ORIGINAL SCIENTIFIC PAPER

RECEIVED: MARCH 2020

REVISED: MAY 2020

ACCEPTED: AUGUST 2020

DOI: 10.2478/ngoe-2020-0015

UDK: 005.32:005.35

JEL: M11, M12

Citation: Šarotar Žižek, S., Nedelko, Z., Mulej, M., & Veingerl Čič, Ž. (2020). Key Performance Indicators and Industry 4.0 – A Socially Responsible Perspective. *Naše gospodarstvo/Our Economy*, *66*(3), 22 – 35. DOI: 10.2478/ngoe-2020-0015

Key Performance Indicators and Industry 4.0 – A Socially Responsible Perspective

Simona Šarotar Žižek
University of Maribor, Faculty of Economics and Business, Slovenia
simona.sarotar-zizek@um.si

Zlatko Nedelko
University of Maribor, Faculty of Economics and Business, Slovenia
zlatko.nedelko@um.si

Matjaž Mulej
University of Maribor, Faculty of Economics and Business, Slovenia
matjaz.mulej@um.si

Živa Veingerl Čič
Doba fakulteta, Maribor, Slovenia
ziva.veingerl-cic@doba.si

Abstract

The main aim of this contribution is to outline the role and importance of key performance indicators in the frame of Industry 4.0 implementation. These key performance indicators are presented as a cornerstone for industry 4.0 implementation in organizational practice, since they represent key input for needed data in digitalized organization. In that framework, the contribution first exposes some of the essential characteristics of "Industry 4.0", followed by the methodology of key performance indicators (KPI). Next, the contribution outlined a proposed methodology for implementing KPIs in frame of Industry 4.0 adoption in organizations. Another section of the paper is dedicatd to the linkage between corporate social responsilbty and KPIs in frame of Industry 4.0. The paper also outlines implications, limitations and further research directions are outlined.

Keywords: Industry 4.0, key performance indicators (KPI), social responsibility

NG OE

NAŠE GOSPODARSTVO
OUR ECONOMY

Vol. 66 | No. 3 | 2020

pp. 22 – 35

Introduction

The term "Industry 4.0" was first introduced at the Hannover Messe Fair in 2011. Industry 4.0 (I4.0) can be defined as »real-time, intelligent, and digital networking of people, equipment and objects for the mangement of business processes in organizations« (Dombrowski et al., 2017). Since the emergence of this new phenomenon, there has been a constant increase of literature on Industry 4.0. It addresses theoretical discussions about the phenomenon of Industry 4.0 (Drath & Horch, 2014; Weyer et al., 2015); case studies on the implementation of Industry 4.0 principles in various industries (Oliff & Liu, 2017; Caricato & Grieco, 2017;

Kuo, 2017); the role and importance of lean management for implementation of Industry 4.0 (Sony, 2018; Mayr et al., 2018); and linkages between implementation of Industry 4.0 and sustainable development (Varela et al., 2019; Duarte et al., 2020).

Despite growth of the body of literature, several issues need to be addressed with regards to the implementation of Industry 4.0 into the practice of organizations. One such challenge is the role and importance of key performance indicators (KPI) in the process of Industry 4.0 implementation. There is literature on KPI, but it is not linked to the Industry 4.0 implementation. Thus, literature offers definitions of KPI (Ballard, 2013; Bishop, 2018, ISO 22400), case studies of implementation of KPIs in organizations, etc.

The role of KPI in implementing Industry 4.0 was neglected in the literature, although KPIs are of huge importance when implementing Industry 4.0 principles. The role of KPI is crucial when organizations prepare blueprints for implementation of Industry 4.0 practices, i.e. defining KPIs, which are foundation for measuring key points in the process and are thus building blocks for measures established in frame of digitalized organizations.

The main aim of this contribution is to outline the role and importance of key performance indicators (KPIs) in frame of Industry 4.0 implementation, while also considering the linkage between corporate social responsilbty and KPIs in frame of Industry 4.0, which has not yet been addresesed in the literature. The paper contributes the following: First, it highlights the role and importance of KPIs in the process of Industry 4.0 implementation. Second, it outlines the theoretical framework for implemenation of Industry 4.0, from identification of KPIs to their implementation. Third, it establishes the linkage between corporate social responsibility and KPIs in frame of Industry 4.0. Finally, it offers recommendations for implementaiton, as well as some directions for further research in this area.

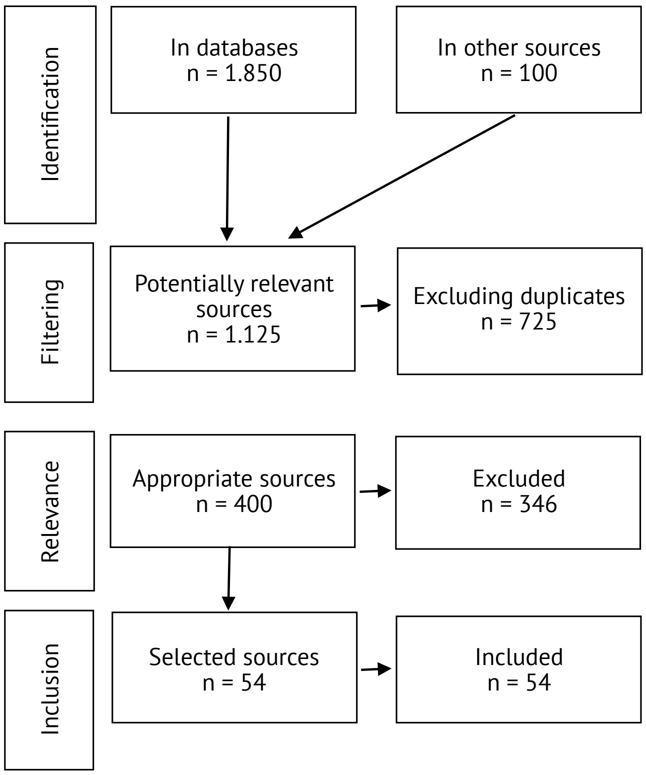
Methodology and Research Approach

In line with identified challenges in Industry 4.0, we proposed the following research question: How can KPIs contribute to a healthy and socially responsible implemenation of Industry 4.0 in organizations? The methodology used is M. Mulej's Dialectical Systems Theory. The structure matches the above overview of the main issues.

Based on a systematic literature search strategy, the databases dLib.si, ProQuest and Cobbis.si were reviewed in 2018. The literature was searched using the following keywords: "Industry 4.0," "KPIs," and "social responsibility." We broaden our search of the literature on the management and systems theory (in conjunction with requisite holism by systemic approach). The limitation resulted from outflow year for the search, because the study covered only publications since 2010; such restrictions were deliberately set, because we wanted to obtain the latest and must current information on the issues. We focused on articles published in Slovenian and English. There were no further restrictions.

Authors researched in the databases of the University of Maribor. Qualitative research methodology, including desk research, which was based on systems theory (Šarotar Žižek & Mulej, 2015), Mulej's Dialectical Systems Theory (Mulej & Dyck, 2014) and the law of requisite holism was used. The search in the databases of the University of Maribor resulted in 1.850 hits. We selected and included 54 sources and researched them; see Figure 1.

Figure 1. Research process flowchart



Quality score review and description of the data processing

The selected sources were published between 2010 and 2018. We excluded the sources that were duplicated or where we estimated the content was not sufficiently connected to the subject, purpose, or objective of our research. For the analysis of the technical and scientific content, we synthesized the results and took into account the availability content and contextual relevance. We chose 54 sources that were appropriately connected with our topic and objectives and contribute with high quality to our research.

Industry 4.0 (I4.0)

I4.0 symbolizes the beginning of the fourth industrial revolution, which is the first revolution that has been announced ahead of its inception. Based on concepts and technologies that include cyber-systems, the internet of things (IoT) and the internet of services, processes in I4.0 include interconnections of the virtual, digital and physical worlds and the learning in production. These connections include machines, products, services, information and communication systems, and staff. The result of I4.0 is a more efficient, adjusted and individualized production.

The essence of I4.0 is a comprehensive and structured use of the digital networking of the creation, logistics and use of products and services. The promoters of I4.0 expect this will lead to significant improvements in industrial processes in manufacturing, engineering, material use, supply chain, and life cycle management.

The essence of the joint program – the platform of the German government and the representatives of its industry sector – I4.0 (in German: Industrie 4.0) lies in a comprehensive and systematic digital networking of the creation, logistics and use of products and services (Hennies & Raudjärv, 2015), aimed to gain power in global production (Sanders et al., 2016).

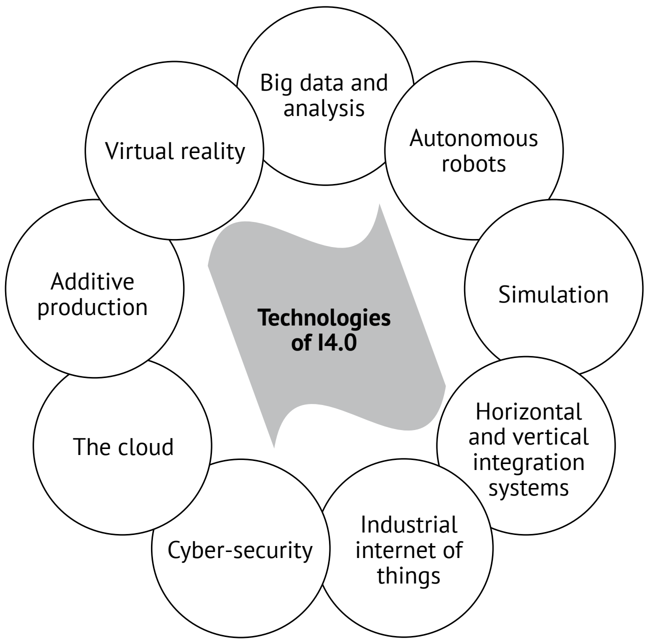
I4.0 is often described as an incentive for the fourth industrial revolution (Hennies & Raudjärv, 2015), or equated with it (e.g. Kamensky, 2017; Dais, 2014). After Hermann and co-authors (2016), I4.0 presents two aspects: 1. this industrial revolution was the first one announced *a priori*, and not observed *ex post facto* (Drath & Horch, 2014); 2. one expects a large economic impact from this industrial revolution, because I4.0 promises increased operational efficiency as well as the development of entirely new business models, services and products (Kagermann et al., 2013; Hair et al., 2014).

Other authors (Alexopoulos et al., 2016; Qin, Liu, & Grosvenor, 2016; Li, 2017) have mentioned thad Industrie 4.0 is also called Industry 4.0 which symbolises the beginning of the Fourth Industrial Revolution. Li Da Xu and co-authors have summarized many authors (Hermann, Pentek, & Otto, 2016; Jasperneite, 2012; Kagermann, Wahlster, & Helbig, 2013; Lasi et al., 2014; Lu, 2017a, 2017b) who have said that Industry 4.0 represents the current trend of automation technologies in the manufacturing industry, and it mainly includes enabling technologies such as cyber-physical systems (CPS), the Internet of Things (IoT), and cloud computing. For our research, GTAI's definition (2014) is also important, as it reveals that Industry 4.0 represents the technological evolution from embedded systems to cyber-physical systems.

Rüßmann and the other authors (2015) define nine technologies of I4.0 (Figure 2):

1. Big data and analysis
2. Autonomous robots
3. Simulation
4. Horizontal and vertical integration systems
5. Industrial internet of things
6. Cyber-security
7. The cloud
8. Additive production
9. Virtual reality

Figure 2. Technologies of I4.0



Dalenogare and coauthors (2018) have mentioned these technologies of the Industry 4.0: (1) Computer-Aided Design and Manufacturing (CAD/CAM), (2) Integrated engineering systems (ENG_SYS), (3) Digital automation with sensors (SENSORING) (4) Flexible manufacturing lines (FLEXIBLE), (5) Manufacturing Execution Systems (MES) and Supervisory control and data acquisition (SCADA), (6) Simulations/analysis of virtual models (VIRTUAL), (7) Big data collection and analysis

(BIG DATA), (8) Digital Product-Service Systems (DIGITAL-SERV), (9) Additive manufacturing, fast protoyping or 3D impression (ADDITIVE) and (10) Cloud service for products (CLOUD).

The concept of I4.0 describes various changes in production systems, which are mostly supported by information technology (IT). These changes have not only technological but also organizational effects. They will mean a change in orientation from production to service in the whole traditional industry. The concept of I4.0 refers to the set of current concepts, which cannot be clearly classified and, in particular, cannot be accurately distinguished in individual cases. These concepts are shown in the Figure 3 (Lasi et al., 2014; summarized after Čančer 2018):

- **Smart factory:** smart technology will be used to operate a smart factory, which will support the management of complex systems and processes. The production will be equipped with sensors and autonomous systems. Communication between machines, products, people and other resources will take place in a similar manner as in social networks. It will be supplemented by communicating of customers with facilities in a smart factory and by communicating with the supply chain.
- **Cybernetic-Physical Systems:** This is a combination of physical and program levels. After inclusion in production, the systems will no longer suffer from a strict separation between software and hardware.
- **Self-organization:** Existing production systems are becoming increasingly decentralized and self-organized. This coincides with decomposition of the usual production hierarchy.
- **New approaches in distribution and ordering:** Distribution and ordering will be increasingly individualized.
- **New approaches to the development of products and services**: The development of products and services will be individualized.
- **Adapting to human needs**: The new production systems will be designed to follow human needs, and not vice versa.
- **Corporate social responsibility** is increasingly at the core of the design of industrial production processes.

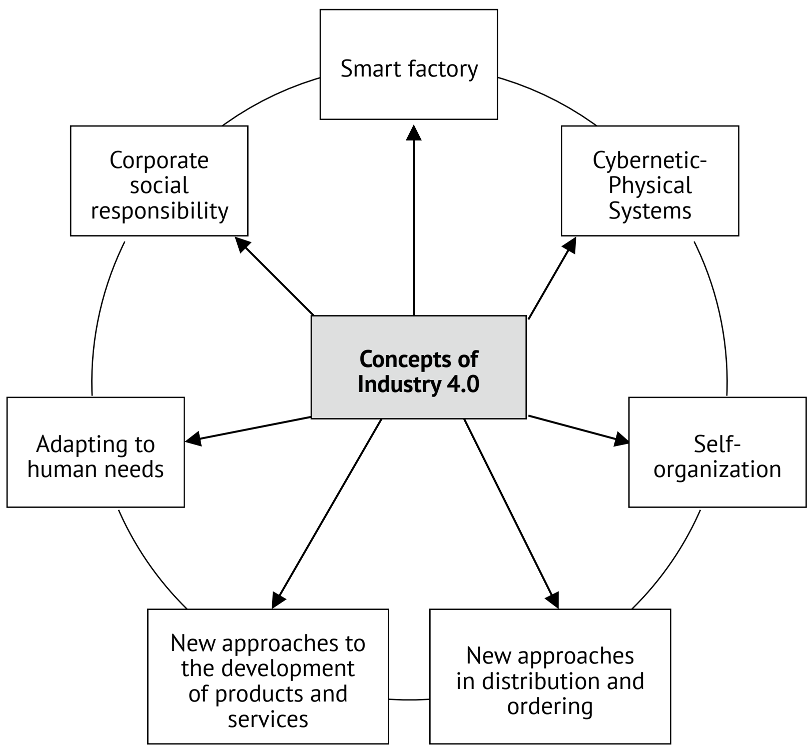
Components of I4.0 are after Hermann and coauthors (2016):

- Cyber-Physical Systems (CPS),
- Internet of Things
- Internet of Services
- Smart Factories

In order to support companies in the definition and construction of I4.0 systems, the general principles for the design of I4.0 (Hermann et al., 2016) are as follows:

- **Interoperability:** the ability of machines, devices, sensors and people to connect and communicate with each other through the Internet of things or the Internet of people.

Figure 3. Concepts of Industry 4.0



Source: Lasi et al., 2014; summarized after Čančer, 2018

- **Information transparency:** Information systems must be able to create a virtual copy of the physical world, enriching it with data derived from sensors. This requires the implementation of raw data obtained from sensors into higher value information.
- **Technical assistance:** The ability of support systems to support decision-making for people by combining and visualizing data. The data are processed so as to be understandable to the people / employees and make it easy to make informed decisions in the shortest possible time. The technical assistance is also the ability of cybernetic-physical systems to physically support people in carrying out tasks that are unpleasant, too hard or too dangerous for humans.
- **Decentralized decisions**: The ability of cybernetic-physical systems to make decisions about their own systems and the decisions that are necessary for the autonomous performance of the tasks envisaged. Aside from some exceptions, disruptions or conflicting objectives, the decision-making requirement is transferred to a higher level.

Hermann and coauthors (2016) have prepared a table in which are six design principles that can be derived from the I4.0 components.

Table 1. Design principles of each Industry 4.0 component

	Cyber-Physical Systems	Internet of Things	Internet of Services	Smart Factory
Interoperability	x	x	x	x
Virtualization	x	-	-	x
Decentralization	x	-	-	x
Real-Time Capability	-	-	-	x
Service Orientation	-	-	-	x
Modularity	-	-	x	-

Source: Hermann et al., 2016

Regarding the challenges of the I4.0, employees are expected to:
- have the necessary knowledge on processes and their use;
- have specific competences to perform work in I4.0. The company must define the required competencies according to the specificity in accordance with strategy 4.0;
- become even more flexible in terms of working time and location, and also in terms of how they face tasks and problems;
- assume much greater responsibility for work and self-initiated knowledge, and collaborate with each other effectively;
- perform a number of tasks (the type of work will be important, not the location - companies will have to consider modifying job descriptions).

The number of routine physical tasks will be (markedly) reduced, while on the other hand, there will be more jobs that require flexibility, problem solving and creativity.

In order to manage and control I4.0, performance indicators are necessary. In the following, we highlight the methodology of key performance indicators.

Key Performance Indicators (KPI)

Why should organizations implement key performance indicators? There is a permanent need to monitor efficiency and effectiveness and a quick and clear overview of the current situation. The requirements of digitization and I4.0 indirectly compel us to do so. We also use key performance factors because a wide range of indicators for comprehensive monitoring of the situation is expanding, as well as the need to integrate fragmented data, ensuring data compatibility across different systems in organizations and in different databases (Matlab, Ms Access, SQL).

A performance measurement system is important. It consists of a set of procedures and indicators that precisely and constantly measure the performance of activities, processes and the organization as a whole, and is a vital aspect in regard to the management of companies (Neely et al., 2005; summarized after Varisco et al., 2018). Lohman (2004; summarized after Varisco et al., 2018) mentioned that a performance measurement system should be able to provide data for monitoring both past and the future performance, to strengthen the strategies and avoid introducing the conflicting indicators, and to support providing data for benchmarking. Therefore the performance measurement system focuses not only on financial procedures and indicators, but also on consumers' aspects or internal processes.

Parmenter (2007) connected a performance measurement system with key performance indicators (KPI). He says that key performance indicators are considered the core of the performance measurement system: they are defined as a set of measures that focus on the main critical activities. Key performance indicators (KPi) are critical to understanding the performance of organization and to the decision-making. They are used by almost all types of businesses by managers, to evaluate effectiveness in achieving strategic and operational goals (Bishop, 2018).

KPI are not only financial but also non-financial indicators that organizations use in order to estimate and define how successful they are, aiming at previously established long-term lasting goals (Velimirović, Velimirovic & Stankovič, 2010). Velimirovič and co-authors (2010) mentioned that

KPI are static and stable indicators that carry more meaning when comparing information. Therefore KPI help to remove the emotion from object of the business, and allow workers focus on the things that joy is really about, and that are making benefit.

„Quantitfiable level of achieving a critical objective. KPI are derived directly from or through an aggregation function of, physical measurements data and/or other key performance indicators.“ (ISO 22400-part I). »ISO 22400 defines a KPI by giving its content and its context.

- Content: a quantifiable element with a specific unit of measure (including the formula that should be used to derive the value of the KPI);
- Context: a verifiable list of conditions that are met«.

The selection and implementation of KPI is influenced by the organizational structure (line-line or process organizational structure or some other), as well as the type of production process, such as non-serial or serial production. Management in a production company is of utmost importance. The extensive and complex production processes can be managed in a transparent and efficient manner with a proper management hierarchy, which includes, in addition to the process and business levels, the production level of management. Management in a production company is based on a system for managing and controlling production processes. An example of such a system is MES, which is usually also computerized and includes classification, data transfer and optimization, allocation and resource status, and document management.

Zorzut (2009, 27) points out that the indicators are at different levels of corporate governance. The lowest level covers individual devices, control loops, process cells, etc. This is followed by the production level, on which one monitors the entire production line or plant. At the highest level, there is the business level, where the business of the whole company is managed.

The dimensions of indicators are as follows (Lohman 2004; summarized after Zorzut, 2009, p. 26):

- The **name** of the indicator.
- **Objective:** Describes the meaning and purpose of using the indicator so that the user knows what a particular indicator represents.
- **Unit of measure:** this is the metric used to calculate the indicator.
- **Scope:** Defines the range in which the indicator values may be located.
- **Level:** which level in the hierarchy of implementation priorities the indicator belongs to.
- **Frame (detailation):** determines how far the company wants to go by measuring the indicator (eg. production line, plant, individual machine, ...).
- **Measurement type**: absolute or recalculated; the indicator can indicate the total quantity (for example, the total energy consumed in one week in kWh) or the calculated quantity (energy consumed per unit of product / service per week).
- **Period:** the period of tracking and calculating the indicator (eg. week, day, shift).
- **Sources of data:** which data are needed to calculate the indicator, where they are captured / measured and who is responsible for them.
- **Owner:** Each indicator also has its own administrator, who is responsible for its calculation, as well as evaluating and making decisions based on the information obtained.

An example of KPI is presented in Table 2.

Table 2. Example of KPI

KPI DEFINITION	
CONTENT	
Name	Availability
ID	
Description	Availability is a ratio that shows the relation between the actual production time (APT) and the Planned busy time (PBT) for a work unit.
Scope	Work unit, product, time period, product
Formula	Availability = APT / PBT
Unit of measure	%
Range	Min: 0% Max: 100%
Cotext	
Timing	On-demand, periodically
Audience	Supervisor, management
Production methodology	Discrete, batch, continuous
Effect model diagram	See A. 10
Notes	Availability indicates how strongly the capacity of a work unit for the production is used in relation to the available capacity. The term availability is also called degree of utilisation or capacity factor

Source: Johnsson, 2006

It is important that each KPI is defined through a formula, a time model and an effect model. In ISO 22400 the following is mentioned:

- »The formula presents the equation that should be used for deriving the numerical value of the KPI. The equation is an aggregation function of physical measurements, data and/or other key performance indicators.

- The time model is used to visualize information about physical measurements used in the aggregation functions. The time models visualize start/stop time for specific measurements, as well as its relationship to other physical measurements etc.
- The effect model can be seen as a root-cause diagram. Each KPI has its own effect model. The effect model is a picture that highlights the relationship between the KPI and its parameters«.

KPI and their values can be presented in different ways (Zorzut, 2009, p. 27):
- Presentation with absolute value (priority: the indicator has a unit known to the user and directly related to the measured quantity, eg. productivity given by the number of pieces of product at the time of production).
- Linear scale - based on a classical evaluation from 0 to 10 or from 0 to 5. The expected value of the indicator is, for example, rated at 8 and represents 80% of the value of the indicator, so the score 10 corresponds to 100% of the value of the indicator.
- Presentation with a normalized value (usually the indicator is 1 or 100% when one assumes the expected value and it represents a percentage improvement of the indicator relative to the expected value of the indicator).

In standard ISO 22400-2: 2014, 34 KPI for production companies are listed, presented in Table 3.

It is very important that KPI be definable at different levels of company management: at the process, production and business levels (Johnsson, 2006; Zorzut, 2009). The process level means that KPI are installed for individual devices, control loops and process cells. With KPI at the production level, one monitors the production line or the production plant. The business level covers the business of the entire company and is also focused on the success of the business.

KPI on the business level

The most influential framework for measuring organizational performance (KPI on business level) is the balanced score card (BSC) proposed by Kaplan and Norton (2000). The BSC responds to the limits of traditional accounting criteria and seeks to translate the strategy into quantitative criteria that uniquely communicate the organizational vision. Based on the BSC, business performance can be measured (Kaplan & Norton, 2000):
- from a financial point of view, with the following indicators: operating profit, profitability of assets and capital, return on investment, economic value (EVA), revenue growth, and the creation of cash inflows;
- from the point of view of business processes, with the following indicators: market share, share of preservation of old clients, share of new clients acquisition, customer satisfaction, and profitability of clients;
- from the point of view of customers with indicators that include quality, productivity, time cycle, and cost measurement;

from the point of view of learning and growth and employee satisfaction, maintaining employees in the organization, productivity of employees, intellectual property of the organization, market innovations, and the ability of the organization to develop new skills.

Table 3. KPI after ISO 22400

Worker Efficiency	Production process ratio	Finished goods ratio
Allocation Ratio	Actual to planned scrap ratio	Integrated goods ratio
Throughput rate	First pass yield	Production loss ratio
Allocation efficiency	Scrap ratio	Storage and transportation loss ratio
Utilization efficiency	Rework ratio	Other loss ratio
Overall equipment effectiveness index	Fall off ratio	Equipment load ratio
Net equipment effectiveness index	Machine capability index	Mean operating time between failures
Availability	Critical machine capability index	Mean time to failure
Effectiveness	Process capability index	Mean time to restoration
Quality Ratio	Critical process capability index	Corrective maintenance ratio
Setup Rate	Comprehensive energy consumption	
Technical efficiency	Inventory turns	

Source: ISO 22400-2, 2014, p. 34

KPI on production and process levels

KPI systems have been developed to support business management at the highest levels of business. In the last decade, indicators on the process and production level of management - pPI are being implemented. Optimal operation of the management systems can be achieved by automatically collecting process data and mapping these data into pPIs, and by forwarding pPIs to interested users. pPIs show a genuinely useful value when users are able to quickly understand the information contained in the submitted production process data; eg. with these data, pPIs detect problems that arise in production or deviate from the set goals and, with timely action, correct the situation.

It is understood that in organizations there is a link between process-level and business-level indicators. Therefore intermediate direct-level production data is consolidated for each end user separately and is transmitted to it. In a process-oriented approach, the data represent a means to achieve the goal, that is, better implementation of processes, as defined in the process organizational structure.

We now present some examples of indicators at the procedural level (Ruel, 2004; Kinney, 2004; Haji-Valizadeth, 2005; Gerry & Buckbee, 2005, 2006; Gordon, 2006; summarized by Zorzut, 2009, p. 30):

- Variance indicator
- Oscillation indicator
- Usability indicator
- Saturation indicator
- Expert tune indicator
- Exit at the border
- Standard output exit
- Average absolute error
- Crossing the reference value
- Absolute integral error
- Robustness
- Efficiency
- Variability
- Reliability
- Time in emergency mode, etc.

The pPIs on the production level of managing are collected within five groups: safety and the environment, production efficiency, production quality, staffing, and implementation of the plan. The pPIs are as follows in the framework of each group (Zorzut, 2004; Rakar et al., 2004):

- Safety and Environment:
  - Number of accidents per DM
  - Number of alarms
  - Freshwater consumption
  - Production from recycled waste
  - Number of exceedances of limit concentrations of harmful substances

- Efficiency of production:
  - Employee/Infrastructure Efficiency (OEE)
  - Consumption of raw materials and energy
  - Product flow time
  - Efficiency of services
  - Production jam

- Quality of production:
  - Percentage of finished products/raw materials/materials that do not meet quality criteria
  - Waste
  - Quality of services

- Implementation of the plan:
  - Realization of the plan
  - The proportion of delayed production
  - The proportion of production that triggers penalties due to delays
  - The proportion of production that was prematurely realized

- Employees:
  - Lost work days due to injuries and/or illnesses
  - Number of suggestions for improvements and other innovations
  - Number of training sessions per employee
  - Fluctuation on working places/employee performance
  - Realization of goals
  - Degree of absenteeism by location/employee performance

The introduction of Ppi is based on its three-level structure, which allows the organization to use indicators in three groups per levels according to the priority of implementation:

- Level 1 are indicators that are related to regulatory requirements for safety and environmental protection and should be implemented first.
- Level 2 are indicators of quality, tracking the work plan and efficiency.
- Level 3 are indicators that describe different aspects in relation to employees.

Depending on the objectives and importance set, the company begins by defining key or implementing simple indicators and moving towards more complex or less influential indicators. The use of indicators is a continuous process that consists of setting goals and measuring effectiveness in achieving these goals.

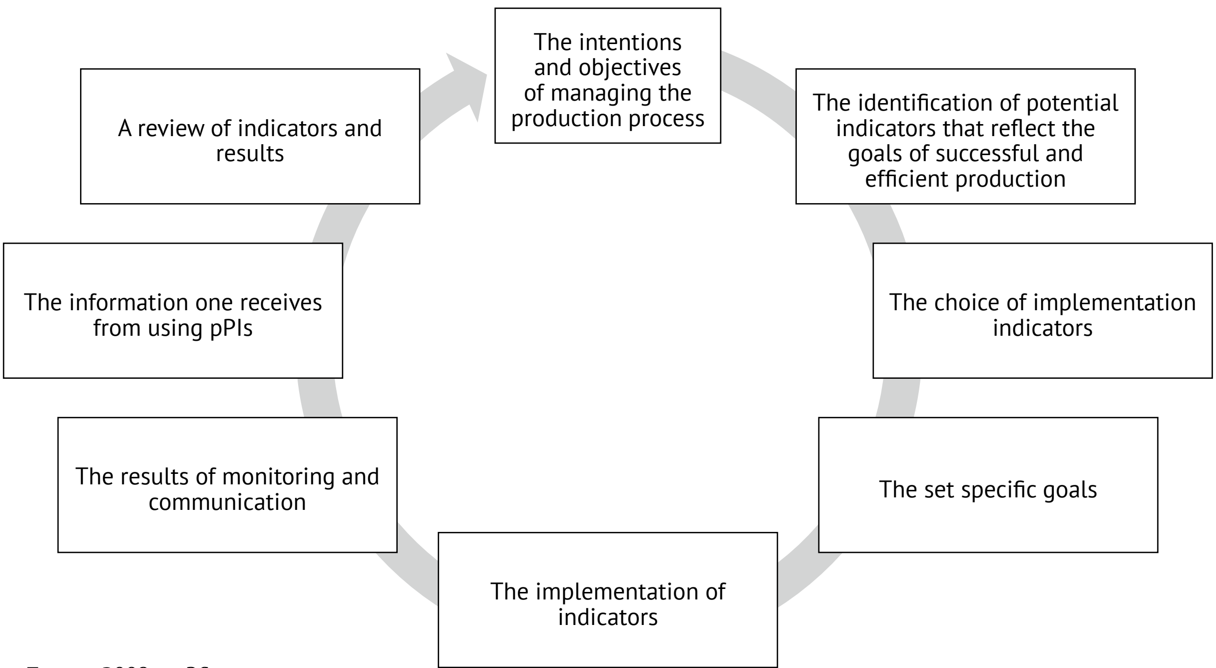
Implementation of Key Indicators in Industry 4.0

The methodology for calculating pPIs (procedural aspect) can be summarized in an 8-step iterative model (Zorzut, 2009):

1. In the first step, one defines the intentions and objectives of managing the production process that are in line with the company‘s mission. The objectives should relate to the main segments of the production process management and encourage employees to make decisions.
2. The second step involves the identification of potential indicators that reflect the goals of successful and efficient production (as many general indicators are used in the vast majority of manufacturing companies).
3. The third step involves the choice of implementation indicators. In addition to the general indicators at this site, one also considers the possibility of implementing additional and/or omplementary indicators specific to the production of the company. In this process, as many employees as possible should participate. One needs the support of the company‘s management, the heads of individual plants, and key employees in production.
4. In the fourth step, set goals, specific goals are set. This allows one to check the achievement of goals over a given period of time, increase the interest of the organization’s managers, and increase the responsibility of those involved in the project. Achieving the goals does not mean that quality of production is satisfactory and that the goal is achieved, but implies the need to set new goals as a process of continuous progress in all aspects of production.
5. The fifth step is the implementation of indicators. It includes data collection, calculation, evaluation and interpretation of results. It is a time-consuming step that requires the participation of a large number of employees in the company. One must take into account the following points of departure:
   - which type of information system will be used for data management,
   - what kind of software will be used for reporting,
   - which employees will collect which information,
   - how employees will be trained to collect data,
   - how to verify the accuracy of the data.
6. The sixth step contains the results of monitoring and communication. In order to be able to talk about continuous advancement, designers and users of the indicators system should periodically evaluate the results of the use of indicators. It makes sense to establish a system for regular evaluation, interpretation and presentation of results to employees and other stakeholders.
7. Step seven: Action based on the information one receives from using pPIs is a key step. In this step, production managers carry out additional measurements and take measures to ensure the necessary or desired conditions in the production processes, thus demonstrating that the implementation and use of indicators make the process of continuous development of the production process.
8. Step eight contains a review of indicators and results. This step is the basis for setting new targets and indicators.

In Fig. 4, this same process is plotted graphically as already outlined, because it is possible to implement KPIs at any level of governance according to this analogy.

Figure 4: Closed loop model of defining, measuring and developing pPIs



Source: Zorzut, 2009, p. 36

So far, the authors have tried to present the methodology of key indicators, taking into account the characteristics of the 4th Industrial Revolution, to which we will all have to adapt to as soon as possible. The authors are aware that the display was not adapted to individual needs, because without making it an integral part of your production process, it cannot be adapted. However, we have tried to show how this could be provided.

The authors are aware that a comprehensive strategy for the implementation of I4.0 needs to be confirmed by the board of directors. In order not to remain on paper, it needs to be transformed into a program of projects for the implementation of Industry 4.0. This will be followed by an operational plan for:

- Choosing KPIs at different levels of leadership
- Implementation of KPIs
- Modernization of production management models and integrated information support for:
  - Level 4 - production planning systems in the broadest sense (ERP)
  - Level 3 - Production Implementation Systems (MES) and
  - Level 0, 1, 2 - systems for production control (SCADA, PLC)
- Monitoring of the results of all activities.

As the process of improvement is never completed, the implementation of the model of required competences and development activities as well as the individual performance model for employees will be followed up on.

The benefits of KPI implementation include the following:

- a more precise standardization of the work of employees, which would be the basis for achieving a higher level of productivity and establishing a reward system or rewarding the performance of employees, which would have a positive impact on the motivation and commitment of employees;
- more efficient exploitation of production facilities, as one would have precise data on capacity utilization or availability of equipment and/or employees;
- more precise planning of production, which would lead to improvement in the achievement of the agreed product delivery times/equipment, to make it possible to specify the maximum production capacities, which could also be timed;
- identification and elimination of bottlenecks in work and technological processes, which would significantly contribute to the increase in productivity;
- realizing the company‘s default strategy - ie. transition to I4.0, which would be reflected in digitization and automation.

Corporate Social Responsibility in Connection With Key Indicators in Industry 4.0

Corporate social responsibility was also mentioned above, but not covered until now. It might be useful as a starting point using the ISO 26.000 citing seven contents, linked by interdependence and holistic approach, and seven principles supportive of the socially responsible behavior per all contents.

One can suggest that the organization collect opinions on how the seven principles are met in every one of the seven contents, how are they implemented in interdependence rather than in mutual separation, and how much holism is attained on this basis.

We add data about global engagement and commitment of employees, which is crucial also in I4.0. The GEEI - Effectory (2018) found out percentages of the commited employees. They are not satisfactory and show crucial reserves for efficiency and effectiveness to be attained by more CSR:

- North America: 39%
- South America: 43%
- Africa: 35%
- Asia: 25%
- Oceania: 26%
- Europe: 27%
- Global average: 29%.

Criteria on (potentially resulting) business aspects of CSR can be summarised as follows (Mulej et al., 2019):

1. Normal and regular gross earnings;
2. Normal investment funds and measures;
3. EFQM business excellence;
4. Such high managerial and proprietary remuneration that people would not be surprised and wonder ‚why they really need it, rather than for showing it off as compensation for the frustration of those with inferior value complexes‘ (Mulej, et al. 2019);
5. A constant circle of excellent business and socially responsible purchasing and sales business partners;
6. Zero legal disputes;
7. The dominance of long-term and broad criteria of business success over short-term and narrow-minded ones;
8. No abuses to affect humans or the natural preconditions for human existence, including high levels of of concern for preventive measures for the health of coworkers and other people throughout the business chain, and broader society;
9. the payment of influential ones on a long-term basis, including payment in shares,
10. Organizational and ownership relations that are as close as possible to the Mondragon Cooperative model;

Table 4. ISO 26.000 and principles of CSR

Principle / **Content**	Accountability	Transparency	Ethical behavior	Respect for stake-holders' interests	Respect for the rule of law	Respect for international norms	Respect for human rights
Organization, management and governance							
Human rights							
Labor practices							
Environment							
Fair operating practices							
Consumer issues							
Community involvement and development							
Interdepen-dence							
Holism							

Source: authors (with items from ISO 26000 by ISO, 2010, after Mulej et al., 2019)

11. Recruiting for influential jobs modeled on the long-term best companies in the world, as identified by Collins and Porras in books on ,visionary companies' and ,the path from average to excellent', so that in practice one uses;
12. Creech's model of the five pillars of total quality (perfect products, perfect processes, managing by example, and commitment, all four being linked by perfect organization), and
13. creative collaboration methods such as ,6 Thinking Hats' by E. De Bono and Nastja Mulej, M. Mulej's USOMID, their synergy, and the like;
14. Renewal or even innovation of business according to the model in the Horus Questionnaire (by IRDO, see www.irdo.si), and
15. Payment of wages according to the Mulej's innovative business model, whereby
16. The state creates and maintains the Prof. Florida's 3T model on rise of the creative class, with invitational conditions making the regions innovative (due to synergy of tolerance, inviting talents and making sense of technology investment).

Concluding Remarks

The authors present the methodology of key indicators, taking into account the characteristics of the 4th Industrial Revolution, to which we will all have to adapt as soon as possible. The authors are aware that the display was not adapted to individual needs, because it is not possible, if one does not become an integral part of your production process. However, the authors tried to show how this could be provided.

The authors are aware that a comprehensive strategy for the implementation of Industry 4.0 needs to be confirmed by the board of directors. In order not to remain on paper, the strategy needs to be transformed into a program of projects for the implementation of Industry 4.0. This will be followed by an operational plan for:

- Choosing KPIs at different levels of management
- Implementation of KPIs
- Modernization of production management models and holistic and integrated information support for:
  – Level 4 - production planning systems in the broadest sense (ERP)

– Level 3 - Production Implementation Systems (MES) and
– Level 0, 1, 2 - systems for production control (SCADA, PLC)
• Monitoring the results of all activities.

As the process of improvement is never completed, the implementation of the model of required competences and development activities as well as the individual performance model for employees will be the next step.

The benefits of KPI implementation are at least the following ones:
• A more precise standardization of the work of employees, which would be the basis for achieving a higher level of productivity and establishing a reward system or rewarding the performance of employees, which would have a positive impact on the motivation and commitment of employees;
• More efficient exploitation of production facilities, as one would have precise data on capacity utilization or availability of equipment;
• More precise planning of production, which would lead to improvement in the achievement of the agreed delivery times / equipment of the product, as it would be possible to specify the maximum production capacities, which could also be timed;
• Identification and elimination of bottlenecks in work and technological processes, which would significantly contribute to the increase in productivity;
• Realizing the company's default strategy - ie. transition to Industry 4.0, which would be reflected in digitization and automation.

KPI may help organizations adopt the I4.0 model, but the human and humane aspects may not be neglected. Success of I4.0 depends critically on employees and other business partners, not only on equipment. The latter seems to be found more important by many authors and managers with more of the engineering than humanistic background. Equipment is crucial, but is it designed, produced and used by humans. Hence, CSR is crucial in I4.0 conditions.

References

Alexopoulos, K., S. Makris, V. Xanthakis, K. Sipsas, & Chryssolouris. G. (2016). A Concept for Context-aware Computing in Manufacturing: The White Goods Case. *International Journal of Computer Integrated Manufacturing*, *29*(8), 839–849. https://doi.org/10.1080/0951192X.2015.1130257.

Ballar, P. J. (2013). Measuring Performance Excellence: Key Performance Indicators for Institutions Accepted into the Academic Quality Improvement Program (AQIP). *Dissertations*, 196. Retriven from https://scholarworks.wmich.edu/dissertations/196

Bishop, D. A. (2018). Key Performance Indicators: Ideation to Creation. *IEEE Engineering Management Review*, *46*(1), 13-15. https://doi.org/10.1109/EMR.2018.2810104

Caricato, P., & Grieco, A. (2017). An Application of Industry 4.0 to the Production of Packaging Films. *Procedia Manufacturing,* 11, 949-956. https://doi.org/10.1016/j.promfg.2017.07.199.

Cooper, J., & James, A. (2009). Challenges for database management in the Internet of things. *IETE Technical Review*, *26*(5), 320–329. https://doi.org/10.4103/0256-4602.55275

Čančer, V. (2018). Uvod v industrijo 4.0. In S. Šarotar Žižek & M. Mulej, (Eds.) *Pametna proizvodnja: pametna proizvodnja - managementski vidik in vidik zaposlenih = Smart production: [smart production - management aspect and the aspect of employees].* (pp. 7-22). Harlow [etc.]: Pearson; Maribor: UM, Ekonomsko-poslovna fakulteta.

Čančer, V., & Mulej, M. (2013). Multi-criteria decision making in creative problem solving. *Kybernetes*, *42*(1), 67–81. https://doi.org/10.1108/03684921311295484.

Dais, S. (2014). Industrie 4.0 – Anstoß, Vision, Vorgehen. In T. Bauernhansl, M. Hompel & B. Vogel-Heuser, (Eds.), *Industrie 4.0 in Produktion, Automatisierung und Logistik: Anwendung, Technologien und Migration* (pp. 625–634). Wiesbaden: Springer Vieweg. https://doi.org/10.1007/978-3-658-04682-8_33

Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics*, *204*(C), 383-394. https://doi.org/10.1016/j.ijpe.2018.08.019

Dombrowski, U., Richter, T., & Krenkel, P. (2017). Interdependencies of Industrie 4.0 & Lean Production Systems: A Use Cases Analysis. *Procedia Manufacturing*, 11, 1061-1068. https://doi.org/10.1016/j.promfg.2017.07.217.

Drath, R., & Horch, A. (2014). Industrie 4.0: Hit or Hype? [Industry Forum]. *IEEE Industrial Electronics Magazine*, *8*(2), 56–58. https://doi.org/10.1109/MIE.2014.2312079

Duarte, S., Cabrita, M. R., & Cruz-Machado, V. (2020). Business Model, Lean and Green Management and Industry 4.0: A Conceptual Relationship. In J. Xu, S. Ahmed, F. Cooke & G. Duca, (Eds.), *Proceedings of the Thirteenth International Conference on Management Science and Engineering Management* (pp. 359-372). Cham: Springer Verlag. https://doi.org/10.1007/978-3-030-21248-3_27

GEEI - Effectory. (2018). *Insights into global employee engagement & commitment.* Retrieved from https://www.effectory.com/request/thankyou-download/?__FormGuid=64b7b54f-f264-4d70-b045-6001f999ee8c&__FormLanguage=en&__FormSubmissionId=7a0ba555-febc-4deb-921c-476d549dc057.

Gerry, J., & Buckbee, G. (2006). The Link Between Automation and Enterprise KPIs: from chemicals and paper to petroleum, fast results generate big cost savings, *Control Engineering*, *53*(7), 9-12.

Gerry, J., & G. Buckbee. (2005). *The Link Between Automation KPIs and Enterprise KPIs*. Retriven from https://www.controleng.com/articles/the-link-between-automation-and-enterprise-kpis/

Gordon, L. (2006). *Prooving Control System Performance: Identifying methods of measuring system performance against project goals can be as important as identifying the goals themselves*. Retrieved from https://www.controleng.com/articles/proving-control-system-performance/.

GTAI (Germany Trade & Invest). (2014). *Industries 4.0-Smart Manufacturing for the Future*. Berlin: GTAI.

Haji-Valizadeh, A. (2005). *Using Key Process Indicators in Prioritizing Control Loop Maintenance Activities*. ISA.

Hennies, M. O. E., & Raudjärv, M. (2015). Industry 4.0: Introductory thoughts on the current situation. *Estonian Discussions on Economic Policy*, *23*(2), 19–23. https://doi.org/10.15157/tpep.v23i2.12491

Hermann, M., Pentek, T., & Otto, B. (2016). Design Principles for Industrie 4.0 Scenarios. In T. X., Bui & R, H. Sprague, (Eds.), *49th Hawaii International Conference on System Sciences (HICSS)* (pp. 3928–3937). Koloa, HI, USA: IEEE Computer Society. https://doi.org/10.1109/HICSS.2016.488

Hermann, M., T. Pentek, and B. Otto. (2016). Design Principles for Industrie 4.0 Scenarios." *Proceedings of 2016 49th Hawaii International Conference on Systems Science*, January 5–8, Maui, Hawaii.

Jasperneite, J. (2012). Was Hinter Begriffen Wie Industrie 4.0 Steckt. *Computer & Automation* 12, 24–28.

Kagermann, H. (2014). Chancen von Industrie 4.0 nutzen. In T. Bauernhansl, M. Hompel & B. Vogel-Heuser, (Eds.), *Industrie 4.0 in Produktion, Automatisierung und Logistik* (pp. 603–614). Wiesbaden: Springer Vieweg. https://doi.org/10.1007/978-3-658-04682-8_31

Kagermann, H., Wahlster, W. & Helbig, J. (2013). *Recommendations for Implementing the Strategic Initiative Industrie 4.0: Final Report of the Industrie 4.0 Working Group*. Acatech-National Academy of Science and Engineering, Germany.

Kamensky, E. (2017). Society. Personality. Technologies: Social Paradoxes of Industry 4.0. *Economic Annals-XXI*, *164*(3-4), 9–13. https://doi.org/10.21003/ea.V164-02

Kaplan, R. S., & Norton, D. P. (1992). The balanced scorecard – Measures that drive performance, *Harvard Business Review*, *70*(1), 71–79.

Kaplan, R. S., & Norton, D. P. (2000). *Uravnoteženi sistem kazalnikov: Preoblikovanje strategije v dejanja*. Ljubljana: Gospodarski vestnik.

Kinney, T. (2004). *Choosing performance assessments*. ISA.

Klun, I. (2008). *Sledljivost proizvodov v informacijskem sistemu: magistrsko delo*. Univerza v Ljubljani, Ekonomska fakulteta.

Kuo, C. J., Ting, K. C., Chen, Y. C., Yang, D. L., & Chen, H. M. (2017). Automatic machine status prediction in the era of Industry 4.0: Case study of machines in a spring factory. *Journal of Systems Architecture: Embedded Software Design,* 81, 44-53. https://doi.org/10.1016/j.sysarc.2017.10.007

Lasi, H., Fettke, P., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering*, *6*(4), 239–242. https://doi.org/10.1007/s11576-014-0424-4

Xu, L. D., Xu, E. L., & Li, L. (2018). Industry 4.0: state of the art and future trends, International Journal of Production Research, *56*(8), 2941-2962, https://doi.org/10.1080/00207543.2018.1444806

Li, L. (2017). China's Manufacturing Locus in 2025: With a Comparison of "Made-in-China 2025" and "Industry 4.0.". *Technological Forecasting and Social Change*. Technological Forecasting and Social Change, *135*(C), 66-74. https://doi.org/10.1016/j.techfore.2017.05.028

Lohman, C., Fortuin, L., & Wouters, M. (2004). Designing a perfromance measurement system design: a case study. *European Journal of Operational Research*, 156, 267-286. https://doi.org/10.1016/S0377-2217(02)00918-9

Lu, Y. (2017). Industry 4.0: A Survey on Technologies, Applications and Open Research Issues. *Journal of Industrial Information Integration,* 6, 1–10. https://doi.org/10.1016/j.jii.2017.04.005

Lu, Y. (2017b). Cyber Physical System (CPS)-based Industry 4.0: A Survey. *Journal of Industrial Integration and Management*, *2*(3). https://doi.org/10.1142/S2424862217500142.

Mayr, A., Weigelt, M., Kühl, A., Grimm, S., Erll, A., Potzel, M., & Franke, J. (2018). Lean 4.0 - A conceptual conjunction of lean management and Industry 4.0. *Procedia CIRP, 72*, 622-628. https://doi.org/10.1016/j.procir.2018.03.292

Mulej, M., Merhar, V., Žakelj, V., Zore, M., Hrast, A., Rašić, K., Toplak, L., Ambrožič, B., & Slapnik, T. (2018). *Uvod v politično ekonomijo družbeno odgovorne družbe*. Maribor: Kulturni center, zavod za umetniško produkcijo in založništvo.

Mulej, M., & Dyck, R. editors and coauthors, with coauthors. (2014). *Social responsibility beyond neoliberalism and charity*. 4 volumes. Shirjah, UAE: Bentham Science.

Oliff, H., & Liu, Y. (2017). Towards Industry 4.0 Utilizing Data-Mining Techniques: A Case Study on Quality Improvement. *Procedia CIRP,* 63, 167-172. https://doi.org/10.1016/j.procir.2017.03.311

Parmenter, D. (2007). *Key Performance Indicators Developing, Implementing, and Using Winning KPIs*. Hoboken, N. J.: John Wiley & Sons.

Qin, J., Y. Liu, & Grosvenor, R. (2016). A Categorical Framework of Manufacturing for Industry 4.0 and beyond. *Procedia CIRP* 52, 173–178. https://doi.org/10.1016/j.procir.2016.08.005

Rakar, A., Zorzut, S., & Jovan, V. (2004). Assessment of production performance by means of KPI, *Proceedings of the Control*, 6–9.

Ruel, M. (2004). Identifying poor performers while the process is running, *ISA EXPO 2004*, Houston.

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015). *Industry 4.0, The Future of Productivity and Growth in Manufacturing Industries*, BCG, The Boston Consulting Group, Boston, MA. Retrieved from http://www.zvw.de/media.media.72e472fb-1698-4a15-8858-344351c8902f.original.pdf.

Sanders, A., Elangeswaran, C., & Wusfsberg, J. (2016). Industry 4.0 implies lean manufacturing: Research activities in industry 4.0 function as enablers for lean manufacturing. *Journal of Industrial Engineering and Management*, *9*(3), 811–833. http://dx.doi.org/10.3926/jiem.1940.

Sony, M. (2018). Industry 4.0 and lean management: a proposed integration model and research propositions. *Production and Manufacturing Research, 6*(1), 416-432. https://doi.org/10.1080/21693277.2018.1540949.

Šarotar Žižek, S., & Mulej, M. (2013). Social responsibility: a way of requisite holism of humans and their well-being. *Kybernetes*, *42*(2), 318-335. https://doi.org/10.1108/03684921311310639

Varela, L., Araújo, A., Ávila, P., Castro, H., & Putnik, G. (2019). Evaluation of the relation between lean manufacturing, industry 4.0, and sustainability. *Sustainability*, *11*(5), 1-19. https://doi.org/10.3390/su11051439

Varisco, M., Johnsson, C., Mejvik J., Schiraldi, M. M., & Zhu, L. (2018). KPIs for Manufacturing Operations Management: driving the ISO22400 standard towards practical applicability. *IFAC-PapersOnLine*, *51*(11), 7-12. https://doi.org/10.1016/j.ifacol.2018.08.226.

Velimirović, D., Velimirović, M., & Stankovič, R. (2011). Role and importance of key performance indicators measuerement. *Serbian Journal of Managmeent*, *6*(1), 63-72. https://doi.org/10.5937/sjm1101063V

Weyer, S., Schmitt, M., Ohmer, M., & Gorecky, D. (2015). Towards Industry 4.0 - Standardization as the crucial challenge for highly modular, multi-vendor production systems. *IFAC-PapersOnLine, 48*(3), 579-584. https://doi.org/10.1016/j.ifacol.2015.06.143

Zorzut, S. (2004). *Zasnova sistema uravnoteženih kazalnikov za podporo vodenju proizvodnje*: magistrsko delo. Univerza v Ljubljani, Fakulteta za elektrotehniko.

Zorzut, S. (2009). *Vodenje proizvodnje v procesni industriji z upoštevanjem ključnih kazalnikov uspešnosti*: *Doktorska disertacija*. Univerza v Ljubljani, Fakulteta za elektrotehniko.

Ključni kazalniki uspešnosti in Industrija 4.0 – družbeno odgovorna perspektiva

Izvleček

Glavni cilj prispevka je predstaviti vlogo in pomen ključnih kazalnikov uspešnosti v okviru implementacije industrije 4.0. Ključni kazalniki uspešnosti so predstavljeni kot temeljno izhodišče za implementacijo industrije 4.0 v organizacijsko prakso, saj predstavljajo ključni input za potrebne podatke v digitalizirani organizaciji. V tem okviru prispevek najprej izpostavi nekatere bistvene značilnosti „Industrije 4.0", čemur sledi metodologija ključnih kazalnikov uspešnosti (KPI). Nato v prispevku opisujemo predlagano metodologijo za implementacijo KPI-jev v okviru Industrije 4.0 v organizacijah. Prispevek nadalje izpostavlja povezavo med družbeno odgovornostjo in KPI-ji v okviru Industrije 4.0. Prispevek prav tako izpostavlja predloge za prakso, omejitve prispevka in predloge za nadaljnje raziskovanje.

Ključne besede: Industrija 4.0, ključni kazalniki uspešnosti (KPI), družbena odgovornost