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DATA TRANSFORMATION FOR PRODUCTION PLANNING AND CONTROL SYSTEMS INTEGRATION

In this paper the method of production planning and control systems (PROEDIMS and SWZ) integration is presented. Both systems are parts of a distributed system which is thought as a replacement of large MRP / ERP systems for SMEs. This idea derived from the needs of several small and medium enterprises. In these kind of enterprises the larger stress is applied rather on technical preparation of production than tackling business problems. Integration is achieved by methods of data transformation and data mapping. The proposed data transformation interface uses neutral data formats like XML, XML schema, Extensible Stylesheet Language Transformations XSLT and XML Path Language. The functional scheme of the module for data exchange which is necessary for the interaction between the production planning module of PROEDIMS system and production orders verification system for a multiassortment, concurrent production (SWZ) has been proposed and various stages of data transformation have been discussed.

1. INTRODUCTION

Recently a significant increase in the number of small and medium enterprises (SME) has been observed. In the EU, SMEs constitute 99.8% of all the non-financial business economy enterprises, representing almost 70% of total employment in the private sector. SME companies are divided into medium-sized (fewer than 250 employees), small (fewer than 50 employees) and micro-enterprises (employing fewer than 10 people). In the manufacturing sector, SMEs constitute 99.2% of enterprises. Especially micro-enterprises, which currently constitute 92% in SME, are certainly in bloom. These include many newly established family businesses, manufacturing companies, as well as commercial and service outlets. It is estimated that employment in micro-enterprises constitutes about 30% of total employment of enterprises in the European Union. Because of a wide range of activities, the high cost of implementation and a need to apply changes within a company's structure, production support management systems are offered on the market and are implemented primarily in large enterprises [3]. The cost and timing for implementation of ERP systems and the specificity of these systems are the main reasons why they are not

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implemented in the group of SMEs (and particularly in a group of micro-enterprises). To meet the needs of such enterprises, resulting from the necessity to reduce production costs and shortening the time involved in design, planning and preparation of production, cheaper and more flexible tools, which allow companies to adapt quickly to the requirements of the customers, are being sought after [5],[11]. Support systems functioning in the sector of SME usually operate in various areas related to the preparation and planning of the production, but they are not integrated. Lack of integration between these systems affects the efficiency in their use and is a potential area where it is possible to increase efficiency, associated with a reduction of costs for SMEs.

The response to demand is described in the research and development project implemented by the Silesian University of Technology, which scientific objective is to develop methods for integrating systems that support business activities in areas of industrial production planning and control, and in the field of production scheduling and rescheduling. The purpose of the project is to develop a model of data exchange and a prototype system supporting the functions of planning, control and management of industrial production. As a result of development and implementation of the system, it will enable increased effectiveness of the integrated areas of decision-making and the creation of virtual organizations in SME enterprises.

In order to meet this goal, modifications to already established systems, operating under a system of preparation and planning of production: proEDIMS (Chapter 2.1), SWZ (Chapter 2.2) and KbRS, will be required. ProEdims system is being developed at the Institute of Production Engineering and Automation at Wrocław University of Technology. Scheduling systems SWZ and KbRS are being developed at the Silesian University of Technology. The cooperation of these systems will be achieved through the development and implementation of a dedicated interface for data exchange.

The paper presents the results of the implementation phase of the data exchange module, needed for proper cooperation of PROEDIMS production preparation module and SWZ system for verification of production orders for the multiassortment concurrent production. A method of data structure formal description, concerning production processes, with regard to available resources has been developed with the use of Extensible Markup Language (XML). The operation of the interface module for data exchange, based on techniques of data transformation and data mapping supporting the integration of computer applications has been shown.

2. PRODUCTION PLANNING AND PREPARATION SYSTEMS SWZ AND PROEDIMS

Decisions related with admission to the execution of the production task need to ensure the profitability of the effects in terms of timeliness and cost of manufacturing. To meet the requirements of their clients, the SME manufacturing companies need to use computer-aided decision systems, in particular with respect to decisions regarding the possible admission of a production order, to ensure the task completion is in accordance with the order, with minimum capital involved.

2.1. ORDER VERIFICATION SYSTEM SWZ

Order Verification System - SWZ 4.0 is a computer implementation of methods supporting rapid decision taking on the acceptability of a production order. In this method, the admissibility of the production flow variants is determined by the limits of quantitative and qualitative conditions. Combinatorial nature of the possible options for the organization of production flow makes this problem practically impossible to be solved in quantitative terms, which means there is no possibility of obtaining the optimal solution within a reasonable time horizon. For the same reason it is equally difficult to determine the allowable flow, i.e. the solution to the problem in terms of quality. This implies the need to abandon the designation of the set of all feasible solutions for the determination of a subset of states achievable solutions. Solving these problems comes down to testing a sequence of arbitrarily selected conditions, where each check is a study of the local balance condition. The fulfilment of all conditions (their conjunction) ensures effective implementation of the order. Lack of local balance provides information about the necessary abandonment of certain conditions of the order, or a necessity of meeting the needs connected with an increase in available production capacities, storage space, etc [10].

The SWZ system sets up distributed control procedures and orders, with quantitative and qualitative indicators of the production system for data specifying the system. Production flow control is accomplished through the cyclically performed local rules for resolving conflicts (LLRKZ) [7]. LRRKZ determines the order of access to the resource and provides at least a single executing operation realization belonging to each of the processes sharing the resource. Access to resources is regulated according to the mode of mutual exclusion. This means that the steady states are generated by sets of LRRKZ assigned to resources. As the work of machinery and equipment is carried out according to the rules generated by the cycle, its characteristic feature is that the relevant norms of production can be defined in an algebraic way. This gives the possibility to form high-level indicators of production, such as the use of resources and stocks of work in progress.

2.2. PROEDIMS SYSTEM

PROEDIMS system belongs to a family of products, which manage product data and processes in the company. PROEDIMS enables creation, collection, management and propagation of all data related to the product throughout the product life cycle and all information and data necessary for the proper functioning of the company.

This system supports various areas and activities related to the product and the company's activities starting from the conceptual phase, throughout design and process management, logistics and relations with customers and suppliers, to the maintenance and products servicing. Phase of the project discussed in this study, is related to the integration of the SWZ system with ProEdims, and intends to complement the PROEDIMS with the module associated with the scheduling of tasks on system resources. Input data uploaded into SWZ from PROEDIMS allows determination of the sequence of operations on the resources of the production system. After transferring them back into PROEDIMS system, they will become the basis for work schedule of the production system generation. The stage of integration requires development of a uniform data structure, successively used in the process of exchanging information between considered systems. The structure will consist of the following models: the production system, the order, the technological process and the planned production. On their basis a neutral format for data exchange will be possible to be created.

The exchange of data between systems is achieved, due to the versatility and convenience in use, with the Extensible Markup Language (XML) [1]. XML is currently very popular and more and more often used in the exchange and analysis of data collected and processed in information systems, supporting the company's management at different levels and functional areas [12]. XML is designed to represent different data in a structured way. The choice of XML as the language for recording data on the need to integrate KbRS and SWZ was dictated by the fact that XML is now very popular and often used in areas related to the exchange and analysis of data collected and processed in the management support systems at various levels and different functional areas (e.g. ERP, PPC, MRP, MES, etc.) [8],[9].

For production system and production order models an XML document structure has been developed [4],[11] with the use of XML Schema, the successor to the DTD standard. This choice is dictated by the way the definition is written/recorded (also implemented using XML) and the fact that XML Schema has greater potential in comparison to DTD standard, which allows to define restrictions on the data. It also enables creating new definitions of the structure, or combining information from several patterns, which is important in the process of acquiring data from management support systems.

Developed for integration needs, XML schema in PROEDIMS system has been divided into four modules [2]:

Planning - including data on production orders and related operations for scheduling. Details such as order status, priority, batch size, registration date, planned starting and finishing times (used when generating schedules, depending on the rule of "forward" or "reverse”) are transmitted in this module.

Production - containing data on currently ongoing orders and related operations. Production data included in this XML module contains information about all the orders and operations carried out at a time on the manufacturing floor. They must be included in the generated production plans. These plans can be modified only in case of their earlier cancellation.

Resources - containing list of production resources together with the calendars of availability. XML module with data on manufacturing resources and availability calendars. Entries in the calendar can be: positive (in which this resource is available - shift, overtime), negative (those in which the resource is not available - failure, review, etc.).

Resource group - containing a list of resource groups - this defines a group of resources that can be used alternately, an example might be the use of resource on which the operation will end sooner.

An example fragment of XML schema containing a definition of the XML document structure for the data from PROEDIMS system has been presented in Fig. 1.

```
<element name="root">
  <complexType>
    <sequence>
      <element name="planowanie" minOccurs="1" maxOccurs="1">
        <annotation>
          <documentation>Lista zlecen do harmonogramowania</documentation>
        </annotation>
        <complexType>
          <sequence>
            <element name="zlecenie" type="edm:Zlecenie_typ" minOccurs="1" maxOccurs="unbounded"/>
          </sequence>
        </complexType>
      </element>
      <element name="produkcja" minOccurs="1" maxOccurs="1">
        <annotation>
          <documentation>Lista zlecen w produkcji</documentation>
        </annotation>
        <complexType>
          <sequence>
            <element name="zlecenie" type="edm:Zlecenie_typ" maxOccurs="unbounded"/>
          </sequence>
        </complexType>
      </element>
      <element name="zasoby" minOccurs="1" maxOccurs="1">
        <annotation>
          <documentation>Lista zasobow</documentation>
        </annotation>
        <complexType>
          <sequence>
            <element name="zasob" type="edm:Zasob_typ" maxOccurs="unbounded"/>
          </sequence>
        </complexType>
      </element>
```

Fig. 1. PROEDIMS XML Schema

XML schema for the SWZ system, developed for integration needs, defines the structure of a XML document for data describing the resources such as: manufacturing system, i.e. machines, work-in-progress stores, input and output stores of the products manufactured in the production system, data on production processes, i.e. technological routes, set-up times, cycle times, production schedule i.e. sequences of manufacturing operations for all production processes in the production order on production resources.

In Fig. 2 a sample XML schema containing the XML document structure definition for data of the manufacturing system has been presented.

```xml
<?xml version="1.0" encoding="utf-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema" version="1.00" id="Production_System_Data">
  <xs:element name="Production_System">
    <xs:complexType>
      <xs:all>
        <xs:element name="Resources">
          <xs:complexType>
            <xs:sequence maxOccurs="unbounded">
              <xs:element name="Resource">
                <xs:complexType>
                  <xs:all>
                    <xs:element name="Id" type="xs:integer"/>
                    <xs:element name="Name" type="xs:string"/>
                    <xs:element name="Capacity" type="xs:decimal"/>
                    <xs:element name="Schedule">
                      <xs:complexType>
                        <xs:sequence maxOccurs="unbounded">
                          <xs:element name="Sequence">
                            <xs:complexType>
                              <xs:all>
                                <xs:element name="Id" type="xs:positiveInteger"/>
                                <xs:element name="Process_Id"/>
                              </xs:all>
                            </xs:complexType>
                          </xs:element>
                        </xs:sequence>
                      </xs:complexType>
                    </xs:element>
                  </xs:all>
                </xs:complexType>
              </xs:element>
            </xs:sequence>
          </xs:complexType>
        </xs:element>
```

Fig. 2. SWZ XML Schema

Processing of data into an XML format in accordance with engineered schemas realized through the expansion of SMR systems and modules PROEDIMS of import / export data.

3. MODULE OF DATA EXCHANGE BETWEEN SWZ AND PROEDIMS

In the previous chapter XML data model used by the SWZ and KbRS systems has been presented. The next step in the implementation of a systems integration project was creating a module for transforming data between different models of integrated planning environment [13]. The transformation process was divided in two, concurrently carried out stages, resulting from the functional areas of integrated systems:

- The stage of calculation, connected with the need of converting the generated sequence of tasks completion on the resources into the form of a schedule, used by PROEDIMS system. This phase is related to the fact that in the PROEDIMS system the schedule of the implementation of operations on resources is associated with the

calendar availability of productive resources, which the SWZ system does not take into account.
- The data mapping stage of the data stored in PROEDIMS system and data set in the previous step with the data which is stored in the data model of the SWZ system.

The implementation process of data mapping has been shown in Fig. 3.

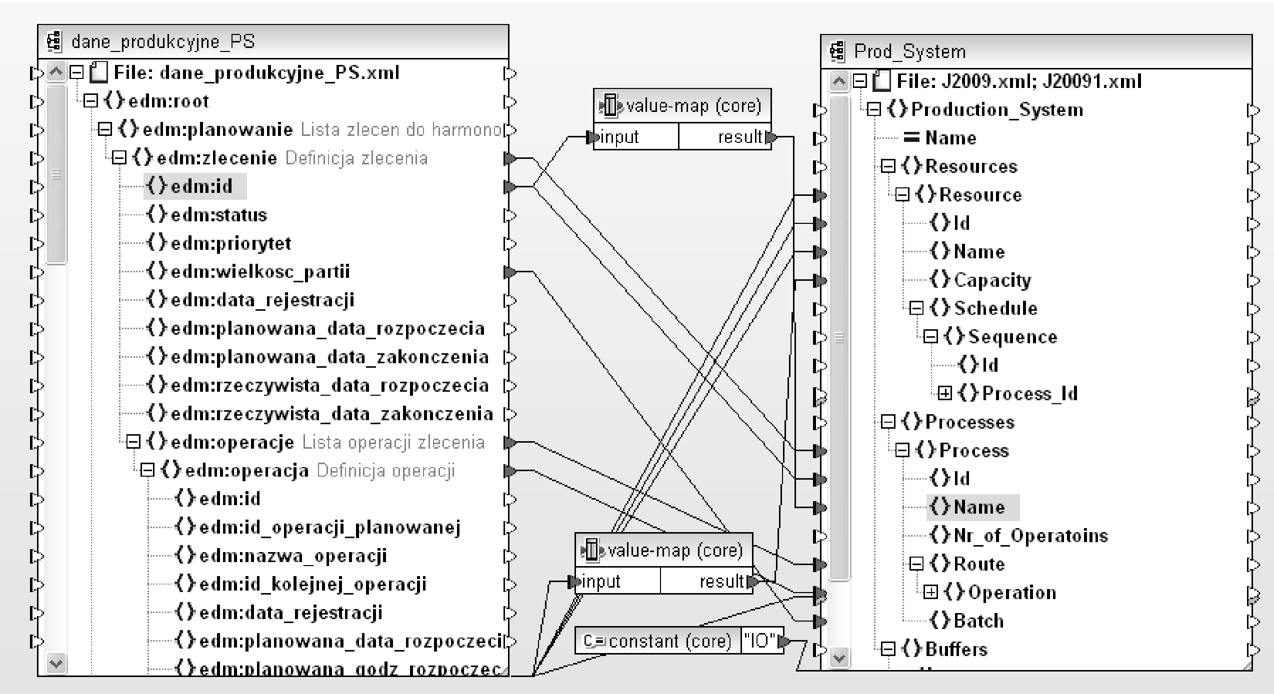

Fig. 3. Data exchange between SWZ and PROEDIMS

For the purpose of automating the process of transformation Extensible Stylesheet Language Transformations (XSLT) [6] has been used. It is recommended by the W3C, it allows to transform XML document into another XML document, Web page, text document or other file type. XSLT is widely used in various software (web browsers, MATLAB), and, like the XML diagrams, the realization of the transformation process based on XSLT document can be executed using the popular processors, like for example XMLSpy, Sablotron for C + +, XSLT, PHP. Functions related to calculations on the data are realized by means of XML Path Language (XPath). XPath is a query language for selecting nodes from an XML document, but may be used to compute values (e.g. strings, numbers, or Boolean values) from the content of an XML document. XPatch language functions might be used in XSLT documents.

The process of PROEDIMS and SWZ systems integration requires the delivery of XML documents into the SWZ system in accordance with the proposed XML schema of the SWZ. That is why the decision was taken to convert the XML document oriented in the structure of a resulting document, which as a result created an XSLT schema in the shape of one complete document. Data transformation module has been implemented into the SWZ system. In Fig. 4 functional scheme of a transformation module in the SWZ system has been shown.

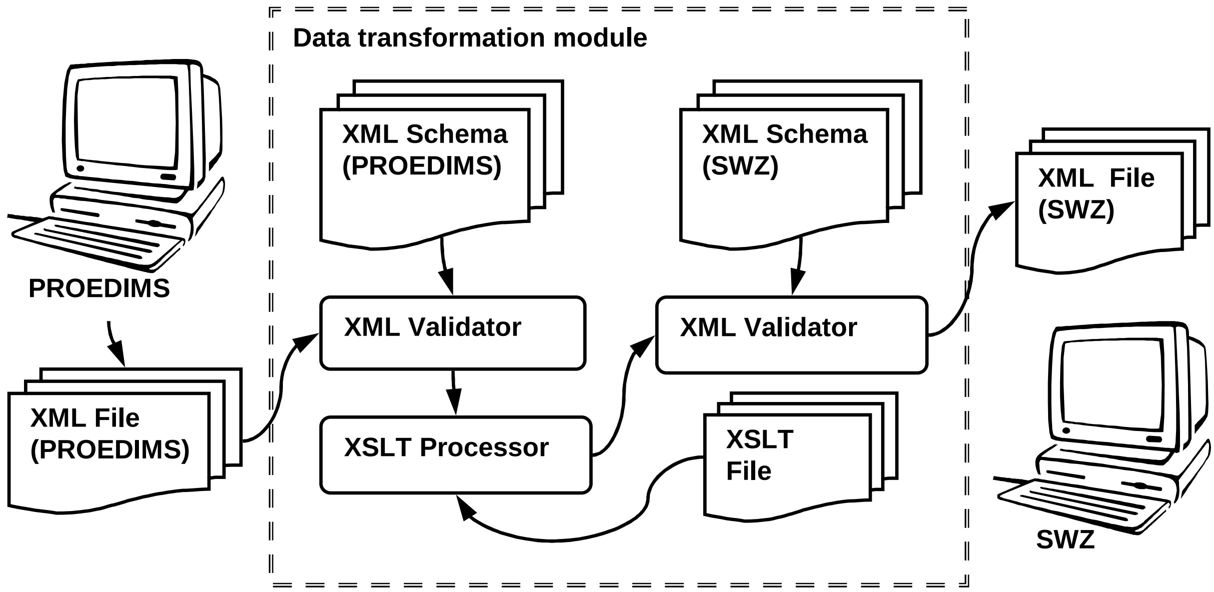

Fig. 4. Data transformation module

Implementation of data transformation process in the developed module of the SWZ system consists of the following steps:

- Loading of the XML document containing information on the planned production from the PROEDIMS system.
- Validation of the loaded XML document based on XML Schema.
- Transformation of the XML document on the base of the XSLT document (mapping data and calculations using XPatch).
- Generating an XML document for SWZ.
- Validation of the loaded XML document based on XML Schema.

The individual elements of the input and output files structure are converted in an order resulting from the requirements of SWZ and KbRS XML document formats, through adequately addressed appeals to the tags (nodes) with the use of the XPath language. Fragment of an XSLT document has been shown in Fig. 5.

The processing of XML files based on the prepared XSLT sheet can be done in two ways. The first (shown above) is based on the user interface developed using the XSLT processor functions. The other one may use the available software that includes XSLT processors (eg, XMLSpy). The next phase of integration will be implemented in the same way, and it will involve processing and transmitting information containing the schedule generated in the SWZ system into PROEDIMS system.

```
-->
<xsl:stylesheet version="1.0" xmlns:xsl="http://www.w3.org/1999/XSL/Transform" xmlns:vmf="http://www.altova.com/MapForce/UDF/vmf" xmlns:n
 xmlns:xs="http://www.w3.org/2001/XMLSchema" exclude-result-prefixes="vmf ns0 xs">
  <xsl:template name="vmf:vmf1_inputtoresult">
    <xsl:param name="input" select="/.."/>
    <xsl:value-of select="'1'"/>
  </xsl:template>
  <xsl:template name="vmf:vmf2_inputtoresult">
    <xsl:param name="input" select="/.."/>
    <xsl:value-of select="'1'"/>
  </xsl:template>
  <xsl:output method="xml" encoding="UTF-8" indent="yes"/>
  <xsl:template match="/">
    <xsl:variable name="var1_root" select="ns0:root"/>
    <Production_System>
      <xsl:attribute name="xsi:noNamespaceSchemaLocation" namespace="http://www.w3.org/2001/XMLSchema-instance">
        <xsl:value-of select="'G:/Toshiba/xml/Prod_System.xsd'"/>
      </xsl:attribute>
      <Resources>
        <xsl:for-each select="$var1_root/ns0:zasoby/ns0:zasob">
          <Resource>
            <Id>
              <xsl:value-of select="string(floor(number(string(ns0:id))))"/>
            </Id>
            <Name>
              <xsl:value-of select="string(ns0:symbol)"/>
            </Name>
            <xsl:for-each select="ns0:kalendarze/ns0:pozytywne/ns0:cykliczne/ns0:kalendarz">
              <xsl:variable name="var2_cast">
```

Fig. 5. XSL Transformation document

4. SUMMARY

The analysis of the facts within the existing state of knowledge on methods, tools and techniques for integrating the functions of design, planning and management of industrial production proved that it is necessary to conduct scientific consideration in this area. The method of exchanging data between different systems assisting in the preparation and planning of production, based on data transformation and data mapping using the Extensible Markup Language (XML) and Extensible Style sheet Language Transformations (XSLT) with the XPath Language, provides the possibility of integration of the systems presented in the article. The proposed integration module will increase the efficiency of planners and performance of production systems, which is associated with the reduction of costs for SMEs. The final result will be a prototype of the project management system for SMEs.

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