

## **The effect of using software on the production processes of smart factory ceramic tiles (case study)**

**Prof. Ayman Ali Gouda**

**Professor of ceramics Department - faculty of Applied Arts- Helwan University**

**Assist. Prof. Dr. Mona Mahmoud Shams Elden**

**Assistant Professor of ceramics Department - faculty of Applied Arts- Helwan University**

**Assist. Dr. Aya Nazez Mohey Abo Lala**

**Teaching Assistant of Ceramics Department –Applied Arts faculty- Helwan University**

[avanazeh@a-arts.helwan.edu.eg](mailto:avanazeh@a-arts.helwan.edu.eg)

### **Abstract:**

The research discussed the impact of the application of some concepts of engineering and design of scheduling tool and modeling programs in solving problems of ceramic tiles production in general, especially in smart factory operations systems, by taking advantage of the size of software and scheduling models, which we hope to expand their application and implementation in the ceramic industry sector. In Egypt, and the dissemination of the experience of its applications. Then the research presented a model of the production process that describes in detail the great development in the smart ceramic tile production process systems as a case study for one of the international companies in the industry and the ceramic sector, in which we focus on the development in the ceramic tile sector by making use of the developed scheduling systems; This is to model problems to find solutions digitally using computer programs. The research also clarified the importance of applying software and manufacturing scheduling systems in improving the quality of the ceramic product with the provision of scheduling models, and a case study of a smart factory for ceramic production that uses the digital approach and applies for smart programs on all its lines to produce ceramic tiles with all variables. The research also dealt with Industry 4.0 and its most important characteristics and benefits for making improvements in the industrial process, as well as addressing product life cycle management in smart factories through a smart powder factory for the ceramic body, innovations designed to improve process efficiency, and a smart production line that ensures forming, drying, decorating and providing fire lines for ceramic tiles and plates in the best possible conditions; To achieve the highest levels of quality, productivity, and operational flexibility. The research showed that the innovative large hydraulic presses in addition to the digital decoration technology, which is the latest in the industry, and that the new thermal machines (dryers and ovens) guarantee high-quality standards, and at the same time, reduce energy consumption and environmental impact, and that smart storage that allows production to be organized in batches, facilitates product change, and increases the efficiency of ceramic production. Depending on the work order, a wide range of machines are offered to sort and pack large tiles and slabs, as well as smart supply chains.

### **Keywords:**

smart factory; software; manufacturing scheduling; Ceramic4.0; digital fabrication software; Ceramic tile; Case study.

### Introduction:

The future direction of the ceramics industry by maintaining the industry's world-leading position in global trade represents the pinnacle of the digital transformation of the industry, as long as the company is able to handle market redefinition and continuous redesign, the ceramics industry will continue to thrive. The evolving requirements and characteristics of the traditional residential building materials industry are expanding its market to include the most advanced and innovative ceramic manufacturers, smart designs (self-cleaning and air conditioning), sustainable tiles, or energy-saving ceramics in new areas of use. A problem and ceramic companies must invest in new technologies to synchronize the production process with the industry, and that the transition from traditional manufacturing to digital manufacturing is only the first step, and it is not enough alone without a business plan that integrates all areas of the company. The actual ceramic tile industry in Egypt needs a dynamic production process, by implementing a professional software service platform designed by an international ceramic factory, and processing the continuous mass customization of products, the need to rely on diversity, and the competitive exclusivity of specialized production.

Production programming is the main problem in the ceramic tile industry and product customization. Reducing the quantity - in terms of the possibility of processing special parts - is a new challenge that modern ceramic manufacturers must face; Therefore, strong, and flexible software applications are required. The complete digitization of the process, the use of shared resources, and the effective management of data are the essential elements for the sustainable development of the new manufacturing model, which is the simulation of the production cycle under control (the ceramic production cycle) . All this is combined with customer needs and flexible production processes, with the help of new digital technology for product customization, the system of integration and interconnection allows to organize the information flow for the entire ceramic production in there , not only ensures orderly balance and correct execution of operations but also helps to give ceramic products their technical and aesthetic characteristics as well as issues related to ceramic production ( the main issues ), some of which are not visible on the surface. Ceramics (fig. 1) (ref. 29) and understanding the nature of the product by developing tailor-made solutions about the ever-changing process parameters of the ceramic industry. (Reference 1)

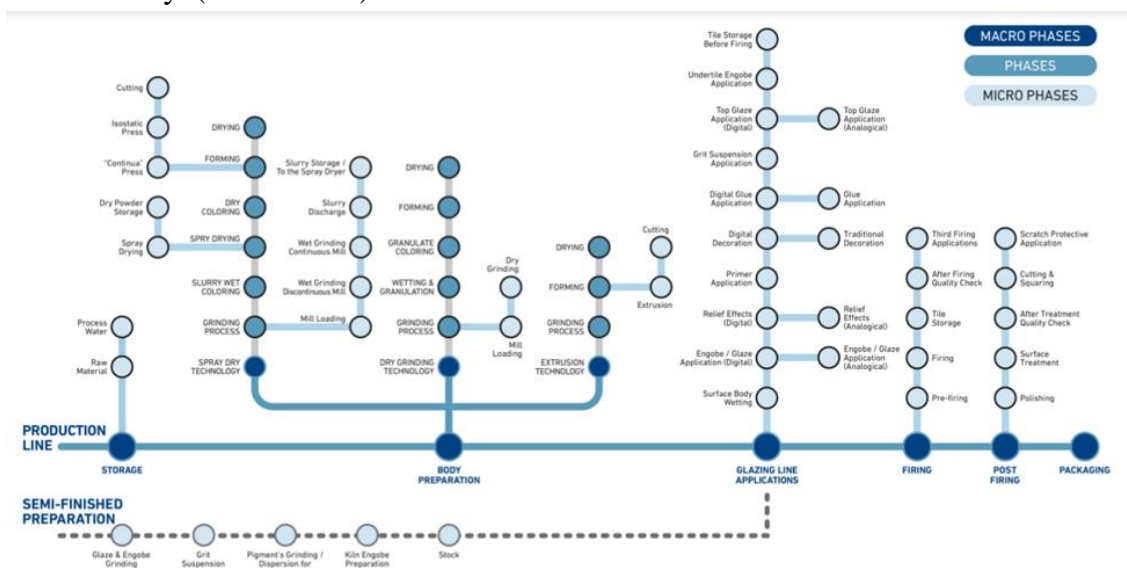


Diagram showing a map of many ceramic production processes related to the arrangement of the process, problems and solutions that are not visible to the naked eye, and that the stages of the ceramic production process continue to appear due to many variables or parameters of each variable or parameter. (Figure 1). (Reference number 17)

The research discusses two problems, firstly, the weak investment of ceramic companies in new advanced technologies to synchronize the production process with the industry. The actual ceramic tile industry in Egypt needs a dynamic production process, through the application of a professional software services platform designed by an international ceramic factory, for the continuous mass customization of products, the need to rely on diversity, and the competitive exclusivity of specialized production. Second: The transition from traditional manufacturing to digital manufacturing is only the first step, and it is not enough alone without a business plan that integrates all areas of the company. The map of many ceramic production processes related to the arrangement of the process, problems and solutions that are not visible to the naked eye, and that the stages of the ceramic production process continue to appear due to many variables or parameters of each variable or parameter. The importance of the research also lies in the possibility of applying standard and scalable digital methods, and the ease of their implementation in developing the digital or smart ceramic industry in Egypt. And that the digital manufacturing program allows full digital control of factory operations and acts as a link between the production environment and enterprise resource planning, allowing manufacturers to control all data flows from the production side, and improve the overall control of the factory through better and faster production, and from here the process turns into fully digital. The ceramics industry is constantly looking for new solutions to simplify the management of the production flow, and the arrival of raw materials directly to the warehouse of finished products. The current ceramics industry faces challenges such as the need for product customization, batch reduction, the ability to process special pieces, and the ability to obtain aggregate data at the same time. The aim of the research is to present case studies of advanced systems using digital programs in the ceramic industry for two models from the company SACMI and Ceramic Systems Group; To prove the degree of digital development, product quality, applicability, but most importantly, capital audacity. Clarifying the role of digitization in the ceramics industry, as well as the integrated control of functions and production processes, which makes manufacturing better and faster, by optimizing every stage of production and creating a new ecosystem that combines technology, personnel, and processes, applying the basic and distinctive characteristics of Industry 4.0.

### **1.The digital transformation of the ceramic industry**

The ceramics industry is one of the most prosperous industries in the global economy, and the ability to quickly link customer needs to the production process is the main reason why ceramic manufacturers maintain a competitive advantage in the global market. The ceramics industry is the largest contributor to the trade surplus; So the ceramics industry can keep up with the pace of the Industry 4.0; Because it is one of the industries which are most invested in research, development, and innovation, it has absorbed new smart manufacturing tools from private companies and public institutions, such as Institute of Ceramic Technology (ITC) or the Spanish Ceramic Tile Manufacturers Association (ASCER). These organizations act as a guide to the company's digital transformation, preventing them from being left behind and out of business.

(Reference No. 5) We find in an international discussion of ceramic manufacturers, a discussion of the latest developments in the ceramic industry 4.0, the main programs and their development for data management are complete and all the embedded technologies are interconnected and can integrate the data and information needed to improve the management of logistics operations. Explain the operation and advantages of a warehouse Industry 4.0, the new production model, identifying the evolution of the new production model with the concepts of “inventory” and “on order” as the basis, and offering the most innovative management solutions from large-scale semi-finished ceramic warehouses. The advantages of intelligent logistics in the production of decorative technologies, coatings, and semi-finished products, which is an integrated solution for the automated preparation of paints and inks, the effective management of raw materials and grinding processes, the storage and processing of semi-finished products delivered to the glass production line, thus reducing errors and waste, and improving process efficiency and the quality of the final product (Reference No. 14).

### **1-1- The smart evolution of product development2020**

Consulting RPD Launched M4 Project ( Remote Product Development ), a new development and manufacturing plan for remote ceramic products that can achieve faster operations and product standardization, and an interesting project has been developed in this field, this new project not only eliminates the problem of physical distance but also turns it into an opportunity to use R&D 4.0 Techniques to revolutionize research and development in the ceramic industry, this digital revolution has brought huge benefits. The assembly and commissioning of remote plants and machines have been successfully completed, and the predictive maintenance of the industry 4.0 production line can organize shipments and deliver on time and solve remote production problems through remote services. As for ceramic tile manufacturers, another area at risk is the development and manufacture of new products, so the strategy has targeted RPD Mainly glazes and colors manufacturers and ceramic tile manufacturers. As for the advantages of remote product development with the help of new digital technologies, companies' development plans are another step towards smart manufacturing methods, and the adoption of remote product development 4.0 brings many advantages, even without the presence of technical personnel, the product development process will be faster while ensuring a high level of Performance in standardization of products. The biggest problem with remote development has always been the replication of laboratory samples on an industrial scale, even if they were produced in a pilot plant; Due to the excessive number of variables involved (types of digital machines, inks, production conditions, etc.), the problem of industrial reproduction is thus solved and managed in the factory. (Reference number 16)

### **1-2- Traditional and digital ceramic manufacturing**

The most common problem in the traditional ceramic sector is that the machines and equipment responsible for each stage of manufacturing are not interconnected, which limits the overall efficiency of the equipment (OEE). Although the digitization of the sector has progressed over the past few years, there is still a long way to go in terms of automating and improving the flow of data and information. The digital transformation is comprehensive and applicable to any production sector, and its goal in the ceramic sector is to move towards more efficient,

productive, and sustainable processes, and works to provide the following competitive advantages:

- Reduce costs:** Interconnection between devices and machine learning models simplifies production processes and optimizes costs.
- Reduce energy consumption:** New smart tools calculate optimal production levels and achieve the same results.
- Reduce the efficiency of the test:** Can digital models and simulation (effective product testing systems and low - cost) shorten the testing process and replace methods of " trial and error " that is slow and costly?
- Reduce operations and turnaround times:** Work area automation and optimization speed up operations and eliminate downtime.
- Product Quality Improvement:** Creating smart designs, innovative products, and ultimate product reliability.
- Reducing waste:** Energy savings and the use of previously wasted materials drive companies to reduce their environmental impact and pollution.

## **2- Basic and distinctive characteristics of Industry 4.0**

The basic and distinctive characteristics of Industry 4.0 lie in the vertical and horizontal integration of intelligent production systems, which is basically the core of Industry 4.0, vertical networks stem from the use of cyber-physical production systems (CPPSs) that allows factories to operate, reacting quickly and appropriately to variables such as demand, inventory, and machine levels such as defects and unexpected delays. Horizontal integration through value chain networks will facilitate integration into the entire product life cycle from production to warehousing, components manufactured to the highest quality, and after-service support. The focus is on improving the company's value chain regardless of size, marketing or supply, logistics, marketing, and sales. Their view is to reduce expenses while maximizing profits, and their Philosophy is to do something better than their competitors and more efficiently. The advantages of Industry 4.0 for SMEs are increased business competitiveness, activity, revenue and employment, IT resource management, and improved manufacturing processes.

### **2-1- The impact of Industry 4.0 systems on the production of smart ceramic tiles**

The impact of Industry 4.0 systems on the production of smart ceramic tile impact of Industry 4.0 systems for smart ceramic tile production processes are thinking of a digital generation that affects all aspects of the industrial world and is a real qualitative leap in the way of thinking, and a different way of dealing with any context. This is achieved in Industry 4.0 that allows the measurement of objective reality (machine, time, function), and provides the most modern and innovative logistics solutions in the world of ceramics that change the vision of many things, and many other small details, that were previously hidden or not taken in consideration, that the data and knowing how to use it allows the knowledge required to build your production philosophy in an accurate and clear manner. Having a digital product allows you to see your factory from a different point of view with a data-driven vision, it is certainly seen as an engine of growth, a natural evolution of the production process, so digital is the right way to go so that we are not left behind. We are taking advantage of the opportunities of a rapidly developing sector. Hence, we believe that the ceramic industry will develop in the future; Because the

digital world is constantly changing, but what will happen is an improvement in the decision-making process at all levels. (Reference No. 1)

The platform has the expertise to gain efficiencies and transform into a 4.0 ceramic production plant, a reference platform in the ceramics industry for the integration, management, and control of plant operations; This is to improve production process control levels, integrated digital tools and applications for the platform, enable advanced and energy-efficient production systems, improve production processes and logistics services in order to achieve improved production management across its value chain, **and connect the different parts of the process in order to standardize information with the following actions :**

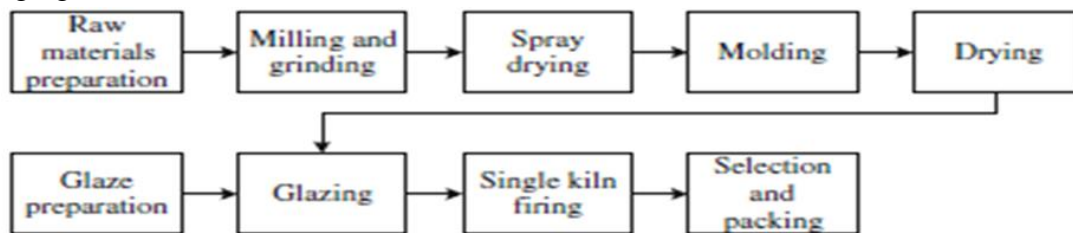
- Implement a tracking system for each piece of multiple product lines and track each of them once they are integrated into the platform.
- Monitor all production system information through an extensive network of IoT sensors.
- Create a comprehensive database to track all information and data flows coming from the global production system, thus obtaining a scale OEE that is more accurate and complex.
- Digital twin design that provides real-time production information. (Reference No. 5)

### **1.Manufacturing Scheduling Systems**

The implementation of manufacturing scheduling systems benefits the successive ceramic tile production processes; Because the implementation of manufacturing scheduling systems is concerned with recording all data and details for all stages of operations from machines, materials, preparation, application, planning, maintenance, and control ... etc., that is, everything that happens from the details of the production line and the management of the whole factory. The scheduling system can be defined as a set of models (representations of scheduling problems), methods (procedures for obtaining effective solutions from scheduling models), tools (software devices to include models and procedures to support scheduling a decision problem), in addition to the human elements that work on the system. These models, procedures, and tools will form the parts to bring all these elements together in a roadmap to guide the development of the scheduling system for ceramic tile production operations. This is an integrated view of manufacturing scheduling systems and the most important models. Track maintenance KPIs such as mean repair time and the average time between failures. The help of interactive reports that are prepared for everything, starting from the stage of the costs and even follow-up phase, performance analysis, the overall effectiveness of the equipment, and other - to make more intelligent decisions about your business. The work center control panel consists of (time tracking + page display + production recording) with a merged order (quality checklists + alerts during the process + record + serial number/number). (Reference No. 23) Production scheduling has become in manufacturing, it is necessary for the manufacturing processes, including multi-stage, multi-ceramic processes and details required to move production facility to the next level. The five components of production scheduling in manufacturing include planning, routing, scheduling, dispatching, and executing. The production guidance is; the process used to determine the path that must be followed by the product. (Reference No. 20)

### **3- The Production Process of Ceramic Tiles**

The production of ceramic tiles includes many different processes, and according to each of them a different end product is produced, and each process mainly consists of the following stages: Clay preparation, either by dry grinding or wet grinding and winnowing, • Forming or casting either by dry pressing or extrusion, • Preparing the glaze, • Drying, glazing, and decoration of tiles, • Furnace fire (also called rapid fire), • Classification and packing, Figure (3). The process of preparing the raw materials, particularly by wet grinding (including spray drying) is usually a separate process and called “winnowing in the form of semi-dry clay granules from the raw body mixture – clay –” may be carried out by other companies or lines for separate production processes. Another process often contracted to third companies, is the preparation of glazes and manufacture of frit glazes and pigments. The correct formation of the physical dimensions of the tile is often referred to as the tile layout, according to the properties of the template used. The drying process is usually in vertical or horizontal dryers (small kilns), after drying, the tiles are decorated in glazing lines, some of them are unglazed, and the tiles move over the conveyor belts, various applications and decorations are implemented. The basic process is to apply the base glaze, and it is referred to as roto colors, and include glazing equipment such as " printers " that can print ceramic tiles primarily in a large assortment of colors, patterns, and motifs. The central stage of the production process is the single fire, the single kiln firing, which is being subjected to chemical reactions inside the furnace during the various stages of the fire and body paint, visual quality control, or mechanical defects lines and packaging.



**Detailed flowchart of the most common traditional ceramic tile production process, Figure (3) Reference No. (21). Depending on the number and importance of defects, other optional production steps for ceramic tiles are shown.**

#### **3-1- Methods of modeling the ceramic tile production process**

- Prototype Initial Model allows us to provide accurate modeling of the scheduling problem arising in the manufacture of ceramic tiles, and the first feature that can be observed for the problem of production of ceramic tiles, (CTPP) ceramic tile production problem is that all products follow a natural flow through the plan, indicating the structure of the flow.
- A More Detailed Model: There are some optional stages such as tile polishing, this produces a production plan with many stages in the regular flow, resulting in what is known as flexible flow lines. In the context of systems HFS, this new phase skip problem is referred to as a Gantt chart, hybrid of the example problem, and hybrid flow shop (HFS), which is a combination of two well-known scheduling problems, the flow workshop, and the parallel machine problem.
- Modeling using a multisystem agent (MAS); It is a computerized system consisting of multiple interacting intelligent agents, and multi-agent systems can solve difficult or impossible problems for a single agent or monolithic system. Recent developments in multifactor systems that have been included in general scheduling problems and in industrial applications have



demonstrated the advantages of the agent technique in complex distributed problems, including modeling using the methodology GENIUS, to develop a targeted solution to the scheduling problem in the ceramic tile factory. This problem can be considered a complex problem that requires robust and flexible software applications. Our approach is trying to improve the production of each form and increase the reliability of the schedule and keep updated schedules, and it seems that the system model (MAS) is a suitable framework for handling the design and development of an application exile, adaptable to the environment, a relevant environment in a very dynamic reality, with the re-order and constant changes in the sector, such as new requirements of the customer, the entrance to the work. The acceptance of multi-agent system development methods in the industry is based on a natural method for solving problems that are distributed in nature, with many proposed approaches to real environments.

### **3-2- A software service platform for tiles from the system ceramic factories group, Prime-System Ceramics**

Prime- System Ceramics platform for software services has been designed and developed by a company, in which an integrated and highly connected system allows the organization of the information flow for entire ceramic production plans, as a form of manufacture process, or management Operations (MOM), and integrating Prime systems fully with ERP management systems, Powering Digital Transformation, full digitization, full graceful traceability, and complete data management. longer Prime is a solution capable of offering a complete view of production processes in their entirety by automating processes that continuously improve performance and continue the path of effective process digitization. The complete digitization of processes, the use of shared resources, and effective data management are essential elements of the sustainable development of the new manufacturing model, digital industrial design. The production cycle is always under control thanks to controlling Prime Digital Twin in the entire ceramic production cycle: from the entry of raw materials to the assembly of the final product selection list. Representing ceramic production systems in all their completeness and dynamism, allows a virtual reconstruction of the entire production cycle, resulting in higher quality and lower production times.

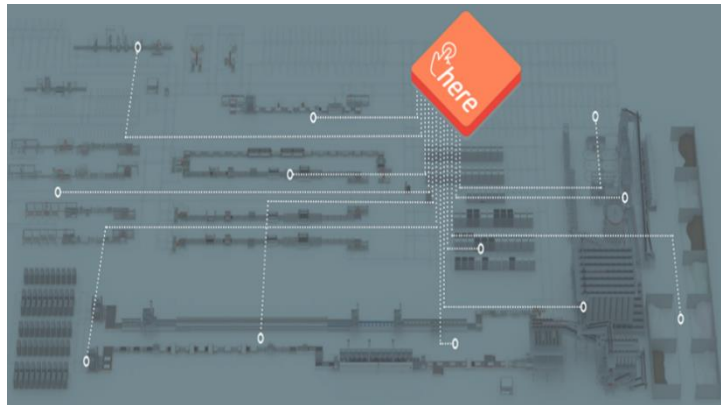


**Figure No. (5), a set of illustrative pictures of the program application maps, Reference No. (5) --- and Reference No. (18)**



### 3-3- Enhanced Digital Fabrication Platform 4.0 HERE for tiles:

Your smart factory is fully controlled thanks to a modular software platform that connects production and ERP with greater productivity, connectivity, and sustainability for the ceramic factory. An innovative software platform developed by SACMI to provide digital control of an integrated system of data and



ceramic processes, covering everything from raw materials to shipping, allows producers to implement new functions via a joint design approach that results in a customized production configuration. An in-depth understanding of the ceramic industry and the ability to provide advanced software and engineering solutions to factories is the ideal partner for factory digitization. Figure No. (6), a set of illustrative pictures of the smart factory application method maps, Reference No. (6) --- and Reference No. (8)

### A case study of the SACMI system 4.0 for the smart factory

A company that uses early development of digital manufacturing solutions and smart innovation strategies, one of the first to implement the principles of Industry 4.0., Figure No. (7)

Doing so required developing new skills in key areas such as electronics, robotics, and data management. The term smart industry refers to the factory of the future, where the physical world of things and the virtual world of control and simulation merge to develop more efficient and sustainable production processes. Industry 4.0 defines the Internet of Things and increases the opportunities offered by new technology, and it envisions the factory as a place where manufacturing is controlled through a digital product process framework for the benefit of customers, corporate competitiveness, and skills enhancement. SACMI develops prototypes for what is now the world's leading " Industry 4.0 " solutions.



**Figure No. (7) A group of images of the SACMI Smart Factory application system and the tiles resulting from the two smart factory applications, Reference No. (7)**

The know-how of the ceramic industry has been developed through SACMI Software, making ceramic manufacturers work ready, by following a co-design approach, adding more functionality to the platform. Precise mapping of the manufacturing plan and flow analysis ensures optimal implementation of the digitization project. In this way, it allows manufacturers

to create " ecosystem " interactive sophisticated links among technology, people, and processes, it is also a flexible approach to achieve many benefits and leads steadily to the factory management integration, from production to major maintenance, information technology to control, from planning to logistics. The ideal part of digitizing a mass-production plan includes optimizing the line condition process, making an optimum use of time, and troubleshooting, leading to higher efficiency. This gives HERE full control of the smart plan, allowing process supervision, from powder preparation to shipment, **has versatile, high-tech advantages through:**

- Calculation of energy performance indicators (enPI) and malfunction notifications.
- Improved production management, tracking every step of the way, and real-time progress updates.
- Management of integrated product processing systems, comprehensive maintenance.
- Real-time overview of line status and automatic calculation of KPIs (KPIs), Data analysis dashboard, automatic and manual collection of data about product quality, raw materials, and process.
- An easy-to-use, trusted partner, known worldwide, can be switched to the digital station, Reference No. (7)

#### **4-1- Stages of applying digital modeling to tile production processes according to SACMI (case study)**

Technological innovation and process automation are Providing machines and systems for ceramic tiles and panels, and machines and systems that are competitive in terms of efficiency, costs, flexibility, and production quality, ensuring energy savings and reduced environmental impact. The smart production lines of the following lines were explained, documented from their sites, and with multiple illustrations.

##### **First: smart powder plant:**

Storage, and preparation of semi-dry granule powder body mix / ceramic body preparation, and innovations designed to improve process efficiency, from automatic management of raw material loading, through recipe dosing, to powder loading in storage silos. Better performance is achieved in terms of energy savings, redundancy, process control, product quality, and consistency, in addition to availability of advanced predictive machine maintenance functions.

##### **Second: The smart baseline**

(Forming, drying, decorating, and burning lines from SACMI), in which the production of tiles and ceramic plates in the best possible conditions to achieve the highest levels of quality, productivity, and operational flexibility, with a large hydraulic pistons and Deep Digital decoration technology which is the latest trend in the industry. The new thermal machines (dryers and ovens) ensure high-quality standards, reduce energy consumption and environmental impact.

##### **Third: Smart Finishing and Logistics:**

Tile storage, handling, finishing, cutting, and sorting allow production to be organized in batches, which facilitates product changeover and increases the efficiency of ceramic

production. The burnt products are dealt with by automatic vehicles in the case of large volume ceramic production, intermediate storage of the burnt product, and subsequent surface finishing and shape cutting, Reference No. (7)

#### **Fourth: Intelligent Line, Digitally Decorative ceramic panels**

The multi-functional smart line, digital decoration methods, are grouped in one production line, show the marks for all the executed quality lines, and it is possible to combine all the processes in one product to create special and unique techniques. The wet and dry digital decoration technology, structured surfaces platform can be synchronized with the Deep Digital SACMI line to provide flexible decoration operations that are centrally controlled by the software HERE, Reference No. (10), Illustrations of the results of the new and digital dry and wet decoration results, Reference No. (10), Pictures of the application methods are taken from the production method demonstration video, the relief and deep body decoration of tiles at all stages, Reference No. (9).

Let's merge DDG and DHD in digital decorating solutions, manufacturers produce panels with unparalleled effects and depth, and the system combines the selective application of double grain with the application of glue, resulting in innovative products featuring a combination of two dry raw materials and two additional wet materials, (digital devices on the lines), with superior clarity, superior flexibility, integrated process control, and fully automatic management of tailored products, the texture feels natural. When DDG and DHD are merged with the line Continua+, the embossing can be digitally coordinated with the structure and body of the ceramic product, a platform for the digital application of both dry and wet texture effects creates digitally regulated, glazed, and embossed products with the highest standard.

#### • **Conclusion and results:**

The concept of " Industry 4.0" is introduced as a new industrial model; As a result, it is a new vector for the development of the industry, which has been introduced only in some developed countries, which may in the future lead to the gradual modernization of other areas of the industry, and has the potential for changes in the current technological situation, the global character of the new industrial model, as it was used to denote the process of transformation in the world in terms of its value chains. And the organization of a global production network operating based on new information and communication technologies and Internet technologies through which the interaction of production objects is carried out. Industry 4.0 is described as the golden age of machinery manufacturing and organized production based on digital technologies and fully automated by basic characteristics, Reference No. (25)

• Numerical consistency of engineering throughout the product (the life cycle and related production system), avoiding technology breaks too much for the sake of theory, without the slightest regard for technology, Reference No. (18)

**The digital future is not as simple as it may have appeared in the beginning, there are many obstacles on its way:**

Obstacle No. 1: The pressure of efficiency in the added core value.

Obstacle No. 2: Different cultures ... and others.

Clarification in reference (18) with the possibility of its application in Egypt. All in all, the best are SACMI and Prime digital platforms for the Smart Factory; Because they have applied preexisted experiences in many ceramic companies and factories, and are familiar with the planning, work, research, and continuous development in the field of ceramics.

### Refernces:

- <http://www.worldceramictiles.org/>
- [https://eg1lib.org/book/2741192/da810fAlasdair Gilchrist Industry 4.0: The Industrial Internet of Things 2016](https://eg1lib.org/book/2741192/da810fAlasdair%20Gilchrist%20Industry%204.0%3A%20The%20Industrial%20Internet%20of%20Things%202016)
- <https://eg1lib.org/book/5395590/702ee4>
- Peter H. Diamandis, Steven Kotler The Future Is Faster Than You Think: How Converging Technologies Are Transforming Business, Industries, and Our Lives2020 Download (epubook)
- [https://www.academia.edu/11197035/Applying\\_Multi\\_Agent\\_System\\_Modelling\\_to\\_the\\_Scheduling\\_Problem\\_in\\_a\\_Ceramic\\_Tile\\_Factory](https://www.academia.edu/11197035/Applying_Multi_Agent_System_Modelling_to_the_Scheduling_Problem_in_a_Ceramic_Tile_Factory)
- <https://nexusintegra.io/digital-transformation-ceramic-industry/>
- [https://repository.systemceramics.com/content/uploads/2021/07/2021\\_Brochure-PRIME-](https://repository.systemceramics.com/content/uploads/2021/07/2021_Brochure-PRIME-)
- <https://sacmi.com/en-US/ceramics/about-us>
- <https://sacmi.com/en-US/Ceramics/Tiles>
- <https://sacmi.com/en-US/ceramics/Tiles/Decoration>
- <https://sacmi.com/en-US/Ceramics/Tiles/Deep-Digital>
- [https://sacmi.com/sharedcontent/media/Documents/Ceramics/catalogue/DEEP\\_DIGITAL\\_20200619-IT-EN.pdf](https://sacmi.com/sharedcontent/media/Documents/Ceramics/catalogue/DEEP_DIGITAL_20200619-IT-EN.pdf)
- <https://thedigitalprojectmanager.com>
- [https://www.academia.edu/17102146/A\\_MAS\\_Approach\\_to\\_the\\_Production\\_Programming\\_Problem\\_in\\_a\\_Cera](https://www.academia.edu/17102146/A_MAS_Approach_to_the_Production_Programming_Problem_in_a_Cera)
- <https://www.ceramicworldweb.it/cww-en/news/education-and-events/increasingly-smart-intralogistics-in-the-ceramic-industry/>
- <https://www.ceramicworldweb.it/cww-en/spotlight/sacmi-here-a-modular-scalable-approach-to-digitalization/>
- <https://www.ceramicworldweb.it/cww-en/spotlight/the-smart-evolution-of-product-development/>
- <https://www.ceramicworldweb.it/cww-it/spotlight/zschimmer-schwarz-ceramco-apparently->
- <https://www.pdfdrive.com/industry-40-in-the-automotive-industry-e38662331.html> Industry 4.0 in the Automotive Industry90 Pages · 2015
- <https://www.planettogether.com/blog/4-components-of-production-scheduling-in-manufacturing>
- <https://www.planettogether.com/blog/five-types-of-production-planning>
- [https://www.researchgate.net/publication/300856811\\_A\\_Case\\_Study\\_Ceramic\\_Tile\\_Produ](https://www.researchgate.net/publication/300856811_A_Case_Study_Ceramic_Tile_Produ) ucti
- <https://www.rockwellautomation.com/en-gb/capabilities/smart-manufacturing/smart->
- <https://www.softwareadvice.com ›Manufacturing› pro- 2021>

- <https://www.springer.com/gp/book/9781447162711> Jose M. Framinan and other "Manufacturing Scheduling Systems An Integrated View on Models, Methods and Tools" Book 2014 Springer Lin
- <https://www.springer.com/gp/book/9783319943091> Editors: Popkova, Elena G., Ragulina, Industry 4.0: Industrial Revolution of the 21st Century© 2019
- <https://www.systemceramics.com/en>  
<https://www.systemceramics.com/en/news/prime-benefits-digitalization-end-line->  
<https://www.systemceramics.com/en/products/smart-factory/prime>  
[https://www.zschimmer-schwarz-ceramco.it/fileadmin/user\\_upload/pdf/\\_02\\_APPARENTLY\\_INVISIBLE\\_EN.pdf](https://www.zschimmer-schwarz-ceramco.it/fileadmin/user_upload/pdf/_02_APPARENTLY_INVISIBLE_EN.pdf)