The Industry of the Future: From Industry 4.0 to Industry 5.0 – Integration of Humans and Technology: New Technologies

Karabegović, Isak

2025

Akademija nauka i umjetnosti Bosne i Hercegovine

https://bastina.anubih.ba/handle/123456789/837

DOI: 10.5644/PI2025.220.05

“Text to 3D Model” Artificial Intelligence (AI) and Additive Manufacturing (AM) in the Field of Product Design, Development and Manufacturing

Adis J. Muminović*[1]

Abstract: *Computer aided design (CAD) 3D modelling is one of the engineering tasks which is largely routine tasks with a large amount of repetition of the same operations to get from the initial idea for a new product to a 3D model ready for manufacturing. As with all other forms of routine tasks, artificial intelligence (AI) will certainly play a significant role in the future and it will largely automate such jobs. On the other hand, additive manufacturing (AM) can use AI generated CAD 3D models to produce finial product without the need (or with minimal need) for human labour. The combination of these two technologies will certainly shape the future of product design, development and manufacturing. Overview of the current possibilities of using artificial intelligence (AI) and additive manufacturing (AM) in the field of product development, design and manufacturing is presented in this paper. From the point of view of CAD modelling, special attention is given to the so-called "text to 3D model" systems. The challenges, possibilities and further directions of development of these technologies are shown through two real case studies (design, development and manufacturing of two stool chairs). Stool chairs design was generated with the help of "text to 3D model" AI System in a form of 3D models. The generated 3D models were then manufactured with the help of AM.In the last chapter of the paper a comparative analysis of the time spent by human labour for the development, design and manufacturing of this two stool chairs using conventional methods and using AI and AM is carried out.*

Keywords: *artificial intelligent, AI, additive manufacturing, AM, product design, CAD, text to 3D model*

1. Introduction

It has become obvious that artificial intelligence (AI) will reshape industry in the future. This process is currently taking place and mostly affects those jobs that require a large volume of the same repetitive work. Various engineering fields have such types of jobs. Although these are jobs that are currently performed by highly qualified people (calculations, engineering, design, etc.), it is still believed that such jobs will be automated by AI. Although monotonous and repetitive jobs will be automated, the knowledge and experience of engineers

*[1]University of Sarajevo, Faculty of Mechanical Engineering, Sarajevo, Bosnia and Herzegovina
E-mail: adis.muminovic@mef.unsa.ba

remains an irreplaceable factor in making final decisions when implementing engineering projects. AI can generate solutions and perform the “physical” part of the work, however, the engineer must have a sufficient level of knowledge and experience to assess and decide whether the generated model or performed calculation is in accordance with all necessary norms, mechanical characteristics and applicable standards. Another part of engineering jobs on which AI will also have a great impact is the creative part of engineering (design). AI can be a great tool in the new product design process where it can be used to generate initial concept design.Also, the experience and knowledge of the user (engineer) comes to the fore here as well. User has to choose a concept that meets all the conditions in terms of stability, stress state, manufacturing possibilities, etc.

In the field of mechanical engineering, there are a large number of repetitive tasks that will certainly be greatly influenced by AI. In the field of product development and design, AI is already widely used, and it will have a particular impact in the field of computer aided design (CAD) 3D modeling. In the field of product development and design process AI is often used to try to replace human based knowledge experience with AI based decision. This is showed in the paper [1] where the authors states that today many approaches suitable for smart manufacturing systems involving maintenance workers are based on Artificial Neural Networks (ANN). They presented an approach to measuring the effectiveness of the use of an IT system supporting the realisation of business processes in the maintenance department and described the empirical research results of maintenance workers (121) within Polish manufacturing companies with automotive branches. In addition, in this paper authors seeks to integrate the first two main research results and ANN, into a novel, decision-making model regarding the implementation of activities and investments aimed at increasing the level of a company’s automation.Extensive research on the use of Big Data and AI in the field of product design was conducted in the paper [2]. Authors claim that traditional product design methods fall short due to their strong subjectivity, lack of real-time data, limited survey scope and poor visual display. The most important goal of paper [2] was to show how different types of collected data can be used in product development and design process. Big data in the product lifecycle contains valuable information, such as customer preferences, product evaluation, market demands and visual display. Product images contain shape, colour and texture information that can inspire designers to quickly generate initial design schemes or even new product images. This is one of the first papers which mention how AI generated images can be used for the inspiration of new products. Paper [2] provides a comprehensive review of big data and AI-driven product design, focusing on how big data of various modalities can be processed, analysed, and exploited to aid product design using AI algorithms. It identifies the limitations of traditional product design methods and shows how textual, image, audio, and video data in product design cycles can be utilized to achieve much more intelligent product design. In paper [3] it is stated that deploying big data analytics to establish industrial intelligence is an active but still under-researched area. In this paper, an intelligent product design framework is proposed to incorporate fuzzy association rule mining (FARM) and a genetic algorithm (GA) into a recursive association-rule-based fuzzy inference system to bridge the gap between customer attributes and design parameters. Taking in consideration the product design process, most researchers agree that the collaboration between designers and AI is the most important thing, not just the full use of AI [4]. This paper is one of the most recent papers which explain the potential of AI and human collaboration in design process. Through this paper, answer to the question "How does AI currently support the design process and how could it do so in the future?" is answered. Result showed that AI agents can potentially assist designers by providing inspirations, defining design problems with constraints, offering grounded metaphors, and exploring design materials. Connection between innovation and AI is explored in detail in the paper [5]. Authors in this paper proposed a framework for understanding the design and innovation in the age of AI. They discuss the implications for design and innovation theory. Specifically, they observe that, as creative problem-solving is significantly conducted by algorithms, human design increasingly becomes an activity of "sensemaking", that is, understanding which problems should or could be addressed. This shift in focus calls for the new theories and brings design closer to leadership, which is, inherently, an activity of "sensemaking".

When it comes to the use of AI in the field of additive manufacturing (AM), most of the current research is related to the application of AI technologies in the field of optimizing AM production parameters. It is known that AM has a large number of parameters that can be adjusted before the part is released for manufacturing. Combinations of different parameters gives different properties to the manufactured parts. It is hard to find ideal combination of parameters to achieve desired properties of manufactured part. This is the reason why AI has found a wide application in this field [6, 7]. In addition, large number of research is based on the development of materials and designs inspired by bio-structures and so-called lattice structures. Such structures together with topology optimizations can have significant advantages compared to standard products designed in a form of solid materials with full volume materials inside [8, 9]. Such materials achieve significant advantages over conventional forms of design and manufacturing. The advantages are primarily reflected in the reduction of the mass of product while maintaining the same or similar stress state. Generative AI techniques, including generative adversarial networks (GAN), genetic algorithms, and large language models (LLMs) offer efficient solutions for optimizing material properties,accelerating the development timelines and reducing manufacturing costs[10].

3D Model creation and the use of AI Technologies in CAD 3D modelling is currently in its early stages. There are currently AI systems that can generate 3D models based on a text query ("text to 3D model") or an image as a reference.There are several commercially available websites, but they are all based on generating simple 3D models. First paper which basically open up this field is paper by the authors from Google [11]. In this paper they presents their system DreamFusion. It is text-to-3D using 2D Diffusion system. One of the best papers that provides a general overview of AI methods and technologies for "text to 3D" generation of 3D models is the paper [12]. This paper present different AI technologies which exist today. Also, this paper presents places of usage of text-to-3D technology in various applications, including avatar generation, texture generation, scene generation and 3D editing, but it lacks mentioning possibilities of usage these technologies in engineering fields for creation of precise CAD 3D models. Paper [13] presents two systems for text to 3D model AI generator Dreamfusion and Magic3D. This paper shows very well that AI is not just chatGPT, AI is much more than that. Authors in paper [14] propose a novel method that generates high-quality and diverse 3D models from text prompts in a feed-forward manner.

In the near future, rapid growth and development of AI systems for generating 3D models based on text descriptions is expected. The current focus of such systems is not on the engineering side but more on generating 3D models that can be used in the field of video game development or virtual and augmented reality. Although the focus of such systems is not currently on engineering and generating usable 3D models for manufacturing, such systems will still have a huge impact on the process of product development and design, and in combination with AM technologies, on the process of automatic manufacturing of generated 3D models. All of the above applies especially to products where high precision is not of crucial importance (such as products from the furniture industry), i.e. to products that are more design-oriented (products where design is more important than precision and engineering).
The time that a person has to spend to get from the initial idea for a new product to a functional product is drastically reduced by the combination of AI and AM compared to conventional technologies for 3D modelling (CAD modelling using software's like SolidWorks) and conventional manufacturing methods like injection moulding.In this paper, we have shown, through a two case studies of the design and manufacturing of a stool chair, how much impact the combination of AI and AM will have on the manufacturing and product development and design process in the near future.

2. Product Design Usign AI – a Case Study

Several commercial systems for generating 3D models from text description or picture appeared this year.Although these are systems that are currently in the early stages of their development, 3D models generated with the help of such systems can already be used for various purposes, such as video games, animations and graphic design. Also, the generated 3D models can be used for the manufacturing of final, fully functional, physical products in areas where precision engineering is not required, such as the furniture industry.In this research, design of chairs is chosen as case studies. More precisely stool chairs. Stool chair is chosen because it is a relatively small product that can be manufactured as a fully functional product using currently available AM devices. In this research web system Meshy AI (https://www.meshy.ai/) is used. Meshy AI can generate 3D models from text description or using image as a reference. In the first step several stool chairs are generated using different text description. For every text input system gives four designs. Figures 1 and 2 shows generated stool chairs for two different text inputs.

Figure 1. AI generated 3D models of stool chairs based on text description: "Design a stool chair inspired by nature".

Figure 2. AI generated 3D models of stool chairs based on text description: "Design a stool chair optimized for additive manufacturing.".

From figures 1 and 2 it can be seen that AI system do not fully "understand" the engineering concepts that are required of it. It can be seen from figure 2 that the system did not generate 3D models ideallyoptimized for additive manufacturing in every variant (design without supports, with less amount of material used, etc.).but the system did incorporate some aspects of topology optimization and some of the chairs could be manufactured almost without support materials such as, for example chair number 4 in figure 2. Also, when the system was asked to design a chair inspired by nature, it can be seen that the designs of all four chairs from figure 1 contain natural shapes.
Generating all of these 3D models of chairs took significantly less time (only few minutes) than it would have taken to manually 3D model all of these variants in some of the CAD modelling software's. After several iteration of generating 3D models for different text descriptions and after analysing generated designs from the field of optimization for manufacturing using AM (printability), two chairs shown at Figure 3 are selected for further manufacturing.This chairs can be considered relatively well optimized for AM, primarily because they donot need much support materials during manufacturing. They will be manufactured in upside down position. Also, this

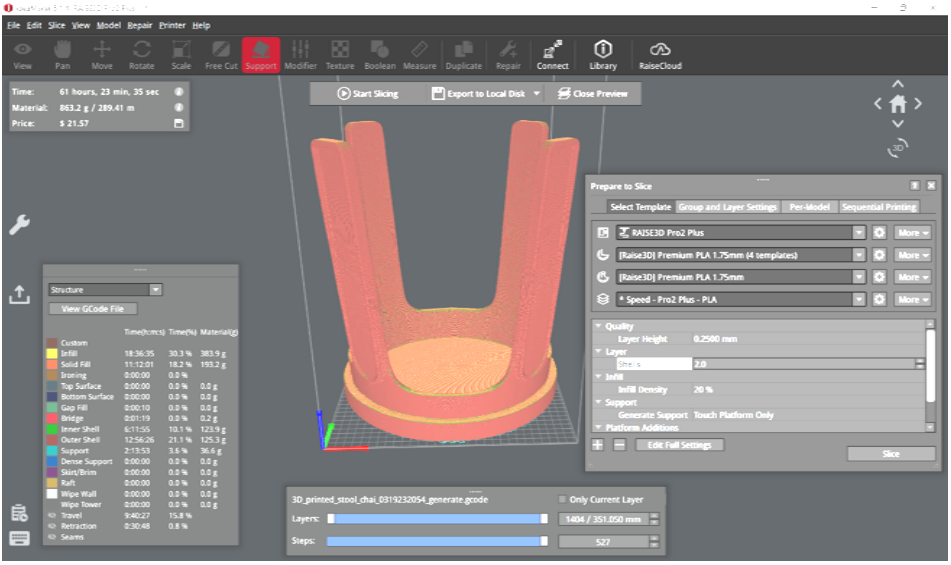
design of stool chair is a good example that such AI systems for generating 3D models should have the ability to further edit the model through text descriptions. In this specific case, the 3D model of these two chairs could be further optimized for AM technologies by levelling the upper surface of the chairs (seat). It should be possible to further edit the 3D model through a text description such as for example: "add additional leg to the design of a chair". More engineering knowledge and experience needs to be imported in this types of systems in the future. Especially from the aspects of stability, mechanical properties, stress conditions, etc.

Figure 3. AI generated 3D models of stool chairs selected for additive manufacturing

3. Additive Manufacturing of AI Generated 3D Models

AM technologies enable the manufacturing of products completely autonomously and practically without the need for human labor. In order to manufacture something with the help of AM, the only form of human labor that needs to be spent is the preparation of a 3D model on a computer for manufacturing and periodic maintenance of the device (3D printer). It is important to emphasize that these tasks can also be partially or fully automated. As for the preparation of a 3D model for production, it is possible to create a larger number of ready-made profiles with set parameters. These profiles can later be automatically called up for every next manufacturing. Device maintenance (changing materials, removing the manufactured model from the device, etc.) can also be further automated with the help of robotic arms and automation.In the case of AM, total human working time is around 1% in the total time of the product manufacturing. Also, one worker can maintain production on significant amount of machines in the same time. In the case of regular 3D printers, it is estimated that one worker can work with up to the 30 devices in the same time. In the case of print farms, it is estimated that 500 devices can be operated by 15 workers. In the case of fully automated print farms it is estimated that one worker can operate more than 100 devices [15, 16]. Much research has been conducted in the field of integrating AM into manufacturing processes and their impact on the human workforce [17, 18].In the case of this research Fused Deposition modelling (FDM) AM technology was used for manufacturing of a two stool chairs showed at Figure 3. Rase3D Pro2Plus AM machine (3D printer) was used. This printer is selected because it has large build volume 305×305×605 mm, which is needed to manufacture AI generated stool chairs showed at Figure 3. First step was to prepare generated 3D model for AM. This is done in IdeaMaker software. The fastest profile with 0.25 mm height was selected. Infill density was 20%. Other AM parameters are left as default for Speed profile and PLA (Polylactic acid) material. PLA material is selected because it is “easy to print” 3D printing material with good mechanical properties. As it can be seen from Figure 4, both chairs will be manufactured in upside down position with a goal to avoid usage of large amount of support material. 3D printing time is approximately 60 hours for both chairs individually. The printing time is this big because this is regular Raise3D Pro2 Plus printer. It is important to notice that upgrade kit can be booth for this printer which can increase printing time up to 5 times, so the printing of this chair will be around 10 hours. Also, other AM technologies, with higher print layer, are available which can reduce the printing time up to only several hours, for example 3D printing head mounted on robot arm with print layer height of 1mm. Prepared AM generated stool chairs for AM are shown at Figure 4.

Regarding mechanical properties of these two AI generated stool chairs 3D printing parameters are selected taking in consideration author experience in the field of AM. Goal was to select parameters which will give the best relation between mechanical properties and the speed of 3D printing. Future optimization of 3D printing parameters are possible using more advance testing of mechanical properties of the chair. It will be necessary to 3D print more chairs with different parameters and make a mechanical test. Stool chairs after the manufacturing process are shown at Figure 5. It is important to notice that this is fully functional chair which can be used on regular basis as it is shown at Figure 6. Figure 6 shows a male with approximately 70kg of weight using the chair.



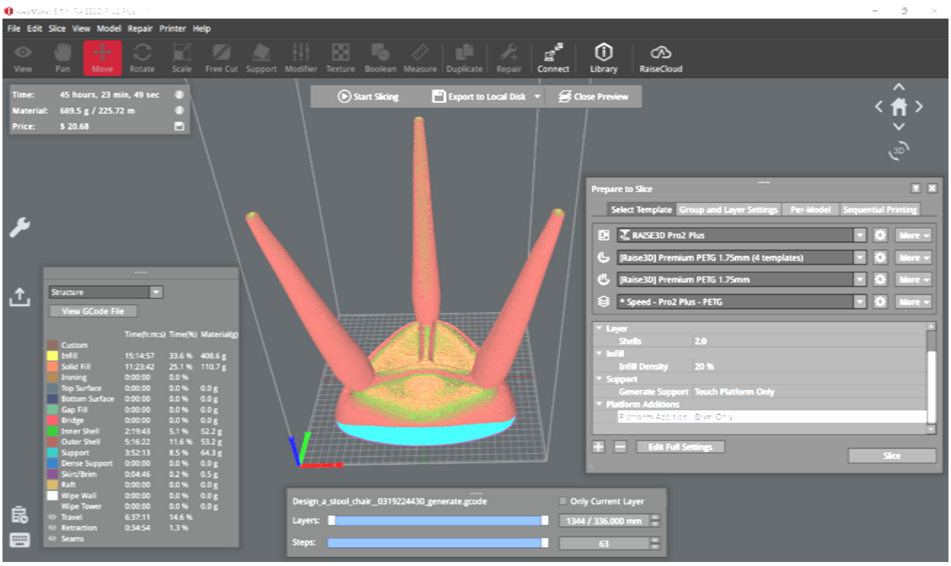


Figure 4. Preparation ofAI generated 3D models of stool chairs for additive manufacturing

Figure 5. AI generated stool chairs after additive manufacturing

Figure 6. AI generated and AM manufactured stool chair in regular use

4. Cost Analysis of Product Design, Development and Manufacturing

To bring a new product from initial idea to final product several steps needs to be carried out. Total development and manufacturing process can be divided in several individual steps. There are a lot of small steps in the process but in this analysis, we will put focus on three main steps: Design, Development and Manufacturing. Also cost analysis will be done for three case studies for one chair. Case study 1: Manufacturing of one chair, Case study 2: manufacturing of 100 chairs and Case study 3: manufacturing of 10 000 chairs. The most important advantages of usage of AI and AM in product development, design and manufacturing is a reduction of human labor working time which needs to be done to design, develop and manufacture a chair. Analysis is done using comparisonof traditional design and development methods and traditional manufacturing technology on the one side and the combination of AI and AM on another side. Injection moulding technology is selected as a representative of traditional technology because it is a polymer stool chair and in the case of traditional technology it will be manufactured using injection moulding. Cost analysis is done using hours as measuring unit instead of money units. This is done because cost of one human hour is different in different part of the world.

2.1. Cost Analysis of Design Stage

As previously mentioned, AI is currently having the greatest impact and application in the design process. The speed of design and generated solutions is significantly improved by the use of AI technologies. To generate concepts design of two stool chairs using traditional methods by drawing concepts designs by hand, one designer will need at least two days. Using AI methods, he can have several designs in few minutes. Reduction of human working time in this stage is significant. To design two chairs shown at Figure 3, total amount of human working time was around 1 hour in comparison to traditional methods where it is around 16 hours which is reduction of time by around 94%. Number of same chairs which needs to be manufactured does not play a role in this phase.

Table 1. Comparison of human working time in design stage for traditional design methods and the usage of AI

Design steps:	***Traditional methods [h]***	***AI [h]***
Concept design and evaluation phase	≈ 16	≈ 1

2.2. Cost Analysis of Development

Development stage is the next stage in the process of bringing product from design to manufacturing. Development stage includes steps like detail CAD 3D modeling, preparation of technical documentation, complete development of the tool for injection moulding and preparation of 3D model for manufacturing (slicing). Total amount of human working time in development stage for one stool chair is shown in Table 1. It can be seen that development stage is significantly reduced in the case of usage of AI tools and AM manufacturing. Mostimportant reduction is in the step of tools development. To produce something using AM technology, tools development is not needed, in comparison to the injection moulding technology. Again, number of same chairs which needs to be manufactured does not play a role in this phase. Total reduction of time is 99.6%.

Table 2. Comparison of human working time in development stage for traditional design methods and usage of AI

Development steps:	Traditional methods [h]	AI [h]
CAD 3D modelling	≈ 3	≈ 0
Preparation of technical documentation	≈ 3	≈ 0
Complete development of the tool for injection moulding including tool manufacturing	≈ 200	≈ 0
Preparation of 3D model for manufacturing (slicing)	≈ 0	≈ 1
Total:	≈ 206	≈ 1

2.3. Cost Analysis of Manufacturing

In the case ofmanufacturing, most important factor is number of chairs which needs to be produced.

2.3.1.Case study no. 1.: One chair needs to be manufactured

In the case that only one chair needs to be manufactured comparison of time needed for manufacturing is shown in Table 3.

Table 3. Comparison of manufacturing time for traditional manufacturing method and usage of AM in the case that only one chair is needed. One injection moulding machine and one 3D printer.

Development steps:	Traditional injection moulding method [h]	AM [h]
Preparation of machine and tool for manufacturing	≈ 8	≈ 1
Time of manufacturing	≈ 0	≈ 10
Total:	≈ 8	≈ 11

From Table 3 it can be seen that approximately the same time is needed to produce only one chair using both technologies. The manufacturing process is significantly lower in the case of injection moulding, but it is needed to prepare the machine, to assemble the tool and the machine, to prepare material, etc. Also, at least one worker needs to attend during the manufacturing process. In the case of AM, manufacturing process of one chair shown at Figure 3 can last around 11 hours, depending on the type of machine (3D printer) which is used and depending on the manufacturing parameters. It is important to notice that manufacturing in the case of AM is fully automatic, human working hours are only few minutes to start the manufacturing process (Table 4)

Table 4. Comparison of human working time for traditional manufacturing methods and usage of AM in the case that only one chair is needed. One injection moulding machine and one 3D printer.

Development steps:	***Traditional injection moulding method [h]***	***AM [h]***
Preparation of machine and tool for manufacturing	≈ 8	≈ 1
Human working time during manufacturing	≈ 0	≈ 0
Total:	≈ 8	≈ 1

Comparison analysis of total time needed to design, develop and manufacture one chair using traditional methods and combination of AI and AM are showed in Table 6.

Table 5. Comparison of total time needed for traditional methods and usage of AI and AM in the case that only one chair is needed. One injection moulding machine in comparison to one 3D printer.

Development steps:	***Traditional methods [h]***	***AI and AM [h]***
Design	≈ 16	≈ 1
Development	≈ 206	≈ 1
Manufacturing	≈ 8	≈ 11
Total:	≈ 230	≈ 13

Regarding the initial investment, it can be seen that usage of AI and AM in the case that only one chair is needed is obvious from Table 6.

Table 6. Cost of investments in the case that one chairs is needed to be manufactured during same amount of time using traditional injection moulding methods and AM methods.

Development steps:	***Traditional injection moulding methods [Euro]***	***AM [Euro]***
Price of machines (one injection machine and 1 3D printer)	≈ 50 000	≈ 5000
Tool development and manufacturing	≈ 50 000	0
Total:	≈ 100 000	≈ 5000

From Tables 4, 5and 6 it can be seen that in the case that only one chair needs to be designed, developed and manufactured AI and AM technologies are better in all three steps and they should be used.

2.3.2.Case study no. 2.: 100 chairs needs to be manufactured

In the case that 100 chairs are needed comparison of manufacturing time is shown in Table 7. From Table 7 it can be seen that in the case that 100 chairs are needed, time to produce these chairs using traditional methods does not change significantly from the case where only one chair is needed. But in the case that AM is used, manufacturing time is 100 time bigger (1000 hours = 41 days).

Table 7. Comparison of manufacturing time in manufacturing stage for traditional manufacturing method and usage of AM in the case of 100 chairs are needed. One injection moulding machine in comparison to one 3D printer.

Development steps:	***Traditional injection moulding method [h]***	***AM [h]***
Preparation of machine and tool for manufacturing	≈ 8	≈ 1
Time of manufacturing	≈ 1	≈ 1000
Total:	≈ 9	≈ 1000

These 41 days are manufacturing time, but human working time is only around 29 hours (Table 9). It is approximated that one worker can pull finished chair from 3D printer in 15 minutes and start a new 3D print. At first these 41 days can be seen as a significant problem, but taking in consideration that manufacturing of all 100 chairs can be operated by only one worker using 100 machines (3D printers) in the same time (fully automated 3D print farm), human working hours are basically quite similar to the traditional methods (Table 10). It is important to notice here, that increasing number of injection moulding machines will not significantly increase the speed of manufacturing using traditional methods because the time of manufacturing is already small (≈ 1 hour) and it does not play significant role in total manufacturing time in the case of traditional methods. Also every new injection moulding machine needs to have one more expensive tool for injection moulding. The question here is: What costs less, fully automated 3D print farm with 100 3D printers and one worker or one injection moulding machine with one worker and a tool. The price of one new injection moulding machine is around 50 000 Euros and the price of a 100 3D printers is around 500 000 Euros.

Table 8. Comparison of manufacturing time for traditional manufacturing method and usage of AM in the case of 100 chairs are needed. One injection moulding machine in comparison to 100 3D printers.

Development steps:	Traditional injection moulding method [h]	AM [h]
Preparation of machines and tool for manufacturing	≈ 8	≈ 4
Time of manufacturing	≈ 1	≈ 10
Total:	≈ 9	≈ 14

Table 9. Comparison of human working time for traditional manufacturing method and usage of AM in the case that 100 chairs are needed. One injection moulding machine in comparison to one 3D printer.

Development steps:	Traditional injection moulding method [h]	AM [h]
Preparation of machine and tool for manufacturing	≈ 8	≈ 4
Human working time during manufacturing	≈ 2	≈ 25
Total:	≈ 11	≈ 29

Table 10. Comparison of human working time for traditional manufacturing method and usage of AM in the case that 100 chairs are needed and fully automated print farm with 100 3D printers are used.

Development steps:	Traditional injection moulding method [h]	AM [h]
Preparation of machine and tool for manufacturing	≈ 8	≈ 4
Human working time during manufacturing	≈ 2	≈ 10
Total:	≈ 11	≈ 14

Buying 100 3D printers can seem as a significant investment but it needs to be taken in consideration that tool development and manufacturing for injection moulding is also a significant investment especially together with buying injection moulding machine and preparing whole manufacturing process and manufacturing factory. In this case detail cost analysis of the investment needs to be done before the appropriate manufacturing technology can be selected. Cost of investment is shown in Table 11.

Table 11. Cost of investments in the case that 100 chairs are needed to be manufacturing during same amount of time using traditional injection moulding methods and AM methods.

Development steps:	Traditional injection moulding methods [Euro]	AM [Euro]
Price of machines (one injection machine and 100 3D printers)	≈ 50 000	≈ 500 000
Tool development and manufacturing	≈ 50 000	0
Total:	≈ 100 000	≈ 500 000

From Table 11 it can be seen that initial investment in AM manufacturing methods in this case is 5 time bigger in comparison to the traditional injection moulding methods. This can be seen as significant difference and traditional methods are seeming to be better in this case, but some additional important factors need to be taken in consideration. In the case of traditional injection moulding methods every new chair design will need a new tool which cost additionally 50 000 Euros. This is not a case if AM is used. Using AM technologies and fully automated 3D print farm with 100 3D printer's different designs of 100 chairs can be manufactured after every new 15 hours. Total time of Design, Development and Manufacturing are again smaller but with bigger initial investment (Table 12). It can be concluded that AI and AM technologies are again recommended in this case.

Table 12. Comparison of total time needed for traditional methods and usage of AI and AM in the case that 100 chairs is needed. One injection moulding machine and 100 3D printer's.

Development steps:	***Traditional methods [h]***	***AI and AM [h]***
Design	≈ 16	≈ 1
Development	≈ 206	≈ 1
Manufacturing	≈ 9	≈ 14
Total:	≈ 231	≈ 16

2.3.2.Case study no. 2.: 10 000 chairs needs to be manufactured

Third case study is manufacturing of 10 000 chairs. Comparison analysis in the case that one injection moulding machine and one 3D printer is used is shown in Table 13.

Table 13. Comparison of manufacturing time for traditional manufacturing method and usage of AM in the case of 10 000 chairs is needed. One injection moulding machinein comparison to one 3D printer.

Development steps:	***Traditional injection moulding method [h]***	***AM [h]***
Preparation of machine and tool for manufacturing	≈ 8	≈ 1
Time of manufacturing	≈ 100	≈ 100 000
Total:	≈ 108	≈ 100 001

From Table 13 it can be seen that manufacturing of 10 000 chairs using only one 3D printer will take 100 001 hours, which is around 4 166 days. It is obvious that it is much better to use one injection moulding machine in comparison to one 3D printer. Using injection moulding machine 10 000 chairs can be manufactured in 108 hours (4,5 days). Using 100 3D printers manufacturing time can be reduced to 1004 hours (41 days). This is still to slow in comparison to the traditional injection moulding methods. (Table 14).

Table 14. Comparison of manufacturing time for traditional manufacturing method and usage of AM in the case of 10 000 chairs is needed. One injection moulding machine in comparison to 100 3D printer’s.

Development steps:	*Traditional injection moulding method [h]*	*AM [h]*
Preparation of machine and tool for manufacturing	≈ 8	≈ 4
Time of manufacturing	≈ 100	≈ 1000
Total:	≈ 108	≈ 1004

If design and development time is included, difference between traditional and AI and AM methods is around 3 times slower in the case of AI and AM. (Table 15).This means that around 300 3D printers are needed to have approximately the same design, development and manufacturing speed as one injection moulding machine (Table 15). This mean that initial investment will be much bigger. This investment can have relative quick return time if different designs of the chairs must be manufactured constantly (Table 16).

Table 15. Comparison of total time needed for traditional methods and usage of AI and AM in the case that 10000 chairs is needed. One injection moulding machine in comparison to 100 3D printer’s.

Development steps:	*Traditional methods [h]*	*AI and AM [h]*
Design	≈ 16	≈ 1
Development	≈ 206	≈ 1
Manufacturing	≈ 108	≈ 1004
Total:	≈ 330	≈ 1006

Table 16. Cost of investments in the case that 10 000 chairs are needed to be manufacturing during same amount of time using traditional injection moulding methods and AM methods.

Development steps:	*Traditional injection moulding methods [Euro]*	*AM [Euro]*
Price of machines (one injection machine and 300 3D printers)	≈ 50 000	≈ 1 500 000
Tool development and manufacturing	≈ 50 000	0
Total:	≈ 100 000	≈ 1 500 000

From above presented three case studies it can be seen that AI and AM can significantly reduce the time and investment for design, development and manufacturing of a new product. Especially in the cases when small amount of products needs to be manufactured. In the future, this will certainly lead to the further development of individual small manufacturers and individual manufacturing units. It is estimated that manufacturing will be distributed from large industrial centres to small individual manufacturers who will use fully automated AI based processes for the development, design and manufacturing of new products. Further and more detailed analyses are needed in order to find the exact limit at which one or another type of manufacturing should be chosen regarding number of products which needs to be manufactured.

3. Conclusion

Artificial intelligence and additive manufacturing are certainly two most important technologies that will fundamentally change the process of product development, design and manufacturing in the future. Creative and digital part of the product development and design process will be effected the most. AI can very easily and quickly generate a large number of potential new solutions for the design of a new product. Also, AI will soon be able to generate 3D models of designed products. Especially in cases where products are design and user oriented, like chairs. Designed products will be able to be manufactured with the help of AM without the need for human labor or with minimal need for human involvement. The mentioned technologies are in their initial development cycle, so their full application requires additional time. In terms of engineering applications, it is expected that a system for generating 3D models will be developed that allows for additional editing of the model after its initial generation via a text query. This primarily refers to editing the model in terms of incorporating the experience and knowledge of the engineer into the design of a new product. The engineer can determine, using personal experience and knowledge, whether the product is well designed in terms of stress analysis, stability or design for manufacturing. It must be possible to further edit the designed product with additional queries in order to achieve some of the above mentioned constrains.

It can be concluded that the use of AI technology will become an integral part of the product development and design process. AM technologies will also become an integral part of the manufacturing processes in the future, but not yet in cases of mass production, although AM devices are rapidly advancing and the speed of manufacturing is rapidly increasing. Additional research and analysis of the possibilitiesis it possible to use print farms to replace traditional manufacturing processes are needed. On the other hand, AM devices will enable a higher level of individual production and further decentralization of production from large industrial centers to small decentralized manufacturers.

Both technologies will lead to a reduced need for ordinary labor (ordinary machine operators), while on the other hand, the need for small number but a highly skilled workforce will increase. Workforce which is familiar with AI and AM systems and at the same time has engineering knowledge.

4. References

[1] Patalas-Maliszewska, J., Pająk, I., &Skrzeszewska, M. (2020, July). AI-based Decision-making Model for the Development of a Manufacturing Company in the context of Industry 4.0. In 2020 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE) (pp. 1-7). IEEE.https://doi.org/10.1109/FUZZ48607.2020.9177749

[2] Quan, H., Li, S., Zeng, C., Wei, H., & Hu, J. (2023). Big data and AI-driven product design: a survey. Applied Sciences, 13(16), 9433.https://doi.org/10.3390/app13169433

[3] Tsang, Y. P., Wu, C. H., Lin, K. Y., Tse, Y. K., Ho, G. T. S., & Lee, C. K. M. (2022). Unlocking the power of big data analytics in new product development: An intelligent product design framework in the furniture industry. Journal of Manufacturing Systems, 62, 777-791.https://doi.org/10.1016/j.jmsy.2021.02.003

[4] Jin, J., Yang, M., Hu, H., Guo, X., Luo, J., & Liu, Y. (2025). Empowering design innovation using AI-generated content. Journal of Engineering Design, 36(1), 1-18.https://doi.org/10.1080/09544828.2024.2401751

[5] Verganti, R., Vendraminelli, L., &Iansiti, M. (2020). Innovation and design in the age of artificial intelligence. Journal of product innovation management, 37(3), 212-227.https://doi.org/10.1111/jpim.12523

[6] Hong-Seok, P., & Dinh-Son, N. (2018). AI-Based Optimization of Process Parameters in Selective Laser Melting. In Advances in Manufacturing Technology XXXII (pp. 119-124). IOS Press.https://doi.org/10.3233/978-1-61499-902-7-119

[7] Pattanayak, S., Sahoo, S. K., & Sahoo, A. K. (2023). Effect of electrode materials and process parameters on deposition characteristics during GMAW-AM. Materials and Manufacturing Processes, 38(14), 1809-1822.https://doi.org/10.1080/10426914.2023.2217895

[8] Muminovic, A. J., Colic, M., Mesic, E., & Saric, I. (2020). Innovative design of spur gear tooth with infill structure. Bulletin of the Polish Academy of Sciences: Technical Sciences, (3).https://doi.org/10.24425/bpasts.2020.133370

[9] Muminovic, A. J., Muminovic, A., Mesic, E., Saric, I., & Pervan, N. (2019). Spur gear tooth topology optimization: finding optimal shell thickness for spur gear tooth produced using additive manufacturing. TEM Journal, 8(3), 788.https://doi.org/10.18421/TEM83-13

[10] Badini, S., Regondi, S., & Pugliese, R. (2025). Enhancing mechanical and bioinspired materials through generative AI approaches. Next Materials, 6, 100275.https://doi.org/10.1016/j.nxmate.2024.100275

[11] Poole, B., Jain, A., Barron, J. T., & Mildenhall, B. (2022). Dreamfusion: Text-to-3d using 2d diffusion. arXiv preprint

arXiv:2209.14988.https://doi.org/10.48550/arXiv.2209.14988
[12] Li, C., Zhang, C., Cho, J., Waghwase, A., Lee, L. H., Rameau, F., ... & Hong, C. S. (2023). Generative ai meets 3d: A survey on text-to-3d in aigc era. arXiv preprint arXiv:2305.06131. https://doi.org/10.48550/arXiv.2305.06131
[13] Gozalo-Brizuela, R., & Garrido-Merchan, E. C. (2023). ChatGPT is not all you need. A State of the Art Review of large Generative AI models. arXiv preprint arXiv:2301.04655. https://doi.org/10.48550/arXiv.2301.04655
[14] Li, J., Tan, H., Zhang, K., Xu, Z., Luan, F., Xu, Y., ... & Bi, S. (2023). Instant3d: Fast text-to-3d with sparse-view generation and large reconstruction model. arXiv preprint arXiv:2311.06214. https://doi.org/10.48550/arXiv.2311.06214
[15] https://www.ien.com/additive-manufacturing/article/21808825/prusa-unveils-fullyautomated-3d-printing-farm?utm_source=chatgpt.com
[16] https://blog.prusa3d.com/a-quick-look-to-our-printing-farm_7474/?utm_source=chatgpt.com
[17] Dehghan, S., SattarpanahKarganroudi, S., Echchakoui, S., & Barka, N. (2025). The Integration of Additive Manufacturing into Industry 4.0 and Industry 5.0: A Bibliometric Analysis (Trends, Opportunities, and Challenges). Machines, 13(1), 62.https://doi.org/10.3390/machines13010062
[18] Xiong, Y., Tang, Y., Kim, S., & Rosen, D. W. (2023). Human-machine collaborative additive manufacturing. Journal of Manufacturing Systems, 66, 82-91.https://doi.org/10.1016/j.jmsy.2022.12.004