using the Demand Forecast Planner more reactive rather than proactive and ensure inventory needs are not overlooked. This should also reduce the number of hours spent using the system, and thus the overall expense of purchasing inventory for the company.

10. Conclusion

Inventory may not be the most important aspect of the direct sales industry, but without proper inventory management a direct sales company is destined for failure. This thesis describes the software life cycle used to design, implement and test a tool called the Demand Forecast Planner. This tool gives precise, current and easily accessible data on past sales, inventory and consumer trends that can be used to manage the purchasing of inventory. The detailed insight given by the Demand Forecast Planner also allows for a more precise estimate of future inventory needs, and thus can be used to reduce the amount of capital committed to working inventory. Additionally, accurate inventory management frees up distributors to do what they do best–make sales. When distributors do not have to worry about if the products they are selling is in stock, they can focus all efforts on selling and thus make the direct sales business model function as designed.

The Demand Forecast Planner not only gives end users detailed information into past sales, inventory and consumer trends, but does so in a clear, easy-to-read manner. One of the key issues that led to the creation of the Demand Forecast Planner was not a lack of information, but rather too much information scattered in different locations. Properly aggregating the raw data into easily understandable objects was one of the major goals accomplished by this tool. This not only made displaying data in a clear and easy-to-read manner possible, but facilitates a logical path for future enhancements.

The well-defined software engineering principals used to build the Demand Forecast Planner not only created an application that met the needs of the customer, but did so in a manner that was concerned with proper documentation, future expansion and completeness of design for the system. Starting with defining requirements and the use of software engineering principals clearly described what the system was to do. The design phase built upon these requirements not only to define how the system would be implemented, but how to do so in an expansion minded and efficient way. Software engineering

principles were used to properly write the source code and define test cases that would test if the requirements were implemented correctly. Lastly, these principles were applied to the maintenance of the system to ensure enhancements adhered to the same software engineering process used to build the system in the first place. Without the use of software engineering principles, it is unlikely the Demand Forecast Planner would be the successful software system it is today.

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