

# Innovative AI-Driven Product Design: Leveraging Language Models and AI Image Generators in Product Development Process—A Case Study on Insole Design for High-Heeled Shoes

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## ABSTRACT

Artificial Intelligence (AI) technologies, is the crucial topic all fields of professionals are researching in, it's one of the icon of this era and its influence on our daily lives is significant, and continuously growing. Incessantly, noticing by designers and making its way into the world of product design. Language Models are to generate ideas and concepts as inspirations, while AI Image Generators are to create graphics as an alternative rapid prototyping. These functional tools are assisting designers in all sorts of ways, as well as Product Design Process (PDP). However, AI's ability related to Ergonomics is still exiled, owing to its trained in a big data of information but not really understanding the application of Human Factor Engineering. The insole of high-heeled shoes is chosen as the product to be designed, in view of their ergonomic needs and 3D modelling logic. With AI tools assisting among stages of PDP, this paper proposed a new process of Product Design, intended to compare the efficiency of and outcomes between Traditional 4D PDP and AI-Driven PDP. This paper underscores the transformative potential of AI in product design, highlighting its ability to merge creativity with analytical precision, thus fostering more efficient and effective design workflows.

**Keywords:** Artificial intelligence in design, Desing process, Product design

## INTRODUCTION

With the rapid development of Artificial Intelligence (AI) technologies, their impact on the design process is becoming increasingly significant. The ever-evolving nature of these technologies is evident through various software advancements. The incorporation of language model databases and AI image generators into the product design development process represents a significant advancement in the field. These technologies streamline ideation, enhance design refinement, and provide comprehensive evaluation, and user-centric products.

However, currently, AI mainly contributes to the conceptual development stage and cannot delve deeper into more complex design aspects, particularly

in functional areas of product design. This limitation of generative software highlights its shortcomings, such as modelling human factor engineering products and 3D modelling reasoning. Thus, this paper intended to present an alternative AI-Driven Product Design Process. With traditional 4D Design Process as the base framework, and adding two types of AI application tools (language models and AI image generator) as assistants. Created a more coherent workflow for product designers in the current era, to follow and refer.

## LITERATURE REVIEW

### Artificial Intelligence

The term “Artificial Intelligence” was coined by John McCarthy in 1955, who defined it as “the science and engineering of making intelligent machines” (McCarthy, 2007). According to the Oxford Dictionary, Artificial Intelligence is defined as the theory and development of computer systems able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and language translation.

Generative Artificial Intelligence (Generative AI) is an AI system capable of learning from vast amounts of data to understand complex patterns and structures, subsequently generating new content that conforms to these patterns. This makes it widely applicable in fields such as natural language processing, computer vision, and artistic creation (Goodfellow, Pouget-Abadie et al., 2020).

### Artificial Intelligence in Design Field

Generative artificial intelligence (GenAI) and large language models (LLM) are transforming the design field, enhancing creativity and efficiency. Hong, Hakimi et al. (2023) detail how these technologies accelerate the emergence of design inspiration and concept formation, though designers must balance inspiration with operational efficiency. Language models, which understand and generate human language, enrich the ideation phase by proposing unique features, recommending materials, and suggesting ergonomic improvements. AI image generators quickly create and refine visual prototypes, allowing for rapid visualization of design modifications.

Fang (2023) conducted an in-depth study on the impact of generative AI on the field of industrial design, with a particular focus on its application in practical design processes and design knowledge acquisition. In a retrospective paper, Lu and Huang (2024) summarized the development of AI applications in creative design. Through literature review analysis and expert interviews, they gathered valuable insights from professionals across various design background.

### Product Design Process

The traditional 4D design process is a structured approach to design that encompasses four key phases: Discover, Define, Develop, and Deliver. This methodology provides a structured framework for developing effective and

user-centered design solutions. By following the four steps, designers can ensure a comprehensive and iterative approach that addresses user needs and achieves project goals. The following flow chart is the 4D Design Innovation Process presented by the British Council.



**Figure 1:** 4D design innovation process (Perez, 2018).

## Design Language

“Design language is a set of rules and principles that guide the design of a product or a system. It ensures consistency and coherence across different touchpoints and channels” (Nielsen, 2019). A design language is an essential framework for creating visually cohesive, user-friendly, and brand-consistent designs. By adhering to a set of defined standards and guidelines, designers can ensure that their products not only look great but also provide a seamless and intuitive user experience (Chandrasegaran, Ramani et al., 2013).

The importance of design language is that, it creates communication between design team and customers. As it elucidates the functionality, design semantic and cognitive instruction straight into the product customer are holding on their hands. As well as bringing design concept into manufacturing phases, transforming the thinking and meaning without misunderstanding (Arnold and Rudolph, 2012).

## RESEARCH METHOD

### Challenges Traditional 4D Design Process is Currently Facing

The traditional 4D design process, while systematic, faces challenges in today’s fast-paced, technology-driven environment. Rapidly evolving user needs and expectations can make lengthy, linear processes less effective (Brown, 2008). Integrating new technologies like AI and AR requires continual learning and adaptation (Gero and Sudweeks, 2012). Time and resource constraints further hinder the 4D process, making it hard to keep up with accelerated market timelines (Saffer, 2010). Its rigid structure also impedes effective collaboration among interdisciplinary teams (Cross, 2023). Additionally, managing vast amounts of data for actionable insights while ensuring user privacy is challenging (Donald, 2013). Integrating sustainability and ethical considerations is complex and resource-intensive (Papanek, 2022). These challenges underscore the need for more flexible, agile, and integrated design approaches.

### Complement AI Applications Can Bring to Product Design Process

AI tools like language models and image generators greatly enhance the design process by boosting creativity and efficiency. Language models like GPT-3 aid in the ideation phase by generating diverse design elements, analyzing user requirements, and providing technical insights (Chakrabarty, 2024). They foster innovative solutions by offering cross-disciplinary insights (Sáez-Velasco, Alaguero-Rodríguez et al., 2024). AI image generators, using technologies like GANs, enable quick creation of visual concepts, facilitating rapid prototyping (Goodfellow, Pouget-Abadie et al., 2020). These tools allow for quick iterations and modifications, enhancing visualization and refinement based on user feedback (Kahng and Chau, 2019). By automating repetitive tasks, AI lets designers focus on complex, creative aspects, leading to improved productivity and a more efficient workflow (Verganti, Vendraminelli et al., 2020).

### Generative AI and Image Generation Techniques

Generative AI is widely applied in art creation and research, with text-to-image technology gaining significant attention. Using text prompts, it can synthesize new images, as seen in applications like Midjourney, Leonardo, and Stable Diffusion. Image generation techniques include various methods such as image-to-image translation, sketch-to-image generation, conditional image generation, text-to-image generation, video generation, panoramic image generation, and scene image generation. Each method is supported by numerous research papers, employing different features and technologies to achieve optimal and effective generative results (Elasri, Elharrouss et al., 2022).

### Experimental Setup

The purpose of this paper is to present a new AI-Driven Design Process for Product Design. In order to do so, the 4 phases of traditional 4D Design Process are set as the framework, with variety of assisting functions of AI applications plugged in, and transformed into an alternative solution of design thinking method.

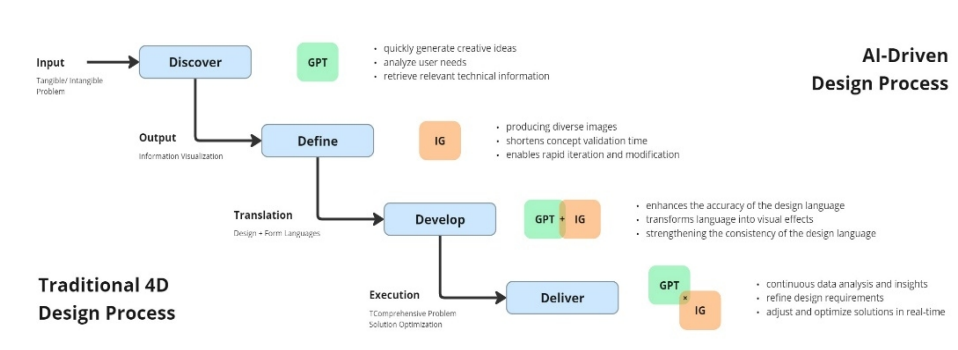


Figure 2: Experiment workflow of this study.

## AI-Driven Design Process

### Discovery - GPT

By leveraging GPT, designers can quickly generate creative ideas, analyze user needs, retrieve relevant technical information, and gain interdisciplinary insights, aiding in uncovering innovative solutions.

### Define - AI Image Generator

Using AI image generation, designers can swiftly create visual concepts, producing diverse images based on specific requirements or keywords. This offers varied design references, shortens concept validation time, and enables rapid iteration and modification, exploring solutions visually and defining problems more precisely.

### Develop (Design) - GPT + AI Image Generator

Combining GPT and AI image generation enhances the accuracy of the language design. AI transforms language into visual, refining design concepts through iterative presentation, and strengthening the consistency of the design language.

### Delivery - ChatGPT x AI Image Generator

Integrating GPT and AI image generation provides continuous data analysis and insights to refine design requirements. AI generates different design versions for visual validation, allowing designers to adjust and optimize solutions in real-time, achieving efficient and accurate problem-solving.

### Pre-Test

The purpose of this pre-test includes, 1. as this paper is a preliminary paper, a pre-test is needed for future research; 2. to try out the feasibility of the framework of AI-Driven DP, mainly on the third phase, **C. Develop (Design)**; 3. to test out the ability of current models of AI applications related to Ergonomics.

As for the setups of this pre-test, 1. The language model/ GPT performed is ChatGPT from OpenAI and AI image generator practiced is MidJourney; 2. The insole of high-heeled shoes is set as design objective.

Three types of operations were practiced, as listed in the chart below. The results are shown in following chapters.

**Table 1.** Types of operation practiced. (Operation A to Operation C-2).

Text to Image I			
A	> Generate prompts from ChatGPT		Prompt X-0
	> Generate image in MidJourney		X-0
Image to Text			
B-1	Image from Midjourney	> Generate prompts in Midjourney	Prompt X-1-a, Prompt X-1-b
B-2		> Generate prompts in ChatGPT	Prompt X-2
Text to Image II			
C-1	Prompts from B-1	> Generate image in Midjourney	X-1-a, X-1-b
C-2	Prompts from B-2		X-2

## RESULTS

Operation A.

Step 1. Design Language, prompting from ChatGPT

Question: If I'd like to put this idea into AI image generator, as for design languages and form languages, what prompts could you suggest?

ChatGPT:






Group A	<b>Prompt 1: Comfort-Focused Insole</b>
	A-1. "Create an image of a high-heel shoe insole designed for maximum comfort. The insole should have a contoured arch support, a deep heel cup, and visible cushioning in the heel and forefoot areas. The material should appear breathable with small perforations and a moisture-wicking surface. Show the insole in a stylish high-heel shoe, highlighting how slim and unobtrusive it is."
Group B	<b>Prompt 2: Advanced Cushioning</b>
	B-1. "Illustrate a high-heel shoe insole featuring advanced cushioning technology. The insole should have gel padding in the heel and ball of the foot areas, a non-slip surface on top, and a metatarsal pad. The image should show the insole both inside a fashionable high-heel shoe and separately to highlight its features."
Group C	<b>Prompt 3: Stylish and Functional Design</b>
	C-1. "Generate an image of a high-heel shoe insole that combines style and functionality. The insole should be slim, lightweight, and feature a sleek design with arch support and a deep heel cup. Include a metatarsal pad and a breathable, moisture-wicking top layer. Display the insole in a variety of colours to match different high-heel shoes, emphasizing its aesthetic appeal."
Group D	<b>Prompt 4: High-Tech Insole</b>
	D-1. "Create an image of a high-tech high-heel shoe insole with ergonomic design. The insole should have a contoured shape for arch support, a deep heel cup, and advanced cushioning materials like gel and foam. Show the insole with a non-slip surface, perforations for breathability, and a moisture-wicking property. Display it inside a stylish high-heel shoe, demonstrating its seamless integration and comfort."
Group E	<b>Prompt 5: Customizable Insole</b>
	E-1. "Illustrate a customizable high-heel shoe insole that can be trimmed for a perfect fit. The insole should have a sleek design with visible arch support, a deep heel cup, and cushioning in the heel and forefoot. Include details like a non-slip top layer and perforations for breathability. Show the insole in a high-heel shoe, highlighting its ease of insertion and the customizable edges."

Step 2. Generate image in MidJourney from prompts of ChatGPT






Group A	<b>Comfort-Focused Insole</b>		Group B	<b>Advanced Cushioning</b>	
	A-0			B-0	
Group C	<b>Stylish and Functional Design</b>		Group D	<b>High-Tech Insole</b>	
	C-0			D-0	
Group E	<b>Customizable Insole</b>				
	E-0				

From each sample group, one of the images was selected. Based on the creativity of innovation idea, reasonability of product design, feasibility of form modelling, and conformity of the design objective.






Operation B-1.

Group A		A-1. photography, white background. Beige high-heeled shoes with a perforated pattern, no background, ultra-realistic photography.
Group B		B-1. A pink, semi-transparent, decadent shoe sole, vector illustration with a white background, vector graphics, simple shapes, low detail, no shadows, front and back views of the shoe sole. The inside view shows a soft sponge material for comfort while walking on hard surfaces. It also includes air pockets to ensure the foot remains cool during long walks or activities in hot weather. The exterior has a beautiful design that adds style without being obtrusive.
Group C		C-1. A high-heeled shoe with a sole and foam heel, featuring a color scheme of purple, black, and yellow against a white background, rendered in 3D. The center depicts the sole of a woman's shoe, the right side shows half of a woman wearing leather slippers, and the bottom left corner contains three small woolen items, all with a simple, minimalist design and high-definition photography, without any shadows on the ground.
Group		D-1. Futuristic high-heel shoe, made of transparent material with gradient colors, patterns and metal texture on the sole, against a white background, 3D rendering, studio lighting.
Group E		E-1. A hand-drawn design of an elegant high-heel shoe, detailed with the structure and materials used in its construction. The shoes should have clear lines showing the sole, heels, upper part, fabric or leather texture details, and reflect light. Include notes about which parts were made from steel, aluminum, plastic, rubber, glass, porcelain, silver metal embellishments, and other unique features that make them stand out as luxurious items for women's fashion on a white background.

Operation B-2.








Group A		A-2. A high-heel shoe insole with an artistic, creative design language. The insole should feature unique patterns, vibrant colors, and artistic textures. Use design elements that are visually striking and expressive, such as abstract shapes or bold graphics. Show the insole in a high-heel shoe that complements its artistic flair, highlighting the creativity and of the design.
Group B		B-2. An image of a high-heel shoe insole with a focus on its internal structure and design features. The insole should be shown from both the top and side views, highlighting its anatomical design. The insole is pink and transparent, revealing detailed features such as gel cushioning in the heel and forefoot areas, contoured arch support, and a textured surface for grip. The design should emphasize the ergonomic elements, showing how the insole supports the foot and provides comfort in high-heel shoes.
Group C		C-2. Create a sleek black high-heeled shoe with a textured surface and a soft purple inner lining. Next to the shoe, place two removable, ergonomically designed insoles—one beige and the other purple—each featuring a distinct, textured surface. The overall look should focus on comfort and style.
Group D		D-2. Create a futuristic high-heeled shoe with a metallic, translucent design featuring a textured surface that resembles scales. The colors should blend from silver and blue to vibrant orange and pink, with glowing interior accents. The shoe should have a glossy, curved heel, reflecting light for a modern and high-tech aesthetic.
Group E		E-2. A detailed technical sketch of a high-heeled shoe design, drawn in a blueprint style. The shoe should have a pointed toe, thin heel, and a visible cushioned or textured insole. Include multiple angles and cutaways, with annotations marking the shoe's key features. The sketch is in monochrome tones with fine lines, shading, and a professional hand-drawn aesthetic.

Operation C-1.

Group A	<b>Comfort-Focused Insole</b>		Group B	<b>Advanced Cushioning</b>	
	A-1			B-1	
Group C	<b>Stylish and Functional Design</b>		Group D	<b>High-Tech Insole</b>	
	C-1			D-1	
Group E	<b>Customizable Insole</b>				


















## Operation C-2.

Group A	Comfort-Focused Insole		Group B	Advanced Cushioning	
	A-2			B-2	
Stylish and Functional Design			High-Tech Insole		
Group C	C-2		Group D	D-2	
					
Group E	Customizable Insole				
	E-2				

**DISCUSSION**

From Operation A to C, it showed the back and forth of utilizing language model and AI image generator in the design process. Originated from the same prompt, yet resulted in images with various features. In Operation A, the idea of a shoe insole is relatively clearer, as the process goes on, it became more as the design of high-heeled shoes. The reason of the development might owe to how designer's/ human's involvement during the process. In this pre-test, the design ability of AI is also tested, hence the designer's interference was done the minimal. As only two parts of the decision making was executed by the author: the selection of Operation A to continue for further steps; and 2 of the 4 prompts chosen in Operation B-1.

<b>Group A</b>	<b>Prompt 1: Comfort-Focused Insole</b>		
	A-0	A-1	A-2
			
<b>Group B</b>	<b>Prompt 2: Advanced Cushioning</b>		
	B-0	B-1	B-2
			
<b>Group C</b>	<b>Prompt 3: Stylish and Functional Design</b>		
	C-0	C-1	C-2
			
<b>Group D</b>	<b>Prompt 4: High-Tech Insole</b>		
	D-0	D-1	D-2
			
<b>Group E</b>	<b>Prompt 5: Customizable Insole</b>		
	E-0	E-1	E-2
			

## CONCLUSION

AI tools like GPT and image generators enhance the design process by boosting creativity and efficiency. GPT generates ideas, refines concepts, and drafts descriptions, keeping designers updated on trends. AI image generators transform text into high-quality visuals, enabling rapid exploration and iteration. These tools improve collaboration, provide clear drafts for communication, and automate repetitive tasks, allowing designers to focus on complex, creative aspects. The result of the pre-test showed that the AI-Driven Design Process is feasible and would continue for further research. As the process was mostly conducted by AI, the outcome went astray towards

the design of high-heeled shoes, rather than the insole of it. The main features of each group of images generated resulted in the one image chosen by the designer to continue. It proved that how important the designer is taking place during the design process. With higher proportion of designer's decision making involved inside the process, the description and details of each phase would be clearer, and a more comprehensive model would be conducted.

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