Database Functionality for the Environmental Assessment of Consumer Products

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Abstract- **McDonough Braungart Design Chemistry, MBDC, is a consulting firm dedicated to revolutionizing industries to ensure that products are reusable in biological or industrial cycles [1]. MBDC analyzes the entire supply chain of materials used to make its products. All the data concerning a product is stored in a database maintained by MBDC. Prior to this project, employees of MBDC would manually sketch a map of a product's supply chain to chart ingredient relationships, identify missing links of information, indicate ingredient assessment status, and display results. The project team has created a tool that allows MBDC to automatically view the status of data in the assessment process as well as any missing links of supplier information. If MBDC has completed assessment of the material, the tool provides indicators concerning the results of the assessment.**

MBDC works with a large amount of customers and it would be very beneficial if they could spend more time working directly with customers versus spending time on routine work. Using the Systems methodology throughout the project, the team first worked with MBDC to understand the requested functionalities of the database and then created a list of requirements based on the functionalities. Based on the requirements, the team generated over twenty alternatives. Evaluation and client input resulted in the selection of the best alternative. The team has constructed a functional prototype of the final system which, based on testing, meets all of the high priority requirements. Based on MBDC estimates of the amount of time saved per project with this tool, the team calculated that it will save the company 2,000 hours a year [2].

I. Introduction

A. Problem Specification/Background

McDonough Braungart Design Chemistry, MBDC, is a consulting firm dedicated to revolutionizing industries to ensure that products are reusable in biological or industrial cycles. The firm focuses on assessing the materials in products in terms of their environmental and human impacts. Each product is awarded a rating of silver, gold, or platinum based on these criteria [3].

To evaluate the materials, MBDC maintains a database of supply chain information for each product. Collecting the data for and from the database was a time intensive part of its work. Part of the data collection process involves creating a visual map to represent relationships between the manufacturers and suppliers; the other part of the data collection involves representing supply chain relationships and assessment status. MBDC employees manually created these visual maps for each product being assessed. This inefficient and repetitive process wasted employees' time and should have been automated to allow them to focus on other business tasks [1].

B. Problem Significance/Motivation

MBDC's founders, William McDonough and Michael Braungart created a design system, Cradle to Cradle. McDonough's vision is to create a world without waste where all materials are endlessly recycled. If MBDC's data collection process and product visualization process are made more efficient, the company will have additional time to spend consulting with more clients. A larger customer base will increase MBDC's impact on the environment. In addition, an organization tool will strengthen the relationships and communication between MBDC, the manufacturers, and the suppliers and allow business to be conducted more efficiently [3].

C. Goals and Objectives

The overall project goal was to understand MBDC's needs and to implement a system that addresses the critical needs. The team established objectives it would like the tool to accomplish to solve MBDC's problem. The tool will enable MBDC to eliminate time wasted on data organization if it achieves the following objectives: allow MBDC to communicate effectively with the manufacturers and suppliers of a product; enable MBDC to see the big picture of each product in terms of suppliers and materials that contribute to it; show the status and results of the material assessment and any missing important information. If all these objectives are met, then the tool will be measured as a success for MBDC [3].

II. System Requirements

The project was completed using the systems methodology–defining the problem, establishing the requirements, generating and evaluating alternates, selecting the best design, and then testing and implementing the final system. Once the problem was defined, the team decomposed the project objectives to specify detailed requirements for the system. Based on input from MBDC, the team created specifications concerning ease of use, necessary functionalities, and technicalities such as compatibility with monitor size, Internet browsers, etc.

The team focused on the requirements that were necessary to complete the project objectives. Supplementary requirements were documented that were not necessary for project success, but their implementation may further enhance the system. Documenting these requirements was an iterative process; upon receiving feedback from the advisor and MBDC, the document was adjusted multiple times. These requirements detail the functionality needs of the system. The high priority requirements for the system are:

1 The system shall represent relevant suppliers for a specified manufacturer's product.
2 The system shall represent the appropriate tiered relationships between the manufacturer and all relevant suppliers to the bottom of the supply chain.
3 The system shall clearly identify the tier each supplier resides in.
4 Data Status
    4.1 The system shall indicate that the supplier has submitted data.
    4.2 The system shall indicate that the supplier has not submitted data.
5 Assessment Status
    5.1 The system shall indicate that a component has been assessed.
    5.2 The system shall indicate that a component has not been assessed.
    5.3 The system shall indicate the chemical level profile if assessment is complete.
6 The system shall display orphan suppliers (i.e. Suppliers who have entered the correct Project Code but did not enter a Direct Customer).
7 The system shall allow a user to view portions of a large supply chain that would otherwise not fit on one screen through an expandable/collapsible feature.
8 The system shall display a minimum of one tier and a maximum of six tiers.
9 The system shall display a minimum of one supplier and a maximum of 100 suppliers.
10 The system shall display a minimum of one component and a maximum of 100 components.
11 Ease of Use
    11.1 An untrained user shall be able to learn how to use the supply chain representation system in less than 10 minutes.
    11.2 With data already entered into the system, a user that self-trains shall be able to:
        11.2.1 Produce a supply chain representation in less than 1 minute
        11.2.2 Manipulate views of a supply chain in less than 1 minute
        11.2.3 Print a supply chain in less than 1 minute
12 The system shall be compatible for at least Windows XP and Mac OS X machines
13 The system shall interface with the existing database system.

III. Prototype Development

To begin the prototype development stage, the team divided the system into the following five distinct subsystems:

- Displaying all of the information in an organized format
- Indicating that data had been submitted
- Indicating that data had been assessed
- Indicating the assessment result
- Limiting the size of the display for a large supply chain

Alternative solutions were created for each of these subsystems. A few alternatives were eliminated in a preliminary screening based on difficulty of coding, the ability to meet subsystem requirements, and the effectiveness for end users. The remaining alternatives for each subsystem were presented to MBDC in a conceptual design review. The conceptual design review presented four alternative systems each comprised of unique combinations of subsystem alternatives. Based on feedback from MBDC, the team discussed and selected the combination of subsystem alternatives that would be used for the final design. The rationale the team used to make the final decision between alternatives is as follows.

The first subsystem was displaying the necessary information in an organized format. Two ideas for the display were a table format and a tree format. The final system uses the table format to show information. Although the tree was the most visually sensible representation of the supply chain and information, its width expanded very quickly. Because a fully expanded tree may violate the constraint of the display fitting on the screen, the tree format was not chosen. The table format is not as visually appropriate, but the representation would better use the screen space. By choosing the table format, the team traded a more visual representation for one that uses screen space more efficiently.

The next two subsystems were indicating data was submitted and indicating a component had been assessed. Because of the similarities of the subsystems, alternatives generated for one were often applicable to the other. Two ideas for these subsystems were using a different type of font (bold, italics, or colors) for the material and displaying yes or no. Displaying yes or no was chosen for both subsystems. The font format would save space on the display whereas the yes/no display would allow MBDC to quickly glance at a supply chain and easily identify suppliers that have not submitted information. By choosing the yes/no display, screen space was sacrificed for ease of use for MBDC.

Another subsystem was displaying the assessment result. Two ideas for this subsystem were making the font

of the material in the color of the result and displaying the assessment result (e.g. green, yellow, red, or orange). One consideration for the system is that people with color-blindness be able to use the system. The first idea of making the font the appropriate color violates this constraint. Another consideration is that the font must be readable. Again, this idea would violate the constraint when a component had a yellow result. A hybrid of these alternatives was chosen. The assessment result was written in black font with a background color that coordinated with the result (e.g. the word "red" is written in black font over a red background). This combination allows people with color-blindness to be able to understand the assessment results. In addition to the text, the final design incorporates the appropriate background color, allowing people with normal eyesight to scan a large supply chain more quickly.

The final subsystem was limiting the size of the display for a large supply chain. Two ideas for the size limitation were making the display expandable/collapsible and having a miniature version of the whole representation. The expandable/collapsible function would allow MBDC employees to temporarily hide rows of the table based on what information they wanted to see. This function would require MBDC to spend significant time expanding the table to its full form. The miniature version of the display would be a small picture of the entire supply chain. Having a miniature version would be a very quick way to see the entire representation, but it would also be very difficult to program. In this case, the team traded the ability to see the full form quickly for ease of programming.

After the combination of subsystem alternatives were selected, the team developed a prototype of the final system. The prototype was developed in PowerPoint and approved by MBDC. Fig. 1 is a screen shot of the prototype that displays all of the selected subsystem alternatives. The prototype also incorporates other requirements, such as showing the suppliers who did not submit a direct customer. The Direct Customer is the company to whom a supplier supplies components.

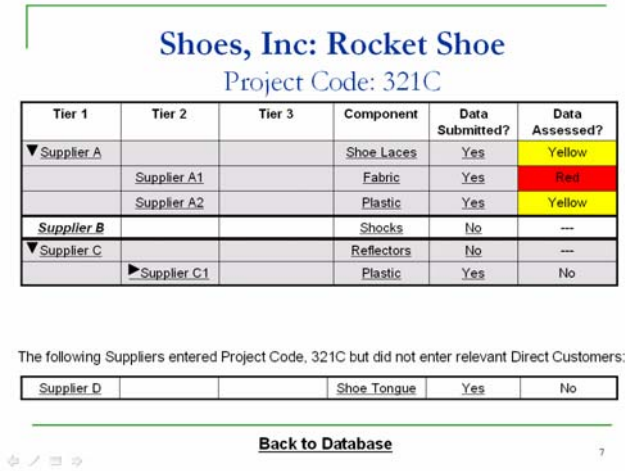

Fig. 1: The Final Prototype

IV. Design Overview

The PowerPoint prototype served as a guide during the development of the final system. The final system incorporates the high priority requirements that are embedded in the prototype.

When MBDC employees log onto the Supply Chain Tool website, they are presented with a screen that has a link to the team's developed system. Upon clicking this link, employees are directed to screen that contains a drop down menu of all of the projects that have been submitted to the database. The employees can then highlight the project they want to see and click the Submit button.

Fig. 2 shows a screen shot of what appears when an employee selects the "Running Shoe" project code. As seen in the figure, the title is displayed in bold font at the top of the screen, allowing employees to easily recognize what product supply chain representation they are viewing. Below the title is a well-organized table containing all of the information that MBDC requested to be incorporated in the representation. The first columns of the table are the supplier tiers, which represent the hierarchy of component suppliers. Tier one suppliers contribute components directly to the manufacturer, tier two suppliers provide components to their respective tier one suppliers, and tier three suppliers contribute components to their respective tier two suppliers. The tier system continues this way until the final supplier of components is reached. The tiers are determined based on the Direct Customer the supplier submitted to the database. Fig. 2 shows the supplier hierarchy. For example, Laces Inc. is a supplier to Soles Inc. and Soles Inc. is a supplier to Bongo. After the columns of suppliers, the table has a column that contains the components that are supplied by the supplier is their respective row. After the component column, there is the "Data Submitted?" column and the "Data Assessed?" column. These columns indicate whether the supplier in the row has submitted information about the component in the row and whether MBDC has assessed the component in the row, respectively. If data has been submitted, the "Data Submitted?" will contain "Yes." On the other hand, if data has not been submitted, the column will contain "No." If data has not been submitted, the "Data Assessed?" column will contain "--." If the data has been assessed, the "Data Assessed?" column will indicate this simply by displaying the assessment result. In addition, the background of the cell will be the color of the assessment result. If the data has not been assessed, the column will contain "No." For example, Soles Inc. has submitted information about the component Shoe Sole and the assessment result is yellow.

Fig. 2 Running Shoe Screenshot

Another feature of the table is the alternating grey and white background colors for tier one suppliers seen in Fig. 2. This feature allows employees to easily distinguish the tier one suppliers' subsequent suppliers and components.

The tables are also expandable and collapsible using the arrows to the left of the suppliers. The default position for the triangle is to point to the right. The triangle points downward after the user clicks on the triangle to see the sub-supplier. This functionality is shown by comparing Fig. 3 and Fig. 4. In Fig. 3, only the tier one supplier, Up and Away Inc., is shown and therefore the arrow is pointing to the right. By clicking the arrow to the left of Up and Away Inc., Fig. 4 will appear and the arrow now points downward. This functionality allows MBDC employees to expand or collapse the table to show information they need. A full table may be an overwhelming amount of information for an employee to see all at once. Employees can temporarily hide or expose rows of suppliers based on the information they want to see.

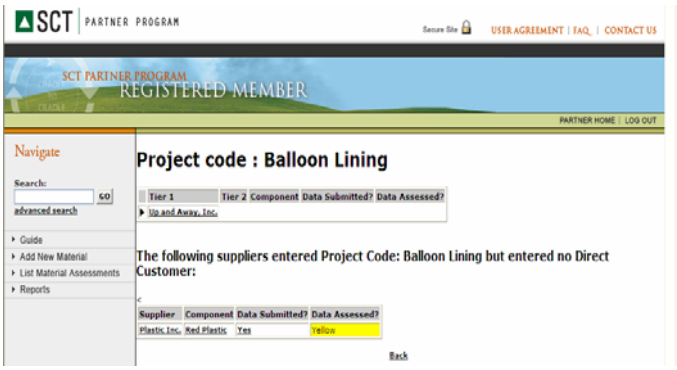

Fig. 3 Balloon Lining Screenshot

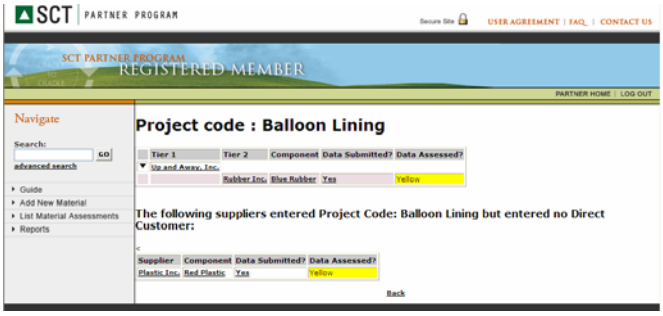

Fig. 4 Expanded Balloon Lining Screenshot

As shown in Fig. 4, below the supply chain representation is another table of suppliers who have submitted information about the product but did not submit a Direct Customer. These suppliers are referred to as orphans. In this case, the suppliers do not fit into the supplier hierarchy and therefore are not shown in the main table. Because they contribute components to the product, it is important that their information be shown on the screen also.

As seen in Fig. 4, under the orphans, there is a link to go back to the previous page. This link allows MBDC employees to quickly return to the drop down list of products and select a new product to view.

Using the system, employees of MBDC can quickly identify suppliers who need to submit information and components that still need to be assessed.

V. Testing

A. High-Level Requirements Testing

The team performed tests on each of the individual functions as they were completed. Table I shows the results of testing each requirement. To test the functionalities, the team entered four products into the database, each with a different number of suppliers and tiers. These products were used to ensure that the system worked for the range of supply chains MBDC needs, as specified in the requirements. The team used these products to test different combinations of functions to check that they worked together. For example, a test ensured that the table expanded and collapsed while displaying the appropriate suppliers in the appropriate tiers. As more functions were created, any existing related functions were tested again to ensure that the implementation of one function did not affect the others. Once the system was completely built, the team conducted thorough testing on the integrated system

B. Complete System Level Testing

To test the overall effectiveness of the system, the team created several testing scenarios. Each scenario had several requirements the system had to meet in order to pass the test. Each scenario contained typical tasks that MBDC would complete. For example, a user was instructed to find the assessment result for a specific component. The team

noted how difficult or easy the task was to complete for the user. The team was able to identify weaknesses in the tool from this form of testing. Changes were made in certain functions that eventually allowed each scenario to be completed successfully.

C. Usability Testing

To test the user-friendliness of the tool, the team created usability tests. The team used its technical advisor and other students to test the system. The team asked the test subjects if there were any visualization aspects (color, font, and layout) of the tool that were distracting or confusing. Finally, since MBDC is the main user of this system, the team will give the tool to MBDC to test. The team asked MBDC to report any final suggestions or problems associated with the tool.

D. Testing yet to be Completed

Some of the usability testing that was initially planned by the team was not completed by the time this paper was due. The following additional tests should be completed by April 27, 2007. The team plans to have each test subject spend time navigating through the tool, performing specified tasks, and then reporting back on their findings. Some tests require the team to time the test subjects while other tests ask the users to rank certain aspects of the tool. The tests ensure that several usability heuristics are present such as error prevention, efficiency of use, recovery from errors, help and documentation, and consistency.

Table I. Requirement Test Results

Req't #	Passed Test?	Comments
1	Yes	
2	Yes	
3	Yes	
4.1	Yes	
4.2	Yes	
5.1	Yes	
5.2	Yes	
5.3	Yes	
6	Yes	
7	Yes	
8	Yes	
9	Yes	
10	No	Probable but not tested yet
11.1	No	Probable but not tested yet
11.2.1	No	Probable but not tested yet
11.2.2	No	Probable but not tested yet
11.2.3	No	Probable but not tested yet
12	No	Probable but not tested yet
13	Yes	

VI. Evaluation of System Impact

Collecting and displaying information about a product's suppliers, components, and assessment results is critical to the success of MBDC. MBDC's process of collecting and displaying information critical to its daily operations was tedious and inefficient; therefore the team's work to improve the process was indispensable. The system will dramatically increase MBDC employees' work productivity. Based on MBDC's estimates, they assess about 400 products a year at a rate of 5 hours per supply chain map. This system saves MBDC about 2000 hours per year. Assuming employees work eight hour days, the system saves one employee 250 days of work per year, almost a year's worth of work. The system allows MBDC to spend much more time on tasks that are making an impact on the environment.

VI. Conclusion

A. Summary

To eliminate MBDC employees' manual process of drawing supply chain maps, the Systems and Information Engineering capstone team designed a web-based system that automatically displays the suppliers, their components, and the assessment results. After generating and evaluating alternatives, a design was selected and a PowerPoint prototype was built. The prototype served as a guide for the technical construction of the final system. The final system accurately displays information that suppliers submit to the database. The representation is organized as a table with a well-formatted title and appropriate column labels. In addition, the system is dynamic so employees can view the display for different products. Based on testing, the constructed system meets most of the specified requirements. The requirements were designed specifically to improve MBDC's processes and therefore the final system satisfies MBDC's needs [4].

B. Recommendations for Future Work

While the constructed system improves MBDC's process of collecting and displaying critical information, there are two additional functionalities that should be constructed to further enhance the system—improved capabilities for expanding and collapsing the table and an administrative interface for MBDC. These functionalities were identified as medium and low priority requirements for the system but were never technically constructed as a part of the system [4].

It would be helpful if there was an option that automatically expanded the table to its full form. Currently, the employees have to expand the table supplier by supplier. A full form table would allow MBDC employees to quickly find specific suppliers and also links of missing information. An additional table functionality that would

be an asset to the system is the ability to hide certain columns. This feature would allow MBDC employees to simplify the table and only see necessary information [4].

The final aspect that needs to be constructed is an administrative interface for MBDC. This capability would allow MBDC employees to alter the system to meet their needs—including anything from changing information to modifying the table structure. For example, MBDC employees could eliminate the orphan suppliers by inserting the correct Direct Customers through the interface. Giving MBDC these administrative abilities would require tightened security measures around the interface. It would be important to construct the interface in a way that ensures that no one but assigned MBDC employees have access to the administrative interface. This recommended additional work would help MBDC to have a more efficient process of collecting and displaying information [4].

REFERENCES

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