ISSN 1330-3651
UDC/UDK 658.5 : 007.3

SUPPORTING PRODUCT DEVELOPMENT PROCESS THROUGH THE ERP SYSTEM

Tomislav Galeta, Milan Kljajin, Mirko Karakašić

Preliminary notes

The primary result of system integration for users in an enterprise should be an easier utilization of system. To support product development process through the Enterprise Resource Planning (ERP) system in small and midsize manufacturing companies we considered integration of selected Product Data Management (PDM) functions. We developed suitable information models and made prototype implementation of models into the considered ERP system: ERPINS-M. Prototype implementation was then estimated according to the previously published metrics and compared with the ERP system before implementation. The proposed model could provide sufficient and well integrated support for product development process.

Keywords: *enterprise resource planning, product data management, product development, computer-aided design*

Podrška procesu razvoja proizvoda kroz ERP sustav

Prethodno priopćenje

Osnovni rezultat integracije sustava za korisnika u poduzeću bi trebao biti lakša uporaba sustava. U cilju podrške procesu razvoja proizvoda u malim i srednjim proizvodnim tvrtkama, razmotrili smo integraciju probranih funkcija za upravljanje proizvodnim podacima. Razvili smo prikladni informacijski model i izvršili prototipnu implementaciju modela u odabrani ERP sustav: ERPINS-M. Prototipna implementacija je potom procijenjena sukladno prethodno objavljenim smjernicama i uspoređena s ERP sustavom prije implementacije. Predloženi model može pružiti dostatnu i dobro integriranu podršku procesu razvoja proizvoda.

Ključne riječi: *planiranje resursa poduzeća, upravljanje proizvodnim podacima, razvoj proizvoda, računalom podržan dizajn*

1 Introduction
Uvod

A modern manufacturing process demands integrated digital data exchange and also digital presentation of the product throughout the company. In most manufacturing companies, two different software systems are used to fulfil demands of "digital manufacturing": the Enterprise Resource Planning (ERP) system enables digital data exchange while Product Data/Lifecycle Management (PDM/PLM) system gives a support to a product development process (PDP). A word "integral" in the first sentence is pointing out the need for the integration of software systems involved in digital data exchange.

Comparing the market of the ERP and PDM systems, it is obvious that the market of the ERP systems is very strong with great annual revenues. According to Miller [1], major ERP vendors are also on the top of the chart for 100 major software vendors. Significant annual revenues and strong competition force ERP vendors to extend the functionality of their products. There is an obvious financial power and a need to support the product development process, since the ERP systems are firmly oriented at manufacturing. Such a need is recognized by several authors [2, 3] and expressed as an incoming issue of the Product Data/Lifecycle Management (PDM/PLM) and the ERP systems integration.

From the other point of view [4], in small and midsize manufacturing companies there is often a lack of funds for investment in major and expensive ERP systems. Because of that, in this paper we have considered the support for the product development process through the specific ERP system specialized for small and midsize manufacturing companies named ERPINS-M. ERPINS stands as an acronym for the Enterprise Resource Planning ININ Solutions, while M annotates a version of the ERP system particularly tailored for the metal industry. We developed appropriate information models and implemented models into ERPINS-M system. After the prototype implementation, in the discussion we estimated the achieved PDP support according to previously proposed metrics [5]. Most of the work presented in the paper was conducted during the preparation of Tomislav Galeta's doctorate thesis [6] and the initial rough model was previously briefly presented at Design Conference [7].

The series of the ERPINS systems were developed on the Oracle architecture. The systems are the result of a twenty year long cooperation between the ININ Company [8] and the Mechanical Engineering Faculty [9], both located in Slavonski Brod, Croatia. The systems are aimed at small and medium enterprises, particularly when enterprises have requirements for which the ERP system has to be specially attuned [4].

The ERPINS-M system has a modular architecture built on common Oracle database (Figure 1). It is composed of subsystems and each subsystem is further composed of modules. Two mostly affected subsystems are DEPTO and BAZAP. DEPTO is a subsystem for the definition of products and technologies. It is the mostly affected subsystem with the implementation of the suited product model. It contains modules: Production Elements; Product Breakdown Structure; Revisions and Versions; Drawing List; Cutting Schemes; Technological Operations; Tooling. Subsystem BAZAP serves as a storage for common data and codes shared in other subsystems. Included modules are: General Enterprise Data; Organization Structure; Partners Data; Capacity Data; Employees; Currencies and Rates; Working Calendar; Enterprise Dictionary; Units; Classification; Report Generator.

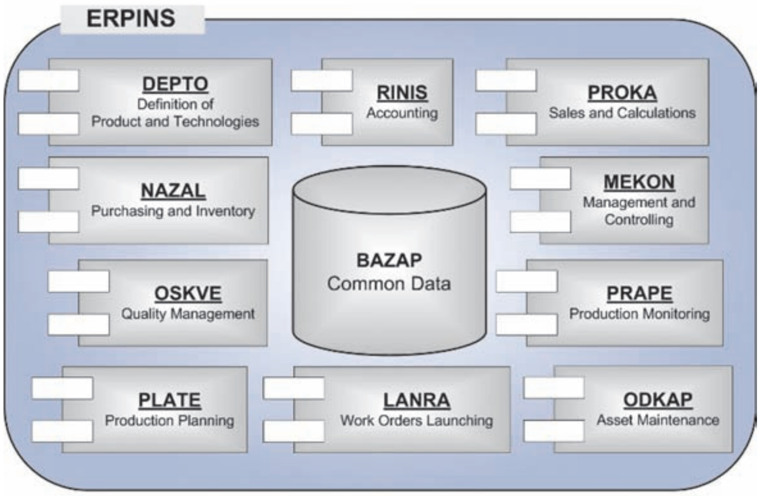

Figure 1. ERPINS-M System Architecture
Slika 1. Arhitektura ERPINS-M sustava

2 Information models
Informacijski modeli

In order to support the product development process, appropriate information models should be accomplished and implemented into the ERP system. Therefore, we had to consider and rationally select from a set of the PDM functions. Some of the conditions for the selection also include: an analysis of the aimed ERP system user groups involved in the product development process; the importance of the particular function for the ERP user; the importance and compatibility of the particular function within the ERP system; and finally, the possibility to conform the considered function or model with present standards like the ISO STEP PDM schema [10].

Just like the majority of today's business applications, so is the considered ERPINS-M developed on the object oriented paradigm. Therefore, models presented under this heading are developed and discussed in object oriented fashion. Object oriented models could be presented clearly through Unified Modeling Language (UML) class diagrams [11] so it is used for the majority of the illustrations in the paper.

2.1 Product and product structure model
Model proizvoda i proizvodne strukture

In the ERPINS-M system, the abstract class "Production Element" is placed in the very basis of the system (Figure 2). It is defined as a basic element of the product definition that could appear in production and according to it enterprise resources are allocated. From the production element derived classes inherit basic attributes and methods. To keep it simple, only attributes and methods relevant for product structure are shown in the figure. The reader could find more complete description in the cited literature [6, 7].

The abstract class Compound Production Element is included in the product model with a purpose to simplify the class structure and implementation in the ERPINS-M system. It determines hereditary class members (attributes and methods) that enable derived classes to have subordinated elements. Product and Assembly are classes whose objects could have subordinated elements, i.e. objects could have a structure. The member list SubordinatedElements contains identifiers of subordinated elements in the first level. If a particular subordinated

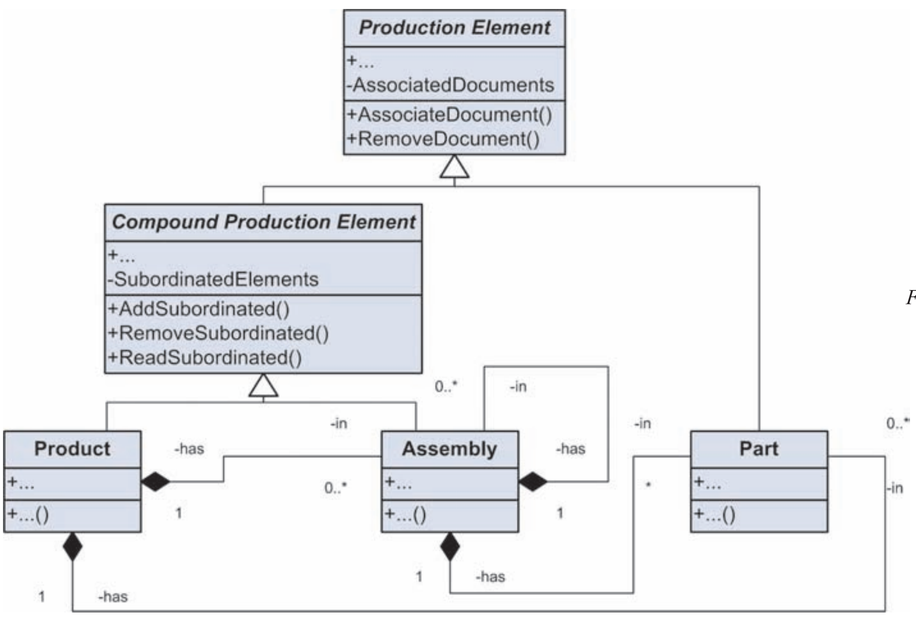

Figure 2. Product model representation
Slika 2. Prikaz modela proizvoda

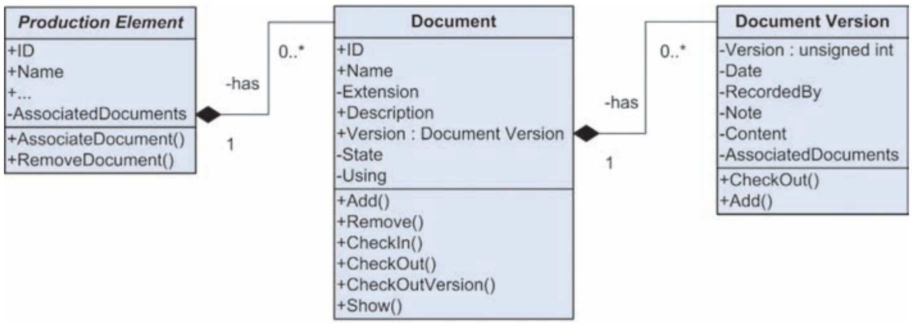

Figure 3. Vault model representation
Slika 3. Prikaz modela trezora

element is also a compound, it has its own list of subordinated elements. To obtain a full structure of compound elements, it is necessary to iteratively read the lists of all subordinated elements.

Objects from class Part could not have subordinated elements, i.e. they could not have structures. Therefore, the class Part is not derived from class Compound Production Element but directly from the top class *Production Element* [7].

2.2 Vault model
Model trezora

In a modern process of product development, the product structure and product shape are mostly developed in parametric and feature-based computer-aided design (CAD) systems, also known as mechanical or mechanical CAD systems (MCAD). Those documents often have internal file associations, for example a part drawing file usually depends on a corresponding part model file; assembly file depends on several part model files referenced in the assembly, etc.

To support the product development process, the ERP system must provide an electronic vault with an appropriate document management capability. The vault model should enable documents association with production elements but it should also enable routines for tracking internal file dependencies within the same production element. Such internal file dependencies are closely dependent on MCAD system used in a particular enterprise. Tracking file dependencies between production elements should not be accomplished through internal file records, but through product or assembly structure as it is stored in the ERP system.

For a successful vault implementation all documents related to the product have to be stored and controlled through the vault. Such a vault model that meets previous demands and is convenient for the ERPINS-M system is presented in Figure 3. The model also supports version tracking for every document in the system. Version tracking is carried out by using attribute Version together with a corresponding class *Document Version*.

2.3 External access model
Model vanjskog pristupa

As an external access to the ERP system we will consider here an access to the system that comes from the computer outside the enterprise's local area network (LAN). Such access is necessary if outsourcing is intensively used in the product development process through subcontractors.

Although it has some advantages, the external access through common ERP applications is not suitable for small and midsize manufacturing companies considered in this paper. Common ERP applications are mostly based on two-tier architecture i.e. on client-server network architecture. Such applications are usually optimized for high network bandwidth usually available in company's LAN. On the other side, for considered companies and their subcontractors it is often hard to invest significant funds needed for external network connections with bandwidth expected from common ERP applications.

Beside bandwidth, there are also issues of compatibility and a licensing that need to be resolved if subcontractors will use common ERP applications. In order to improve performances, common ERP applications are programmed for targeted operating system. Even if bandwidth and compatibility issues are resolved, it still remains the issue of subcontractor's readiness to license applications from the ERP vendor and to install and license the targeted operating system.

Open issues can be successfully overcome by developing a web application for external access to the ERP system. Since the web application is running within a Web browser (like Microsoft Internet Explorer, Mozilla Firefox or Opera) and it is accessed over the network (the Internet or an intranet), therefore it could simply resolve issues of compatibility and licensing. It can also resolve demands on bandwidth if it is carefully written regarding bandwidth. Therefore, we are proposing the web application for external access to the ERP system for subcontractors involved to PDP.

3 Prototype implementation
Prototipna implementacija

In order to test previously presented information models, we realized prototype implementation in the considered ERPINS-M system. Implementation was performed in three levels: an upgrade of the relevant ERPINS-M subsystem DEPTO; development of an interface for the chosen MCAD system; development of a web application for the external access to the ERP system.

To implement information model we had to upgrade the scheme of the ERPINS-M database. Two completely new tables were added into the database and related to the existing tables: for storing structured documents and for storing non-structured product documents. Several existing tables were related and also upgraded with additional

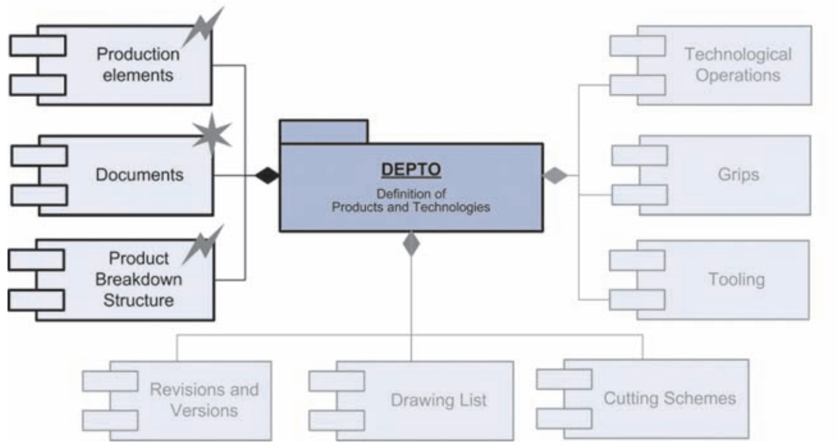

Figure 4. Upgraded (↯) and added (✶) DEPTO modules
Slika 4. Nadograđeni (↯) i dodani (✶) DEPTO moduli

attributes: basic production elements table; user access level table; user login data table and basic user data table. All mentioned tables are equally used at all three levels of the prototype implementation.

3.1 ERPINS-M implementation
ERPINS-M implementacija

The first prototype implementation we performed was into the ERPINS-M subsystem for the definition of products and technologies, named DEPTO. DEPTO is the subsystem which is greately involved in a support of the product development process. Inside the structure of the DEPTO modules, prototype implementation is reflected in the upgrade of the modules Production Elements and Product Breakdown Structure (Figure 4). Also, a new module Documents was developed for handling structured and non-structured product documents. Because of compatibility, the programming code was written in the same integrated development environment as the other ERPINS-M subsystems [12] and with intensive use of the Application Programming Interface (API) for the chosen MCAD application - Autodesk Inventor Professional.

The implementation of proposed information model demanded also an interface upgrade of the DEPTO modules (Figure 5).

Text box for search by name and list of production elements serves for easier choice of active production element. Elements with a structure are shown shaded with different colour in the list. The module also enables an assignment of starting raw material for the production of a particular element. The starting material is recorded and represented as a subordinated element to the assigned production element. Therefore, it is possible that non-compound production element, like part, is presented with a shaded row, if it has starting material assigned.

The structure presentation frame shows hierarchical structure presentation of the active production element in a table. The numbers in circles in front of a table row designate the subordination level of a particular production element. For example, element 120 - Pin has subordination level 3 which means it has two superior production elements in the hierarchy. Just before the unique identifier (ID) of the particular production element, an icon could be present to mark that production element has associated MCAD documents. If the icon is missing before ID, then the element does not have associated MCAD documents but it still could have associated documents of other types, like manuals or so.

Implemented element operations on the selected element are available through the context menu. In the first group in the menu there are operations for structure handling of the active element: addition, substitution and removal of the particular subordinated element or complete structure removal. Operations for the definition of technology are in the second group. The third group contains operations for changing the basic production element data like ID, name, sort and similar as for the addition of a new production element in the structure of the active compound element.

Operation "Add Document" associates structured MCAD documents and documents of other type to the active production element. It is also available in the context menu inside the associated documents frame. The associated documents frame contains all documents associated with the active production element. Therefore, MCAD documents are presented hierarchically with the model of part or assembly on the top, regarding the sort of the production element. Implementation allows association of only one part or assembly model document with the production element, what is in conformity with a common development procedure for parts and assemblies. Subordinated documents, like representation or drawing file types, are listed bellow the row of the main associated document. For easier distinction, appropriate icons conformed to those of considered MCAD system are depicted just before the document name. If there are other types of documents associated with the active production element than structured MCAD documents, it will be listed in the additional row bellow MCAD documents.

The associated documents frame shows only the latest document version, but module keeps track of all previous versions. Access to a particular version of the document is available through the appropriate command on the document operations context menu. Also, all implemented document operations are available through the same context menu.

If routine for document association is started and MCAD document selected for association internally refers to other MCAD documents, implemented algorithm reads referenced documents and makes them available for association. The document selected for association together with all selected referenced documents is then written in the

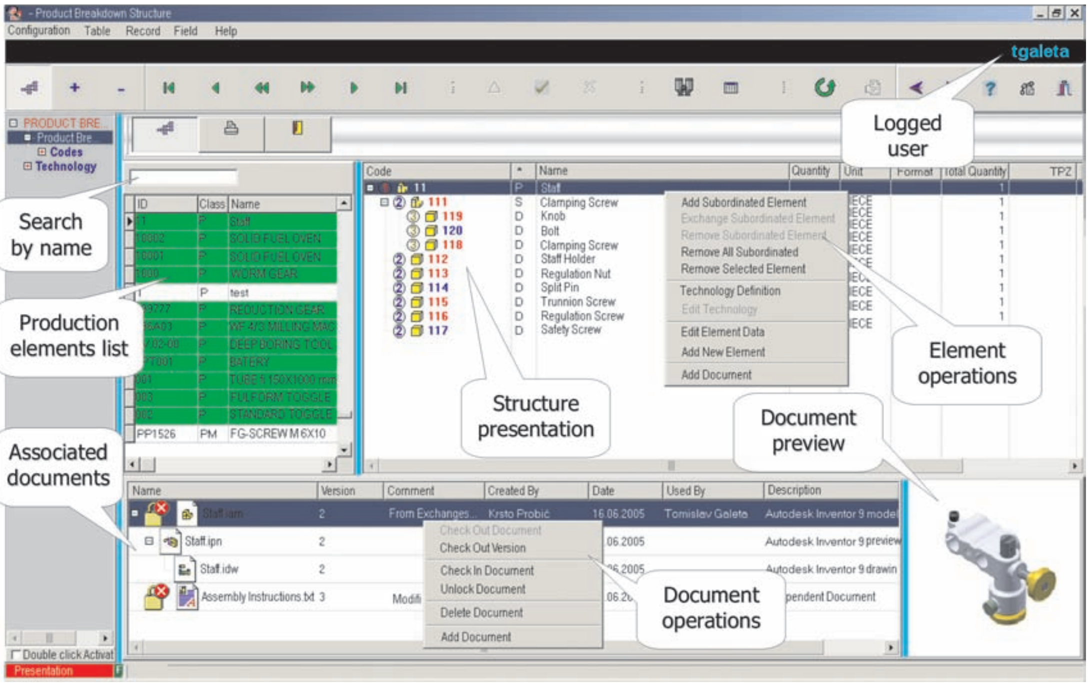

Figure 5. Upgraded DEPTO interface
Slika 5. Nadograđeno DEPTO sučelje

ERPINS-M database while keeping internal document relations. The implemented routine for the document association takes care of the sort of the production element, so it is not possible to associate part MCAD document with a compound production element or to associate assembly document with a simple production element.

The routine for checking-out structured documents is implemented in such a manner to check-out and write in the user's folder the selected document together with all necessary subordinated documents. After the check-out routine is completed, the document is locked for all other ERPINS-M users. In actual implementation, only the user who checked-out the document or the system administrator can unlock the document.

During the check-in operation, new content is written as the new record for the same document but with a version number incremented by one. Only the user of the locked document can cancel changes and unlock the document for other users. After the new document version is checked-in, the document is again available to all users.

For safety purposes, deletion of a document which has more than one version, deletes only the last version. Therefore, to remove completely the document from the database, it is necessary manually to delete version by version backwards. The same rule is applied for removal of documents referenced in the structure: it is not allowed to remove particular part or assembly a document as long as there are documents associated with the production element which refer to a particular document. Prior to removal of the referred document, it is necessary to remove all documents that refer to it.

A frame for a document preview is implemented to enable easier navigation through associated MCAD documents. A preview can also be opened in a separate window to provide a bigger picture for the user.

3.2 MCAD Interface
MCAD sučelje

Since the work on the development of product model and its components is mostly done in MCAD applications, it is necessary to enable interface to the ERPINS-M system as close as it is possible to MCAD users, namely in MCAD application environment where designers do most of the work. For this reason, in the prototype implementation we realized interface and routines inside the considered MCAD application for handling structured documents and for association of documents with production elements defined in the ERPINS-M. The considered MCAD system was Autodesk Inventor Professional version 9. We have chosen Inventor because it has a significant market-share in our region and because it has an open API [13].

The implementation of the MCAD interface is realized as a distinct application upgrade through functionality of external modules that Inventor supports by its open architecture. Most of other MCAD systems also have open architecture and API, what makes easier the future translation of realized modules. However, with all available means, translation of external modules is not an easy task.

The module code was written in a programming language Microsoft C#, object oriented language developed for the project .NET Framework [14]. In the module programming we used object oriented approach so in the module code we created and used several classes with its members and methods. The main module class named ERPINS is realized as an interface to other classes but also as an interface to the user of MCAD system through a drop-down menu. All other classes that do concrete tasks between Inventor and ERPINS-M system are called through the appropriate methods of the main class ERPINS.

Inside the Inventor, functions of the implemented external module are available through the drop-down menu ERPINS-M (Figure 6). All module functions are available

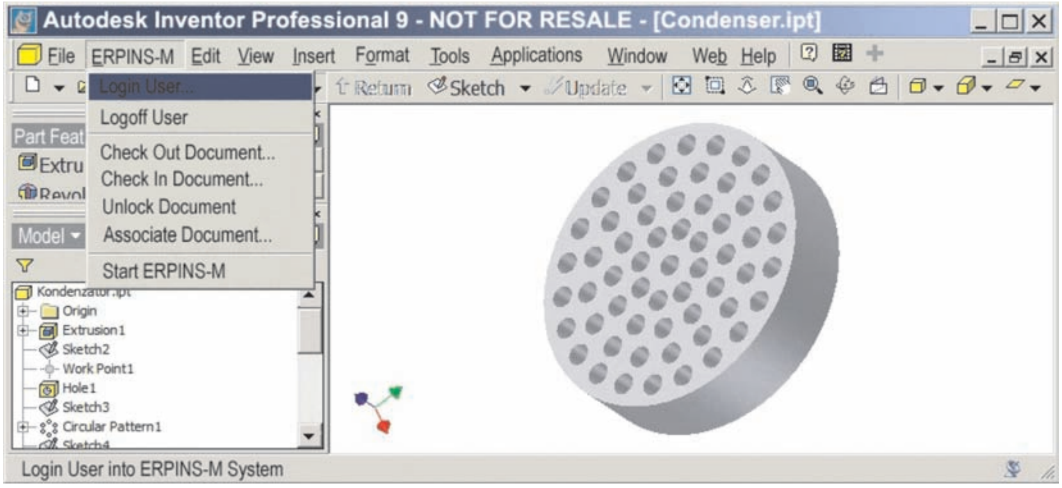

Figure 6. Implementation of the MCAD interface
Slika 6. Implementacija MCAD sučelja

only after the user login into ERPINS-M system with valid user name and password. Menu items or commands are also sensitive on state of the main application so a particular command is available only if particular conditions are satisfied.

A command Check Out Document enables selection and opening of the selected document from the ERPINS-M. It is available immediately after a successful user login. After finding all related subordinated or superior documents, the routine removes the documents locked by other users and shows available documents in the appropriate list for a document check-out procedure. After a check-out activation, the selected documents are written to the selected user folder and locked in the ERPINS-M system for other users. Custom attributes are added to the document written in the user folder to make easier further document handling regarding ERPINS-M system. Routine will then try to open the selected document in Inventor. Document opening does not necessary have to be successful if some of the related files were locked by other users.

The basic command for association of an Inventor document with an ERPINS-M production element is executing for active Inventor document but also for related documents whether related documents are opened or closed. If the active document is a compound (model, representation or assembly drawing), routine executes recursive synchronization for the production element structure with the structure of the subordinated part or assembly documents.

A document check-in is available only if at least one document is opened in Inventor and if active Inventor document has appropriate attribute values which describe the document as previously checked-out from the ERPINS-M system. Not only the active document, all related documents are also analysed and checked-in if necessary. Likewise, if the active document is a compound, eventual structural changes are examined and synchronized with the associated production element in the ERPINS-M.

It is possible to unlock the active document only if it has appropriate attribute values which describe the document as previously checked-out from and if it is still locked in the ERPINS-M system. If the document relates to subordinated or superior documents, the user can select which documents to unlock in a dialog. After unlocking, all document changes from the point when the document is carried out from the vault are thrown away and it is again available for other users.

3.3 Web Application
Web aplikacija

The web application for external access to the ERP system for subcontractors involved into PDP was also developed on Microsoft (MS) .NET Framework and written in MS C# programming language as MCAD interface. Although the web application is written in the same language, it was not possible to simply the transfer code for appropriate routines because of significant differences between two application environments.

The web application was installed on the HTTP server supported by MS Internet Information Services for Windows operating systems. The application uses ERPINS-M database which was installed on standalone Oracle server for testing purposes. The access to application is through the Internet browser by inputting the full server address. The speed of the first application initiation is based on actual user's connection speed and on actual load of server connection. Once the application is loaded to the user's computer memory it performs faster, although for queries to the ERPINS-M database it still depends on connection speed.

At the beginning, the external user is asked for valid user name and password to access the application. The external access through the Internet browser is very unsafe and it could be performed from any computer in the world. To ensure the security after a successful login, application creates the authorized card for the user which is valid only in a predefined time frame. The card is encrypted and written into cookie file. After the allowed time has expired or the user has logged off, cookie is removed from the user's computer.

After the successful login, in the starting module of prototype web application, it is possible to search and preview production elements regarding basic types - product, assembly or part (Figure 7). In the search text box it is possible to input the element name to search for. If the search box is left empty, search routine will return all elements available in the system for the selected type. The element list is limited to one screen in order to provide better overview and faster operation. If there are more elements found, then it can be listed in one screen, and additional listing screens are available through the numerical link available at the bottom of every particular listing screen.

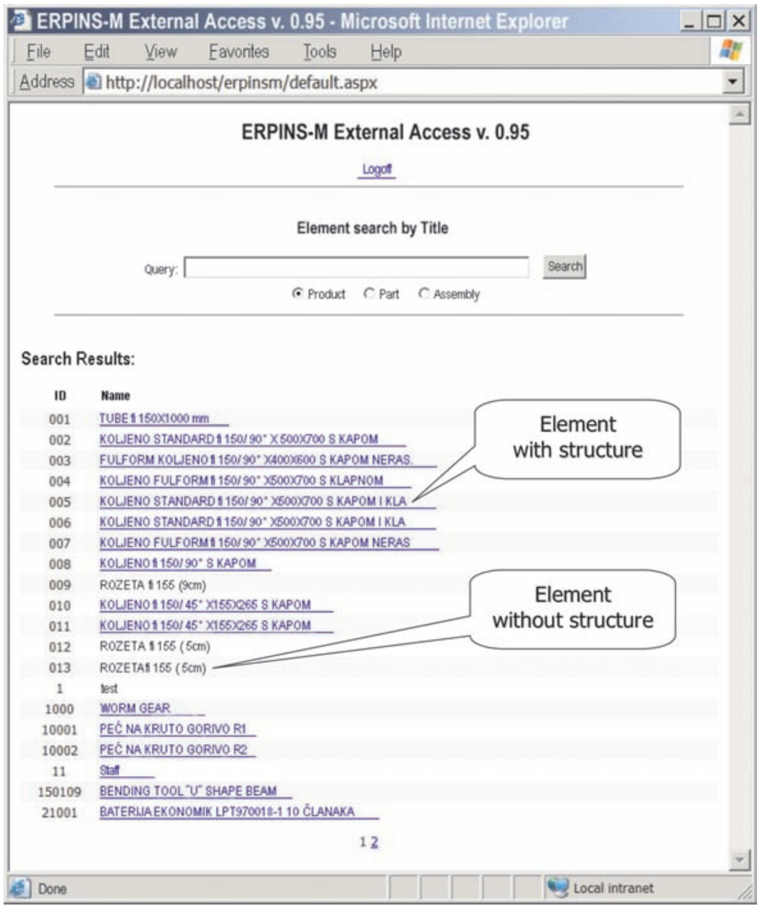

Figure 7. Web application for external access to the ERP system
Slika 7. Web aplikacija za vanjski pristup ERP sustavu

In element listing, the names of production elements which have a structure written in the ERPINS-M system are presented in a highlighted manner and set up as a hyperlink to a structure presentation of a particular element. Elements without the structure are listed without highlighting and hyperlinks.

The structure presentation of the selected compound production element is carried out in a hierarchical way like in upgraded DEPTO interface (Figure 5). Also in the presentation of the structural components the web application is consistent so the names of the elements which have associated documents are also presented in a highlighted manner and set up as a hyperlink to documents, while names of the elements without associated documents are presented as a plain text. In the prototype implementation of external access, the users are not allowed to change the structure of the compound production element, as not to associate a new structured document. For testing purposes we implemented only main document operations, those for check-out and check-in of documents.

Beside the common hierarchical presentation of the compound element structure, we embedded also the structure presentation in Extensible Markup Language (XML) format [15, 16]. Together with great breakthrough of the Internet, in recent years XML came up as the main general purpose mark-up language with the basic task to simplify data sharing between various systems especially to those connected over the Internet. Due to actual application range and related importance of XML additional effort is made to translate specially developed exchange standards and languages into XML format. Neither ISO STEP nor EXPRESS is an exception from that trend [16].

XML record is, according to the language rules, hierarchically structured with the obligatory basic element and in that structure all belonging elements are nested. Owing to those rules, the language is also very convenient for the presentation of compound production element structure and records are sufficiently readable both to humans and to computers (Figure 8). Even more important is that XML has the capability to describe many various data types so the structure presentation could be easily expanded with additional attributes according to the user needs. Unfortunately, the price for good readability and adaptability is paid in size records so documents stored in XML format are usually larger than those in specialized formats.

In the prototype web application, XML presentation is created on the server and written into appropriate XML file that can be either viewed in a browser or stored locally on the user's computer for eventual further processing.

```
<?xml version="1.0" encoding="utf-8" ?>
- <element id ="11" name="Staff" >
  - <element id ="111" name="Clamping Screw" >
      <element id ="118" name="Clamping Screw" />
      <element id ="120" name="Bolt" />
      <element id ="119" name="Knob" />
    </element>
    <element id ="112" name="Staff Holder" />
    <element id ="113" name="Regulation Nut" />
    <element id ="114" name="Split Pin" />
    <element id ="115" name="Trunnion Screw" />
    <element id ="116" name="Regulation Screw" />
    <element id ="117" name="Safety Screw" />
  </element>
```

Figure 8. XML presentation of the product structure
Slika 8. XML prikaz strukture proizvoda

4
Discussion
Diskusija

To estimate an implementation success of PDM functions, ERP developers and also potential and actual ERP users, need metrics, i.e. guidelines, to evaluate such a specific functionality. Therefore, in previously published paper we have discussed and proposed appropriate evaluation guidelines for the PDM functionality of the ERP systems [5]. In the meantime, new results from CIMdata's survey became available to public and we attuned our guidelines according to those results [17]. According to survey results, not all of the PDM functions have equal significance to users; therefore we proposed unequally distributed values for evaluated functions.

In order to simplify the estimation procedure, PDM functions are sorted in two groups: (1) core functions and (2) extended or utility functions, while level of integration into the ERP system is considered separately. As core functions we considered: controlled secure storage and management of product data in a database, product structure management, workflow and process management, program management and classification of parts.

All other functions are sorted into a group of extended functions, mainly because such functions could be found in many other computer programs or as simple standalone applications. Some of extended functions could be communication and notification; data transfer and translation; image presentation; system administration…

In an ideal implementation, the ERP system would include a full set of PDM functions. Such implementation could be evaluated with maximum amount of points or percentage, like 100 % of PDM functionality, as we did in the above mentioned paper and thesis [5, 6]. In the following estimation we chose a more descriptive approach in order to achieve clearer and more concise evaluation.

We divided metrics for the PDM functionality of the ERP system in five evaluated levels: (1) level of the core functionality implementation; (2) level of the extended functionality implementation; (3) level of the integration of PDM functionality inside the ERP system; (4) level of the accomplished product data integrity and (5) level of the accomplished product data security.

The level of the core functionality implementation is the mostly affected with the proposed model and prototype implementation. The functions for management of product structure and data vault are also the mostly used functions according to the survey results. Before the prototype model implementation, the ERPINS-M system had a support for the product structure in scope of production elements enclosed inside the systems. Implementation has brought an open model for structure management with the support for structured MCAD documents and with a possibility to synchronize the product structure originally generated or altered in MCAD system. In most of the considered small and midsize manufacturing companies it will be sufficient, but it could be a limitation in the distributed product development process.

Considering a set of product data vault functions, before prototype implementation, the ERPINS-M system had a very strong meta-data model and a possibility to assign one non-structured document with one production element. Implementation has extended the possibility to assign several either structured or non-structured documents with one production element with the purpose of better support to the process of product development. The level of the core functionality could be raised even more if the full set of functions for handling independent documents is implemented, but such documents are not so important for the product development process so we did not consider it in this paper.

Data transfer estimated in the level of the extended functionality implementation is carried out in such a manner that access to stored data is possible exclusively through the modules of the ERPINS-M, therefore the user does not need to know where data are actually stored in the computer network. Before the model implementation, the system had the appropriate solution for data transfer, but with extension in the level of core functionality we completed data transfer functions for PDP. Furthermore, the level of the extended functionality implementation is extended with implemented functions for the preview of structured and basic document types inside the ERPINS-M system. For further upgrade in that direction we considered the possibility to insert comments and review marks on documents.

To properly estimate the level of integration inside the ERP system, it should be perceived that the prototype implementation is fully realized as an upgrade inside the ERPINS-M system with storage of PDM data inside the ERPINS-M database so we accomplished highest available integration.

Although the level of the accomplished product data integrity depends mostly on the organization of servers and on the ERPINS-M database, the realized availability of all needed product data through the ERPINS-M system has significantly enhanced data integration.

Product data security from unauthorized access was already adequately deployed in the system through the user authorization before the prototype implementation. The level of the accomplished product data security is somewhat increased with data encryption in the web application for external access. Security could be even more increased with implementation of the user rights over the particular objects and with user groups despite actual user rights defined for a particular subsystem or a module. Since such implementation causes large changes inside the system structure, the developer must carefully consider benefits and costs.

In some estimated levels, the prototype implementation does not bring significant advancement regarding the PDM functionality. The reasons are ambiguous and depend on the particular function. In the level of the core functionality for functions dedicated to project management and to classifications of components as in the level of the extended functionality implementation, we estimated actual functionality level of the ERPINS-M system to be well developed and adequate to complete previously mentioned tasks with a small adaptation of users toward the system.

Communication and notification functions together with data translation are those functions for which most of the ERP users already use standard protocols and common applications. Time invested to develop and implement all those functions inside the ERP system cannot easily pay off because there is a great probability that the users will not adopt them. For example, the developers could implement function for data translation from specific MCAD file format to standard STEP file format, but there is a small probability that the users will run translation inside the ERP system instead in MCAD application in which the file is created. Therefore, for such functions we suggest the use of the available common applications and already accepted protocols.

Since the prototype implementation of external access does not belong to the set of PDM functions, we did not include it in the previous estimation of the model implementation. However, external access is an important precondition in the distributed product development process. Thus we made it as an example and as an eventual guideline for development of further ERPINS-M modules for external access.

5
Conclusions
Zaključci

In our analysis of the PDM concept we emphasized the modern way of product presentation through digital spatial models of parts and assemblies produced in MCAD systems. Nowadays, MCAD systems are very important in the product development process, since the product structure is mostly defined in it. Based on that fact, we also emphasized two core PDM functions for implementation into the ERP system: product structure management and data vault. We proposed a suitable information model to implement those functions into the considered ERPINS-M system.

Prior to proposition of the information model, we analysed the influence of present standards in scope of product data sharing, primarily the ISO STEP PDM schema and we considered the possibility to adjust standard scheme for implementation into the ERPINS-M system. Specific architecture of the ERPINS-M system does not allow full implementation of the schema because it will demand writing the new architecture for the system and writing the new program code for most of the subsystems. It is also questionable if full implementation of schema will alleviate sharing of product data since it is not implemented in significant rate in the production. However, fundaments of the PDM schema could serve as good guidelines and we used them as such to set a suitable information model.

A suitable information model is conceived in order to expand possibility of authorized sharing of the product data through the ERPINS-M system. The data vault model is carried out in such a manner to enable product document handling regarding the product structure management and to enable an association with production elements of the ERPINS-M system. The model complies with specific features and specific architecture of the ERPINS-M system but it also complies with specific features of structured MCAD documents.

The estimation of model and its prototype implementation according to proposed metrics, leads to conclusion that after their implementation into the ERPINS-M system, the ERPINS-M system could give quite sufficient and well integrated support to the product development process in considered small and midsize manufacturing companies.

A question rises if developers of the considered ERP systems for manufacturing companies should tend to accomplish the full PDM functionality in order to give a complete support to the product development process. We assume that there is no perfect answer, because surveys show that in most cases only the main PDM functions are in use so before implementation of a particular PDM function into the ERP system it is necessary to examine the targeted market. Therefore it should also be taken into consideration if a particular function can be fulfilled with modules already implemented into the system. For example, the ERPINS-M system has very modern and powerful subsystems for production and projects planning that could be easily used for planning and tracking of the product development process with specific time for the user adaptation.

Acknowledgment
Zahvala

The authors especially wish to thank Professor Niko Majdandžić and the management of ININ Company for their contribution in the prototype implementation and to Professor Željka Rosandić for proof-reading the manuscript. The work presented in this paper was financially supported through several projects by the Ministry of Science, Education and Sports, Republic of Croatia.

References
Literatura

[1] Miller, L. The Top 100 Software Vendors. MSImag - IT for Manufacturing Executives, July, 2004.
[2] Paul, R. et al. Mehr Flexibilität bei der Integration von ERP- und PDM-Systemen. B.I.M.-Consulting mbH, Magdeburg, 1999.
[3] Ou-Yang, C.; Cheng, M. C. Developing a PDM/MRP integration framework to evaluate the influence of engineering change on inventory scrap cost. International Journal of Advanced Manufacturing Technology, vol. 22(2003), str. 161-174.
[4] Majdandžić, N. Izgradnja informacijskih sustava proizvodnih poduzeća". Strojarski fakultet u Slavonskom Brodu, 2004.
[5] Kljajin, M.; Galeta, T. Metrics for the PDM Functionality of ERP System". Proceedings of 8th International Design Conference - Design 2004, Dubrovnik, 2004.
[6] Galeta, T. Sharing Product Data through ERP systems. Mechanical Engineering Faculty, Slavonski Brod, 2005.
[7] Galeta, T. et al. Product Model Suited for the ERP System. Proceedings of 9th International Design Conference - Design 2006, Dubrovnik, 2006.
[8] ININ d.o.o. Informatički inženjering, Slavonski Brod. http://www.inin.hr/, 2007.
[9] Strojarski fakultet u Slavonskom Brodu - Mechanical Engineering Faculty in Slavonski Brod. http://www.sfsb.hr/, 2007.
[10] Ungerer, M.; Buchanan, K. Usage Guide for the STEP PDM Schema Release 4.3. PDM Implementor Forum, Darmstadt, 2002.
[11] Booch, G. et al. The Unified Modeling Language User Guide. Addison Wesley Longman, Inc., Reading, 1999.
[12] Borland Delphi 7 Developer's Guide. Borland Software Corporation, Scots Valley, 2002.
[13] Autodesk Inventor API Reference Guide. Autodesk, Inc., 2003.
[14] Visual Studio.NET 2003 Combined Help Collection. Microsoft Corporation, 2006.
[15] Harold, E. R.; Means, W. S. XML in a Nutshell. O'Reilly Media, Inc., Sebastopol, 2002.
[16] Kimber, E. XML Representation Methods for EXPRESS-Driven Data. ISOGEN International Corp., Gaithersburg, 1999.
[17] CIMdata Online Polls: What PLM functions do your users utilize most? http://www.cimdata.com/images/polls/results_03.25.05.gif, CIMdata, Inc.

Authors' addresses
Adrese autora

Tomislav Galeta, PhD ME
University of Osijek
Mechanical Engineering Faculty
Trg I. B. Mažuranić 2
HR-35000 Slavonski Brod
Croatia
www.sfsb.hr
tgaleta@sfsb.hr

Milan Kljajin, PhD ME, full time professor
University of Osijek
Mechanical Engineering Faculty
Trg I. B. Mažuranić 2
HR-35000 Slavonski Brod
Croatia
www.sfsb.hr
mkljajin@sfsb.hr

Mirko Karakašić, BSc ME
University of Osijek
Mechanical Engineering Faculty
Trg I. B. Mažuranić 2
HR-35000 Slavonski Brod
Croatia
www.sfsb.hr
mkarakas@sfsb.hr