Storytelling with Data in the Context of Industry 4.0: A Power BI-Based Case Study on the Shop Floor

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Abstract. Industry 4.0 (I4.0) is characterized by cyber physical systems (CFS) and connectivity, paving the way to an end-to-end value chain, using Internet of Things (IoT) platforms supported on a decentralized intelligence in manufacturing processes. In such environments, large amounts of data are produced and there is an urgent need for organizations to take advantage of this data, otherwise its value may be lost. Data needs to be treated to produce consistent and valuable information to support decision-making. In the context of a manufacturing industry, both data analysis and visualization methods can drastically improve understanding of what is being done on the shop floor, enabling easier decision-making, ultimately reducing resources and costs. Visualization and storytelling are powerful ways to take advantage of human visual and cognitive capacities to simplify the business universe. This paper addresses the concept of "Storytelling with Data" and presents an example carried out in the shop floor of a chemical industry company meant to produce a real-time story about the data gathered from one of the manufacturing cells. The result was a streaming dashboard implemented using Microsoft Power BI.

Keywords: Visualization · Storytelling · Industry 4.0 · Power BI

1 Introduction

The Third Industrial Revolution (3rd IR) brought computers and automation to the manufacturing system. The Fourth Industrial Revolution (4th IR) adds to these two mechanisms the concepts of cyber physical systems (CFS) and connectivity [1]. Industry 4.0 (I4.0) is characterized by CFS, preparing the way to an end-to-end value chain, using

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Internet of Things (IoT) platforms supported on a decentralized intelligence in manufacturing processes. Connectivity is a key-factor in I4.0 environment, ensuring an automatic data collection, but in return responsible for the large amount of data present in most industrial environments that intend to embrace the challenge of I4.0 [2, 3]. In addition to these challenges, there is an urgent need for organizations to take advantage of this large volume of data; otherwise, the value of information will be lost. This data needs to be treated to produce consistent and valuable information to support decision making in organizations. Data science, a scientific approach that uses several mathematical and statistical techniques supported in computer tools for processing large amounts of data is becoming an invaluable area in I4.0 environments, since it can transform data into information and this in useful knowledge for the business. In addition, big data integrated with agile information systems can promote the solutions to convert those data in valuable information [2] improving at the same time the organization's capacity in response to internal, organizational and environmental changes in real-time [4].

According to Narayanan and Kp [5] "For a business to exist competently, the two things to keep up are: the management of time and better understanding of current status of the organization". Behind these issues is the importance of data visualization. In the context of a manufacturing industry, both data analysis methods and data visualization methods can drastically improve understanding of what is being done on the shop floor, thus enabling easier decision-making, ultimately reducing resources and perhaps costs. In fact, the human brain is an expert in memorizing data as images, so data visualization is just a clever idea to uncomplicated the business universe [5].

On the other hand, business intelligence (BI) is defined as "automatic data retrieving and processing systems that can help make intelligent decisions based on various data sources" [6]. Most of the BI solutions offer data analysis and data visualization which with the correct data capture technology should be able to treat data in real-time [7]. Some of the advantages of using BI tools are denoted by Stecyk [8] as the ability of linking to any data source, building up analyses in real time and having an intuitive and straightforward interface that helps in data visualization. However, to obtain this, some areas of knowledge need to be consistent and strong such as the ability to get data from a variety of sources, the aptitude to properly structure and relate the database and techniques about building key indicators (economic or performance) as well as dynamic reporting (visualization techniques) [8]. In addition, it is common sense that "the communication of information is an important capability of visualization" [9] and recently, literature has laid eyes on the new concept, more specifically the "Storytelling with Data" concept. This concept refers to a set of processes and mechanisms that help organizations to prepare multifaceted information, based on complex sets of data, with the purpose of communicating a story [9], including the arrangement of three elements: data, visualizations and narratives [7]. To address these issues, companies can use BI tools, but before it is important to choose the correct amount of information to deliver a message and adding to that the techniques that should be applied to produce story-like statements [9].

One of the open source BI tools referred to in the literature that allows achieving these objectives is the Microsoft Power BI, representing a tool gifted to create "shareable and customized visualizations to communicate data-based stories" [9], while providing visibility of the information flows [2].

In nutshell, despite the potential advantages in implementing the phenomenon of I4.0, organizations must be prepared to deal with the huge amount of data that IoT will bring. In addition, for that to happen it is essential that information flows be cleared and organized between all the departments in organizations. After that work done it is possible to implement BI tools in order to visualize what is going on in the shop floor. Considering these concerns, this paper intends to clarify the "Storytelling with Data" concept based on a literature review, and at the same time, pretends to describe methods and results carried out in a manufacturing company's shop floor, in order to implement the above concept. The study will be conducted in a chemical industry enterprise and the last goal set is to have a real-time story about the data that is gathered from one of the manufacturing cells. To tell this story we will have a streaming dashboard implemented by a BI tool, the Microsoft Power BI.

2 Background

2.1 Industry 4.0, Cyber Physical Systems and Digital Twin

Industry 4.0 principles are governed by the interconnection and transparency of information for decentralized decision making [10], requiring for that the combination of sensors, artificial intelligence, and data analytics [11]. This concept relies on the idea of combining optimized industrial processes with cutting-edge technology and digital skills and is the promotor of 'Smart Factory' or 'Factory of the future', concepts that are becoming the ambition of any enterprise. [12] Giving the concept behind smart factory and taking into account that it is still a utopia for many, it is important to understand the prerequisites to enable the smart in 'Digital Factory' [10]. According to [13], digital factory "refers to a new type of manufacturing production organization that simulates, evaluates and optimizes the production process and systems". While the Digital Factory provides tools for planning in Virtual Reality, the Smart one operates and optimizes the factory in real-time.

Information systems will be pivotal to achieve the vision of "real-time enterprise", remembering that they are "made of computers, software, people, processes and data" [10]. These components plan, organize, operate and control business processes [14], so they are pivotal in the integration of information flow.

Cyber physical systems are at the core foundation of Industry 4.0 and they intertwine physical and software components, each operating on different spatial and temporal scales. At the same time these components interact with each other in a multitude of ways that change with context [11].

The shop floor is the basic element of manufacturing, so the convergence between the physical and the virtual space becomes imperative [15].

As mentioned by Qi [16] "The digital twin paves the way to cyber-physical integration". This concept aims to create virtual models for physical objects in order to understand the state of these physical entities through sensing data (allowing predict, estimate and analyze dynamic changes). So it can be also assumed as a real-time representation of manufacturing systems or components [17].

This concept incorporates dynamic and static information, where data is transferred from the physical to the cyber part [18]. The data in digital twins are composed by physical world data as well as virtual models [16]. Digital twins combine and integrate

data from multiple sources in order to achieve a more accurate and comprehensive information [15].

The digital twin is a prerequisite for the development of a Cyber-physical Production System although some difficulties must be overcome, such as data security concerns, standardization of data acquisitions, high costs for new IT-environments that inhibit the application of vertical industry 4.0 and the creation of a central information system which can be combined with decentralized data acquisition (taking into account that in-house implementation of industry 4.0 is frequently insufficient) [19].

2.2 Business Analytics, Visualization and Storytelling

Business analytics and business intelligence are assumed, in the Industry 4.0' context, as areas that can actually help to increase productivity, quality and flexibility. The importance of making quick and right decisions is even more fundamental for efficient and effective problem solving and process upgrading [20]. Today these two-knowledge fields have been valorizing the real-time production data, having influence in decision making [21].

Business analytics is a field which goal is to measure the company's performance, evaluating its position in the market and at the same time find where there is a need for improvement and what strategies should be carried out [22]. For that, statistical, mathematical and econometric analyses of business data need to be done in order to support operational and strategic decisions [23].

Visual analysis tools are assumed as technology products that combine information from complex and dynamic data in such a way that support evaluation, planning and decision making [24].

The understanding and the communication of information is supported by visualization that allows the abstraction of raw data and complex structure [25]. Therefore, data visualization is concerned with methods to obtain appropriate visual representations and interactions which accept users to understand complex data and confirm assumptions or even examine streaming data [26] Visualization is seen as a significant tool in many areas for clarifying and even perceive large and complex data [27] and affords the user to obtain more knowledge about the raw data which is gathered from a diversity of sources [22].

Although visualization plays an essential role in providing insights on real-time data, this may not be the exact solution for analyzing a large volume of data, as an adequate data extraction process must be carried out [22]. In the industry 4.0's context, where the big data concept carries a huge weight, the main goal of big visualization is to acknowledge patterns and correlations [28]. Newly, visual storytelling is receiving attention from the academic community, where authoring tools have been developed in order to create stories and provide visual support [9]. The entire process of modifying data into visually shared stories includes exploring the data, passing it into a narrative and then communicating it to an audience [29]. Stories offer an effective way of stowing information and knowledge and make it easy for people to perceive them [30].

There are already many communities that emphasize the importance of storytelling in data visualization [31] and this concept has also captivated significant interest in visual analytics. Texts and hyperlinks connecting to bookmarked visualizations can constitute a story which can embrace also graphical annotations [9, 29]. It is assumed that visual storytelling can be critical in contributing to a more intuitive and fast analysis of broad data resources [32]. Even in the scientific approach, the storytelling concept urges as scientific storytelling, which means telling stories using scientific data. Visualization is used in academia to validate experiments, explore datasets or even to transmit findings, so if properly done, such visualizations can be highly effective in conveying narratives [33].

The Microsoft Power BI software is a business intelligence tool where visualization seems interactive and rich, allowing the creation of dashboards in matter of minutes. Although there is the option of running a R script, the software doesn´t require programming skills. The program is able to connect to various data sources in order to extract and transform them, creating information [28].

Currently and as evidenced by Gartner's Magic Quadrant, the Power BI software has assumed the first position in the ranking, since February 2019, ahead of Tableau, which until then was recognized as the most used tool within the subject of business intelligence[1].

In the next sections an example developed using Power BI is presented that used a Drill-Down Story allowing the user to select among particular details, putting more attention on the reader-driven approach [32].

3 Construction of a Dashboard Reflecting a Manufacturing Cell

3.1 Context Goals and Methods

The case study presented in this article was carried out at a company whose production focuses on flush toilets. Belonging to the chemical industry, its production is divided into two sectors, injection (made up of several injection molding machines) and assembly (made up of several cells that cover different parts of the flush toilet). In the assembly area, there are numerous manufacturing cells where automation can effectively make a difference. The currently most automated one, having data capture through IoT mechanisms, is the tap cell. The data acquired in this cell do not have any meaning to the decision-maker; yet they may produce potentially relevant information.

The goal of this case study is the construction of a dashboard where it is possible to view the manufacturing cell data in a way capable to help understanding the actual production state and thus support decision-making. It uses data analysis and visualization techniques, as well as storytelling.

[1] https://powerbi.microsoft.com/en-us/blog/microsoft-a-leader-in-gartners-magic-quadrant-for-analytics-and-bi-platforms-for-12-consecutive-years (visited, Jan, 2020).

For the construction of the dashboard to be possible, firstly an analysis of problem, including the software, was carried out, through its modelling in Unified Modelling Language (UML). After this modelling and after understanding the data generated, exporting them to Excel was essential to better understand the problem. Through Power BI Software Power Query, several transformations were possible, obtaining a fact table of relevant information. This table was built using M and DAX language and in the end, the application of graphic elements was done, creating the final dashboard.

It is important to denote that the process of creating the dashboard application involved three representative company divisions (actors), namely, the data analyst, the IT technician and the head of continuous improvement. These three types of users contributed to understand the dashboard requirements, as well as what advantage would be derived from the use of this streaming data to assist in decision making.

3.2 Result with Some Software Dashboard Interfaces

Concerning the dashboard application, it was created following a user-centered approach. Figure 1 presents the first dashboard menu, where the user can choose among viewing station stops, cadences, actual production and efficiency levels of the station.

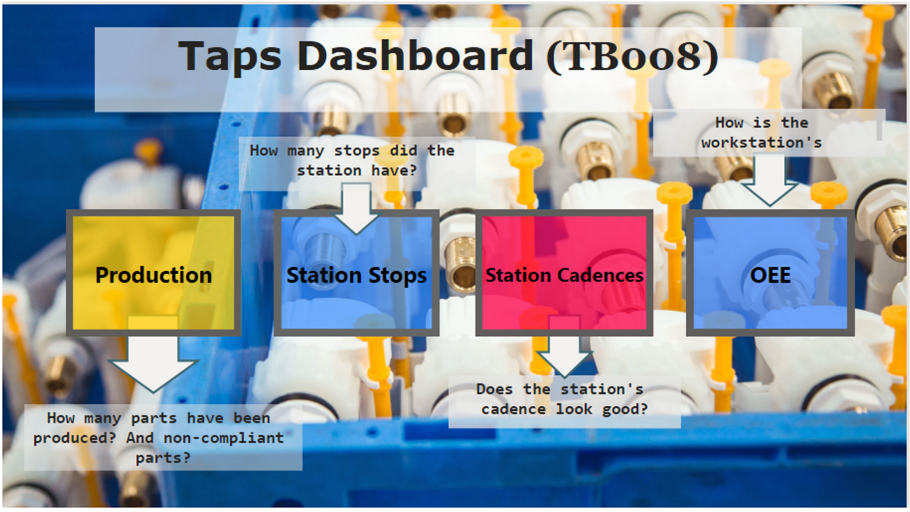

Fig. 1. Menu dashboard

In the "Production" (Fig. 2) bookmark the user can find the total amount of parts produced by the station and the total number of non-compliant parts. Once more, there are two filters, one is the date and the other is the product family.

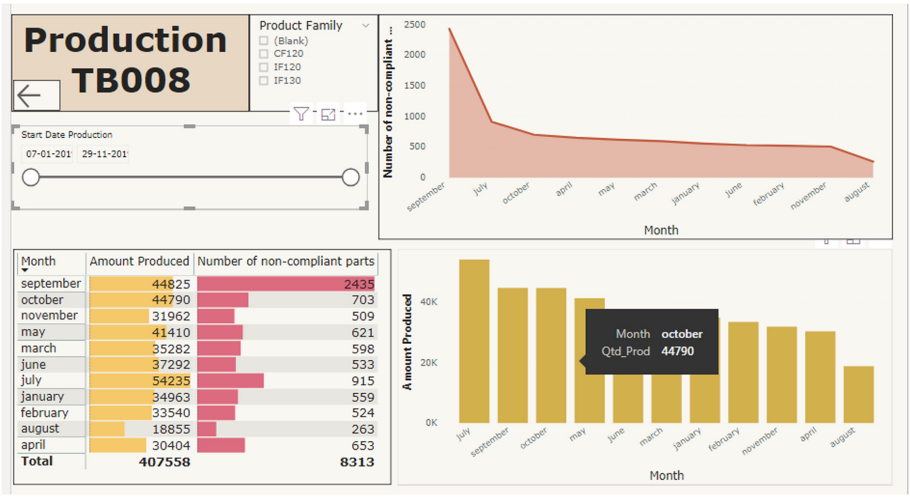

Fig. 2. Production bookmark

In the "Station Stops" (Fig. 3) bookmark is possible to visualize the total number of stops at the station, the total number of scheduled stops, micro stops and the total time available for production. The analysis can be filtered according to the date and product family chosen by the user.

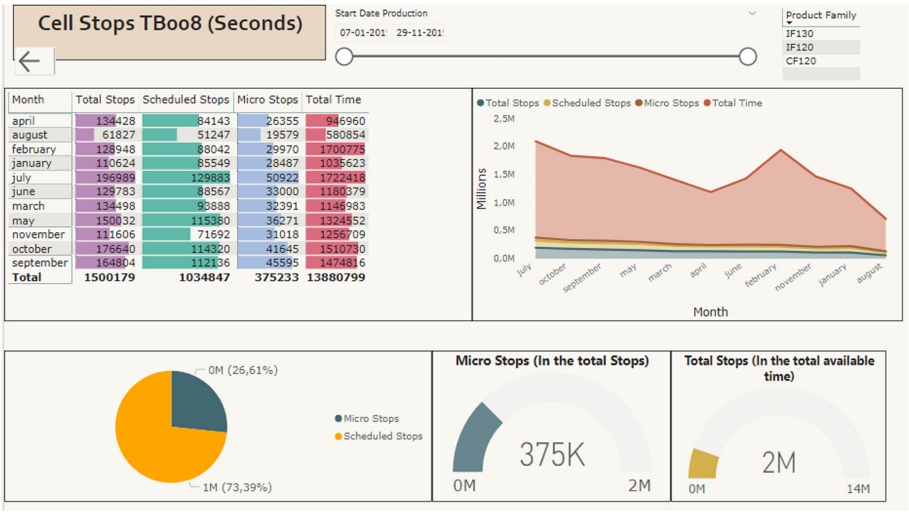

Fig. 3. Station Stops bookmark

The "Station Cadences" (Fig. 4) is another bookmark where the real cadence and the theoretical one can be compared.

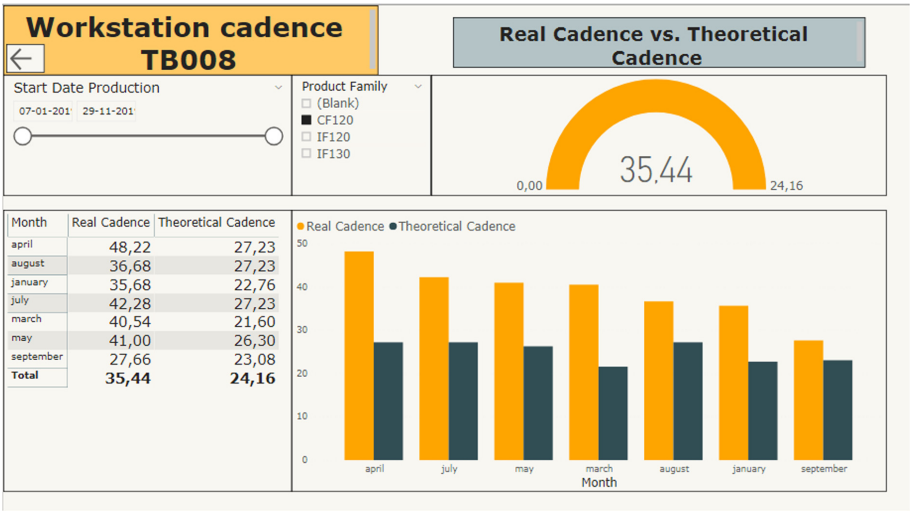

Fig. 4. Workstation Cadence bookmark

The final bookmark "OEE" (Fig. 5) displays the station efficiency levels, calculated by the concept of Overall Equipment Effectiveness. Here, the OEE Availability, OEE Operator/Performance and OEE Quality are calculated along time and the multiplication of the three allows us to obtain the global value (OEE Global). Filtering it is also possible using date and product family (Fig. 5).

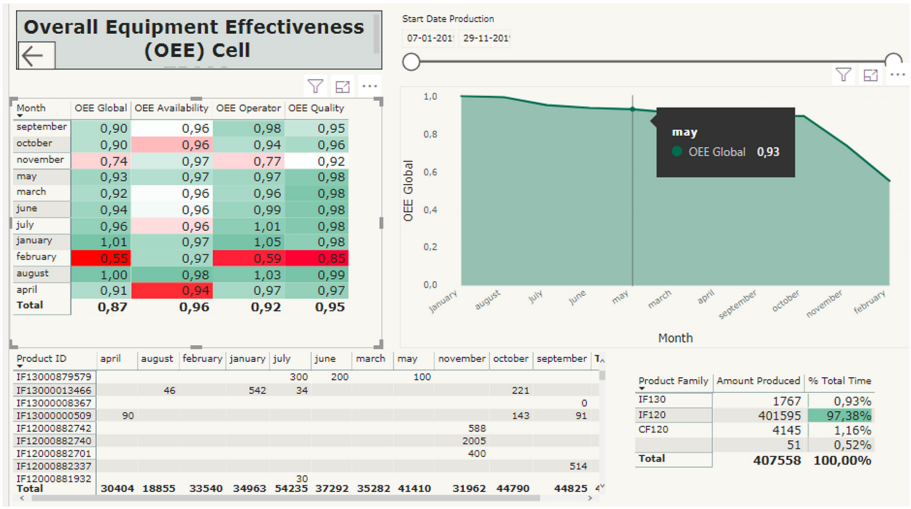

Fig. 5. Overall Equipment Effectiveness bookmark

4 Final Remarks and Future Work

The created dashboard allowed showing an informative overview to the user in order to facilitate the interpretation of the data resulting from the cell's production. Power BI proved to be a tool capable of representing data visually "telling a story" about how the cell is operating that can be easily understood by the user providing insights into the cell's activity.

More and more, particularly in the context of industry 4.0, the use of data becomes essential in order to bring value to the organization and easy decision making. The introduction of IoT mechanisms on the shop floor brings the need to take advantage of the data collected, using data visualization, data analytics and, more recently, storytelling tools. The ability to convey information in a more perceptible way has become a concern, considering the numerous resources and data sources scattered throughout the manufacturing space. Expertise in data processing and visualization is currently one of the foci of hiring companies and software such as Power BI facilitates these activities since they appear to be intuitive and accessible for people without advanced programming skills.

As future work, there is a need to test the dashboard with other types of users in order to evaluate it as a proof of concept, as well as to extend the dashboard to other manufacturing cells, so that operators in the shop floor can have better understanding of the data and of the complete manufacturing process. The application of the dashboard on the shop floor will allow acting in real time in the face of errors or discrepancies that may occur along the processes.

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