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Integration of Systems of the Exemplary Model Using Modern Tools of Industry 4.0

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Abstract. Industry 4.0 is a common term that is constantly evolving. It involves the participation of different disciplines and areas of knowledge, as well as the integration of multiple technologies, both mature and emerging. Industry 4.0 defines things like the increase in demand for products that are customised. Personalisation goes hand in hand with differentiation in small batches, unique products and high production flexibility. That is why manufacturing companies use advanced technologies to accurately prepare for changes in global production. The authors aim to present an example of an integrated management system designed in line with "Industry 4.0" using the military sector as an instance. The developed integrated system combines: an ERP system, a CAD system, a PDM plug-in, an ERP Plus plug-in, a database system and a mobile application.
Keywords: systems integration, ERP, mobile application, PDM, CAD

1. INTRODUCTION

Systems integration, i.e. the merging of different areas of the enterprise, shows that the boundaries between the different subsystems are becoming increasingly less clear [1, 2]. Integrated systems used for comprehensive business management (*Enterprise Resource Planning* – ERP) is an enterprise IT solution that some experts see as an enabling system for effective risk management (*Enterprise Risk Management* – ERM) or provide an equivalent concept for these systems [3]. ERP consists "of a number of modules such as marketing, sales, purchasing, distribution, product design and development, production and resource management, finance and accounting [4, 5]. In contrast, the next step to ERP systems are ERP II systems, which combine two elements: ERP and systems for the management of relationships with current and potential customers (*Customer Relationship Management* – CRM) [6, 7]. The systems that make up an integrated production system include [8]:

1.1. Systems responsible for cooperation, whose task is to act in the field of material and raw material supply and to link together the various subsystems of industrial and cooperative enterprises that supply materials, parts and components.
1.2. Systems responsible for manufacturing: *Computer Integrated Management* – CIM[9], *Manufacturing Execution System* – MES, *Product Lifecycle Management* – PLM, *Product Data Management* – PDM).

CIM is a system designed for the integrated execution of production orders and is made up of multiple systems. Examples of such systems are CAD (*Computer Aided Design*), i.e. computer-aided design programmes for the creation of design documentation and the development of 3D models, and CAM (*Computer Aided Manufacturing*), i.e. computer-aided manufacturing programmes for the control of machine tools, robots, assembly lines [10]. MES is a system that allows the automatic collection of data on the progress of production processes (data can be collected directly from machines in real time) and the monitoring of these processes, allowing real-time decision-making and reaction to possible errors [11].

PLM, on the other hand, is the system responsible for managing the life cycle of a product from its conception, through design, market analysis, production, quality control, operation, sales, provision of spare parts to its end of life [12]. PDM is an information system that processes data on a product that is produced in engineering systems [13].

1.3. Systems responsible for distribution of finished products: *Customer Relationship Management*, *Supplier Relationship Management*, *Supplier Chain Management*, *Warehouse Management System*, and *Distribution Relationship Planning*.

CRM is a system that allows the supervision and maintenance of customer relationships. It covers sales, marketing campaigns, call centres, transactions, customer service and even conducting market analysis and supply management [14]. SRM is a system that allows the management of supplier relationships, making it possible to build supplier databases. This leads to the ability to integrate operations, graphically clear product presentation and the ability for suppliers to work [15]. SCM is a system that aims to support the management of the flow of goods and materials within a company, which helps to maintain continuity of supply and secure optimum stock levels [16]. WMS is a system that supports warehouse management. It allows the reduction of delays in the execution of production orders and the acceleration of sales processes and, consequently, the service of the final customer [17]. DRP is a system for distribution planning. Based on sales forecasts [18] it calculates the demand for the product/service. In addition, it also allows for the planning of product transport and monitors ongoing changes in the sales market. All this data is passed on to other systems, e.g.: ERP.

The use of these systems (1.1, 1.2, 1.3) makes it possible, among other things, to reduce inventory, speed up the flow of goods, exchange data accurately with suppliers and better manage team members. As a result, this provides the opportunity to meet the needs of discerning customers. The tools that are used for production management and logistics management must combine into a single decision-making process that is multidimensional and multi-criteria, and that takes into account the various aspects of the organisation's structure and the specifics of its operation. The correct process is ensured by a large amount of data (information on employees, products, orders, etc.). The personalisation of products present on the market lead to the need for the integrated systems described above to enable the conscious management of products from conception to disposal. The information gathered indicates that personalisation will play an even greater role in the future in the circulation of goods. An example of this is the already wide range of car versions (multiple models and equipment versions – leading to the need for tracking of individual units in the production process). The same can apply to clothing or everyday appliances. The background to personalisation is provided by concepts, such as: *design thinking* [19], *digital twin* [20, 21], process automation or *additive manufacturing*) [22].

It is with these tools that engineers are able to produce an innovative prototype. The first step in designing such a prototype is to use a method for creating new products/services based on user needs – so-called design thinking, a concept originally defined at Standford University in California, where one of its main creators is Professor David M Kelley, co-founder of IDEO (a design company), which is famous for creating new ideas for companies such as Apple – nowadays, the world's best-known brands start their design processes using this method. Such is the case with modelling according to the *digital twin* [20] concept, a virtual representation of the final product or system throughout its life cycle, which allows for miniaturisation and, above all, the reduction in the costs associated with prototyping and production of the finished product. These and many other concepts bear witness to personalisation in the context of global production assumptions, which constitute the elements of the Industry 4.0 concept [23]. There are now many works presenting ideas for according to the concept of Industry 4.0. One of them is the work [24], which describes the possibilities of implementing the Industry 4.0 concept from the transport sector in terms of communication alternatives (rewritable cards, GPS, RFID) to speed up the processes of data processing, description of the entire journey and monitoring. Further, example analyses companies [25] representing the Italian manufacturing industry and the benefits they have achieved by applying selected Industry 4.0 tools. The speed with which the benefits of transformation are realised is closely related to the level of sophistication of the organisation before the introduction of the changes. The demands of dynamic growth in industry are creating pressure for process modernisation within companies – across entire industries globally.

In this paper, the authors aim to present the production process of a selected product using an integrated management system, with a view to designing it in line with the concept of Industry 4.0. The scope of the work includes the demonstration of system integration in line with the concept of Industry 4.0. A computer-aided manufacturing system was implemented for this purpose. Today, companies are starting an *industrial revolution*, which involves the integration of both production and dedicated business management systems. As a result, a business concept has been developed that uses advanced tools to help streamline the company's processes.

2. MATERIALS AND METHODS

This article is based on presenting the possibilities of integrating systems according to the concept of Industry 4.0. To this end, a system design has been proposed that can be used as an example of a functional and IT model for an industrial company. A diagram of the project data flow is shown in Figure 1.

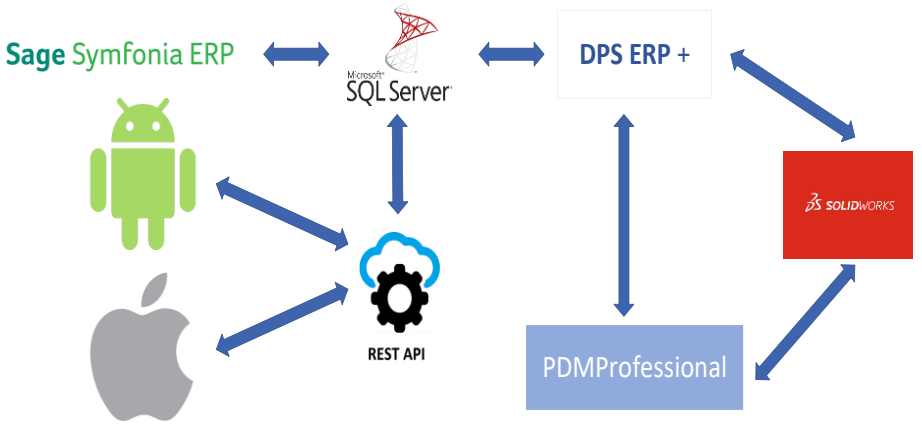

Fig. 1. Data flow in the system design.

The project is based on a SQL Server database system, supported and developed by Microsoft [26]. The database stores all the information about the processes in the company.

The Sage Symfonia ERP system (https://symfonia.pl/) is the second component of the project. Two modules are relevant from the perspective of the exemplary company:

- Administration – allowing the start of a company profile and add any other necessary information, such as contact details and a company profile description;
- Trade – enables the complete processing of orders and the management of the goods produced.

Sage Symfonia ERP uses a Microsoft SQL database by default, which is configured when installing Sage Symfonia ERP.

Other related software includes the ERP Plus plugin, PDMProfessional and SolidWorks. Design and manufacture of prototypes and finished products using SolidWorks, which is CAD software. Among other things, the role of PDMProfessional is to speed up the engineering work by monitoring the changes made to the models during the various design phases and by storing the models themselves. The ERP Plus plug-in allows the addition of selected products to a Microsoft SQL database on the basis of the models stored in PDMProfessional. All this is done directly from the SolidWorks window. The records that are added to the database in this way will be visible in the Trade module of the ERP system.

The web service, the mobile application for Android and iOS, are the last group of components of the system. The Web Service implements a REST API [27], which defines the rules governing how applications or equipment communicate with each other.

This service is to communicate with the SQL Server database and receive requests from clients (in this case, mobile applications) and send responses to the requests.

This project deliberately omits describing issues, such as client authentication or resource backup, as these are outside the focus of this article.

For the sake of illustration, the simplified data flow diagram (Fig. 2) is simplified without affecting the presentation of the integration of the discussed systems and the main solutions from the point of view of the computer-aided production process.

A suitable driver is required for the mobile application to communicate directly with the database. The communication between the database and the mobile application took place within the local network, while the test environment was implemented on a local machine running Windows 10.

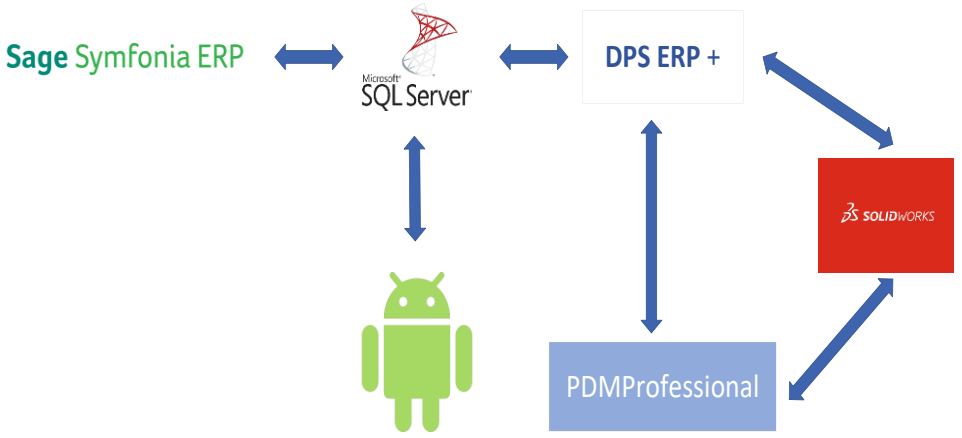

Fig. 2. Simplified diagram of data flow in the system design

3. RESULTS

Using the mobile application developed for Android, a potential customer can place an order containing two types of products: universal product lists (combat helmets in various sizes) and personalised products (helmet inserts). The orders placed by the customer are automatically entered into the ERP system of the company (Fig. 3).

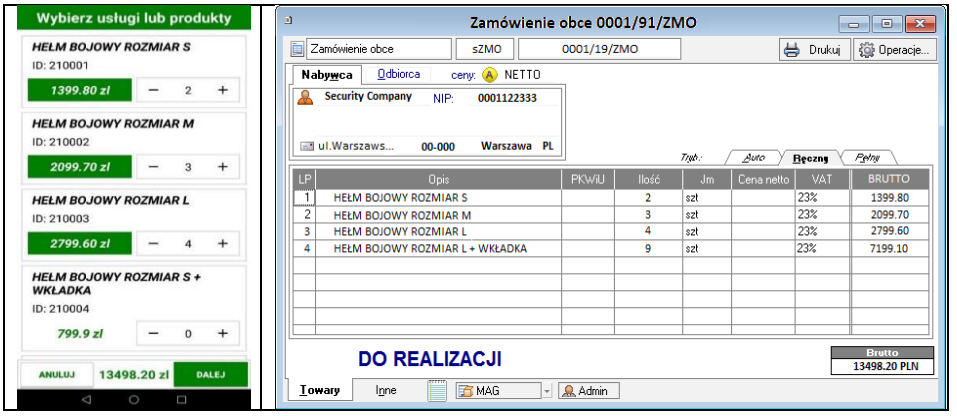

Fig. 3. An example of an order ready to be placed in the mobile application (left) and a view of an order ready to be processed in the ERP system (right)

The order is passed for processing once it has been entered into the ERP system. If the order includes personalised products, it is necessary to arrange with the customer an appointment for a 3D scan, which will be used to create a 3D model of the insert. The 3D scan, produced using a 3D scanning device, is sent to the engineers, who design a 3D model of the insert using CAD software. Figure 4 shows an example of a 3D scan and the designed insert.

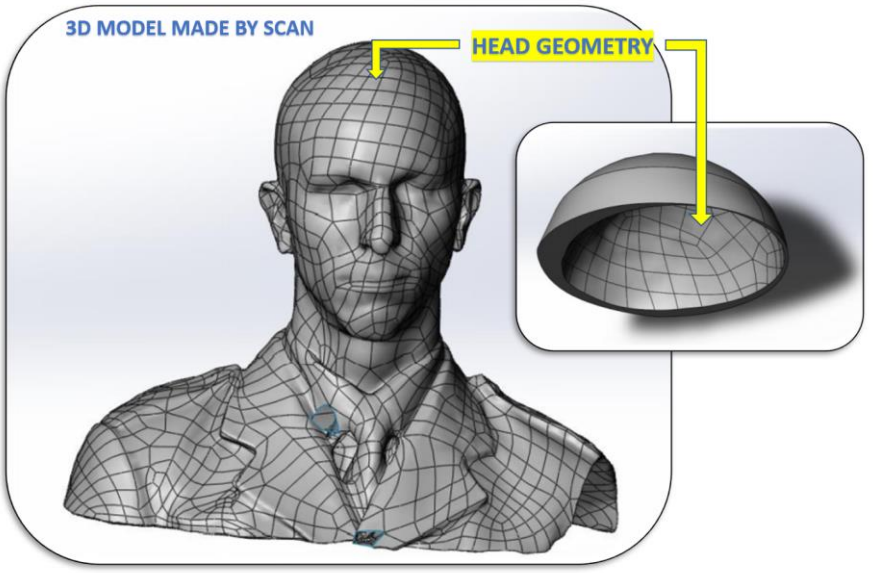

Fig. 4. Client's 3D scan and a 3D model of the insert

The 3D model of the insert prepared in SolidWorks was added as a product to the relevant ERP module using the ERP Plus plug-in. The plug-in panel for adding a commodity index in SolidWorks is shown in Figure 5.

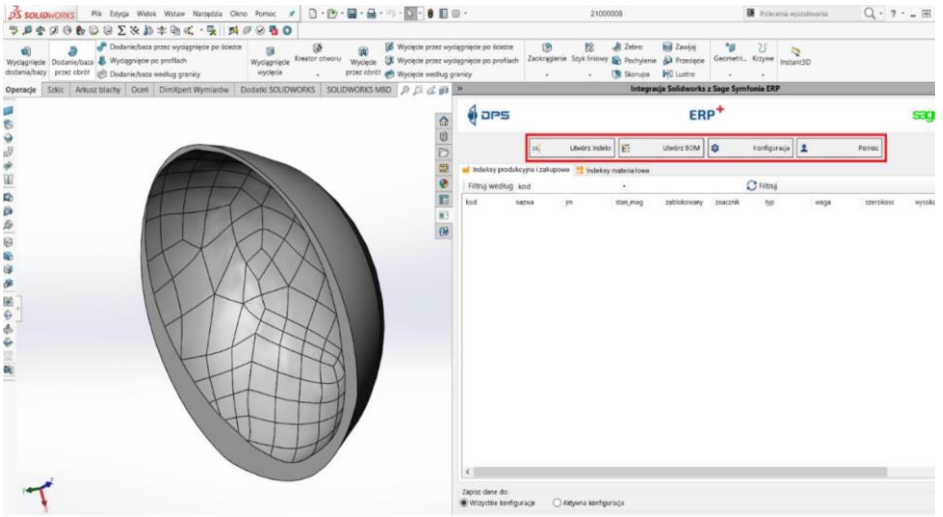

Fig. 5. ERP Plus integrated 3D model of the insert and side panel.

The finished 3D model, which is the target product, is submitted for 3D printing at this stage of the work. Once the entire order has been completed, the status of the task in the ERP system is changed to "completed," informing the customer in the mobile application that their order has been completed (Fig. 6).

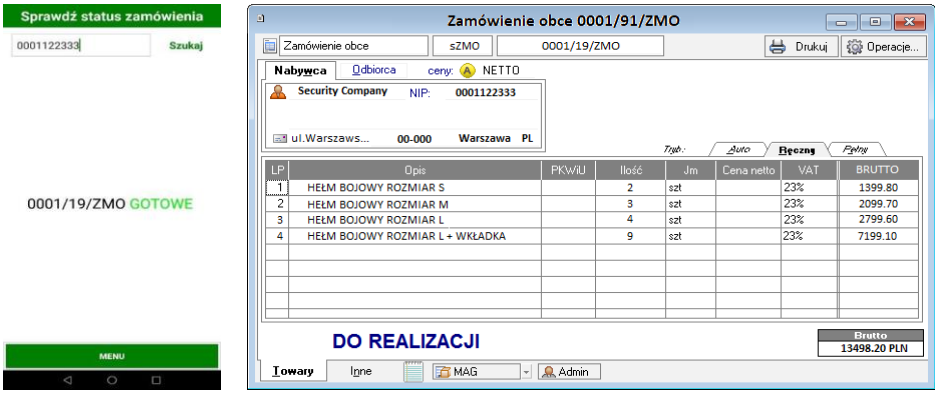

Fig. 6. Information about the completed order in the mobile application (left) and example of a completed order finished in the ERP system (right)

4. CONCLUSIONS

Increasing the effectiveness of the production processes through the use of ERP systems in the context of "Industry 4.0" assumptions is linked to the innovations that large manufacturing companies are making in order to achieve higher profits, thereby reducing labour input.

Specifically, companies that have partially or fully digitised their business, including digitising the documentation workflow. The ERP system is now the product that is at the heart of the move from paper to electronic documentation. This study is based on the assumption that there is a need to be able to transfer information from the engineer who designs the goods/product in the CAD system to the ERP system where, among other things, data such as order planning is collected. After reviewing the available solutions, the authors selected appropriate software: an ERP system – whose database can store all the data; a CAD system – which enables the creation of a product and can be implemented in the ERP system as a product that is sold by the company; an ERP+ system – allowing to combine these two systems; and a PDM system – which allows the storage of file information. The company's electronic documentation workflow was presented by analysing functional assumptions and identifying solutions currently available on the market.

The proposed work is to extend the system by adding new functionality to the current client application. All purchasing activities can be carried out quickly and securely with the addition of options such as stock visibility, online payment via the app or the introduction of an order status notification system.

This solution is successfully used in today's consumer market and is growing in popularity. The additional activities associated with extending the current model would be required for this. Introducing extensions in terms of changes to existing code, changes to the database communication protocol or adding a new component to a model should be done through a well thought out testing and validation process. The presentation of the data flows between the systems is intended to demonstrate the possibilities of combining several tools. The project also shows that the integration of systems has a significant impact on the speed of business processes, reduces costs and improves the communication between the employees of the company and between the company and the customer.

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Integracja systemów przykładowego modelu z wykorzystaniem nowoczesnych narzędzi Przemysłu 4.0

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Streszczenie. Przemysł 4.0 to pojęcie powszechnie i podlega ono ciągłej ewolucji. Obejmuje udział różnych dyscyplin i obszarów wiedzy, a także integrację wielu technologii, zarówno dojrzałych, jak i dopiero powstających. Przemysł 4.0 definiuje między innymi wzrost zapotrzebowania na produkty, które są dostosowane do indywidualnych potrzeb klienta. Personalizacja idzie w parze z różnicowaniem w małych seriach, unikalnych produktach oraz dużą elastycznością produkcji. Dlatego firmy produkcyjne wykorzystują zaawansowane technologie, aby precyzyjnie przygotować się do zmian w skali globalnej produkcji. Celem autorów jest przedstawienie przykładu zintegrowanego systemu zarządzania, zaprojektowanego zgodnie z założeniami "Przemysłu 4.0" na przykładzie sektora wojskowego. Opracowany zintegrowany system łączy ze sobą: system ERP, system CAD, wtyczkę PDM, wtyczkę ERP Plus, system bazodanowy oraz aplikację mobilną.
Słowa kluczowe: integracja systemów, ERP, aplikacja mobilna, PDM, CAD