Event Classification System to Reconsider the Production Planning

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Abstract: On-going production planning can be affected by unexpected events that modify the planned scenario. Decision makers must react in some way to avoid problems in the production system when these events appear. Thus providing information about these events can be critical for decision makers, as events can affect not only operational processes but also previously made decisions. We herein propose an event monitoring system that classifies events into different impact levels. This information helps production decision-makers to consider changes in the on-going production planning. Furthermore, a risk matrix can be built, which determines the significance of the risk from the impact level and the likelihood. This likelihood of occurrences of these events can be estimated from the historical information of the event monitoring system. A prototype has been built following this proposal.

1 INTRODUCTION

Planning deals with finding plans to achieve some goal (Barták 1999) and production planning is a partial planning approach for a particular function of a company (Buzacott et al. 2012). Production planning also usually covers the allocation of activities to factory departments, which is a typical scheduling task. Production planning uses information to generate processing routes and to find what raw material should be ordered and when (Barták 1999).

Once production planning decisions have been made and planning is ongoing, unexpected events can appear. Any cause (e.g. machine breakdowns or changes in firm orders) that endangers current production plan validity could lead to re-generating the entire plan (Özdamar et al. 1998). However, the difficulties of adapting the production plans produces that often no changes are made (Van Wezel et al. 2006). The conception and implementation of appropriate information and communication systems is a basic condition for identifying critical incidents (Shamsuzzoha et al. 2013). In this sense, Scala et al. (2013) indicate that data collected from sensors must trigger a chain of events leading to changes within enterprise business process, collaboration mechanism or organizational framework. Such changes can be achieved in terms of simple sense-act enterprise behaviour (direct link between sense and act) or more complex sense-plan-act approach (decision level). Hence the first objective of an event monitoring system is to sense production information about a real-time environment and to detect events.

Enterprises normally use tools that provide them with information to make decisions. According to (Chen 2004), Decision Support Systems (DSSs) are designed to use decision makers' own insights and judgments in an *ad hoc*, interactive analytical modeling process, which leads to a specific decision. So an event monitoring and management system should interact with DSSs to manage events that might affect previously made decisions. It should act as a supra-system that identifies when previous decisions are still valid or need to be reanalyzed. Thus traditional DSS configuration should be extended to treat event management by a monitoring and management system, which monitors internal and external information (Boza et al. 2014). This event information can also be represented in the form of rules, such as IF–THEN. For example, if a firm order exceeds a specific value, an alert is triggered. This set of rules represents an expert system: it contains information obtained from a human expert, which is represented in form of rules (Liao 2005).

According to the ISO/Guide 73:2009 (2009), risk is the combination of the probability of an event and its consequences when exploiting any vulnerability.

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So, with the information of events, risks can also be identified. We propose herein a monitoring software application, based on rules, that detects unexpected events in production planning and identify risks produced by these events. In order to explain our purpose in this paper: Section 2 reviews problems in production planning in the literature; Section 3 deals with event management; Section 4 defines expert decision support system based on the literature; Section 5 explains our proposal to monitor and classify events; Section 6 offers a prototype of this proposal; Section 7 presents the conclusions drawn from this approach.

2 INCIDENCES IN PRODUCTION PLANNING

Production planning can be affected by different unexpected events or incidences, for example, a broken machine or a huge order. In the literature, authors have dealt with these problems in different ways. Chan et al. (2006) indicate that frequent changes in the current schedule may lead to disturbances in production, and may result in lateness orders or increased production costs. Weinstein and Chung (1999) explain that when production equipment displays signs of failure, or they occur after, this may adversely affect both production plan integrity and product quality. Poon et al. (2011) explain that in the actual manufacturing environment, shop floor managers face numerous unpredictable risks in day-to-day operations, such as defects in supplies of components or raw materials, or errors, failures and wastage in various production processes. Baron and Paté-Cornell (1999) indicate that during the manufacturing process, unexpected interruptions appear, which could be accidents, machine breakdowns or human errors. In a cookie factory case, Van Wezel et al. (2006) study planning flexibility and classify events according to their source: a) Customer (e.g. rush order, change in order volume, or earlier/later delivery date); b) Product (e.g. raw material out of stock, too little or too much stock of end product(s), or product sent back); c) Process (e.g. setup/cleaning time variation, more/less waste, or higher/ lower production speed; d) Machines/staff (e.g. long disruptions, shortage or surplus capacity, or variation in run-in times). All these planning problems need to be managed and it is necessary to decide how to deal with these events.

To deal with the events, their detection is a very important task. Once an event occurs in a company, event information is stored in the system and analysis information is delivered. With this information, decision-makers decide what action must to take to solve the problem. If the detection of the event is slow, the troubles will be bigger. In this sense, new technologies like Internet of Things can help in this purpose. A quicker identification of relevant events is necessary to make a quicker analysis of their consequences. SAP (2014) highlights how value diminishes as time elapses between when data is first captured and when an action or decision is triggered. This analysis must include not only a short-term point of view, but also the consequences for the on-going production planning.

3 EVENT MANAGEMENT

Event management consists in anticipating and planning solutions for business events before they appear rather than reacting after damage is produced. The literature includes various authors who deal with event management not only for a company but also for business networks, such as Virtual Organizations (Carneiro 2013) or Collaborative Networks (Vargas et al. 2014). Baron and Paré-Cornell (1999) provide an analytical and dynamic link between the Risk Management System and the long-term productivity and safety performance of the physical system. Barash et al. (2007) purpose a decision support tool for the business impact analysis and improvement of the incident management process in IT support organization. Bartolini et al. (2010) present an approach to assess and improve the performance of an IT support organization in managing service incidents based on the definition of a set of performance metrics and a methodology. This guided analysis allows users to find the root causes of poor performance and to decide about the corrective actions to be taken. Liu et al. (2007) develop an approach for modeling event relationships in a supply chain through Petri nets as a formalism for managing events. Söderholm (2008) aims to outline different categories of unexpected events that appear in projects as a result of environmental impacts and how these are dealt with. Bearzotti et al. (2012) present an agent-based approach for the Supply Chain Event Management problem, which can perform autonomous corrective control actions to minimize the effect of deviations in the plan currently underway. These approaches made different event classification to manage the unexpected events: according to its impact (Baron and Pate-Cornell 1999), according to its supporting (Bartolini et al. 2010)and according to specific groups given by the company (Liu et al. 2007; Bearzotti et al. 2012). Only one of these research made a monitoring system to detect events (Bearzotti et al. 2012). But all these approaches require an expert engineer to define the rules.

A very accepted classification of events is according to their impact in the organization on a scale from 1 to 5, where 1 represents the least level and 5 the strongest (Shamsuzzoha et al. 2013). Knowing the severity of the event, risk can be identified by the occurrence likelihood of this event. Thus a risk matrix can be used to classify events. This matrix has several categories, "probability," "likelihood" or "frequency", for its columns and several categories, "severity," "impact" or "consequences", for its rows. It associates a recommended level of risk, urgency, priority or management action with each row-column pair; that is, with each cell (Cox Jr. 2008).

These risk matrices have been widely praised and adopted as simple effective approaches to risk management. According to Cox (2008), their main advantages are that they provide: (1) a clear framework for the systematic review of individual risks and portfolios of risks; (2) convenient documentation for the rationale of risk rankings and priority setting; (3) relatively simple inputs and outputs, often with attractively colored grids; (4) opportunities for many stakeholders to participate in customizing category definitions and action levels; (5) opportunities for consultants to train different parts of organizations on "risk culture" concepts at different levels of detail. So the risk matrix is an appropriate tool to classify events.

4 EXPERT DECISION SUPPORT SYSTEM

DSSs are normally used as a tool to make decisions when faced with certain problems. They are defined as computer systems that deal with a problem where at least some stage is semi-structured or unstructured. A computer system can be developed to deal with the structured portion of a DSS problem, but decision makers' judgment must consider the unstructured part, to hence constitute a human-machine problem-solving system (Shim et al. 2002). The primary purpose of DSSs is to help decision-makers develop an understanding of the ill-structured complex environment represented by the model (Steiger 1998).

Turban and Watkins (1986) described the Expert System like a computer program, which includes a knowledge base that contains an expert's knowledge for a particular problem domain, and a reasoning mechanism for propagating inferences on the knowledge base. The benefits generated by expert systems include (Cohen and Asín 2001): (1) less dependence on key personal; (2) facilitating staff training; (3) improving the quality and efficiency of decision making; (4) transferring the ability of making decisions. Integrating an Expert System into DSSs helps obtain more benefits. These benefits can be used in several dimensions (Turban and Watkins 1986): Expert Systems contribution, DSS contribution, and the synergy resulting from the DSS/ES combination.

5 PROPOSAL OF AN EVENT MONITORING SYSTEM FOR CLASSIFICATING EVENTS TO RECONSIDER THE PRODUCTION PLANNING

An event monitoring application should interact with the DSS used in the production planning system by decision makers. However, expert knowledge is necessary to identify and classify potential events by their impact level. Given the advantages of the Expert DSS presented in the previous section, we propose an Event Monitoring System (EMS) based on an Expert DSS, which identifies and classifies events (CE) that have an impact on on-going production planning and interact with the DSS used in production planning (PP) systems, dubbed as EMS-CE-PP. Depending on its likelihood and impact level, the system indicates the seriousness of the event in the previously shown standard risk matrix. This likelihood can be estimated by the system, counting the number of times that an event appears.

The proposed expert DSS does not use an Expert System like an intelligent program, which automatically makes a decision, but uses it like a support system for decision makers.

5.1 Event Monitoring System (EMS) Framework

Some enterprises generate their production planning with DSSs that use mathematical models (Model-

Driven DSS). The decisions made with these Model-Driven DSSs can be affected by different events. A significant set of events to be identified includes those that affect the planning generated by these Model-Driven DSSs. The mathematical models used in these DSSs are written in modeling languages, such as Modeling Programming Language (MPL). So it is possible to extract parameters and decision variables from these models that can be affected by events. The parameters and decision variables form a set of attributes of the models.

This is the starting point for our proposal, where an expert in production planning systems selects the set of attributes that require a control. These attributes will be used to make rules. A rule is a condition defined by the decision maker to identify the events: if this condition goes into effect, an event alert appears. These rules are made by the expert, a person with high knowledge about event detection in production. This expert is usually the decision maker.

The objective of these rules is to identify changes in the production system to reconsider the current production planning generated by the DSSs between each re-planning period. The current information about the production systems can be significantly different from the previous information used by the DSSs when the current planning was generated.

This proposal extends the DSS proposed by Boza et al. (2014), which includes three phases: (1) model and attributes selection: experts select decision models and the attributes (of these models) that can be affected by events; (2) criteria creation and visualization: experts create alert criteria about previously selected attributes; (3) execution: validation of the alert criteria conditions executed manually or automatically. Our proposal herein intends to extend the previous proposal to include the event classification and risk identification based on the risk matrix. This information allows the decision-maker reconsider the current production planning. The following paragraphs review these phases and detail our proposal.

5.2 Model and Attributes Selection

An expert in production planning systems selects the mathematical models used in the planning production decision system to analyze the alert criteria on them. After selecting the models, experts can identify the model's parameters and decision variables to create the alert criteria to identify events. These selected attributes must have impact into the production planning and its variation can produce a modification in the production decisions. For example: variation in demand or machine setup times.

5.3 Criteria Creation and Visualization

Alert criteria can be defined according to the selected attributes and a classification of the events can be made. We propose using five impact levels for each criterion: Extremely Serious Level, Serious Level, Substantial Level, Moderate Level and Low Level. Each level is achieved according to a logical operation formed by constants, attributes and functions. Alerts are triggered when a true value appears in these logical operations. Constants are values that are introduced directly by the expert; attributes are the previously selected parameters and decision variables; functions are operations formed by attributes and constants, such as addition, averages, etc.

Enterprise information is dynamic, so any unexpected development of an attribute should be analyzed. In order to consider this development in the alert criteria, it is necessary the *current* and/or *previous* values for each attribute in the alert criteria; i.e., attributes values are taken from the current production system state and/or from the previous state (when the production planning was made). Thus, decision makers introduce rules (using logical conditions) to identify events. *Table 1* shows combinations in these logical conditions (A -logical condition- B).

Table 1: Possible combinations of logical operation to criteria creation.

A		B
Current Attribute Value	**Logical condition**	Previous Attribute Value
Current or Previous Attribute Value		Constant Value
Current or Previous Attribute Value		Function Result
Function Result		Constant Value
Function 1 Result 1		Function 2 Result

Alert criteria can also be defined for *particular* objects (e.g. the demand limit value of a specific product), or from a *general* perspective, (e.g. the demand limit value of all the products).

5.4 Execution

After creating the alert criteria, decision makers can use the Event Monitoring Systems to evaluate the situation with these criteria. This evaluation can be made automatically (e.g. by time intervals: hourly, daily or weekly) or manually. During these evaluations, the EMS-CE-PP checks the criteria (using the rules previously introduced) with the enterprise information, and as a result, events can be detected and decisions makers are alerted.

5.5 Event Impact Classification

Decision makers obtain new information after each execution. This information shows detected events related with each criterion and the impact level that produces that event. Also, the information about the number of occurrences of the event is stored to have historical information in order to obtain the likelihood and calculate the risk.

The impact of the event had been indicated previously by the expert and the likelihood is estimated by the system with the information of previous executions. This information allows decision makers to identify the impact of the event in order to evaluate the situation, try to solve the problem and, if necessary, change the on-going production planning, and to obtain information about the event risks.

Figure 1 shows the event monitoring system framework proposal.

6 EMS-CE-PP PROTOTYPE

An Event Monitoring System prototype to Classify Events to reconsider the Production Planning was developed using Java libraries. The main elements used in the application were:

- Mathematical models used for the DSS to propose the production planning. The mathematical models have been defined in Mathematical Modeling Language (MPL).
- Databases with information about production. These databases include information about the current situation of the production system and the previous information of the production system when the DSS proposed the production planning.
- An internal database which includes the knowledge database.

The internal database has four main tables: *attributes* table to save the attributes of the model selected by the user; a *criteria* table, which stores the criteria created by decision makers; an *execution criteria* table, which saves information on execution (if execution is automatic or manually, interval time, etc.). Once execution has been run, the results are saved in the *results* table, which saves the information on each alert criterion (attributes values, event significance, event frequency, etc.).

6.1 Model and Attributes Selection

The EMS prototype allows the user to select an MPL file in order to load the attributes used in this model. An expert can select between these attributes, which will be used to create the alert criteria. Furthermore, a link must be created between the attribute and

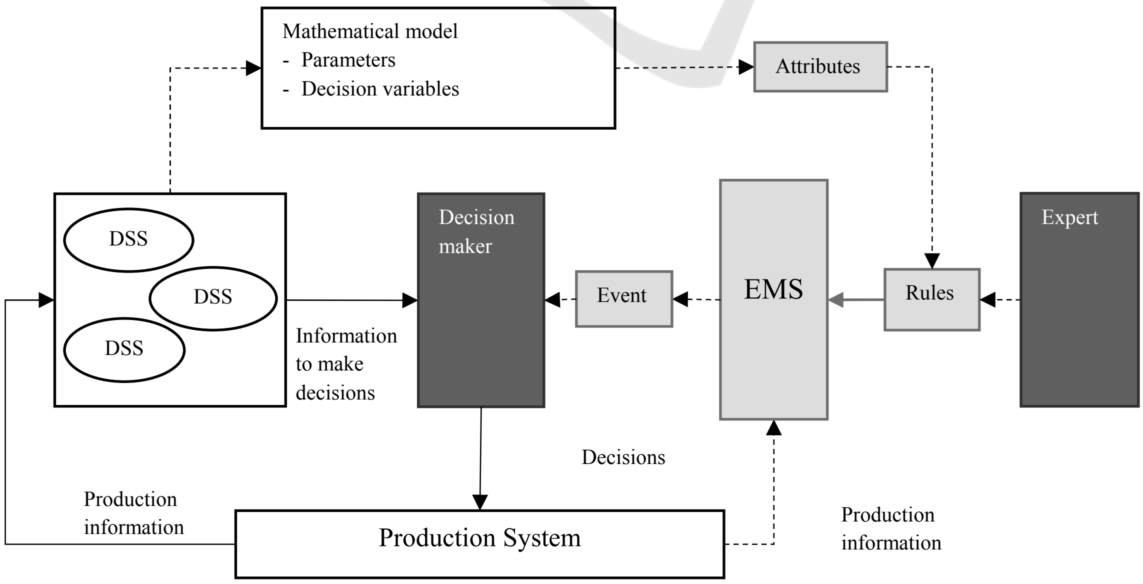

Figure 1: The event monitoring system framework.

the database (table and column) that contain their values.

The criteria creation form includes name, criteria operands, the logic operation to be performed with these operands, the impact level and a description. Also, some attribute characteristics need to be identified: (1) the attributes data in the criteria can be obtained from *current* values or *previous* values; (2) the alert criteria is general or for a particular object. This information is stored in the internal database.

6.2 Execution

Periodical or manual monitoring can be made using the EMS-CE-PP prototype. The event monitoring system obtains information from the production databases in order to evaluate the criterion previously defined. This evaluation of each criterion allows identifying the impact levels for each criterion: Extremely Serious Level, Serious Level, Substantial Level, Moderate Level and Low Level. If an alarm appears in several levels for the same criterion, it is stored the most serious level.

6.3 Event Impact Classification

The information is presented like a criterion list. A warning icon appears and indicates that an alarm occurs in this criterion. Production information is shown in green, yellow or red according to the impact level. This information can be evaluated for the decision-makers to reconsider the validity of the current production planning.

7 CONCLUSIONS

Production processes include quite complex decision making, and consequently, production plans are launched. Unexpected events can appear while these plans are on-going, which could have a major or minor impact on these on-going plans. If the impact is major, it can force a change to be made in the established planning. This research proposes an Event Monitoring Software Application based on an expert system to identify the events and to classify them according to their impact level on production planning.

Experts can create production system alert criteria. In this way, decision makers can monitor these events and check if there are any unexpected events.

This proposal presents some advantages: i) own creation of impact criteria (rules) according to each production system to classify events; ii) connection with the DSS models used in the production planning and the production information system; iii), information to alert decision makers to decide whether to change production plans or not.

Some future research lines of this system are:

- As mentioned earlier, the EMS-CE-PP alerts the decision makers about the critical events in their production system. However, it does not evaluate their economical impact. Our proposal could be improved if a cost/benefits analysis is included in order to provide further information.
- Most organizations have a hierarchical structure and make hierarchical decisions. The system could consider different hierarchical levels in production planning and define different sets of criteria at each planning system level.
- Using IoT technologies: IoT technologies are able to give further information about the Production Systems. An Event Monitoring System could take these technologies into account in order to identify quickly relevant events in the Production System and to extend the EMS analysis with new information gathered with these technologies.

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