

Developing a platform for SME's tailored Industry 4.0 integration

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Abstract: Recent technological advancements have reshaped business landscapes, posing challenges to traditional corporate production processes and models. Small and medium-sized enterprises play a pivotal role in the Italian economy, yet their limited financial capacities hinder significant investments in research and development. The competitiveness of artisanal SMEs relies on their unique know-how and the originality of their creations. However, the sustainability of these enterprises in the global market faces threats of product imitations and counterfeiting. This paper presents the GALATEA project and its first results. The project is funded by PNRR aiming at implementing a digital platform to support the business activities of artisanal SMEs. The first goal of the project is to analyse the artisanal SMEs sector to understand the average level of digital maturity and process sustainability among similar businesses companies. Within the scope of the project there is a focus on Industry 4.0 technologies and their potential implementation in the artisanal company's processes. This preliminary phase included the selection and implementation of an automated track and trace system for semi-finished products, seamlessly integrated along the production process. Furthermore, Industry 4.0 technologies were explored to develop the Digital Twin of the artisanal product and mint its Non-Fungible Token (NFT) to guarantee product authenticity and traceability throughout the supply chain, fostering transparent information exchange with consumers.

Keywords: Digital Twin, Track & Trace, Supply Chain, Sustainability, Industry 4.0

1. Introduction

Recent advancements in technology have significantly transformed the business environment, presenting challenges to conventional corporate production methods and frameworks. Although small and medium-sized enterprises (SMEs) play a pivotal role in Italian economy, their limited financial resources hinder significant investments in research and development. The competitive edge of artisanal SMEs is rooted in their distinctive expertise and the creativity of their products. However, the long-term sustainability of these enterprises in the international marketplace is threatened by the proliferation of counterfeit products and imitations. To tackle these challenges, it is imperative for researchers and industrial stakeholders to collaborate closely, devising strategies that leverage on the distinctive strengths of artisanal SMEs while safeguarding their intellectual property and market position.

This paper details the initial phases of the PNRR funded GALATEA project, in partnership with Le Panier Srl, a luxury artisanal leather company, and Etna Digital Growth Srl, a software enterprise. Focusing on small and medium-sized enterprises characterized by artisanal manufacturing and niche "Made in Italy" production, this collaboration provides a valuable opportunity to examine the current landscape of such businesses, promote innovation and enhance competitiveness in the global market for these companies. It also aims to advance scientific knowledge through the development of new processes and services,

supported by Industry 4.0 technologies. In fact, according to some authors (Qureshi, 2023; Tabrizi et al., 2019), an effective digital transformation process should not merely impose Industry 4.0 technologies from above, as it is crucial to consider their impact on the daily tasks of human employees. This perspective signals a transition towards Industry 5.0, which places humans at the centre of innovation, with the goal of improving safety, ergonomics, and consequently, productivity.

The case study provided by the artisanal company, partner of this project, presents an opportunity to explore the complexities of a digital transformation process tailored for artisanal operations. Therefore, a crucial activity of this project involves a thorough audit of the company and its employees. This is not only to understand the production processes, products, and materials but more notably, to identify the unique needs and expectations that are known solely to the workers themselves. Operators, especially craftsmen who may not always possess advanced digital skills, require user-friendly interfaces capable of assisting them and, crucially, overcoming the typical resistance to innovation and digitization often encountered by small and medium-sized enterprises, especially artisanal ones.

The primary objective of the GALATEA project is to implement a digital platform that will integrate seamlessly into existing workflows, leveraging Industry 4.0 technology. By capturing each phase of the production process and recording the associated digital data, GALATEA will be able to create a digital twin of each

artifact produced. The digital twin, represented as a Non-Fungible Token (NFT), will not only ensure the artifact's authenticity but can also include unique narrative details to enhance its distinctiveness. This approach is expected to equip the company with a powerful tool to customize products and offer innovative experiences, empowering it to thrive in the global market. Consequently, customers will receive not just a product, but a dynamic, brand-enhanced experience that evolves and becomes more personalized with their stories.

The paper is structured as follows: Section 2 introduces the research context; Section 3 presents the companies involved and the steps of the project; Section 4 outlines the implications for the protection of authenticity and the fight against counterfeiting, as well as the expected benefits for artisanal businesses; Section 5 presents future perspectives and conclusions.

2. Research context

The modernization of the enterprise is driven by the Key Enabling Technologies (KET) of Industry 4.0 like Internet of Things, blockchain, cloud storage and cloud computing, big data, advance manufacturing solutions, additive manufacturing, augmented and virtual reality, cyber security, and simulation. The process leading SMEs shifting their production and organizational mindsets towards Industry 4.0, as well as the implementation of digital projects, can be indicated as Digital Transformation (DT). As discussed in (Kidschun et al., 2020), DT would enable the digitalization of the entire value chain, reshaping relations between producers, consumers, and suppliers, unlocking a vast portfolio of possibilities to offer innovative services or products and be ready for new business opportunities. According to the most recent trends and studies, the DT process must accomplish several pillars (Furr et al., 2022; Oliveri et al., 2023) which are not as prohibitively expensive as many years ago, thanks to the diffusion of open-source software and of new integrated technologies, like the Internet of Things paradigm and cloud storage, that allow cheaper but effective interconnection between heterogeneous hardware, software and legacy systems.

However, there are also challenges associated with the adoption of these technologies. One major issue is the initial cost and complexity of implementing NFTs and blockchain technology, which can be a significant barrier for smaller enterprises with limited budgets (Teng *et al.*, 2022). Additionally, there is a learning curve associated with these technologies, and businesses must invest in training and development to effectively utilize them.

Moreover, it must be pointed out that, nowadays, their outstanding know-how – which lead to highly specialized manufacturing and quality products – is not sufficient to stay competitive in the global market (Pozzo, 2021) and guarantee the uniqueness and originality of their products from competitors' imitations and from the scourge of counterfeit Made in Italy.

The reports of Agenzia Accise, Dogane e Monopoli di Stato, referring to the period from 01-Apr-2022 to 30-Sep-2022, show that 335.870 counterfeit Made in Italy products

were seized; this corresponds to an equal value of 1.397.755€ (Bollettino Statistico Trimestrale 2022, 2022). Furthermore, almost daily, the Italian Finance Police (Guardia di Finanza) seize products sold illegally as Made in Italy, even by unsuspecting resellers.

In this scenario, sustainability, authenticity, and traceability are crucial key elements to build a strong brand identity (AL-Issa et al., 2022) and gain customers' attention, therefore the Italian SMEs are called to evaluate how new technologies can modify their business models and rethink the foundation of their productive processes. Regarding sustainability, (Heim and Hopper, 2022) highlighted how blockchain, smart tags and non-fungible tokens (NFTs) are showing promising solutions to support the companies' behavioural change towards a circular economy.

As outlined by (Appio et al., 2021), an effective process of modernization in the direction of the Digital Transformation requires an enterprise to: evaluate its situation, the “as it is” status, with respect to its digital maturity; identify the desired goals in terms of business; weight potential management and process changes; and give a quote in terms of investment capability. But, due to limited technical and financial resources, SMEs (and in particular the Italian organizations) cannot invest considerably in Research & Development and most of time they are not aware and capable of undertaking, with their own strength, a process of Digital Transformation. Big companies in the IT and technology services sector have been able to seize the opportunities offered by the need for digital transformation, providing standardized solutions for the industry. However, precisely because these solutions are standardized, they often fail to meet the specific needs of artisan SMEs. The main objective of the GALATEA project is to bridge this gap by providing SMEs with an easily implementable platform built around their unique requirements.

Shifting the focus on the luxury sector, it is crucial to consider the dramatic changes of consumer culture (Giovannini et al., 2015). With the rapid adoption of digital technologies, luxury brands are compelled to establish their online presence and embrace technological innovations to connect with the modern luxury consumer. While physical stores and traditional offline experiences continue to play a substantial role in the luxury fashion market, multiple studies suggest that the future undeniably incorporates a significant digital dimension (Jung et al., 2021; Martin and Vacca, 2018). As a result, luxury brands must be attuned to various digital trends to remain competitive in this evolving landscape.

According to Vogue Business (2021) (“Resale, rental and NFTs: Vogue Business Index reveals top trends in innovation | Vogue Business”, n.d.), luxury brands have wholeheartedly adopted NFTs, recognizing their compatibility with the industry's values of exclusivity and prestige. Furthermore, it is crucial for fashion and luxury brands to harness NFTs strategically (Colicev, 2023). Companies and brands across various industries have had to adjust to the digital commerce landscape and fundamentally reevaluate their business models. The fashion and luxury sectors are no different in this regard.

As highlighted in (Angari, 2023), the exploration of digital technologies to enhance the value of 'Made in Italy' fashion brands is a pressing concern. Presently, it is primarily luxury fashion that possesses the resources to invest in cutting-edge digital trends like NFTs, as exemplified by SuperGucci (Liu, 2023). However, the importance of innovation within the luxury-fashion industry through technologies such as NFTs extends beyond high-end brands to encompass Small and Medium Manufacturing Enterprises (SMEs) and artisanal companies. These smaller enterprises are preparing to confront the challenges of the global market and are increasingly recognizing the necessity of embracing such technologies to maintain competitiveness and establish their distinctiveness (de Gois et al., 2023). Unlike their luxury counterparts, SMEs and artisanal businesses often lack the substantial resources for extensive research and development. However, the adoption of NFTs and similar digital innovations can enable them to carve out a unique position in the market. These technologies offer SMEs and artisan companies the opportunity to showcase the authenticity, craftsmanship, and heritage associated with 'Made in Italy' products, which are highly valued by consumers worldwide. As the luxury-fashion industry leads the way in embracing NFTs and digital trends, it is imperative for SMEs and artisanal enterprises to adapt and leverage these technologies intelligently. Doing so will not only allow them to compete on a global scale but also to preserve and promote the rich cultural and artistic traditions that are synonymous with 'Made in Italy' craftsmanship.

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This paper concentrates on the critical aspects of artisanal SMEs proposing a digital platform specifically designed to be adaptable to the artisanal company's needs. This initiative seeks to bridge the existing gap between the current state of the art and practical application, ensuring that the solutions offered are both innovative and directly relevant to the industry's unique challenges. By addressing both the positive potential and the inherent challenges of digital transformation, the GALATEA project aims to provide a balanced and practical approach to modernizing artisanal SMEs.

3. The project

In this section, we delve into the description of the project, exploring the details of its phases. Following the presentation of the artisanal company under study, we outline the three essential phases of the project.

3.1 The companies

The luxury artisanal leather company is composed by a group of direct and satellite laboratories between Sicily and Tuscany. The main laboratory in Acireale (Sicily) is devoted to the development, (CAD design, pattern making,

prototyping) industrialization, and production of special pieces, samples and small quantities, but also in research, experimentation and professional training. Etna Digital Growth S.r.l. (EDG) is an innovative startup that provides consultancy services for streamlining productive organizations through their digitalization, including software design, development, and planning.

3.2 The preliminary concept of the digital platform

In order to create a cohesive ecosystem tailored to enhance the operational efficiency and product authenticity of artisanal companies, the GALATEA digital platform will exploit an advanced multi-layered technological stack that integrates cutting-edge digital technologies. This concept will be refined based on the needs analysis of the artisanal company and the findings from the literature review.

Figure 1 shows the main components of the GALATEA digital platform. As shown, two actors can be identified: the smart industry on the top left and the smart end-user on the bottom right. The smart industry leverages the assets comprising the three layers on top (in green), while the smart end-user relies on the assets of the bottom three layers (in cyan). At the centre (in orange) are the main technological infrastructures serving as a bridge between productive and consumer layers.

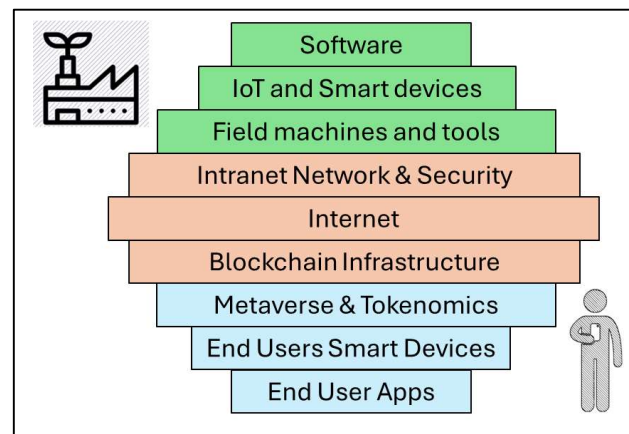


Figure 1: multi-layered technological stack.

Elements shown in figure 1 are described below.

Software Layer: This top layer comprises software solutions specifically developed for the artisanal company. It includes customized applications that manage production workflows, enhance data integration, and facilitate real-time decision-making. The software layer is pivotal in interfacing with IoT and smart devices, thereby enabling seamless automation and monitoring of production processes.

IoT & Smart Devices: Directly beneath the software layer are the IoT and smart devices, which are integral to the digital transformation. These devices collect data from various points in the production process, providing critical insights into machine efficiency, product quality, and workflow optimization. This layer ensures that field machines and tools are interconnected, enhancing operational transparency and efficiency.

Field Machines and Tools: This layer includes all physical machinery and tools used in the artisanal manufacturing process. These are retrofitted with sensors and connected devices that communicate with the IoT infrastructure to enable data-driven management. This connectivity allows for the real-time tracking of materials and semi-finished products, critical for quality control and inventory management.

Intranet Network & Security: Security and network integrity are maintained through a robust intranet network that facilitates internal communication and data transfer while protecting sensitive information against external threats. This layer supports all internet-dependent functions and is crucial for maintaining the operational continuity of the digital platform.

Internet Infrastructure: The Internet infrastructure layer serves as the backbone for the blockchain, and broader connectivity needs of the platform. It ensures that data flows seamlessly across different layers and that the platform remains connected to external networks and services, which is vital for integrating with global supply chains and markets.

Blockchain Infrastructure: At the core of the platform's security and authenticity measures is the blockchain infrastructure. It underpins the Metaverse and Tokenomics layers, providing a secure, immutable ledger for all transactions and product data. This layer is crucial for ensuring the traceability of products from production to end-user, thereby combating counterfeiting and unauthorized reproductions.

Metaverse & Tokenomics: This innovative layer leverages blockchain technology to create a unique digital presence for each product in the form of Non-Fungible Tokens (NFTs). These NFTs facilitate product authentication, ownership transfer, and engagement in digital spaces like the Metaverse, where consumers can interact with the brand in immersive ways.

End User Smart Devices: The platform extends its reach to the end user through smart devices that run sophisticated applications allowing users to interact with the digital twins of purchased products. This interaction enhances customer engagement by offering personalized experiences and product histories.

End User Apps: The final layer directly interfaces with the customer through user-friendly applications available on their smart devices. These apps utilize the data from the blockchain to provide authenticated product information and foster a transparent and interactive customer relationship.

3.3 The phases of the project

The project will be developed following to three main macro-phases:

1. state-of-the-art analysis of artisanal SMEs;
2. artisanal partner's process analysis and collection of requirements;
3. implementation validation and tests of the digital platform.

The first phase is crucial to build and consolidate the knowledge about the three pillars of the project:

- Small and Medium Enterprise characterization;
- Digital Technologies;
- Sustainability of the SMEs artisanal production processes.

Referring to industrial research and sustainability of artisanal production processes, the combination of these three pillars represents an innovative research challenge. In fact, it is important to point out that, although Digital Technology is commercially mature, it has not yet been integrated effectively in the small and medium artisan enterprises (Bravi and Murmura, 2021). Such kind of organizations suffer of peculiar issues and require satisfying other needs aiming, for instance, at increasing their visibility in the market, at measuring and optimizing their production to save costs and improve sustainability, and at proofing the authenticity of their products. Therefore, to consolidate the basic of this research project, a thorough state-of-the-art review about the artisan and niche Italian SMEs, their production processes, and the cutting-edge Key Enabling Technologies of Industry 4.0 was carried out, starting from previous studies (Oliveri et al., 2024), comparing Barcode, Beacon BLE, RFID and NFC solution.

The process analysis of the luxury artisanal leather company will be carried out to determine the most suitable technologies for integration within the production processes and areas. The expected goal is to enhance the company's digital maturity and the sustainability of its production processes. This phase will end with a requirement analysis to communicate needs and strategic goals with the IT partner company. A feasibility study will be developed to identify the technological solutions that enable the implementation of the platform and achieve the strategic objectives of the artisanal company. A set of KPIs will be defined to assess actual performances of the processes (“as is” configuration) and to set expected improvements due to technological solution implementation.

In the second phase of the project, the focus will shift to the design and implementation of on-site infrastructure within the artisanal company. This will involve installation of sensors, cameras, IoT devices, and the required IT devices. Moreover, during this phase, the IT company will develop the software applications of the platform, creating a system for the digital management of production phases linked to sensors and field devices, integrated with a blockchain infrastructure for the creation of digital twins and NFTs of products. This will enable the development of additional value-added services for the company's narrative, brand identity construction, product tracking, certification, and anti-counterfeiting.

The final phase of the project will be dedicated to verifying the functionality of all components of the platform. Comprehensive tests will be executed to validate the prototype in the operating environment, with necessary adjustments made if required.

4.The case study

Based on the operational approach adopted by Le Panier Srl in its product manufacturing, response to demand, and production volume management, it is possible to state that the production process is characterized by:

- Part-based production: Upon completion of the product, it becomes feasible to trace back to the elemental constituents comprising it (reversible process). The product assembly thus entails the integration and assembling of diverse parts, often of varying nature.
- Single-order manufacturing: Product design starts after customer orders. The planning and execution of each order are non-repetitive and according to Wortmann classification is an Engineer To Order (ETO) production. These products exhibit high differentiation and often necessitate the development of tailored project specifications and a specific processing regimen.
- Unitary production: The company fabricates precisely the quantity stipulated by the customer,

given that the item possesses unique attributes specifically requested by the client. Consequently, it cannot be utilized to generate inventory reserves.

In Table 1 are summarised the goals of the project and the key performance indicators (KPIs) which will be used to measure the improvements of the company after the completion of the project. The KPI associated to the goal 1. Increase Operational Efficiency is Production Lead Time i.e. the order-to-delivery cycle time intended as the time interval between the moment the order is placed (tin) and the moment the requested goods are delivered (tout), tracked by the information system. The average lead time LT_m for each order is the sum of the i -th lead time for a specific order line in the same order, according to the workflow in Figure 2:

$$LT_m = \sum_{i=1}^N LT_i$$

Table 1: Project Goals & KPIs

SMART Goals	KPI
1: Increase Operational Efficiency	Production Phase Lead Time: This KPI measures the amount of time required to complete each phase of the production process. A reduction in lead times can indicate increased efficiency.
2: Improve Order Management	Order Management Accuracy: Evaluating the accuracy in scheduling and executing orders can be an important KPI. For example, one could monitor the percentage of orders delivered on time.
3: Efficient Customization	This KPI measures how easy it is to make changes to projects to meet customer needs. Greater adaptability may indicate the ability to manage customized projects more efficiently.
4: Product Traceability	Evaluating the ability to trace the product's history can be crucial to ensure its authenticity. The number of tracked products and the completeness of traceability information could be indicators.
5: Customer Engagement	Measuring customer adoption of the software application can be an important KPI. For example, the number of customers using the app to access product history.
6: Promotion Efficiency	This KPI could measure the effectiveness of promotional campaigns, such as the conversion rate of customers reached through promotion.
7: Regulatory Compliance	Evaluate how well the project adheres to regulations regarding authenticity and traceability of artisanal products.
8: Customer Satisfaction	This KPI could be measured through surveys or customer feedback and could assess how satisfied customers are with the company's ability to provide authentic and personalized products.

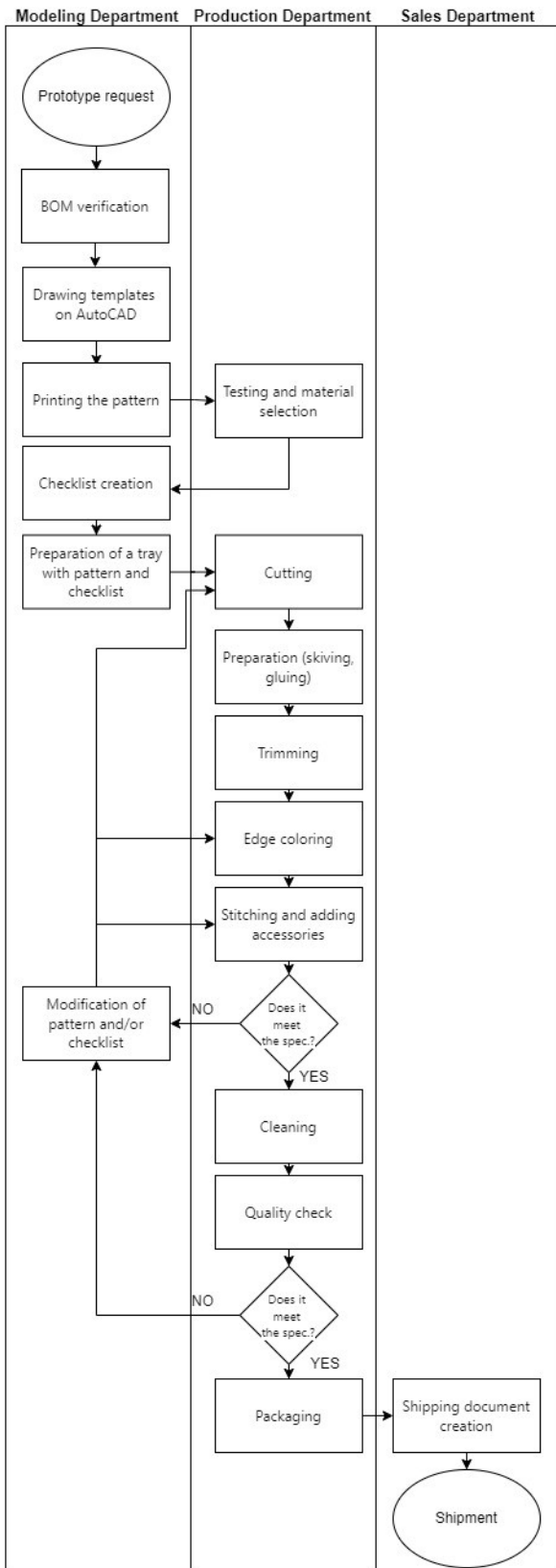
4.Implications and expected benefits

At the core of this project is the enhancement of digital competencies among artisans. By integrating Industry 4.0 technologies into daily operations, the platform will allow for a thorough analysis of current production processes and will identify limitations that can be addressed through digital solutions. This not only will improve efficiency but also will equip operators with the confidence and skills to embrace new technologies rather than fear them.

The GALATEA project aims to integrate an open and interoperable digital ecosystem into the working and production environments of artisanal companies, facilitating a comprehensive digital transformation. This transformation will allow the company to:

- Increase brand visibility and penetrate new markets.
- Make quicker, data-driven decisions to boost productivity and performance.
- Enhance the safety and ergonomics of the workplace.
- Improve the management of product life cycles.
- Engage consumers through personalized experiences and interactive storytelling.

Figure 2: Prototype Production Process Workflow.



Further, as shown in Figure 3, each product's digital twin, represented as a Non-Fungible Token (NFT), will serve as a certificate of authenticity and a vessel for unique narrative details. In the production of an artisanal bag, IoT and smart devices will play a crucial role in capturing and embedding

unique digital narratives throughout the manufacturing process. As the bag moves through various stages of production—from the initial cutting of materials to the final assembly—smart devices strategically placed around the field machines and tools will capture high-definition images, videos, and other sensory data (such as sounds and tactile feedback).

Each piece of content captured will reflect significant moments in the creation process, chosen based on the artisan's vision and the story they wish to convey about the bag. These moments might include the selection and treatment of the leather, the craftsmanship involved in stitching, or the application of custom features like embroidery or hardware, all contributing to the bag's unique narrative.

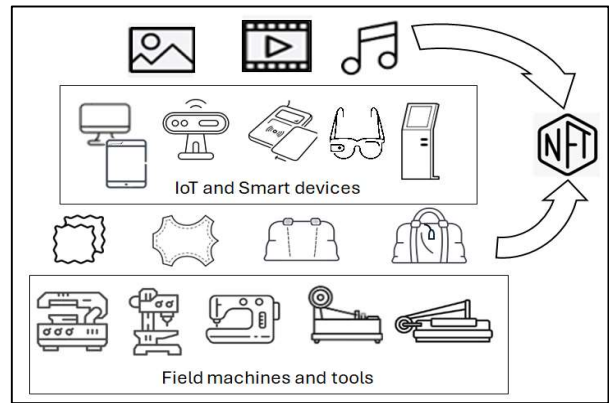


Figure 3: multi-layered technological stack.

This data will be then processed and linked to a digital twin of the bag, to generate a Non-Fungible Token (NFT). The NFT will serve not only as a digital certificate of authenticity but also as a vessel carrying the rich, personalized history of the bag's creation. Consumers who purchase the bag will be able to access this digital token to view the exclusive content, allowing them to experience the craftsmanship and story behind their unique product. This approach not only will enhance the value of the artisanal bag through transparency and storytelling but also will foster a deeper connection between the creator and the consumer.

5. Conclusions

This project represents a significant endeavour aimed at revolutionizing the artisanal production and fashion design sectors through the implementation of an open and interoperable digital ecosystem. By leveraging Industry 4.0 technologies and embracing the principles of Digital Transformation, the project seeks to empower artisanal businesses, enhance their competitiveness in the global market, and preserve the authenticity of their products. As the project progresses, initial observations suggest the potential for increased operational efficiency, improved order management, efficient customization processes, product traceability, enhanced customer engagement, effective promotional strategies, regulatory compliance, and heightened customer satisfaction. These findings underscore the importance of integrating digital technologies into artisanal production processes to drive

innovation, efficiency, and sustainability. Looking ahead, the implications of this project extend far beyond its immediate scope. The envisioned evolution includes creating new digital cultural services based on product traceability and extending best practices to additional industrial sectors. In summary, this project highlights the transformative power of digital technologies in preserving tradition while driving innovation and sustainability in artisanal production. By embracing these advancements, artisanal businesses can not only thrive in the digital age and compete on a global scale but also contribute to shaping a more resilient and prosperous future for the entire industry.

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