Складальне виробництво реалізує виробничий аутсорсинг для задоволення потреб в компонентах складальних виробів. Аутсорсинг компонентів складальних виробів базується на моделі відносин між підрядником та виробництвом, між виробництвом та складальними деталями та іншими процесами, а в останній час між складальними деталями та продажами. У виробничому аутсорсингу, як правило, відсутні способи зв'язку між підрядником/постачальником та складальною групою щодо проблем, які можуть виникнути в процесі складання. Технологія електронного обміну даними (ЕОД) як спосіб електронного зв'язку між компаніями може бути реалізована для складальних груп та постачальників, так щоб перші могли передавати проблеми складання компонентів в процесі складання. Для поліпшення координації та зв'язку з зовнішніми діловими партнерами, в рамках виробничого аутсорсингу необхідна технологія ЕОД для швидкого та точного зв'язку.

Для того, щоб зробити технологію ЕОД більш корисною, цей метод можна інтегрувати з виробничою системою планування, що називається автоматизованою системою технологічної підготовки виробництва (АСТПВ). АСТПВ є зв'язуючою ланкою між проектуванням та виробництвом в середовищі комп'ютерно-інтегрованого виробництва. АСТПВ, що звичайно використовується інженерами-виробниками, можна застосовувати для розробки плану виготовлення продукції. Метою цього дослідження було розробити ініціативу щодо інтеграції веб-додатків між ЕОД та АСТПВ, яка може бути використана як засіб зв'язку між складальною групою та постачальником, щоконкретно допоможе складальній групі планувати процес складання компонентів для виключення або зменшення ручного втручання у планування складання.

Ключові слова: складання, АСТПВ, зв'язок, ЕОД, виробничий аутсорсинг, постачальник

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AN INTEGRATED WEBSITE OF ELECTRONIC DATA INTERCHANGE AND COMPUTER-AIDED PROCESS PLANNING IN PRODUCTION OUTSOURCING

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1. Introduction

Electronic data interchange (EDI) is an electronic communication method – a technology that is used to exchange information or data between organizations/companies. EDI is one of the options available for connecting a company electronically [1]. EDI implementation can affect all functions at a company and significantly impact the relationship between the company and their business partners. EDI is an important technology and many industry benefits can be gained from EDI web-based system implementation by connecting suppliers through EDI technology [2]. Even though there are many studies about the benefits and advantages of EDI, however, actual development of this system has occurred on a comparatively limited scale [3]. Research on EDI technology can be done by implementing EDI in one of the supply chain activities to gain a competitive advantage. One of the activities in the chain supply is outsourcing [4] and there are not many investigations that have been completed to date in this area.

Outsourcing is an agreement between a manufacturer and supplier to provide goods or services within the scope of established agreements [5, 6]. Nowadays, many companies outsource their core production activities such that they are no longer involved in production [7]. This is called production outsourcing. Production outsourcing is the best way for manufacturers to obtain production flexibility and profit [8]. The assembly industry generally implements production outsourcing to meet the needs for product components. However, in the outsourcing process, there are often no formal communication patterns set up between the assembly team and the supplier by which to communicate problems within the production process about components that are provided by the supplier. Communication with a supplier could be defined as an essential need for maintaining a relationship's quality with a supplier [9]. A company's communication policy is a basic plan for inward and outward communication activities for positive effects both internally and externally. Communication is expected to be more organized with a company communication policy in place that is established by the company director and/or the company management team and which is subsequently evaluated with regard to its implementation. Therefore, to facilitate communication between an assembly team and a supplier, a web-based EDI can be developed.

EDI implementation will be more useful if it is integrated with a manufacturing planning system or another business function like quality, process planning, or product manipulation [10]. For that reason, in the present study, a website that integrated EDI and CAPP was built as a process planning system for production outsourcing in an assembly industry environment.

CAPP is one of the component/product assembly planning systems in the manufacture industry. CAPP aims to automate process planning activity [11]. Planning process is defined as a function within the manufacture activity that defines production process and the parameters that are used to change a material from their initial form to another form according to the desired design [12]. Planning process is a link between design activity and production activity. Planning process must be optimal; production process must be finished in time with low production cost. This process needs a computer-aided system that can perform a process planning function that can be called Computer Aided Process Planning. According to the surveys conducted by Alting and Zhang, Maropoulos, and Kiritsis, there are three approaches to develop computer-aided process planning systems for various part types that are based on one or more of three basic methods: variant, semi-generative, and generative [13–15].

In this study, EDI was integrated with computer-aided process planning (CAPP) to make communication between a supplier and assembly team easier and to help the assembly team to plan component assembly for a product. Each component that was coded with group technology represented input for the assembly team to be able to obtain that component's data faster.

2. Literature review and problem statement

Outsourcing has evolved from including predominantly manufacturing activities to including all possible activities within a firm such as product development, market intelligence, logistics, administration, sales, information technology, and business process services [17–19]. The elements of outsourcing have further transitioned from traditional manufacturing and peripheral functions to critical activities. Outsourcing has moved on from focusing on peripheral activities such as cleaning, catering, and security to encompass more critical business activities such as production, design, manufacturing, marketing, human resource management, and logistics. Many organizations and firms increasingly use outsourcing as a critical element of their organizational strategy [20].

Nowadays, many companies implement production outsourcing, especially the production activities that require significant assets and new technology (Fig. 1).

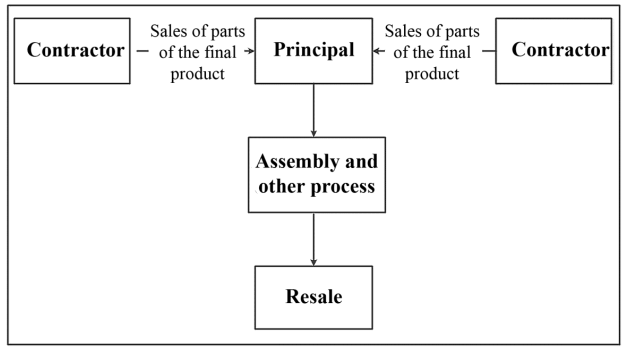

Fig. 1. Outsourcing model for product component assembly [21]

Based on the outsourcing model presented in Fig. 1, a company successfully fulfills the need for product components by buying or obtaining the components from the relevant contractors/suppliers. Then, the components from the contractors are given to the assembly team to be assembled with other components into a cohesive product. Problems that can be present include attainment of the wrong component, wrong dimension, or a broken component or the development of a residue on the component, trouble during assembly, and/or an error that occurs because of a broken component. These issues affect production time and production efficiency. When an issue presents, it then must be forwarded and communicated by the assembly team to a supplier via an internal team (procurement team). This communication pattern is not efficient; instead, for a faster resolution, communication could be shortened by establishing a direct communication line between the assembly team and the supplier to relay information about the problem during the production process.

Successful production outsourcing in the assembly industry requires good communication patterns and relationships with suppliers. To enhance communication and coordination with business partners, EDI technology is needed so that stakeholders can communicate faster and more accurately.

EDI is referred to technology as the exchange of business information from one organization's application to the computer application of a trading partner [22]. EDI promotes swifter and better communication between trading partners, reducing staff costs and errors in the exchange of business documents, forging stronger links between business partners, making the company more flexible, and bringing on many other benefits [3]. EDI as technology allows a company to increase the speed and quality of their communication and decrease costs dramatically. EDI also represents a business strategy that utilizes technology to achieve company objectives and enhance business relationships [23].

It is expected that EDI will be more powerful if integrated with the manufacturing planning system. One such system is CAPP. CAPP is the use of computer technology to aid in the process planning of a part or a product in manufacturing. CAPP constitutes a link between the computer-aided design and computer-aided manufacturing concepts. It provides for the planning of the process to be used in producing a designed part. The benefits of CAPP implementation can standardize company practice, increasing planner productivity and leading to a better program user interface. CAPP can be classified into the categories of variant approach and generative approach. In a variant

CAPP approach, a process plan for a new part is created by recalling, identifying, and retrieving an existing plan. This approach requires an operator to classify the parts, input the parts information, retrieve an existing plan for a similar part from a database (i. e., a library of previous plans), and make the necessary modifications for a new part. In some systems, parts are grouped into part families, while, in others, they are arranged by their similarities in manufacturing methods or technology [26]. Generative approach process plans are generated by means of decision logic, formulas, technology algorithms, and geometry-based data to perform as high a number as possible of unique processing decisions for converting parts from raw materials to finished products. This approach generates a new plan for each part based on the input received regarding the part's features and attributes. Due to the complexity of this approach, generative CAPP is more difficult to design and implement as compared with the variant approach.

3. The aim and objectives of the study

The aim of the study is to design and develop an integrated website of EDI and CAPP that can be used as a communication medium between the assembly team and the supplier, which will specifically help the assembly team to plan component assembly process.

To achieve this aim, the following objectives are accomplished:

1. Designing a data flow diagram of EDI-CAPP system. A data flow diagram is a visual representation of the information flows within EDI-CAPP system. It can explain about system requirements graphically. In EDI-CAPP system, a data flow shows the scope and boundaries of the system that consists of 3 external entities (assembly, supplier, and production) whereas each external entity is connected through the integration of EDI and CAPP. This external entity can exchange information based on their needs of data.

2. Designing a database of EDI-CAPP system. In this task, data is organized to make it easier to find relevant information. Data in EDI-CAPP consists of component data, claim of component, supplier, assembly plan, and etc.

3. Implementation the EDI-CAPP website by using verification test. Verification is the process of evaluating EDI-CAPP system to determine whether they meet the specified requirements. This test ensures that the system is built according to the requirement and design specifications.

4. Designing a website architecture and design

The first step in website implementation is performing research. A good understanding about user requirements requires thorough testing and brainstorming to know features that should be shown on the website, and this is the first thing to do. A keen and accurate information-gathering effort on the part of the client is needed to understand the general idea of the website. This process includes asking about the target audience, goals, and other variables that may affect the system. Fig. 2 shows the results of user requirements.

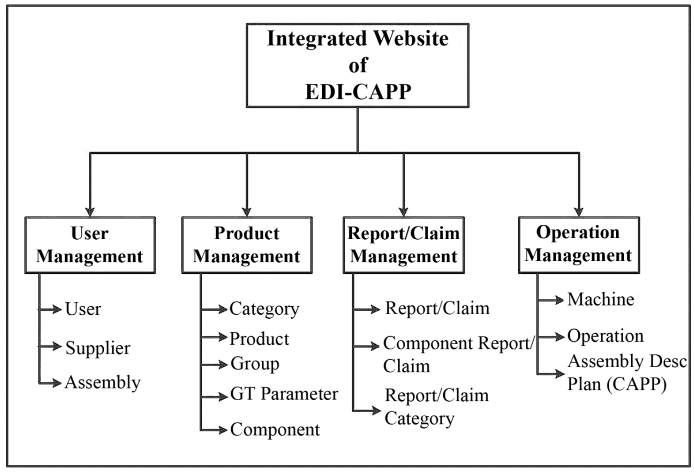

Fig. 2. Example of the website architectural structure

4. 1. EDI-CAPP Integrated Website Flow

The main source of the data is the assembly process as well as information from components reports saved into the system. Other relevant data that are considered include assembly data, supply data, and production data. Ideally, using the website, the user can manage reports/claims, view feedback, and review the status of reports. Additionally, the supplier can receive component reports/claims from the assembly team and send feedback regarding a report/claim, while the production team can view the report/claim of the component. Fig. 3 shows the electronic data interchange system flow.

4. 2. Database Design

After gathering enough information for the database, the entities identified must be used to design and classify the necessary relationships. Following the process of creating lists and tables, a database design process as shown in Fig. 4 is completed.

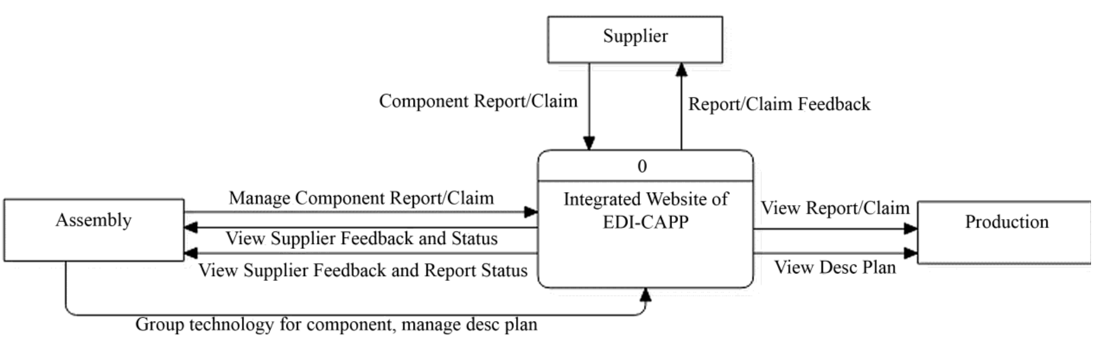

Fig. 3. Context flow diagram of the data exchange system.

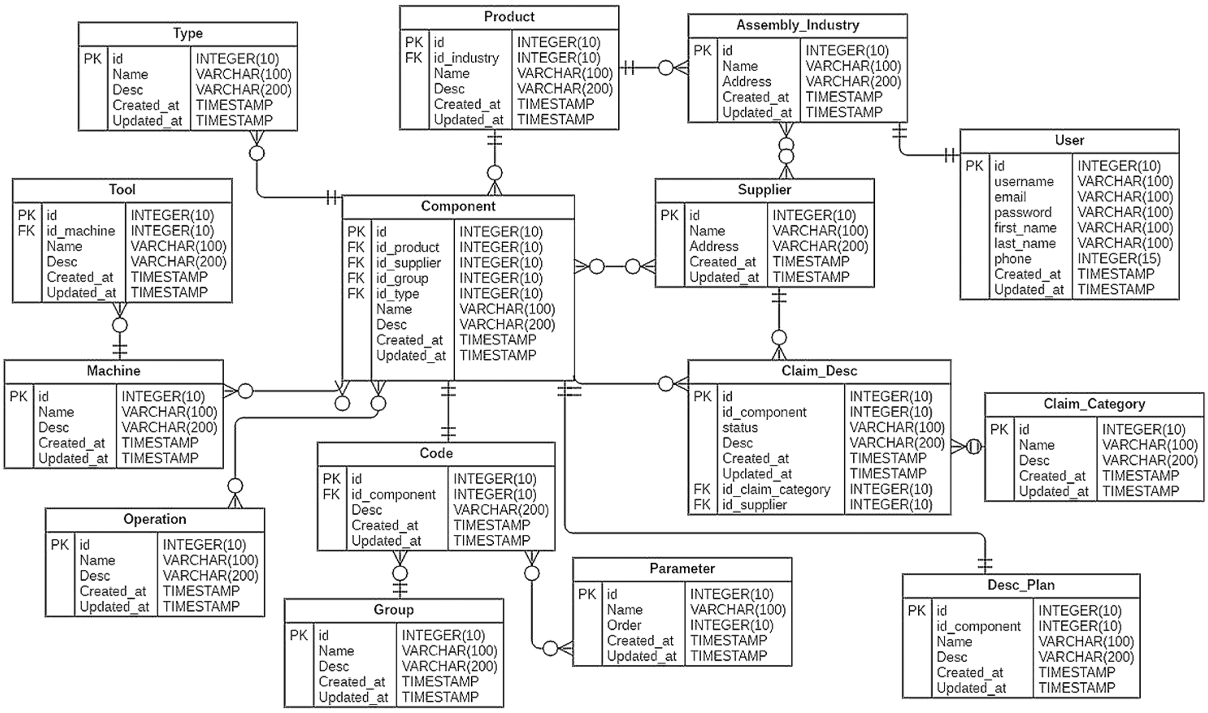

Fig. 4. ERD model of the system

4. 3. Tools to Develop A Web-based EDI-CAPP

The existing primary problem is the decision of what is the basic structure of the system, which involves determining what kind of tools should be used to build the system. The following is an example of a list of the tools that could help to build the system.

– *Hypertext Markup Language (HTML) 5*: a markup language that is supported in all modern browsers. This markup language provides a common interface that makes loading website elements easier and faster.

– *Cascade Style Sheet 3*: this makes it faster and easier to design for the web.

– *jQuery*: this cross-platform JavaScript library is commonly utilized because it simplifies a lot of the complicated things inherent in JavaScript.

– *JavaScript*: This programming language is used to make web pages interactive. It is also used to enhance HTML pages and is commonly found embedded in HTML code.

– *Bootstrap*: this is an open-source JavaScript framework that is used for creating a website. There are some design templates and classes available for interface components.

4. 4. Framework Used

When developing a system, a framework is generally used to add system functionalities as well as for improving the design. Laravel (Taylor Otwell, Massachusetts Institute of Technology, Cambridge, UK, USA) is an accessible yet powerful option that provides the tools needed in large, robust applications. Laravel framework in Fig. 5 is a web application framework with expressive, elegant syntax. It is based on the model–view–controller (MVC) development pattern. The MVC software architectural pattern separates an application into three main logical components: the model, the view, and the controller. Its design pattern decouples these major components, allowing for efficient code reuse and parallel development. Laravel is a powerful MVC PHP framework, designed for developers who need a simple and elegant toolkit to create full-featured web applications.

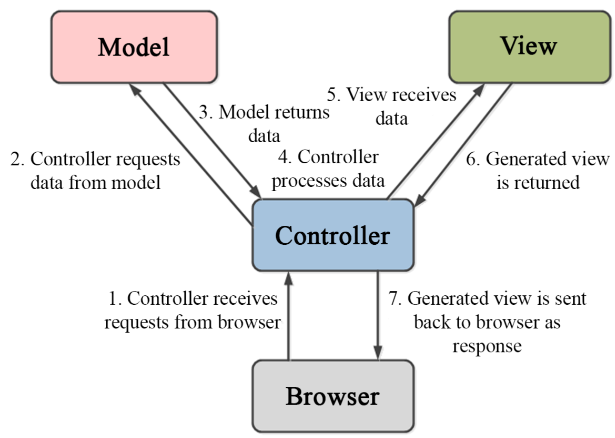

Fig. 5. Laravel MVC diagram

4. 5. Database

The database that was used to develop the system is MySQL (Oracle Corp., Redwood City, CA, USA), which is an open-source relational database management system (RDBMS). MySQL is a commonly used database management system due to its reliability, performance, and simplicity. MySQL can save large amounts of data and information. This ensures that the work output is fast and easy to manage. The software is developed on the policy of the American National Standards Institute/International Organization for Standardization standard query language. The MySQL database server is used to manage large datasets because of its enhanced features. This software also connects well with client servers or on embedded systems.

4. 6. Implementation Process

At this stage, with all designs being implemented with a programming language to create a web-based EDI-CAPP application and with data input saved in the database and output, communication between the supplier and assembly team about assembly parts and component assembly plans can be realized.

5. Results. System User Interface Screenshots

Fig. 6 shows the login page of the developed EDI-CAPP website. The function of this page is to manage user data in the EDI-CAPP system. Through this page, users can add, delete, and update their data.

Fig. 7 shows parameter lists for each component that were put together by users based on the characteristics of various components. The users for this feature are those on the assembly team and they can add, delete, and update component parameters. On this page, component coding is initiated based on the parameters chosen by users.

Fig. 8 shows the component list for the group technology.

Fig. 9 shows the main feature of this system, that is, the EDI feature that allows stakeholders (i. e., assembly team, supplier, production team) to communicate their needs and documents quickly, accurately, and efficiently. The document that can be communicated here is a report or claim about wrong components and component difficulties during the assembly process. The report or claim is transferred directly by the assembly team to the supplier and the supplier can provide a response to the problem.

Fig. 10 is a page for a component assembly planning description feature. The input for the assembly planning description includes component descriptions (general component information), process structures, and information for each component's operation.

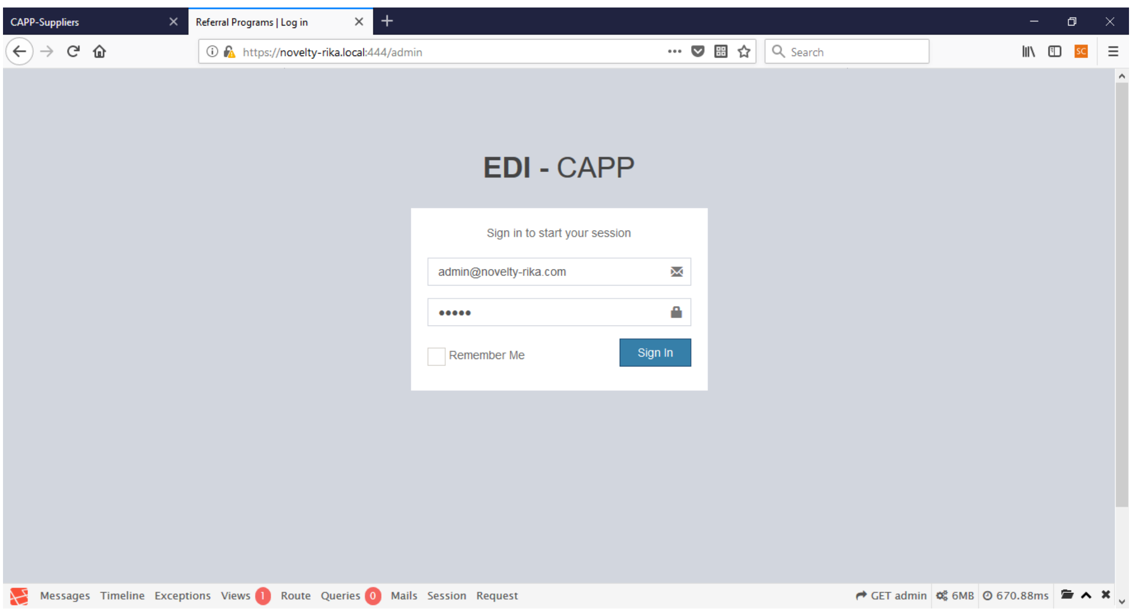

Fig. 6. Login system

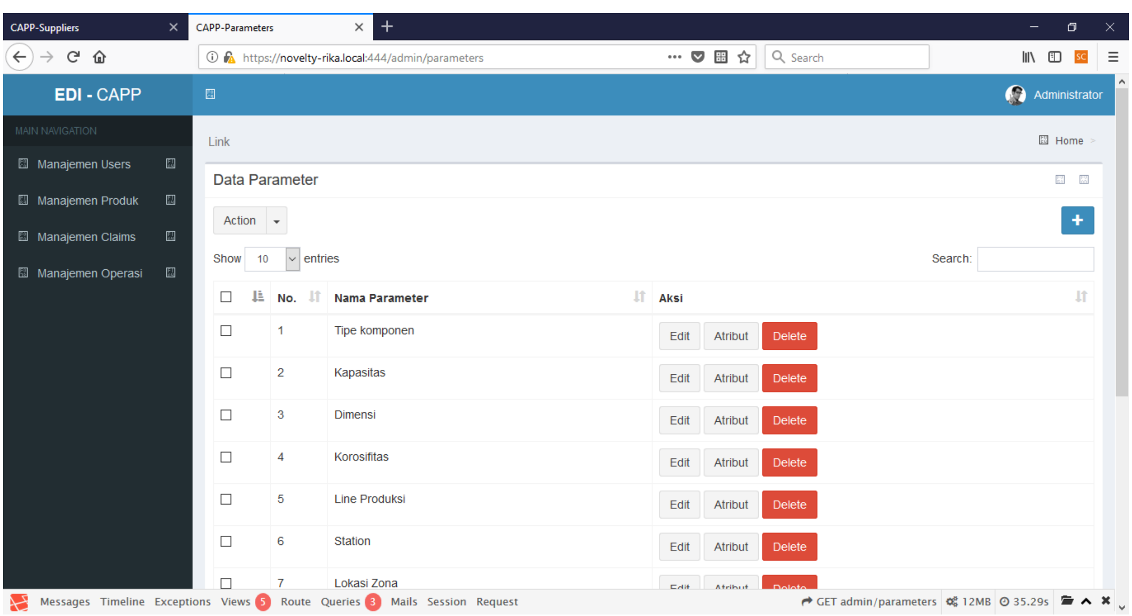

Fig. 7. List of component parameters

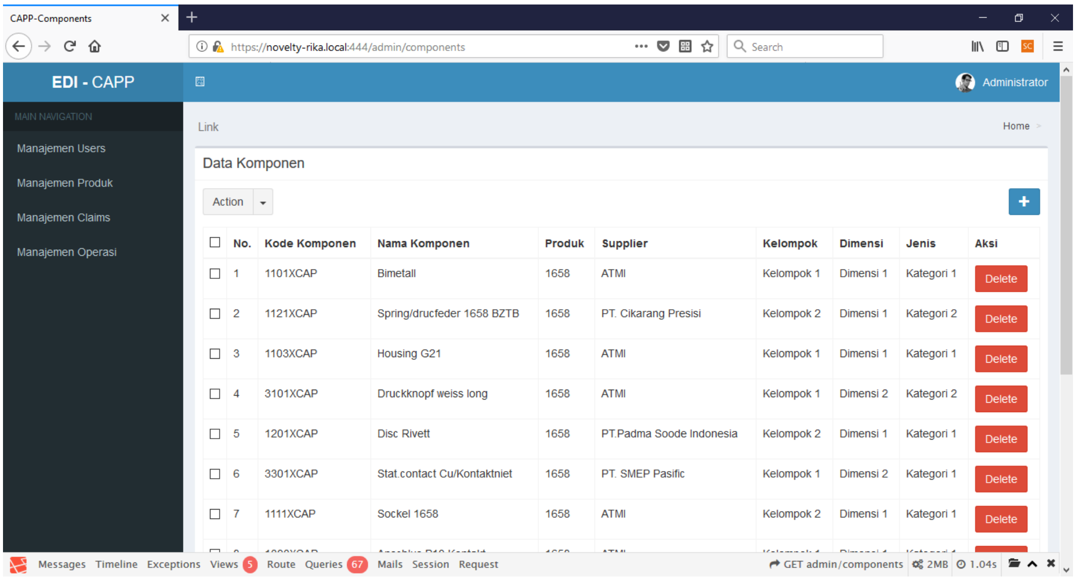

Fig. 8. List of components for each product

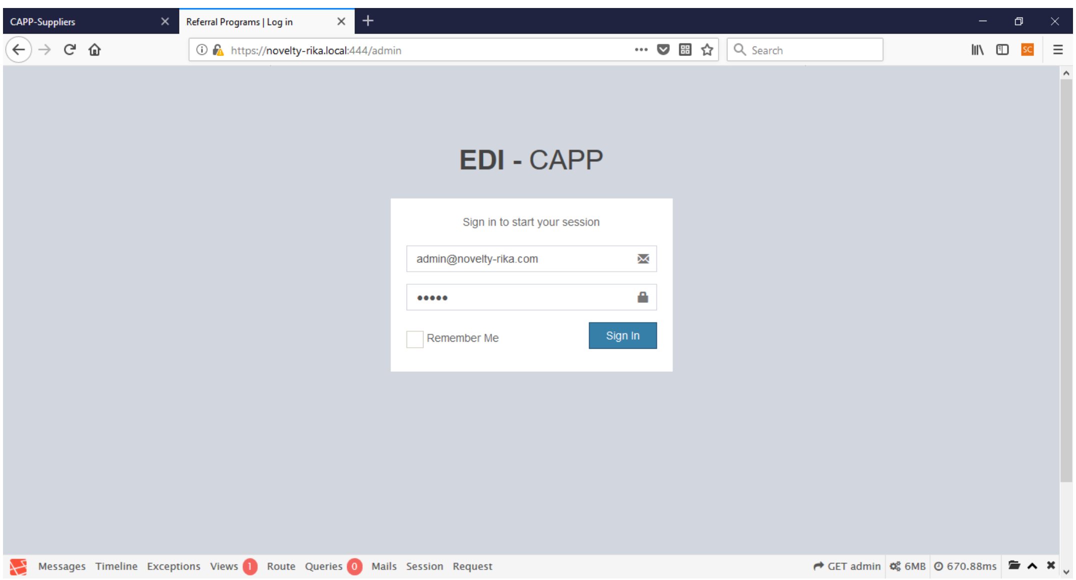

Fig. 9. List of component report/claim

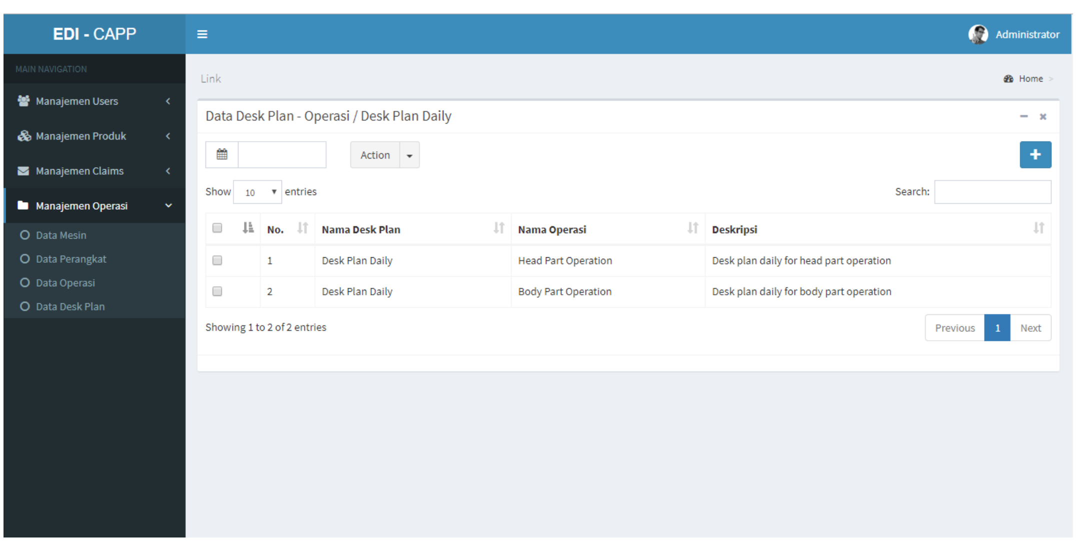

Fig. 10. List of desc plan

6. Discussion of experimental results

In this study, the EDI-CAPP integration application was designed and built. The features of the EDI-CAPP system include an electronic data interchange (EDI) feature that is used by the assembly team to communicate with suppliers about component problems during the assembly process. In this EDI feature, the assembly team can send reports and claims in a certain format to suppliers who will be able to respond to the report according to the problem more quickly and effectively. The next feature is computer-aided process planning (CAPP). In this feature, the assembly team can get help in the form of an assembly plan for certain components based on similarities with the previous components that have been stored in the database so that the assembly process becomes more efficient and effective.

Once the prototype for the integration application of the EDI-CAPP website was finished, the next important stage was the testing stage. During this stage, the EDI-CAPP system's design and application are tested. Testing is the last stage of the implementation circle and includes a verification test.

The verification test is conducted to find out whether EDI implementation has been done correctly or not. The test is completed by way of comparing the initial design, pseudo-code, and finished the program. By comparing all of that, it can be seen whether or not the program is in accordance with the initial design (Table 1).

From the results of the verification test above, it can be seen that the system is in accordance with the analysis and design that had been developed beforehand and fulfills the functionalities needed, which are as follows:

1. Login: the system can provide a login form with the input of the correct user identification and password. Users can access menus according to their role and permission.
2. Entry and update data: the system provides a form for the user to add/update the master data related to EDI-CAPP.
3. Manage component data: the system provides a form for the user to add/update new component data for each product.
4. Component coding: the system provides a form for the user to create code for each component based on their characteristics using the group technology method.
5. Claim component data report to the supplier: the system provides an EDI form for the user so that the assembly team can make a report about a wrong component, difficulties, or broken components to be sent to the supplier.
6. Assembly plan description: the system provides a form for the user so the user can obtain an assembly plan description for a new component based on similar component data that were saved in the database previously.
7. View data: the system provides alternatives for the user so that they can see the data that is saved in the database.

Table 1

The result of the verification test

No.	Description	Procedure	Input	Output
1	Logging into the system	Run the application, input user identification and password, and click “OK”	Correct user identification and correct password	A form will appear according to the user's role that is used when logging in
			Wrong user identification and correct password	A message will show that login failed
			Correct user identification and wrong password	A message will show that login failed
			Wrong user id and wrong password	A message will show that login failed
2	Managing component data	Choose menu “Manajement data produk-komponen”	Choose a component	Show product components and descriptions
3	Component coding	Choose menu “Manajement data produk-parameter -komponen”	Choose a parameter	Show product parameters that show characteristics from each component and show component coding with group technology
4	Plan Description (CAPP)	Choose menu “Manajement Data Operasi – Data Desk Plan”	Choose a data claim	Show assembly plan description for the chosen component
5	Components claim data report to the supplier (EDI)	Choose menu “Manajement Data Klaim”	Choose claim data	Show components that will be mentioned on the broken components claim report; show difficulties encountered when components are assembled
6	Data entry	Choose menu “Entri Data”	Input the data according to form	Data are saved
			Form not filled in completely	There is an error message to inform the user that the data are not filled completely. The data must be filled completely in order to save to the database
			Field name is filled with number or symbol	Data are rejected by the system
			Field phone number is filled with string	Data are rejected by the system
7	View data	Choose Menu “View Data”	Choose data that should be displayed	Data are displayed

Based on the explanation above, it can be concluded that the EDI-CAPP prototype has been successfully implemented in accordance with the initial design.

In this research, we have found some limitations that can be addressed in the future work. The shortcomings of this system are related to the implementation that is too specific and closed, technical constraints, which are related to the transfer of data through computers, requires special hardware/software and also human resources training and software transition takes a long time. In the future work, eliminating some sources of uncertainty in a database system is suggested and also how to make this EDI-CAPP system more dynamic.

7. Conclusions

1. A data flow diagram of EDI-CAPP system has been successfully designed. This data flow diagram is used to graphically represent the flow of data in EDI-CAPP system. In this system, data flow diagram consists of three external entities: assembly, supplier, and production. An assembly team sends report and claim related with the component problem of the product to the supplier through EDI-CAPP system. And the supplier gives response related to the report and claim. EDI-CAPP system also displays the assembly plan to the assembly team for the similar component.

2. A database of EDI-CAPP system has been successfully designed by using entity relationship diagram (ER Diagram). An ER diagram is used for modeling technique that graphically illustrates system's entities and the relationship between those entities. This database consists of 15 entities: type, product, assembly_industry, tools, component, supplier, user, machine, code, claim_desc, claim_category, operation, group, parameter, and desc_plan.

3. The implementation of this website is accomplished by running this EDI-CAPP system in several sites of manufacturing area which is used in production outsourcing.

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