Design and Development of a Product Database for Brake Lining: A Case Study of a Brake Lining Factory

Tongmean Teang[1], Thanathorn Karot[2]
[1, 2]Faculty of Engineering and Industrial Technology, Silpakorn University
Email: teang_t@silpakorn.edu[1]

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Abstract

The automotive parts manufacturing industry is characterized by intense competition, rapidly changing customer demands, and particular customer requirements. As a result, precise design and rapid development of new products are essential for maintaining competitiveness. Our case study is a lining brake factory with several thousand stock-keeping units. Managing all product-related data, such as engineering of change, bill of material and engineering files is crucial yet challenging due to the complexity of the products, manufacturing processes, and supply chain. This study aims to design and develop a product data brake lining management system to centralize product data within organization. It presents three main modules: the Input Data module, the Query Data module, and the Security module. The system is developed following the Software Development Life Cycle (SDLC). The system is based on web application technology, utilizing PostgreSQL for the database, React.js for the client side, and Express.js for the server side. The key technology used in this study is also discussed. The system evaluated through questionnaires completed using a user satisfaction form. User feedback indicated a satisfaction level of 4.48 out of 5 and a standard deviation 0.53. Moreover, it can reduce working time for all teams to create product data or search and retrieve product data from 131.6 min to 52.6 min, which reduces working time by 60% compared to the traditional method.

Keywords : Product Data, Database Management, SDLC, Bill of Material, Automotive Parts

Introduction

The global industrial landscape has been significantly influenced by Industry 4.0 policies and the adoption of digital technologies to improve competitiveness through reduced manufacturing costs, enhanced product quality, and flexible production systems [1]. Furthermore, increasing competition, rapidly evolving and highly specific customer demands have compelled organizations to adapt [2]. This shift has led to greater product diversity and increasingly complex manufacturing processes [3]. Effective product data management is a key aspect of maintaining competitiveness in such an environment. However, due to outdated or limited technological infrastructure, organizations often face technical challenges, such as decentralized product data. Product data is often not readily shared across teams, primarily due to technological limitations. Currently, Microsoft Excel remains the predominant tool for managing data within organizations. Consequently, different teams maintain isolated Excel files for their respective data, resulting in a fragmented and decentralized product data management system. This fragmentation poses significant challenges, including data integrity issues and reduced operational efficiency.

In this case study factory, the current process of new product development, product data such as the Bill of Materials (BOM), and Product Specifications are sent to related teams via Excel files. This approach has duplicated datasets across the organization, with each team maintaining its version of the product data. Due to the limitations of Excel, which does not support efficient cross-team sharing, several issues have arisen. These include inconsistencies between teams' datasets, wasted time in data transmission and queries, and a lack of synchronization in product data.

This study aims to design and develop a database for brake lining product data to centralize product data within organization, enabling cross-team usage throughout various team within organization. The system consists of three main modules: the Input Data module, the Query Data module, and the Security module. The system is developed following the Software Development Life Cycle (SDLC) methodology and utilizes web-based technologies.

Objective

1. To Design and Development Database Product Data Brake Lining
2. To Centralize Product Data Within Organization

Methodology

In order to achieve the research objectives, the research step is as follows.

1. Related Theory

1.1 Web Application

A web application is a software program accessible via the internet without requiring local installation. Additionally, it can be accessed by using a browser (Chrome, Safari) and then able to start using a web application right there online [4].

1.2 Software Development Life Cycle (SDLC)

The system development process will be carried out following the software development cycle or Software Development Life Cycle (SDLC) [5] as follows:

- Planning: Begin with requirements either from a customer or user.

- Analysis: Determine the scope of the project or software and the resources which are used to accomplish it.

- Design: Software design of the user response screen (User Interface: UI) and Software Coding, including database and network design.

- Development: The software development phase is practical by developing the software as already designed to become a reality which can be used to meet the requirements of customers or users efficiently.

- Testing and Implementation: Testing is a way to find bugs. The software must be tested until software errors or bugs are minimized. A visual environment is created to deploy the system.

- Maintenance: After using it for a while, customers or users may find additional software errors (bugs). They can notify the admin to fix the bug. Then, periodically fix the bugs once they occur.

2. Related Research

Yang & Zhang, (2014)[6] presented a solution for small-and medium-sized enterprise product data management systems, designed and developed for certain industries, as users require. This research analyzes the system and business solution system architecture based on the net framework. It also describes the main functions of systems, such as drawing management, project management, and security management, and then discusses some key technologies used in the current system. The results show that it can improve the enterprise's product data management efficiency.

Watcharapong, (2022)[7] analyzed, designed, and developed database systems for new production tires in order to serve the manufacturing flexibility of case study tire

manufacturers. This study aims to reduce working time for new tire feasibility studies and to support the investment decision on machine investment. The results of this study prove that it is possible to reduce the time for a new tire model feasibility study from 5 weeks to 2 weeks, which reduces working time by 60% compared to the original method, increases data accuracy and reduces human error. Our study proposes a multi- role database system specifically for brake lining manufacturing, emphasizing data security and accessibility across production, sales, and procurement teams.

3. Design and Develop

The system development process will follow the Software Development Life Cycle methodology containing six steps, as outlined below:

3. 1 Planning: This step begins with collecting all product data related to the manufacturing processes. The product data is categorized into four sections: Work in Process (WIP), Work in Process Drill (WIP DR), Work in Process Finished Goods (WIP FG), and Bill of Material (BOM). Additionally, relevant personnel must be identified. Afterward, all materials associated with the system need to be gathered. It includes planning the system's scope and estimating the timeline for its completion. The users are divided into two parts: one creates product data consisting of the APQP (Advance Product Quality Planning) team, and the other uses product data consisting of the production team, accounting team, procurement team, and sales team.

3.2 Analysis: This phase involves gathering and analyzing users' requirements and understanding the system's domain. It also includes a detailed analysis of user roles and the various modules within the system.

3.3 Design

3.3.1 Module Design: In this design, the system comprises three mains modules, as outlined below:

- Data Input: This module includes two functions: one allows data entry through an MS Excel file, while the other supports form-based input. It also updates data using form-based input.

- Data Output/Query: This module includes two functions: one enables data experts to work with data through an MS Excel file while the other function is able to select specific records and copy then paste them into any spreadsheet program.

- Security: This module enables the system to validate users through their login credentials (email and password) to ensure that all user data are accurately captured during any system activity or interaction, such

as creating, updating, and deleting data.

3.3.2 User Base design: In this design, the system comprises three main user group as follows

- admin: The system provides full access to all functions, including data input, querying, deletion, updates, and user management.

- creator: The system provides key functionalities, including data input, querying, deletion, and updates, excluding user management.

- user: The system only allows access to query data.

3.3.3 Database Design: In this design, the database architecture was illustrated using an Entity-Relationship Diagram (ER-Diagram) to represent entities and their relationships, as shown in Figure 1.

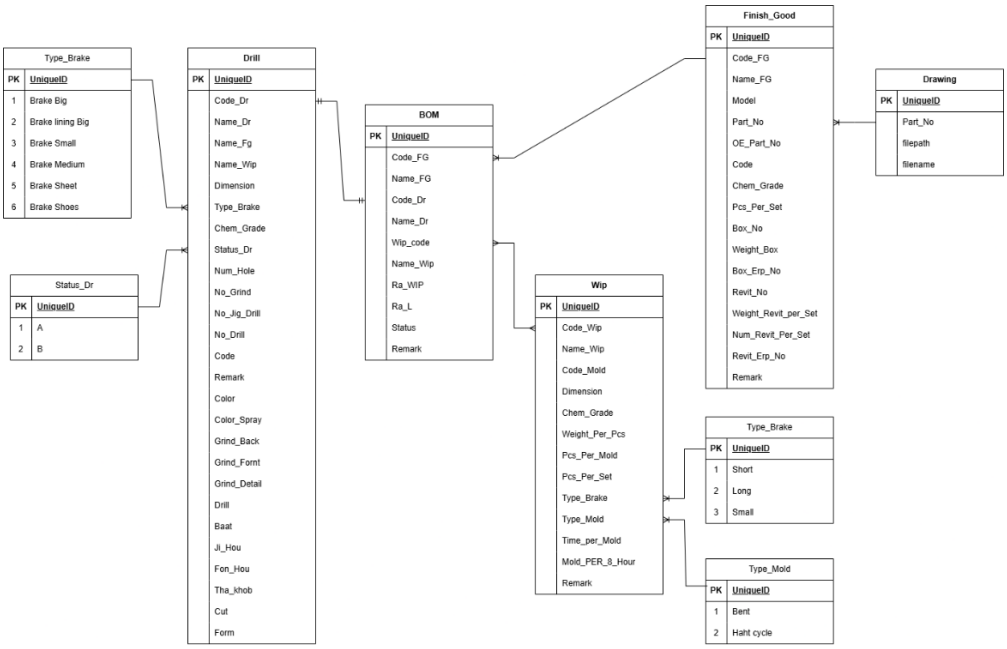

Fig. 1 Database Design using ER-Diagram

3.3.4 Development: This system was developed using web-based technology, running on the Node.js JavaScript runtime environment. Express.js is used on the server side, while React.js is employed on the client side. PostgreSQL serves as a database. Communication between the server and client is facilitated through API, with Postman used to test API calls. Visual Studio is the integrated development environment (IDE) for code development [8].

3.3.5 Testing and Implementation In this phase, testing ensures the

system functions according to the expected outcomes. It involves comparing the expected and actual results to verify that the system operates correctly based on the given requirements. The database system was deployed on local area networks, and all related teams were able to access the database system. After that, related teams will be trained in utilizing the database system by providing user manuals, and the database system will be tested in the workplace.

3. 3. 6 Maintenance: After implementation, close communication with users is essential to address bugs and prevent server downtime promptly.

4. Sample

In this study, the sample is divided into two groups as follows:

- Creator user: This group consists of 3 employees from the APQP team who are responsible for creating product data.

- Query user: This group consists of 6 employees who need to query product data for internal use. These users are distributed across various teams within the organization: one from the production team, one from the accounting team, two from the procurement and two from the sales team.

5. Statistics Tools

The questionnaire was a method for data collection in this study and was divided into two parts. First, personal information was collected from the sample using a checklist questionnaire from each team, which was analyzed using the percentage value. Second, the collection of user satisfaction data after utilizing the database system. was analyzed using Likert Rating Scales. which consist of five levels scales [9]:

- Level 1 denotes very unsatisfied.
- Level 2 denotes unsatisfied.
- Level 3 denotes neutral.
- Level 4 denotes satisfied.
- Level 5 denotes very satisfied.

After gathering the data, the researcher converts the score using interval criteria.

- The range of values from 1.00 to 1.49 denotes very unsatisfied.
- The range of values from 1.50 to 2.49 denotes unsatisfied.
- The range of values from 2.50 to 3.49 denotes neutral.
- The range of values from 3.50 to 4.49 denotes satisfied.
- The range of values from 4.50 to 5.00 denotes very satisfied.

The research analyzes trends of information distribution of questionnaires by using mean and standard deviation.

6. Result Evaluation

6.1 Employee Satisfaction Evaluation

This research collects personal information and employee satisfaction from those who utilize database systems within case study companies by performing a survey and using questionnaire tools. The topics used for satisfaction assessment after using the database system are divided into four parts: System Information Display, System Quality and Accuracy, System Efficiency, and System Procedures. Table 1 presents an evaluation form for assessing satisfaction with the database system.

Table 1 The form for evaluating satisfaction after using the database system

Question	Satisfaction Level				
	5	4	3	2	1
System Information Display					
1. Clarity and simplicity of menu tab categorization					
2. Suitability of displayed data in various menus (data arrangement/orderliness)					
3. Size, clarity, and format of text displayed on the screen					
System Quality and Accuracy					
1. Accuracy of system processing when adding new record					
2. Sufficiency of data sections (columns) for usage					
3. Ability to utilize product data for operational purposes					
System Efficiency					
1. Speed in response, processing, and data display					
2. Speed in display and report generation					
3. Security management and access rights configuration					
System Procedures					
1. Appropriateness and ease of understanding system procedures					
2. Reduced steps and faster product data retrieval compared to traditional methods					
3. Reduction in redundant data retrieval compared to traditional methods					

6.2 Working Time Evaluation

This research starts with a study process and the standard time of each team, including the production team, the account team, the procurement team, and the sales team, to retrieve and search for product data. The production team uses product data for production planning. The account team uses product data to calculate the standard cost for each finished product. The sales team uses product data to check whether the product exists or not before accepting an order from the customer. The procurement team uses product data to check product specifications before accepting purchasing orders. It is necessary to retrieve and search for product data to ensure the completion of these processes. This study measures the approximated standard time required for retrieval and searching product data in each process. The working times were then compared between the traditional method and the method using a database system.

Results

The results of this research consist of three parts as follows:

1. Result of Database Product Data Brake Lining

The database system was developed based on the module designed as follows:

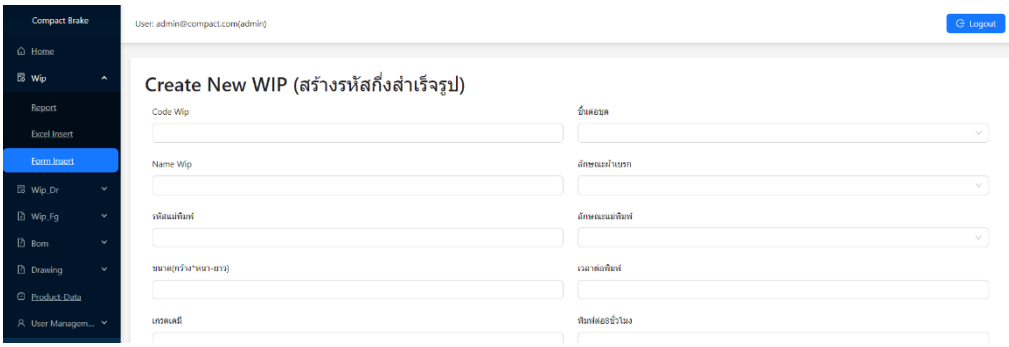

Fig. 2 Form-based Input

Figure 2 presents a form-based input interface designed to capture and store data into the database, structured according to user requirements.

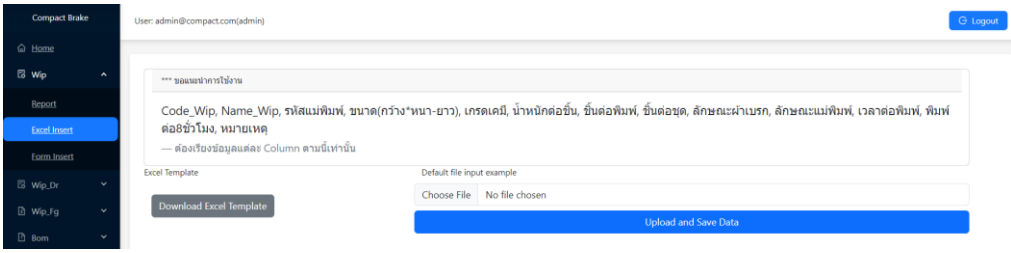

Fig. 3 MS Excel file Input-based

Figure 3 illustrates an MS Excel file-based input interface designed to capture and store data in a database structured according to user requirements. The Excel file must either follow the original header format or can be downloaded as an Excel template.

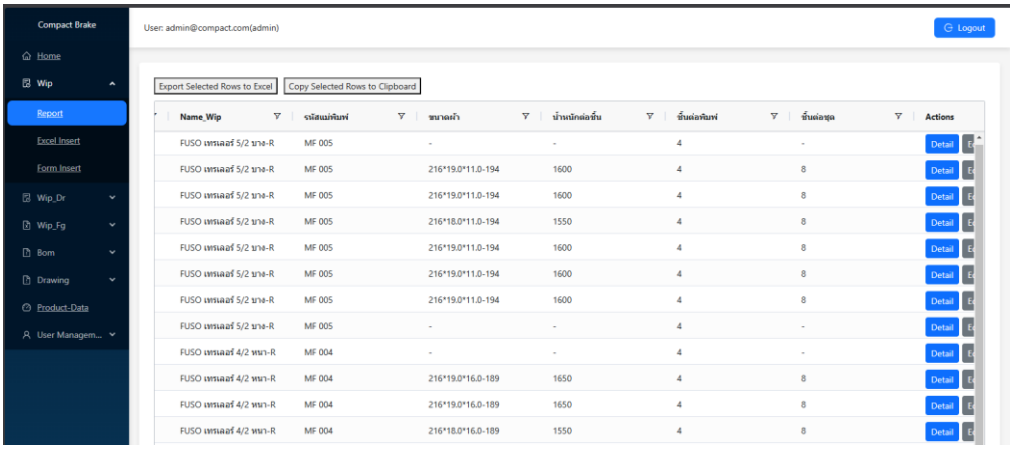

Fig. 4 Report Webpage

Figure 4 illustrates the report data interface. On this web page, users can press the 'Detail' button to view detailed information, the 'Edit' button to update specific records, and the 'Delete' button to remove specific records. Additionally, users can select specific records to export as an Excel file. Users can also select specific records and copy and paste them into any spreadsheet program.

2. Result of employee satisfaction

Table 2 The result of employee satisfaction

Sample Characteristics	Percentage (%)	Satisfaction Level	Mean	SD
APQP Team	33.3	Very Satisfied	4.63	0.48
Procurement team	22.2	Satisfied	3.95	0.35
Sales team	22.2	Satisfied	4.25	0.45
Account team	11.1	Very Satisfied	5.00	0.00
Production team	11.1	Very Satisfied	4.91	0.27
Total	100	Satisfied	4.48	0.53

According to Table 2, the number of employees who use a database system is divided into the APQP team, which accounts for 33.30%; the Procurement team, which accounts for 22.20%; the Sales team, which accounts for 22.20%; the Account team, which accounts for 11.10%, and the Production team, which accounts for 11.10% of the total sample.

The overall level of employee satisfaction after using the database system is satisfied, with a mean of 4.48 and a standard deviation (SD) of 0.53. The account team's highest satisfaction is very satisfied, with a mean of 5.00 out of 5.00 and a standard deviation (SD) of 0.00. Due to this, the database system can help the sales team retrieve product data more conveniently than the traditional methods. The lowest satisfaction is the procurement team level satisfaction, with a mean of 3.95 out of 5.00 and a standard deviation (SD) of 0.35 because the interface should be improved to make it more attractive and effective.

3. Result of working time

Table 3 Standard time of the traditional method and using the database system

Teams	Process	Before (Minute)	After (Minute)	Difference time (Minute)	Percentage (%)
Procurement team	Search and Retrieval Product Data	30	5	25	83.30
Sales team	Search and Retrieval Product Data	35	10	25	71.42
Account team	Search and Retrieval Product Data	40	25	15	37.50
Production team	Search and Retrieval Product Data	10	5	5	50
APQP team	Create Product Data	16.60	7.60	9	54.21
Total		131.60	52.60	79	60

Table 3 compares the standard time of the traditional method and new method for each team. The standard time to complete creating product data before and after using the database system is 16.6 minutes and 7.60 minutes, with a 54.21% difference. The standard time to complete the search and retrieve product data before and after using the database system for the procurement team, sales team, account team, and production team is 30 minutes and 5 minutes with 83.3% difference, 35 minutes and 10 minutes with 71.42% difference, 40 minutes and 25 minutes with 37.5% difference, 10 minutes and 5 minutes with 50.0% difference, respectively. Overall, the total standard time for these tasks was reduced from 131.6 minutes to 52.6 minutes, representing a 60% improvement across all teams. The highest difference is the procurement team, 25 minutes or 83.30%. The lowest difference is the account team 15 minutes or 37.50%. These findings highlight the system's effectiveness in reducing data management effort.

Conclusion

This research focuses on design and develop product data database to centralized product data in sample factory which enable various teams to access product data more conveniently than the traditional methods. By transitioning from an Excel-based data management system to a web-based centralized platform, the study successfully addresses key issues, including data fragmentation, inconsistencies between teams' datasets, and excessive time spent accessing product data. The time-saving objective was a critical focus of this study. representing a 60% improvement. This reduction benefits all teams, with the procurement team showing the highest improvement of 83.30%. Such efficiency gains underscore the potential of centralized systems to streamline operations in manufacturing environments. The system achieves a 60% reduction in working time, significantly enhancing efficiency across all teams. The new system enhances operational efficiency and reduces working time to access product data within case study factories.

In addition, The overall employee satisfaction at level 4.48 out of 5.00 and a standard deviation 0.53. Furthermore, the system's modular design, incorporating Input, Query, and Security modules, allows for streamlined data management. Web-based accessibility, combined with React.js, Express.js, and PostgreSQL, ensures the system is scalable and adaptable to meet evolving business needs.

In future work, the organization should consolidate all data into a centralized system to further enhance

database efficiency and reduce time-related inefficiencies in accessing and managing data. Additional features, such as AI-driven search tools, Data-Driven and predictive analytics for further efficiency gains, could further increase the value and accessibility of data for decision-making.

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