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Industrial 4.0 and an Application in Corum Industry*

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Abstract

Industry 4.0 can be summarized as adding value to human life by combining advanced research in the fields of biology, technology and industrial automation to improve the living conditions of today. Now, we are faced with systems that operate on their own and communicate with their environment. In this context, it can be said that Industry 4.0 opens a new era (Boschrexroth, 2017). The term Industry 4.0 takes its meaning from the combination of significant innovations in digital technology, biology and hardware automation (CGI, 2016). The cyber systems used today can make simple decisions on their own. They are connected to each other in cyber space and can communicate through the Internet of Things (IoT). In business life, the ability to solve urgent problems in a short time is important (Del Mar Rodriguez Masdefiol & Stävmo, 2016; Doleitte, 2017). Cyber physical systems are able to make their own decision or physically support people in a number of jobs that are not possible for people. From health to environmental services, from agriculture to the weather forecast area and all other production facilities, cyber systems are located in each area, and self-deciding systems are activated. Get more power, lighter weight, quicker interventions etc. to improve the properties of materials and the processes (Donanimgunlugu, 2015; Endustri40, 2018a; Endustri40, 2018b; Engineering, 2016). In this study, applications performed in manual systems were compared with automatic processes within Industry 4.0. According to the results obtained from the study, glazing errors encountered in manual systems are not found in automatic systems. The continuity of the works carried out within the scope of automation is also reflected in the numbers. Although there are more transactions, fewer errors are made. The quality of the operations directly affects the final product quality. This situation positively affects the health of employees (Industry4Magazine, 2017).

*This study is derived from the Master's Thesis which was defended with the same title in 2019 at Hitit University, Institute of Social Sciences.

Keywords

Industry 4.0, Industrial Revolutions, Big Data, Robotic Systems, Virtual Reality

1. Introduction

Industry 4.0 is not only an industrial transformation, but also the role of new machinery, equipment and software from procurement to production, planning to after-sales services, and how important these tasks is in many aspects such as current and future costs, health, qualification management, and instant market responses. The developments in recent years also clearly emphasize that this situation exists (Schwab, 2017; haber.tobb, 2016).

At Corum Organized Industrial Zone, the difference and importance created by such innovative solutions at points such as how full automatic glazing systems are used by a company operating in vitrified production to glaze its products, affect productivity in production, and change the role of the employee, and what are the investment costs.

2. Industrial Revolutions and Industrial 4.0

The transition from production techniques based on human and animal power to production methods using machine power was called the Industrial Revolution. In the 18th and 19th centuries in Europe, the capital accumulation in Europe has increased with the great stage in the industry, where the iron and coal constitute the main energy source and raw material, and with the effect of new inventions and steam-powered machines. This process has been called the Industrial Revolution (Özdoğan, 2017: p. 1; Banger, 2017; Fortune Turkey, 2017).

The population has increased in Europe since the 16th century, besides the Renaissance and Reform movements in Europe after the Middle Ages, religious, political, scientific and philosophical ideas in the 16th and 17th centuries encouraged the European people to free thought. The development of the steam machine, which was invented by Thomas Newcomen at the end of the first quarter of the 17th century, but which was not used outside the mining area, was developed by James Watt as a source of energy in the industry and played an important role in the development of production, transportation, and technical developments. With the invention, establishment, and development of railways, it reached its peak in the first quarter of the 19th century. It is accepted that the first Industrial Revolution ended in the mid-19th century. In the factory system production type, the Second Industrial Revolution was accepted as the age of the production methods started with the development of Henry Ford's walking belt assembly technique (Fordist Production Technique) at the beginning of the 20th century and the revolution reached its peak with the invention of the transistor (Görçün, 2016: p. 1; Banger, 2017; marmarasosyaldergi.org, 2017; matematiksel, 2017).

Research needs underlying free-thinking; while leading to geographical discoveries, the colonial movements that these discoveries initiated enriched Europe. In the financing of these developments, the resources obtained by England from their colonies played a decisive role. The raw materials brought from these countries were sold to other countries processed in Europe and put into the cycle of the current system (Özdoğan, 2017: p. 1).

With the introduction of new energy production sources and tools such as coal, electricity, oil, internal combustion engine, steam machine in technology, the need for manpower has decreased, and the production capacity has increased greatly with the new machines that are the return of the process. On the other hand, trains and ships working with this technology have played an important role not only in production areas, but also in the connection of production areas, raw material resources and, of course, the market with the use of steam power (Schwab, 2017; tandfonline, 2017; techradar.pro, 2018).

The emergence of Microchip technology in the 1980s found its use in many areas of the industry and even caused the emergence of new areas of use. This period is also called the Satellite Dish Revolution. With the Third Industrial Revolution, the current effective system had to redefine itself. The telecommunications industry and other electronics-based industries are counted as the cornerstones of this revolution. While the transfer of production technologies until the Third Industrial Revolution or knowledge—knowledge and skill sharing, also known as know-how, cannot be in question, with this new revolution, the transfer of advanced technology products, production technique, technology and knowledge-accumulation, the market expands and income and with the thought of increasing profits (Schwab, 2017: p. 1).

Whatever the conditions of the day necessitated, industrial revolutions consisted of inventions, inventions, and improvements made to meet these requirements. Industry 4.0 can also be considered as a new structuring process as a result of the needs and developments in different fields that affect each other after the third transformation. These new needs, automation systems, and inter-device communication system called IoT (Internet of Things) have become indispensable components of industry 4.0 (Balasingham, 2016).

In order to understand the emergence process of the term Industry 4.0, it is necessary to take a closer look at the stages of the industrial change process in Germany, which is the locomotive of the machinery industry in Europe. The German Ministry of Education and Research introduced as an action plan in 2011 as 10 main projects, combining the works carried out and to be carried out in order to strengthen the progress in the future, where predictions can be made, taking into consideration the current conditions. These programs, called "Future-Project", were published under the name "Future Projects of High-Technology Strategy 2020" (Özdoğan, 2017: p. 1; Proente, 2018a; Proente, 2018b; Proente, 2018c; Proente, 2018d; Proente, 2018e; Proente, 2018f).

The other important project promoted by reducing carbon emission values, switching to environmentally-smart cities, increasing the use of environmentally friendly renewable substitute energy sources instead of existing fuels, and expanding smart grids is the German-language "Industrie" Industry 4.0 is launched as "4.0". It is stated that the German government has full confidence in this project. This paved the way for the studies carried out in order to make the process understandable. The government has allocated 200 million Euros to the project as a starting step. Subsequently, the document, which was announced at the Hannover Fair in 2013, was prepared under the leadership of the Federal Academy of Science and Research of the Industry 4.0 Strategy Document. Although this document has been prepared with more consideration of Germany, it draws important lines regarding the characteristics of the new transformation. With this aspect, it opened the curtains of the new industrial age to the world. Basically, Industry 4.0 aims to ensure that the departments in the production facilities communicate with each other, to obtain this data in real-time from the first moment the communication begins, and thus to reach the highest added value that can be achieved through these data (Akeson, 2016; Alexandre da Silva Correia, 2014; tandfonline, 2017).

In order to ensure that Industry 4.0 does not remain in theory, in 2013, three organizations, VDMA (Der Verband Deutscher Maschinen un Anlagenbau), BITKOM (Bundesverband Informationswirtschaft, Telekommunikation und Neue Medien) and ZVEI (Zentralverband und Elektronikindustrie) launched the "Industry 4.0 Platform" (https://www.plattform-i40.de/PI40/Navigation/DE/Home/home.html). This institution; It aimed to support the development of new technologies, to determine the basic standards in transformation, to identify new emerging business models and to carry out studies in order to adapt the society to this transformation in this process (Akeson, 2016; Alexandre da Silva Correia, 2014; Cdn.endüstri40, 2017).

The interest and contribution of both the academic community and the business world to the subject has expanded the concept, as it has accelerated the process of dissemination. It has already become one of the important agenda items of the countries planning this transformation for their countries. Legal figures are also taken into consideration and efforts are made to prepare the ground for more effective opportunities for this transformation process on products and processes (Sclötzer, 2015; Weidmüller, 2017).

3. Implementation of Industry 4.0 in Vitrified Industry

The application is to evaluate the differences between manual glazing systems and robotic glazing systems in terms of Industry 4.0 in a vitrified production facility in Çorum Organized Industrial Zone, and to evaluate robotic automation glazing systems in terms of Industry 4.0 production systems. The company name is not specified, as it does not allow the use of the company name.

3.1. Methodology

The main raw materials of ceramic production are clay, kaolin, feldspar, and quartz. The traditional production method in vitrified production is the casting system. In this system, the slurry is poured into plaster molds and the liquid in the slurry is removed with plaster within the specified time. At the end of the period, the non-absorbed slurry is released to regenerate. The stages of the process; It results in mass preparation, glaze preparation, mold preparation, shaping, drying, glazing, and cooking processes.

Preparation of mass: The main ceramic raw materials such as clay, kaolin, feldspar are mixed according to a specific recipe and then grinded in a water mill to obtain ceramic mud.

Glaze preparation: Ceramic minerals such as kaolin, quartz, and zirconium, which form coating ceramics, are crushed and ground according to a specific recipe when the ceramic glaze is obtained. The color of the colored products is added to the varnish.

Preparation of the mold: In the facilities where gypsum molds are used, plaster and other reinforcing materials are molding processes in which the molds forming the product are formed by mixing.

Forming: Here, the shaped product is molded into the gypsum or synthetic resin molds using various casting techniques. The slurry is brought to the desired consistency during the preparation phase of the composition. In the molds, the body of the body, which reaches a sufficient wall thickness, is removed and left to dry.

Glazing: The molded and dried semi-finished product is glazed by hand or robot in the glazing area and dried again.

Baking: Drying glazed semi-finished products are baked at about 1250˚C. Cooked products are checked and products are repaired a second time and baked with repairable defects at about 1200˚C. The products to be decorated afterward are subjected to a decoration process and are subjected to quality control. The products classified in the quality control section are stored. The casting process is increasing day by day with synthetic resin molds, which provides a faster and more efficient casting process than plaster molds in the casting process, and it is an important handicap for this type of production. As we will examine in our simulation instead of manual glazing, robot glazing systems have started to take more roles today. As a result of the calculations that occur in the final stage of firing, the oven capacity of the products controlled after glazing, loading is carried out for firing in an array. As in other production processes in the ceramic industry, stoves that directly burned instead of indirect combustion took place in factories and saved energy, capacity and time.

After the quality control, the products that were regained and returned to the II. It is ready to be offered to the market with firing.

3.2. Simulation

Ceramic sanitary ware surfaces are tried to be applied by spraying, dipping, pouring in order to give raw or fused glaze muds to the final product such as decoration, smoothness, transparency, opacity, opacity, mechanical strength and scratch resistance.

In the glazing spray, the products dried after casting become semi-finished products with 1% to 1.5% moisture, the aqueous slurry mixture is sprayed onto the surface and a thin glaze layer is formed on the surface. The secret is thrown on the product with special spray guns. The secret thrown by the piston creates a stable surface. Particular attention should be paid to the borehole, blast pressure, nozzle density, and spray distance parameters of the gun. Spraying can be done manually or automatically. The recessed surfaces of the products are usually glazed manually.

The manual glazing technique is based on experience considerably. It is an important skill, practice and motivation job to spray the glaze with the pistol evenly on every point of the product surface. If it is not glazed with such a sensitive approach and there is no uniform distribution on the surface of the product, various errors such as color tone differences and pinol occur after firing.

Tools used for successful glazing;

Boumeter: Used to measure glaze density.

1-liter graduated cylinder or flask: Used to determine the glaze density in the scale.

Sieve: To eliminate secrets.

Compressor: It is used to produce compressed air.

Piston: A spray gun that sprays watery secrets with certain air pressure.

Glazing cabinet: It is the cabin where the glasses are made with pistons, the secret of which is absorbed and attracts.

Glazing tourette: The table where the product is glazed rotates around its own axis.

Mixer: Used to mix the secret to prevent collapse.

Sable Brush: It is used to complete the secrets of unglazed areas.

Sponge: To erase secrets on the surface of the oven.

Knife: To scrape more secrets.

Glaze bucket: Secret chamber to mix secrets.

These tools and apparatus to be used should be checked continuously.

The spraying method and glazing steps are as follows. These steps are the same for automatic glazing systems. The dust of the semi-finished product is removed. If necessary, it is slightly moistened. The glaze density is measured with Boumeter or adjusted by weight per liter. Glaze density should be 60/65 liters, approximately 1650 g/lt. The air pressure of the compressor is checked. Air pressure should be 7 - 8 bars. The mouth of the pistol was adjusted.

The biscuit product is placed on the turntable on the glass cabinet. The room is filled with glaze. The glazing distance is adjusted. The glazing process is carried out. During glazing, Turnet is rotated at a certain speed. It is envisaged that the glaze sprayed from the gun will be distributed evenly on the product surface. The glassed product is brought to the table. The secret is touched. The glaze spraying from the gun is distributed evenly over the entire product surface. The underside of the bottom surfaces of the oven plate is wiped with a sponge.

All these parameters are approached precisely at every point, and each step should be checked by the relevant glacier and department officer and even if it is available in the facility, the laboratory should be archived accordingly and arrangements should be made according to raw material planning.

In robotic glazing systems, all of these steps mentioned above are done automatically, the density of the glaze can be controlled before exiting the pistol, the spray distance and the aperture can be adjusted according to the product. In manual glazing systems, it takes almost six months for a skilled glazer to catch up, while in robot glazing systems, this system is achieved by teaching once.

This step of ceramic sanitary ware, which also constitutes a significant problem for worker health, minimizes problems with the robotic glazing systems. Another difficulty of glazing due to manpower causes fatigue due to holding the pistol for about eight hours, sometimes causes color difference errors on the surface of the product. At some points, early diagnosis is not possible and causes significant material and time loss in glazing.

When finishing with spraying, the finishing on the surface of the product should show a homogeneous distribution. In order to ensure homogeneity, the glazing process (glazing, finishing) should be done by glazing movement on vertical and horizontal surfaces. In these manual movements, errors increase as the constant line or curve continuity depends on motivation and power losses.

In automated glazing systems with robots, this process is carried out with automated robot arms, and orders placed by the software are strictly followed.

The modeling process on 3D programs before retouching, or the product, whose 3D map was created by manual scanning method, is also simulated by complementary programs. This process is also called Product Teaching.

Regardless of the product type or model; after the semi-finished finishing process, the glazing process begins with the loading of the conveyor belt to the loader employee to reach the robotic glazing system. Depending on the conveyor belt capacity, the lavatory, toilet and toilet loader continues to progress to turnets on the glazing cabin step by step, with the employee marking the relevant code on an electronic panel. In one of the two hands on the cabin, while the glazing continues, there are products or products waiting for the glazing order in the other hand. The product is loaded on these hands via the manipulator. At the same time, the glazed products are loaded on the conveyor that extends towards the furnace trolleys after the reverse movement of the same manipulator. The products that come in front of the glazing robot arm with 180 degree movements on the cabin continue to be transported to the conveyor before the oven trolley, with the 180 degree movement, which will be done by the end of the glazing times. At this stage, the human hand is not touched, but the bottom wiping of the product to be loaded on the oven carts is completed with a slight motion of the oven car loader and loaded on the oven car, and it is ready for the vehicle to be filled for cooking.

Figure 1 shows the manual product placement system. In the first one, the

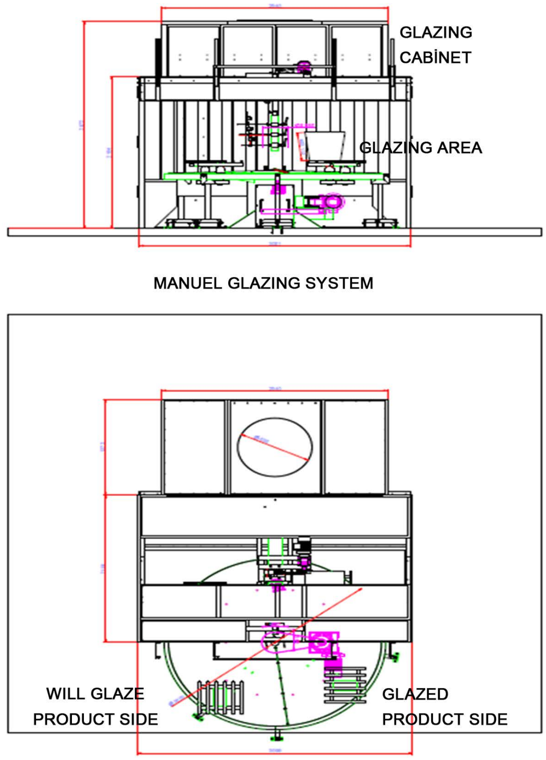

Figure 1. Manuel glazing systems.

working systematic of the manual glazing system is shown. In the second part of the figure, the products whose glazing process is completed and the products whose glazing process is completed are shown together.

3.3. Industrial Internet of Product and Self-Organized Production Support System

The system, which consists of two conveyor belts, a manipulator, a three-arm turnet and a robot arm, is the product that moves to the glazing point and then to the furnace car, with the loader employee marking the relevant code on the electronic panel. It moves towards the manipulator according to the order of loading, while the product, in turn, is waiting for the glazing of the products in front of it for the last step before glazing by the manipulator while the product in the other hand is glazed.

As a result of the robot arm measurements, the glaze density, the air pressure, without any problem, finish the glazing of the relevant product within the framework of the teachings and gives the information that it is prepared for the other product by pulling itself back, cleaning the needle. Turnet glazed products displace the product waiting to be glazed, the robot arm starts the new glazing process although it is sure of all parameters. When the turnet finishes its movement, the positioning range data is determined by the manipulator working with servo motors for precise transportation and the loading of the oven carriage is carried out. Meanwhile, to fill the empty turnet arm with the product waiting for glazing, the product to be manipulated by the manipulator is placed around the robot arm to be glazed in the cabin. Taking the information that the glazing is finished, it moves towards the moving conveyor and takes the product to be glazed over the belts, and the 90 degree directional movement and loading process ends the process, it waits for its position to continue the cycle until the glaze ends.

Figure 2 shows a fully automated robotic product placement system.

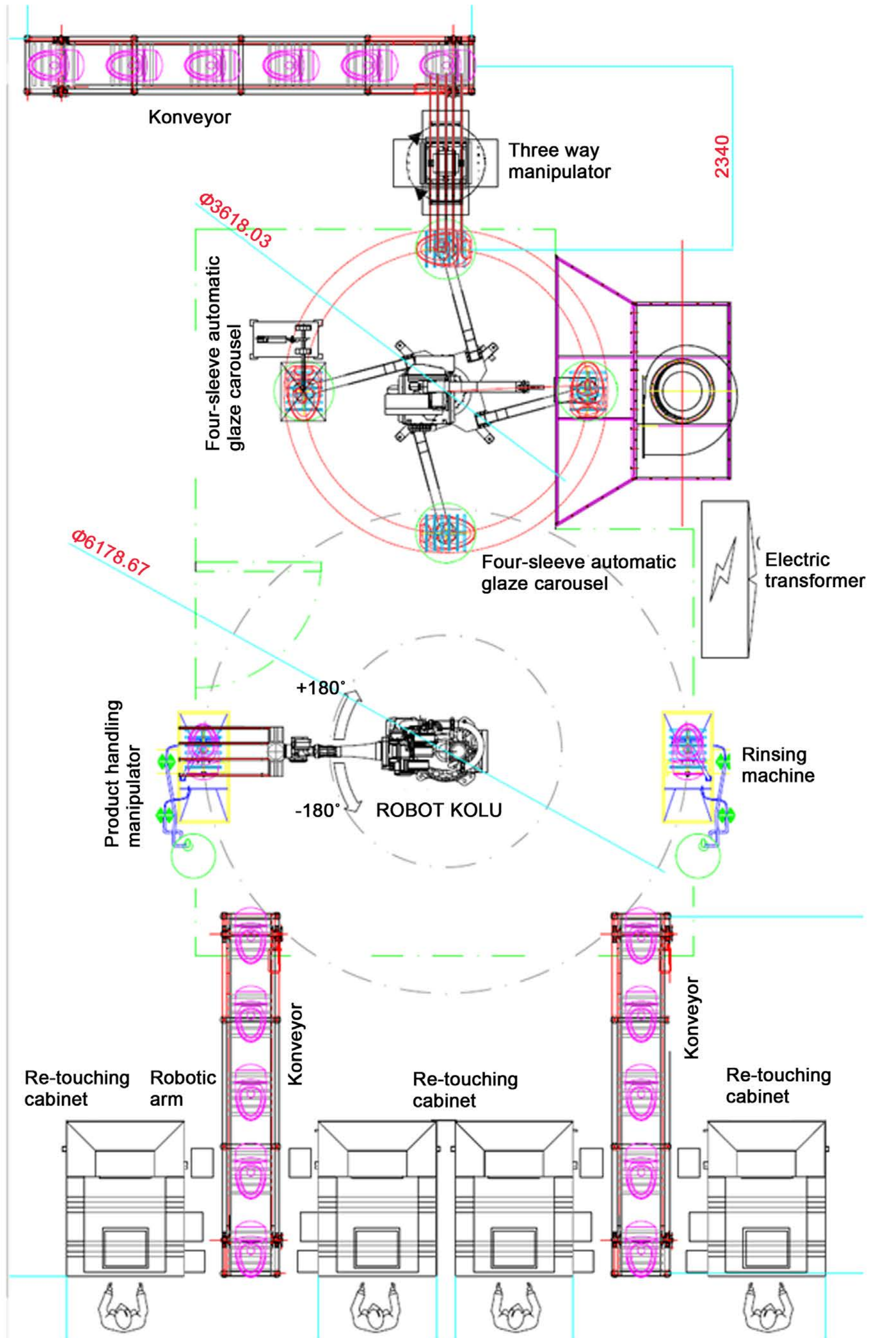

Figure 2. Full automatic robotic placement systems.

3.4. Result of Simulation

While manual systems require four employees: retouchers, glazers, post-glaze retouchers and car loaders; this number drops to two as semi-finished retouchers and car loaders in automatic glazing systems. Secret values are constantly checked automatically. While no main fault is observed in the robot arm or conveyor belt systems as long as the main maintenance is done on time, errors are more frequently encountered in manual glazing due to the physical difficulties of the work and the dependency of the related steps.

The continuity of the work done is also reflected in the numbers, while the average of 220 products/overtime (eight hours) is glazed in the robotic glazing system, this figure is around 150 - 160 in manual systems. On the other hand, since the maintenance of equipment such as pistols, needles, and manipulators are automatically included in the process, product usage times—the number of operations are also increasing.

3.5. Findings

In the developed countries whose methodology is examined on-site, product quality glazing systems stand in a very important place for the production of vitrified, which is increasingly discontinued from production or automated. In other words, each transition in the production process steps directly affects the final product quality.

As seen in the process monitoring stage, it is expected that the automatic glazing systems with robotic glazing systems will replace the manual glazing systems not only in our country but also in the vitrified manufacturer countries, in order to achieve the health problems and the targets to find and maintain qualified employees in the vitrified industry, which is considered as one of the heavy industry branches. It can be seen that the trend will increase. The situation described above can be seen in Table 1.

4. Result and Evaluation

With the very important contribution of automation processes in the factories to be conceived with Industry 4.0, the existing machinery, equipment and/or devices in the facility will be able to communicate with each other and determine the production processes within themselves and convey the possible setbacks to the relevant device, which is a regulator and even a planner at the point of daily activities in production planning. It means that they will undertake roles in such a way that it is close to the emergence of facilities that can prevent the bottlenecks that may arise by placing the necessary resource order automatically in case of need for supply at any stage of production.

Cyber-Physical Systems will enable significant differences not only in production but also in critical units of businesses such as Sales-Marketing, Research-Development, and Design. A manufacturing facility to be invested can be simulated before it is built, and all necessary calculations can be made, revealing the

Table 1. Manual glazing systems and automatic robotic glazing systems.

Manual Glazing System and Robotic Automatic Glazing Systems Comparison											
	Investment Cost	Average Number of Products/ Work	Machinery and Equipment Cost	Personal Number	Health Factor	Effect on Automation	Annual Maintenance Number	Maintenance Cost	Efficiency Rate	Fixed Expenses	The Unit Cost
Manual Glazing	178,7500 TRY/Unit (32,8585 $/unit)	155	0.11	1.2962963	5	2	6	0.0074074	90%	0.0296296	14.392593
Robotic Automatic Placement	965,2500 TRY/Unit (177,4357 $/unit)	210	0.0635556	0.4166667	1	5	3	0.0333333	98%	0.0222222	2.6788889

*Health Factor 1 - 5 rated as 1 most negative 5 most positive; *Effect on Automation is scored as 1 most negative, 1 most negative, 5 most positive; *Annual Maintenance Number. Some of the issues identified in the survey studies conducted during the production process are as follows; A glazing employee that works in manual glazing cabinets, when considering the mixed product portfolio (closet, sink, foot, halal stone, etc.) in different sizes and sizes, circa 150 - 160 products. The glazing success rate is around 90% in these numbers, which are carried out within eight hours of working hours. While this efficiency rate is of great importance within the overall efficiency rate, it affects factory efficiency by up to 5%. Such an inefficient stage for a sanitary ware enterprise is a very important factor in terms of costs, and the ability to recycle and, if not, disposal costs directly affect the profitability of the companies. However, considering the product portfolio in different sizes and sizes in robotic glazing systems, the average is around 200 - 220. In addition to this, since the values in the glaze are subject to automatic control, errors related to the glaze are detected before the operation begins. Therefore, it enables early intervention, thus, inefficiency can be prevented and less flow, pinol and color difference problems are encountered. The efficiency ratio of robotic glazing systems is around 98%, which affects overall efficiency much less. Costs and profitability are also optimized for the glazing effect. If we take into account the costs of machinery equipment investment, which is another side, the manual ready glazing systems cost around 180,000 TL, while these figures increase with maintenance costs and employee costs. In robotic glazing costs, these costs are lower than maintenance cost and employee cost, and it is around 1,000,000 TL. Due to employee cost, efficiency, stability and maintenance costs, we can see that the depreciation process is much earlier considering the employee need in manual glazing systems.

scope and costs of almost all processes. In this context, we can say that Cyber-Physical Systems offers the ground of tomorrow in the emergence of solutions and productivity-oriented production facilities, which are not yet imagined today, and in increasing effective resource utilization.

Gradually by professionalizing these processes; ERP (Enterprise Resource Planning) stands for ERP stands for enterprise resource planning. These are systems and software packages used by organizations to manage daily business activities such as accounting, procurement, project management, and production, MRP (material requirement planning) computer-aided application that performs material requirement planning, production planning, and inventory control activities. MRP II production resources planning (manufacturing resource planning) uses these systems, which are very important software tools for manufacturers, such as the applications used to effectively plan all resources of a manufacturing firm, and if their team and equipment are familiar with these titles, they will gain significant advantages in transition to the Industry 4.0 process.

In addition, Cloud IT, an important pillar, enables future factories to obtain more economical, flexible and agile data management, IaaS (Infrastructure as a Service) for hardware service, PaaS (Platform as a), which provides an environment where improvements and corrections related to changing and developing processes can be made. A service network that includes three models such as

SaaS (Software as a Service), which provides instant use of software services by the servers, will be offered to the companies. It can be preferred according to the needs or will give these tools to the service of the enterprises to use it completely. These applications, which will reduce investment costs and operation costs, will bring people together due to production facilities, directly related or indirectly related services in the medium and long term. The important benefit of today is that the responsibilities are handed over to the service providers and the companies support the companies in spending more time on strategic steps. Security heading for Cloud IT, which has been discussed since the first day, helps companies and public institutions in their processes and creates solutions with new perspectives and developments in Industry 4.0.

Catching the rapidly developing technology with Industry 4.0 is of great importance in the sanitary ware industry or in the ceramic sanitary ware industry as it is in almost every sector. It is getting harder every day to find, train and retain qualified personnel in the light of the current conditions. In addition, human errors are the primary factors that directly affect productivity. In the vitrified sector, it is possible to design and manage unmanned processes followed up to semi-finished drying, glazing and firing processes after casting after mud and glaze preparation. However, at this point, the fact that bilateral, vitrified and informatics technologies, who do not have any knowledge-trained personnel who can manage these processes are an important deficiency for our country, unfortunately, it is valid not only for the vitrified sector but for all sectors. Fortunately, sensitive studies have been initiated recently regarding the training steps in this business, and graduates will be graduated as digital operations managers and training opportunities will be offered to today's youth.

In the sanitary ware industry, we can see how important advantages have been gained in terms of the control and controllability of production facilities with Robot Glazing Systems in accordance with the Industry 4.0 principles, which we have just reviewed at one stage.

Here, I strongly recommend that the producers in the sanitary ware sector and other business lines stay away from the developments in production mentality and not to stay away from this issue and foreigners. Competition conditions in both the domestic market and the foreign market make smart factories the smartest measure to take.

At this point, it is critical not only for companies but also for the interests of the country, for governments and employers to work closely and create projections within a finely detailed program. It is indispensable that the action plan to be created must be carried out by individuals and institutions that have grown up in this regard and will continue to cultivate themselves. It is known that it emerged as a result of an accumulation of Industry 4.0 process, but this process, which does not have a static structure for later, compels both a collective approach and a progressive perspective.

As a result, it is also important for firms to increase their competitive power and maintain their continuity in the sector in which they exist. Today, adaptive and automation-based technologies have been replaced by traditional technologies, and the outputs of such R&D-based studies shed light on hi-tech (advanced technology) based systems as well as new ideas and provide a future.

The adaptation of such technologies to the facilities creates an important technology exchange opportunity for developing countries, and it helps to increase the market share by providing better services to the market with the developing and increasing efficiency facilities.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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