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Profit per hour as a target process control parameter for manufacturing systems enabled by Big Data analytics and Industry 4.0 infrastructure

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Abstract

The rise of Industry 4.0 and in particular Big Data analytics of production parameters offers exciting new ways for optimization. The majority of factories in process industries currently aim for example, either for output maximization, yield increase, or cost reduction. The availability of real-time data and online processing capability with advanced algorithms enables a profit per hour operational management approach. Profit per hour as a target control metric allows running factories at the optimal available operating point taking all revenue and cost drivers into account. This paper describes the suitability of profit per hour as a target process control parameter for production in process industries. The authors explain how this management approach helps to make better operational decisions, trading off yield, energy, throughput, among other factors, and the resulting cumulative benefits. They also lay out how Big Data and advanced algorithms are the key enabler to this new approach, as well as a standardized methodology for implementation. With profit per hour an agile control approach is presented which aims to optimize the performance of industrial manufacturing systems in a world of ever increasing volatility.

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1. Introduction

Industrial companies are currently facing challenging times due to globalization, rapid changes in both, supply and demand markets and innovation in technology [1]. Key challenges such as volatility and uncertainty are steadily increasing in today's business environment [2,3]. The volatility of revenues and profitability in US firms for example, doubled between the years 1960 and 2000 [4]. The pressure on manufacturing industries intensifies due to their typically high capital employed and the resultant incurred costs [5].

In this constant state of change, organizations that recognize and react quickly and intelligently to market swings increase their competiveness [6]. More effective and quicker decisions might be achieved through transformation of the data volumes now available into information and knowledge [7]. The availability of data is driven by innovation in advanced manufacturing technologies. The integration of digital and intelligent technologies enables companies to raise the level of management with the objective of finding its best operating model [8].

Digitalization as one of the core themes for the upcoming fourth industrial revolution is commonly discussed under the umbrella term "Industry 4.0". The goal of this research is to enable smart operational decision making to optimize operations for maximum profitability using a time-based operations management approach.

This paper is structured in six chapters. After this introduction, chapter 2 reviews the evolution of data-based decision making. In chapter 3 the profit per hour approach is explained. Chapter 4 presents the application of the developed approach in the process industry on an Ammonia production process. Finally, the results are discussed in chapter 5, prior to a brief summary and outlook in chapter 6.

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2. Evolution of data-based decision making

Data has always been the basis for management accounting and control systems, which aim to increase transparency in decision making. Management control chooses operating rules for elements of an organization and the prioritization for operating rules in order to maximize the overall objective function [9]. Maximizing this overall function comprises the effective and efficient use of resources [10]. Management accounting research considers the economic structure of a firm and identifies the overall objective in finding an output-input combination that derives the maximal profit [11].

Thinking further into the future, this might all result in a formula that could even make human decision making dispensable. As long ago as 1955, however, Peter Drucker said a magic formula to take the place of the decision-making process is purely irrational. The best possible outcome is to make judgement possible by narrowing down the multiplicity of an issue and its available alternatives [12].

2.1. Performance measurement

Management accounting and control systems led to the development of performance management systems. These systems provide an overall framework and cope with both operational and strategic management activities. Furthermore they include different performance measurements due to the co-existence of various target dimensions to assess and control the overall performance [13]. Balanced scorecards combine different performance measurements, goals and objectives in a systematic manner [14]. The set of metrics used to quantify both the efficiency and the effectiveness of actions define a performance measurement system. Categorization of performance measures (Fig. 1) exists in various forms [15].

Quality	Flexibility
Q1: Performance	F1: Material quality
Q2: Features	F2: Output quality
Q3: Reliability	F3: New product
Q4: Conformance	F4: Modify product
Q5: Technical durability	F5: Deliverability
Q6: Serviceability	F6: Volume
Q7: Aesthetics	F7: Mix
Q8: Perceived quality	F8: Resource mix
Q9: Humanity	
Q0: Value	
Cost	**Time**
C1: Manufacturing cost	T1: Manufacturing lead time
C2: Value added	T2: Rate of production introduction
C3: Selling price	T3: Deliver lead time
C4: Running cost	T4: Due-date performance
C5: Service cost	T5: Frequency of delivery

Fig. 1. The multiple dimensions of quality, time, cost and flexibility [15].

Despite the different dimensions of capturing performance, the lasting value from performance measurement systems lies in the linkage from data to suitable decision-making and to the actions and feedback derived from them [16].

2.2. Big data for decision making

Using and analyzing data to support decision-making has a long history in industry [6]. Data-based decision making has evolved from decision support, to executive support with a focus on data exploration in order to make decisions at top-management levels. As an emerging development starting in 1990, online analytical processing introduced software tools to analyze multidimensional data. At the same time business intelligence tools focusing on reporting evolved to support data driven decisions. The next step in the evolution of data-driven decision making came with analytics emphasizing mathematical analyses. At the present time the immense volumes of unstructured and rapidly changing data sets are processed under the umbrella of Big Data [17]. The expected benefits from better strategic and operational decisions based on real-time data, e.g., supplied by Industry 4.0 technologies, extend across all industries [18,19].

2.3. From management control to operational process control

In the context of control levels, the authors distinguish in the following between the management level with a scope of overall plant or company related tasks, and the operations level focusing on processes (Fig. 2). Scope, processes and time dimension vary across these control levels.

Level	Scope	Exemplary processes	Time dimension
Management	Company Plant	Corporate strategy Operations strategy Sales and Operations Planning	Years Quarters Months Weeks
Planning		Control	
Operations	Plant Process	Start-up and shut-down optimization Overall Equipment Effectiveness Yield, energy, throughput, quality optimization	Weeks Days Shifts Real-time

Fig. 2. Control levels.

When investigating the operations level in more detail, true value added is the linkage from data to set actions [16]. Data driven, automated process control on the operations level in the past had the objective of operating a process safely and efficiently [20]. The advancement of computer controlled systems in manufacturing enabled process optimization towards best operating conditions [21]. So called advanced process control (APC) systems evolved through the combined efforts of engineering knowledge, statistical methods and powerful modelling. The benefits of APC systems in process industries, e.g. refineries, are well proven [22]. Nevertheless suitable control systems for more-complex processes and the usage of APC for smaller and secondary processes have long been lacking. Upcoming technologies enable new manufacturing analytics methods, see Fig. 3 [23]. Big Data and advanced data analytics in particular enable automated decision-making prescribing as well as causing actions on a real-time operational basis [24].