International Journal of Industrial Engineering and Management (IJIEM), Vol. 4 No. 2, June 2013, pp. 95 – 101
Available online at www.iim.ftn.uns.ac.rs/ijiem_journal.php
ISSN 2217-2661

Research paper

An Application of Period Batch Control Principles and Computational Independent Models for Supporting the Overhaul Process of the Railway Braking Devices

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Received (15 April 2013.); Revised (20 May 2013); Accepted (27 May 2013)

Abstract

The overhaul of railway braking devices is a complex process. It relies on many supporting processes such as spare parts production and supplying. In order for the overhaul to proceed smoothly and all the required work to be accomplished efficiently, an appropriate planning system has to be applied. It must be accompanied by good process coordination and integration of all activities. In this paper is presented a case study of the overhaul process, the proposed planning system and integrative information system support.

Key words: *Overhaul process, Planning, Period batch control, Information system*

1. INTRODUCTION

Coordination and integration of any system is a complex task. Successful operating of every business/industrial system concerns the optimal use of its limited resources in the competitive environment. Often, the good performance of one process is dependent on the timing and the effectiveness of some other processes in the system. In these situations it is important to plan the activities within a process and to integrate processes within the system. This integration is mainly done by means of information system (IS). Contemporary ISs are software intensive. The software being developed within the IS development process should support business processes of an organization. The importance of business process modeling in the context of IS development is three folded: to deconstruct organizational complexity; to understand, describe and validate business needs and the business context for the proposed system; and to tackle the problem of changing or evolving underlined systems. Unfortunately, lots of software development projects failed due to the poor modeling caused by a deep gap between domain experts and business analysts with their requirements, on the one side, and software developers, on the other side. In the paper we emphasize the importance of computational independent models that comprises business process models in the context of IS development and processes' integration.

In Section 2 a short review of production planning systems is given. The importance of computational independent models, alongside with notations for their specification is presented in Section 3. Section 4 is devoted to a case study of an overhaul process, its coordination and integration.

2. PRODUCTION PLANNING SYSTEMS

There are a lot of production planning and control systems which were developed over the years. Having in mind repetitiveness of the production process and the planning period factors in the case study presented in this paper, the most interesting production planning and control systems are: Period Batch Control (PBC) and Material Requirements Planning (MRP), alongside with its successors Manufacturing Resource Planning (MRP II) and Enterprise Resource Planning (ERP).

The origin of Period Batch Control (PBC) as a production planning and control system has its roots in the years before Second World War (the second half of the third decade of 20th century) [1]. It was initially created by UK engineer R. J. Gigli and further developed and analyzed by Burbidge in [2] and [3], Zelenović and Tešić [4], Kaku and Krajewski [5], Benders and Riezebos [6], Rachamadugu and Tu [7], Fernandes and Filho [8] and others. It is based on the idea of setting a fixed period of the time in which the production of parts is done. The production is just one phase in the whole process. PBC system consists of several phases including order acceptance, work orders creation, production, assembly and sales. PBC system is appropriate for repetitive systems [9].

According to Riezebos [10], PBC system applies three principles to configure planning system:

- single cycle ordering (parts have same ordering frequency as parent products);
- single phase (all work orders are released at the same time); and
- single offset time [11] (lead times are equal for a certain phase).

The PBC system designed in this way is known as basic unicycle system [12]. PBC system relies on the parts grouping, a methodology advocated by Burbidge in [13] and [14].

Orlicky in [15] set up the foundational principles of Materials Requirements Planning (MRP) systems. MRP uses the fixed period idea from PBC, but allows planned lead times for work orders to vary. Furthermore, the frequency of ordering parts and products needs not be the same. The MRP works on the logic of calculation of material needs by using the forecasting quantities of final products and their bills of materials. In [16] Whybark and Williams have explained the impact of uncertainty on operating the MRP. MRP evolved later to MRP II, to increase the field of activity from just material requirements planning to manufacture resource planning. The main goal of MRP II is to provide consistent data to all subjects in the manufacturing process. Therefore, it has to rely on an integrated automated information system in order to minimize so called information errors. They generalize errors like:

- missing data,
- redundant data,
- inconsistent data,
- inaccurate and/or unreliable data,
- data conflicting with the possible states and business rules of a real system,
- bad decisions based on incorrect and/or obsolete data, etc.

Enterprise resource planning (ERP) systems, as business information integration systems, are successors of MRP and MRP II systems. They are aimed to facilitate the flow of information between all business functions inside the boundaries of the organization and manage the connections to outside stakeholders. Unlike the PBC, MRP based planning systems are good for non-repetitive systems [9]. But, they are more complex to manage than PBC based planning systems, taking into account different work order release moments and different work order lead times.

3. COMPUTATIONAL INDEPENDENT MODELS

Integration of the business/industrial systems is mainly done by means of IS. This integration can be between the parts of the enterprise or between the enterprise and its environment, like customers and/or suppliers (customer relationship management systems and supplier relationship management systems). Contemporary ISs are software intensive and they are growing in scale and complexity. The software system is the core component of an IS. A great effort is made by the software engineering community to improve software development processes. Unfortunately, lots of software development projects are challenged or even failed. These systems fail not because of technical flaws, but because they do not adequately support the underlying business processes [17]. It happens due to the poor modeling, mostly. The main reason for that is a deep gap between domain experts and business analysts with their requirements, on the one side, and the experts of the design and construction of suitable software system executable artifacts (software developers), on the other side. In the model-driven approach to software engineering (MDSE) a set of methodologies is proposed to bridge the existing gap. The abstraction of implementation details, by focusing on models as first class entities is promoted as the leading idea. Models are used to capture business context and business requirements and to specify, simulate, test, verify and generate code for the software system to be built. Model transformation tools and services are used to align the different models and to refine models from business requirements to software solutions. Thus, conceptual and process modeling becomes a prerequisite for successful software intensive systems design.

OMG's (Object Management Group) Model-Driven Architecture (MDA) currently is the most mature formulation of MDSE paradigm. The basic idea behind MDA initiative is to provide a means for using models to direct the course of understanding, design, construction, deployment, operation, maintenance and modification of software systems [18]. MDA approach promotes the use of models at four different levels of abstraction [19]:

- Computation Independent Models (CIMs) that capture business context and business requirements (business context models);
- Platform Independent Models (PIMs) focusing on the operation of a system while hiding the details necessary for a particular hardware and/or software platform (software specification models);
- Platform Specific Models (PSMs) that combines the specifications in the PIM with the details that specify how that system uses a particular type of hardware

and/or software platform (software realization models); and

- Executable program code.

Another important issue in MDA is the transformation among those models starting from CIM, through set of PIMs and PSMs towards executable program code. Software engineering community, both researchers and practitioners, showed a great interest in PIMs, PSMs, program code and transformations between them. But, till now CIMs have not received sufficient attention [20]. A CIM does not display details of software system to be built but represents business processes of the organization for which the IS will be developed in a way that can be understood by domain experts. It is specified using the vocabulary of the domain's practitioners and the stakeholders. System modeled in this way can be better understood and analyzed ([21], [22]). There is still no unified standard for creation of CIM. Sharifi and Mohsenzadeh in [19] propose that it would be represented with at least two models:

- requirement model and
- business process model.

The first one is a use case model that represents the functional aspect of the system alongside with business actors and business functionalities that are intended to be realized. The behavior aspects are represented by business process model. Aguilar-Saven in [23] and Johanson et al. in [24] systematically present business modeling techniques and languages for the specification of business process model like: Integrated Definition for Function Modeling (IDEF) [25], Unified Modeling Language UML [26], Event Driven Process Chains (EPC) [27] and Business Process Modeling Notation (BPMN) [28].

UML is the de-facto standard industry language for specifying and designing software systems, but it may be used for CIM specification, too. In the paper we use UML use case diagrams to specify requirement model, and UML activity diagrams to specify business process model.

4. CASE STUDY - OVERHAUL PROCESS OF THE RAILWAY COACHES AND RAILWAY BRAKING DEVICES

In the case study, the company which overhauls the railway coaches and the railway braking devices is analyzed. The company has three plant locations deployed at a distance of 20 km. In Figure 1 they are labeled by letters *A*, *B* and *C*. In the figure are not shown the actual distances between factory plant locations and the actual layouts inside the factory plants. In the factory plant *A* the railway coaches are overhauled. The testing, overhauling and repairing of railway braking devices are carried out in the factory plant *B*. The warehouse of spare parts of the overhauled and repaired brakes is situated there, too. Some spare parts are purchased from the company's suppliers, while the others can be made within the company in the factory plant *C*.

There is a problem of coordination and integration of the processes of parts purchasing (locations *A* and/or *B*) and parts production (location *C*). The goal is to improve the coordination and the integration of these processes in order to minimize wastes (of time, of money, e.g.) during their execution.

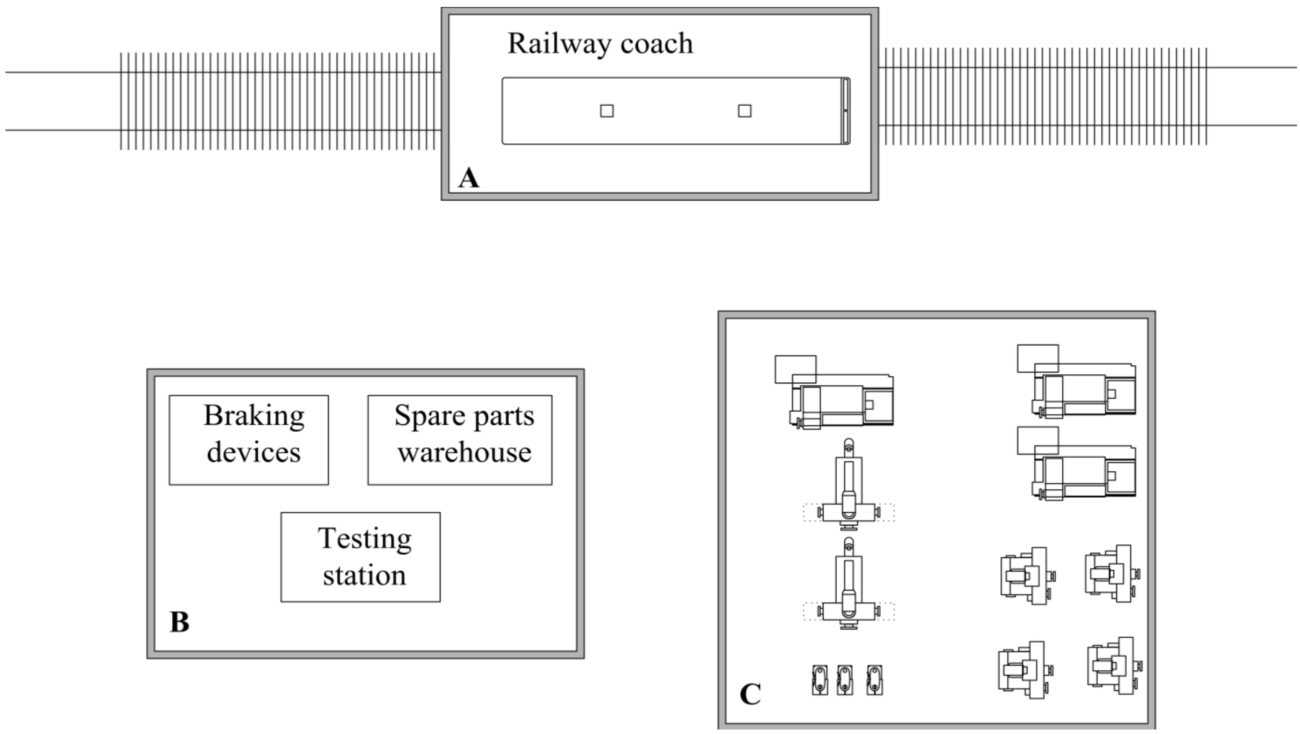

Figure 1. Three plant locations of the company

4.1. **The coordination of the overhaul process**

The overhaul process is periodically repeated for a railway braking device. Therefore, we propose the application of Period Batch Control system to improve the coordination between the processes. For every railway braking device exists a fixed period of time after which they must be overhauled to provide safe and reliable operation, to prolong device's life, and to increase the mean time between failures. Besides, they contain some parts that must be replaced after a period of time, which is strictly stipulated. Consequently, the ordering cycle can be predicted. This enables good planning base for parts manufacturing and their later installation for the overhauled device assembly. The process can be coordinated through four phases:

- ordering,
- parts manufacturing,
- overhaul and
- sales.

Every phase can have the equal time period length because the cycle time for the overhaul operations is standardized and it can be used as a basis for the period length determination. Part shapes are standardized and there are no new parts introduced. This causes increasing the workers expertise in the shop floor and finishing all work operations on time. The manufacturing process is repetitive and lot sizes are low. With the appliance of PBC system, the complexity of the production process planning and control is avoided. The PBC for the observed case is shown in Figure 2.

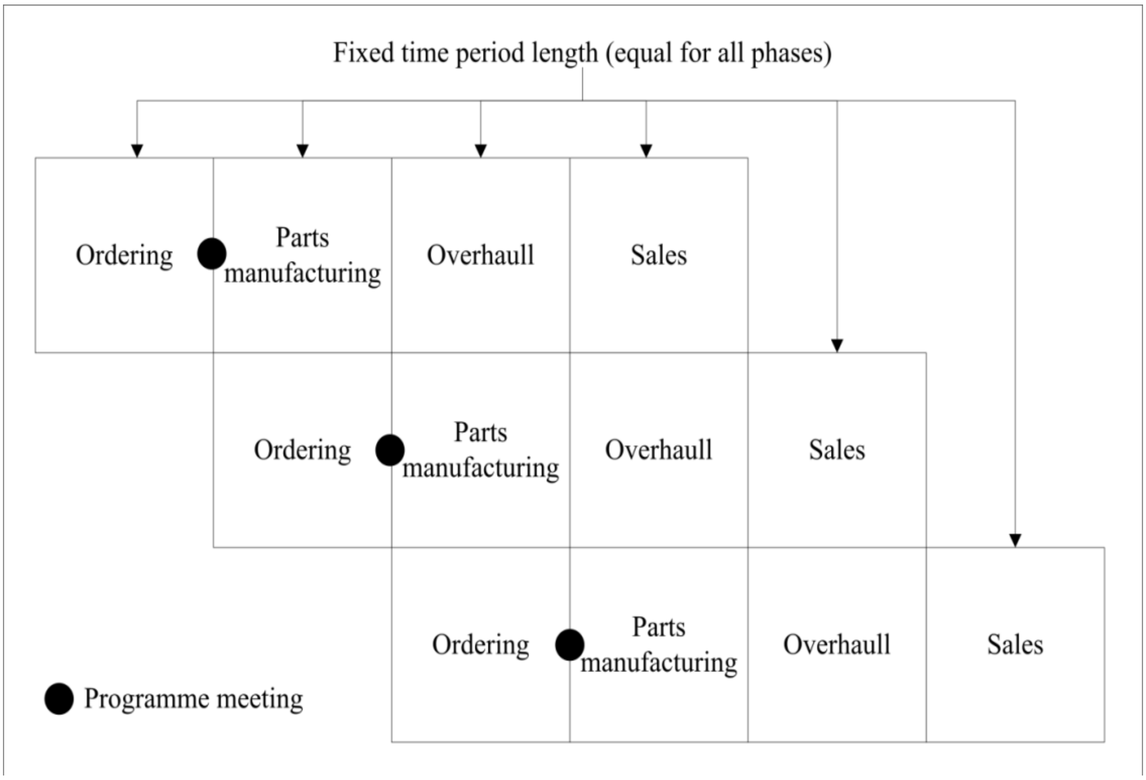

Figure 2. Period Batch Control system as a support for the overhaul process

4.2. **The integration of overhaul process**

In Section 3 we emphasize the importance of CIMs for the understanding of underlined system and for the bridging the gap between the domain experts and software developers. Since the integration of processes should be done by means of an information system to be built, the first step is to model the system's requirements and business processes. In this section we present a CIM of braking device overhaul process, containing a requirements model expressed by means of UML use case diagram and business process model expressed by means of UML activity diagram. The UML use case diagram in Figure 3 contains the overhaul process main functions and actors. The actors are: Customer, Overhaul worker, Manufacturing worker and Supplier. Main functions are: Overhaul identification, Overhaul, Manufacturing and Supplying. The UML activity diagram (Figure 4) gives the further description of the activities of the process. For the purpose of the paper, the activity diagram for overhaul of the railway braking devices is shown. The presented activity diagram may be used as a pattern for the development of activity diagrams for wide range of similar overhaul processes (like the overhaul of the railway coach, e.g.).

The process is initiated by a customer who knows after which period a braking device needs to be overhauled, and transports the braking device/devices to the company’s overhaul department. The overhaul department receives the braking device, after which the service work order is created.

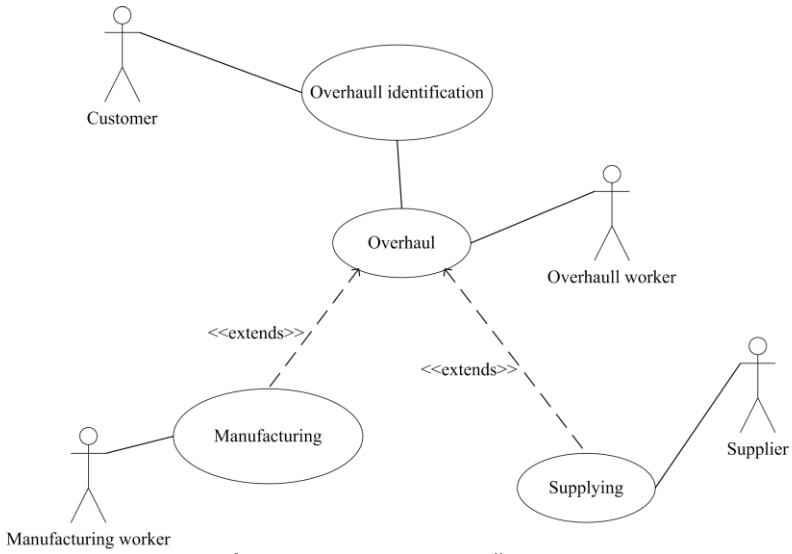

Figure 3. UML use case diagram

Every braking device needs to be thoroughly cleaned and inspected, after which the spare parts needs are identified. Some parts can be purchased and some can be produced in the manufacturing shop floor which is previously organized by principles of PBC system. After the spare parts are assembled the braking device is thoroughly tested on a testing station. If all the output testing results are satisfactory the service is invoiced and customer pays for the service.

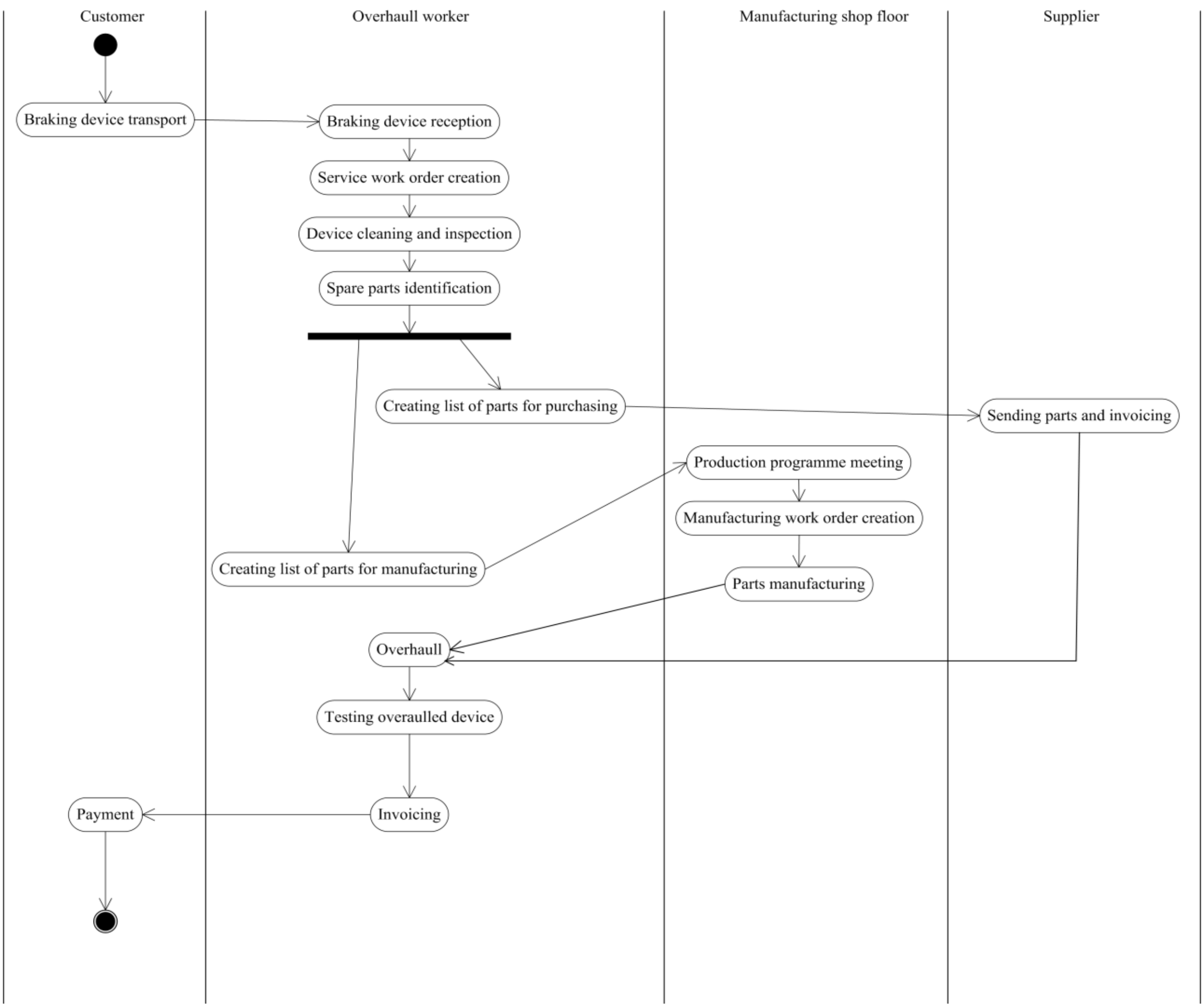

Figure 4. UML activity diagram of overhaul process

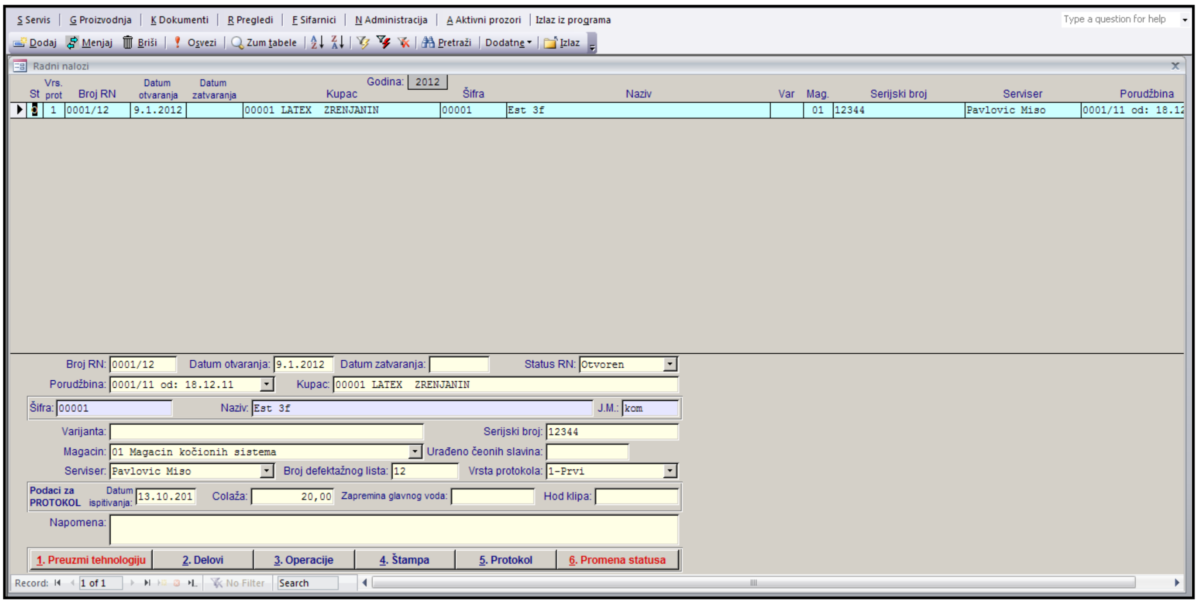

Figure 5. Work order entry form

Process activities can be integrated through the design and implementation of an information system which is supporting them. It is important to integrate the overhaul work order release with the warehouse management inside locations *A* and *B* and with manufacturing and supplying activities. The information system should allow the creation and management of:

- product data,
- work operations and parts data,
- worker data,
- locations data,
- machines data,
- overhaul work orders,
- overhaul protocol report,
- manufacturing work orders,
- other reports etc.

A possible layout of entry forms aimed at work order data and parts stock data maintenance are shown in Figure 5 and Figure 6, respectively.

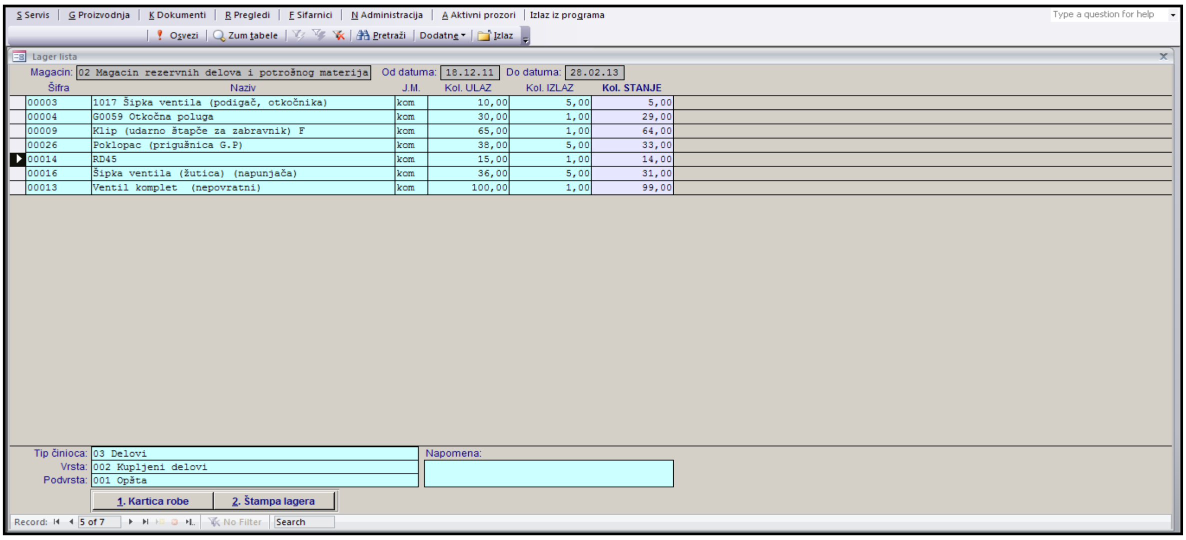

Figure 6. Parts stock list preview

5. CONCLUSION

In the paper is presented a case study of developing a planning system for manufacturing and overhaul activities and their integration. The application of PBC planning system is proposed to improve the coordination between the processes. A CIM of braking device overhaul process is specified by means of UML notation. We believe that it can contribute to better understanding between domain experts, business analysts and software developers. Besides, CIM can be reused for the reengineering of IS and business processes that the IS supports, and that may be one of the derived research ideas. Further research would take the wider scope, in the terms of automating the process of overhaul identification in the ”Serbian railways” with the existing overhaul process at the company, which would contribute to the higher level of integration and organization.

6. ACKNOWLEDGEMENT

Research presented in this paper was supported by Ministry of Science and Technological Development of Republic of Serbia, Grant TR-35050, Title: "Development of software to manage repair and installation of brake systems for rail vehicles", for the period 2011th-2014th year.

7. REFERENCES

[1] Benders, J. (2002), "*The origin of Period Batch Control (PBC)*" International Journal of Production Research, vol. 40, pp. 1-6.

[2] Burbidge, J. L. (1962), “*Principles of Production Control*“, MacDonald and Evans, Plymouth.

[3] Burbidge, J. L. (1996), “*Period Batch Control*”, Oxford University Press.

[4] Zelenović D., Tešić Z. (1988), "*Period batch control and group technology*", The International Journal Of Production Research, vol. 26, no. 3, pp. 539-552.

[5] Kaku, B. J., Krajewski, L. J. (1995), "*Period Batch Control and Group Technology*", International Journal of Group Technology, vol. 33, no. 1, pp. 79-99.

[6] Benders J., Riezebos J. (2002), "*Period batch control: classic, not outdated*", Production Planning & Control, vol. 13, no. 6, pp. 497-506.

[7] Rachamadugu, R., Tu, Q. (1997), "*Period Batch Control for Group Technology - An Improved Procedure*" Computers & industrial engineering, vol. 32, no. 1, pp. 1-7.

[8] Fernandes, F. C. M., Moacir G. F. (2007), "*Sistemas de coordenação de ordens: revisão, classificação, funcionamento e aplicabilidade*", Gestão & Produção, vol. 14, no. 2, pp. 337-352.

[9] Mcarthy, B. L., Fernandes, F. C. M. (2000), "*A multi-dimensional classification of production systems for the design and selection of production planning and control systems*", Production planning and control, vol. 11, no. 5, pp. 481-496.

[10] Riezebos J. (2001), “*The Design of Period Batch Control System for Cellular Manufacturing*”, Groningen: University of Groningen.

[11] Steele, D.C., Malhotra, M.K. (1997), "*Factors affecting performance of period batch control*", International journal of production research, vol. 35, no. 2, pp. 421-446.

[12] New, C.C. (1977), “*Managing the manufacture of complex products: co-ordinating multi-component assembly*”, Business books communica europe, London.

[13] Burbidge, J. L. (1975), “*The Introduction to Group Techology*”, Wiley.

[14] Burbidge, J. L. (1989), “*Production Flow Analysis for Planning Group Technology*”, Clarendon Press, Oxford.

[15] Orlicky J. (1975), “*Material requirements planning: the new way of life in production and inventory management*”, McGraw-Hill, New York.

[16] Whybark, C. D., Williams, G. J. (1976), "*Material Requirements Planning Under Uncertainty*", Decision Sciences, vol. 7, no. 4, pp. 595-606.

[17] Barjis, J. (2008). "*The importance of business process modeling in software systems design*", Science of Computer Programming 71, pp. 73–87.

[18] Selic, B. (2008). "*MDA Manifestations* " *UPGRADE, IX*(2), 12-16.

[19] Sharifi, H. R., Mohsenzadeh, M. (2012), "*A New Method for Generating CIM Using Business and Requirement Models*", World of Computer Science and Information Technology Journal (WCSIT) ISSN: 2221-0741 Vol. 2, No. 1, 8-12.

[20] Bousetta, B., El Beggar, O., Gadi, T., (2013), "*A methodology for CIM modelling and its transformation to PIM*", Journal of Information Engineering and Applications www.iiste.org ISSN 2224-5782 (print) ISSN 2225-0506 (online) Vol.3, No.2.

[21] Dorador, J.M., Young, R.I.M. (2000), "*Application of IDEF0, IDEF3 and UML methodologies in the creation of information models*", International Journal of Computer Integrated Manufacturing, vol. 13, no. 5, pp. 430-445.

[22] Kim, S.H., Jang, K.J. (2002), "*Designing performance analysis and IDEF0 for enterprise modelling in BPR*", International Journal of Production Economics, vol. 76, no. 2, pp. 121-133.

[23] Aguilar-Savén R. S, (2004) "*Business process modelling: Review and framework*", International Journal of Production Economics, Volume 90, Issue 2, pp. 129-149.

[24] Johansson, L-O., Wärja, M., Kjellin, H.,Carlsson, S. (2008), "*Graphical modeling techniques and usefulness in the Model Driven Arcitechture: Which are the criteria for a “good” Computer independent model?*", Proceedings of The 31st Information Systems Research Seminar in Scandinavia (IRIS31).

[25] Marca, D. A., McGowan, C. L. (2006), “*IDEF0 and SADT: A Modeler's Guide*”, OpenProcess, Inc.

[26] Fowler, M. (2003), “*UML Distilled: A Brief Guide to the Standard Object Modeling Language*”, Addison-Wesley Professional.

[27] Scheer, A. W. (2000), “ARIS: Business Process Modeling”, Springer.

[28] Wohed, P., van der Aalst, W., Dumas, M., ter Hofstede, A., Russel N. (2006), "*On the suitability of BPMN for business process modelling*", Business Process Management, vol. 41, no. 2, pp. 161-176.

Primena principa upravljanja periodičnim serijama i računarski nezavisnih modela za podršku procesa remonta kočionih sistema šinskih vozila

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Primljeno (15. april 2013.); Recenzirano (20. maj 2013.); Prihvaćeno (27. maj 2013.)

Rezime

Remont kočionih sistema šinskih vozila je kompleksan proces. Taj proces zavisi od mnogih drugih procesa podrške kao što su proizvodnja delova i nabavka. U cilju da se remont odvija bez zastoja i da se svi poslovi obavljaju efikasno, potrebno je primeniti odgovarajući sistem planiranja. Pored sistema planiranja potrebno je da postoji i dobra koordinacija i integracija svih aktivnosti procesa. U ovom radu je prikazana studija slučaja za proces remonta, dat je predlog sistema planiranja i integrativne podrške putem informacionog sistema.

Ključne reči: *Proces remonta, Planiranje, Upravljanje periodičnim serijama, Informacioni sistem*