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Industrial Design Structure Plus: Industrial Design Structure method implemented with Theory of Inventive Problem Solving and Conceptual Method

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ABSTRACT

This paper introduces a novel design methodology, designated Industrial Design Plus (IDeS+), which incorporates a range of techniques for the collection of technical specifications, thereby facilitating informed decision-making on the part of the user. The integration of Industrial Design Structure (IDeS) with other methods, such as the Theory of Inventive Problem Solving (TRIZ) and Conceptual Methods, allows for a comprehensive approach to design, thereby facilitating the resolution of challenges related to adaptation and cultural impacts on consumer behavior. Effective communication between departments is essential for the dissemination of development progress and the resolution of change requests. The proposed methodology aims to align the industry towards a customer-centric product concept, where design plays a central role in product individualisation and customer suggestions directly influence business organisations. However, the existing method has shortcomings when applied to complex or contradictory projects, leading to unresolved requests. Overall, the integration of the IDeS method with other techniques facilitates innovation, organisation, and project reviews while ensuring the delivery of quality products to society.

Keywords: Industry 4.0; Engineering; Industrial design structure; Conceptual method; Quality; Theory of inventive problem solving

INTRODUCTION

In recent years, the incorporation of Artificial Intelligence (AI) tools into the product development process has demonstrated efficacy in responding to market demand and ensuring the continuous evolution of products and services [1-3]. The growing use of digital tools in companies in various areas, including product conception, feasibility analysis, design consistency assessment, prototyping, quality control and logistics, has made the importance of AI as a support tool for these processes increasingly evident. The incorporation of AI has resulted in enhanced knowledge, particularly within the domains of research, analysis, and documentation. This integration is regarded as a pivotal step for organisations and product development departments, as it enables the research and development department to be supported by a tool that implements human knowledge, which is invaluable as a filter and manager of the information received from these tools [4-6]. It is imperative that those engaged in research and development facilitate the integration of information to be shared with other organisational units at the earliest possible stage. This enables the immediate transmission of pertinent data and the establishment of a framework that facilitates prompt contact with relevant stakeholders, who can provide invaluable input into the product development process. Furthermore, the dissemination and anticipation of information gathering can facilitate the development of a product that strikes a balance between high quality and economic feasibility [7-10]. In the field of industrial design, interdisciplinary collaboration has become a crucial aspect in the pursuit of

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innovation and efficiency. Organisations were most effective if they provided an environment that conveyed sufficient feedback to the technical core, thereby achieving a balance between technological and process development. Despite the considerable complexity, uncertainty and interdependence faced by this core, accurate feedback from management is necessary to gain a deeper understanding of the requirements for major changes in technology and know-how, which in turn would lead to significant changes in the organisation itself. By adopting quality tools, integrating sustainability considerations, and implementing strategic approaches, organizations can effectively balance economic value creation with a focus on sustainability in their product development processes, ultimately gaining a competitive advantage in the market [11-14]. Kohli and Jaworski proposed an organisational approach that prioritises customer satisfaction, aligning companies with a market-oriented theoretical framework. Subsequently, Ramani and Kumar and DiRomualdo et al. developed this model with the incorporation of interactive cycles, with the objective of facilitating change [15,16]. While it is challenging to establish a fully customer-oriented organisation, necessitating the integration of market analysis and business processes, companies are utilising sophisticated data analysis tools to identify profitable customers and new market opportunities. This enables them to create value for customers, which in turn has a positive influence on the entire value chain. In response to the market preference for customised products, companies are adopting customer-centric processes in order to meet individual needs. The volatility of consumer behaviour makes customisation an effective method for market analysis. The use of Industry 4.0 tools enables companies to gather detailed information and find optimal solutions to production challenges [17-19]. The objective of this study is to assess the capacity of the Industrial Design Structure (IDeS) methodology to impact the advancement of industrial projects by establishing a connection between the design phase and the broader organisational structure. This study proposes an innovative approach based on the IDeS method, which is combined with the Theory of Inventive Problem Solving (TRIZ) and methodologies enhanced by the use of AI. The main objective is to improve the IDeS method by developing a structured system that can be replicated in different contexts, with a particular focus on the early stages of product development, including planning and defining the architectural framework. The aim is to develop innovative and competitive industrial products [20-23]. The Quality of Design (QFD) methodology, combined with the theory of inventive problem solving (TRIZ), has already been used to generate innovative solutions to design problems. By integrating the methods, it has been shown to be useful to simplify both in order to achieve an innovative design that addresses multiple areas of interest [24,25]. The study commenced with the IDeS method, which provides a systematic approach to industrial design, thereby ensuring the timely completion of projects and facilitating collaboration between various company departments. This was complemented by the TRIZ method, an innovative approach to solving design problems, integrated into the conceptual method to provide further solutions. The TRIZ methodology has found application in many areas, including technical problem solving, innovation, technology strategy and business management. Over time, different versions of TRIZ tools have been developed for specific areas such as business, finance, marketing, customer satisfaction and education. These adaptations have allowed TRIZ to extend its influence far beyond its initial use in the technical field. Although TRIZ may show less efficiency in solving non-technical problems, it still provide useful results in virtually any field when applied appropriately. TRIZ's ability to provide innovative and strategic solutions also makes it valuable in less traditional contexts. This demonstrates its versatility and TRIZ's potential to be an effective tool for addressing a wide range of challenges [26-28]. The conceptual method incorporates core functions by offering different definitions and solutions for each requirement, which are then combined into different variants. The truly innovative aspect of our approach is the use of Artificial Intelligence (AI) to improve and expand the research. AI has proven to be extremely useful in the design of complex objects, such as vehicles, by expanding human knowledge through machine learning. However, to be effective, it requires continuous monitoring and specific training [29-32]. This study presents an examination of the methodologies involved, showcasing their alignment with the IDeS method through a case study in automotive design. The results of the case study indicate that the integrated approach improves efficiency and creativity in the industrial design process. The systematic application of IDeS, TRIZ and conceptual methods together with AI enables designers to address complex projects, identify innovative solutions and optimise design results. Furthermore, the integration of AI facilitates access to real-time information, enabling the formulation of design strategies. This study presents a comprehensive approach to the conceptualisation of industrial design 4.0. The integration of IDeS, TRIZ and AI methodologies enables the generation of innovative products and provides industrial designers with effective tools for problem-solving and the advancement of products and services. The paper demonstrates how an interdisciplinary approach involving multiple departments can facilitate a more collaborative and comprehensive design process. To provide technical solutions that directly address market needs, aspects such as requirements, benchmarking and a what/what matrix are considered. The company's experience, combined with its ability to assess economic feasibility and evolving market needs in light of technological advances, enables the creation of products and services in line with market demands. Future research will focus on improving AI algorithms for design optimisation and investigating their applications in a range of fields.

METHODS

Theoretical Framework

Industrial Design Structure (IDeS): The Industrial Design Structure (IDeS) is a methodology for the assessment of innovation in products, services, and processes [33]. This method facilitates the identification of product characteristics that necessitate improvement, thereby enabling the subsequent implementation of innovative activities. It is an industrial project resolution methodology developed by Professor Leonardo Frizziero. According to Frizziero (2022), this methodology takes a holistic approach by combining various design and development tools to foster an innovative environment for product creation [34]. The method has been successful in various industries, including the automotive sector, where it has facilitated the development of sports cars with shared platforms. It has contributed to the design of an electric bicycle and other industrial projects related to sustainable mobility. The IDeS method is founded upon a series of analytical and evaluative instruments, including the Relationship Matrix and the What-How Matrix, which facilitate the identification of product characteristics necessitating innovation and the delineation of the interrelationships between these characteristics. Moreover, the IDeS method furnishes a numerical rating for each product attribute, thus enabling the assessment of its relative importance in comparison to the others. The principal benefit of utilising the IDeS method is that it facilitates the exact delineation of pivotal areas within a product that necessitate enhancement, thereby enabling innovation endeavours to be concentrated on the most pertinent domains. Moreover, the IDeS method offers a transparent and systematic framework for innovation analysis, which mitigates the likelihood of overlooking crucial elements of the product [35]. Its purpose is to organize and optimize the design process by hierarchically structuring design elements and delineating their interconnections. The goal is to create an environment for efficient problem-solving and innovative ideation. IDeS is a comprehensive framework that covers all stages of the design process, from concept generation to final product realization. Its structured approach enables designers to navigate complex design challenges, ensuring coherence and effectiveness throughout the design process. The hierarchical structure of IDeS is very effective, as it allows designers to break down design goals into manageable components, facilitating the exploration and methodical evaluation of design alternatives. IDeS adopts a philosophy based on structured organization and systematic problem solving, making it a valuable asset in enhancing the efficiency and effectiveness of industrial design projects, propelling them towards successful completion. The method's ability to integrate customer feedback and technical specifications makes it versatile and effective in product development. **Figure 1** illustrates the method's structural underpinnings. The operational structure of the company is divided into three main areas of operation. For each area, the primary task is indicated. The structure is a sequence of actions carried out by various individuals from different departments, particularly during the decision-making phase. This allows all relevant company members to be involved and updated on the project at the same level. The method commences with a set of five probing questions aimed to define elements from a customer-centric perspective. This lays the groundwork for the ensuing design discourse [36,37].

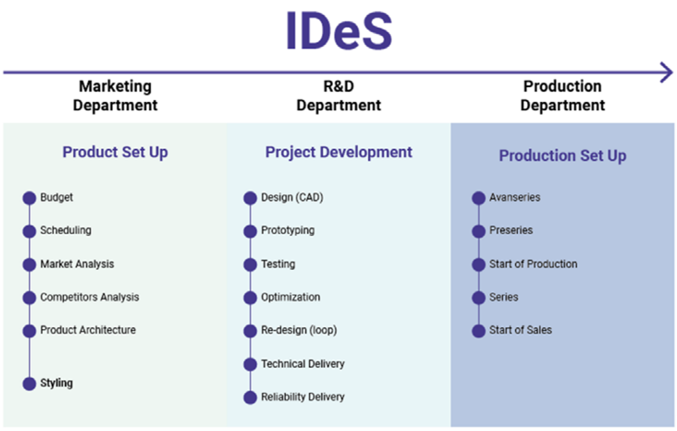

Figure 1: IDeS method

Theory of Inventive Problem Solving (TRIZ): The TRIZ method is a comprehensive and methodological framework designed to foster innovation and address intricate problems effectively. Originally, an acronym for 'Theory of Inventive Problem Solving' in Russian, the method is rooted in the meticulous analysis of numerous successful patents and inventions [38,39]. This enables the identification of recurrent patterns and overarching principles. Russian engineer Genrich Altshuller developed the method. Quality tools like TRIZ facilitate the generation of innovative and creative solutions to challenging problems. By leveraging these tools, companies can develop unique products and services that set them apart from competitors [40-43]. TRIZ is a systematic approach to innovation that guides organizations towards breakthrough discoveries and transformative solutions. Its robust methodologies empower practitioners to unlock new realms of possibility, driving progress and innovation across the global landscape. This method offers practitioners a variety of tools to overcome obstacles and generate innovative solutions [44,45]. TRIZ enables organizations to streamline their development and design processes, enhancing overall efficiency and effectiveness. The systematic nature of TRIZ promotes a structured and strategic approach to problem solving, fostering a culture of innovation and continuous improvement across diverse sectors. TRIZ is widely used in various industries, from industrial design to technological innovation, due to its versatility and effectiveness [46-49]. It provides a systematic framework for addressing challenges and fostering creativity, enabling organizations to navigate the complexities with confidence and chart a course towards sustained growth and evolution. **Figure 2** presents a selective overview of the methodology employed in the method and case study. Although the TRIZ methodology is an effective tool for solving inventive problems, it presents certain challenges that make its practical application challenging. One of the primary obstacles is the perception of rigidity and the difficulty in adapting it to diverse situations. This perception is, to some extent, attributable to the extensive range of tools available within the TRIZ methodology, which can prove overwhelming for those seeking to utilise it. Indeed, the selection of appropriate tools from the extensive toolkit of TRIZ can be a challenging and confusing process. Furthermore, there is a dearth of clear instructions regarding the appropriate timing and context for utilising each instrument. This ambiguity may result in uncertainty and errors during implementation, thereby reducing the efficacy of the methodology. Furthermore, the extensive scope and intricate nature of TRIZ contribute to this challenge, rendering it difficult for many to fully comprehend and correctly apply the proposed tools. Furthermore, the intrinsic complexity of TRIZ tools may result in inefficient use of resources if they are not applied correctly. In the absence of adequate guidance and comprehension, users may expend time and energy on processes that fail to yield the desired outcomes. These challenges underscore the necessity for the development of superior and more accessible educational resources to facilitate the actualization of the TRIZ methodology. Notwithstanding the aforementioned challenges, TRIZ offers a systematic methodology for innovative problem-solving and constructive brainstorming. It assists in the identification and resolution of contradictions, the clarification of problems, and the release of psychological inertia. This makes it a valuable tool for generating new and novel ideas, which can lead to breakthrough solutions and innovation. Furthermore, TRIZ enables accelerated innovation processes, forecasting future trends, and anticipating technological evolution. It also enhances teamwork by providing a shared language for problem-solving within groups. Therefore, while TRIZ can be complex and challenging to apply, its benefits in fostering innovation and improving problem-solving capabilities are substantial when used correctly [50-53].

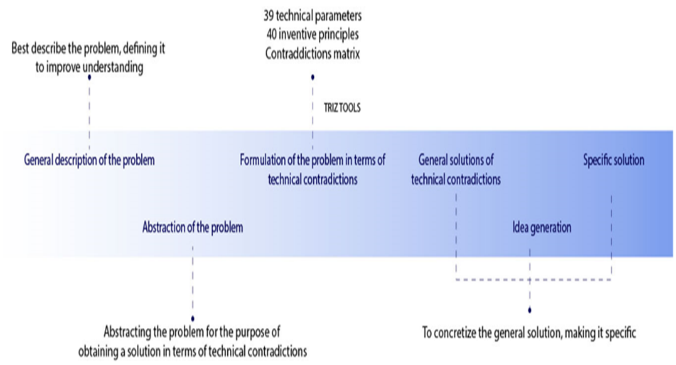

Figure 2: Phases of TRIZ Method

Conceptual method and morphological matrix: The conceptual method is a design technique that combines creative and analytical faculties to generate new ideas by exploring the relationships between seemingly disparate concepts. The method involves identifying a concept, typically with a partial function, and providing several specific solutions regarding technical characteristics. These values will be combined within a morphological matrix to generate multiple variants capable of addressing the design question identified at the beginning of the project. The objective is to uncover fresh insights and innovative solutions by combining elements that are not typically associated with the same project [54,55]. The Morphological Matrix methodology represents an approach for organising alternative solutions for each function of a system. This approach allows a wide range of variants to be combined in order to meet system-level design requirements. Common methodologies to enhance the innovative capacity of designers include the decomposition of the design task into subtasks, thus reducing the cognitive effort required, and the generation of diverse conceptual solutions to increase the probability of identifying innovative solutions. The Morphological Matrix is an effective tool for the documentation of solution information pertinent to specific functions, thereby facilitating the cognitive process involved in the generation of system-level design solutions [56,57]. The conceptual method is characterized by flexibility and creativity in idea generation, encouraging practitioners to think outside the box and explore unconventional ways of solving problems; by creating an environment that encourages free thinking and imagination, this method opens up new opportunities for creative exploration. It allows individuals to break free from traditional boundaries and explore uncharted territories of possibility [58-60]. **Figure 3** shows the morphological matrix, which is a useful tool for design and product development. It breaks down complex problems into smaller components arranged in a structured table or matrix. Each column represents a potential option or face of the problem, laying the groundwork for a systematic exploration and evaluation of alternative paths. Ostertag's (2012) seminal work exemplifies the versatility and efficacy of the morphological matrix in the realm of machinery and mechanical constructions. The matrix played a pivotal role in selecting the most appropriate solution for a manipulator travel frame design [61-63]. Weber (1998) broadened the methodological horizons by integrating the theory of coupling. This addressed the challenges of identifying independent design functions and determining the compatibility of solution alternatives, building on the foundational work [64]. This demonstrates the potential of the morphological matrix to facilitate the development of optimal design solutions.

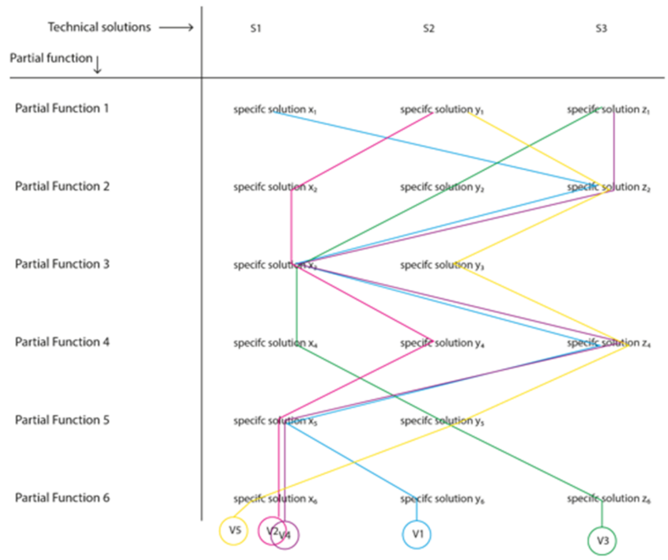

Figure 3: Example of morphological matrix

Conceptual method: The new method involves two parts of TRIZ and the Conceptual Method, positioned between the requirements and benchmarking phases of the product development lifecycle. Additionally, the method includes a Selection Matrix, which allows the user to choose the best technological requirements for an innovative industrial product based on realistic and innovative design criteria. It ultimately converges on the final delineation of the product architecture, as shown in **Figure 4**. This methodology aims to achieve a refined and well-implemented product architecture by integrating the above methodologies and using AI with text-to-text tools. In some parts of this research, we used an advanced

AI-based Natural Language Generation (NLG) system called ChatGPT 3.5. ChatGPT 3.5 is an artificial intelligence based chatbot developed by OpenAI that employs deep learning techniques to generate text that is similar in style and content to that produced by humans [65-68]. It is a Large Language Model (LLM) that can generate text, translate languages, write different types of creative content and answer your questions in an informative way. The model has been pre-trained on a large dataset of text, including books, articles and websites, so that it can understand the pattern and structure of natural language when given a prompt or starting point. It then uses this pre-trained knowledge to generate text that continues the given input in a consistent and natural way. It has many advantages to be used in scientific research, such as analysing large amounts of data and identifying patterns that may not be obvious to humans, it can also find relationships and trends between a lot of data, another thing is that it can extract information from scientific texts and be trained to use these terms when giving answers for a research [69-72]. On the other hand, it may lack accuracy, in fact, some results may be incorrect or misleading, and it is very important to verify the data with reliable sources. The basis of the new method starts with a well-known IDeS, which ensures effective and consistent feedback in the product development process by enabling communication and collaboration between different departments. To this we add two other parts of another method to generate a new solution. For the conceptual method, we use the phases that concern the definition of the elementary functions of a requirement, which is crucial to get the real meaning of a requirement. In a second moment we write the best requirement in a matrix, comparing it with technical solutions, in this phase we should use ChatGPT 3.5, in this way we can get a large number of technical data that can fill the empty space of the lines related to a particular requirement of the matrix. Then we create some variants in a hybrid modality with human and artificial intelligence, then we make a selection with a weighted analysis of the results, and the variant with the highest weight is considered the most suitable for the project solution. In this way, we provide a technical response to the needs of the markets. The second method we have added is TRIZ, we have chosen not to use all the phases of the method, just the ones we need to solve our problems [73,74]. This method is used in the benchmarking phase and it compares the different technical requirements, once we have the ones that are in conflict, we proceed with Altshuller's matrix and 40 inventive principles, which are used to inspire the development and search for new design solutions based on the values obtained. Then we can find out which ideas are the innovative ones, having been helped by ChatGPT to find the common data. Once this is done, the most innovative ideas for an industrial project are taken forward to a technical solution. The selection matrix is a new component that helps to make decisions and obtain an advanced product architecture [75]. To create it, we compare the previous results of the other analyses in two matrices: The first one is between the result of the TRIZ method and the result of the What-How matrix, then we compare the data obtained with the winning variant obtained from the conceptual method. At the end of this process, an innovative product architecture with a large number of defined components is created. The process shown in Figure 4 contributes to greater control in product realization.

This is because all areas of development are thoroughly explored, enabling the designer and other company stakeholders to make well-considered decisions. The advantages of this integrated method are many, in fact we can obtain a large number of data using new methods integrated with Artificial Intelligence, which helps a lot in the creation of an innovative product based on new technology that implements human knowledge with worldwide knowledge that is always evolving. The disadvantages are that if you do not know the IDeS method or how to interact with an artificial intelligence, it can be risky because you don't understand what you are doing or the data you are getting. The other thing is to rely completely on artificial intelligence without checking the veracity of the data and sources [76,77].

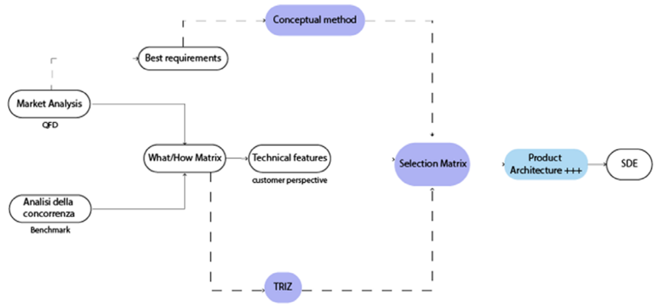

Figure 4: IDeS+ scheme

Research methodology: The method described was executed considering the various stages of the traditional IDeS method. With the emergence of new technologies, particularly the significant role of artificial intelligence in research, it was necessary to review the method and integrate these technologies [78]. This tool can assist students in conducting research by providing a wide range of data for evaluation [79,80]. Previous studies have also explored design methods that cover a larger amount of data not considered by IDeS, making it even more comprehensive. The first method introduced is the conceptual method. It provides an interpretation of the data by generating accurate definitions of the requirements. This approach directs and segments the research, covering various aspects and details of the project. In this way, it has been seen how the creation of multiple solutions and the validation of the data obtained, the integration of artificial intelligence tools will bring real value to research and innovation [81]. This is because providing specific definitions and generating targeted requests for the search engine that utilizes artificial intelligence leads to more accurate and precise answers [82]. It is important to use a search tone that is consistent with the desired answer and to direct the technology towards the desired results by requesting more or less technical information. These are research methods that can also be used in corporate contexts, where different VPNs are used to protect corporate knowledge, while ensuring that all employees have access to the same information about the desired data [83,84]. The potential that this method can combine with the IDeS method mainly concerns the possibility of choosing a variant by means of an objective analysis of the requirements by means of generic questions, answering those posed by an average user of the product in question. The importance of combining it with the IDeS method arises from the fact that this analysis is based only on the requirements aspect from the customer's point of view, and from these it generates technical solutions that were already on the market [85]. What is important from this combination is that the methods can be compared in order to create a much more selective benchmark and at the same time provide for the generation of a solution that also takes into account the technical aspects obtained from the What/How matrix. Another method introduced is TRIZ. This method has been observed to have potential because it creates innovative solutions by introducing elements that may not exist on the market or taking an element into consideration and making it useful in the context of use. It may even require creating a part of the project from scratch, providing valuable insights for the designer [86-89]. This method focuses on identifying and addressing specific design needs rather than considering all possible design solutions. It aims to provide innovative solutions to the contradictions within a project. It aims to provide innovative solutions to contradictions within a project. It aims to provide innovative solutions to the contradictions within a project. It is a method that involves a long process, but in this case only the useful parts were selected, in fact thanks to the integration with IDeS, one can see how contradictions can arise from requirements and benchmarks that are very difficult to resolve with one's knowledge base [90]. In these cases, the real contradictions, which as already mentioned, only concern parts of the project, are checked and analysed with the tools provided by TRIZ: Altshuller matrix and 40 inventive principles. Again, the use of artificial intelligence of the definitions provided by the 40 inventive principles is useful here, so that the research is expanding and more ideas are provided [91]. The importance of combining this method with the other two relates to its innovative and inventive aspect. In fact, compared to those methods that exploit innovations already on the market, with this one it is possible to generate unexpected solutions that can allow the exploration and generation of customized solutions designed for the specific project that can lead to innovations and inventions, generating high corporate and personal know-how [92,93]. The different purposes of the various projects made them all integrable, and this laid the foundation for the subsequent integration of TRIZ and the conceptual method, as illustrated in **Figure 5**. At the same time, the tools associated with the introduced methodologies are also presented. The integration of these methods generates a large amount of data, which can be used to build an innovative project. However, this can cause problems in data management, as all data is specific and usable, but not all of it adds value to the project [94-97]. To address this issue, a means of selecting data were introduced to create a well-defined product architecture. Here, we introduce the pre-selection matrix. This matrix brings together and selects all data based on the principle of redundancy and the weight of the data in relation to a specific requirement, which has been acquired through previous analyses. Early involvement is essential as it saves time and leads to informed decisions based on thorough research [98,99]. This proactive approach also results in cost efficiencies by providing a well-defined solution that eliminates the need for further investigation. This methodology improves operational efficiency and creates a more streamlined and cost-effective product development process by intervening strategically in the early stages of development. The aim of this method is to optimize the strategy for product development. To achieve this, the user must consider all the data obtained in the previous phases and analyse them, particularly in light of any new variations that have emerged in the early stages of the investigation. The amount of information generated is significant, providing the user with a large database to consult when necessary, even in the future or for design modifications or alternatives. This iterative and adaptable method is based on technical-scientific principles, and can be applied in various disciplines, such as biomedicine and automotive. Methodological choices are prioritized over stylistic elements, demonstrating the flexibility and scalability of the method across different application domains by introducing key components at different stages [100-102].

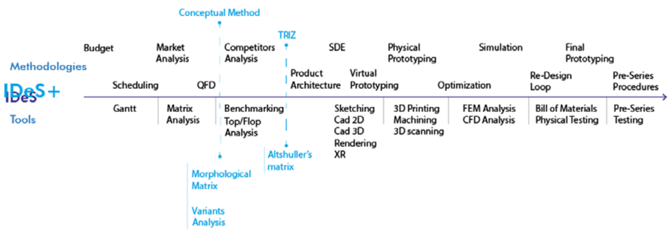

Figure 5: Comparison of IDeS and IDeS+ methods

Case study: As a result of several studies, a case study is given to show how the method works. For the purposes of this paper, we will focus only on the stages of the method; a city car will be developed to show the complete design process. **Figure 6** illustrates the stages of the project, concluding with virtual prototyping. The diagram illustrates a robust framework to support the initial stages, accompanied by tables that provide specific examples to clarify important aspects. Artificial Intelligence (AI) is essential in enhancing research efforts, enabling in-depth investigation and careful grouping of results to avoid duplication [103-105]. This leads to unparalleled innovation and efficiency. After reviewing the project phases, it is evident that the first step, after setting budgetary constraints, is to create a detailed project plan that outlines a range of activities to drive the project to completion. In the early stages, costs are carefully evaluated, and resources are allocated across various production phases, including human capital, machinery, raw materials, and equipment. The environmental analysis phase offers an opportunity to comprehend the context in which the product exists and predict its future based on current conditions. This phase also enables a thorough examination of conceptual frameworks and projects, providing a theoretical foundation for future discussions [106]. The market analysis phase is crucial. The process involves a thorough analysis of the target audience's preferences and tendencies, based on a comprehensive understanding of customer demand dynamics. Product requirements are then carefully defined, providing guidance to navigate the complex process of product development (**Figure 7**). The method incorporates the transformative potential of Artificial Intelligence (AI) integration, representing a significant shift in product development methodologies [107,108].

Figure 6: IDeS+ method used in case study

Figure 7: Stages of the conceptual method

Conceptual method: The conceptual method is a crucial aspect of product development methodologies. It entails identifying and describing the most significant requirements and their corresponding functions to provide clarity on the necessary functional attributes for successful completion [109]. The morphological matrix is built upon the confluence of requirements and basic functions, as shown in **Figure 8.** The table presents various solutions that meet the specified requirements. The table presents solutions in an organized manner, with clear columns and rows for easy reference. It contains a range of options that meet the specified requirements [110]. Developing a product involves navigating various nuances to create solutions that meet these requirements. After completing the morphological matrix, the next step is to generate different variants, as shown in **Figure 9.** This phase is crucial as it produces a range of solutions that meet the requirements outlined in the matrix. To explain these solutions, we propose a hybrid approach that combines Artificial Intelligence (AI) with the user's natural abilities [111-113]. AI plays a crucial role in the research phase by precisely defining requirements and offering quick solutions. Crafting a precise inquiry is essential for this project. The queries should encapsulate the necessary improvements, such as reducing the operational costs of a city car while considering fuel cost savings, maintenance requirements, and parking. Use clear and concise language, avoiding complex terminology and ornamental language. To improve the text, maintain a logical flow of information by establishing causal connections between statements [114]. Ensure that the text is grammatically correct and free from spelling and punctuation errors. Use the precise subject-specific vocabulary when necessary and avoid biased language. Adhere to style guides and maintain a formal register. During the variant generation phase, AI plays a crucial role in expediting the process by creating solutions that are both parsimonious and novel, while adhering to the stipulated requisites outlined by the R&D team, such as cost constraints and technological requirements. Subsequently, the development team must carefully select the best variant, which marks a crucial phase in the product development trajectory (**Figure 10**). During the initial phase, a comprehensive analysis of the value is conducted, as shown in **Figure 3**. The various options are then carefully examined using a set of design questions to determine their effectiveness and value [115]. The answers to these important questions reveal the usefulness and functionality of the different variants. A binary system is employed to evaluate the variables, assigning positive values to those demonstrating effectiveness and utility, and negative values to those that do not. This approach provides a detailed understanding of the viability and effectiveness of each variant. The variants are comprehensively assessed for their utility and efficacy, leading to invaluable insights [116,117]. The product development trajectory is iteratively refined and enhanced through scrutiny and appraisal. This facilitates the development of design paradigms that meet the requirements of the modern industrial landscape. When selecting the final variant, it is important to carefully consider all options and evaluate their value objectively. This stage is critical in the product development process, as illustrated in **Figure 11**. If multiple options are deemed suitable after value analysis, they should be compared based on how well they meet the customer's overall requirements and their respective weights. Each option is compared to a set of generic customer requirements, and its effectiveness is evaluated based on weighted averages [118]. The most important variable is determined through analytical scrutiny, based on its alignment with customer requirements and weighted averages. The best option is chosen by carefully evaluating different options based on their effectiveness and usefulness. This marks the end of an important phase in the product development process. The selected option is the outcome of a meticulous development process that fulfils customer demands and aims for excellence. This design approach has the potential to transform the industry with its efficiency and practicality. After achieving the initial outcome depicted in **Figure 12**, the subsequent phases involve conducting a market analysis, followed by benchmarking. These critical stages form the foundation for two distinct paths of exploration. The first part examines the what/how matrix, where additional technical solutions are envisioned. This analytical framework objectively evaluates potential technical solutions, promoting the emergence of innovative design paradigms.

	solution 1	solution 2	solution3	solution 4	solution 5	solution 6
praticality						
adaptive steering	based on speed	based on the angle	rear steering	electronic	predictive	
vehicle accessibility	electrically operated doors	air suspension system	simplified opening handles	keyless entry	retractable decks	
enjoyability						
stability and precision in curves	ESC stability control	ESD differential and electronic control	AWD all-wheel drive	Drive mode select	TCS transmission control	sport or adjustable suspension
multipurpose						
adapt the interior space, places felxibility, fluidity of spaces	retractable/ modular	binary	removable	lowered floor / adjustable height	electronic control for internal configuration	
security						
driver	ANVS advanced night vision systems	PMS driver fatigue monitoring systems	IPAS preventive accident protection	ANC indoor noise impact reduction	V2X	advanced adaptive lighting
environment	external airbags/active pedestrian protection	PDS pedestrian detection system	TRS traffic signal recognition	IVS speed limitation in sensitive areas	ACMS animal collision mitigation system	ODS obstacle detection system
small size						
narrow streets, limited parking, parking costs	reduced angle steering	park assist and parking pilot	navigation system with 3D visualization	ABSM Advanced Blind Spot Monitoring	autonomous driving	
usage costs						
fuel costs, maintenance, parking	hybrid/electric motors	start&stop	regenerative breaking	telemetry-based predictive maintenance	low rolling resistance tires	
design						
modern trends	minimalist and clean	sporty and dynamic	retrò/ modern	innovative/ eco-friendly	integrated futuristic	urban-chic

Figure 8: Example of Morphological Matrix

Figure 9: Morphological Matrix with variants

	Does it meet the request of the brief? (styling project of a futuristic car of the type citycar)	Has a high rate of innovation?
Variant 1	+	+
Variant 2	+	-
Variant 3	+	-
Variant 4	+	-
Variant 5	+	+
Variant 6	+	+

Figure 10: Value analysis, variations in the rows and general questions in the columns

REQUREMENTS			VARIANT 2		VARIANT 5		VARIANT 6	
	Importance	Importance %	Score	Weighted score	Score	Weighted score	Score	Weighted score
Ergonomic	22	4,93	8	0,39	7	0,35	9	0,44
Sicurity	29	6,50	9	0,59	8	0,52	9	0,59
Usage costs	27	6,05	7	0,42	8	0,48	7	0,42
Capacity	19	4,26	6	0,26	7	0,30	8	0,34
Multipurpose	30	6,73	8	0,54	9	0,61	7	0,47
Indipendence	18	4,04	7	0,28	8	0,32	7	0,28
Design	27	6,05	9	0,54	8	0,48	9	0,54
Multiplace	10	2,24	6	0,13	7	0,16	8	0,18
Customization	8	1,79	7	0,13	8	0,14	7	0,13
Small size	29	6,50	8	0,52	7	0,46	8	0,52
Resistance	27	6,05	8	0,48	7	0,42	8	0,48
Price	18	4,04	7	0,28	8	0,32	7	0,28
Speed	6	1,35	8	0,11	8	0,11	9	0,12
Ecology	22	4,93	8	0,39	9	0,44	8	0,39
Silence	12	2,69	8	0,22	9	0,24	8	0,22
Digitalization	28	6,28	7	0,44	8	0,50	7	0,44
Autonomy	26	5,83	8	0,47	7	0,41	9	0,52
Maintainability	14	3,14	8	0,25	9	0,28	7	0,22
Praticality	33	7,40	8	0,59	8	0,59	7	0,52
Inclusivity	11	2,47	7	0,17	8	0,20	7	0,17
Entertainment	30	6,73	8	0,54	9	0,61	8	0,54
Total	446	100	160	7,75		7,94		7,83

Figure 11: Final choice of variant

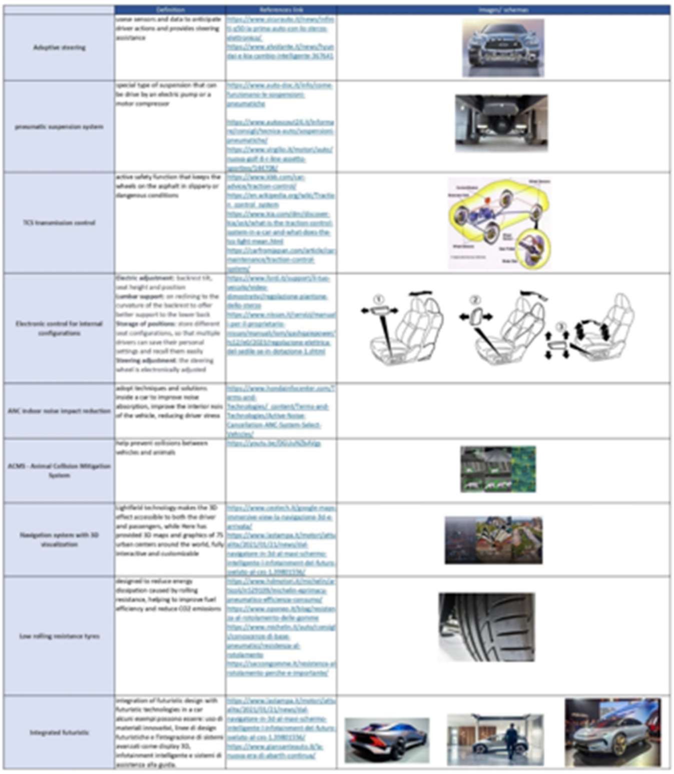

Figure 12: Example of variant with definition, reference link and images/ operating diagrams

TRIZ method: The alternative trajectory pertains to the TRIZ phase, as illustrated in **Figure 13**. In this paradigm, the initial phase involves a comprehensive comparison of all technical parameters, identifying those that exhibit technical contradictions, as shown in **Figure 14**. At this crucial stage, technical parameters are compared and evaluated to identify any inherent contradictions [119]. This analysis sets the stage for innovative design paradigms that surpass conventional limitations and constraints. After completing this phase, the technical parameters are clearly defined and expressed, providing a foundation for their comprehensive analysis. The technical parameters are then rigorously examined using the Altshuller matrix, which includes 39 distinct technical parameters and 40 inventive principles [120]. In this analytical framework, the collaboration between human ingenuity and AI proficiency is of utmost importance. AI algorithms are used to enhance research efforts and expand the foundational knowledge of product developments. The significant findings are then distilled, with emphasis on the most frequent and crucial points. Relevant data for research and development is collected and requires careful curation and filtration. This process is crucial for achieving a well-defined and refined product architecture that aligns with the necessary parameters for a specific industrial product. By curating and filtering data, a design paradigm can emerge that has the potential to revolutionize the industry landscape with its efficacy and utility [121].

Figure 13: TRIZ scheme applied to the method

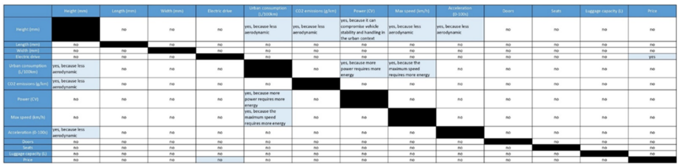

Figure 14: Example of contradictions created starting from the benchmark

Selection matrix: The Selection Matrix is a phase that occurs after obtaining all values from the Conceptual Method (A), What/How Matrix (B), and TRIZ Method (C), as illustrated in Figure 15. During this phase, the values obtained from the What/How Matrix (B) and TRIZ Method (C) are integrated and compared [122]. The rows list the values of B, while the columns list the macro-areas of C. This allows for the integration of technical features from the customer's perspective with the technical solutions derived from TRIZ (**Figure 15**).

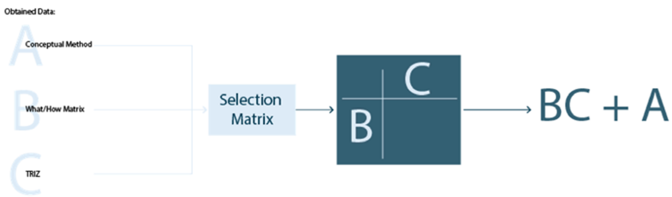

Figure 15: Operation diagram of the Selection Matrix

RESULTS AND DISCUSSION

After obtaining the results, a detailed evaluation is conducted to identify the most significant and recurring parameters for each proposed value. These crucial parameters are carefully assessed and then combined with the solutions obtained from the Conceptual Method. Following this intricate process, the comprehensive matrix is completed with great attention to detail, paving the way for the creation of macro-areas, as illustrated in **Figure 16**. These macro-areas are the primary divisions within the product architecture, where the most common values are incorporated. The analysis and interpolation process sets the stage for the emergence of a refined product architecture, which aims to revolutionize the industrial landscape with its unparalleled effectiveness and utility. The final phase is a crucial step in the iterative process of product development. It represents the attainment of a well-defined product architecture with a robust segmentation framework. By establishing macro-areas, the complex network of interrelated components and subsystems is organized and defined, providing a comprehensive roadmap for subsequent phases of product development. This structured approach improves the efficiency and effectiveness of subsequent endeavours and fosters seamless collaboration and synergy among multidisciplinary teams. By clearly defining the product architecture and establishing distinct macro-areas, innovative design paradigms can be achieved that surpass conventional limitations and constraints. This will usher in a new era of industrial innovation and advancement.

Engine	Integrated magnetic wheel drive, piezoelectric devices, regenerative braking energy recovery systems, solid state battery
Technology	Keys with RFID or connection to apps/ keys NFC, TCS, ANC, AMS, predictive algorithms, navigation with 3D display
Lighting	Uses of LEDs and screens
Design	Interior: modular, overall: futuristic and integrated

Figure 16: Macro areas for definition of the product architecture

CONCLUSION

The IDeS+ method represents a significant advancement in the enhancement of product design research, establishing a more robust structural framework. The integration of the established IDeS methodology with innovative elements such as Artificial Intelligence (AI) aims to effect a paradigm shift in product development methodologies. It is important to note that Artificial Intelligence (AI) serves to augment and reinforce human activities, but does not replace human involvement. Conversely, AI integrates human efforts, enhancing both efficiency and creativity. The objective of the IDeS+ methodology is to reduce product development times and encourage inter-functional collaboration within an organisation, in alignment with the principles of Industry 4.0. Adopting a multidisciplinary approach, IDeS+ transcends traditional boundaries, facilitating comprehensive understanding of complex domains. This holistic approach enables integration of diverse perspectives, thereby fostering innovative and effective solutions. A fundamental tenet of the IDeS+ approach is the precise delineation of task segmentation. This clarity of definition enhances comprehension, facilitates the exchange of knowledge, and encourages collaboration among disparate sectors within a company. The decomposition of complex tasks into more straightforward segments allows for more efficient and effective collaboration between teams. The methodology encourages a culture of continuous improvement and learning, wherein feedback is actively sought and utilized to refine processes and outcomes. One challenge in the study is the introduction of the method to future users, as the procedure is not always straightforward. It is therefore evident that an educational and training component is essential prior to utilization, despite which the results are highly efficacious. A further crucial aspect is the length of the method, which continues to necessitate a considerable investment of time, both in terms of comprehension and implementation. As this method is still in its infancy compared to the previous, well-established one, future improvements will aim to enhance its user-friendliness in terms of comprehension and operational speed. The incorporation of increasingly sophisticated and implemented technologies could potentially yield significantly futuristic outcomes and facilitate the streamlining of the method itself. In conclusion, the IDeS+ method represents an innovative approach with the potential to reshape industrial design and development in the context of ongoing technological advancement and digital transformation. By leveraging AI and fostering a collaborative, cross-functional environment, IDeS+ provides a robust framework for developing cutting-edge products that meet the evolving needs of the market. This methodology not only enhances the product development process but also positions organisations to better navigate the challenges and opportunities presented by the rapidly changing technological landscape.

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CONFLICT OF INTEREST

There are no conflicts of interest.

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