Digital transformations

Driving innovation and value creation across the tire production industry via the strategic development and implementation of digital technologies

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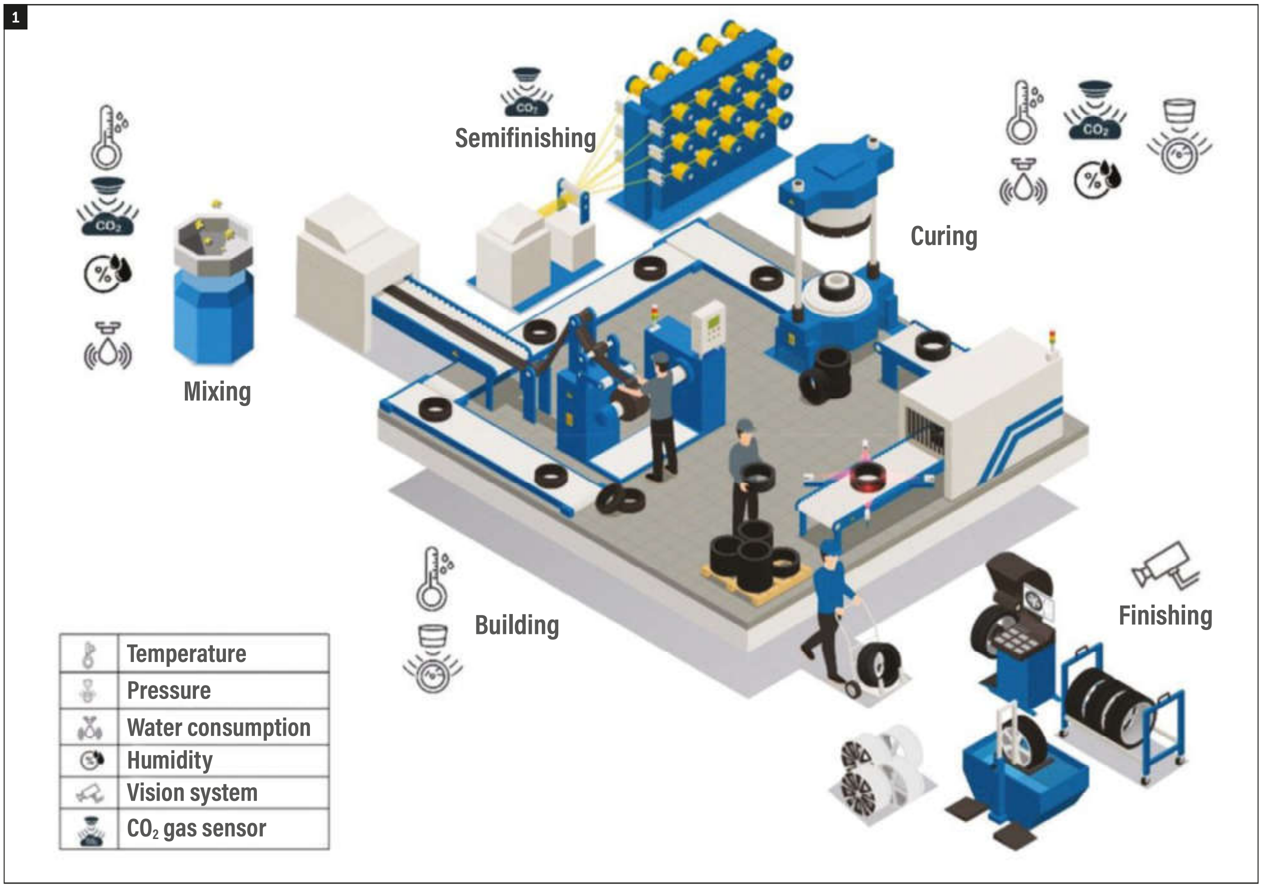

Figure 1: The digital transformation framework in the tire industry

Technological developments have transformed companies' operations in many industries, opening vast opportunities to optimize production processes, improve product quality and reduce environmental impact. The competitive environment has primarily been affected by new technologies that have enabled the penetration of some actors who, thanks to innovative models, have become threats to traditional organizations. New technologies have greatly influenced consumer behavior, redesigning access to information and the purchasing path or preferences for certain types of products and services.[1] Nowadays, industry executives know that digital technology can significantly improve their business performance. Therefore, an increasing number of companies across all industries are on the verge of embarking on a digital transformation – or have already begun implementing one. For Barez, digitalization meant ensuring that each task was driven by data, and completed on target with zero faults. This enabled the company to be more agile and efficient.[2]

Data is the fuel in digital transformation, providing the main source of innovation and value creation. The impacts extend beyond the digital economy, with all economic sectors increasingly affected. The concept of Industry 4.0 has emerged to describe the digital transformation by which industry in all sectors integrates digital innovations within its business strategies as an essential means of creating value. There are various definitions of Industry 4.0, many of which list its potential technological components. From a technological perspective, Industry 4.0 can be characterized as resting on three pillars: the Internet of Things (IoT), which enables objects to interact with each other and cooperate with their neighboring smart components; cyber-physical systems (CPS), integrating computation and digital processes where embedded computers and networks monitor and control physical processes; and smart factories that are context aware and assist people and machines in the execution of their tasks.[3]

In recent years, digital transformation has started to be felt throughout industry. In a survey of EU businesses, 75% of respondents said they regarded digital technologies as an opportunity, but over 41% had yet to adopt any of the new advanced digital technologies.[4] Digital transformation provides consumers, managers and industry-affected people with a wide range of functions such as production, marketing, supply chain planning, energy management and productivity improvement.

It should be noted that digital transformation is not just about using new technologies but also about emphasizing the need to develop a strategy. Furthermore, it is expected to have a positive effect on productivity and economic growth. The current challenge is the integration of emerging technologies such as the IoT, artificial intelligence, additive manufacturing, cloud computing and augmented reality to develop a single flow in the processes of organizations, which would benefit in operational, organizational and strategic terms.

It must also be noted that the correct application of Industry 4.0 requires overcoming limitations such as inadequate information on the infrastructures for data collection to achieve the goal set, and dealing with legal uncertainties.[5] To address limitations through implementing digital transformation and acceptance of Industry 4.0 technologies, many recommendations are highlighted, such as transparency and user engagement, training, and support to understand the benefits and overcome privacy and security concerns. Another critical aspect concerns the quality of the data collected as a primary source for analysis and enabling the best decisions to be made.

Digitalization has a significant impact on organizational performance in terms of operational efficiency, flexibility, responsiveness to customer needs and product quality, as well as reducing production costs and increasing profitability. There are four key elements in the successful implementation of digital transformation: digital data, automation, connectivity, and customer access.[6] The digital transformation thus influences business integration, competitiveness and direct customer dialog, making a significant contribution to reducing human errors and increasing overall equipment effectiveness (OEE). In particular, digital transformation has a major impact on the automotive industry's relationship between manufacturers and suppliers. The use of digital technologies and product-related services enables a stronger relationship. It increases the resilience of the manufacturing ecosystem but requires adequate infrastructure, staff training, technical support and system and tool integration.

Digitalization in the tire industry

The term Industry 4.0 becomes the reference paradigm of a new industrial revolution and goes beyond the simple introduction of automated systems. Therefore, the tire industry has much to do to fulfill customer requirements and remain competitive.

There are several approaches, technologies and techniques that would positively affect product quality, generating a positive effect on the environment. Among these new trends, automated processes supported by smart digital applications are the driver of innovation and enable companies to produce high-quality tires in connected and automated factories against a background of increasing variant diversity and high quality standards.

Moreover, tires themselves are also becoming smart, and their integration into IoT systems is giving rise to new business models based on data-driven services. For instance, the IoT is used to detect tire defects to extend product life and enable companies to act promptly to deal with the defects. Furthermore, systems with artificial neural networks can be tested in tire work environments. Therefore, several matching solutions for every process step are developed, from the production of rubber compounds and components, tire building, vulcanization and the final finish, right through to end-of-life tire recycling.

It is worth noting that the survey of European businesses shows that the technologies most commonly being implemented to achieve sustainability goals are IoT and AI, especially in the construction sector.[7]

Another aspect of digital transformation in the tire industry concerns the application of technologies related to the production processes, focusing on two overlapping directions: advanced tools for optimizing the production chain, and specific technologies for sustainable production.

From increased efficiency to better quality control and cost savings, there are many advantages of leveraging digitalization in tire manufacturing. It has become increasingly important in the tire industry in recent years, as it can help increase efficiency, reduce costs and improve the quality of products.[8] Digitalization can be used in a variety of ways to improve the quality and quantity of tires that can be produced. In addition, this approach can help reduce the time spent on manual assembly and inspection, and ensure that all tires are of the highest quality.

Digitalization can also be implemented to streamline the supply chain for tire manufacturing. By collecting data on orders, suppliers and customers, digitalization can help reduce the time and resources needed to track orders and deliveries. This leads to reduced costs and improved

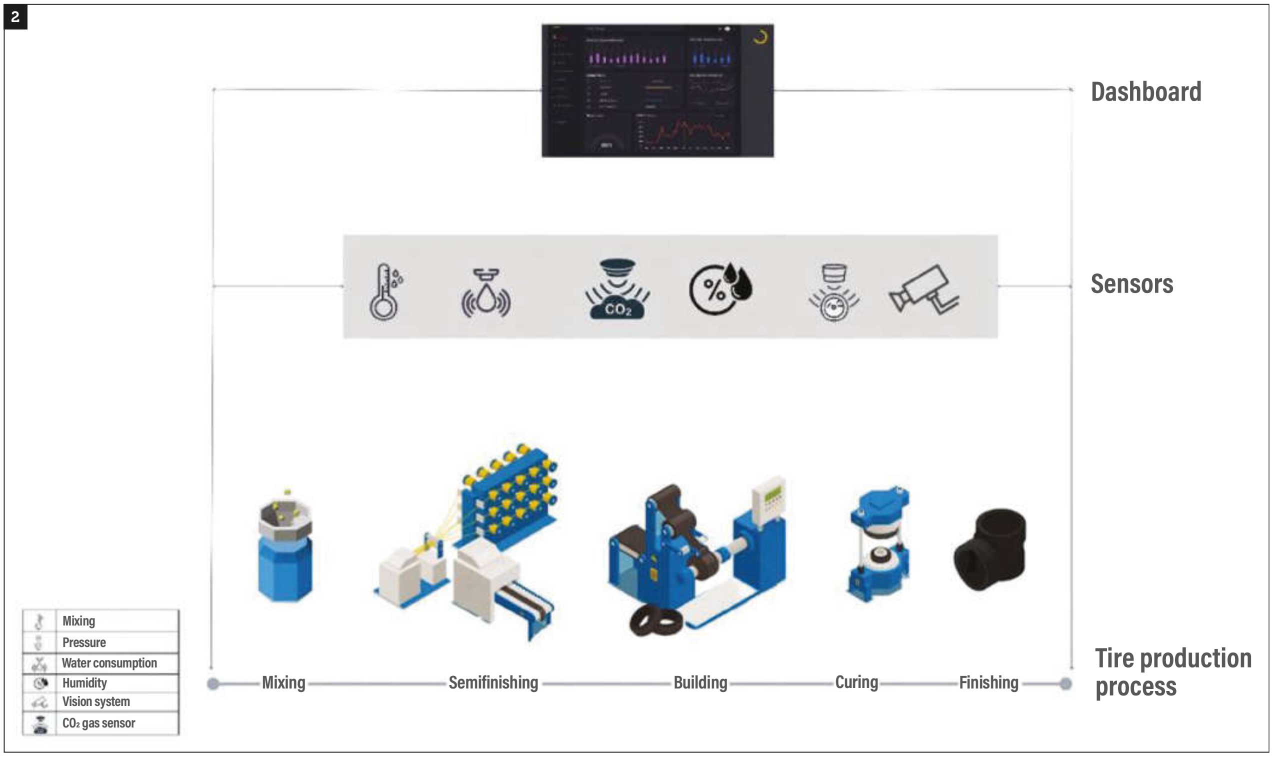

Figure 2: Reference framework for digital transformation in the tire industry

customer satisfaction as orders are received more quickly and are accurately tracked.

Finally, digitalization can also be used to increase the innovation and efficiency of tire manufacturing. By using digital tools such as analytics, predictive modeling and machine learning, tire manufacturers can gain insight into customer preferences and behavior and forecast future trends. This knowledge can be applied to create more efficient workflows and processes and produce high-quality tires that meet customer demands.

The virtual design phase of the tire industry consists of modeling and simulation of all production stages. This enables optimization of the layout, testing of different configurations and identification of potential problems or inefficiencies before implementation. For example, the sensors necessary for quantifying water consumption and carbon emissions in the production line are classified as follows (Figure 1):

- Mixing: CO_2 gas sensor, humidity sensor, water consumption sensor, temperature sensor;
- Semifinishing: CO_2 gas sensor;
- Building: temperature sensor, pressure sensor;
- Curing: temperature sensor, water consumption sensor, pressure sensor, humidity sensor, CO_2 gas sensor;
- Finishing: vision system.

In the collection and analysis phase of the framework, the data identified needs to be collected and elaborated by a reference dashboard, enabling the verification of the current trend in real time, and a simulation section to verify how to modify the current setting parameters to improve the results without affecting product quality.

In general, the application of digital transformation in the tire manufacturing process offers a wide range of possibilities. It can be customized to a company's specific needs concerning environmental impacts. For example, an accurate and real-time virtual replication of the process was developed by Barez to optimize operations, improve quality and ensure efficient and competitive production. The final reference framework for applying the proposed digital transformation is shown in Figure 2.

One of the most important aspects of digital transformation is the use of disruptive technologies, which are being introduced at an unprecedented rate. Some of the important aspects of implementing these technologies in the tire industry are considered below.

Industrial Internet of Things (IIoT)

The IIoT creates an opportunity to revolutionize manufacturing operations by enabling the acquisition and accessibility of greater amounts of data, at far greater speeds. IIoT applications are enabling companies to leverage technology and expertise to digitally transform operations.[9]

To reduce production costs in tire manufacturing, any IIoT-based solution must help to increase machine utilization, reduce scrapping of raw materials, eliminate errors in final production and increase labor productivity. However, tire manufacturers are increasingly looking to digitally transform their operations, changing from manual work practices to automated, digital, software-based and data-driven ways of working.

Reducing the throughput of machines causing increased machine cycle time is one of the challenges in tire manufacturing. To solve this problem, monitoring machine component cycle time and key parameters such as steam temperature, pressure and flow to determine the cause of increased cycle time can be considered. Making informed decisions to improve overall equipment effectiveness is the potential benefit of this solution.

Artificial intelligence

AI is one of the emerging technologies that can create value in different industries. Tire manufacturers have begun integrating this technology into all business processes, to evolve from production- and sales-oriented entities to those providing end-to-end mobility solutions. These steps give this industry a competitive edge by making business processes simpler and more efficient while acting as significant leverage for supplying added-value goods and services to customers.[10]

All that is needed is for tire companies to be enthusiastic and courageous enough to take the necessary steps to collaborate with technology. The tire industry should plan strategically to elevate its customer-centric culture through a business transformation powered by AI data insights and to create resilient manufacturing systems that can respond to an uncertain future. For example, AI can be used to identify the factors that most affect tire production, providing support for managerial decisions. In addition, a framework can be developed to support resilience in industrial production, making it possible to identify and manage anomalies or disruptive events.

Digital twins

Digital twins are also making a significant impact in tire production.[11] Every tire manufacturer knows that minimizing bottlenecks is critical to optimizing operations. But identifying throughput obstacles across the entire manufacturing process is perplexing. For many tire producers, the first step toward better material flow is a better understanding of machine capacity across each process area. With digital twin software, they can use a virtual machine and plant model along with historical data, including the mean time between failure (MTBF) of equipment on production lines. Then, the software can simulate probable production disturbances to determine realistic throughput and potential bottlenecks.

Tire manufacturers are also leveraging digital twins and dynamic simulation to optimize scheduling across their plants. For example, one company trained a simulation model using data from production assets, the manufacturing execution system (MES) and historical records. When a process disturbance occurs, such as equipment downtime, the system uses operational simulation to determine the optimal adjustments to minimize the downstream impact. Also, the digital twins can be used to speed time-to-market for new product offerings and test the feasibility of running new designs on existing equipment.

Analysis revealed that the tire industry is beginning its digital transformation path. Currently, the industry is characterized by limited deployment and employment of technological assets, and is not fully able to address sustainability commitments. For this purpose, literature often suggests technologies such as AI and IoT to enhance production processes and assets in terms of flexibility, customization and adaptability, enabling process monitoring and optimization. The findings suggest that digitalization is transforming the tire industry, as it fits into the broader context of future mobility, which is a strongly digitalized sector. In the face of this reality, tire manufacturers are adapting their organizational strategies to take advantage of new sources of value.

Considering our research published in the 2023 issue of the *Tire Technology International Annual Review*,[12] it is worthwhile to note the key trends gaining traction across the tire industry value chain, as highlighted in Table 1.

Considering the journey toward a comprehensive digital transformation in the tire industry, an extensive suite of digital solutions covering

Table 1: Key trends across the tire industry value chains

Raw material	Mixing	Stock preparation	Building	Curing	Finishing
• Nanotechnology for sustainable material development (such as carbon black) • Vertical integration with suppliers • Leveraging mobile technology	Advances in compound preparation by modifying material types and chemistry (on materials such as resins, silica and aramid fibers)	Integration of machine control systems with advanced systems such as laser and imaging to optimize processes and maintain efficiency	• Modernized assets to increase productivity (increased automation in servicers and building drums) and consistency (image and laser guidance)	• Advances in mold technology • Retrofitting sensors and modules for condition-based monitoring	• Laser carving tools • Noise-testing equipment

Product advances

Integrated sensors to measure tread depth and temperature and provide real-time alerts to drivers	Runflat tires including self-sealing tires and self-inflating tires	Air-free tire technologies	Noise-reduction or noise-dampening tire technology (important for quiet electric vehicles)

the entire manufacturing value chain of this industry is offered in Table 2. Each solution and its constituent components is geared toward addressing specific business levers and offers tangible potential impact across the value chain through its adoption. **tire**

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Table 2: Digital solutions covering the entire manufacturing value chain of this industry

Solution	Value chain applicability	Key components	Potential impact
Digital production	Across the value chain	• Integrated system to capture machine parameters • Digital logbooks to capture manual inputs • IoT and analytics platform for comprehensive insights and management reporting • Barcode-enabled scanning of input and output material • The system checks to ensure a streamlined process without errors • Bladder and mold management • 4M traceability	• OEE (10-25%) • Consumable cost (5-15%)
Digital quality	• Mixer • Calendering units • Extruders	• Advanced process controller detecting process anomalies • Ideal operating envelope for controllable parameters to achieve high throughput and quality • Real-time recommendations to avoid probable quality rejections	First pass ratio (5-10%)
Digital maintenance	• Mixer • Extruders • Cutters • Tire building machines • Curing presses	Integrated reliability-centered maintenance solution comprising: • Digital FMEA • Digital fault tree • Asset remaining useful life and failure prediction of critical assets • Spares management	• Availability (5-10%) • Maintenance and spares cost (5-15%)
Digital supply chain	• Raw material procurement • Production • Dispatch	• Digital SI&OP brings together forecasting, capacity planning and material resource planning • Inputs for actual production capacity and constraints are leveraged from the connected factory solution	• Plan adherence (10-20%) • Inventory reduction (10-15%) • OTIF (5-10%)
Digital production	Across the value chain	Digital cost-based value stream map with inputs from connected factory	• SKU-wise cost and margin • Visibility • Profitability analysis (2-5% uplift)
Digital health and safety	Across the value chain	• Digital datalogging and reporting for all HSE-related KPIs • Video analytics-based worker and site safety (for example, PPE violation detection, perimeter protection and intrusion detection) • ID-based access control for critical areas to ensure access for relevant stakeholders	LTIFR reductions