Industry 4.0 and Its Importance in Statistical Process Control

Francisco Levi de Oliveira Merlo
Researcher in the Department of Mechanical & Industrial Engineering
NOVA School of Science and Technology
Caparica, Portugal
f.merlo@campus.fct.unl.pt

Ana Sofia Leonardo Vilela de Matos
Associate Professor in the Department of Mechanical & Industrial Engineering
NOVA School of Science and Technology
Caparica, Portugal
asvm@fct.unl.pt

Madalena Sabino Teixeira
Master in Industrial Engineering and Management in the Department of Mechanical & Industrial
Engineering
NOVA School of Science and Technology
Caparica, Portugal
ms.teixeira@campus.fct.unl.pt

Abstract

Nowadays, with the enormous competitiveness in the market, companies must adopt techniques that not only allow them to deliver a quality product but also help them predict situations of uncertainty regarding customer demand. Thus, it is imperative that some tools are integrated simultaneously throughout the production processes to achieve this goal. It is the only way for many companies to spot themselves in a significant market position, given that modern manufacturing demands not only more intelligence but also safer and more reliable process monitoring systems (Cheng et al. 2019).

The study supervised in this document aimed to analyze the application of Statistical Process Control (SPC) in Industry 4.0. For this purpose, a systematic literature review was conducted, which allowed identifying the main approaches used to integrate statistical analysis with production processes in Industry 4.0, as well as the main tools and technologies employed for this purpose. A total of 21 articles were analyzed, considering inclusion and exclusion criteria related to the subject matter, with greater importance given to articles that explicitly addressed the integration between Industry 4.0 and SPC.

According to the conducted systematic review, it was concluded that digital technologies are transforming SPC in Industry 4.0 in several ways. Some of the main transformations include: i) Real-time monitoring, as digital technologies allow processes to be monitored in real-time, enabling immediate problem detection and informed data-driven decision-making; ii) Automation, as there are models and systems that already work with SPC and Industry 4.0 technologies in a fully automated manner, increasing process efficiency and reducing the need for human intervention; iii) Advanced analysis, where digital technologies enable advanced analysis of collected data, allowing the identification of patterns and trends that would be difficult or impossible to detect manually; iv) Integration with other technologies, as SPC can be integrated with other Industry 4.0 technologies such as artificial intelligence, internet of things, big data, among other tools, to create more comprehensive and efficient solutions.
In other words, digital technologies are enabling a significant transformation in SPC in Industry 4.0, making it more efficient, accurate, and integrated with other available technological solutions.

The results showed that there are three major combined uses between SPC and Industry 4.0 technologies. The first, according to Atalay et al. (2020), Parto et al. (2020), Testik et al. (2020), and Udugama et al. (2020) describes how to apply Industry 4.0 tools in the context of SPC, but it is not applied in practice. This approach mentions the use of Sensors, Machine Learning, and Deep Learning.

In a second approach, according to Chen (2022), Destro et al. (2020), Fogliazza et al. (2021), Packianather et al. (2019), and Blanco-Montenegro et al. (2007) it is mentioned how Industry 4.0 tools complement SPC with limited automation. The mentioned tools are Expert Systems, Machine Learning, Deep Learning, Data Mining, Machine Vision, and Motion Caption System.

Lastly, in a final approach, according to Bodur et al. (2020), Dutta et al. (2021), Cohen and Singer, (2021), and Singer and Cohen (2021) it was concluded that there are models and systems that already work with SPC and Industry 4.0 technologies in a fully automated manner. The discussed tools included 3D printing, Internet of Things, Cyber Physical System, Machine Learning, and Deep Learning.

Ultimately, it can be concluded that, in the short term, Industry 4.0 and its new business models are the key, however, the market will continue to evolve to a point where all organizations will need to adapt to new trends (de la Torre and Sanchez 2022). According to Yüksel (2020), it can be stated that companies that produce highly technological products are more likely to develop Industry 4.0 applications and to implement Industry 4.0 technologies.

Industry 4.0 and SPC are areas that are constantly evolving and offer many opportunities for future work. As the literature shows, it is possible to work with these two major approaches together, and in this document, only an analysis of what already exists is presented. However, it is relevant to emphasize that several case studies can be developed based on the conclusions drawn here. One possibility is the development of artificial intelligence systems to enhance SPC, as AI can be used to analyze large amounts of real-time data collected through sensors and help identify patterns and anomalies in processes. In summary, the results of this study demonstrate that Statistical Process Control can be a valuable tool to improve the efficiency and quality of industrial processes in Industry 4.0, as long as it is applied appropriately and integrated with available digital technologies.

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