Small Scale ERP Engine Design

By:

Colyn Dickson

Matt Haymond

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Abstract

This project set out to create a 1) low-cost, 2) dynamic, and 3) user-friendly small scale ERP software tool. These three key attributes position this product against complex and expensive systems such as SAP or Oracle. While the product still retains the dynamic and financial capabilities any good ERP system should have, the biggest value proposition is its simple and user-friendly interface. The software has a dual product-market fit: for small businesses as a low-cost planning tool, and for universities as a teaching tool. In the design phase, the team kept a primary focus on ergonomic software development while maintaining a subsidiary focus on bringing the product to customers. Through the rapid prototyping process and one scope change, the team was able to meet software functional requirements and develop a go-to-market strategy for this ERP software solution.

Introduction

There is a high demand for a low cost, user-friendly software tool that can be used to plan and generate orders for small businesses. The goal of this project is to design a small-scale, dynamic Enterprise Resource Planning (ERP, also referred to as MRP – Manufacturing Resource Planning) software tool using Microsoft Access, a relational database management system. The software will be applicable as a resource planning engine in a small business setting, however, it will also serve as a teaching tool in Dr. Pouraghabagher's IME 410 class and possibly other teaching environments.

The key features of software include:

- Input Data for MRP/ERP System
- Output MRP Tables
- Financial Reports
- Engineering Changes of Product Structure
- Advisory System for Past Dues
- Data Maintenance
- 3 Layers of Security/Passwords
- Ergonomics of User Interface

The main output of an ERP system are manufacturing orders and purchasing orders, and attaching financials to these orders. Financials calculated include Return on Investment (ROI) and Net Present Worth (NPW). The three main inputs to the system are the Master Production Schedule (MPS), Bill of Materials (BOM), and Inventory Master File (IMF). The "small scale" nature of the software refers to constraints in both the quantity of data stored and the system horizon. The software is designed to handle roughly 5 – 10 end item products with 3 – 5 product levels each. These are not hard and fast software limitations, but rather a general guide to limit the magnitude of data within the system. The system planning horizon covers 12-weeks, or 1 fiscal quarter. This is a strict limitation of the software. Two prominent features of the software engine are an allowance for engineering change of product structure as well as an algorithm for past due orders and proceeding corrective actions. Product maintenance is a very critical feature of any company that wishes to stay current and competitive. This software allows for impromptu changes to the product structure which correspond to automatic updates in the output. The algorithm for past dues is implemented in an advisory system that displays

warnings whenever a schedule is input that will lead to a late order. These warnings give possible solution alternatives to the user for how to proceed with the corresponding financial consequence of each option.

A few other features are built into the engine to give it the robust functioning quality. The Graphic User Interface (GUI) is highly user friendly with all relevant displays and other ergonomic factors considered. The user also has the ability to access where-used and pegging reports. Lead times for orders will have a variable functionality, enabling the user to delay or expedite orders. The software's functional scope will not include the implementation process of the tool into the business operations, orders outside of the 12-week horizon, or any Customer Relations Management (CRM).

The solution approach required modularizing development of the system into four stages: MRP tables, financials, product configuration change, and finally ergonomics (in that order). Each of these modules are highly intricate and complex, and a rapid prototyping solution approach ensured that every element of the system architecture was developed thoroughly.

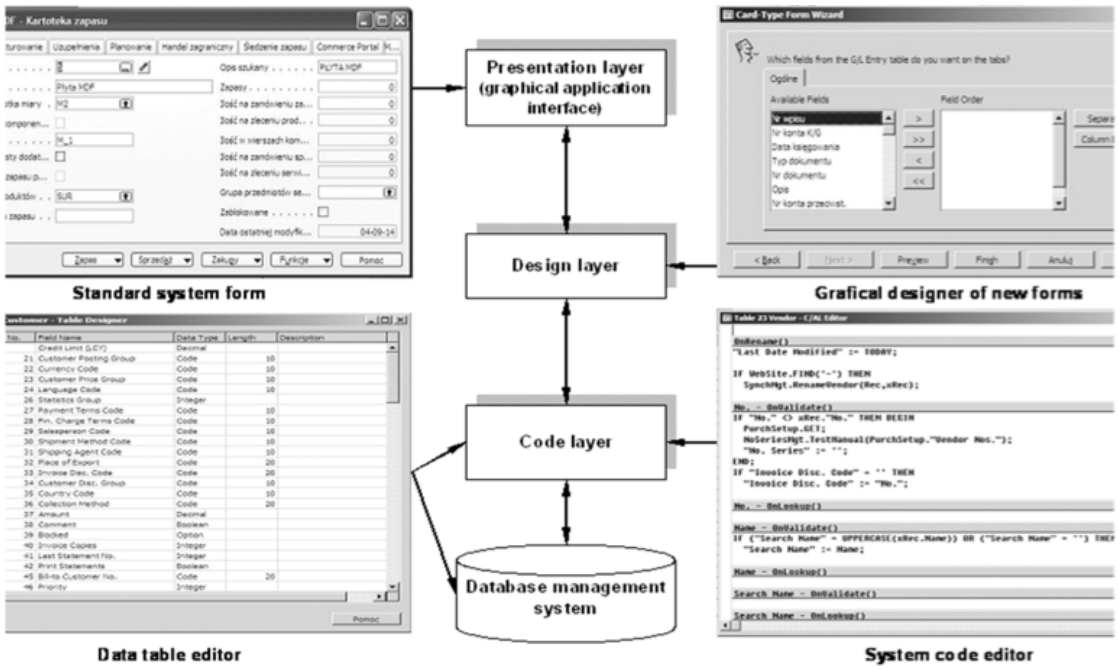
This project required knowledge and skills in four key Industrial Engineering topics. Knowledge of the MRPII Business Model, learned in IME 410, was paramount as the structure of an ERP system was replicated in the system architecture. To develop this engine, Microsoft Access coding skills learned in IME 312 and CSC 232 were utilized. To calculate the financial component of orders generated, analysis techniques taught in IME 239 and IME 314 were likewise applied. Finally, IME 319 and IME 429 knowledge was incorporated to develop a highly user-friendly GUI.

Background

To put this project in context, it is necessary to explain the basic knowledge and terminology regarding the main concepts and tools used in the software. This can be broken down into three distinct categories: the functionality of a basic MRP system, the key attributes of a relational database, and the common accounting measures in costing a project.

There are three inputs to an MRP (Manufacturing Resource Planning) system: MPS (Master Production Schedule), BOM (Bill of Materials), and IMF (Inventory Master File). The MPS is the production plan at the end-item level. The BOM states the necessary components and assemblies to manufacture each end item. The IMF lists important attributes of each part such as on-hand inventory, the lot size the part may be ordered in, and the safety stock required for the part. All of this information is gathered and utilized by the MRP engine in order to output the specific manufacturing and purchasing orders for every single part. In doing the calculation, other useful information is derived such as the various inventory levels across the planning period.

There are a few common tools used in a relational database management system which are referred to in discussing the software's design. Forms are windows in the user interface which display information and access to functionality for the user. These forms often contain buttons that perform operations and subforms which report data. Data is stored in Tables much like Microsoft Excel and this data can be manipulated through queries or directly by coding. The following graphic illustrates these concepts:



Source: Kaminski, 2010

In the financial analysis module of the software, a number of accounting measures are used to analyze the economic impact of the orders generated in the system. These terms are now introduced and defined:

- **Net Present Worth (NPW):** The difference between the present value of cash inflows and the present value of cash outflows.
- **Return on Investment (ROI):** A performance measure used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments.
- **Accounts Receivable (A/R):** Money owed by customers (individuals or corporations) to another entity in exchange for goods or services that have been delivered or used, but not yet paid for.
- **Accounts Payable (A/P):** An accounting entry that represents an entity's obligation to pay off a short-term debt to its creditors.

- **Inventory Cost:** The cost to hold inventory depending on the holding costs per part.
- **Direct Labor (DL):** Direct Costs related to the production of a product.
- **Overhead Costs (OH):** All ongoing business expenses not including or related to direct labor, direct materials or third-party expenses that are billed directly to customers.

These measures are generated in the Financial Analysis section of the software, based upon the proper given data.

Literature Review

Many times, ERP implementation fails. This is often due to choosing the wrong software for the business environment. In one study, "A theme often discussed in interviews was the fact that often users did not understand why the organisation had undertaken the ABC [ERP] implementation and did not believe that it was necessary. Many wondered why a system that cost so much was being implemented when it was not providing any greater functionality, and at times was less efficient than legacy system." (Kemp, Low, 2008) The software developed in this project is an intuitive, user-friendly database ERP system that is a valuable tool for many small businesses. It fills a large gap in the market. There is no standard ERP solution that provides a low cost, user-centered approach. Choosing the right ERP software is crucial: "Implementing an ERP system is not an inexpensive or risk-free venture. An estimated 40-70% of ERP implementations experienced some degree of failure. That is why an organization should select the most appropriated ERP systems for their business needs." (Pacheco-Comer, González-Castolo, 2012) ERP implementation is especially crucial for small businesses (Malhotra, Temponi, 2010). Existing software such as SAP and Oracle are designed as

powerhouse engines that can handle very large, complex systems. This is great for Fortune 500 companies and even mid-sized ones, but it does not meet the needs of customers who desire a low-cost, user friendly alternative.

SAP Business One ® Software costs thousands of dollars per user for licensing (How Much, 1). According to academic research, "There is a direct relation between the size of the company and the amount of money that it can invest on an ERP system" (Pacheco-Comer, González-Castolo, 2012). The product provided in this project is designed for the companies at the small end of the spectrum. For these users, a complex system will decrease its usefulness. In BooYoung Chung's Ph.D. dissertation, a study was conducted consisting of 281 ERP software users, most of whom used high-end products like SAP or Oracle. One of the main conclusions drawn in the dissertation was: “The ERP system should be easy to use. A complex system decreases its usefulness, which also make users reluctant to use it. The system should be carefully designed to be user friendly, considering screen design, user interface, page layout, help facilities, and menus.” (Chung, 2007) This software is not overly complex. It was uniquely designed with the end user in mind, as is lacking is other alternatives. According to research regarding ERP integration in small businesses, “Have an ERP package with an intuitive and easy-to-use interface to minimize training and user support costs. The satisfaction and needs of the user are usually overlooked; rather, instructions are forced upon them since upper management's decisions are accepted as efficient work processes” (Malhotra, Temponi, 2010). "It has become clear that ERP implementation differs from traditional systems development where the key focus has shifted from a heavy emphasis on technical analysis and programming towards business process design and human elements." (Matende)

There are a number of goals that were set to develop a thoroughly user-friendly interface. A valuable set of guidelines can be found in the ISO 9241 certification regarding human-computer interaction. Parts 12-17 are listed below:

Part 12	Presentation of Information. The current draft deals with specific ergonomic issues involved in presenting information in visual form. Specific topics include organization of information in areas, windows, groups, tables, and lists; data field, label, and cursor presentation; textual, graphical, and symbolic codes; and visual highlighting technique.
Part 13	User Guidance. The current draft contains design guidance and requirements for various forms of user guidance. Specific topics include prompts, feedback, and status displays; on-line help; and error prevention, management, explanation, and recovery.
Part 14	Menu Dialogues. The current draft contains design guidance and requirements for menu-based dialogues. Specific topics include menu structure, presentation, and navigation, and menu-option structure, syntax, selection, and execution.
Part 15	Command-language dialogues (CD): The current draft contains design guidance and requirements for command-based dialogues. specific topics include command language structure and syntax, command names and abbreviations, function keys and hot keys, and command input, output, feedback , and help.

Part 16	Direct-manipulation dialogues (CD): The current draft contains design guidance and requirements for direct-manipulation based dialogues. Specific topics include: user interface metaphors, design and manipulation of objects and attributes, and direct manipulation of windows, controls, text, graphics, and labels.
Part 17	Form-filling dialogues (WD): The current draft contains design guidance and requirements for form-based dialogues. Specific topics include form structure and layout, field formats, text entry, option selection, and feedback methods; and form-navigation techniques.

Source: Billingsey, 1994

There are also a few general measures that were investigated to evaluate the high level usability of the software. An AHP-TOPSIS (Analytical Hierarchy Process - Technique for Order of Preference by Similarity to Ideal Solution) model for ERP software selection was created to rank these measures:

1. **Software Performance and Technical Infrastructure (SPI)**: Software Security and Software Reliability ,Software operating speed, software development time, web based application, customization and deployment time, advanced reporting services, adaptation with current operating system, hardware and database.
2. **Cost:** Software development cost , maintenance cost.
3. **Flexibility:** compatibility with innovation(research and development) , adequacy of answering to customer requests , user-friendly interface, international flexibility (Language , currency unit legislation).
4. **Service Level:** Velocity of support after sale, Online Help After Sale

Source: Nurgül *et al*., 2011

In summary, the ideal ERP system for small businesses is effective, low-cost, and highly ergonomic. The necessary modules for an effective system include but are not limited to: MRP table generation, financial reporting, engineering changes of product structure, and an advisory system for past due orders. All of these features, as well as many more auxiliary features are included in this project's software ERP system, and are outlined in the Design section of this report.

Design

Specifications

System architecture design was divided into several modules, accomplished through rapid prototyping phases. Their descriptions, functionalities, and user interface are presented below:

Login & Multiple User Types

The system is password protected and configured for three types of users: general user, master scheduler, and admin. The general user can view and print information, but cannot edit anything. The master scheduler and admin can edit information, but only the admin can view and edit the code behind the project. The code is protected by a separate password, which is not entered at the login screen. Upon login, the user is brought to the Homepage:

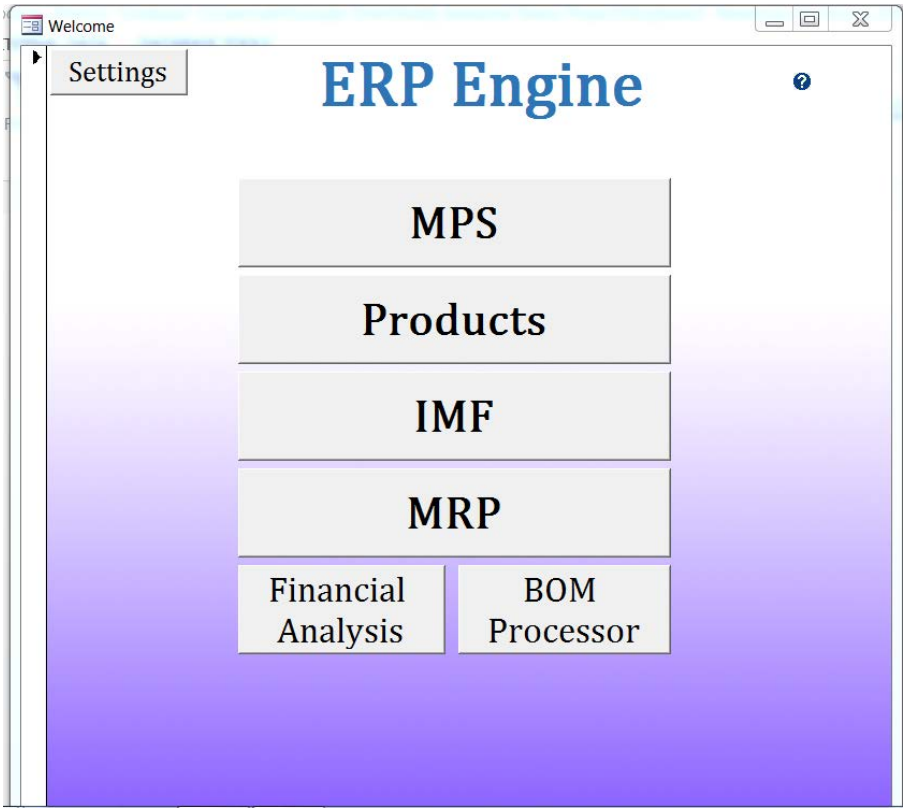


Figure 1: Homepage

MRP Table Outputs

The ERP system can calculate requirements and generate purchasing and production schedules necessary to satisfy the MPS. These reports are easy for the user to read, sort through, and print, as can be seen through the print screen for MRP tables below:

PART: Chair — Manufactured

Period	1	2	3	4	5	6	7	8	9	10	11	12
GR	0	0	0	0	372	203	18	98	117	90	451	715
SR	0	0	0	0	0	0	0	0	0	0	0	0
PA	42	42	42	42	15	22	19	26	29	29	28	18
NR	0	0	0	0	345	203	11	94	106	76	437	702
POrec	0	0	0	0	345	210	15	105	120	90	450	705
POrel	0	0	345	210	15	105	120	90	450	705	0	0

PART: Desk — Manufactured

Period	1	2	3	4	5	6	7	8	9	10	11	12
GR	0	0	0	0	402	187	55	197	506	1158	872	649
SR	0	0	0	0	0	0	0	0	0	0	0	0
PA	12	12	12	12	10	13	13	11	10	12	10	11
NR	0	0	0	0	400	187	52	194	505	1158	870	649
POrec	0	0	0	0	400	190	55	195	505	1160	870	650
POrel	0	0	400	190	55	195	505	1160	870	650	0	0

PART: Desk Back Leg — Manufactured

Period	1	2	3	4	5	6	7	8	9	10	11	12

Figure 2: MRP Tables

Financial Reporting

This module takes into account all of the cashflows from production and purchasing, as well as overhead and inventory rates. It uses cost roll-up to calculate the NPW and ROI of all existing orders. This form allows the user to perform sensitivity analysis, changing the production schedule, inventory levels, and so on, before they view the corresponding output in financials.

Engineering Changes of Product Structure

BOMs can be quickly and easily edited using the BOM Editor interface. This is only available for master scheduler and admin users. The form below allows users to quickly move up and down through product structures, allowing for engineering change management wherever necessary:

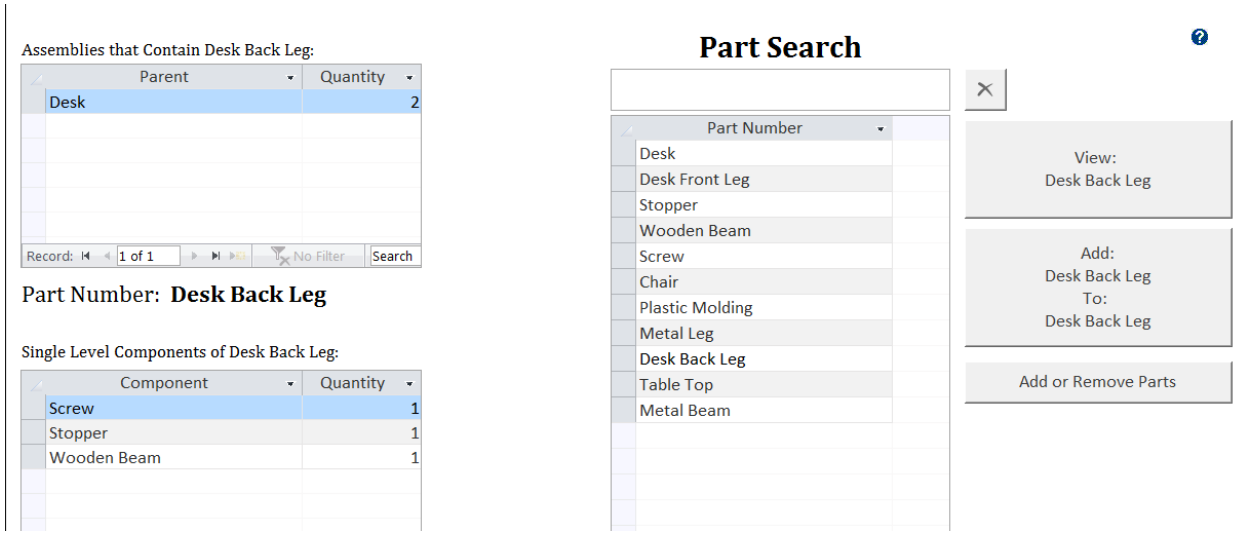


Figure 3: BOM Editor

Advisory System for Past Due Orders

Orders that cannot be satisfied by MRP because they are past due are reported to the user, who is presented with multiple options. These options include expediting the order (the system will reduce the lead time for that order and possibly increase cost) and splitting the order. The user will be able to define the costs associated with expediting orders depending on what item is being expedited and by how many weeks the lead time will be shortened.

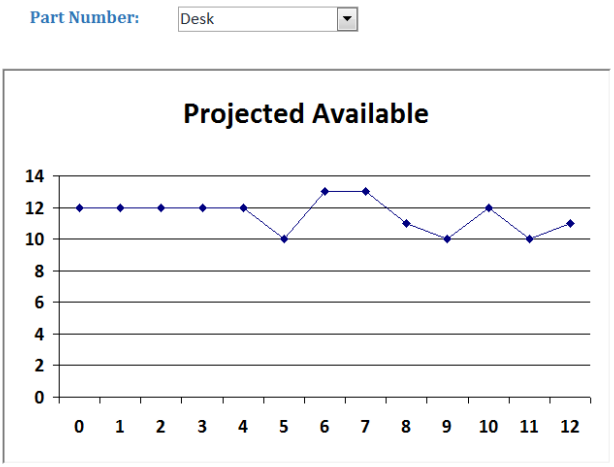


Figure 4: Inventory Report

Ergonomics and User-Friendliness

For every form, the design is consistent and intuitive. Help options accompany many of the controls, and a user guide and global help module are provided. Below are two examples of ergonomics in action: the easy sorting of the Production schedule based on a user's preference, and the physical representation of inventory data in the in the inventory reports.

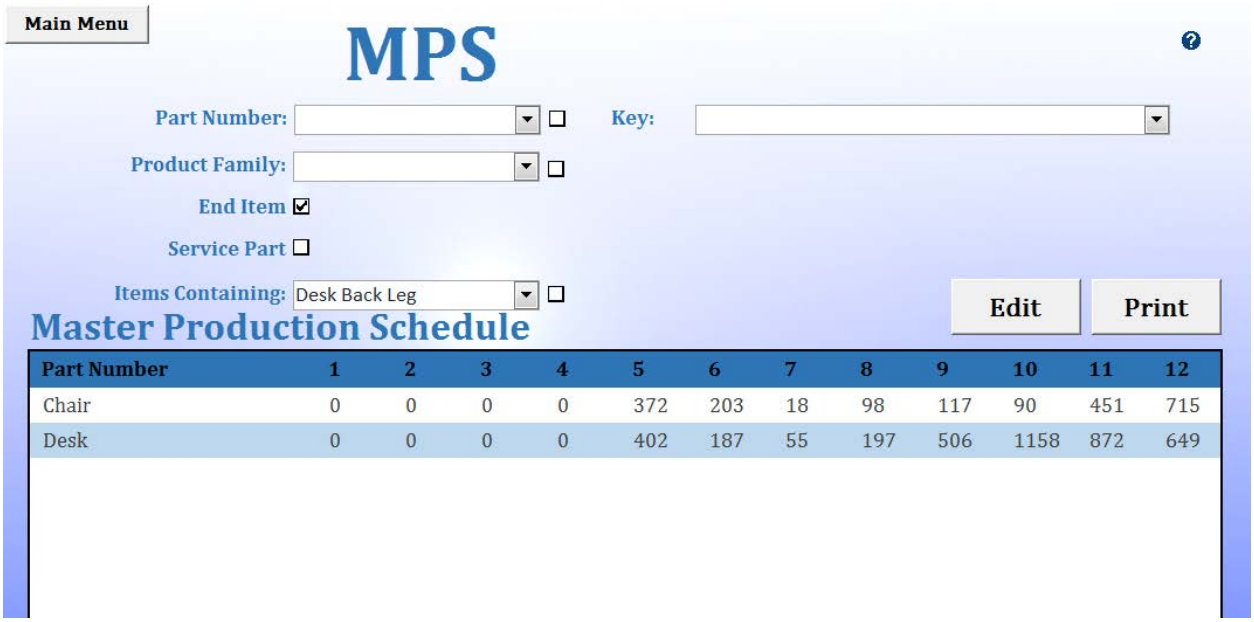


Figure 5: Production Schedule

Data Input and Maintenance

For higher level users (master scheduler or admin), the master schedule, scheduled receipts, IMF, BOMs, and other data may be input and edited through various user-friendly and intuitive interfaces.

Constraints

Microsoft Access has many predefined controls and functionalities, allowing for the creation of almost anything the developers can imagine. What Access lacks is a way to efficiently process large amounts of data. Although the software meets all of the functional requirements in the scope of this project, it is fairly slow at processing data. For this reason, the system may only be able to be used for small-scale schedule generation. If there are too many BOMs for the system to process, it will take an undesirably long time to process the data, and may even fail. As will be discussed in the methodology section, load testing will occur in order to define the limits of the system. Additionally, Access' weak client-server architecture inhibits the program from being a legitimate platform option for a larger scale system where multiple users could use the program and edit information simultaneously.

Platform Switch

In an attempt to increase the efficiency of the MRP table generation, the data was linked to Microsoft Excel in such a way that raw data was transferred to Excel, processed, and then sent back to Access during MRP calculations. Unfortunately, the data links between Access and Excel could not be refreshed while both applications were open at the same time. Due of this, the only solution was to constantly close and reopen both Access and Excel during the MRP algorithm. This would require yet another platform switch. Visual Studio could potentially be used to perform this operation, but the act of opening, saving, and closing multiple files tens or hundreds of times would only decrease the efficiency of the system, so the Access-only system remained the best option.

Methodology

Once the development phase of the system was complete, the next step was to properly test the interface and underlying logic to make sure that they operate accurately, consistently, and with optimal ease of use. This entails beta testing, and subsequently, load testing.

Beta testing occurred through operating the software from a user perspective. This initially involved adding in product structures, defining a demand schedule, and verifying the generated MRP tables. After that, product structures and demand were be altered to simulate multiple scenarios. In all of these scenarios, the varying financial impact was verified and analyzed to simulate marketing games. It was also ensured that past due orders were handled correctly, providing warnings and multiple solution approaches. In all of this testing, ergonomics was intensely scrutinized to verify minimal complexity. The product was also be tested by subjects without involvement in design to simulate a brand new user's experience.

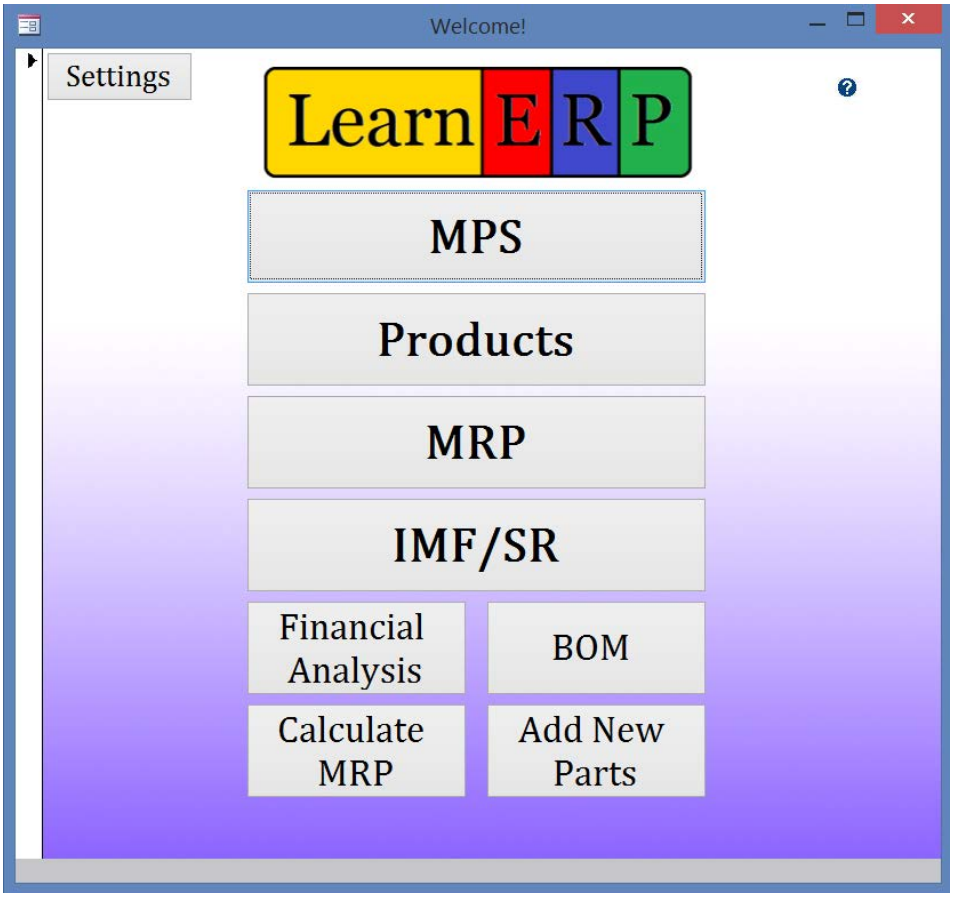
Load testing entailed testing our software to its limit. Product structures were made larger and larger and all other inputs will be made as large and complex and possible to find the limitations of the software. These limits are defined in the software so the user will understand the scope of its capabilities.

Finally, a strategic roadmap was also brainstormed. This meant investigating phase 2 (go-to-market) plans for the software upon completion of beta testing and load testing.

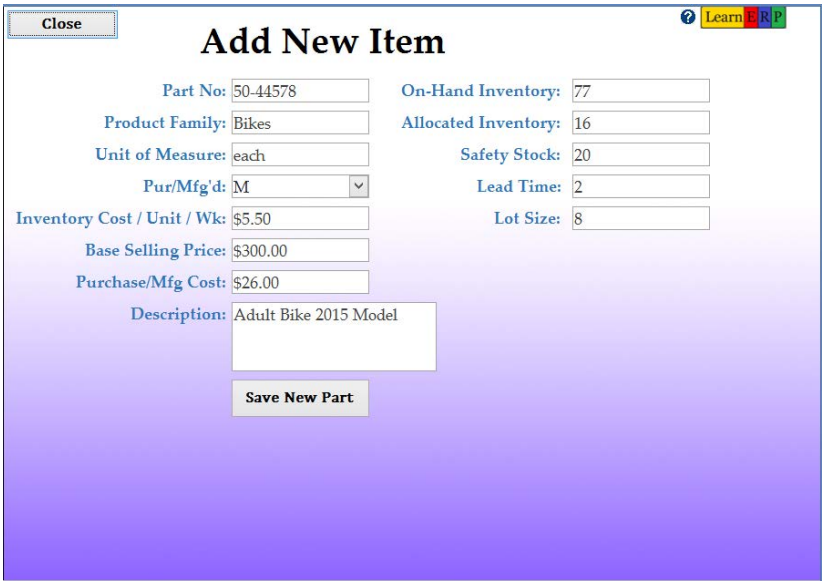
This planning began preliminarily with the help of Ty Lee on the Industrial Advisory Board (IAB). The team is currently investing a freemium model to compete with existing cloud ERP solutions. The strategic roadmap was not a necessary requirement for the completion of the project, but is necessary to decide if/how the product would be marketed.

System Walkthrough

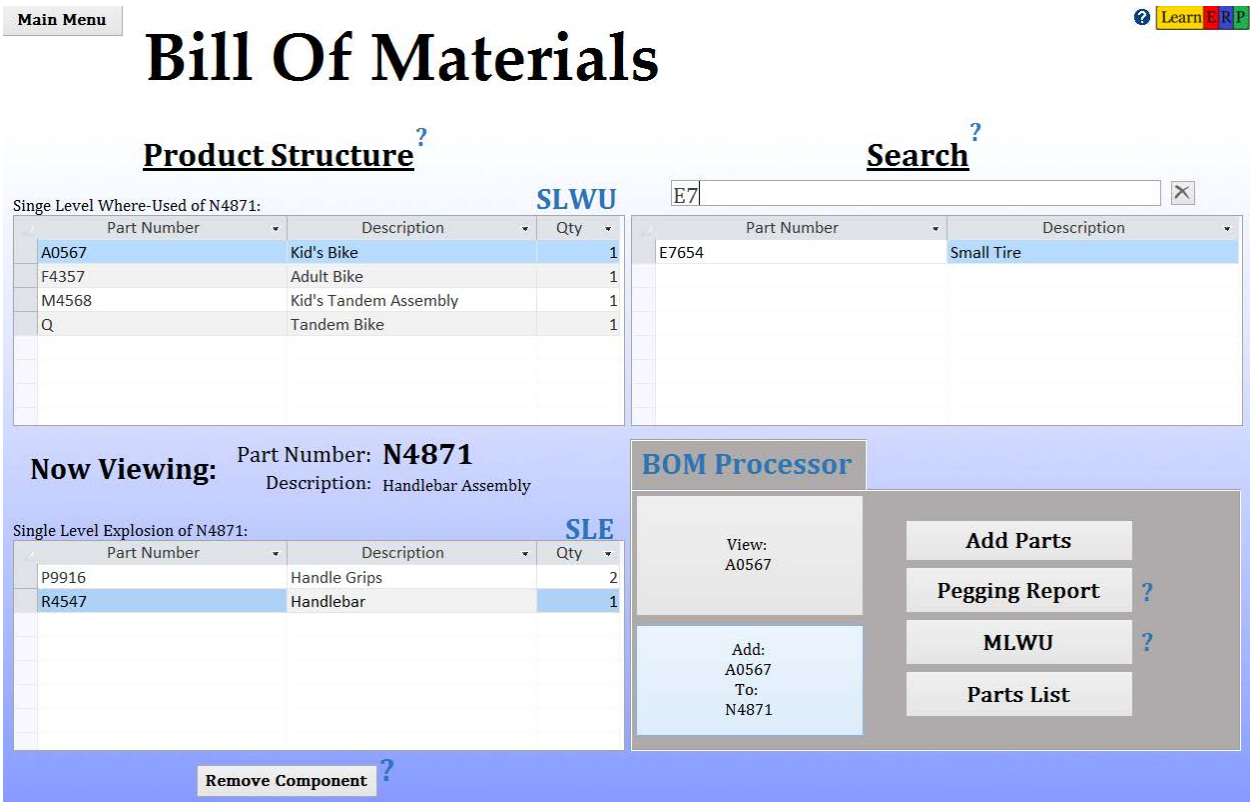
- Here is the HomePage.



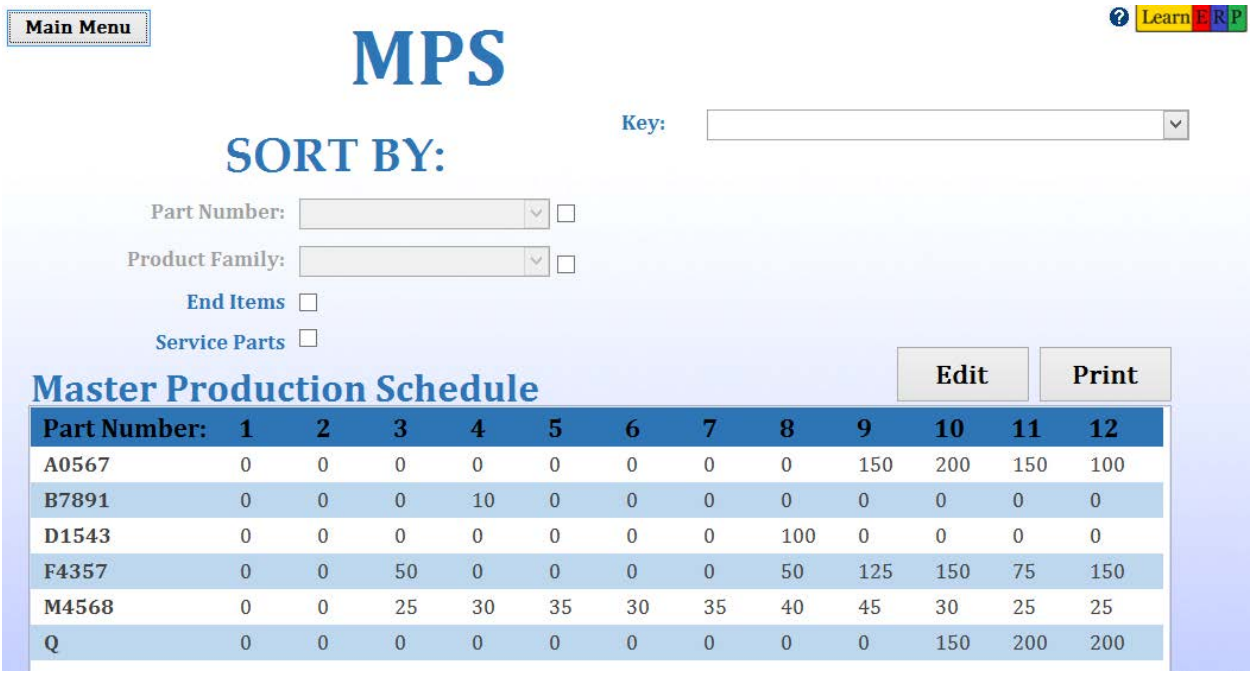
- First, click the 'Add New Parts' button on the HomePage form to view the New Item form seen below. Define all the fields and click 'Save New Part'. Do this for all parts.



- When done adding items, close that form, and click on BOM on the HomePage. Edit the BOM, adding parent-component relationships.

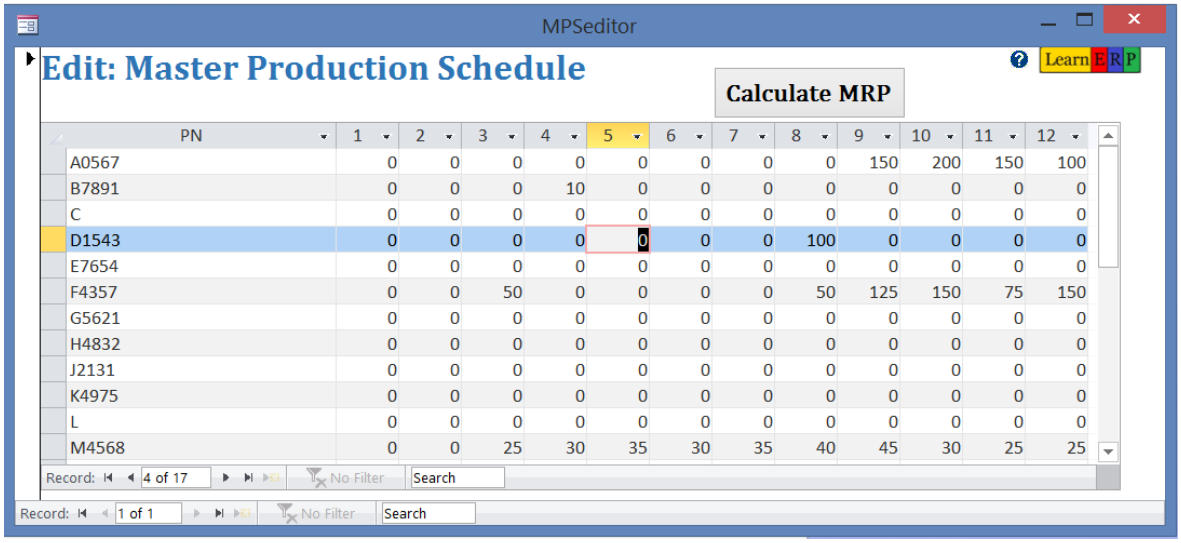


- Now close the form and click MPS on the HomePage.



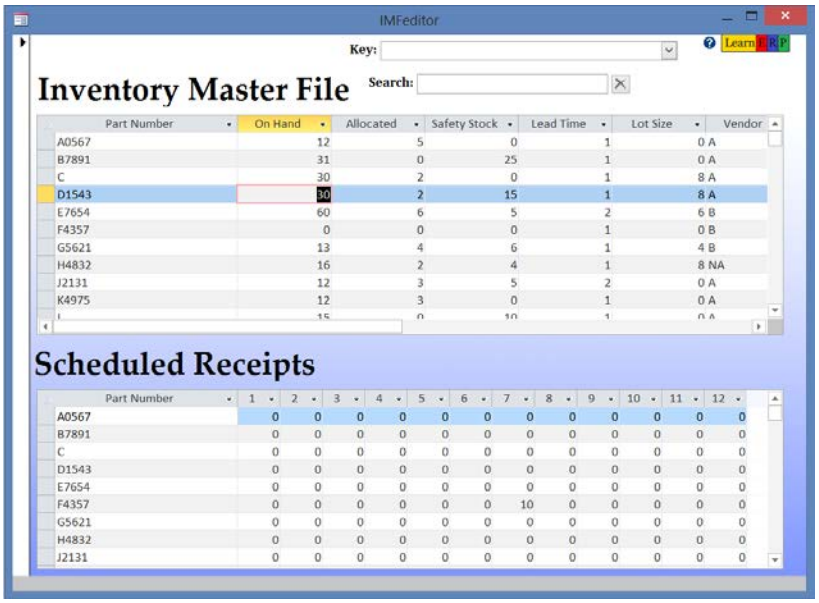
Part Number:	1	2	3	4	5	6	7	8	9	10	11	12
A0567	0	0	0	0	0	0	0	0	150	200	150	100
B7891	0	0	0	10	0	0	0	0	0	0	0	0
D1543	0	0	0	0	0	0	0	100	0	0	0	0
F4357	0	0	50	0	0	0	0	50	125	150	75	150
M4568	0	0	25	30	35	30	35	40	45	30	25	25
Q	0	0	0	0	0	0	0	0	0	150	200	200

- Next, click the Edit button, defining demand for end items and service parts.

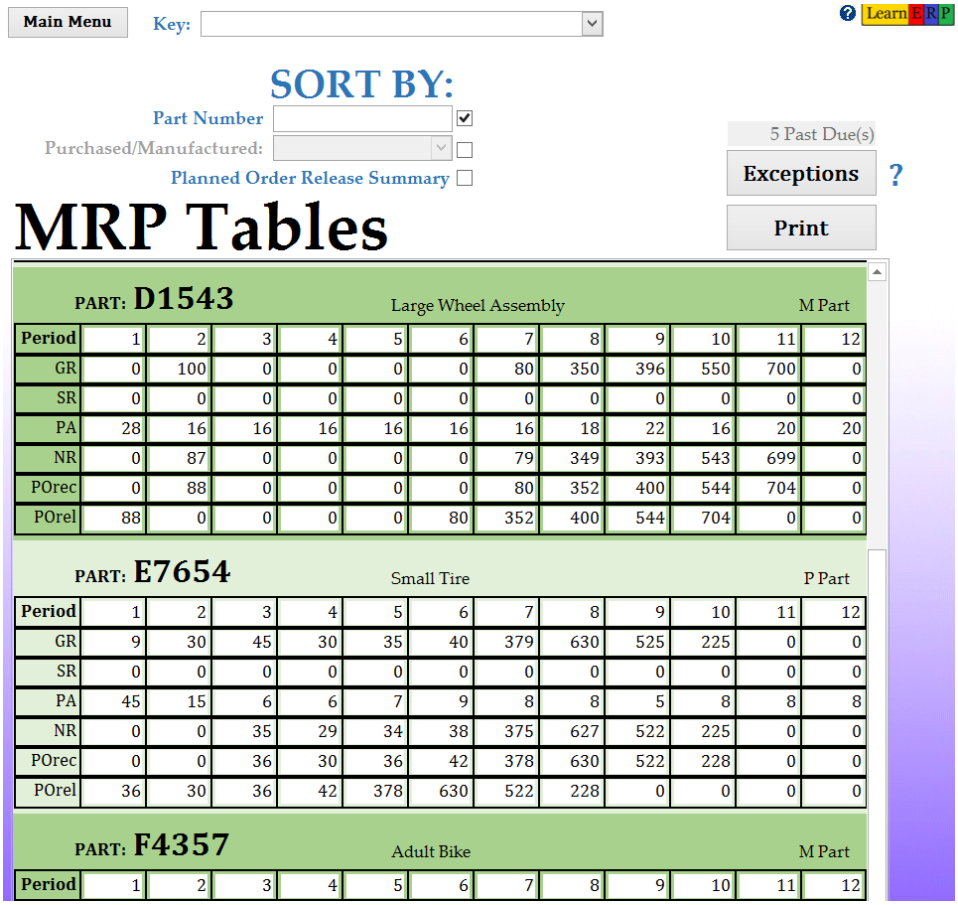


PN	1	2	3	4	5	6	7	8	9	10	11	12
A0567	0	0	0	0	0	0	0	0	150	200	150	100
B7891	0	0	0	10	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0	0	0	0	0
D1543	0	0	0	0	0	0	0	100	0	0	0	0
E7654	0	0	0	0	0	0	0	0	0	0	0	0
F4357	0	0	50	0	0	0	0	50	125	150	75	150
G5621	0	0	0	0	0	0	0	0	0	0	0	0
H4832	0	0	0	0	0	0	0	0	0	0	0	0
J2131	0	0	0	0	0	0	0	0	0	0	0	0
K4975	0	0	0	0	0	0	0	0	0	0	0	0
L	0	0	0	0	0	0	0	0	0	0	0	0
M4568	0	0	25	30	35	30	35	40	45	30	25	25

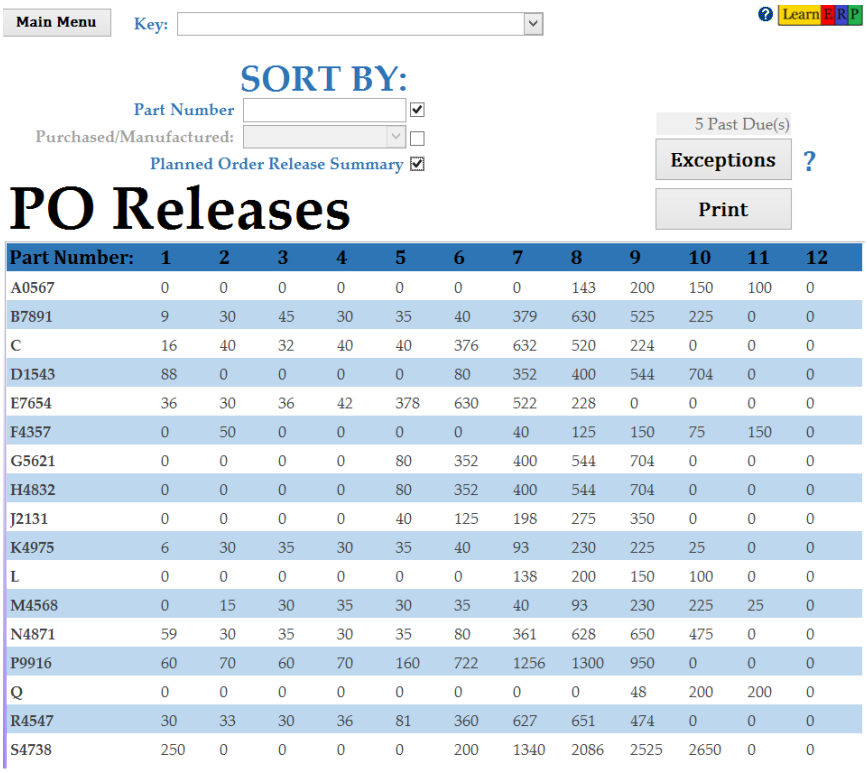
- Next, close that form, return to the HomePage, view the IMF and edit any inventory data by clicking 'Edit IMF/SR'.



- Close that form, return to the HomePage and press 'Calculate MRP'.

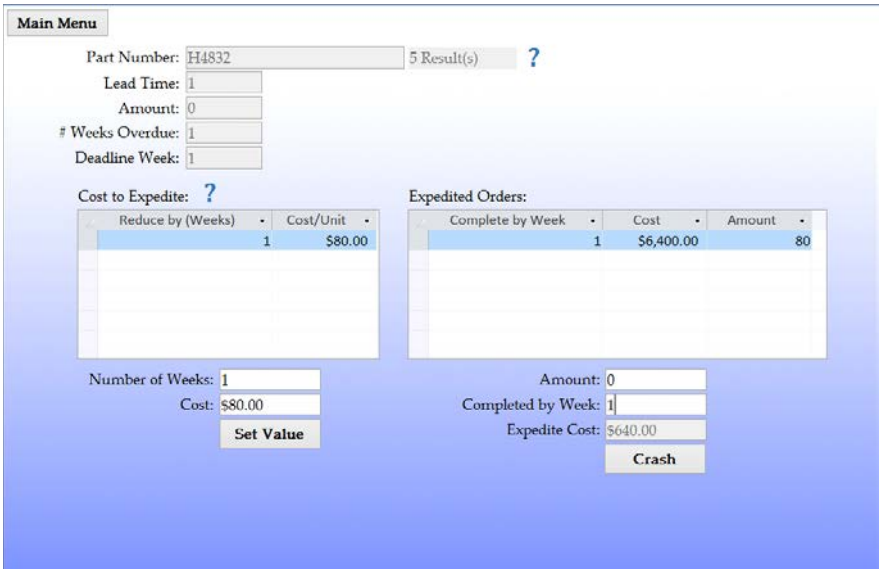


- The PO Release Summary can be seen by checking the PO Summary checkbox.



Part Number:	1	2	3	4	5	6	7	8	9	10	11	12
A0567	0	0	0	0	0	0	0	143	200	150	100	0
B7891	9	30	45	30	35	40	379	630	525	225	0	0
C	16	40	32	40	40	376	632	520	224	0	0	0
D1543	88	0	0	0	0	80	352	400	544	704	0	0
E7654	36	30	36	42	378	630	522	228	0	0	0	0
F4357	0	50	0	0	0	0	40	125	150	75	150	0
G5621	0	0	0	0	80	352	400	544	704	0	0	0
H4832	0	0	0	0	80	352	400	544	704	0	0	0
J2131	0	0	0	0	40	125	198	275	350	0	0	0
K4975	6	30	35	30	35	40	93	230	225	25	0	0
L	0	0	0	0	0	0	138	200	150	100	0	0
M4568	0	15	30	35	30	35	40	93	230	225	25	0
N4871	59	30	35	30	35	80	361	628	650	475	0	0
P9916	60	70	60	70	160	722	1256	1300	950	0	0	0
Q	0	0	0	0	0	0	0	0	48	200	200	0
R4547	30	33	30	36	81	360	627	651	474	0	0	0
S4738	250	0	0	0	0	200	1340	2086	2525	2650	0	0

- Now go to homepage=>MPS=>Edit MPS. Put an order in early to create a past due. Click calculate MRP. Now past dues have been created. Click on exception reports. Here in the Past Dues/Advisory System, Past due orders can be expedited.



- Now close this form, return to the HomePage, and go back to BOM to implement ECM. Click on calculate MRP to view the updated tables

Conclusion

This project successfully resulted in a simple, efficient, and user-friendly ERP software tool. Additionally, a number of other goals were met along the way. The team was fortunate enough to experience learn by doing with regards to software development project management. Valuable techniques that were learned include the storyboard planning method and the rapid prototyping process. Through the physical software development, the team also enhanced technical VBA coding and MS Access usage capabilities, as well as gaining a more holistic understanding of the production planning process. Although the project was successful there are a few things that would have been done differently if it were to be completed again. Ideally the scope should have been refined earlier. More work would have been done up front about what is reasonable to accomplish given the platforms available. Despite that, the team is pleased to deliver a product that is an effective teaching tool with the ability to be expanded to other domains.

References

Billingsey P. (1994). "Ergonomic Standards go Beyond Hardware" *Interface*

Chung, B. (2007). "An Analysis of Success and Failure Factors for ERP Systems in Engineering and Construction Firms", *Civil and Environmental Engineering Theses and Dissertations*

"How Much Does SAP Business One Cost?" The SAP Ask Engine. N.p., n.d. Web. 12 Mar. 2015.

Kaminski A. (2010). "Computer Integrated Enterprise in the MRP/ERP Software Implementation" *Foundations of Management.*

Kemp M, Low G. (2008) "ERP Innovation Implementation Model Incorporating Change Management" *Business Process Management Journal.*

Malhotra R, Temponi C. (2010). "Critical Decisions for ERP Integration: Small Business Issues" *International Journal of Information Management.*

Matende, Samwel, and Patrick Ogao. "Enterprise Resource Planning (ERP) System Implementation: A Case for User Participation." *Procedia Technology* 9 (2013): 518-26. Web. 13 Mar. 2015.

Motwani J, Subramanian R. (2004). "Critical Factors for Successful ERP Implementation: Exploratory Findings from Four Case Studies" *Science Direct.*

Nelson, Klara and Somers, Toni, "Exploring ERP Success from an End-User Perspective" (2001). AMCIS 2001 Proceedings.Paper 206.

Nurgül *et al.* (2011). "Fuzzy AHP-TOPSIS Two Stages Methodology for ERP Software Selection: An Application in Passenger Transport Sector" *15th International Research/Expert Conference*

Pacheco-Comer A, González-Castolo J. (2012). "An Empirical Study in Selecting Enterprise Resource Planning Systems: The Relation Between Some of the Variables Involve on it. Size and Investment" *SciVerso Science Direct*

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