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Design and evaluation of an analytical framework to analyze and control production processes

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Abstract

Decision makers in industry use IT systems to enrich task fulfilment with information systematically. Next to engineering-driven concepts, the application of Operational Business Intelligence (OpBI) is discussed to support production-specific decisions and to organize production processes. Currently, this discussion focusses rather on practicability studies than on certain implementations. Therefore, we introduce a framework to analyze industry processes using design science research. Evaluation is carried out with data from a rod and wire rolling process in forming industry. In conclusion, the framework approach improves capabilities of users to analyze a steel's rolling behavior during rolling experiments automatically.

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Keywords: Operational Business Intelligence; Decision Making; Prototyping; Standardization; Rolling

1. Introduction

Manufacturing companies use IT systems to execute, record, model, or control production processes [1]. Common examples are automation systems, tools for product development, or operational execution systems [2]. Moreover, manufacturing managers need intelligent and integrated decision support systems that provide information from different viewpoints of production processes systematically [3]. In order to gain such benefits from using information systems in production, data from different sources (e.g. automation systems) have to be collected, harmonized and integrated [4]. However, dynamic and networked process structures challenge organizations in integrating data from IT systems used in production environments [5]. Integration approaches come along with a huge amount of manual work and lack in standardized and reusable methods [3]. Consequently, analysis of production data is time-consuming and happens in different subsystems, which do not share information for a decision making automatically [4]. In order to address these challenges in integrating and analyzing production data, manufacturing companies have the opportunity to consider IT concepts from an analytical information systems' perspective. Recently, literature studies discuss OpBI as a beneficial strategy to generate decision-relevant information out of production data, which stem from different IT systems [6]. However, this discussion deals rather with a common applicability of OpBI in production environments [7], than with implementations of certain methods and tools for an automated acquisition, consolidation, and analysis of production data. Thus, there is no evidence that the concept of OpBI actually works in practice. Efforts, benefits and obstacles of integrating and analyzing production data automatically remain fuzzy in a particular application scenario. The paper's goal is therefore to investigate an actual implementation of OpBI in a certain production environment.

There are currently no studies that deal with an automated integration and analysis of production data in a standardized and reusable way. Discussions about Smart Manufacturing [8], Manufacturing Intelligence [9], or Industry 4.0 [10] demand admittedly a data-driven decision support in production environments, but they do not elaborate on tangible tools and methods in order to prepare and analyze data of production processes adequately. To support such activities, we apply design science research to develop an OpBI framework that joins capabilities like data modelling, data transformation or data manipulation for an integrated analysis and control of

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production processes. The evaluation happens during a framework application in context of integrating data from a rod and wire rolling process. Analytical tools and methods are used to demonstrate functional reliability of OpBI in an industry-driven use case. Finally, process engineers perform an assessment of the OpBI application in comparison to the traditional approach of analyzing rod and wire rolling data. To the best of our knowledge, this paper is the first contribution that discusses efforts, benefits and obstacles in integrating and analyzing real-world production data by use of established tools and methods from analytical information systems' perspective, yet. We document practical knowledge about an actual implementation of OpBI in a production environment, so that practitioners and researchers gain a standardized guideline to design an automated data-driven management support for production-specific decisions.

The paper is structured as follows: Chapter 2 discusses the status quo of OpBI and its application in production environments. The paper uses phases of design science research presented in Chapter 3. Chapter 4 introduces our framework and Chapter 5 demonstrates its evaluation using an example process of forming industry. A discussion of results follows in Chapter 6. Finally, Chapter 7 concludes the paper's implications and highlights further research perspectives.

2. Problem Refinement

OpBI supports analytical IT system capabilities that collect, integrate, and present business relevant information in a decision-oriented way [11], which allows an analysis of process performances to identify control actions for a continuous improvement of process design and execution. Production environments open a broad potential application area for OpBI [12]. Manufacturing companies collect a lot of data about products, manufacturing processes or quality issues. Furthermore, automation systems, sensor technologies or computing devices make large amounts of data available. [4] The demand for a pervasive and ubiquitous usage of data in production environments is even increased by future-oriented smart factory initiatives [13]. A tracking of products through plants and working stations represents an exemplary scenario for data usage in a smart factory. In that context, production cockpits [14] are able to visualize throughput times, upcoming bottlenecks, material consumptions, or overall efficiencies.

An important qualification for such capabilities in a smart factory is an accurate, fast and automated integration of underlying production data [13]. OpBI offers standardized tools and methods in this context, which form a basis to take production-specific decisions, e.g. an allocation of new work to idle capacities. It has to be noted that such decisions cannot be easily reversed, if continuous workloads require a steady processing of production orders. Wrong decisions increase risks of defective products and lead to additional efforts for a correct task fulfilment. To avoid such inconvenient situations, the OpBI's activities to consolidate and harmonize production data have to ensure that decision makers are well provided with high-quality information. A seizure of quality in terms accessing and representing information can be guided by the following requirements [15]:

- Concise representation requires compactness and precision of information to avoid overwhelming and unnecessary information.
- Consistent representation requires a coherent and invariant format of information.
- Interpretability requires the usage of appropriate units, definitions or labels.
- Understandability requires unambiguously and comprehensible information.
- Ease of operation requires easy manipulations of information.

A compliance of information quality in context of an automated integration and analysis of production data has not been investigated, yet. Literature studies theorize generally a positive effect of analytical IT approaches like OpBI on aspects of information quality, i.e. decision time and accuracy [16]. However, a usability of OpBI concerning the abovementioned quality criteria has not been confirmed in empirical investigations [17]. The paper investigates therefore the effect of OpBI usage on information quality aspects in production environments.

3. Research Design

Our research follows principles of design science research (DSR) [18]. We refer to five phases of DSR in order to develop and evaluate an OpBI framework for a production-specific decision support (Cf. Figure 1).

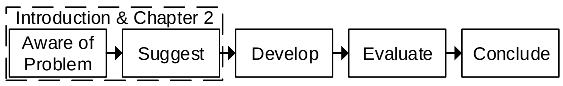

Fig. 1. Phases of DSR according to [19]

The first phase aims to raise awareness for the given problem domain and results in a proposal. This is followed by a suggestion of a tentative design. In context of our research, the first two phases are carried out in the introduction of the paper and in Chapter 2. We discussed a need for an automated data integration to support decisions in production environments and suggest an application of OpBI techniques within this problem area. Subsequently, an OpBI framework will be developed and evaluated in the course of this paper.

4. OpBI Framework

Figure 2 illustrates the schematic overview of our framework. We build up on framework requirements stemming from a specific process design and operation. First, there is a need for layout data regarding to the process equipment (e.g. machines, measuring points and instruments) and in terms of measurement parameters. Second, operational data from different process runs are required. This concerns for example planned input and output data for each process step, machine settings, or measured values. Therefore, it has to be ensured