AUTOMATED MANUFACTURING IN LUMINAIRES HOME APPLIANCE INDUSTRY

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In any company, the need for digitization, automation and sustainability is essential for growth. Transition to industry 4.0 is a necessity to remain competitive on the market, sustainable material is required, minimizing costs and certainly lower waste rate.

This paper focuses on digitalization and the cooperation between humans and robots in manufacturing. The paper details the case study of a company acting in lighting system for domestic appliances. The company analyzed its manufacturing requirements and the number of deliveries the customer requires. The top management team decided to implement changes in the company, to increase the visibility in the client's eyes. Internal changes towards Industry 4.0 are decided, such as investments in CNC machines, robotic arms, semi-automatic and automatic packing machines.

The company has reduced its workforce in the metal workshop area and in the pallet wrapping area, too. For one CNC machine and one robotic arm, the company obtains a reduction ranging between 66% to 75%. For the pallet wrapping area, the automatic packing machines get a reduction of 50% instead of semi-automatic packing machines.

Keywords: industry 4.0, cobots, packing machine, robot arm, efficiency

1. Introduction

Manufacturing companies in almost all industries are facing multiple challenges, both from customers and markets as well as, from integrating information technologies in manufacturing to shifting manufacturing paradigms [1–4].

Where in the near past market developments, production volumes and customer needs were relatively stable and limited, the globalization and regionalization of markets and the customers' demand for increasing customised options have shaken and shattered the stability and predictability contained therein [5–8].

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These changes dramatically impact the target hierarchy for production systems in terms of what is the most important aspect of the factory within the design process (i.e. costs per unit manufactured, economies of scale, versatility, robustness, flexibility) [2, 5, 9, 10].

Flexibility and agility of the production systems are becoming more and more important, due to these market-side developments.

The same pressure towards change can be observed when looking at the technological side, encompassing both manufacturing technologies as well as the entire IT-infrastructure applied within the manufacturing sector. The digitalization of the industrial manufacturing is gaining more and more momentum [4, 11–13].

Technologies like artificial intelligence (AI), additive manufacturing, collaborative robotics, cyber-physical systems (CPS) and cloud computing are getting more and more advanced, affordable and easy to use, offering companies entirely new ways to communicate, manage and organize their production systems [10, 11, 14, 15].

European policy in the field of lighting or lamps is closely related to the European Union (EU) energy efficiency and environmental objectives and directives. These policies are designed to promote usage of more power efficient and less environmentally damaging light sources with the goal to decrease energy consumption and lower carbon footprint [16].

The EU has adopted several Energy Efficiency Directives that set energy efficiency standards for lighting products. These include the Eco-design Directive and the Energy Labeling Directive. These directives impose strict limits on the energy consumption and energy efficiency of lighting products, as well as requirements for their labeling with energy efficiency information.

The EU began phasing out the production and sale of incandescent bulbs starting in 2009 to promote the use of more energy-efficient bulbs such as compact fluorescent bulbs (CFLs) and energy-saving bulbs.

The European Union encourages the adoption of light emitting diode (LED) lighting due to the important energy efficacy and longer life of these light sources. European policies and initiatives aim to stimulate innovation and reduce costs for LED technologies to facilitate the transition to this type of lighting.

The EU has introduced policies and programs to promote the efficient use of energy in public institutions and government buildings, including upgrading lighting systems to more energy efficient technologies.

European policy promotes eco-design and ecological design of lighting products, which means that they must meet certain criteria of energy efficiency, durability and recycling.

In general, European lighting policy aims to promote the use of more energy-efficient and less environmentally harmful light sources, in line with the overall energy efficiency and environmental protection objectives set by the EU.

These policies encourage innovation and the transition to more environmentally friendly technologies, such as LED lighting, and focus on reducing energy consumption and greenhouse gas emissions associated with lighting [16].

Meanwhile, robotized work, as the need for aligning to these trends, remains equivalent, or at least even significant. Quality is vital for every process or product and needs to be included at strategic stage for continuation during digitalization.

Technology development, much quicker than was before, and organizations stand, as well as methods, operations, systems, details, and administration, must keep ahead [17].

Implementing a company digital approach will not void of obstacles. Difficult tasks which span all industries and electronic capability positions challenge company resilience [17]. There is a consensus among professionals that automation – whether through CNC, cobots or automated packaging machines – increase operational efficiency, enhance flexibility, safety and productivity, and contributes to sustainability by optimizing resource use, reducing waste, and improving overall energy efficiency in production processes [18, 19, 20].

CNC machines improve material usage, cobots enhance worker safety and energy savings, and both semi-automated and automated packaging machines reduce waste and energy consumption.

Starting from a real case study of a company acting in the luminaires industry, within the EU policies framework, the study aims to detail the challenges and the constraints while automating the manufacturing processes and implementing sustainability goals in the pursuit of greener and more efficient manufacturing practices.

2. Experimental methodology

The immediate problem involves Glorious Lighting, a company that is part of the Liting Universal Ltd. group of companies based in Hong Kong, with over 20 years of experience in manufacturing lighting fixtures. Established in 2017 in Braila, the company initially focused on developing floor lamps, ceiling lamps, wall lamps, wall clocks, jars, and bottles. Now, Glorious Lighting aims to increase its visibility in the marketplace without raising prices, despite significant inflation.

Regarding the competitors, the case study company is the single one supplier in Romania. The other competitors are in India, Pakistan, China, Poland, Italy, Sweden and North America.

In line with the sustainability development goals (ISO 26000 and the 17 SDGs), IKEA has a Supplier Code of Conduct that emphasizes ethical sourcing, including labor rights, environmental responsibility, and transparency. They conduct regular audits and assessments to ensure compliance with these standards. IKEA collaborates with technology companies to develop compatible devices.

Benchmarking the results with other suppliers, the company Glorious Lighting identified the need for better technologies. In this case the multifunctional team meets once a week to discuss regarding the impediments that our company face with and, after one month of regular meeting and brainstorming, the options that are the most relevant in our case have been outlined (table 1).

Table 1

No.	Option	Requires	Benefits	Issues
1.	Maximize the equipment that are already internal	Put people to work on more position	Increase the capacity of products made it and will need fewer people to make it	Cause health and safety issues of the operators
2.	Buy some equipment	Train the operators and technicians	Can help operators to work faster	Time and money investment

Some strategic issues identified in the upper rows of the table include competitor behaviors, rivalry, economic conditions, and workforce and talent.

As also visible online, the net profit in Euro is has improved over the year, but some changes need to be done as soon as possible so the financial of the company will increase and will get profit. This information can be found in table 2 (the information is taken from RisCo – a national database that integrates official data and information about companies collected from National Trade Register, National Agency of Fiscal Administration, Ministry of Finance, Ministry of Justice, National Government, aiming to visualize and aggregate relevant financial indicators).

Table 2

Sales, Net Profit, Employees – Glorious Lighting SRL			
	2021	2022	2023
Sales – EUR	17.892.412	26.595.156	31.201.801
Net Profit – EUR	- 3.327.917	- 3.549.169	- 746.467
Employees	585	702	717

As visible in the table above, the company increased the number of people along the time, in 2024 – the number of employees is 850.

After the analysis was completed by the multifunctional team and accepted by the company owner, the decision was made to invest in CNC machines, robotic arms, and packing machines. The plan is to purchase them from China, as the costs will be lower. Additionally, some experts from China will be brought in to adjust the parameters of the equipment. To monitor the results, the reduction in time will be tracked.

Additionally, the man-hours replaced by the new equipment will be calculated, along with the corresponding cost reduction.

The timeframe for this action should be less than half a year so the company can afford to keep the same prices on the market until May 2024.

3. Results and discussion of implemented projects

The manufacturing industry is strongly influenced by mass customization trends and product lifecycle dynamics. This requires the digitization of some processes to reduce staff and increase production capacity. The risk of injury, both from machinery (which, if not used properly, can cause serious accidents), but also from lifting of heavy objects, should be minimized, too.

With that in mind, the results discuss the effects of the three implemented projects: CNC machines, co-bots and semi-automatic and automatic packing machines, mainly in terms of the number of operators reduction.

3.1 CNC machines

As can be seen in Fig. 1, the operator is working simultaneously on two semi-automatic CNC machines, producing two different types of components at the same time.

Figure 1 – Processes redesign using CNC machines in the case study company.

Manufacturing processes with semi-automatic CNC machines brings improvements in shortening working time and, at the same time, reducing the number of operators. In this case, the reduction is 50%, from 2 operators, one for each machine, a single operator operates both simultaneously.

This type of machine with numerical control, helps track the parts produced in a time interval, shortening an operator's time to count the parts produced at the end of the shift. In this case the operator must count only the parts that are not ok and should be scrapped and subtract them from the total amount of parts produced on that machine.

In this moment, in the entire metal workshop, CNC machines can be found so the company no longer needs to invest in this area for this project.

This project contributed to the reduction of the employees and the costs.

Glorious Lighting brought 100 CNC machines, that means 50 people working on it instead of 100 people (reduction of 50%).

The man/hour is 21 lei that means 168 lei/day. The reduction of 50 people means the company's savings of 8.400 lei/day.

For the CNC machines, the biggest issue that arises every time the power is turned off is that the part being made at that time will come out defective. The technician has tried to fix this problem but seems that cannot be solved yet, so the corresponding cost should be excluded from the savings.

3.2 Robotic arms

As can be seen in the image below, the real advantage to using robots' arm in the company is that once programmed, the machine not needing an operator to monitor it any more or to remove the components from the machine. This kind of arms takes the steel disc that is placed on the table on the left side and put it on the CNC machine (Fig. 2). After the program is finished, the robotic arm picks up the component from CNC machines and places it on the right side table.

In the future, the company proposes to purchase more robots arm, so the time and the cost are expected to reduce.

So far, the disadvantage that could be observed was that when the metal discs have metal filings left between them, the suction cups of the robot arm do not differentiate between one disc and several discs, which led to the destruction of several metal discs. After the issue was observed and better cleaning of raw material was done, the percentage of defects has decreased significantly. For this purchase, the reduction of cost is visible, as for each CNC machine, the company decreases the operators, which means salary decreasing.

In this moment the company bought just 20 robots' arm. As previously mentioned, the man/hour is 21 lei that means 168 lei/day. That 20 robots arm cover the activity for 10 people meaning a cost saving of 1.680 lei/day.

For the robot arms, two issues were found in time.

Figure 2 – Robotic arm working on CNC machine in Glorious Lighting

The first issue was found in area when the metal discs that need to be processed were having extra material between them or small metal particles that cause the sticking of parts. When the robot arm tries to pick up the metal discs and place them on the machine the operators discover that more discs were picked up. This issue created a lot of scrap, fortunately things were quickly solved. The supplier was notified regarding the issues, so they can be more careful before sending the metal steel discs. For the quantity already in stock, the operator blew out with an air gun all the material particles between the metal parts before the raw materials were placed near the robot arm.

The second issue appeared where the robot arm had certain errors and when it tried to pick up the metal disc instead of placing the disc on the CNC machines, it threw it away, so (as seen in Fig. 2) these robot arms have a metal fence surrounding them to ensure the safety of the operators in that area.

3.3 Automatic packing machines

For the semi-automatic packing machines, as seen in Fig. 3, the process is easy. The pallet needs to be put in the middle of the circle, four straps need to be attached to the pallet, two straps on width and two straps on length, the wrapping foil must be attached to one of the bottom corners of the pallet. After this, a button for start is pushed and the foil goes through all the faces and edges of the pallet when the circular part of metal rotates. In client's specification, the pallet needs to have three layers of wrapping paper, so the foil that will move to cover the whole pallet will go up and down three times to finish the pallet.

The semi-automatic packing machine stops, and the pallet has the correct packing, the operator needs to break the foil that is stretched between the pallet and machine. For the wrapping foil that remained unstick, the operator needs to catch it with tape.

The semi-automatic packing machine is inferior to an automatic packing machine because it takes more time, requires a forklift to bring the pallet from the line, put into the circle area, to wait until the packing is done and after to bring again a forklift to take the pallet and put it in the required area. Besides that, a lot of time is consumed, and a minimum of two operators are required. One operator needs to take the pallet from the line and to proceed the packing and another one needs to take the finished pallet and to bring it to the finished good area.

The advantage of these machines is that they take up much less space than an automatic packing machine [21].

Figure 3 – Semi automatic packing machine in the case study company

The machines, seen in Fig. 4, have smaller conveyors that bring the pallet from the lines and put in the necessary area of the machine where the pallet will be foiled.

One of the advantages is that the pallet doesn't need to have anymore the plastic straps and under them the small protection cardboard corners, because the automatic packing machine put the vertical straps from the same packing foil that also the pallet is packed.

The second advantage is the reduction of the time of operators. As mentioned before, to get the pallet in the necessary area for the packing at semi-automatic packing machine, an operator with a forklift is required. The automatic packing machine has a specified space to put the pallet and when the pallet has all the products on it and can be packed, just a button needs to be pressed. The mini conveyor comes to each line that pressed the button in the order of its pressing. There the pallet is moved to the special space where the pallet will be foiled. After the packing is done, the pallet will be moved to the end of the packing machine. In that moment an operator needs to take it with a forklift and deposit it in the finished goods warehouse.

The third advantage, as can be visible from the second one, the necessity of the operators is reduced by half, it is necessary just one operator to take the packed pallet and to put it in the finished goods warehouse.

Regarding the reduction of the number of operators by half, one man/hour for this aria is 17 lei. Because of the limited space that company has in this area, the cost reduction with the automated packing machine is just 136 lei/day (one day of working for one operator)

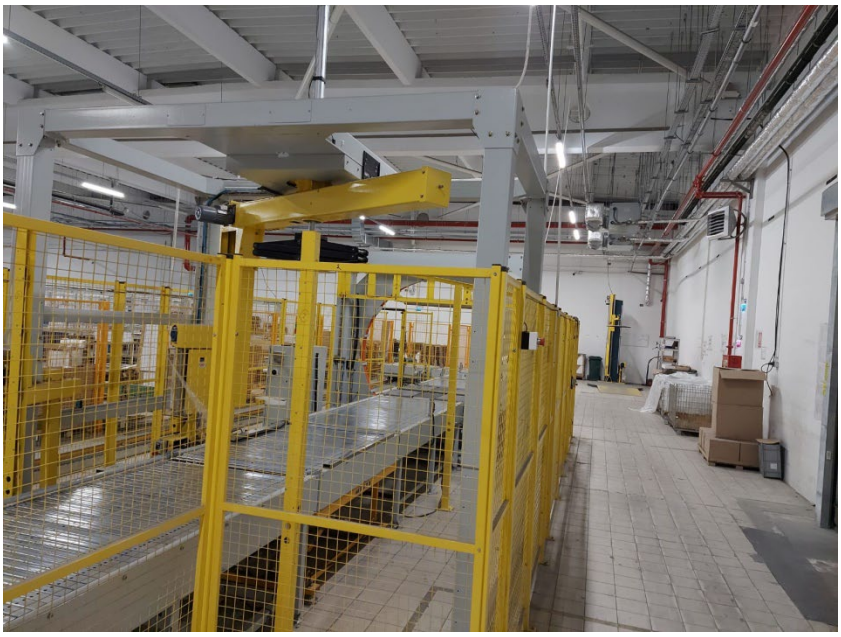

Figure 4 – Automatic packing machine

For semi-automatic and automatic packing machines, the company has again a reduction of cost and employees.

Over time, after more automated machines were brought in, the company register the results and benefits. These benefits help both on the economic side, but also shorten working time and reduction of the number of operators.

Based on the preliminary results, the company will keep and continue to work with automatic packing machines and with the semi-automatic packing machines because the space is not enough to install one more automatic packing machine and, in the future, the company will buy more robotic arms, so the people is expected to reduce significantly.

For the semi-automatic packing machine and for automatic packing machine, the issue was related to the height of the pallet to be packed. When a new project, with the pallet height smaller than the rest of the pallets, was needed to be produced, the sensor on the packing machines could not detect it and this created many issues until the technicians managed it. For the automatic packing machine, after technician changed some parameters in the equipment, the packing was working normally. For the semi-automatic packing machine, the problem was solved by placing two pallets on top of each other for wrapping. Finally, the operator will cut the foil between these two pallets to create a wrapping according to the specifications.

4. Conclusions and future work

For improved perception on the market and to meet the customer requirements, the company analyzed the needs and started processes automation to implement Industry 4.0.

The study aimed to detail the opportunities and the constraints while automating the manufacturing processes in a Romanian supplier company for IKEA, the results showing more efficient manufacturing practices, with the number of operators reduction.

Based on solutions' research done by the multifunctional teams in the company, the decision was to improve the technologies by purchasing different types of machines: CNC, robotic arms, semi-automatic and automatic packing machines.

In conclusion, the company got benefits, reduction of employees and cost minimization, for each type of machine that was purchased, but several issues should be improved by future work.

From this experience, several lessons have been learned, as follows. These lessons need more investment with future work in procedures and practices implementation.

First, safety needs to be more carefully addressed, as these kinds of machines may be potentially dangerous. Apart of the manufacturing procedures, understanding and strictly adhering to safety protocols have been implemented to prevent accidents and ensure the well-being of workers.

When talking about CNC machines, strict attention had to be awarded to precision, as one marginal error can cause a lot of significant issues in the area and can create non-conformities.

Calibration, careful programming, and maintenance are the keys for all the machines that are semi-automatic and automatic. Closely related, preventive and corrective maintenance have become to prevent breakdowns and ensure optimal performance. A proactive maintenance schedule has been implemented to minimize downtime and extend the lifespan of these expensive machines.

These machines can increase efficiency and productivity, but it also represents a significant financial investment. Before the automatic implementation, the company needed to take in consideration factors like maintenance costs and return on investment (ROI).

For the reduction of costs after all the investments in CNC machines, robotic arm and packing machine, cost reduction result is 136 lei + 1.680 lei + 8.400 lei = 10.216 lei/day, that means a significant decreasing of costs, approximately 3.5 salary/month in one day is saved.

Maintaining consistent quality standards is necessary, especially in industries like manufacturing. Regularly monitoring output, conducting quality checks, and implementing corrective measures, when necessary, can prevent costly defects and customer dissatisfaction. In terms of operational discipline, the implemented projects required more investment in adjusting the processes sequences, drafting the procedures and working instructions and training the staff accordingly.

Last, but not least, team collaboration revealed mandatory. Effective collaboration between engineers, operators, maintenance technicians, and other stakeholders was crucial for successful implementation and operation with these types of machines. Clear communication and teamwork were essential for resolving issues efficiently and driving continuous improvement.

The approach of identifying from multiple sources the strategic projects and further on to implement them, together with the potential overpassed constraints and lessons learnt, may be transferred to other industrial sectors to better comply with the sustainable goals and improve productivity and efficiency.

REFERENCES

[1] *H. P. Wiendahl, J. Reichardt, P. Nyhuis*, Handbuch Fabrikplanung: Konzept, Gestaltung und Umsetzung wandlungsfähiger Produktionsstätten, Hanser, München, 2009

[2] *P. Burggräf, G. Schuh, M. Dannapfel, M. Swist, M. E. Esfahani,* Vollständig neu bearbeitete und erweiterte Auflage, Springer Vieweg, Berlin, 2021

[3] *G. Schuh, A. Gützlaff, K. Thomas, J. Ays, H. Brinkmann*, Flexibilitätssteigerungen im Produktionsnetzwerk, ZWF 2020

[4] *J. Pistorius,* Industrie 4.0 – Schlüsseltechnologien für die Produktion: Grundlagen - potenziale - anwendungen, Springer, 2020
[5] N. Luft, Aufgabenbasierte Flexibilitätsbewertung von Produktionssystemen, Verl. Praxiswissen, Dortmund, 2013
[6] *N. Luft, A. Luft*, Leitfaden: Systematische Kompetenzentwicklung im Umfeld der Smart Factory in Handbuch Digitale Kompetenzentwicklung: Wie sich Unternehmen auf die digitale Zukunft vorbereiten, Ed. Hanser, München, 2021
[7] *A. A. Alogla, M. Baumers, C. Tuck,* The Impact of Additive Manufacturing on the Flexibility of a Manufacturing Supply Chain. Applied Sciences, 2021
[8] *S. Rogalski*, Entwicklung einer Methodik zur Flexibilitätsbewertung von Produktionssystemen, Universitätsverlag Karlsruhe, Karlsruhe, 2009
[9] *A. Luft, S. Bremen, N. Luft*, A Cost/Benefit and Flexibility Evaluation Framework for Additive Technologies in Strategic Factory Planning, 2023
[10] *A. Luft, N. Luft, K. Arntz,* A Basic Description Logic for Service-Oriented Architecture in Factory Planning and Operational Control in the Age of Industry 4.0, Applied Sciences, 2023
[11] *N. Luft, A. Luft,* Guide: Systematic Competence Development in the Smart Factory Environment in Digital Competence and Future Skills: How companies prepare themselves for the digital future; Ramin, Ed. Hanser, München, 2022
[12] *E. Sisinni, A. Saifullah, S. Han, U. Jennehag, M. Gidlund*, Industrial Internet of Things: Challenges, Opportunities, and Directions, IEEE Trans. Ind. Inf. 2018
[13] *B. Bauernhansl, T. Hompel,* Handbuch Industrie 4.0; Vogel-Heuser, Ed. Springer Berlin Heidelberg, 2016.
[14] *S. Fischer,* Digital Competence Development from the Viewpoint of the German Association of Personal Managers BPM Berlin in Digital competence and future skills: How companies prepare themselves for the digital future, Ed. Hanser, München, 2022
[15] *C. Schröder,* Herausforderungen von Industrie 4.0 für den Mittelstand, Friedrich-Ebert-Stiftung, Abteilung Wirtschafts-und Sozialpolitik: Bonn, 2016
[16] *M. A. Pollack, C. Roederer-Rynning & A. R. Young*, Policy-Making in the European Union, Oxford University Press, November 2020
[17] Schut. Available online: https://asq.org/quality-resources/quality-4-0 (accessed on 18 April 2024)
[18] *J. A. Harvey*, CNC Trade Secrets: A Guide to CNC Machine Shop Practices in Industrial Press, Inc., Vol. 1, October 2014.
[19] *Z. Mehar , R. Noureddine & F. Noureddine*, Petri net modeling of a machining robot cell, in U.P.B. Sci. Bull., Series D, Vol. 85, Iss. 4, 2023.
[20]. *A. Regattieria, F. Pianaa, M. Gamberia, F. G. Galiziab & A. Castoa,* Reliability assessment of packaging automatic machine by accelerated life testing approach in 27th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM2017 in Procedia Manufacturing 11, 27-30 June 2017.
[21]. *I. Doci, V. Baxhuku*, Forklift opetarions in warehouse – design and analysis with graphical modelling and simulations, U.P.B. Sci. Bull., Series D, Vol. 86, Iss. 1, 2024.