Article

Not peer-reviewed version

Product Development Anxiety: A Contingency Planning Model for Innovative Production Companies

Mihai Dragomir * , Aurel Mihail Țîțu * , Ștefan Bodi , Tiberiu Oșanu , Alexandru Radu

Posted Date: 10 June 2024

doi: 10.20944/preprints202406.0472.v1

Keywords: new product development; contingency planning; Industry 5.0; artificial intelligence

Article

Product Development Anxiety: A Contingency Planning Model for Innovative Production Companies

Mihai Dragomir [1,*], Aurel Mihail Țîțu [2,*], Ștefan Bodi [1], Tiberiu Oșanu [1] and Alexandru Radu [1]

[1] Technical University of Cluj-Napoca, Romania; mihai.dragomir@muri.utcluj.ro (M.D.); stefan.bodi@muri.utcluj.ro (Ș.B.); osanu_tiberiu@yahoo.com (T.O.); radualex994@gmail.com (A.R.)
[2] Lucian Blaga University of Sibiu; mihail.titu@ulbsibiu.ro
* Correspondence: mihai.dragomir@muri.utcluj.ro, mihail.titu@ulbsibiu.ro

Abstract: This paper investigates the possible failure modes of the product development process in production companies that are active in the B2C markets with a focus on household products. Since these cases require short lead times and are difficult to differentiate, in many instances the end result will not be the desired one and could affect profitability for a season or for good. A model of these possibilities is created and an approach to plan contingencies for their solutioning is proposed in the article. The main guideline is to switch from failure probability determination to accepting failure as inevitable and using digital solutions to reinforce the development process in order to offset its impact. For this goal, an Industry 5.0 Abatement Factor (abbreviated IFAF) is introduced in the contingency planning approach, that factors in the evaluation the low cost of digital instruments and the proper mix of Technology, Humans and AI (abbreviated THAI). The new working procedure based on these concepts and their interlinkages is discussed based on specific examples.

Keywords: new product development; contingency planning; Industry 5.0; artificial intelligence

1. Introduction

The manufacturing industry is as important to a country's economy as it is sensitive and complex to change. Production systems have grown more intricate in the past few decades and the resources invested in their operations are significant, in most cases. Although the delocalization and offshoring trend is still present, many countries are investing considerable effort in developing advanced production capabilities that are adapted to the challenges of the present, from resilience to sustainability. The new product development (NPD) process is a key component of this industrial landscape, as it compounds the technological side with the human centered perspective, in which creativity is called upon to develop ever new and ever successful solutions to keep the companies competitive on the market.

As pressures intensify, the talk of failure becomes taboo, and the risk management process is seen as a panacea for solving any situation. However, despite the best practices and the best people, NPD sometimes fails and sends the production company into deep anxiety about its future survival. In the current paper, the authors propose and test a different approach to managing risks in this process, not by trying to avoid them, but rather embrace them as an inevitable part of a firm's life and develop contingency mechanisms to handle them "online", as soon they are manifested, making use of the best new technologies and human resources approaches.

By changing the paradigm, it is possible to make valuable use of hidden creativity mechanisms and to facilitate the achievement of more significant and disruptive innovations. Even if the current technologies are possibly not sufficient to mitigate all possible dangers, in the long run, it is possible to uncover a large value-added potential that will remarkably change the return on investment

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 June 2024 doi:10.20944/preprints202406.0472.v1

associated with NPD. The framework proposed in this article makes use of AI instruments at its core, but it is similarly rooted in aspects related to failure management and production system resilience, thus enabling a robust method for overcoming the above-mentioned anxiety and finding valuable solutions that can translate into products that are able to reach higher maturity levels in the design phase and, consequently, are more successful on the market..

The conceptual development is based on the existing literature and over 20 years of experience in the field of production engineering, while the model proposed is founded on a conceptual framework and detailed through an application procedure. Also, the validation of the development is realized using interviews and industrial cases from the innovation and entrepreneurship ecosystem that the authors collaborate with. The discussion included in the paper touches upon the advantages and disadvantages of using such an approach and makes a future projection about the possibilities to further evolve the methodology as technical capabilities become more advanced and the access to them becomes cheaper and easier.

2. Materials and Methods

The current study is based on a straightforward, but robust research methodology that makes use of the current state of the art, as well as the industrial experience of the authors and their working ecosystem for product development and manufacturing (see Figure 1 below).

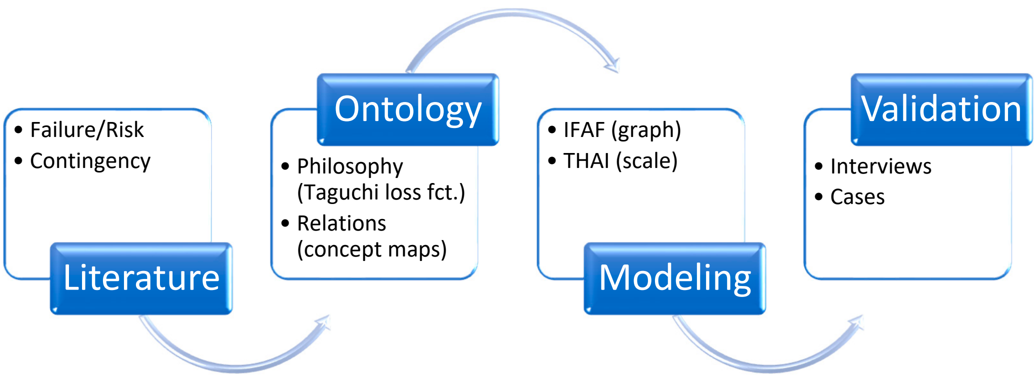


Figure 1. Research methodology for studying NPD failures and developing improved contingency plans.

In the first step of the undertaking, a thorough literature review has been performed using as a frame of reference the past 5 years (2020-2024) and applying the MEAL plan, which consists of the following tasks for each conceptual area: Main idea – Evidence – Analysis – Link. Three main scientific databases have been used, namely Science Direct, Google Scholar and Web of Science to collect and analyze a number of 37 research papers responding to the keywords: "product development failure", "product development risk" and "product development contingency" and ascribed to the area of generic industrial and household products that can be manufactured by production facilities (excluding thus complex – like medical devices – or specific products – like foodstuff). The second step of the methodology has been dedicated to creating an adequate basic ontology to address the identified and encountered issues in the area of identifying, treating and avoiding unwanted outcomes of the product development process. The basic philosophy proposed by the authors stems from the concept of Loss function proposed by Genichi Taguchi, which inverts the positive impact into a minimally detrimental outcome. As Taguchi considers quality to be "minimal loss to society", in this case the authors consider successful NPD as the minimal number of failures possible, thus considering that current technological instruments such as CAE, AI and robotics are developed enough to treat any and all risks, without the need for complex identification, categorization and assessment procedures. Also, in this phase, concept maps are being used to establish the main connections and relationships between associated topics, to be used in the next phase to model NPD risks. In the third step, the authors propose the introduction of two related notions, based on brainstorming and interviews with industry representatives. The first one is called the industry 5.0 Abatement Factor (IFAF) and complements the two-dimensional risk analysis in terms of severity and probability with the capability of Industry 5.0 related technologies to solve any issues, thus turning the assessment space into a three dimensional one where recognition is more important than evaluation and most, if not all, risks can be mitigated on the go. Should any risks persist, it would be advisable to address them through alternative instruments outside of the production system (e.g., change management, organizational culture, insurance, etc.). Furthermore, in order to define the IFAF, a new classification of available tools is introduced, and proper scale of understanding is proposed using the THAI acronym: Technology, Humans & Artificial Intelligence. Finally, the theoretically proposed approach is validated using a series of interviews and case studies from various industries, which are summed up in the final chapter of the paper. A discussion on the strengths and weaknesses of the framework is included and elements to further develop the study in the future are proposed.

3. Results

3.1. Literature Review

Thoroughly analyzing the fields of NPD and contingency planning is a complex endeavor, whose results are presented below to gauge the context in which the research work was carried out. Contingency is a complex concept, with philosophical ramifications [1], and a myriad possible complex implementations and applications [2], from business development to emergency management and cybersecurity. Its accomplishment in the area of manufacturing and, especially, the NPD process draws on contributions from psychology, engineering and quality management, thus making it a complex endeavor, well-suited for the use of advanced technologies as included in the Industry 5.0 concept. As mentioned by one of the consulted studies [3], NPD is a structured and coherent form in which the entrepreneurial orientation of the company (its owners and employees) is manifested through the adequate business model, thus underlying the need to think about success and failure in a flexible manner, that could interconnect human intuition and machine reasoning. It can range in target from concrete physical products (either industrial or for consumers) to more nuanced interface and interaction design *[4]*, and even to creating entire virtual worlds, such is the case for gaming industry.

The results of the PDMA 2021 global survey [5] show that the best performance in NPD is achieved by companies oriented towards new markets and new technologies, that have a mature long-term risk culture and that are willing to invest considerably in this process. Based on a sample of 436 manufacturing companies in Canada, the study of [6] reinforces the importance of learning valuable lessons after the often encountered and mostly difficult failure of innovation projects. The authors underline the transformative power of failure and propose various interventions to strengthen and deploy it to its fullest extent, through employee involvement, an adequate risk culture and conscious proactive management. Literature shows an important link between contingency and learning from one's own mistakes, as underlined by [7], which finds that team dynamics and cohesiveness is the most important factor in fostering learning, while project complexity and various sources of disturbances and uncertainty have a negative effect. Under these conditions, the authors recommend a higher tolerance for ambiguity, doubled by adaptability within the organization. Another research [8], which surveyed a number of 237 project managers that lead advanced NPD projects, reached the conclusion that simple learning from failure is not sufficient. Instead, the authors recommend developing the long-term experience of managers dealing with NPD failures, increasing their error handling skills and separating the failure moment and the learning phase by a considerable time period.

The authors of *[9] o*utline the role of product development failure in business strategy with application in the pharmaceutical industry, which is known for its complex and highly regulated product development. The study shows that companies experiencing failure are more likely to seek contingency solutions in the form of business alliances that have not been previously explored. The authors of [10] studied the impact of using big data in the South African mining industry, using a sample of 520 questionnaire answers, identifying a strong relationship between supply chain performance and green product development. This is, however, contingent on increasing the skill levels of employees involved in this process, as is the case in the manufacturing sector, too. The ability to learn and integrate knowledge quickly in the organization is just as important as the ability to unlearn swiftly and thoroughly in order to foster new waves of innovation and to increase its originality, as revealed in a study addressing responses from 242 Chinese firms *[11].*

While analyzing 249 Chinese companies, the authors of [12], while analyzing the use of big data analytics concerning the customers in the NPD process, have found that exploitative learning from customers must be balanced by high levels of market understanding to achieve the desired results, while also diminishing the impact of external technological changes. Also, in preparation for the successful use of customer analytics, the firms should be able to develop their own internal knowledge integration approaches.

For the past 50 years, the NPD field has been dominated by well-structured methodologies, with clear techniques to implement them and many examples of improvement methodologies applied to them [13]. However, in the article [14], the researchers identify a number of limitations of approaches like Kansei Engineering, Kano Model, Quality Function Deployment and Theory of Inventive Problem-Solving related to subjectivity, rigidity and low communicability, while the new, more unstructured AI-based tools bring to the process a larger requirements base, an ability to work with dynamic data and advanced representation capabilities. The authors of [15] review the possibilities of applying various AI approaches in design engineering endeavors and arrive at a complex landscape that requires guidelines and procedures for adequate selection of the tools. At the same time, the team publishing article [16] identifies, based on literature, applications of AI multiple forms across all the stages of the product life cycle, from initial ideation to monitoring and improvement during use. These are important factors in considering the automation of risk management proposed in the current paper, as it indicates that at the moment the main downside is not the absence of the proper instruments, but rather the difficulty in using them, either due to too many options or insufficient proficiency.

The article [17] performs a complex analysis of 364 articles about the use of AI in corporate innovation, covering delicate topics such as open innovation, market performance and business models, defining a new comprehensive framework. In this perspective, AI becomes critical to maintaining the competitive advantage of companies, and AI management structure is recommended to coordinate the internal process of its technological diffusion. Cooper [18] performs a meta-analysis of published research in the field of NPD using AI and concludes that there are considerable benefits related to this issue, from reducing time to market, to enhancing product functionality and improving customer engagement. The article urges the immediate integration of AI technologies in the NPD process, as a game-changing tool. However, a study conducted with 459 participants [19] showed that there is a significant human bias in evaluating the creative performances of AI systems, especially for product with low novelty and high usefulness, and when the persons assigning scores perceived their jobs to be threatened by AI. This leaves open at the moment an important niche for AI to contribute to the innovative products in ways that can command a market premium. Lee [20] explores a more subtle connection between using AI in NPD and social sustainability. The analysis the author performs encompasses 52 publications and concludes that there is a positive effect upon the needs of the society of using AI, and also big data, in creating new products, and that the diversity of social impacts of product development is increasing over time.

According to [21], when using AI, it is possible to address in the product development and design stages a large number of variable (significantly more than when relying exclusively on humans) responding in a better way to the needs and requirements of the customers. The authors of the study point out that thus will lead to products that are more human-centered and can be manufactured in more human-centered processes. Ultimately, this seems paradoxical, but comes to reinforce the idea that AI has the capability to augment human thinking for the benefit of other humans, if properly employed. Other researchers [22] consider that ChatGPT alone has a good potential to support design innovation, but also related functions such as training and education, and knowledge management, which may influence the output of an NPD process. They also identify its limitations in terms of accuracy, limited experience and possible "AI hallucinations" determined by its prediction algorithms. Some authors [23] emphasize the strengths of both sides in creating hybrid innovation teams, which can deliver better results using established innovation frameworks. Their paper discusses also the more delicate issues of trust between humans and AI and the possible unforeseen outcomes of this collaboration.

In parallel with using AI as a tool, NPD processes are asked nowadays to deliver results in terms of sustainability and materials employed [24], to answer the important threats to the natural environment. In the study [25], the authors approach the topic of NPD for lowering the carbon footprint, through a customized Design for X methodology. Their conclusion is that by implementing the 30 design principles validated through the Delphi method by a panel of 14 experts, there is a high change to reduce carbon emissions, at the same time demonstrating the flexibility of the NPD process in the face of new and complex challenges. In another work [26], the NPD process is conceptualized through the lens of the business strategy, as a key component of achieving competitiveness from the start-up phase, and the recommendation of the authors also focus considerably on sustainability, including advanced materials, enhanced recyclability and smart features for the studied furniture products.

According to [27], ensuring the success of NPD is encountered at the intersection of a multitude of internal and external factors, from organizational governance to team dynamics and technological trends. In this perspective, it stands to reason that risks ca be generated from a variety of causes, which can never be completely analyzed and even, if they are, they will soon change, therefore the risk management process is never complete.

In article [28], a number of 61 articles regarding risk management in product development are analyzed and connected within an overall understanding of the topic, which is of critical importance to the manufacturing sector. The findings describe an eclectic nature of the field, with many aspects to consider and a wide array of techniques to use, but at the same time based on underlying and knowledgeable process. The authors of the paper [29] develop an interesting conclusion regarding the possibility of the NPD process ending in failure, which is actually the most common outcome, as they find that companies experiencing both success and misfires are more likely to terminate risky projects early. In our view, this is a consequence of the need to free up the time and creativity of people sooner for more auspicious projects, rather than engage in endless review cycles.

Another aspect to consider, according to [30] is the shifting dynamics and perceptions of risk, which tend to vary with time and the organizational structure. As the authors of the study uncovered, as companies mature there is a tendency to become more risk averse and switch to time tested solutions or low risk innovations, but this complacency can be dangerous in a very competitive marketplace. Introducing AI into the risk management process has the advantage of being immune to psychological factors and the preparation for contingency situations can become more unbiased.

3.2. Ontology Development

The approach presented in this paper is based on a paradigm shift concerning the conceptualization and operationalization of the concept of risk in manufacturing enterprises. As detailed in section 3.1 above, risk is approached as a probable negative event that might affect the expected course of events in the design and production phases of industrial and consumer goods. The authors propose that risk determination and classification, that usually follows risk identification, can be significantly simplified by adopting the philosophy of the Taguchi Loss Function [31], namely that in the product development phase risk will be manifested no matter what approach to mitigate it is adopted, thus the best course of action is to aim for a minimal amount of disruption. This relies on two complementary approaches: risk identification should be performed as detailed and extensive as possible and modern, AI-based and, if possible, automated instruments to

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 June 2024 doi:10.20944/preprints202406.0472.v1

diminish them as they occur should be implemented in all situations. By adopting this line of thinking, considerable human resources can be freed, and their contribution can be oriented towards increased creativity, where AI is far less adequate to provide solutions. At the same time, other technological support instruments like visualization and big data analytics, together with the intuition and know-how of the involved personnel, can further contribute to the a priori limitation of various types of risks. This means that the occurrence probability will not constitute a concern anymore (as it will be considered to be 100% in all cases) but will be substituted with the capability of the mentioned tools to limit the severity of the impact for all risks.

A considerable amount of effort and anxiety in the NPD process is generated by the uncertainty associated with the occurrence of risk and their transformation from potential events into real problems that must be addressed. The main goal of changing the way in which risks are treated is to be able to redirect the capabilities used for managing this potentiality towards the actual work that must be performed by product developers and designers. Even if some risks are overlooked or improperly addressed by the technological components, which is to be expected in the beginning, still the value added of freeing this time and creative energy could offset the drawbacks.

An important aspect in creating a new risk ontology for the NPD process in production companies is to rethink the relationship between the main concepts involved in the risk management process, including hazards, occurrence probability, severity of impact, detectability of issues, mitigation measures, documentation and learning & actualization, required skills, monitoring and decision making, follow-up actions, management instruments, technological tools, AI powered tools, etc. A proposal for this modified network of relations is presented in Figure 2 below, using the concept map approach implemented in the yEd Graph editor software using the Entity relationship graphic formalism. While elaborating this chart, the methodological base of the international risk management standard ISO 31000:2018 [32], as well as some well-known qualitative risk methods like FMEA (Failure Modes and Effects Analysis) and FTA (Fault Tree Analysis) have been observed to maintain compatibility with existing frameworks.

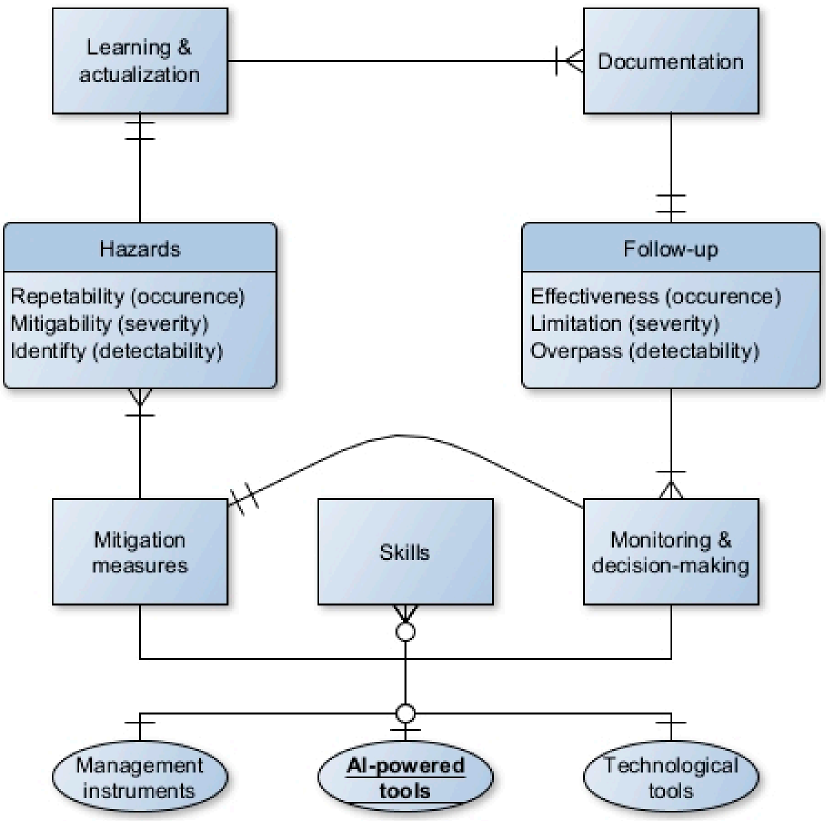


Figure 2. Concept map for the modified risk management approach.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 June 2024 doi:10.20944/preprints202406.0472.v1

As can be noticed, the AI-powered tools will form the center of the new approach, requiring zero human implication to transform the hazards into quasi-automated follow-up measures that remove the risk of failure in new product development. Moreover, this also removes the anxiety of failure and makes available the human capabilities for innovation, while technology is responsible for contingency planning.

3.3. Risk Process Modeling

In the following stage of investigation, the risk management process and its transformation according to the concept map has been modeled. For this to be achieved, the notions of Industry 5.0 Abatement Factor (IFAF) and Technology-Humans-and-AI instruments (THAI) will be made explicit.

The IFAF represents the mathematical and graphical transformation of qualitative risk methods from the impact-probability two-dimensional space to a three-dimensional space that can verify the capability of inline mitigated risk to be overlooked in the NPD phase. All technological instruments, human resource skills and AI-powered tools that can be deployed without additional analysis or oversight are included in this concept that modifies the classical risk matrix, which has intervention zones maker with colors ranging from green to black into a spatial representation, showcasing the limited and acceptable risks in the new approach [33]. The IFAF will have a value between 0 and 1 depending on the mix of measures that are used to remove and diminish the risks (if the value is 0 then the measures are completely successful and if the value is 1 then the measures are ineffective).

In the following, an example of utilization of the new approach is provided. In Table 1, a classical situation in which a group of 3 risks is analyzed on the probability and severity dimensions, with their product and resulting intervention zone being calculated and assimilated to a usual form of recommended action, as based on “common knowledge” and standardized requirements.

Table 1. Classical risk approach in NPD with two-dimensional assessment.

Risk identification	**Probability (scale 1-5)**	**Severity (scale 1-5)**	**Product (PxS) / Interv. zone**	**Recommended actions**
Risk 1	3	5	15 / Red	Emergency
Risk 2	2	2	4 / Yellow	Delay/Ignore
Risk 3	1	4	4 / Orange	Address

Further on, in Table 2, the IFAF is introduced as a third factor in the product, modifying the intervention zone into “green” and thus acceptable risks in all exemplified cases. As the IFAF is between 0 and 1, it will reduce the impact of the overall score and will also modify the position in the risk visualization stage.

Table 2. Enhanced risk approach in NPD by using IFAF as modifier.

Risk identification	**Probability (scale 1-5)**	**Severity (scale 1-5)**	**IFAF (scale 1-5)**	**Product (PxSxI) / Interv. zone**
Risk 1	3	5	0.2	3.0 / Yellow
Risk 2	2	2	0.5	2.0 / Yellow
Risk 3	1	4	0.3	1.2 / Yellow

In Figure 3, the position of the three risks is plotted in the risk matrix that use the two evaluation directions as a modeling space. Depending on the color of the risk zone, the recommended actions can be conceived to diminish or mitigate the risk, depending on the intervention being upon the process/probability or the impact/severity scale.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 June 2024 doi:10.20944/preprints202406.0472.v1

P / S	1	2	3	4	5
5					
4					
3					Risk 1
2		Risk 2			
1				Risk 3	

Figure 3. Visualization of the classical risk approach using a risk matrix.

By adding a new evaluation dimension, related to the technologies, human factors and AI instruments that can change risk perception or solution, the matrix becomes a three-dimensional space, where the three studied risk of the NPD process have considerably lower values and significantly changed position in the risk space (Figure 4). Due to this modification, they can all now be considered tolerable risks, which can be tackled without prior time and resources consumed for their classification and assessment.

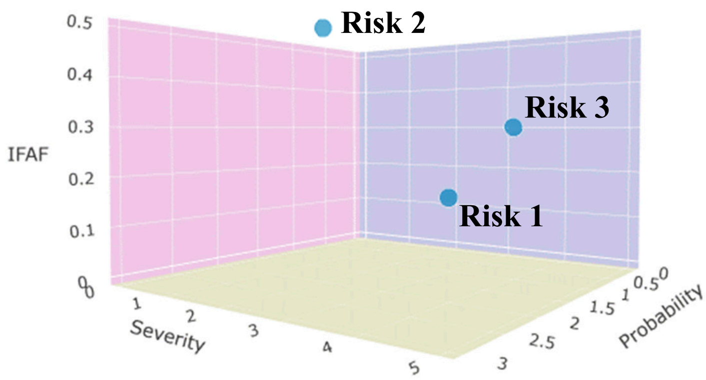


Figure 4. Visualization of the modified risk space using 3D Chart Maker [34].

From a mathematical point of view, the changes are simple, as the product (risk score), goes from two factors to three factors, as can be seen in Tables 1-2 and Figure 3-4. The method is more impactful on the graphical dimension, as the risk matrix in Figure 3 becomes a 3D graph in Figure 4 with the z-scale allocated to the IFAF. For the values of the IFAF, the following approach is proposed that considers possible course of action when reducing probability (more common) and severity (less common) of hazards:

The make-up of the IFAF and its value is highly dependent on the related concept of THAI that is operationalized as a mind-map of the most common elements encountered for each of its categories created also with yEd (Figure 5). This presentation is a limited snapshot of the possible database of elements that fall under this definition, having the capability to influence risk treatment in significant ways.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 June 2024 doi:10.20944/preprints202406.0472.v1

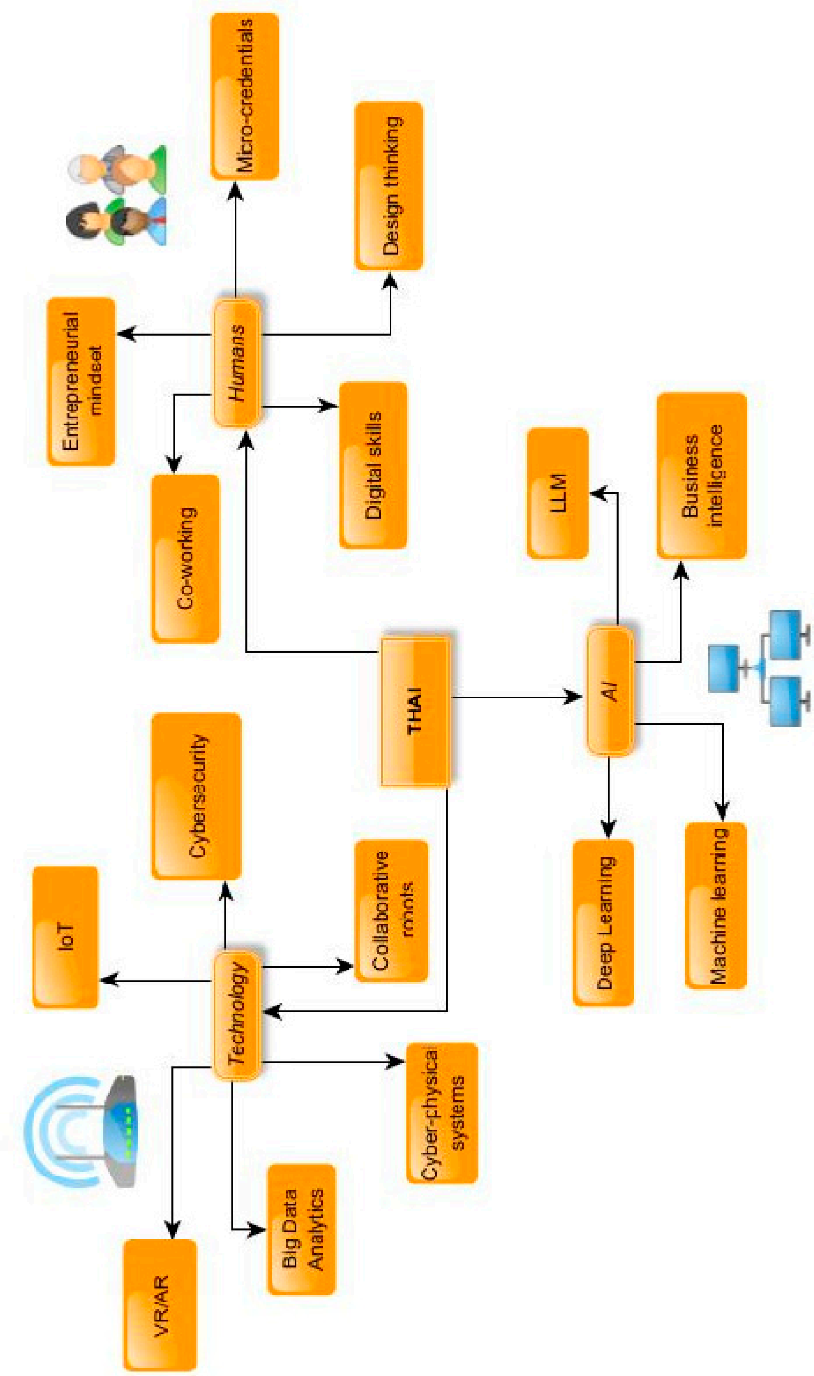


Figure 5. THAI concept definition by mind-mapping.

The combined use of IFAF and THAI is a qualitative intervention in the risk management and contingency planning process, and it is not meant to be performed continually, but rather to check periodically for adherence to its principles, in a historical perspective. The evaluation of the THAI factors should take place holistically, based on the experience of the company and the input of experts in the field of Industry 5.0 and AI, to determine the value of the IFAF on the scale presented in Table 4 and recalculate certain risks beyond the classical approach. It is possible, in the early stages of deploying these technologies that will continue to impact the well-known probability and severity scores, for some risk to be overlooked and produce unwanted consequences, but with time this should diminish to the point of disappearing and will be compensated by an increased productivity.

Table 4. IFAF proposed evaluation scale depending on the impact of THAI elements.

IFAF value	IFAF descriptor
0.0	Risk is completely removed
0.1	Some commonly unnoticeable risk elements remain
0.2	Some commonly noticeable risk elements remain
0.3	Risk probability considerably reduced; severity considerably reduced
0.4	Risk probability considerably reduced; severity slightly reduced
0.5	Risk probability is halved, severity is indifferent
0.6	Risk probability slightly reduced; severity slightly reduced
0.7	Risk probability slightly reduced; severity is unaffected
0.8	Some commonly noticeable risk elements are removed
0.9	Some commonly unnoticeable risk elements are removed
1.0	Risk is completely unaffected

3.4. New Risk Approach Validation

The validation of the proposed risk approach was carried out in two steps, the first one including a semi-open interview with 8 company representatives and the second one in the form of a case study treating 2 different situations in the NPD process. This is a qualitative interpretation of the needed validation and should be followed by a more comprehensive quantitative evaluation.

The interviews took place in April and May 2024 and involved companies from the area of Cluj-Napoca in Romania, involved in automotive, machinery and furniture manufacturing, under the aegis of an important "Interreg Danube Region" project called Circular Innovation Hub - CI-Hub (https://interreg-danube.eu/projects/ci-hub), supporting SMEs to improve their innovation capabilities and adoption of green and digital technologies in their NPD and manufacturing processes. A summary of the guidelines used for the interviews and the answers received is presented in Table 5 below.

Table 5. IFAF proposed evaluation scale depending on the impact of THAI elements.

No.	Direction of questioning / example questions	Main answers / resulting discussion
1	Role, impact and complexity of the NPD process - what types of products do you develop? - what is their use by the customers? - what is the lifecycle of your products? - what regulations are impacting NPD? - how is the development process structured?	- NPD process is mature and well understood - results are expected to be price competitive - sustainability requirements must be addressed
2	Effort and resources committed to risk managem. - what procedures are employed for risk manag.? - what measures/consequences are implemented? - how do the customers check your work/results? - what standardized methods are employed?	- risk management is performed mostly voluntary - classic approaches to risk manag. dominate the process and results' analysis
3	Inefficiencies and redundancies of risk managem. - how often the process is deficient/insufficient? - what number of person-hours does it consume? - which is the impact of external requirements? - did you detect a learning curve in the firm?	- risk management is labor and time intensive - some companies have dedicated personnel - repetition is common

 doi:10.20944/preprints202406.0472.v1

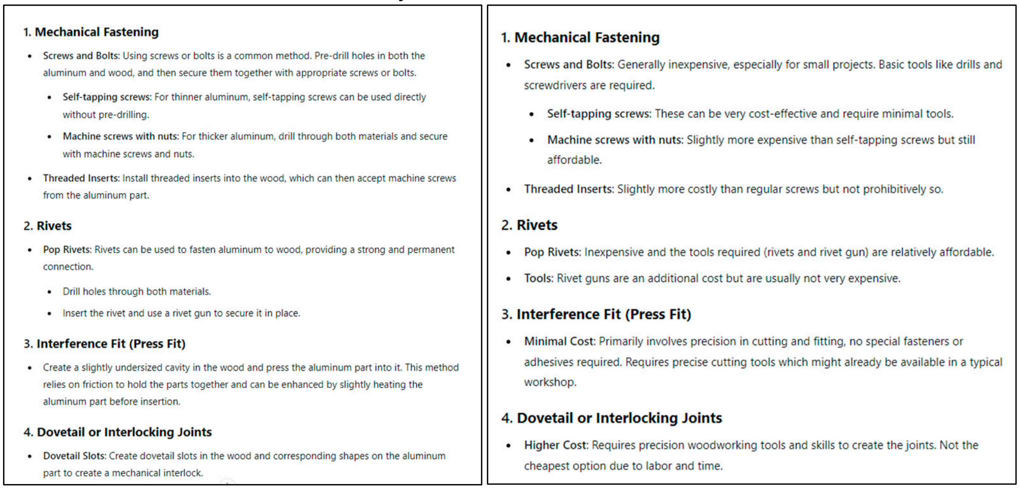
4	Main Industry 4.0 to 5.0 technologies adopted - what advanced technologies do you employ? - what is their yield and return-on-investment? - are all capabilities fully utilized by NPD?	- IoT, (collaborative) robotics and machine vision are most common - NPD integration is weak
5	Role and involvement of personnel in NPD - what professional roles are involved in NPD? - what type of expertise/competence is sought? - what is the level of autonomy of the staff?	- almost exclusively engineers are involved in NPD - usual mechanical/ind. engineering background
6	Employment of AI instruments in NPD - what AI instruments are used in NPD stages? - is AI work supplemented/corrected by humans? - is AI used for feedback from the production line?	- GPT tools are used to investigate ideas - media generation is used for visualization
7	Costs related to the possible new risk model - can you estimate the release time/creativity? - can you compare costs vs. benefits? - do you need additional technologies or training?	- at least 1 person/company could be relieved - Big Data Analytics is mandatory for NPD
8	Acceptance of the possible new risk model - is the new approach understood fully? - does the personnel accept its use? - what are the main challenges for adoption?	- full scale studies should demonstrate viability - personnel is interested, management is uneasy

Since this was carried out in a semi-structured manner, not all results are directly related and comparable to each other, but an important structuring of the undertaking can be achieved for future use. Elements of the transition from Industry 4.0 technologies to Industry 5.0 elements are detectable and there is at the moment no consensus on the actual benefits or feasibility in terms of risk management for the NPD process. The potential of the proposed approach is recognized and each element of it is accepted, but full integration is still difficult to accept. For this reason, the authors of the paper have also proposed a qualitative case study, using 2 common situations that each of these companies have faced in their previous relations with their customers.

In order to test the proposed approach, the authors have collaborated with a smart furniture producing company, which has been working on developing a new product idea. This is focused on creating a smart desk lamp with an innovative design and digital features. The body of the lamp has a new creative shape, appreciated by potential customers and makes use of a small quantity of solid wood with aluminum insertions to create an attractive combination. From a functional point of view, the lamp has integrated a capacitive touch pad for increasing the luminosity of its LED panel in 4 steps and an internet connected weather station that relates the main information about environmental conditions through a wireless outdoor sensor (temperature, humidity, forecast) beside calendar, clock, alarms and reminders. The company manufactures the bi-material body and outfits the LED, touch pad and weather station into the final product. The classical risk management approach has shown that the assembly of the aluminum insertions into the milled wood body presents a significant threat to the overall functionality of the product and could also influence the main selling point - a retro-futuristic design that host smart functions while providing the needed elegance for an office space.

Assembly issues have been rated at 4 on the probability scale and 3 on the severity scale (risk score is 12), thus falling into the red zone and requiring significant mitigation actions. The selling issue has been assessed as 2 on the probability scale and 5 on the severity scale (risk score is 10), also in the red zone. Since both of them are related, the decision that the company is weighing is to replace the aluminum insertions with tampographic imitations made with a metallic powder-based paint that imitates the insertions and must be performed by an outsourcing company, specialized in this process.

We present below, two excerpts from the applied tools (Figures 6 and 7) that can be used online and inline as the problems arise to provide robust solutions and continue the NPD process up to industrialization and future marketability.

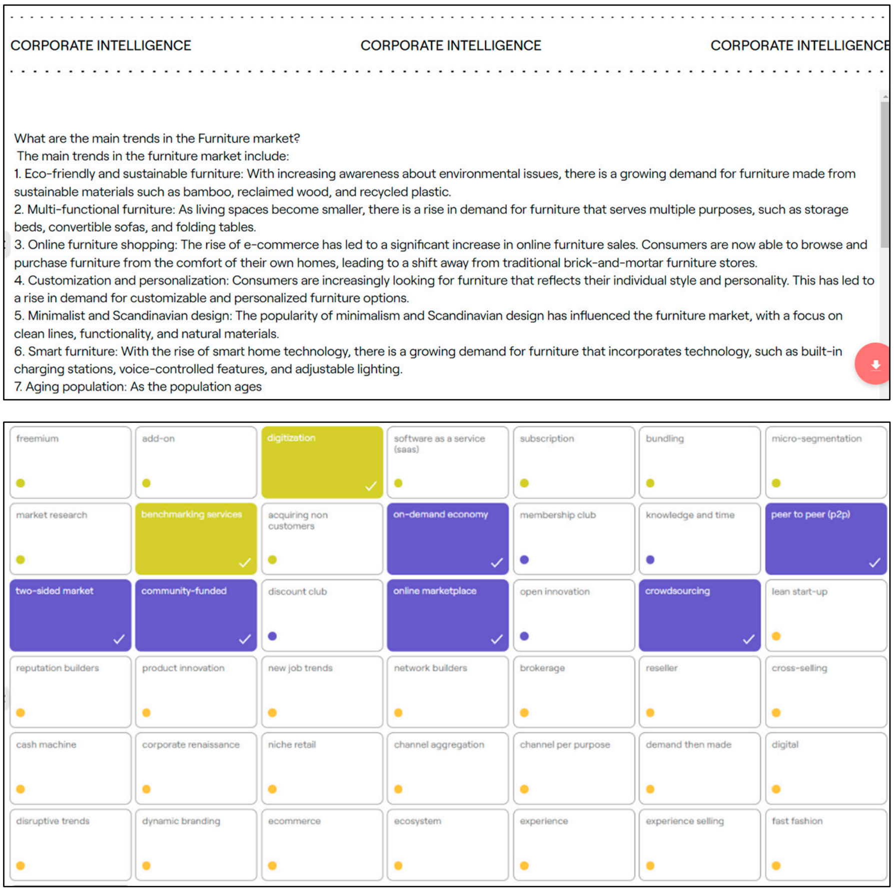


1. **Mechanical Fastening**
   - **Screws and Bolts:** Using screws or bolts is a common method. Pre-drill holes in both the aluminum and wood, and then secure them together with appropriate screws or bolts.
     - **Self-tapping screws:** For thinner aluminum, self-tapping screws can be used directly without pre-drilling.
     - **Machine screws with nuts:** For thicker aluminum, drill through both materials and secure with machine screws and nuts.
   - **Threaded Inserts:** Install threaded inserts into the wood, which can then accept machine screws from the aluminum part.
2. **Rivets**
   - **Pop Rivets:** Rivets can be used to fasten aluminum to wood, providing a strong and permanent connection.
     - Drill holes through both materials.
     - Insert the rivet and use a rivet gun to secure it in place.
3. **Interference Fit (Press Fit)**
   - Create a slightly undersized cavity in the wood and press the aluminum part into it. This method relies on friction to hold the parts together and can be enhanced by slightly heating the aluminum part before insertion.
4. **Dovetail or Interlocking Joints**
   - **Dovetail Slots:** Create dovetail slots in the wood and corresponding shapes on the aluminum part to create a mechanical interlock.

1. **Mechanical Fastening**
   - **Screws and Bolts:** Generally inexpensive, especially for small projects. Basic tools like drills and screwdrivers are required.
     - **Self-tapping screws:** These can be very cost-effective and require minimal tools.
     - **Machine screws with nuts:** Slightly more expensive than self-tapping screws but still affordable.
   - **Threaded Inserts:** Slightly more costly than regular screws but not prohibitively so.
2. **Rivets**
   - **Pop Rivets:** Inexpensive and the tools required (rivets and rivet gun) are relatively affordable.
   - **Tools:** Rivet guns are an additional cost but are usually not very expensive.
3. **Interference Fit (Press Fit)**
   - **Minimal Cost:** Primarily involves precision in cutting and fitting, no special fasteners or adhesives required. Requires precise cutting tools which might already be available in a typical workshop.
4. **Dovetail or Interlocking Joints**
   - **Higher Cost:** Requires precision woodworking tools and skills to create the joints. Not the cheapest option due to labor and time.

Figure 6. Open AI ChatGPT recommending assembly techniques and analyzing their cost.

In the modified risk approach, the company has employed large language models in the form of Open AI's ChatGPT (https://chat.openai.com/) to discover alternative assembly techniques and Vizologi business intelligence (https://vizologi.com/) to refine the selling process based on the unique feature envisioned. Considering the use of these two AI instruments in conjunction with modern CNC equipment and highly trained personnel, as part of the THAI evaluation, the IFAF score has been set at 0.4 which would transform the initial risk score assessments into 4.8 and 4.0, respectively, making them thus manageable online.



CORPORATE INTELLIGENCE CORPORATE INTELLIGENCE CORPORATE INTELLIGENCE

What are the main trends in the Furniture market?
The main trends in the furniture market include:
1. Eco-friendly and sustainable furniture: With increasing awareness about environmental issues, there is a growing demand for furniture made from sustainable materials such as bamboo, reclaimed wood, and recycled plastic.
2. Multi-functional furniture: As living spaces become smaller, there is a rise in demand for furniture that serves multiple purposes, such as storage beds, convertible sofas, and folding tables.
3. Online furniture shopping: The rise of e-commerce has led to a significant increase in online furniture sales. Consumers are now able to browse and purchase furniture from the comfort of their own homes, leading to a shift away from traditional brick-and-mortar furniture stores.
4. Customization and personalization: Consumers are increasingly looking for furniture that reflects their individual style and personality. This has led to a rise in demand for customizable and personalized furniture options.
5. Minimalist and Scandinavian design: The popularity of minimalism and Scandinavian design has influenced the furniture market, with a focus on clean lines, functionality, and natural materials.
6. Smart furniture: With the rise of smart home technology, there is a growing demand for furniture that incorporates technology, such as built-in charging stations, voice-controlled features, and adjustable lighting.
7. Aging population: As the population ages

Figure 7. Vizologi analyses regarding competition and the business model.

The THAI solutions enable fast decision making when and if the problem arises, limiting the number of resources spent on forecasting risk and enabling the department head to make better use of the time of its members.

4. Discussion and Conclusions

The current work is focused on proposing a simpler approach to risk management in the NPD process, making extensive use of advanced technology, AI and trained people. This is meant to serve as a more direct route to achieving fast results in manufacturing industries, without cumbersome documentation and audit processes, internalizing the fact that the solutions available most likely solve any possible negative events in almost real time. The definitions and evaluations procedures proposed here have been discussed with company representatives from the production sector in semi-structured interviews, revealing enthusiasm on the part of the design engineers and caution and apprehensiveness on the part of management. Still, in both cases, they seem to welcome new solutions to solve the current NPD anxieties related to the technical issues themselves, but also to the extensive risk management approaches. By qualitatively evaluating the THAI factors on the provided map (and its future extensions) and relating the established level to a quantitative score on the IFAF scale, the risk scores change drastically, and the contingency measures needed to be implemented fall mostly in the "recommended" section.

The situation encountered during the interview stage is revealing to a considerable extent to the efforts needed to popularize and clarify the capabilities of new technologies for product design and manufacturing, in the proposed form or other similar ones. Also, the case studies performed show that the use of common or more specialized AI instruments can lead to significantly different decisions compared to the classical risk approaches, allowing the design team to maintain their design intent, without making important changes due to manufacturing constraints.

It is advisable to consider the limitations of the current proposal, which conceptualizes a more philosophical approach to risk and seeks more validation in the various industries and various situations, both from a quantitative and qualitative perspective. Moreover, since the components of the approach at the moment are rather independent and scattered, a more cohesive integration into future risk management standards, procedures and guidelines will serve to make the work of product developers easier. In this respect, however, there is no significant difference to the classical methods, which have also required a long time to become standardized and systematic.

Author Contributions: Conceptualization, M.D. and A.M.T.; Formal analysis, M.D., A.M.T. and S.B.; Investigation, M.D., T.O. and A.R.; Methodology, M.D., A.M.T. and S.B.; Software, S.B., T.O. and A.R.; Supervision, M.D.; Validation, A.M.T.; Visualization, T.O. and A.R.; Writing—original draft, all authors; Writing—review and editing, all authors. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data is contained within the article.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. S. Hollis, "Contingency, crises & disasters: Broadening the research agenda," *Journal of Contingencies and Crises Management,* vol. 32, no. 1, p. e12538, 2024.
2. N. Rhinehart, J. He, C. Packer, M. A. Wright, R. McAllister, J. E. Gonzalez and S. Levine, "Contingencies from Observations: Tractable Contingency Planning with Learned Behavior Models," in *2021 IEEE International Conference on Robotics and Automation (ICRA 2021)*, Xi'an, China.

3. J. L. Ferreras-Méndez, J. Olmos-Peñuela, A. Salas-Vallina and J. Alegre, "Entrepreneurial orientation and new product development performance in SMEs: The mediating role of business model innovation," *Technovation,* vol. 108, p. 102325, 2021.
4. M. Fulea, M. Kis, D. Blagu and B. Mocan, "Artifact-based approach to improve internal process quality using interaction design principles," *Acta Technica Napocensis. Series: Applied Mathematics, Mechanics, and Engineering,* vol. 64, no. Specia Issue IV, pp. 697-706, 2021.
5. M. P. Knudsen, M. von Zedtwitz, A. Griffin and G. Barczak, "Best practices in new product development and innovation: Results from PDMA's 2021 global survey," *Journal of Product Innovation Management,* vol. 40, pp. 257-275, 2023.
6. K. Rhaiem and N. Halilem, "The worst is not to fail, but to fail to learn from failure: A multi-method empirical validation of learning from innovation failure," *Technological Forecasting & Social Change,* vol. 190, p. 122427, 2023.
7. M. Balzano and G. Marzi, "Exploring the pathways of learning from project failure and success in new product development teams," *Technovation,* vol. 128, p. 102878, 2023.
8. X. Tao, P. J. Robson and C. L. Wang, "To learn or not to learn from new product development project failure: The roles of failure experience and error orientation," *Technovation,* vol. 127, p. 102830, 2023.
9. J. Bae and U. Ozmel, "The interplay between product development failures and alliance portfolio properties in the formation of exploration versus exploitation alliances," *Journal of Business Research,* vol. 177, p. 114622, 2024.
10. S. Baga, L. C. Wood, L. Xud, P. Dhamijaf and Y. Kayikcig, "Big data analytics as an operational excellence approach to enhance sustainable supply chain performance," *Resources, Conservation & Recycling,* vol. 153, p. 104559, 2020.
11. C. Lyu, F. Zhang, J. Ji, T. S. Teo, T. Wang and Z. Liu, "Competitive intensity and new product development outcomes: The roles of knowledge integration and organizational unlearning," *Journal of Business Research,* vol. 139, p. 121–133, 2022.
12. S. Ozdemir, Y. Wang, S. Gupta, V. Sena, S. Zhang and M. Zhang, "Customer analytics and new product performance: The role of contingencies," *Technological Forecasting & Social Change,* vol. 201, p. 123225, 2024.
13. D. Dragomir and Ș. Bodi, "Increassing design process robustness in the case of durable consumer goods," *Acta Technica Napocensis. Series: Applied Mathematics, Mechanics, and Enigineering,* vol. 63, no. 2, pp. 169-174, 2020.
14. H. Quan, S. Li, C. Zeng, H. Wei and J. Hu, "Big Data and AI-Driven Product Design: A Survey," *Applied Sciences,* vol. 13, p. 9433, 2023.
15. N. Yüksel, H. R. Börklü, H. K. Sezer and O. E. Canyurt, "Review of artificial intelligence applications in engineering design perspective," *Engineering Applications of Artificial Intelligence,* vol. 118, p. 105697, 2023.
16. D. O. Ogundipe, S. O. Babatunde and E. A. Abaku, "AI and Product management: A theoretical overview from idea to market," *International Journal of Management & Entrepreneurship Research,* vol. 6, no. 3, pp. 950-969, 2024.
17. S. Bahoo, M. Cucculelli and D. Qamar, "Artificial intelligence and corporate innovation: A review and research agenda," *Technological Forecasting & Social Change,* vol. 188, p. 122264, 2023.
18. R. G. Cooper, "The AI transformation of product innovation," *Industrial Marketing Management,* vol. 119, pp. 62-74, 2024.
19. E. A. Hattori, M. Yamakawa and K. Miwa, "Human bias in evaluating AI product creativity," *Journal of Creativity,* vol. 34, p. 100087, 2024.
20. K. Lee, "A Systematic Review on Social Sustainability of Artificial Intelligence in Product Design," *Sustainability,* vol. 13, p. 2668, 2021.
21. C. Liu, W. Tian and C. Kan, "When AI meets additive manufacturing: Challenges and emerging opportunities for human-centered products development," *Journal of Manufacturing Systems,* vol. 64, p. 648–656, 2022.
22. X. Wang, N. Anwer, Y. Dai and A. Liu, "ChatGPT for design, manufacturing, and education," *Procedia CIRP,* vol. 119, no. 33rd CIRP Design Conference, pp. 7-14, 2023.
23. S. G. Bouschery, V. Blazevic and F. T. Piller, "Augmenting human innovation teams with artificial intelligence: Exploring transformer-based language models," *Journal of Product Innovation Management,* vol. 40, pp. 138-153, 2023.

 doi:10.20944/preprints202406.0472.v1

24. F. Popișter, H. Ș. Goia, P. Ciudin and D. Dragomir, "Experimental Study of a 3D Printing Strategy for Polymer-Based Parts for Drone Equipment Using Bladeless Technology," *Polymers,* vol. 16, p. 533, 2024.
25. D. S. D. Blagu, D. Dragomir, C. Neamțu and D. Popescu, "Offering Carbon Smart Options through Product Development to Meet Customer Expectations," *Sustainability,* vol. 14, p. 9913, 2022.
26. D. Dragomir and R. Comes, "Establishing the focus of the product development strategy in a furniture start-up," *Economics and Business,* vol. The 4th Advanced Research in Scientific Areas, pp. 50-54, 2015.
27. M. Falahat, S. C. Chong and C. Liew, "Navigating new product development: Uncovering factors and overcoming challenges for success," *Heliyon,* vol. 10, p. e23763, 2024.
28. J. Oehmen, A. Guenther, J. W. Herrmann, J. Schulte and P. Willumsen, "Risk management in product development: risk identification, assessment, and mitigation - A literature review," in *Proceedings of the Design Society: DESIGN Conference*, Zagreb, 2020.
29. M. Lévesque and A. M. Subramanian, "The inseparable two: Impact of prior success and failure on new product development project discontinuation," *Journal of Operations Management,* vol. 69, pp. 305-336, 2023.
30. R. E. Browder, C. J. Crider and R. P. Garrett, "Hybrid innovation logics: Exploratory product development with users in a corporate makerspace," *Journal of Product Innovation Management,* vol. 40, pp. 451-474, 2023.
31. D. Kiran, "Quality Loss Function," in *Total Quality Management - Key Concepts and Case Studies*, Butterworth-Heinemann, 2017, pp. 439-445.
32. ISO - UNIDO, ISO 31000:2018 - Risk management - A practical guide, Geneva: ISO, 2021.
33. P. Dean, "How to read a risk matrix used in a risk analysis," November 2022. [Online]. Available: https://www.assessor.com.au/resources/news-articles/how-to-read-a-risk-matrix.
34. Barcelona Field Studies Centre, "3D Chart Maker - 3-Dimensional Chart Creator," 7 March 2024. [Online]. Available: https://geographyfieldwork.com/3D-Chart-Maker.htm.