ARCHIVES
of
FOUNDRY ENGINEERING

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (1897-3310)
Volume 10
Issue 2/2010

27 – 32

5/2

A possibility of Business Rules application in production planning

J. Duda, A. Stawowy*
Faculty of Management, AGH University of Science and Technology, Gramatyka 10, 30-067 Krakow, Poland
*Corresponding author. E-mail address: astawowy@zarz.agh.edu.pl

Received 07.04.2010; accepted in revised form 10.05.2010

Abstract

The complexity of scheduling problems in production systems and their impact on production functioning (in the area of technology and economics) cause that it is necessary to search for and develop new methods and algorithms solving such problems. One of the latest approach to computer support of business activities is Business Rules Management (BRM). This approach can be used for quantitative as well as qualitative decisions support, among them for production planning. The paper describes Business Rules application in scheduling and planning problem for manufacturing iron castings. Our research confirm that BRM can be employed as a heuristic module in production planning systems.

Keywords: Application of Information Technology to the Foundry Industry; Production Planning

1. Introduction

The main goal of an efficient production planning system is to correctly distribute production tasks in the periods of time. In the contemporary enterprises it is not enough to minimize a production cycle, as this criteria does not include customer needs and cost aspects. Owing to a growing competition the enterprises must provide a whole range of individualized products, while the customers expect that the ordered products will be delivered on time. Such requirements caused in turn the development of new organizational methods, e.g. Lean Management or Just in Time, which presume the proper quantity of products should be manufactured and delivered in a precisely given time. The planned tasks should be completed on time, as both earliness and tardiness are undesirable [1].

A common way to support a production management is to use hierarchical information systems built on the basis of different decision support tools integrated with a common database [2]. MRPII or ERP type system is usually the core of such multi-step systems. This kind of systems cannot solve many essentials problems concerning direct production management. This is true especially for hard and unstructured decision. An opinion of E. Hackmach from Voest Alpine steelworks, who is the co-author of the integrated Production Planning and Control System in this enterprise, is typical [3]. He claims that the software available on the market cannot be directly applied for metallurgical industry.

The complexity of scheduling problems in production systems and their impact on production functioning (in the area of technology and economics) cause that it is necessary to search for and develop new methods and algorithms solving such problems. After many years of saying “it is not a problem to produce something, but to sell it”, theoreticians and practitioners of management come to conclusion that production planning and scheduling is one of the key factors to success. That is because the increasing competitiveness is the main effect of the adequate planning and control in the environment with rapid demand changes and dynamic production. Intelligent planning and scheduling allows the enterprise to be less sensitive to the changes in demand as well as its structure, to shorten its production cycles and to decrease inventory levels (of raw materials, work in progress, finished products) and simultaneously to keep a high level of service – products quality assurance and keeping delivery dates. Proper tool for planning and scheduling can become a link between management, marketing, production process, inventory management, logistics, distribution and even a technology. Intelligent planning and scheduling system helps planners to make a decision concerning raw and other materials allocation, capacities and other resources, including financial ones.

A short-term planning problem in steelworks and foundries is especially complex, because production processes in such manufacturers are of a continuous-discrete type. Their production programs can be characterized by a very high level of quality requirements for particular products and simultaneously a large number of relatively small orders. On the other hand, bottleneck machines usually exist in technological lines in such industries.

2. Business Rules concept

Business Rules Management (BRM) is one of the latest approach to computer support of business activities: BRM concept is implemented in business practice as Business Rules Management Systems (BRMS). According to R. G. Ross [4] the Business Rule Approach represents a major paradigm shift in business-system design and development. Business Rules approach is defined as a formal way of managing and automating an organization's business rules so that the business behaves and evolves as its leaders intend [5].

2.1. BR as a business asset

The commonly accepted description of rules concept is The Business Rules Manifesto [6], according to which:

– rules are essential for business models, business rules are a vital business asset,
– rules are explicit constraints on behavior, not process and not procedures,
– rules should be expressed declaratively in natural-language sentences for the business audience,
– rules should arise from knowledgeable business people,
– business people should have tools available to help them formulate, validate, and manage rules.

Business rules are divided into five categories [4]:

– integrity rules – define integrity constraints; assertions expressing conditions that should be met; e.g. *machine has to be replaced within 3 days,*
– derivation rules – may use reasoning and can perform calculations on the basis of existing facts; they consist of conditions and conclusions; e.g. *machines >5 years old and have weak effectiveness are to be replaced,*
– reaction rules – response to events triggered by a user or another rule; they always include expression, which triggers the rule; e.g. *if machine has been replaced then calibrate it,*
– production rules – include conditions and post-conditions; they may trigger events; e.g. *if machine effectiveness is weak then check its condition,*
– transformations rules – consist of transformation trigger, condition and transformation result; may for example transform data from relational database model into equivalent object model.

2.2. Knowledge representation

The Business Rules approach requires a source rule repository which is a form of knowledge base. Knowledge base has hierarchical structure and – at the first level – consists of rule sets; rule set is a group of coherent rules. The further hierarchy levels look as follows:

– rule consists of atoms e.g. *IF machine has weak effectiveness THEN machine is to-be-replaced,*
– single atom consists of terms e.g. *machine has weak effectiveness,*
– term is a word or expression that has a precisely limited meaning in a given knowledge base e.g. *machine, weak effectiveness, to-be-replaced.*

The business knowledge can be represented in various forms as decision tables, decision trees, decision grids, and textual form [7].

Decision tables are built of premises (input data) and conclusions (possible decisions) put in rows and rules which can be read in columns; an example is given in Figure 1. The first rule from exemplar table can be read as: *IF less than 50 units is ordered AND payment is cash on delivery AND customer is wholesale outlet THEN discount rate equals 4%.*

Less than 50 Units Ordered	Y	Y	Y	Y	N	N	N	N
Cash on Delivery	Y	Y	N	N	Y	Y	N	N
Wholesale Outlet	Y	N	Y	N	Y	N	Y	N
Discount Rate 0%				X				
2%		X	X					X
4%	X					X	X	
6%					X			

Fig. 1. The example of decision table

Decision trees are simply graphical forms of decision making process; an example is given in Figure 2.

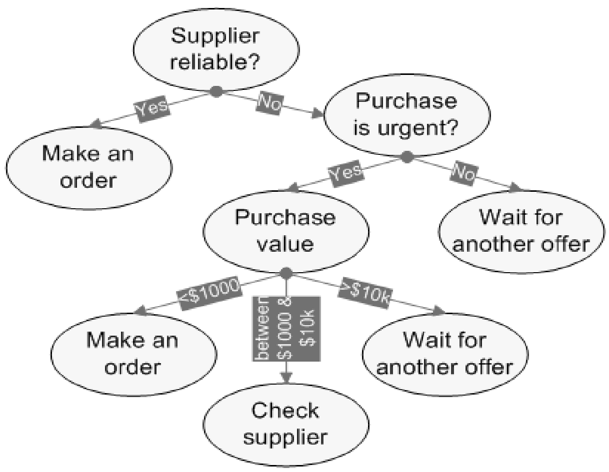

Fig. 2. The example of decision tree

Nodes represent a choice between alternatives (attributes), arrows represent value of attribute, and leafs represent decisions (class). One of the rules form exemplar tree can be *IF supplier is unreliable AND purchase is urgent and purchase value < $1000 THEN make an order*.

Decision grids present rules as functions of two or more inter-related conditions; an example is given in Figure 3.

	Supplier	Reliable	Unreliable
Order value	Rules	Rule1	Rule2
High	Rule1	Make an order	Wait
Low	Rule2	Make an order	Make an order

Fig. 3. The example of decision grid

For example, the first rule from the above grid can be read as *IF supplier is reliable AND order value is high THEN make an order*.

Textual form is sentence expressed in a pseudo-natural language:

IF *atom-condition* [AND *atom-condition*] THEN *atom-action*.

An exemplar of textual form can be *IF supplier.reliability = 'unreliable' AND order.value <$1000 THEN make-an-order = 'yes'*. In some rules editors it is possible to use OR in premises and/or ELSE clause in conclusions, e.g. *IF supplier.reliability = 'reliable' OR order.value <$1000 THEN make-an-order = 'yes' ELSE make-an-order = 'no'*.

2.3. Business Rule Management Systems

A Business Rule Management System is a computer system used to define, distribute, execute, monitor and maintain the decision logic. The major objective of BRMS is to allow describing business and technological processes independently of the software system to be implemented.

A BRMS typically consist of:

– rules repository, which allows decision logic to be externalized from core application code,
– tools to define and manage rules repository by both IT staff and business analysts,
– a runtime environment, allowing applications to fire decision logic and execute it using a business rules engine.

The top benefits of a BRMS include [8]:

– reduce time and resources required to deploy changes,
– author and maintain rules using non-technical language so business experts can manage and validate decision logic with a little, if any, help from IT staff,
– increased control over implemented decision logic for better guide and control the business,
– the ability to express decision logic with increased precision, using a business vocabulary syntax and graphical rule representations,
– improved processes efficiency through increased decision automation.

The core elements of BRMS architecture [7] are presented in Figure 4.

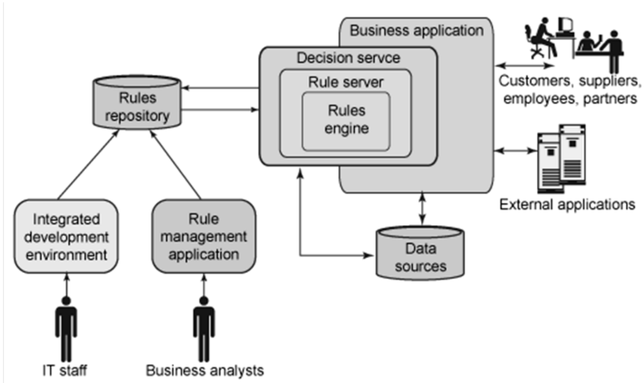

Fig. 4. BRMS architecture

2.4. BRMS application

Rule-based decision tools can be used for quantitative as well as qualitative decisions. Situations in which knowledge-based systems have proved useful include:

– CRM systems (rules describes e.g. an individual client's profile),
– customer assessment systems (e.g. credit rating, customer value),
– sales systems (e.g. complex price lists and cross-selling offers),
– systems supporting supply chain management (e.g. supplier selection),
– cost control and budgeting (e.g. cost accounting, cost estimation, budgeting rules),
– production management (e.g. scheduling, machine maintenance, fault diagnosis, inventory management),
– energy management (power distribution networks, power plant management).

3. Business rules for production planning and scheduling

3.1. Knowledge-based systems in production management

One of the first rule-based system supporting decisions in production management was R1/XCON which went to use in 1980 in one of DEC's plants. The system finally had about 2500 rules and by 1986 it processed over 86,000 orders with 95-98% accuracy [9]. Exemplary XCON rule is shown in Figure 5.

IF:
THE MOST CURRENT ACTIVE CONTEXT IS ASSIGNING A POWER SUPPLY
AND AN SBI MODULE OF ANY TYPE HAS BEEN PUT IN A CABINET
AND THE POSITION IT OCCUPIES IN THE CABINET IS KNOWN
AND THERE IS SPACE IN THE CABINET FOR A POWER SUPPLY
AND THERE IS NO AVAILABLE POWER SUPPLY
AND THE VOLTAGE AND FREQUENCY OF THE COMPONENTS IS KNOWN
THEN:
FIND A POWER SUPPLY OF THAT VOLTAGE AND FREQUENCY
AND ADD IT TO THE ORDER

Fig. 5. Exemplary XCON rule

According to estimations the XCON system brought about $25 millions of yearly savings for DEC [10].

Encouraged by this success researches tried to develop similar systems for supporting more complex decisions in production management, especially for production planning and scheduling.

The first widely described knowledge-based system for production scheduling process was Intelligent Scheduling and Information System (ISIS) developed by Fox and Smith [11] between 1980 and 1984. It dealt with the classical job-shop scheduling problem, which can be defined as finding a sequence of operations in order to complete an order. This is done by the assignment of time and resources (e.g. machines, labour) to each operation. Even this simple to define scheduling problem is NP-hard, which means that there does not exist an algorithm to solve it with polynomial time complexity. Beside this in real production planning there are a lot of constraints which must be satisfied by planners. Thus the ISIS system incorporated a lot of constraints of various nature, which can be grouped into following [11]:

- organizational goals (e.g. due dates, work-in-progress, cost, quality, shifts),
- physical constraints (e.g. machines characteristics, processing and set-up times, quality),
- casual restrictions (e.g. precedents constraints, alternative routes, resources requirement),
- availability constraints (e.g. resource reservations, machines down-times, shifts),
- preference constraints (e.g. operation and machine preferences, sequencing preferences).

The ISIS-2 system was tested in Westinghouse Turbine Components Plant in North Carolina, but restricted only to the part of the plant manufacturing steam turbine blades. Thousands of different type blades were produced and 100-200 different orders were processed in the shop floor at the same time. Each blade had 10-15 operation which were proceeded on 50 machines and human-manned manufacturing cells.

The next generation knowledge-based system was introduced by Smith and Ow in 1985 and called Opportunistic Intelligent Scheduler (OPIS) [12]. It was based on the same assumptions regarding the scheduling problem, however a solving method was different. The complex scheduling problem was gradually decomposed into simpler and relaxed problems in order to satisfy all the shop floor constraints.

ISIS and OPIS systems utilized the model of knowledge based on schema. It is different approach comparing to simple IF-THEN rules model. Schema can be treated as a class in the object-oriented modeling. It means activities, machines, resources etc. are treated as domain objects, both abstract and physical [13]. The rules are encapsulated in the schemas themselves. An exemplary schema for milling operation from ISIS system [11] is shown in Figure 6. It contains e.g. some preceding rules.

milling-operation
{IS A operation
WORK-CENTER: milling-center
DURATION {INSTANCE time-interval DURATION: 5}
NEXT-OPERATION: drilling-operation
SUB-OPERATION: milling-setup milling-run
ENABLED-BY: enable-milling}

Fig. 6. Exemplary ISIS schema

Similar schema-based approach was used in Callisto and OPAL systems [13].

Adiga and Lin [14] presented object-oriented architecture for knowledge-based production scheduling system. They extended Berkeley Library of Objects for Control and Simulation of Manufacturing (BLOCS/M) with the objects, which stores the scheduling rules, however they allowed for the classical IF-THEN rules at the policy selection knowledge level. Such a rule could look like e.g.: *IF shop-state is normal AND no workstation are constrained THEN use FIFO policy.*

3.2. Rule-based representation in production planning systems

Simultaneously with more complex knowledge representation also typical rule-based systems were developed by many researchers. Some examples of rule-based scheduling systems developed at that period has been gathered in Table 1.

Table 1.
Rule-based scheduling systems

Name (authors)	Features
DISPATCHER (Acock, Zemel)	constraint-driven, rule-based automated material handling; developed for DEC
(Bensana, Correge, Bel, Dubois)	job shop scheduling, rule-based
(Bruno, Elia, Laface)	flexible manufacturing system (FMS) scheduling; rule- and simulation based
FSAS (Litt, Chung, Bond, Leininger, Hall)	rule-based; developed to schedule a multi-pass glassing and furnacing operation for glass-lined vessels
ISA (Orciuch, Frost)	assists in scheduling computer assembly; rule-based system
(Kerr, Ebsary)	rule-based production scheduling in a small manufacturing company
(Kim, Funk, Fichter)	FMS scheduling
LMS (Sullivan, Fordyce)	distributed logistics management system developed for IBM
RBD (Clancy, Mohan)	rule based dispatcher using sequencing rules finding jobs to be processed next

Source: on the basis of [13] and [15].

Rules in such systems express empirical associations between decision-making conditions and problem solving actions. They are usually encoded using IF-THEN rules models [16]. Exemplary rule from Bensana et al. system looks like this: *IF a lot is available and could be scheduled but it is known that an essential machine must undergo maintenance in a short time THEN delay this lot and try to schedule another.*

In 1985 the prototype expert priority scheduler (PEPS) was proposed by Robins [15]. Unfortunately no detailed information about this system can be found at this time, PEPS was a ruled-based system dealing with shop floor scheduling, but it was unable to address uncertainty and downstream data dependency.

Logistics Management System (LMS) was developed by IBM and implemented in its semiconductor manufacturing facilities in Burlington. It improved product output on various tools by 20-80% [17]. LMS system can be seen from three levels. Lowest level integrates real-time data collected from various control systems. At the middle level heuristics stream of data is monitored and heuristics based on rules create alerts for decision makers (e.g. about machine down). At the highest level rules may be applied on the basis of state information, part information and organizational objectives either automatically or in decision-support mode, to make actual control decisions [16]. Rules assigning lots to machines (assuming that three advocates give the lots score from 0 (veto against assignment) to 1 (must be assigned) [17]:

IF lot is vetoed (0) THEN drop the lot from selection
IF lot is a must (1) AND no other lot is must lot THEN assign lot
IF there is no must lots THEN assign lot with highest avg score
IF there two or lot are must lots THEN assign lot with highest avg score.

3.3. Fuzzy rule-based scheduling systems

More recently researchers tried to address the uncertainty of many parameters (e.g. operation duration, machine breakdown or material availability) in production system, which must be taken into account by planners. Contrary to the traditional scheduling systems where the rules must be stated in a deterministic way like [13]: *"IF the cement is of type A THEN action-3 will take 5 days"* fuzzy rules can be written as *"IF the cement is of good quality THEN action-3 will take about 5 days"*.

Custodio et al. [18] proposed three level short-range production planning and scheduling system based on rules and fuzzy theory. The main goal was to match demand with production amount while keeping work-in-progress (WIP) level as low as possible under resource failures and demand variations. Similar system was described by Tsourveloudis et al. [19]. This time they proposed rules for three fuzzy control modules (line, assembly and disassembly) while the objective was to WIP inventory and cycle time at low levels, along with high machine utilization and throughput.

Subramaniam et al. [20] proposed ruled-based fuzzy scheduler for job-shop problem. The scheduling process is shown in Figure 7.

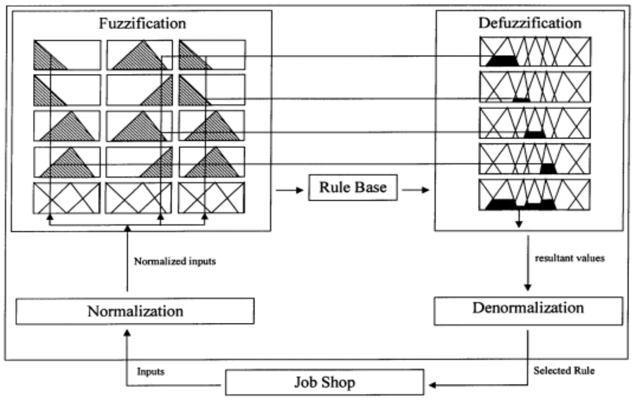

Fig. 7. Fuzzy rule-based scheduler. Source: [20]

4. Conclusions

Business rules can successfully support a wide range of technology and management decisions, starting from sales management and marketing activities, through product design and configuration, up to production planning and scheduling.

Knowledge base utilizing business rules approach combined with modern architecture of computer integrated systems allow for decision making at various production stages i.e. product design, production planning and manufacturing execution and control. Example of such a system for iron casts designing process was described by Feng [21]. Web-based intelligent agent system was used to integrate both the design information and manufacturing process information (knowledge base) for selection of manufacturing processes and resources during iron casts design process. The main purpose of this platform was to support product preliminary design, optimize product form and structure, and reduce the manufacturing cost in the early design stage.

The aim of this paper was to indicate possible applications of rule-based approach in production planning and scheduling. Many solutions described in the paper can be implemented also in the computer decision support systems for iron cast manufacturers.

Acknowledgements

This research has been partially supported by the Innovative Economy Operational Programme EU-founded project (UDA-POIG.01.03.01-12-163/08-03).

References

[1] D. Waters, Operations Management: Producing Goods and Servicess, FT Prentice Hall (2001)
[2] M. van Eck, Advanced Planning and Scheduling. Is logistic everything? BWI paper, Universiteit Amsterdam (2003)
[3] E. Hackmack, VAI-PPC – An Integrated Production Planning and Control System for Steel Industry, Proceedings of CPC'93, Seul (1993) 218-228

[4] R.G. Ross, Principles of the Business Rule Approach, Addison Wesley (2003)

[5] B. von Halle, L. Goldberg (ed.), The Business Rule Revolution. Running Business the Right Way, Happy About, Silicon Valley (2006)

[6] The Business Rules Manifesto, www.business-rulesgroup.org/brmanifesto.htm

[7] The role of a rules architect, www.ibm.com/developerworks/library/ar-busrules2

[8] ILOG Business Rules Management System, www.ilog.com/products/businessrules/index.cfm

[9] A. Günter, C. Kühn, Knowledge-Based Configuration. Survey and Future Directions, Lecture Notes in Computer Science, vol. 1570 (1999) 47-66

[10] C. Huyck, Lectures on Knowledge Based Systems for Business, Middlesex University (2008)

[11] M.S. Fox., S. Smith, ISIS: A Knowledge-Based System for Factory Scheduling, Expert Systems Journal, vol. 1, No. 1 (1984) 25-49

[12] S.F. Smith, M.S. Fox, P.S. Ow, Constructing and Maintaining Detailed Production Plans: Investigations into the Development of Knowledge-based Factory-scheduling Systems, The AI Magazine, vol. 7, No. 4 (1986) 45-61

[13] S.J. Noronha, V.V.S. Sarma, Knowledge-Based Approaches for Scheduling Problems: A Survey, IEEE Transactions on Knowledge and Data Engineering, vol. 3, No. 2 (1991) 160-171

[14] S. Adiga, W.T. Lin, An object-oriented architecture for knowledge-based production scheduling systems, Journal of Intelligent Manufacturing, vol. 4, No. 2 (1993) 139-150

[15] S. Smith, Knowledge-based production management approaches, results and prospects, Production Planning & Control, vol. 3, No. 4 (1992) 350-380

[16] K. Metaxiotis, D. Askounis, J. Psarras, Expert systems in production planning and scheduling: a state-of-the-art survey, Journal of Intelligent Manufacturing, vol. 13, No. 4 (2001) 253-260

[17] G. Sullivan, K. Fordyce, IBM Burlington's Logistics Management System, Interfaces, vol. 20, No. 1 (1990) 43-64

[18] L. Custodio, J. Sentieiro, C. Bispo, Production planning and scheduling using a fuzzy decision system, IEEE Transactions on Robotics and Automation, vol. 10, No. 2 (1994) 160-168

[19] N.C. Tsourveloudis, E. Dretoulakis, S. Ioannidis, Fuzzy work-in-process inventory control of unreliable manufacturing systems, Information Sciences, vol. 127, No. 1-2 (2000) 69-83

[20] V. Subramaniam, T. Ramesh, G.K. Lee, Y.S. Wongand, G.S. Hong, Job Shop Scheduling with Dynamic Fuzzy Selection of Dispatching Rules, The International Journal of Advanced Manufacturing Technology, vol. 16, No. 10 (2000) 759-764

[21] S.C. Feng, Preliminary design and manufacturing planning integration using web-based intelligent agents, Journal of Intelligent Manufacturing, vol. 16, No. 4-5 (2005) 423-437