Doctoral Dissertation

Strategic Innovation in Taekwondo: A Systematic Framework for Business Idea and Design Concept Generation Using Patent-Based Knowledge and Generative AI

テコンドーにおける戦略的イノベーション：特許情報と生成AIを活用した事業アイデアおよびデザインコンセプト創出フレームワークの構築

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AIZA SYAMIMI BINTI ABD RANI

Graduate School of Sciences and Technology for Innovation,
Yamaguchi University

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ABSTRACT

Intensified modernization within Taekwondo (TKD) systems is imperative due to recent advancements in technological innovation, particularly in artificial intelligence (AI)-driven training systems and smart wearable devices within the sports sector. Nevertheless, the evolution poses considerable challenges for TKD-focused social enterprises (SEs), which frequently operate under limited financial and human resources. This study proposes a strategic framework for generating novel design concepts for future TKD systems.

Patent and non-patent trends were analyzed related to TKD and technologies, including blockchain, information technology and systems (IT/IS) by utilizing the cooperative patent classification codes (CPC) and co-occurrence networks created from text mining to identify important keywords. The patent trends were also analyzed using the novelty potential concept, assessed by the Word2vec algorithms. The novelty potential concept refers to the idea that the more different two abstract concepts are, the more novel their combination would be. Consequently, business ideas are proposed such as an advanced video platform integrating AI, IoT and blockchain technologies.

Additionally, three idea generation methodologies were employed, including the novelty potential/void matrix, a design catalogue based on cooperative patent classification (CPC) codes, and generative artificial intelligence (Gen AI). Concepts with high novelty potential and minimal technological saturation (void) are identified through patent abstracts analysis before generating novel conceptual combinations with ChatGPT. Consequently, an innovative design concept consisting of a smart scoring system enhanced by an emotion-responsive platform is produced. Based on comparative evaluation data, the proposed ideation approach yields concepts with superior originality and no overlap with LLM-generated ideas, suggesting a more substantial potential for first-mover advantage than ideas generated solely through LLM models.

Although the differences were not statistically significant ($p>0.05$), the trend still suggests that the proposed method may offer higher novelty compared to LLM-generated ideas. A detailed assessment of relevant CPC codes is also conducted to validate the novelty of the proposed concepts. The results confirm the absence of analogous patents, underscoring the uniqueness of the identified combinations for TKD SEs. Additionally, the basketball example is presented as an exploratory application rather than a full second case study.

Furthermore, semi-structured interviews with representatives from the blockchain organizations, SMEs and LEs from sports organizations were conducted to gain insights into industry challenges. Additionally, the interviews were also conducted with Malaysian Taekwondo Federation and clubs, procuring expert insights and feedback on the design catalogue. Conclusively, this study presents a novel ideation methodology that can enhance the innovation capacity and competitive positioning of TKD SEs, aligning with broader objectives related to the Sustainable Development Goals (SDGs).

CHAPTER 1

INTRODUCTION

1.1 Background of the study

The Global and Malaysian Sports Industry

The sports industry comprises individuals, businesses, and organizations engaged in a wide range of sports-related activities. In recent years, particularly post-COVID-19 pandemic, the industry has experienced rapid advances driven by wearable technologies, artificial intelligence (AI), immersive augmented reality (AR)/virtual reality (VR) and sustainability-focused innovations that support performance optimization and fan experience. These technological advancements are reshaping how sports are managed, performed and consumed globally. According to Statista, the global sports market is projected to increase steadily, reaching approximately US$99.38bn by 2030, with a compound annual growth rate (CAGR) of 3.35% between 2026 and 2030 [1].

Furthermore, the global sports technology sector is also expanding rapidly, with the expected market size to reach 60 billion USD by 2030, increasing at a compound annual growth rate (CAGR) of more than 20% [2], as organizations increasingly adopt data-driven performance tools, digital systems and innovative equipment across a wide range of sports domains. While the global sports industry continues to expand rapidly, Malaysia has recognized sport not only as a domain for physical excellence but also as a strategic sector for technological and economic development. The Ministry of Youth and Sports introduced the Vision Sporting Nation 2030 (VSN2030) initiative, which identifies sports technology and industry development as key strategic priorities through agencies, such as the National Sports Institute (ISN) [3].

These initiatives aimed at strengthening Malaysia's sports ecosystem growth as a sustainable industry with innovation, data analytics, and high-performance systems to enhance industry competitiveness. Consequently, the Malaysian sports industry has emerged as one of the significant contributors to the national economy, generating approximately RM49.5 billion in economic value in 2022, representing a growth rate of 12.1% compared to the previous year, as shown in Figure 1.1 [4].

Additionally, the Malaysian sports and wellness tech market is projected to grow from USD 45.2 billion in 2025 to USD 112.8 billion by 2032**,** representing a CAGR of 13.9%, largely driven by the increasing adoption of wearable devices and mobile wellness applications that enable health monitoring, tracking activities, and personalizing fitness programs [5]. By 2032, the market is expected to experience further expansion for personalized wellness recommendations through the deepening implementation of AI, machine learning, and predictive analytics [5]. Nevertheless, the pace and depth of technological integration differ widely between different sports organizational sectors (profit, non-profit and public), including martial arts such as TKD, which offer similar services but differ in the way they gain revenue and operate their business.

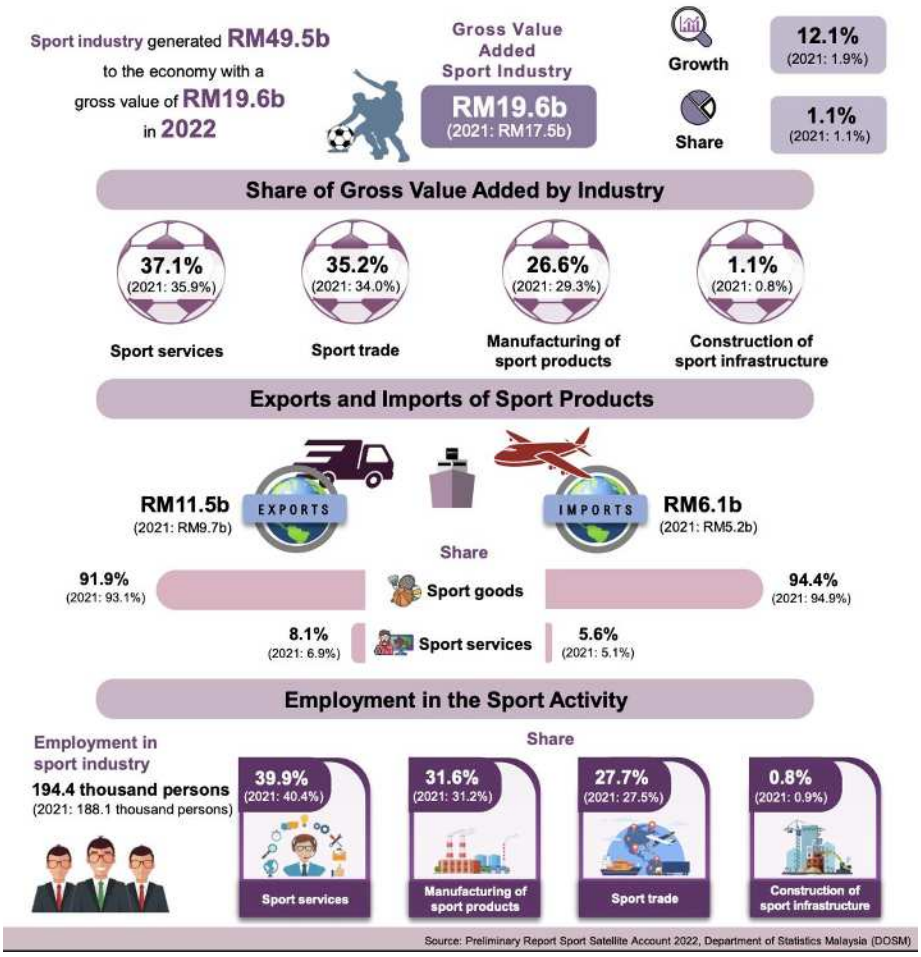


Figure 1.1 Economic contribution of the Malaysian sports industry

(Department of Statistics Malaysia (DOSM), Sport Satellite Account 2022)

The Sports Industry Sectors and Characteristics

Figure 1.2 illustrates the contemporary sports management sector's model, comprising three different sports sectors: public sector, profit organizations (POs)/commercial and non-profit organizations (NPOs) [6]. The public sector includes national, state or provincial, regional and local governments as well as special agencies responsible for formulating sports policy, providing financial support and performing specialized duties, including elite athlete development and anti-doping regulation. Furthermore, POs or the commercial sector, include professional and commercial sport organizations, sporting goods manufacturers and retailers, media corporations, stadium operators, and event coordinators who manage their business to generate income for themselves. Many of these sports organizations are associated with highly commercialized sports, such as football and basketball.

Meanwhile, NPOs consist of community-based clubs, governing bodies, national, state and local sport organizations and school sports/college and university sports. The international sport organizations are also considered as NPOs that facilitate competition and participation opportunities, regulate and maintain sporting rules and codes and organize major sporting events. These organizations' main purpose is to address a social cause, a particular interest and to meet their own needs. They generate revenue by offering products and services to customers, being funded by the community, government subsidies, business sponsors or private donors. In fact, these NPOs can be recognized as social enterprises (SEs) [7-8].

SEs are NPOs that generate income using strategies that combine social and commercial activities to enhance the delivery of social values [9] and also provide market-based solutions to solve social problems [10]. Thus, SEs can be defined as NPOs that conduct activities similar to POs to deliver their social mission more effectively. Many factors are related to more NPOs transitioning to SEs—for example, reducing funding and increasing competition between POs and NPOs [11]. In order to achieve sustainability within sports organizations, an understanding of effective management processes is critical. There are two methods for managing sports organizations. The first method is to treat them as commercial enterprises where the primary goal is to gain revenue. Meanwhile, the second acknowledges that sports organizations possess unique characteristics to which not all managerial practises used in the commercial sectors apply [12].

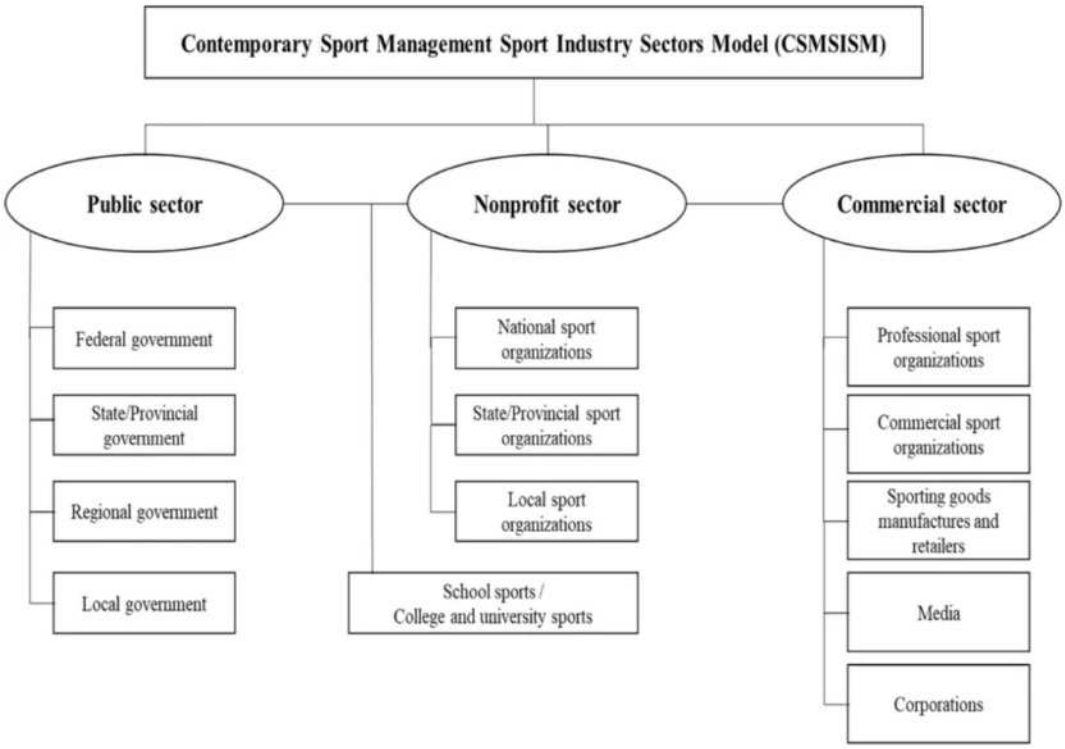


Figure 1.2 Contemporary sports management (CSM) sports industry sectors model [6]

Certain sports, including martial arts, are built on community engagement and social activities rather than commercial enterprises, which positions them more closely within the NPOs sector. This market differs from the POs or commercial sector, where business strategies are more essential in identifying competitive positions. The sports industry's uniqueness can be identified through several distinct characteristics that differ from other industries [12]. These characteristics influence how sports organizations operate, generate value and compete within the marketplace. The characteristics are identified as follows:

i) Emotional engagement and strong fan loyalty

First, sports are heterogeneous and entail fleeting experiences involving fans, who are passionate for sporting teams, athletes and competitions. These fans celebrate achievement, success and performance outcomes in a way that is unique from other social and economic activities. For instance, the Tokyo 2020 Olympic Games allowed fans to witness and support each athlete's determination and competitive spirit. This emphasizes sports' power to connect people from diverse backgrounds through experiencing various emotions and passions, which suited the motto for the Olympic Games sought to represent, "united by emotion."

The sports industry is also characterized by strong brand loyalty, meaning fans are unlikely to switch their support to other teams, which can be disadvantageous for some sporting organizations that want to increase market share and attract new fans or members. Sports fans also exhibit high degrees of optimism, believing that their team will win despite continuous losses, which can lead to vicarious identification, such as buying products that sports celebrities endorse.

ii) Focuses on winning over revenue

Second, the sports industry focuses on winning over revenue. POs emphasize generating revenue and increasing shareholders' wealth. By contrast, in professional sports clubs, the focus is on sports performance and results, including ranking and wins. More wins translate to a better reputation for the sports organization. Restrictions that prevent certain sports clubs and teams from gaining a monopoly in the market can help increase revenue for all members of sports leagues and their competition. This differs from businesses in other industries, which aim to defeat all rivals and gain a monopoly. Anti-competitive behavior has been utilized by professional sports to boost their commercial impact, protect their brands and increase profit through collective marketing initiatives.

iii) Competitive balance and cooperative competition

Third, the sports industry has varying levels of quality, balanced competition and anti-competitive behaviour characteristics. Game outcomes in which one team dominates are usually unpredictable, reducing the attractiveness of the games or tournaments. Therefore, the variability of sports makes it difficult to guarantee quality in the marketplace relate to providers of other customers' products. Sports teams must compete with rivals on the field while simultaneously cooperating off the field to benefit the industry as a whole [13].

iv) Limited availability

The fourth unique aspect of the sports industry is the limited availability. Sports are limited by the number of scheduled games or season length. This differs from other industries, which can increase production to meet customers' demand in the market. Therefore, the capabilities of sports clubs to maximize profit through tournament ticket sales, for instance, are limited. Both sports and business have a common interest in value creation and branding, funding new profit streams, product innovation and market expansion.

However, the sports industry is more concerned with beating opponents, winning trophies, sharing revenue and fostering passion of both players (employees) and fans or customers [14]. Athletes are currently considered business assets that attract fans, sponsors, and media exposure. Hence, unlike other businesses, sports players can earn much higher incomes than their superiors, the sports managers. Regarding martial arts, such as TKD, they differ from other businesses in terms of product and service offerings, target customers, fees, and sales promotion, among other aspects.

For instance, in TKD schools, membership fees are the main concern as these may affect current and future members' decision to participate in TKD clubs or schools. High member enrolment is important to offset the cost of location and sparring equipment and to generate revenue. TKD members will also consider other costs, such as tournament fees, belt test fees, training equipment, and additional related fees, before joining a specific club. To attract more members, TKD schools need to offer new and unique products and services that differentiate them in the market.

Martial Arts, Taekwondo as a Case Study

Martial arts are very well-known and have existed for more than 3000 years, categorized as both sports and exercise with hundreds of various styles. IBIS world has reported the total profit reaching a CAGR of 6.3% to $21.0 billion in 2025, with 72,029 businesses in the martial arts studios industry in the United States (US) [15]. This rising popularity is driven by a growing demand for structured activities that enhance resilience, adaptability and personal growth [6]. Nevertheless, as economic conditions continue to improve, demand for martial arts is expected to increase.

Originating in Korea, TKD is a globally recognized Korean martial art that has evolved as an official Olympic sport, characterized by its emphasis on fast and dynamic kicking techniques and mental discipline. It is derived from the Korean word, comprising three parts: 'Tae' meaning foot or strike, 'Kwon' meaning fist or fight, and 'Do' referring to the way or discipline, translating to "the way of the foot and fist." [16]. The sport is popular among individuals across all ages, recording over 80 million practitioners in more than 200 countries, making it one of the world's most popular sports [16]. It is monitored by five Continental Unions (Africa, Asia, Europe, Pan America and Oceania) from many national and international organizations, including the Global Taekwondo Federation (GTF) and American Taekwondo Association (ATA).

The primary governing bodies overseeing TKD are the International TKD Federation (ITF) and the World TKD Federation (WT), which played significant roles in maintaining the integrity of the sport, monitoring rule development, competitions and international relations despite the split [16]. WT focuses on Olympic sport sparring, while the ITF centers on traditional and self-defence-oriented training. Overall, TKD contributes significantly to athletes' personal well-being through both physical fitness and mental activities, including reducing mental health disorders and enhancing self-defence ability [17,18], which are distinct focus areas compared with other sports. With the rise in mental health issues across the world, martial arts such as TKD thus aid in the maintenance of mental balance, which has stirred consumer interest, attracted newcomers to the market, and led to a rise in market competition.

However, the rise of martial arts is attributable not only to demand among practitioners but also to the sustained efforts of industry leaders [19]. This demonstrates the growing importance of this sport in society. In addition to its social and health benefits, the TKD industry also demonstrates strong economic potential. The global TKD equipment industry is projected to expand at a CAGR of 6.30% from 2023 to 2030 [20]. Countries in the Asia Pacific region, including China, Japan, and Malaysia, account for a significant share of the market, representing more than 22% of global revenue and a CAGR of 8.0%. This growth is due to a strong martial arts tradition and an increasing emphasis on physical fitness and self-defence [20]. Malaysia's TKD industry is one of the well-established and growing sectors, supported by national associations, training academies, and a competitive market.

Furthermore, in the post-COVID-19 era, the research in TKD has shifted towards smart, interactive, and artificial intelligence (AI)-driven systems to improve accuracy and enhance training performance. Behavior-based AI learning support systems [21] and intelligent recognition systems based on deep-vision learning for dynamic sports gestures [22] are among recent technological innovations in TKD. Based on the number of patents, TKD demonstrates an increasing growth trend superior to other sports, including Judo and Karate, reflecting increasing technological innovation [23]. Consequently, TKD was chosen as a representative case due to its rapid growth in patent filings, technological innovation, and strong social significance.

1.2 Problem Statement

The growth of the martial arts industry, including TKD, has intensified competition, resulting in a highly competitive business environment. The sustainability and the success of TKD organizations depend on their ability to adapt to rapid changes in the marketplace. This adaptability has become even more crucial owing to the COVID-19 pandemic, which has accelerated the social and economic conditions globally, and transitioning toward a "new normal" that involves aspects such as digitalization, working from home (WFH), social distancing and changing consumer expectations. Consequently, digital transformation has emerged as a critical factor for organizations seeking to remain competitive. However, despite the rapid adoption of digital technologies, only approximately 48% of digital transformation initiatives achieve or exceed their expected business results, highlighting persistent challenges in extracting strategic benefits from digital investments [24].

These challenges are particularly faced by numerous TKD organizations that operate as NPOs, which often have limited resources and funding, restraining innovation capabilities in developing new and advanced systems despite technological advancements and innovations. TKD schools continue to rely heavily on membership fees as the primary source of revenue and face challenges in retaining members [25]. Consequently, NPOs that offer similar sports activities as POs are more likely to face higher competition than NPOs that consider more unique programs [26]. To remain competitive, these NPOs must transform into SEs to generate commercial revenue by introducing revenue-seeking business activities as POs, and developing a profit model for their existing social products and services. They must also find opportunities for business partnerships and collaboration with POs [27].

In the current VUCA (volatility, uncertainty, complexity and ambiguity) and digital transformation (DX) era, innovating their business model, introducing new products or services, and leveraging new technologies are crucial to sustain their business. Furthermore, reliance on one system is no longer feasible and an integrated system based on the perspective of system of systems (SoS) [28, 29] is crucial. Leveraging interconnected subsystems also enables TKD SEs to achieve higher innovation potential, competitiveness, and long-term sustainability than isolated technological solutions. However, a lack of systematic methodologies to support TKD organizations, particularly SEs, in generating ideas and innovating remains.

Therefore, this study proposed a novel approach to increase innovation in TKD SEs by generating business ideas and creating novel design concepts for future TKD systems and businesses. First, patent and non-patent trends were analyzed related to TKD and technologies, including blockchain, information technology and systems (IT/IS) by utilizing the cooperative patent classification codes (CPC) and co-occurrence networks created from text mining to identify important keywords. Second, case studies are conducted to support and validate novel design concepts creation in the early stages of product development. First approach analyzed patent data by utilizing the novelty potential concept (word2vec), which refers to the idea that the more different two abstract concepts are, the more novel their combination would be. The proposed ideas were then validated through patents investigation.

The second case study which is the main contribution of the study's methodology, further extends the novelty potential approach by employing three idea generation methodologies, mainly the novelty potential/void matrix, patent-based design catalogue and Gen AI models, including ChatGPT. Gen AI is incorporated as a supporting tool to enhance and refine the generated concepts derived from the proposed methods. It is also used a comparison benchmarking with the ideas generated from our proposed method to demonstrate the effectiveness of our proposed approach. Additionally, the proposed ideas were then benchmarked with large language model (LLM)-generated ideas evaluated by independent experts and CPC codes for verification.

Semi-structured interviews with the sports industry, large enterprises (LEs) and small and medium enterprises (SMEs), a blockchain provider and Malaysian TKD Federation and clubs were also conducted to obtain practical insights into innovation challenges and feedback on the proposed design catalogue. This study focused on a single case (TKD) for initial validation, which is a reasonable approach to confirm the effectiveness of the proposed design methodology. Additionally, the use of CPC codes and abstracted design knowledge enables potential application to other domains. Finally, important, logical relationships were determined, and new business ideas and novel design concepts were recommended. This approach is relatively new, specifically for the sports industry and TKD SEs, to which it offers unique insights into the creation of new business ideas and strategies based on the proposed methodologies.

1.3 Research Objectives

The primary objective of this research is to propose a strategy for generating business ideas and novel design concepts for TKD SEs to support business model innovation. This research employs several methodologies, including patent and non-patent analysis, the novelty potential/void matrix, a patent-based design catalogue and Gen AI. The proposed methodologies provide a systematic and structured idea generation methodologies combining human-AI collaboration to produce novel design concepts, without relying on conventional and single ideation methodology, aiming to help TKD SEs enhance and increase innovation. This research addresses the following research objectives:

RO1: To identify technological trends, innovation gaps, and unmet opportunities in the sports industry through patent, non-patent, and industry analysis.
RO2: To develop an integrated framework for generating novel product, design, and business concepts.
RO3: To gain insights on challenges and to evaluate and validate the novelty, relevance, and practical applicability of the proposed framework and generated concepts for TKD SEs through systematic novelty assessment and stakeholder feedback.

1.4 Research Questions

The research question of the research is:
"How to create a systematic framework for generating new business ideas and novel design concepts for Taekwondo social enterprises (SEs) to support business model innovation?"

1.5 Significance of the Study

The significance of this study lies in its potential to advance innovation practices in both academic research and practical applications within the sports industry, specifically for TKD SEs. Figure 1.3 summarizes the significance of the study across four sectors; government, industry, academic and society. The findings are expected to benefit sports practitioners and TKD organizations, offering insights into potential innovation opportunities, creation of new products, services and revenue streams and technological trends that may influence future sports services and training systems.

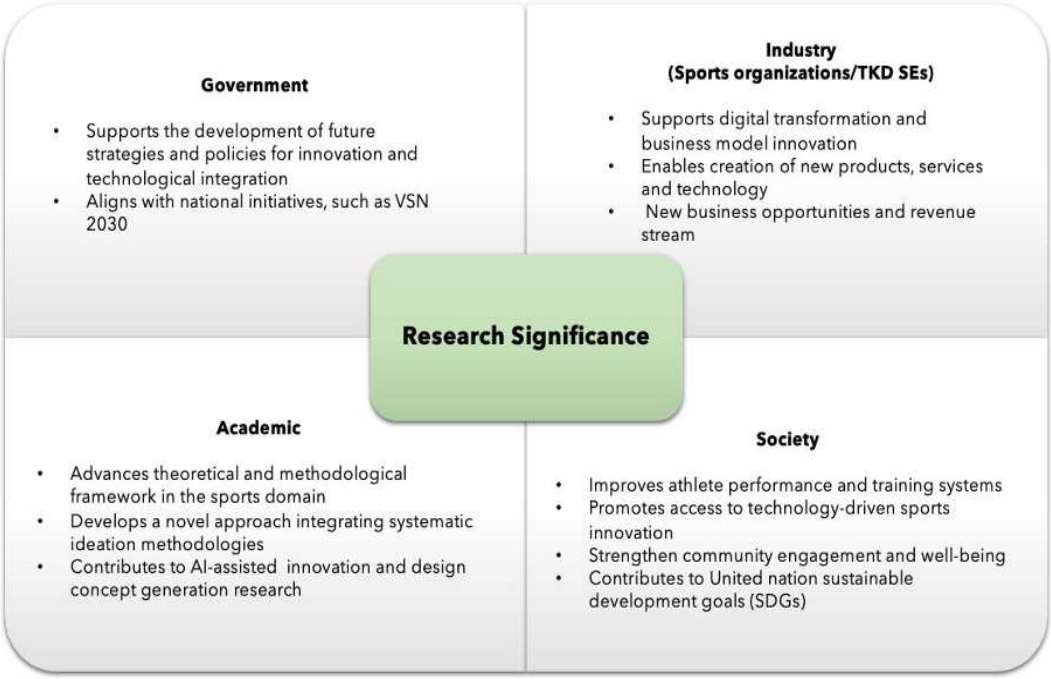


Figure 1.3 Thesis significance diagram

Additionally, it also offers valuable insights for policymakers and sports governing bodies by providing evidence that may support the development of strategies and policies aimed at promoting innovation and technological integration within the sports industry, while aligning with national initiatives such as VSN2030. Furthermore, this study contributes to the broader academic discourse on innovation and design concept generation within the sports sector for researchers and scholars, by advancing theoretical and methodological frameworks, including extending the novelty potential theory into sports domain and developing a novel approach for systematic ideation methodologies.

It also provides a foundation for future research and innovation practices aimed at transforming the TKD ecosystem and the wider sports industry, while contributing positive societal impact through athlete development, community engagement and contribution to the United Nations (UN) SDGs. Overall, the study highlights the significance of structured innovation methodologies in supporting the long-term sustainability and development in an increasingly technology-driven environment.

Figure 1.4 presents the thesis structure overview, illustrating the systematic alignment between each research objectives, the applied methodologies in patent and non-patent investigation, application and validation through case studies, semi-structured interviews and the contributions.

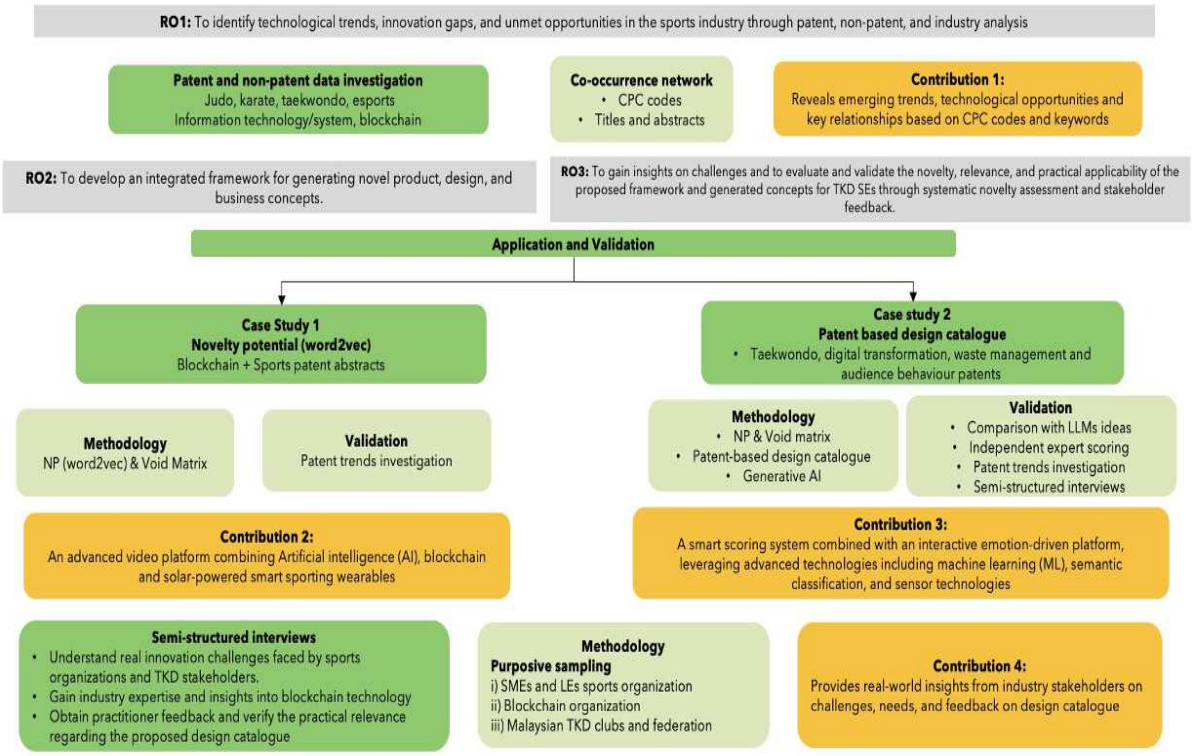


Figure 1.4 Overview of thesis structure

1.6 Organization of the Chapters

The chapters are organized according to the following manner:

Chapter 1 Introduction

This chapter provides an overview of the research topic, beginning with the research background, highlighting the global and Malaysian sports industry landscape, the structure and characteristics of the sports industry, and martial arts, with TKD chosen as a case study. The chapter subsequently outlines the problem statement, focusing on the challenges faced by TKD organizations, particularly the transition from NPOs to SEs. The research objectives and questions are then presented to define the direction and scope of the study, followed by the significance of the study and the chapter's organization.

Chapter 2 Literature Review

This chapter reviews previous studies relevant to the research topic obtained from various sources such as books, journals, peer-reviewed articles, and conference papers. It covers areas

including the martial arts industry, TKD technological innovations and challenges, idea generation and design concepts, including the use of LLMs and Gen AI and the relevant theoretical frameworks. Finally, our proposed research approach was presented.

Chapter 3 Methodology

This chapter outlines the research methods and configuration, including how the patent and non-patent data are collected, prepared and analyzed. Ethical considerations, including informed consent, data anonymization and accountability in AI-generated content, are also addressed.

Chapter 4 Results

This chapter presents all the research findings and analysis derived from the data collection. It focuses on presenting the gathered findings in a structured and meaningful way to facilitate the subsequent discussions and recommendations, which will be presented in Chapter 5. The patent and non-patent analysis findings are presented to identify trends and important keywords, followed by the application and validation findings through case studies, including novelty potential (word2vec) and patent-based design catalogue. Finally, semi-structured interview findings from various stakeholders are presented, including challenges and feedback on the design catalogue.

Chapter 5 Discussions and Recommendations

This chapter further discusses the research findings and recommends some possible solutions and strategies that can be implemented, particularly for TKD SEs. This includes strengthening business model strategies and recommendations on new business ideas and novel design concepts.

Chapter 6 Conclusions

This chapter concludes all the chapters in the study by summarizing the key findings and highlighting the academic and practical contributions. It also discusses the limitations of the study and provides recommendations for future study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the foundation was established by reviewing previous studies conducted in the relevant areas of study. Through the utilization of insights and findings derived from previous studies, the existing knowledge base serves as a guiding principle throughout the research process. This study expands on various streams, particularly those focused on (i) Martial arts (Taekwondo), technological innovations and issues and challenges, (ii) Idea generation and design concepts creation, including theoretical foundations, novelty potential/void matrix, patent-based design catalogue, LLMs and Gen AI and finally (iii) Research approach.

2.2 Martial arts (Taekwondo)

TKD is a globally practiced Olympic martial art with millions of practitioners across more than 200 countries and nearly 80 million people worldwide. The global impact of COVID-19 has significantly disrupted traditional sports systems worldwide, including TKD and particularly practice-based disciplines that depend on physical interaction, direct coaching, and structured competition environments. In response to these disruptions, the sports industry has accelerated its transition toward innovation and digital transformation, integrating technologies such as AI, ML, DL, and wearables to support training and performance. Nevertheless, beyond technological adaptation, the pandemic has also introduced substantial psychological and emotional challenges for athletes.

Several researchers have examined the challenges and impact of COVID-19 faced by athletes, including anxiety and emotional tension [30,31]. For instance, Jeon et al. examined the impacts due to COVID-19 faced by TKD athletes through questionnaire data from 184 adult TKD athletes, analyzed using text mining, the latent Dirichlet allocation topic modelling algorithm. Main impacts were anxiety caused by training restrictions, self-management challenges arising from competition postponements and career uncertainty caused by game cancellations [30]. The performance of the TKD athletes was maintained through private

training and competition preparations during personal quarantine. Hence, new ways to support training and competition need to be discovered in the case of similar future disruptions [30].

Similarly, Predoiu et al. (2022) also investigated the impact of COVID-19 in martial arts athletes across Europe, including kickboxing, karate, boxing, TKD and Muay Thai [2]. They found that those who tested positive for COVID-19 experienced significantly heightened psychological stress and emotional tension, including denial and behavioral disengagement, compared to those who were not infected [31]. The study offers significant implications for martial arts coaches, athletes, sports psychologists and parents to suggest the most effective strategies for managing negative stress due to the pandemic for long-term effects on the athletes' mental health and well-being [31].

The challenges experienced during the pandemic also highlighted the weaknesses in traditional competition and evaluation systems. In particular, the heavy reliance on physical presence, human judgement and centralized competition formats limited the adaptability and resilience of TKD systems under disrupted conditions. Several researchers have highlighted the inherent difficulty of achieving reliable, accurate scoring and decision fairness in TKD sparring and Poomsae competitions. Therefore, the development of reliable and unbiased scoring systems has emerged as a critical area of innovation in TKD.

For instance, Chi et al. (2005) explored the application of ubiquitous and wearable computing technologies in the sparring ring environment of martial art tournaments [32]. The study utilized piezoelectric force sensors, transmitting signals wirelessly to detect significant impact on the competitor's body, aiming to facilitate judges in accurately scoring the sparring competitions. Consequently, the system should comply with competition regulations, providing real-time responsiveness, and cope with non-expert operators of the system [32].

Leveaux, R. (2012) examined decision-making technologies during the 2012 Olympic Games to ensure the fairness and transparency of decisions through discussion groups and interviews with 31 elite international referees [33]. The findings indicated that the technologies functioned as effective tools in ensuring decision accuracy and supporting refereeing. Such technologies contributed to a fairer platform during competitions, enhanced athletes' performance and made the competition more attractive [33]. The study highlights the potential for additional technologies to further complement referees in ensuring fair competition and enhancing the overall quality of decision-making [33].

Subsequent developments in scoring systems, particularly the introduction of the Protector and Scoring System (PSS), have aimed to address concerns related to judging bias and game manipulation. Moenig (2017) argued that while the PSS has contributed to reducing

disputes and improving transparency in scoring decisions, its implementation has also introduced unintended consequences, including an overreliance on low-impact, front-leg kicking techniques and the emergence of unconventional scoring strategies [34]. The shift is primarily attributed to the unmanaged introduction of the PSS, which transformed TKD competition from a full-contact combat sport into a more light-contact, point-based format [34].

Accordingly, the study examined the necessity for the PSS based on previous literature, personal experience, discussions, and observations, and concluded that current TKD leadership has eventually recognized a decline in the quality of TKD sparring and competitions. Nevertheless, it remains uncertain whether WTF can resolve the issues [34]. Similarly, Razman et al. (2019) examined the validity and reliability of a PSS body protector using a customized mechanical pendulum. The study revealed significant concerns regarding the reliability and validity of the PSS, emphasizing the need for more rigorous evaluation before the PSS system can be implemented in future competitions [35].

Furthermore, relatively few efforts have been made to systemize TKD Poomsae competition [36] Abualkibash (2009) investigated a hierarchical approach for detecting movement landmarks in TKD Poomsae videos, representing a significant shift in a series of movements. The study found that 70% of landmarks are correctly detected [36]. Choi (2016) also proposed the development of a remote TKD Poomsae evaluation system, which judged and examined the accuracy of practitioners' movement with that of a black belt athlete, recognizing movements through specific joint regions. Additionally, the study also assessed each algorithm's accuracy using various motion recognition technologies and proposed a platform based on system configuration, module architecture and overall process for the remote TKD Poomsae evaluation [37].

Consequently, the COVID-19 pandemic has exposed the vulnerability of conventional training and competition systems, emphasizing the importance of adaptability and resilience in sports environments. Recent studies have increasingly explored the integration of technological innovations to enhance the objectivity, accuracy, and efficiency of TKD training and competition systems.

2.2.1 Technological Innovations in Taekwondo

In recent years, specifically post-COVID, various technological innovations have been integrated, such as AI, VR, wearable devices, Internet of Things (IoT), machine learning (ML) and deep learning (DL) to enhance training, performance evaluation, and competition systems. Recent studies have utilized ML and DL for kicking recognition and classification, performance improvement, and training optimization [38-42]. For instance, Velásquez et al. (2025) analyzed the application of ML techniques to predict match outcomes using official data from the Peruvian TKD Sports Federation. The findings revealed the effectiveness of ML in identifying technical and contextual variables which influence match results, providing support for enhancing performance, optimizing training and strategic planning in TKD [38]. Liu et al. utilized ML, including algorithms such as support vector machine (SVM) and decision trees, combined with accelerometer data to recognize different TKD kicking techniques in a free-living situation [39]. They found that the optimal choice was utilizing SVM model on waist data, which obtained high accuracy with fewer accelerometers [39].

Amelia et al. (2024) proposed an automated TKD kick classification system using inertial measurement unit (IMU) sensors and SVM algorithms to recognize kicking techniques in real time, supporting athletes to improve their movements independently, reducing the likelihood of technical errors in TKD kicks during home-based training due to the absence of instructors [40]. The findings indicated that the SVM algorithm effectively categorizes the various types of TKD kicks [40]. Similarly, Dharmmesta et al. (2022) explored the performance of SVM and KNN (K-Nearest Neighbors) algorithms in classifying TKD foot kicks, which can effectively classify TKD foot kick types [41]. Ueda et al. (2024) have explored the use of ML to replicate expert-based evaluation processes in martial arts by developing an acceleration-based model to capture key movement features that reflect instructors' implicit evaluation criteria, enabling the translation of tacit knowledge into measurable parameters [42].

On the other hand, Zhang Q (2025) examined the application of DL to improve the technical skills of TKD practitioners and evaluated the practical contributions to the field. It analyses how to use DL in movement recognition, prediction of athletes' actions, injury risk prevention and tactical and opponent analysis [43]. They found that DL models can process large-scale datasets and deliver immediate feedback, enabling athletes to optimize the training process, enhance competitive performance and mitigate sports injuries [43]. Similarly, Xu and Fan (2024) proposed an intelligent recognition system utilizing deep vision learning, using

TKD as a case study for dynamic sports gestures, which obtained an accuracy of 95.6%, revealing the effectiveness of the proposed method [44]. Barbosa et al. (2021) investigated the DL techniques for the classification of TKD movements during training sessions on real-time data. They found that convolution layer models, such as CNN plus Long Short-Term Memory (LSTM) and Convolutional Long Short-Term Memory (ConvLSTM) DL models, achieved the best results, with an accuracy validation of more than 90% [45].

Several studies have also examined the impact of VR technologies in transforming the traditional education model. In TKD college courses, VR technology has demonstrated unique benefits and potential in basic training skills, simulated combat, tactical strategy exercises, and remote guidance training [46] Zhang Q (2025) conducted an experimental comparison between a VR-assisted group and a traditional training group, demonstrating that VR training method is more effective in enhancing the special skills of TKD and provides significant advantages in increasing students' interest in learning [46]. Huang and Li (2025) also found that VR-based and interactive applications significantly improve students' engagement and motivation levels in both theoretical and practical training, through the online questionnaire surveys and semi-structured interviews results [47]. The incorporation of an AI-based training program was shown to support long-term skills in athletes, with notable improvements in accuracy and speed, which also enhances communication between students and teachers [47].

Xie (2023) highlighted that integrating VR-based training environments into TKD training can assist trainers in performing difficult demonstration movements and complex technical points, optimizing teaching effectiveness [48]. Jelani et al. (2019) introduced the virtual TKD training environment (V2TE) as a supplementary platform to support self-directed training, developed using Motion Capture (MoCap) and VR [49]. The study showed that TKD trainees "highly agreed" on the presence of the VT2E in terms of usefulness, engagement, ease of use and satisfaction, and only "agreed" on presence of the VT2E, showing potential to enhance TKD trainees' performance and skills [49]. Shin et al. (2024) explored the development of TKD through AI, using a literature review obtained from six electronic databases [50]. The study proposed an AI-based TKD performance analysis and evaluation system, including a metaverse-based virtual TKD poomsae and sparring training platform, analyzed through an AI-based movement tracking [50].

Beyond the traditional coach-centered training model, interactive and gamified learning platforms can improve retention, engagement, skill acquisition, and motivation in TKD training. For instance, Konarivand et al. proposed TaekFunDo, an emotion-based, gamified platform that incorporates storytelling, reward-based systems, and interactive drills shown to

increase attendance rates, learner engagement and motor skill development, particularly among young practitioners, compared to traditional discipline-focused programs [51]. Performance-oriented technological solutions have emerged to support objective evaluation and reduce reliance on subjective judgment in both training and competition contexts. Ardha et al., (2024) developed a mobile-based statistical application to analyze match data, tactical behaviors, and attack–defence patterns, enabling more accurate and efficient competition preparation for athletes and coaches [52]. Similarly, Romanenko et al. (2024) proposed a computer-assisted evaluation method, such as mobile applications designed to assess athletes' "Go/No-Go" reaction responses to quantify sensorimotor and cognitive performance factors that are critical in combat sports, including TKD [53].

One of the critical areas of technological innovation in TKD concerns scoring systems in poomsae and sparring competitions. Traditional judging systems are predominantly reliant on human observation and subjective interpretation, leading to inconsistencies, bias, and limited reproducibility. To overcome this, Mahdi et al. (2022) investigated the application of DL techniques for the classification of TKD poomsae movements, utilizing a CNN algorithm to classify image data of 6 types of TKD martial arts movements [54]. The study achieved its highest test accuracy under the configuration with 6 convolutional layers, 6 hidden layers and no dropout. The study highlights the benefits of integrating the CNN in classifying TKD movements into an Android-based mobile application [54].

Fernando et al. (2024) proposed a skeleton-based evaluation system using computer vision and a long short-term memory-based (LSTM-based) ML model to assess TKD poomsae movements, reducing subjectivity while enabling self-evaluation and skill improvement. The model achieved an accuracy of 61% compared to expert evaluations [55]. Such approaches highlight the potential of ML not only for performance recognition but also for supporting objective and standardized evaluation systems in TKD, reducing reliance on subjective human judgment and enhancing the objectivity of performance assessment. [55].

Abanto and Guzman (2024) also proposed a low-cost scoring system for Arnis, the Philippines national sport, utilizing a Smartfoam architecture integrated with an RFID-based sensor and a Velostat-based thin film impact sensor, obtaining a high rate of accuracy of 99%. [56] However, a small number of missed hits were observed, which were attributed to limitations in the RFID reader and tags embedded in the Smarfoam and Arnis stick. Accordingly, the study recommends further experimentation to enhance the RFID components for better performance [56]. Table 2.1 summarizes selected studies that reflect the

technological trends in TKD, categorized based on technology themes, purpose, methods, findings and references.

Nevertheless, most existing research primarily focuses on enhancing or optimizing existing systems, including improving scoring accuracy, automating motion analysis or validating performance metrics, rather than developing systematic methodology for generating ideas and novel design concepts.

This presents a significant challenge for TKD organizations, particularly SEs, which often face financial and resource constraints that hinder their ability to adopt and implement advanced technological innovations.

Table 2.1 Summary of Technological Innovations in TKD

Technology themes	**Purpose/Focus**	**Methods**	**Findings**	**References**
Machine learning (ML)	Kick recognition and classifications, performance analysis, expert evaluation modelling, match outcome prediction	SVM, KNN, Decision Trees, IMU sensors, ML model with focus-point feature extraction using smartphone-based acceleration data, long short-term memory-based (LSTM-based) , predictive ML model	Accurate classification of kicking techniques; supports real-time feedback; Improves evaluation accuracy through ML-based evaluation system, enables match outcome predictions	Liu et al. (2024); Amalia et al. (2024); Dharmmesta et al. (2022); Ueda T. et.al (2024), Velásquez et.al (2025)
Deep learning (DL)	Motion recognition, performance prediction, injury prevention, skill development	CNN, RNN, CNN-LSTM, deep vision learning	High accuracy (>90%) in classifying TKD techniques; effective for dynamic gesture recognition and real-time feedback	Zhang Q. (2025); Xu & Fan (2024); Barbosa et al. (2021)

VR and Immersive technologies	Training enhancement, simulation-based learning	Mixed-methods (survey & interviews); VR-based training systems; immersive simulation environments; interactive applications; experimental comparison (VR vs traditional training), Literature review	Improves engagement and motivation, enhances learning effectiveness and skill acquisition, supports visualization of complex techniques, AI and metaverse training platform	Zhang Q. (2025) Huang & Li (2025); Xie (2023); Jelani et al. (2019), Shin et.al (2024)
Gamified and interactive learning systems	Learner engagement, motivation, and skill acquisition	Gamification (storytelling, reward-based systems, interactive drills), emotion-based learning platforms	Increases retention, skill acquisition, motivation among young learners	Konarivand et al. (2025)
Mobile applications	Match and tactical analysis, reaction performance assessment	Mobile-based statistical application, computer-assisted evaluation, Go/No-Go testing	Improves performance analysis, decision-making and cognitive assessment	Ardha et al. (2024); Romanenko et al. (2024)
Scoring technologies	Poomsae movement evaluation and objective scoring	ML model, Smartfoam architecture, RFID-based sensors, Velostat thin-film impact sensor	Improves poomsae and sparring evaluation accuracy	Mahdi et al. (2024), Fernando et al (2024), Abanto and Guzman (2024)

2.2.2 Issues and Challenges

Despite the increasing adoption of technological innovations in TKD, several critical challenges remain at the industry and organizational levels. These challenges are particularly faced by numerous TKD organizations that operate as NPOs, which often have limited resources and funding, restraining innovation capabilities in developing new and advanced systems despite technological advancements and innovations. In response to the decrease in traditional funding sources and increased competition, the creation of commercial revenue streams enables traditional NPOs to increase financial sustainability [57]. Hence, to remain viable, they need to strategically transform into SEs to gain similar profit-generating opportunities. [57].

However, Ko and Liu (2021) suggest that the transformation of NPOs into SEs requires several forms of institutional work across different sectors, including adopting commercial profit strategies, developing professional organizational structure and legitimizing a socio-commercial business models [57]. TKD primarily main profits generation comes from the collection of class fees through students' enrolment, which then expanded to other services and products, including grade examination, apparel, and competition performance [58]. Fu et al. (2025) highlighted several challenges related to marketing management, including the absence of long-term strategic planning, weak coaching ability leading to student retention, as well as limited marketing products and services [58].

These issues highlight the need for improved management, digital marketing trends adoption, enhancing coaches' professional quality, and developing new products to meet actual consumers' needs [58]. Despite these efforts, existing approaches remain largely fragmented and lack systematic methodologies to support TKD organizations, particularly SEs in generating innovative ideas and developing sustainable solutions. The subsequent section reviews prior studies related to idea generation and design concept generation.

2.3 Idea Generation and Design Concepts Creation

The generation of novel design concepts during the conceptual design stage is essential in developing innovative products, as early exploration of unconventional solution alternatives in the early stages of product development enhances market competitiveness [59]. Product design and development typically start with problem definition, followed by the generation of ideas [60]. Idea generation or ideation can be referred to as the process of generating, developing and communicating ideas, where an idea is regarded as a fundamental element of thought in the forms of either visual, concrete, or abstract [61] Idea generation essentially determines the type of design outcomes generated, and is recognized as having a critical role in the development of novel concepts and for achieving business success [62].

Several approaches and tools have been created to facilitate creative idea generation in design. For instance, conventional tools, including brainstorming [63] TRIZ [64] and six thinking hats [65]; advanced design approaches such as bio-inspired design [66,67], design by analogy [68], and the 77 design heuristics [69]; computational tools such as the Combinator [70,71], virtual concept generation process [72], Idea Inspire 3.0 [73] and the Concept Generator [16]; and more recently large language models (LLMs) such as utilizing ChatGPT to enhance TRIZ process [75]. The previous studies of design concept generation can be generally categorized into two approaches, namely an empirical approach and a theoretical approach [59].

The empirical approach focuses on the practical study of design concept generation processes and extracts some thoughts on patterns that serve as knowledge to assist designers [59]. For instance, TRIZ is a prominent technique for this approach, which was built upon the analysis of 2.5 million patents and formalized them into the thinking process patterns [59]. Sankar and Sen (2025) developed a novel idea generation tool utilizing a structured conversational AI (CAI) system, including LLMs, to facilitate product designers in addressing initial latency and ideation constraints [76]. The ideas generated by both methods were reviewed by experts, revealing the superiority of the proposed tool for creating variety, novel and meaningful ideas [76].

Zhou et al. (2022) proposed a new tool to support the cross-cultural design process utilizing deep learning techniques, which gained positive feedback in terms of usability. The empirical findings revealed that the method can increase cultural awareness among designers. While the tool helps to generate ideas and rapid prototyping, it would only facilitate designers, rather than substitute for human designers [77]. Han et al. (2018) developed an ontology-based

computational tool called “the Retriever” containing a knowledge database of patterns of analogical reasoning. This tool can assist designers in generating creative ideas through the expansion and exploration of the design space [78].

Meanwhile, a theoretical approach focuses on defining factors associated with designers’ creative thinking processes and subsequently develops a prescriptive mode for concept generation based on those factors [59]. There is a strong emphasis on the evaluation of creativity and design outcomes [79]. For instance, Shah et al. (2003) introduce creativity metrics such as novelty and variety, calculated using a function tree created during the design process, and quantity representing the number of created ideas during the design process [80]. Ranjan et al.(2018) define novelty and usefulness as two primary metrics, calculated based on the degree of requirement-satisfaction [81].

Filippi (2023) measured the impact of ChatGPT to foster design concept generation based on four metrics (quantity, novelty, usefulness and variety) evaluated by supervisors [82]. These metrics enable an easier exploration of potential relationships between personality traits and ChatGPT usage, as prior studies have established associations between the design activities and big five personality traits [82]. Joonsten et al. (2024) compared ideas generated by human professionals and an AI system by assessing idea quality using three key metrics (novelty, customer benefit and feasibility, utilizing a 5-point Likert scale [83]. In order to reduce potential bias, the study used a cross-group blind evaluation to rate each idea in randomized order to reduce potential bias [83]. These assessment theories can support designers in enhancing creativity throughout the design process.

Since creativity generally depends on the designer's tacit thinking process, both approaches are highly dependent on humans’ ability in practical applications [59]. For instance, pattern adaptation to an actual design problem based on the empirical approach and the evaluation of the designers’ creative thinking process. Therefore, it has been a challenge to develop a scientific theory that is not dependent on humans’ ability [59]. Nevertheless, while the prior studies provide fundamental insights, they do not offer systematic methodologies to support design concept generation [59].

For instance, brainstorming is one of the most widely used techniques for developing novel concepts due to its simplicity and ease of learning; however, it is not a systematic approach that is highly dependent on a designer’s ability [59]. Additionally, some of the tools are challenging to master, highly dependent on users’ experience and different tools vary depending on personality characteristics and applications [84]. There is also a potential for a lack of creativity and challenges in transforming generated ideas into physical designs [82].

2.3.1 Related Theoretical Foundations

This section reviews several related key theoretical foundations, such as combinational theory, absorptive capacity and design thinking (DT), providing essential perspectives on how novel ideas emerged and are transformed into practical solutions. Three forms of creativity that can be achieved in our human mind, including exploratory creativity, transformational creativity and combinational creativity [85]. Exploratory creativity involves navigating within a conceptual space or structured thinking style. Transformational creativity entails modifying the conceptual space to generate ideas in a novel, structured style of thinking.

On the other hand, combinational creativity refers to the unfamiliar combinations of known ideas, which is considered the easiest type of creativity to achieve [85]. Such creativity may be formed through different elements, including words, ideas, concepts, sounds and images, and even abstract domains, such as music styles and artistic genres. Hence, combinational creativity has been broadly implemented across design and various applications [85]. Han et.al (2019) investigated the key drivers of combinational creativity by proposing three driven approaches: problem, similarity and inspiration, grounded by previous studies on design process, cognition and strategy [85]. The approach was evaluated through a case study, which revealed the effectiveness of all three approaches, which can be applied both independently and complementarily. These approaches can serve as idea generation methods, facilitating designers in generating innovative design ideas [85].

Furthermore, Han et al. (2020) explored conceptual distances for forming combinational ideas through computational perspectives, indicating different measurements revealed different outcomes of conceptual results [86]. The study emphasized that combining distantly related concepts or ideas could lead to more innovative outcomes [86,87]. Deo et al. (2021) highlighted that while many idea generation methods have been studied, the underlying factors that drive the effectiveness of those methods are not yet fully understood [88]. The study investigated the role of individual mechanisms in influencing the outcomes of idea generation by selecting idea-promoting mechanisms: classification and combination from the process category, and stimulation and building on others from comparable mechanisms. The ideas were assessed based on originality, quantity and novelty, and found that these mechanisms enhanced ideation performance and can be integrated into any idea generation method [88].

Chen et al. (2023) examined the capability of the computational model, DALL·E, which can generate creative visual concepts from textual input [89]. The study evaluated the model in achieving combinational creativity compared with the capabilities of human designers based on Turing test, expert test and computational test. The study revealed that the model can generate a comparable level to that of designers [89]. Nevertheless, to generate high-quality combinational ideas presents a significant challenge, which requires synthesis and conceptual reasoning [90]. Chen et al. (2024) proposed an enhanced AI foundation model approach that supports combinational creativity aimed to facilitate humans in externalising and verbalising combinational ideas [90]. The findings demonstrated that the combinational ideas generated using the proposed approach achieved higher scores compared to those without the use of a combinational strategy or an AI foundation model.

Consequently, a combinational creativity tool, "Combinator X," was developed to support idea generation. It helps improve combinational idea generation, reduces human effort and assists in refining combinational idea generation [90]. Similarly, Wang et al. (2025) highlighted that idea generation is an essential stage in the engineering design process, allowing the development of innovative prototypes and concepts. The study proposed an Object Combination Generative Adversarial Network (OC-GAN) for combinational creativity, advancing collaboration between humans and AI in generating ideas [91]. The findings revealed that the approach enables effective cross-domain concept combination, while also improving designers' workflow processes and enhancing the novelty of generated design concepts. It also highlights the viability of enhancing creativity in human-AI collaboration [91].

Absorptive theory is defined as an organization's ability to effectively utilize external knowledge through a sequential process in recognizing the value of external knowledge and integrating it through exploratory learning, and applying it to create new knowledge and value [92]. The prior studies of absorptive capacity primarily focused on innovation and learning, particularly in relation to the organization's performance and ability to acquire, integrate, and apply external knowledge. For instance, Cousins (2018) linked the absorptive capacity and dynamic capability theory for strategic consideration of DT in terms of organization design, learning and strategy [92]. The findings suggested that DT can function as a dynamic capability that enhances an organization's ability to integrate, learn and reconfigure external knowledge to gain competitive advantage [92].

Kohtamäki, et al. (2020) examined the interaction between absorptive capacity (ACAP) and entrepreneurial orientation (EO) by utilizing practice theory. The study analyzed K-means cluster with a quantitative dataset and found that the interaction between ACAP and

EO was associated with high profitability [93]. Three practices were identified, including proactive generation of ideas, benefit-driven product development and market-driven product commercialization, shaping strategic agility in innovation [93]. Similarly, Pattison (2022) explored the generation of ideas in GasTec by analyzing employees' interaction with a shared boundary object. The study demonstrated that such discussions and participation between employees enhanced the ability to absorb both internal and external knowledge [94].

DT theory emphasizes a human-centered approach that prioritizes empathy and user needs to develop meaningful solutions [92]. For instance, Uribe-Ocampo and Kaminski (2023) integrated DT and TRIZ approaches, whereby TRIZ focuses on technological evolution and DT emphasizes a user-centered approach. The model was found to effectively support problem clarification and facilitate the search for innovative solutions from both technological and users' perspectives [93]. Similarly, Silva et al. (2020) employed DT and TRIZ to improve new product development during the conceptual development stage in the automotive industry [94]. The study highlights the complementary strengths of DT and TRIZ, whereby DT focuses on user-centered understanding, while TRIZ provides systematic tools to produce the final product concept [94].

Prior studies highlighted the related theoretical foundations, including combinational creativity, absorptive capacity and DT, which provide important foundations for idea generation and innovation. Nevertheless, relying only on a single idea generation method and theories may be insufficient, as it limits the capabilities to generate novel ideas and design concept generation.

2.3.2 Novelty Potential Theory and Void Matrix

Although several idea-generation and design concept methods are available, only focusing on traditional approaches, such as brainstorming and mind mapping [95, 96], is insufficient and presents challenges to generating new and high-quality ideas. Nomaguchi et al. (2020) proposed a method supporting designers to generate novel design concepts based on the novelty potential concept. It assumes that combining different abstract concepts can lead to novel design concepts [97]. The novelty potential is quantitatively measured using lexical and distributional models such as WordNet and Word2Vec, which measure the similarity between concepts [97].

Previous studies focusing on analogical distance and concept generation performance, the analogy from the knowledge of the distant or unrelated domains tends to lead to high novelty concepts [98,99], supporting the assumption. Analyzing patent documents and

extracting abstract concepts may also result in the identification of unexplored high-novelty combinations. Furthermore, opportunities for innovation can be highlighted when combined with the void matrix to identify areas without existing patents. Based on the concept, Tachibana et al. (2022) generated novel ideas by combining sports and blockchain patents [100]. The ideas were evaluated with lexical and distributional word similarity, such as Word2vec [101], which is a neural network for processing corpus to extract abstract concepts from patent documents and to measure the concept distance.

By leveraging these two matrices, the novelty potential matrix and the void matrix, designers can systematically identify high-potential concept combinations that are both novel and underexplored [100]. Syamimi et al. (2022) also produced new business ideas to create an advanced video platform integrating blockchain technologies, AI and IoT devices for TKD SEs, utilising a similar concept [102]. It uses Word2vec to measure concept distance and the Continuous-Bag-of-Words (CBOW) model, which predicts the center word based on the surrounding words. The proposed methodologies offer new and unique insights, specifically for the sports industry [102].

Consequently, novelty potential evaluation facilitates the identification of highly novel concept combinations by presenting relationships between abstract concepts that are less frequently associated. However, several limitations remain. The process of concept extraction from patent documents is largely manual and labour-intensive, limiting scalability and reproducibility. Furthermore, the accuracy of novelty potential is dependent on the underlying semantic representation models, including Word2Vec or the universal sentence encoder (USE). Finally, the subsequent idea generation from novelty potential often relies on human interpretation and creativity.

2.3.3 Patent-based Design Catalogue

Design problems are often addressed by employing similar existing issues and their solutions from different domains [103]. Design catalogue created by Roth [2,3] is recognized as a foundational contribution in mechanical design, which emerged as a powerful tool for design concept generation by providing a systematic way to explore design possibilities. It organizes collections of design knowledge, solutions, and components that give a foundation for generating new concepts, which can then be combined and adapted to address new design challenges, enabling designers to explore potential solutions [104,105]. Figure 2.1 shows an example of Roth's design catalog.

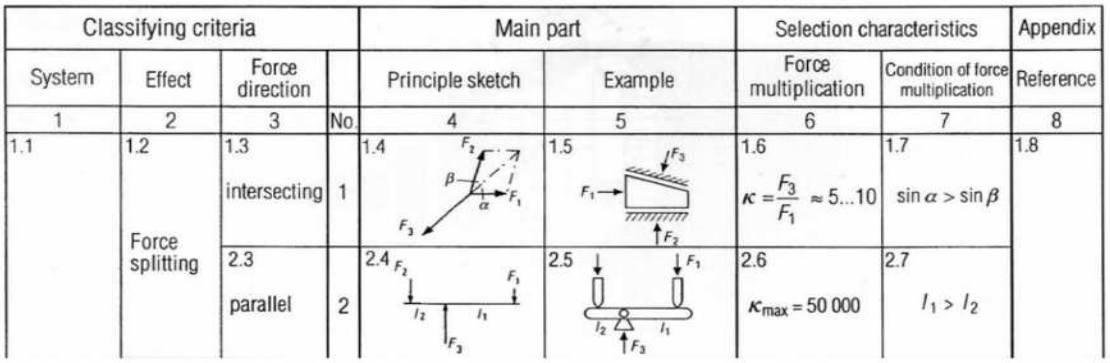


Figure 2.1 An example of Roth's design catalog illustrating the function of replicating mechanical force without supplement energy [3]

Its structure is that each row represents a pair of problems and solutions. Multiple solutions for a single problem are summarized, making it possible to compare and consider various solutions to the same problem. Solutions are expressed using elements such as sketches, examples, and conditional expressions. This tool is especially useful in the early stages of design, where the objective is to explore a wide range of ideas and identify promising concepts. However, most of the design catalogues' content is limited to the mechanical engineering sector, and their versatility is limited [105].

In addition, since they are developed manually, maintaining and updating the content is very time-consuming and requires a lot of effort. This proves to be difficult for designers to find the solutions they are looking for because the classification criteria are not clear [105]. Using classification systems such as CPC, patent-based catalogues enable cross-industry knowledge transfer. Despite certain limitations, Roth's design catalog provides a general form of design knowledge representation in the form of problem (*the classifying criteria or function*) and solution (*design principles*) pairs, adopted across many approaches [106].

Previous studies have been extensively conducted on extracting and generalizing problems and their solutions from existing design cases to reuse knowledge [104,105,107,108]. For instance, within the TRIZ framework [109], Altshuller analyzed and abstracted huge patent records and organized the generic solution patterns as inventive principles. Mann (2002) introduced a systematic approach to innovation and creative problem-solving based on the TRIZ framework, wherein the 40 inventive principles enhance versatility by abstracting problem-solving in diverse domains and integrating them into a pair of contradictions (design problem) and innovation principles [107].

Similarly, Rosen and Choi (2024) proposed a configuration design method for the design of mechanical metamaterials with the design library, which organizes physical principles and subtypes of metamaterial structure as pairs [110]. Chen et al. (2024) developed knowledge graphs as support tools to extract keywords from patents and documents related to the ecology of living organisms, which allows the identification of similar knowledge searches according to their relevance [108]. Nomaguchi et al. (2025) proposed a systematic method for generating design catalogues from patent documents, utilizing LLMs to extract problem–solution pairs from patent documents and presenting them as general purpose-means pairs. The effectiveness of the approach has been demonstrated for martial arts devices and in generating new design concepts based on the catalogue [106].

Although these approaches provide practical benefits and applications, the extracted keywords do not necessarily correspond to problem-solution pairs. However, they remain useful in supporting designers in exploring potential solutions relevant to specific design problems [106]. Nevertheless, creating the catalogue still entails human effort to extract knowledge from design cases and define the classification criteria.

2.3.4 Large Language Models (LLM) and Generative Artificial Intelligence (Gen AI)

Traditionally, ideating and generating new product innovations has been primarily the responsibility of designers, engineers and marketers. More recently, however, the emergence of large language models (LLMs) and foundation model-based Gen AI, including ChatGPT, has been widely applied in various sectors to brainstorm new product and service ideas, support design concept development and automate idea generation during the innovation process. Increasingly, it has also been integrated with traditional design tools, such as TRIZ, brainstorming, and DT, facilitating more effective human-AI collaboration. Such technologies facilitate the exploration of larger problem and solution spaces, augmenting humans to strengthen innovation outcomes [111]. Consequently, the concept of hybrid intelligence, where AI and humans will work together, prompts a re-evaluation of how innovation is approached and managed [111].

Several researchers examined the role of Gen AI in enhancing the TRIZ framework to improve idea generation during problem-solving [112-115]. For instance, the tool enhances the TRIZ methodology, facilitating the ideation process in eco-design by generating guidelines based on the latest technical advancements from patents [112]. Čok et al. (2025) examined the

role of LLMs in enhancing TRIZ-based problem solving within industrial product development by processing huge volumes of data and generating ideas [113]. The findings from comparing team-generated solutions solely by LLMs and those supported by TRIZ-enhanced LLMs revealed that although LLMs accelerate idea generation and offer practical solutions, the additional incorporation of TRIZ principles offers unique insights [113]. Phadnis and Torkkeli (2025) investigated the effectiveness of integrating GenAI with TRIZ in real innovation projects addressing a similar customer-defined problem, based on the degree of similarity, depth, and breadth [114].

The comparative case study demonstrated that the TRIZ-GPT combination can generate feasible, cross-domain preliminary conceptual directions supported with satisfactory scientific grounding. Furthermore, it also significantly reduces the time exploring preliminary concepts and problem-solving in idea generation [114]. Similarly, several AI-integrated tools were introduced within the TRIZ framework that provide structured analysis, imaginative recombination and facilitate cross-disciplinary insights [115]. For instance, a systematic idea generation tool that categorizes resources and recommends strategic modifications to components or processes to support innovation within existing systems. Other tools include the resource innovator for non-engineering, which helps extend the applicability of TRIZ beyond traditional engineering domains into areas such as education, nursing, and communication [115].

Prior studies have also explored the integration of Gen AI into the DT framework. [116-118]. Chans et al. (2025) investigated the impact of incorporating GenAI tools, including ChatGPT, Perplexity, and Gemini, into various stages of a product DT activity by employing a single-group pretest-posttest design [116]. The findings indicated a significant increase in the perceived usefulness of AI and moderate improvements in affective empathy, suggesting that GenAI can facilitate student creativity using idea generation while expanding end users' consideration in product design [116]. Asadi (2023) adopted an autoethnographic approach to examine the integration of LLMs, such as ChatGPT and Google Bard, as supportive tools in the DT process, providing unique insights and potential tools for innovation for design practitioners and UX researchers [117].

Furthermore, Fischer et al. (2023) investigated the integration of ChatGPT with a DT workshop by utilizing the tool across all DT stages, including empathize, define, ideate, prototype and test. They found that ChatGPT enables design thinkers to gain a fast overview of the problem and evaluate it based on given criteria. Notably, the study highlights the tool's capability to generate a large number of ideas and adjust based on given input [118].

On the other hand, Chen et. Al (2024) employed a mixed-method approach involving the System Usability Scale (SUS) questionnaires and interviews with graduate students to evaluate the integration of ChatGPT into the DT framework. The scores demonstrated moderate usability between "OK" and "Good", focusing on areas of idea generation and data exploration [119]. Several challenges were identified, including repetitive and vague responses, limited capability to advance, doubt to answers and difficulty in digitizing data. Structured guidance on prompt and introduction on digital tools is recommended for improving usage [119].

Additionally, ChatGPT is employed as a concept generation tool that aids in improving the number and novelty of the generated concepts [82]. Moreover, LLMs can also generate a greater variety of design concepts when multiple prompts are applied in parallel. Each prompt uses a professional persona or is given a sequence of prompts with several professional personas to gradually generate and refine the design concepts [120]. Joosten et al. (2024) also conducted a comparative study evaluating the ideation quality of Gen AI against human professionals, revealing that AI-generated ideas achieved significantly higher scores in novelty and customer benefit, while scoring similar to human ideas in terms of feasibility [83].

Furthermore, analysis of evaluators' emotional and cognitive responses indicated no significant bias between the idea groups, suggesting organizations can benefit by incorporating Gen AI into their conventional idea-generation processes [83]. Guo et al. (2025) proposed a benchmark system (IdeaBench) to address the lack of a systematic evaluation framework for benchmarking and comparing LLMs through a reference-based metric that aligns with human assessment to quantify idea quality with LLM assistance. Despite revealing strong capability in generating novel ideas, feasible ideas remain a challenge [121]. Among the limitations of utilising ChatGPT is its ineffectiveness compared to traditional design methods [82]. The complex prompt engineering may also pose challenges to the design process in human-computer interactions [112].

Although ChatGPT can support human capabilities, it cannot substitute human design thinkers and human-generated insights [118]. By solely incorporating ChatGPT in DT, the creativity technique loses its human touch and important focus on empathy, especially deep perspectives through observation and interviewing users [118]. Furthermore, the chatbot is not trustworthy based on market data, including incorrect information, inconsistency, or unavailability of the correct reference. Therefore, it is essential to specify the information during the DT process, as failure to do so poses a high risk of gaining misleading information [118]. While AI serves as an effective tool for rapid idea generation, it lacks user empathy [14].

In contrast, designers' core competencies in creative problem solving and user-centered design remain essential, particularly in refining, expanding ideas and providing solutions through empathy and human-centered insight [122]. Consequently, the complementary collaboration between AI and designers enhances both design efficiency and creativity [122]. Another limitation regarding these types of tools is that while they can be beneficial for designers to inspire novel ideas, they still exhibit limited capacity to discern technically feasible ideas [123-124]. Furthermore, there are also challenges, including failures of LLM self-evaluation and their limited diversity in generation [124].

Consequently, depending solely on Gen AI, such as ChatGPT to generate novel ideas may be inadequate. While it can primarily facilitate humans during the problem definition and idea generation stages, the processes of idea selection and evaluation remain predominantly driven by human judgment [125]. Therefore, a hybrid intelligence model collaboration between AI and human innovators is proposed in the idea generation phase to facilitate human innovators [126]. Viewing AI as a complementary tool within the design process in collaboration with human creativity and AI-generated ideas, is essential. Human oversight in AI-assisted design processes is also vital to ensure creativity, feasibility, relevance, and alignment with real-world applications.

2.4 Research Approach

Although numerous ideation tools are available, few studies have specifically addressed developing novel design concepts for TKD SEs. Consequently, this study suggested a comprehensive strategy to increase innovation in TKD SEs by generating business ideas and creating novel design concepts for future TKD systems and businesses. First, patent and non-patent trends were analyzed related to TKD and technologies, including blockchain, information technology and systems (IT/IS) by utilizing the cooperative patent classification codes (CPC) and co-occurrence networks created from text mining to identify important keywords.

Additionally, the patent trends were also analyzed using the novelty potential concept, assessed by the Word2vec algorithms. The novelty potential concept refers to the idea that the more different two abstract concepts are, the more novel their combination would be. Finally, multiple ideation methodologies, namely the novelty potential/void matrix**,** CPC-based design catalogue**,** and Gen AI, such as ChatGPT were integrated.

This study considered ChatGPT not a standalone ideation tool, instead it helps refining ideas generated from structured frameworks, including novelty potential, void matrix, and design catalogue. The integrative approach enabled synthesizing diverse ideation techniques, facilitating innovative design concept generations tailored to the unique requirements and constraints of TKD SEs.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter presents the research methodology employed to achieve the objectives of this study by adopting a mixed-method approach as presented in Figure 3.1. Both quantitative and qualitative data were obtained from patent and non-patent data, including journals and semi-structured interviews to provide comprehensive richer insights. First, patent and non-patent investigation are conducted to identify technological trends, key knowledge sectors and emerging opportunities. This stage establishes a data-driven foundation for identifying innovation gaps and technological directions.

Second, case studies are conducted to support novel design concepts creation in the early stages of product development. The first case study analyzed patent data by utilizing the novelty potential concept (word2vec) to evaluate semantic distances between concepts and identify high-novelty combinations. It assumes that the more different the two chosen concepts are, the more novel the subsequent combination would be.

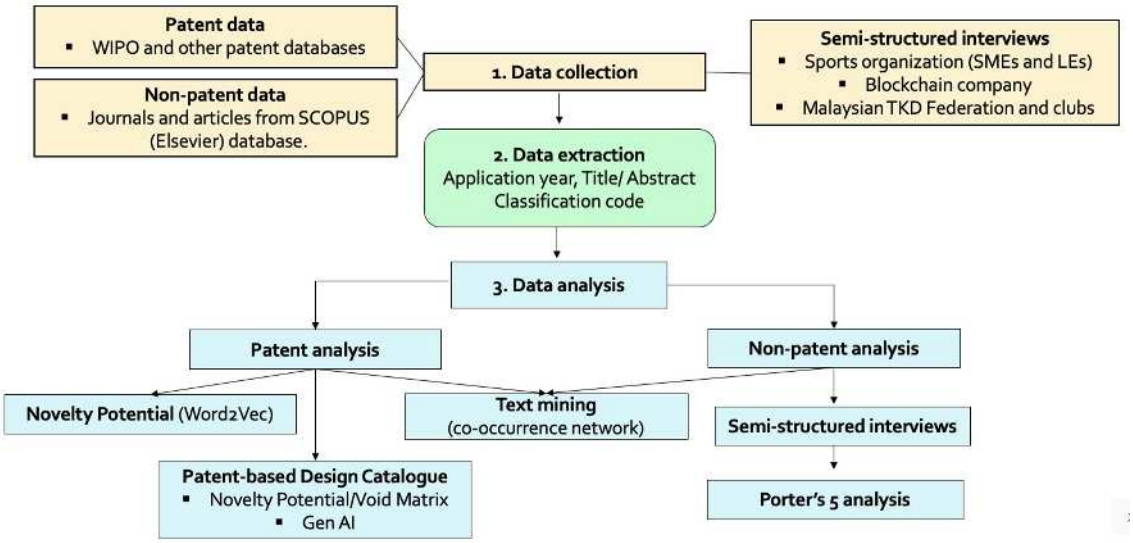


Figure 3.1 Research methodology flowchart

The second case study which is the main contribution of the study's methodology, further extends the novelty potential approach by employing three idea generation methodologies, mainly the novelty potential/void matrix, patent-based design catalogue and Gen AI models, including ChatGPT. Gen AI is incorporated as a supporting tool to enhance and refine the generated concepts derived from the proposed methods. It is also used a comparison benchmarking with the ideas generated from our proposed method to demonstrate the effectiveness of our proposed approach.

Additionally, qualitative data were gathered through semi-structured interviews with representatives from stakeholders, including POs (SMEs and LEs in the sports industry), a blockchain technology organization and the Malaysian TKD Federation and clubs. The interviews provided practical insights into business models, innovation challenges and feedback on the design catalogue usability and potential implementation in real-world applications. Finally, ethical considerations were addressed, including informed consent procedures, data anonymization and secure storage and intellectual property and accountability in using AI-generated content.

3.2 Patent and Non-Patent Data Investigation

Patent analysis can provide valuable insights for examining a technical area or an innovative mechanism. Patent records are a valuable data resource if the evidence is analyzed systematically, as in general, patent information reflects the state of the industry. Non-patent data include scientific papers and books, among others, which provide information from the latest research in specific areas. Both patent and non-patent data are essential to obtain the complete and actual picture of TKD and other industries for the current study.

Therefore, this study conducted patent and non-patent data investigation to identify and compare trends across various industries, including sports, martial arts, and technology sectors by observing the changes in the number of patents by application year and technological focus area using CPC codes. Co-occurrence network analysis was also conducted to identify potential keywords and trends. Additionally, a comparison between the number of documents between patents and non-patents was conducted by performing statistical analysis to measure the strength of the relationship between them. Figure 3.2 presents the methodology flow for patent and non-patent data investigation, including data collection, data extraction, data preparation and data analysis.

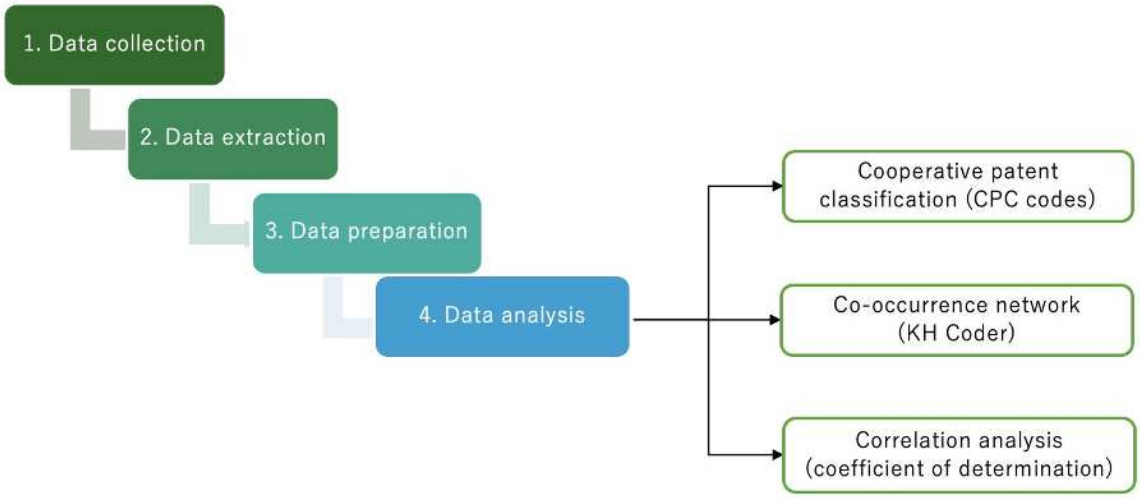


Figure 3.2 Methodology process for patent and non-patent data investigation

3.2.1 Data Collection and Extraction

The first step is to collect the patent and non-patent data and extract the desired information from it, including titles, abstracts, application year and CPC codes. We collected patent data from the World Intellectual Patent Organization (WIPO) and other patent databases, while non-patent data were sourced from the SCOPUS database, including journals and articles. The keyword searches were related to sports and martial arts such as "taekwondo," "karate," "judo," "e-sports," "baseball," and "basketball," in the Title OR Abstract OR Claims fields for the 2000-2019 period. For other technology-related sectors, keywords such as "blockchain," "distributed ledger," "smart contracts," "information technology," and "information system" were searched in similar fields and periods.

3.2.2 Data Preparation

Before analysis, the raw text collected from patent and non-patent data undergoes several pre-processing procedures to ensure data quality and consistency, resulting in clean textual inputs appropriate for computational analysis. This process involved excluding irrelevant special characters, symbols, punctuation and stopwords, which are referred to as highly common words that produce little value to the content analysis, such as "the" and "an." Following pre-processing, quantitative analysis is performed using co-occurrence network graphs to analyze and visualize the patent and non-patent data.

3.2.3 Patent analysis: Cooperative Patent Classification (CPC)

This section describes the patent data analysis using CPC codes to examine trends and other relevant information. Patent documents contain rich metadata, including application dates, applicants, classification codes, graphical information and textual descriptions, which provide valuable insights into technological development. Among these elements, patent classification codes play a central role in identifying the technological domain of an invention, including CPC, IPC, and those used domestically such as ECLA USPC, FI, and F-term. Although the IPC system has already been defined for patent classification, it has limitations in terms of the classification of novel technologies as well as detailed classifications [127].

Meanwhile, CPC code is a refinement of the current IPC, which includes more subdivisions and additional text used for searching and examining patents based on a hierarchical system for classifying inventions [128]. It is a patent classification system jointly developed by the European Patent Office (EPO) and the United States Patent and Trademark Office (USPTO) to significantly enhance the retrieval performance and classification accuracy of patent documents [128]. CPC system extends the IPC system by incorporating more detailed subgroups that include a new domain (Y-section), which allows for a broader and more comprehensive range of technology classifications than the IPC, encompassing over 260,000 detailed taxonomies [127]. The CPC system employs a hierarchical five-level structure that enables systematic refinement from broad technological domains to highly specific technical subject matter [129].

For instance, Figure 3.3 shows a complete CPC code such as A01B33/08. The first letter is the “section symbol” consisting of a letter such as “A” (Human necessities) to “G” (Physics) to “Y” (new technologies). Next is the “class symbol” which consists of a two-digit number (“A01” which represents “Agriculture; forestry; animal husbandry; trapping; fishing”). Finally, the final letter makes up the “subclass” (A01B represents “Soil working in agriculture or forestry, parts, details, or accessories of agricultural machines or implements”), followed by a 1 to 4 digits “group number”, an oblique stroke and a number of at least 2 digits representing a “main group”, “subgroup” or “lower sub-group.” Patent examiners designate CPC classifications to patent applications and other related documents at the most detailed level that appropriately captures the technological content and scope of the invention.

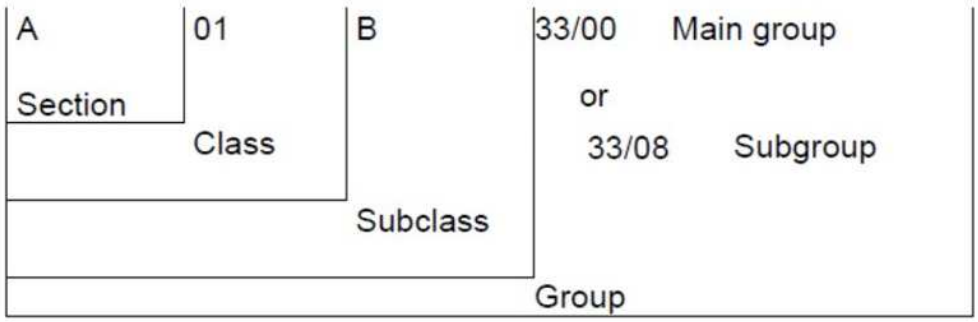


Figure 3.3 A structure of Cooperative Patent Classification (CPC) (retrieved from the USPTO website) [129]

This allows for a more accurate analysis of patent documents and is particularly beneficial in fields with rapid technological advancements, such as AI and IoT, where detailed classification can uncover hidden trends and convergence points. Building upon this hierarchical structure, CPC codes have been extensively utilized in prior research to analyze technological convergence and innovation dynamics across diverse fields. Previous studies have employed similar approaches using patent classification codes to investigate technology convergence trends [130-132]. For instance, the convergence of IoT and wearable technologies has been investigated using CPC codes, revealing frequent convergence areas and trends over time [130].

Patent information is particularly valuable for such analyses, as it captures accumulated technological knowledge and reflects the direction of innovation within specific domains. Consequently, CPC codes play a critical role in global patent research and enable more precise identification of technological domains, evaluating patent value, and understanding technological convergence compared to the IPC. In this study, key patent metadata, including application name, title, application year, and abstract, were collected and extracted alongside the CPC codes to examine the underlying technological structure, emerging innovation areas and CPC technological domains that are most relevant for TKD.

First, the descriptive information was presented to examine publication trends by application year and the technological development trends based on top CPCs. Second, a co-occurrence network analysis of CPC codes was conducted to reveal conceptual linkages and relationships between technological domains. This approach enabled a clearer understanding of the recent technological landscape and highlighted the CPC codes that TKD SEs should prioritize.

3.2.4 Co-occurrence Network

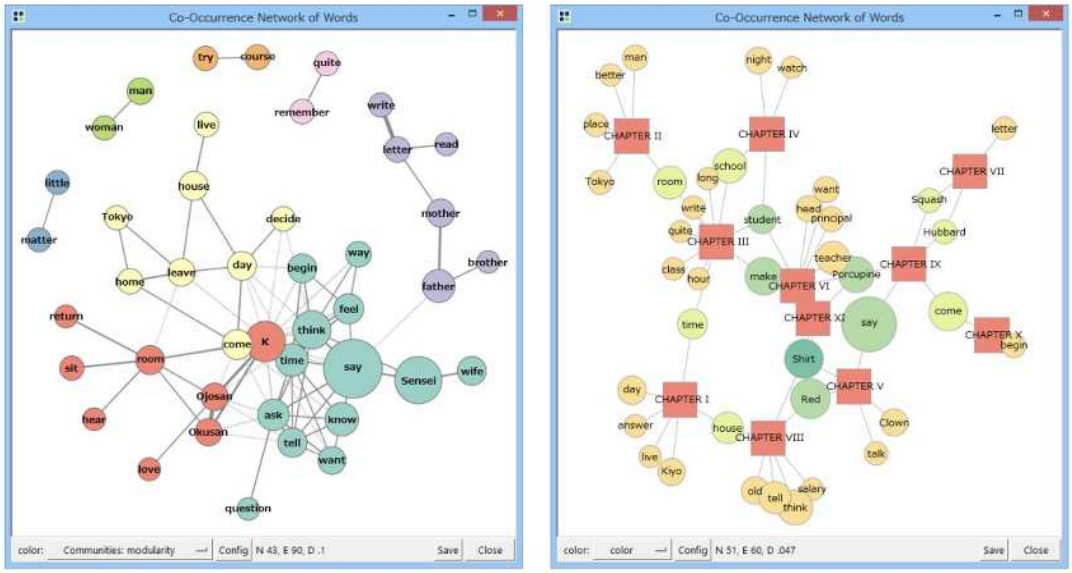
This section outlines the methodology employed using co-occurrence network graphs to analyze and visualize the data, revealing hidden trends and conceptual relationships from both patent and non-patent abstracts, including CPC information, through conventional text-mining procedures. Text mining refers to the process of discovering new and previously unknown insights through computers, by automatically extracting information from various written resources [133]. Unlike structured databases, text mining identifies patterns extracted from natural language text to uncover information that has not been explicitly discovered or formally recorded [133].

(i) The use of KH Coder

This study utilizes a free and easy-to-use software, KH Coder [134], designed for text mining and quantitative content analysis to construct the co-occurrence network diagram. The software is capable of handling large-scale data through automated document pre-processing, frequency and co-occurrence analysis, coding and advanced multivariate statistical techniques, including correspondence analysis and hierarchical cluster analysis. These functions enable the identification of clusters, relationships, and conceptual structures within extensive text datasets.

However, the software poses certain limitations concerning the volume of data it can handle [134]. Figure 3.4 presents an example of co-occurrence network graphs generated by KH coder using word-word and word-variable. For instance, the association between words and headings presents the headings of chapters (“Chapter II”) and frequently appearing words such as “man,” “Tokyo,” “better,” and “place,” and how they connect. The co-occurrence network serves as a graph illustrating word interactions that represent co-occurring patterns within the text data [135] and has been extensively applied in various graph-based NLP applications, including keyword extraction [136] and word sense discrimination [137].

It is specifically suitable for analysing sparse data by offering a graph-based representation of potential relationships between key entities, including concepts, individuals, organizations or ideas. It is constructed by linking words (nodes) that frequently appear together within a corpus, known as co-occurring neighbours. Node size represents the word frequency, while edges (lines) connecting nodes indicate co-occurrence relationships, with the strength of edges between two words is determined by the value of Jaccard coefficient [135].



(a) Words–words network (b) Words–variable/headings network

Figure 3.4 Example of co-occurrence network (retrieved from KH coder manual)

In order to evaluate the strength of associations between words, the Jaccard coefficient was employed. Jaccard coefficient measures the similarity between two words based on their shared neighbors, with values ranging from 0 to 1, where higher values indicate stronger co-occurrence. Words that frequently appear together within the same sentence or paragraph typically reach a Jaccard coefficient close to 1, signifying a strong relationship. To ensure the readability and interpretability of the network, only the strongest co-occurring pairs were included by applying a threshold value for the Jaccard coefficient. This prevented overcrowding and highlighted the most meaningful connections.

(ii) Network structure: Modularity and betweenness centrality

Once edge strength was determined, network structure analysis was conducted to identify clusters and influential words. Groups of highly connected words form neighbourhoods representing conceptual clusters within the dataset. Within each cluster, words that were more closely connected form communities or subgraphs, distinguished by a specific color in the diagram based on modularity. The co-occurrence network is divided into thematic clusters, with each color-coded group representing words that frequently co-occur, indicating conceptually related domains or terms by the modularity structure [134]. High modularity suggests that a network consists of densely connected words within subgroups and weak connections between words belonging to different subgroups.

There are three primary measures of centrality — betweenness, degree and eigenvector commonly applied in social network analysis to determine how influential each word is within the network [134]. Betweenness centrality measures the extent to which a node lies on the shortest paths connecting other nodes, thereby indicating its role as a bridge or mediator between distinct concepts or domains [138]. This study utilized betweenness centrality to identify keywords with high betweenness centrality, which were considered influential. Furthermore, they connected otherwise disconnected clusters, facilitating the flow of information and association within the co-occurrence network.

The co-occurrence network analysis provided a systematic means to extract, visualize, and interpret meaningful relationships between terms in both patent and non-patent abstracts, including CPC information. By integrating measures such as modularity and betweenness centrality, it revealed thematic clusters and key conceptual linkages that may not be easily visualized in isolated texts.

3.2.5 Correlation Coefficient Analysis

Correlation analysis was employed to evaluate the degree of association between non-patent literature (e.g., journal publications) and patent activity in key technological areas such as blockchain. The analysis aimed to quantify the extent to which academic research outputs correspond to innovation activities in industry, as reflected through patent filings. Accordingly, it indicates knowledge transfer and technological responsiveness between academia and industrial domains. The annual publication trends of patent and non-patent data were compared and calculated using the coefficient of determination (R^2) to assess the strength of the linear relationship between the two variables.

The correlation coefficient (r) is sometimes criticized for its limited interpretability; therefore, the square of the correlation coefficient (R^2), referred to as the “coefficient of determination” is often reported to represent the proportion of variance in one variable explained by the other [139]. In this study, R^2 represents the proportion of variance in patent activity explained by non-patent publication trends. The coefficient of determination values range from 0 to 1, where values closer to 1 indicate a stronger positive correlation between the two variables. To facilitate interpretation, the correlation strength was categorized using standard threshold values [139-140] as presented in Table 3.1.

Table 3.1 Interpretation of the Correlation Coefficient Values

R^2 Range	Correlation Strength	Interpretation
0.0 – 0.10	Negligible correlation	No meaningful correspondence between research and patent activity
0.0 – 0.39	Weak correlation	Minimal correspondence; research and patent activities evolve largely independently
0.40 –0.69	Moderate correlation	Moderate correspondence with notable independent variation
0.70 – 0.89	Strong correlation	High synchronization between research and patent activity
0.90 – 1.00	Very strong correlation	Near-perfect correspondence; research outputs highly correspond to innovation trends

Values above 0.7 interpreted a strong correlation, values between 0.5 and 0.7 suggested a moderate correlation, and values below 0.4 indicated a weak or no correlation. Higher R^2 values (≥ 0.70) signify a strong degree of synchronization between academic research and industrial innovation, suggesting that developments in scholarly publications are closely reflected in subsequent or concurrent patent filings. This trend may indicate effective knowledge transfer between academia and industry, or that both sectors respond similarly to emerging technological opportunities. Conversely, lower R^2 values (< 0.40) suggested that research and patent activities evolve independently, suggesting limited interaction between the two sectors due to divergent priorities or barriers to knowledge transfer.

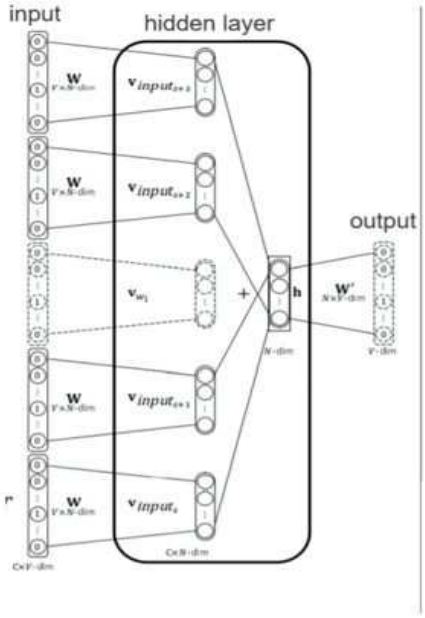
3.3 Novelty Potential (Word2Vec) and Void Matrix

As part of the methodology, the novelty potential concept was used in this study to discover new ideas by combining sports and blockchain patent data. Generating new design ideas in the conceptual design phase is a foundation for developing innovative products and combining existing abstract concepts will result in the creation of new ones. Therefore, the idea of novelty potential was introduced to determine the potential of the two function concepts, the combination of which would lead to novel concepts based on their corresponding patent

abstracts. It assumes that the more different the two chosen concepts are, the more novel the subsequent combination would be [97]. The combination is calculated with a distributional semantics method known as Word2vec [101] and a neural network for processing corpus.

Word2Vec was selected compared to more advanced model such as Bidirectional Encoder Representations from Transformers (BERT) as this study prioritized measuring semantic relationships and conceptual distances between abstract concepts from patents data rather than contextual sentence interpretation. Word2Vec is a group of related models that are used to produce word embeddings. These models are shallow, two-layer neural networks that are trained to reconstruct linguistic contexts of words. It takes as its input a large corpus of text and produces a vector space, typically of several hundred dimensions, with each unique word in the corpus being assigned a corresponding vector in the space.

Word vectors are positioned in the vector space such that words that share common contexts in the corpus are located close to one another in the space. The vector space gives a cosine similarity between two vectors. There are two different methods in the Word2Vec algorithm, including Continuous bag of words (C-BOW) and Skip-Gram (SG). This study utilizes the supervised learning method, C-BOW to predict the center word from the surrounding words. It takes surrounding words as input data and outputs the center word. Figure 3.5 shows the C-BOW neural network, where h in the hidden layer is the average of the results of each word and W.



$$\mathbf{h} = \frac{1}{C}\mathbf{W}^T(\mathbf{x}_1 + \mathbf{x}_2 + \cdots + \mathbf{x}_C)$$
$$= \frac{1}{C}\left(\mathbf{v}_{w_1} + \mathbf{v}_{w_2} + \cdots + \mathbf{v}_{w_C}\right)^T$$

Figure 3.5 C-BOW neural network.

Furthermore, the novelty potential analysis using Word2vec only utilized patent abstracts instead of CPC codes to analyze semantic relationships between abstract concepts and measure conceptual distance. Figures 3.6 and 3.7 show the creation flow of new ideas based on the novelty potential concept and the relationship between entity and abstract concepts in the analysis process. The first step is the collection of patent data abstracts related to sports and blockchain based on keywords search, followed by concepts extraction, concepts classification, creation of novelty potential and void matrix and finally the creation of new ideas based on novelty potential and void matrix. With these proposed methods, TKD SEs can increase their innovation activities and generate business ideas to increase revenues.

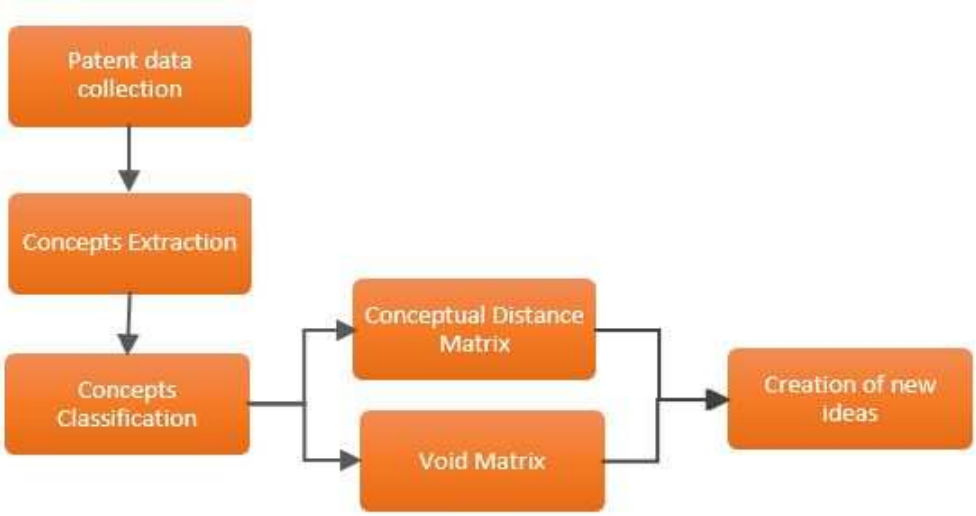


Figure 3.6 Flowchart of patent data analysis related to blockchain and sports

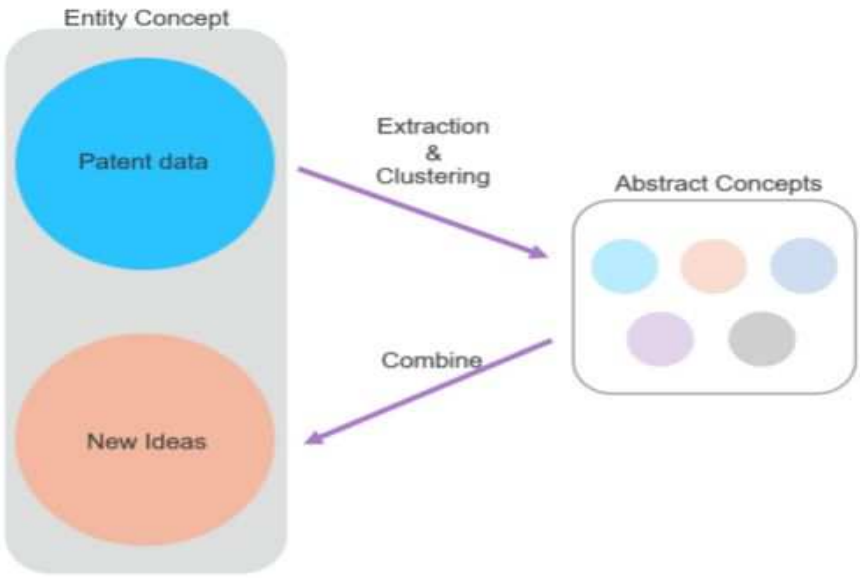


Figure 3.7 The relationship between entity and abstract concepts in the analysis process

3.3.1 Patent Data Collection

The text of the abstracts of the patents related to the technical area to be analyzed was examined. Using the keywords "sports" and "blockchain," the patent abstracts from the patent database was extracted from 2000-2019. To improve the classification accuracy of the concepts contained in the patent text, pre-processing was performed on the patent information.

3.3.2 Concepts Classification

The hierarchical structure of the concepts in the abstracts was constructed using the following procedure.

(i) *Step 1*- Normalizing the word vector, taking their average in one sentence, and using it as the sentence vector.

(ii) *Step 2*- Calculating the cosine distance between sentence vectors.

The distance between all sentence vectors and between each concept was assessed by measuring the cosine distance, as shown in Equation 1. Here, u and v represent the two sentence vectors, respectively. The cosine distance represents the similarity of the tendencies of the content of two sentences; the smaller the value, the shorter the distance, meaning that the two sentences tend to have similar contents. We hypothesized that a group of abstract concepts close to each other corresponds to a higher-level abstract concept.

$$Cos\ distance = 1 - \frac{uv}{|u||v|} \qquad (1)$$

(iii) *Step 3*- Build a hierarchical structure with dendrogram using Ward's method for grouping.

3.3.3 Creating Concept Novelty Potential and the Void Matrix

The novelty potential between the abstract concepts sets was measured. The length between abstract concepts is the concept distance, which influences the novelty potential. The values in a matrix with abstract concepts arranged vertically and horizontally were placed. Next, a void matrix based on information such as the type of abstraction contained in each patent was created. For example, if the abstract concepts of patent A and patent B intersected with each other, it assumed that there was one patent that included both concepts A and B.

3.3.4 Generation of a New Design Concept

When combinations with long distances between concepts are selected, the novelty is high. Common cells with a greater distance in the novelty potential matrix and void (0) cells in the

void matrix can be new idea concepts. In the subsequent section, methodologies using a patent-based design catalogue was presented.

3.4 Patent-based Design Catalogue

This study utilizes idea generation methodologies, novelty potential/void matrix, design catalogue based on CPC codes, and Gen AI to support novel design concepts creation in the early stages of product development. The approach is grounded in three complementary theories: combinational creativity, absorptive capacity and DT, which together create a robust theoretical foundation for knowledge-driven innovation. Creativity in the human mind can be generated through three approaches, including exploratory creativity, transformational creativity and combinational creativity [85]. Among these, combinational creativity is considered the easiest approach to creativity by combining ideas that were previously unrelated or indirectly related. Such combinations can be derived through different elements such as concepts, ideas, words, sounds and images [85].

Absorptive capacity theory defines a firm's ability to utilize external knowledge through a sequential process. The process enables firms to identify the value of external knowledge, incorporate it through exploratory learning and apply it to generate new knowledge and value [92]. Finally, DT focuses on a human-centered approach, which emphasizes empathy and prioritizes user needs to create meaningful solutions [92]. Therefore, relying on a single idea generation method may be insufficient, as it limits the capabilities to produce novel outputs. Table 3.2 summarizes the theories' relation to the research approach.

Table 3.2 Theories' relation to the research's approach

Theory	Definition	Relation to approach
Combinational creativity	Generating novelty by associating ideas that were previously unrelated or indirectly related	Combining unrelated patents such as TKD and audience behavior to create new design ideas
Absorptive capacity	The organization's ability to identify, acquire, assimilate and exploit external knowledge	Leveraging on external patent information such as CPC codes to recombine ideas
Design thinking	Human-centered problem framing to recognize most vital aspects of problems and creating solutions from potential solutions	Applying human evaluation and empathy to address TKD challenges in selecting possible solutions generated by GenAI

The flowchart of patent data analysis for generating new design concepts and overview of creating design catalogue and design knowledge retrieval are shown in Figures 3.8 and 3.9. The design catalogue creation process consisted of patent data collection, design knowledge extraction from the patent data, and clustering design knowledge pieces into abstract purposes and means. Firstly, the design catalogue method, which utilizes patent data as information sources, was utilized to extract the purpose-means pairs known as design knowledge [106]. In this study, *P* denotes purpose, *M* represents means, and *F* is the design problem. A retrieval approach was then suggested with the design catalogue to generate a design concept [106].

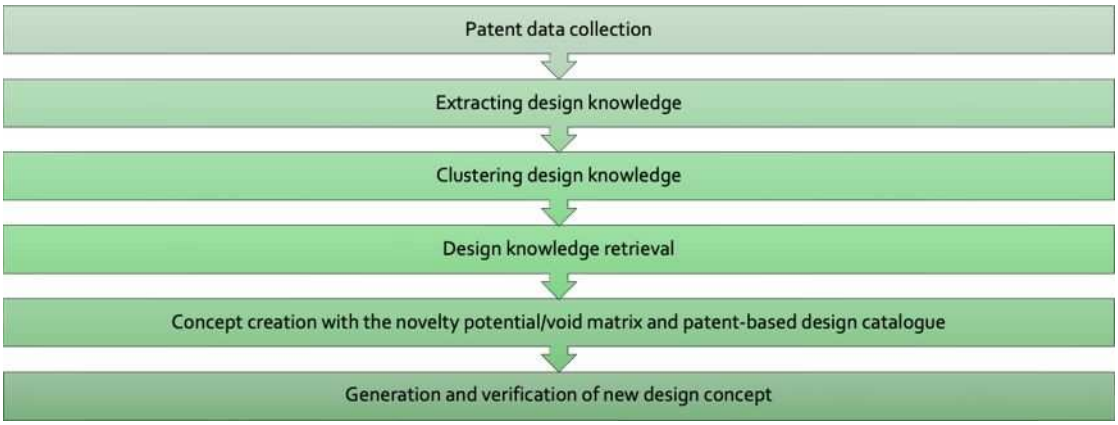


Figure 3.8 Flowchart of patent data analysis for generating new design concepts

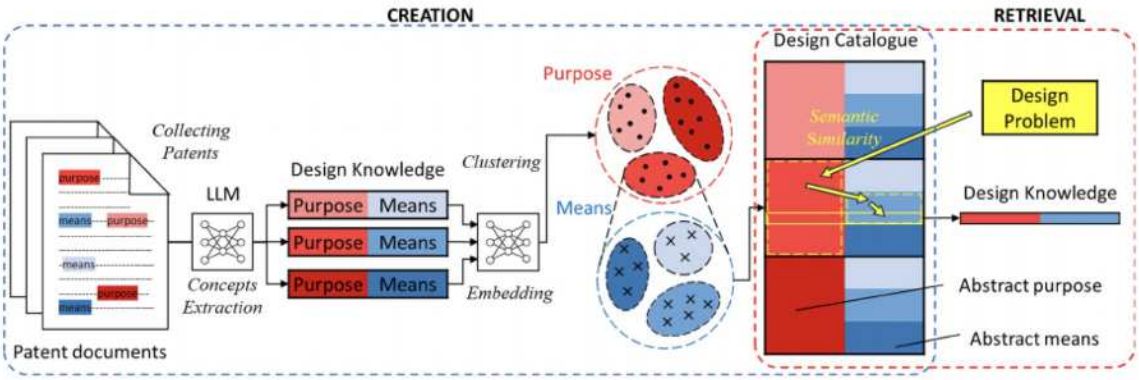


Figure 3.9 Overview of creating design catalogue and design knowledge retrieval [106]

Finally, new design concepts were created and compared with the ideas generated by LLM models, including ChatGPT, Gemini and DeepSeek. All ideas were independently evaluated by expert reviewers based on novelty, feasibility and market potential. A CPC code investigation was also performed to verify the proposed novel ideas. Furthermore, semi-structured interviews were conducted through online and face-to-face meetings with the representatives of the Malaysian TKD federation and clubs on innovation challenges and feedback on the design catalogue.

3.4.1 Patent Data Collection

A keyword search in the field of "Title" OR "Abstract" OR "Claim" enabled patent data collection from patent databases involved in this study. Valuable information was extracted, such as titles, abstracts, application year, and CPC codes, from 2000 to 2019. In this study, "Audience Behavior (ab)" and "Taekwondo (tk)" were considered to be related to "digital technology" as keywords that are relatively close to design problems. Furthermore, "Digital Transformation (dx)" and "Waste Management for Public Health (wm)" were selected to drive innovative design concepts, considering their growing importance driven by the recent emphasis on promoting sustainable development goals (SDGs). The keywords applied are shown in Table 3.3.

Table 3.3 Keywords search in patent database: Application year 2000-2019

Patent Name	Keywords
Taekwondo (tk)	("taekwondo" OR "taekwando" OR "tae-kwon-do" OR "tae-kwan-do" OR "taekwon-do")
Audience Behaviour/Emotion technologies (ab)	("player emotion" OR "audience emotion" OR "crowd emotion" OR "fan emotion" OR "viewer emotion" OR "player behavior" OR "audience behavior" OR "crowd behavior" OR "fan behavior" OR "viewer behavior" OR "viewer cheering" OR "audience cheering" OR "crowd cheering" OR "fan cheering" OR "viewer excitement" OR "audience excitement" OR "crowd excitement" OR "fan excitement" OR "player gesture")
Digital Transformation (dx)	("digital transformation")
Waste Management (wm)	("waste management")

3.4.2 Extracting Design Knowledge

Following patent data collection, design knowledge pieces described in the patent from the title and summary of patent data were obtained with the feature OpenAI in GPT-4 [141]. The model can perform various tasks through few-shot learning, carefully leveraging constructed prompts with relevant examples and instructions rather than focusing on reinforcement learning. This study also constructed a prompt that included an instruction outlining the task of extracting *P–M* pairs, an example sentence illustrating the desired output format, and the title and summary of the target patent. Furthermore, the large language model (LLM) was instructed to include

the original text segment ("Source") from each design knowledge piece to mitigate hallucination, where the model might generate inaccurate or unsupported design knowledge. The step allowed human evaluators to assess the validity and traceability of the extracted information.

3.4.3 Clustering Design Knowledge

The extracted *P* and *M* in design knowledge pieces in this study were clustered as follows:

(i) *Step 1*- Distributed representations of *p* and *m* for the texts representing the *P* and *M* of design knowledge were derived with GPT-4 represented by a 1532-dimensional vector.

(ii) *Step 2*- Abstract purposes were identified by clustering a set of *p*. A design knowledge collection with an abstract purpose was then referred to as a *p-cluster*. The distributed representation captures the meaning of each text, with the text nearest to the centre of gravity of the cluster reflecting the overall meaning. The text of *P* nearest to the centre of gravity of the *p-cluster* was selected as the representative *P* for the abstract purpose.

(iii) *Step 3*- The design knowledge pieces were clustered in the *p-cluster* by *m*. Each cluster denoted an abstract means in the *p-cluster*, referred to as the *m-cluster*. The *M* nearest to the centre of gravity of the *m-cluster* was then chosen as the representative *M* of the abstract means.

This study applied Ward's method, an agglomerative hierarchical clustering technique, in *Steps 2* and *3*. The classification was determined by the cosine distance between the distributed representations expressed in Equation (1).

$$\cos(\boldsymbol{u}, \boldsymbol{v}) = (\boldsymbol{u} \cdot \boldsymbol{v}) / (||\boldsymbol{u}|| \, ||\boldsymbol{v}||) \quad (1)$$

3.4.4 Design Knowledge Retrieval

A design catalogue offers a designer various alternative *M*s corresponding to the *F* by retrieving design knowledge with an abstract purpose. In this study, the following steps were performed according to design problem similarities:

(i) *Step 1*: The similarities between *F* and each *P* of *p-clusters* were assessed according to Eq. (1). An abstract purpose from the *P*s corresponding to *F* was then selected, denoted by *P*.

(ii) *Step 2*: The *M*s list representative of the *m-clusters* in *P* provided an overview of alternative multiple *M*s corresponding to the *F*. Subsequently, similarities between *F* and each representative *M* from the *m-cluste*r were evaluated based on Eq. (1) and the most relevant

M was then selected. *Step 3* was performed if investigating more specific means was desired.

(iii) S*tep 3*: The *M*s list from *M* indicates the specific means. An *M* corresponding to the *F* can be selected by assessing the similarities between them with Eq. (1).

3.4.5 Concept Creation with the Novelty Potential/Void Matrix and CPC Code-Based Design Catalogue

In this study, representative concepts were evaluated with text mining co-occurrence network analysis based on the four extracted data types *(p, pm, p-m,* and *m*) to determine the most suitable type for assessing the novelty potential/void matrix for idea generation. Combinations with long distances between concepts were chosen during the new design concept combinations selection, indicating considerable novelty and zero void, which reflected no similar patents. Following combinations selection from the novelty potential/void matrix, a new design catalogue was generated according to CPC codes, yielding suitable means.

The procedure was performed by referring to the original patent information collected, ensuring consistency and accuracy. The CPC scheme is a hierarchical system that permits patent searches and analyses by categorizing inventions according to their technical domains, a more granular and detailed extension of the international patent classification (IPC) system [128]. Consequently, the CPC framework is particularly well-suited for identifying design cases and facilitating computational analysis, as patents are systematically classified by technical fields, including those defined by the IPC [106].

3.4.6 Generation and Verification of New Design Concept

ChatGPT was provided with the new design catalogue to recommend means (solutions) based on technological trends (CPC codes). Based on the suggestion, an example of CPC combination for TKD SEs was logically selected. ChatGPT was then employed to refine the new idea combinations. To further illustrate the adaptability of the framework, an additional exploratory example was conducted in another sports domain, basketball. The proposed method ideas were then compared and benchmarked with the ideas generated by LLM models, including ChatGPT, Gemini and DeepSeek based on the number of outputs and diversity. Additionally, all ideas were independently evaluated by expert reviewers through a Google form based on three key variables:

1. Novelty: the uniqueness compared to the existing market.
2. Feasibility: the ease of converting the idea into a commercial product.
3. Market potential: the likelihood that the idea can gain adoption and generate value in real-world environments.

A 5-point Likert scale (1 – very low; 5 – very high) was used to score each idea. In order to minimize bias, evaluations were conducted blindly with the order randomized. A total of eight evaluators from Osaka University participated, specializing in the mechanical and applied engineering department. The evaluators included one associate professor, three PhD students, one master's student and three undergraduate students. The results were analyzed using the Kruskal-Wallis H Test, suitable for comparing more than two independent variables under a non-normal distribution of data. A CPC code investigation was also performed to verify the proposed novel ideas. Furthermore, semi-structured interviews were conducted through online and face-to-face meetings with the representatives of the Malaysian TKD federation and clubs. Finally, a new system for future TKD SEs was developed.

3.5 Semi-structured Interviews

To complement the patent and non-patent data analysis, novelty potential/void matrix and patent-based design catalogue method, semi-structured interviews were conducted to gain deeper contextual insights into participants' perspectives, experiences and challenges. Semi-structured interviews provide a powerful means of exploring the qualitative aspects of a subject, enabling for detailed narratives, diverse perspectives, and nuanced insights. Methodologically, they offer a balanced approach combining structured inquiry and open-ended exploration, allowing the interviewer to probe emerging ideas beyond a predetermined set of questions.

Semi-structured interviews also allow for open-ended discussions, giving participants sufficient time and space to articulate their opinions on the topic in depth [142] promotes a more relaxed and candid dialogue, encouraging authentic responses between interviewer and participant. Compared to unstructured interviews, which often lack clear direction, semi-structured interviews remain flexible and adaptable while maintaining the intended direction at the same time. Moreover, this approach provides substantial contextual depth information, capturing information that is often overlooked in more structured formats [142]. The adaptability enables the interviewer to pose new and open-ended questions based on the

participants' responses, allowing necessary adjustments, while still maintaining the intended focus. This encourages participants to provide comprehensive responses, thereby allowing the interviewer to conduct a more in-depth analysis of the topic.

Consequently, the interviewer is enable to conduct richer, more detailed insights into industry-specific challenges, organizational practices, business models, future expectations, and strategic considerations, making it highly suitable for exploring technological and organizational themes. Additionally, semi-structured interviews support comparability by ensuring consistent data collection and in the key questions asked across all participants, while still allowing variation in individual responses, perspectives, and emergent themes. They also serve as a qualitative validation by offering contextual insights and practitioner perspectives to supplement the quantitative results.

3.5.1 Data collection and participants

Participants were selected through purposive sampling to ensure representation of key stakeholder groups with substantive knowledge and experience in technology innovation, adoption practices, and domain-specific challenges in the sports industry and martial arts sector. Purposive sampling is a commonly employed non-probability sampling strategy in qualitative and mixed-methods research due to its emphasis on capturing a detailed and contextual understanding [143]. It involves the intentional selection of specific types of units, including individuals, events or cases that are most relevant to the research questions, thereby enabling researchers to explore complex phenomena in depth [143].

This sampling strategy is particularly effective when the research requires a specific type of participant, such as experts, individuals with unique experiences, or those with particular demographic characteristics. Accordingly, this study engaged representatives from: (i) companies in the sports industry (LEs and SMEs), (ii) a blockchain technology provider, and (iii) the Malaysian TKD Federation and affiliated TKD clubs. Engaging directly with diverse stakeholders enabled the study to uncover rich qualitative insights regarding real-world industry and organizational challenges, innovation practices, and technology adoption. The valuable input on recommendations and feedback on the proposed design catalogue was also obtained.

i) Industry Stakeholders (SMEs, LEs, Blockchain provider)

The study engaged 4 representatives from Japanese retail companies specializing in the sports industry, including: (i) LE, specializing in sports equipment and sportswear, and (ii) SME,

specializing in martial arts goods. The semi-structured interviews with company representatives focused on the organizational business model, challenges, technology, competitive landscape and strategic expectations for future innovation in the sports industry. Based on the interviews, the stakeholders provided valuable insights into the organizational practices and the comparisons were made between the LEs of the sports industry with those of SMEs. Additionally, a technology provider specializing in blockchain applications was interviewed to gain industry expertise and insights into blockchain technology trends, current and emerging applications and potential applications for organizational innovation, which can be useful for TKD.

ii) Malaysian TKD Federation and Clubs

Semi-structured interviews were conducted with 18 representatives of the Malaysian TKD Federation and affiliated TKD clubs, including individuals with specialized expertise: federation president, national coaches from sparring and poomsae divisions, club owners, instructors and athletes. The interviews were conducted to obtain practical insights into organizational challenges, the importance and necessity of innovation, feedback and recommendations on the design catalogue as an innovation tool for idea generation and future hopes for the sport.

3.5.2 Data analysis and processing

All the semi-structured interviews were conducted based on open and closed-ended questions developed in relation to the companies' business and their industry, where the participants were provided with a list of questions they could answer freely. Due to time and mobility constraints, the interviews could not be conducted through a face-to-face meeting with all representatives. Hence, some of the interviews were conducted through online meetings through the Zoom application over the course of 30 minutes to 45 minutes on average. Before each interview, participants received the interview guide regarding the study objectives and consent-informed procedures, highlighting confidentiality protocols, the voluntary nature of participation, and the right to withdraw without penalty.

Based on participants' consent, online interviews were recorded and transcribed using Zoom's built-in transcription tool, enabling accurate transcription and analysis while preserving naturalistic dialogue. Additionally, detailed notes were taken both during and after the interviews to capture the context of the participants' narratives more accurately. The data are documented in their original form to ensure the results accurately represent the views and experiences of the participants. This approach enables the collection of rich, in-depth data and

diverse perspectives from participants directly involved in the issues discussed. Such qualitative depth contributed to a more comprehensive understanding of the challenges and innovation practices within the industry. Finally, the study considered the responses as the private opinions of the individuals, not the opinions of the entire federation.

3.6 Ethical Considerations in Research

Ethical considerations in research are fundamental to responsible research practice, particularly in technology-enhanced disciplines involving AI-generated content and secondary data usage. This section outlines the key areas incorporated in this study: (1) informed consent procedures, (2) data anonymization and storage, and (3) intellectual property and accountability in AI-generated content.

3.6.1 Informed Consent Procedures

The study involved the primary data collection of human participants, particularly during expert interviews and feedback sessions. To ensure ethical compliance, participants were provided with both verbal and written confirmation of their willingness to participate under clearly stated conditions. Prior to the interviews, participants were provided with an informed consent form outlining the study's objectives, their voluntary participation, how their contributions would be used and the confidentiality measures in place.

In cases involving international participants or language barriers, documents were translated into the preferred language of participants to ensure transparency and comprehension. Participants' rights to anonymity and withdrawal at any stage without consequences were stated throughout the study. These procedures adhered to international ethical standards and were designed to protect the rights and dignity of all participants. Key ethical principles include:

- Voluntary Participation: All participations were entirely voluntary and free from coercion. Participants also had the right to withdraw at any time without penalty
- Confidentiality: All participant responses were kept confidential and used solely for research and analysis purposes. No personal information was disclosed or shared.
- Data Usage: Data collected was used solely for academic research purposes and handled in accordance with ethical data management standards.

- Clear Communication: All relevant information regarding the research, including the study's purpose, methodologies, potential risks, and benefits, was communicated in language that is easily understood by participants.
- Risk and Compensation: Participants were informed that there were no known or anticipated risks associated with participation and no financial compensation was provided.

3.6.2 Data Anonymization and Storage

This section outlines the procedures undertaken to anonymize and securely store both primary qualitative data, obtained from semi-structured interviews and secondary research data (e.g., patent and non-patent documents). For interviews, all personally identifiable information (PII), such as names, organizations, locations and any contextual details that could reveal identities, was anonymized during both transcription and data analysis to protect participants' personal and sensitive information. This process employed techniques such as pseudonymization and data masking to ensure participants could not be re-identified while retaining the meaningful content and usefulness of the qualitative data for analysis.

An example (e.g., "Respondent 1") was used in place of real names and affiliations to preserve participants' confidentiality. All anonymized data, including interview recordings, transcriptions and analyzed results, were securely stored on encrypted digital storage with limited access to ensure secure handling and storage. Access to these files was restricted to the researcher only to prevent any unauthorized access. Additionally, backup protocols were established to avoid data loss. These measures were implemented to uphold the highest standards of data integrity, confidentiality and compliance with ethical research practices throughout the research lifecycle.

3.6.3 Intellectual Property and Accountability in AI-Generated Content

The study utilized AI tools, particularly LLMs such as OpenAI's model GPT-4, Gemini and DeepSeek as part of its methodological framework for idea generation and development of a patent-based design catalogue. Additionally, other AI tools such as Perplexity, Scispace and Semantic Scholar were employed to assist in literature search and writing. Several guiding principles were applied to ensure ethical and responsible use of AI, including attribution, transparency and responsibility. The first guiding principle is attribution, whereby all outputs generated through AI tools were acknowledged transparently and misrepresentation as entirely

human-authored was strictly prevented. Consequently, the AI was employed as a supportive tool to enhance the methodological process and does not represent an autonomous author.

Secondly, the extent and nature of AI involvement applied in the generation of study output were disclosed, including specifying the stages of the study where AI tools were employed. Finally, the researcher maintains full accountability for the originality and integrity of the final outputs and acknowledges the evolving legal landscape regarding intellectual property rights in AI-generated outputs. This includes critically reviewing and cross-verifying against academic sources and patent databases to mitigate the ethical risks associated with AI-generated hallucinations and plagiarism. Plagiarism detection software and human review were employed to ensure originality, accuracy and alignment with academic standards and the contextual framework of the study. The outcomes of applying the proposed methodologies to generate novel design concepts are discussed in subsequent sections of the study.

CHAPTER 4

RESULTS

4.1 Introduction

This chapter discusses the results as follows: 1) Patent and non-patent analysis, 2) Application and validation; a) Case study 1: Novelty potential (word2vec) and b) Case study 2: Patent-based design catalogue with GenAI and 3) Semi-structured interviews.

4.2 Patent Analysis Findings: Intellectual Property Trends

In the patent analysis results, sports industry (basketball, baseball), martial arts (judo, karate) and new sports (e-sports) patent trends were compared with TKD based on the application year and the number of patents. Other technology sectors, including blockchain and information technology/systems patent trends, were analyzed by their application year and top technological fields based on CPC codes. Based on the patent results, the relationship with non-patent data extracted from journals was compared and analyzed using statistical analysis. Additionally, text-mining results using a co-occurrence network were conducted in both patent and non-patent data to identify critical keywords and trends.

4.2.1 Sports Industry Comparison using Patent Information

Figure 4.1 compares the number of patents concerning different sports—TKD, basketball and baseball from the application years 2000 through 2018 using patent databases. Basketball and baseball have a higher number of patents than TKD, largely attributed to their greater global popularity and larger number of players. These two sports are listed among the top 10 most popular sports worldwide, with an estimated 800 million and 500 million fans, respectively [144] compared to TKD which has approximately 80 million practitioners [145]. Based on the observations, basketball patents are increasing, though not at a constant rate, indicating continuous innovation and investment. Similarly, TKD patents showed an upward trend, particularly post-2015 compared to baseball, which has almost reached a plateau following consistent growth until 2012.

This may indicate a decline in popularity and a slowdown in innovation efforts within the baseball domain. While the number of TKD patents is relatively low compared to the other two sports, the upward trend suggests rising technological engagement and innovation potential, which is expected to increase the number of patents in the future. Patents are strongly correlated with increased innovation, knowledge sharing, and economic growth. More fans or players could mean significant innovation in the area. The subsequent section expands this analysis by comparing martial arts patent trends, including judo, karate, and new sports such as e-sports with TKD to contextualize innovation dynamics across traditional combat sports and new sports further.

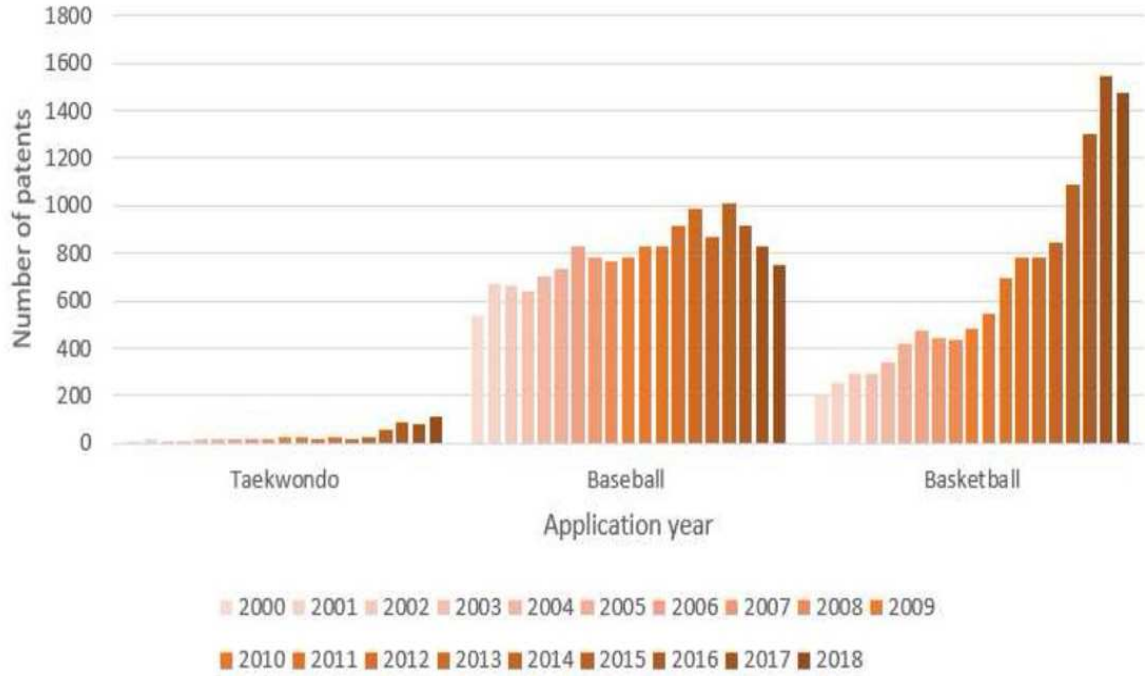


Figure 4.1 Comparison of patent trends during 2000-2018: Taekwondo, Baseball and Basketball

4.2.2 Martial Arts Industry Comparison: Taekwondo, Judo, Karate and E-sports Patent Trends

The number of patent applications filed between the years 2000 and 2019 and a comparative summary the total number of patents, peak year and peak value across four sports domains, including TKD, judo, karate and e-sports are presented in Figure 4.2 and Table 4.1. TKD dominated the landscape with a total of 629 patent applications, followed by e-sports (328), judo (282), and karate (252).

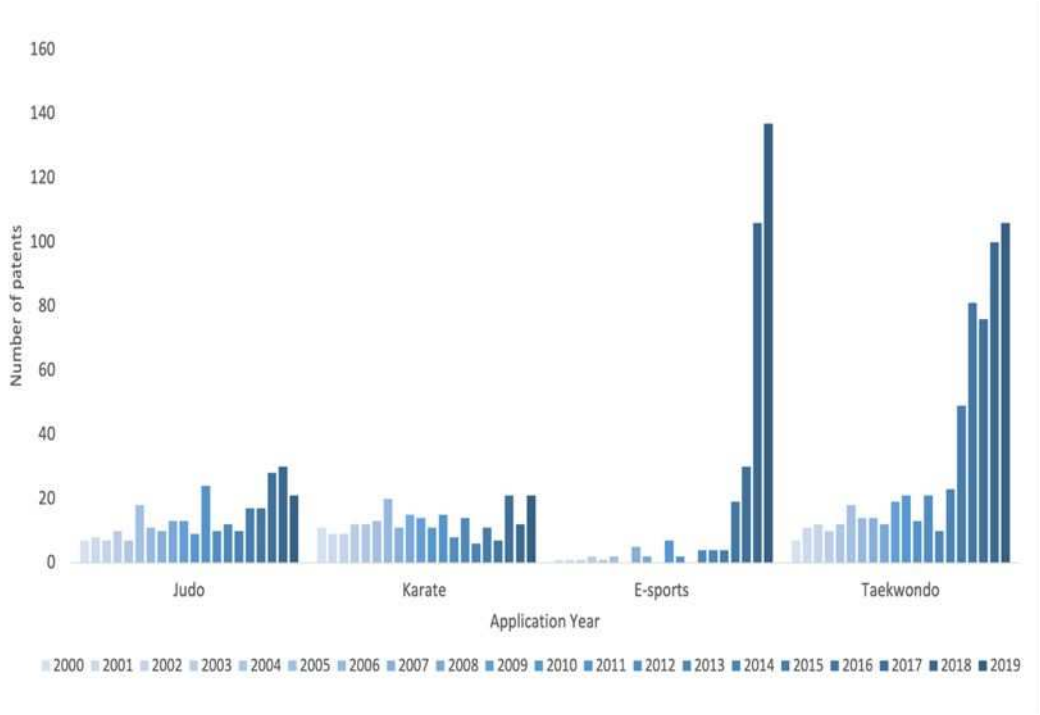


Figure 4.2 Comparison of patent trends during 2000-2019: Taekwondo, Judo, Karate and E-sports

Table 4.1 Comparative summary between TKD, Judo, Karate and E-sports

Sport	Total Patents (2000–2019)	Peak Year	Peak Value
Taekwondo	629	2019	106
E-sports	328	2019	137
Judo	282	2018	30
Karate	252	2019	21

The sudden increase in TKD patents is visible post-2015, with an exceptional rise from 49 in 2015 to annual counts rising above 100 patents by 2019, indicating a significant shift in innovation activity. The rapid growth signals a technological acceleration in TKD innovation due to the approval of a 5-year strategic plan between 2015 and 2020 for the development and expansion of the sport by the World Taekwondo Federation (WTF) Council. The plan consists of 5 main areas—competition, research, education, development, and partnerships—designed to provide a framework for the WTF to implement innovative programs and reforms for para-taekwondo globally [146].

Furthermore, the surge appears to be largely driven by China due to the country's broader economic strategy under its 13th Five-Year Plan (2016–2020) which prioritized innovation, technology advancement and sustainable development. Consequently, China's

research and development (R&D) spending reached 2.17 trillion yuan in 2019, representing 2.19% of its GDP, a 56.3% increase from 2015 [147].

Similarly, e-sports showed an exponential growth in the number of patents from 2015, reaching its peak with 137 patents in 2019, overtaking both judo and karate despite being a relatively new sport. The patent rise aligns with the exponential growth of the e-sports industry due to the industry's commercial and technological expansion. The growth of revenue from 325 million (2015) to 1.137 billion (2021) is expected to reach USD 5.27 billion in 2029. In addition, esports' audience base and user engagement increased from 235 million in 2015 to 490 million in 2021, and are projected to surpass 640 million by 2025 [148]. This growth not only reflects heightened global interest in competitive gaming but also incentivizes technological and business innovation.

Judo and karate, on the other hand, exhibit relatively stagnant patent trends, with no major surge in filings, remaining below 30 patents annually**.** The relatively flat trendlines implied that these traditional martial arts remain largely rooted in conventional practices within the sport's practice and equipment, with slower adoption rates of advanced technology and fewer commercial or institutional incentives driving modernization. Consequently, the patent trends comparison highlighted a divergence in innovation intensity, whereby in recent years, TKD and e-sports have gained more recognition; thus, more innovation is happening in this area.

It is expected that the number of patents will also increase in the future; therefore, innovation should be developed. Patent activity often mirrors market dynamics; therefore, greater popularity and investment tend to foster more innovation, as seen with basketball and baseball. The co-occurrence network graph between TKD and e-sports was analyzed based on CPC codes to identify trends and correlations in the subsequent section.

4.2.3 Co-Occurrence Network: Taekwondo CPC Codes vs Esports CPC Codes

A co-occurrence network graph was used to identify the technological trends and potential relationships between TKD and e-sports based on CPC codes. Two different clusters were identified and selected as an example in the co-occurrence network of TKD CPC codes as presented in Figure 4.3. The circles indicate the CPC codes; the larger the circle, the higher the frequency of CPC code occurrence. Meanwhile, the colors range from dark blue to light yellow, implying high to low degree centrality. The CPC codes with higher degree centrality represent

highly significant roles in the network and lines indicating co-occurring relationships.

In Cluster I, the A63B category (apparatus for physical training) constitutes most CPCs for TKD, has a slight connection with other categories, such as G09B (educational or demonstration appliances; appliances for teaching) and A4D1 category (outerwear, protective garments, and accessories). However, in Cluster II, G06Q50/205 (systems or methods specially adapted for specific business sectors) and G06Q20/12 (payment architectures) still represent minority categories for TKD. This reflects limited integration of digital management, analytics, and platform-based solutions, signalling a high potential for new technology and CPC combinations to be developed in this area.

For example, combining G06Q20/12 (payment) with H04L2209/38 (chaining) for TKD. Nevertheless, both clusters have the potential to be developed into new business areas. Furthermore, the co-occurrence network analysis revealed that CPC codes related to A63B2220/801 (contact switches) and A63B 71/08 (body protectors for players or sportsmen) exhibited the highest betweenness centrality. This suggests that innovations relying on sensing-based contact systems and wearable protective gear currently act as the key technological enablers connecting diverse CPC clusters.

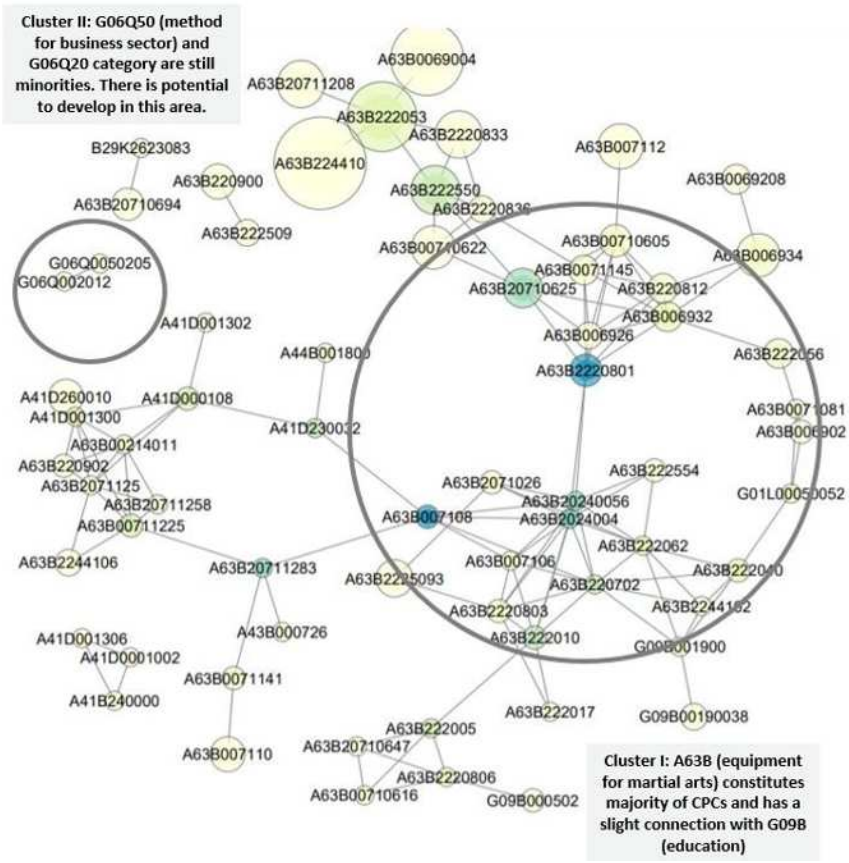


Figure 4.3 Potential relationships between TKD's CPC codes

Meanwhile, Figure 4.4 visualizes the relationships between CPC codes extracted from e-sports-related patents, which majority constituted of G07F/17 (coin-freed or like apparatus) and A63F/13 (video games). Two different clusters with high-centrality CPC codes representing key technological components were identified and selected as main examples. Cluster I revealed CPC code G07F17/3225 (data transfer within a gaming system), connection with minority CPC such as G06Q50/34 (internet betting or bookmaking). Meanwhile, cluster II highlighted the CPC code A63F13/22 (setup operations), which is linked to the minority CPC code G06F3/011 (arrangements for interaction with the human body, such as for user immersion in virtual reality).

Among the CPC codes, only a small subset of CPC codes (36 CPCs, approximately 5.10%) overlaps with TKD CPCs, suggesting limited convergence between e-sports and TKD. The core innovations and technological priorities differ, indicating that these two fields have yet to be meaningfully integrated. Therefore, by strategically combining distinct CPCs from both sectors, new hybrid technological applications may be developed, particularly in areas that are currently underexploited.

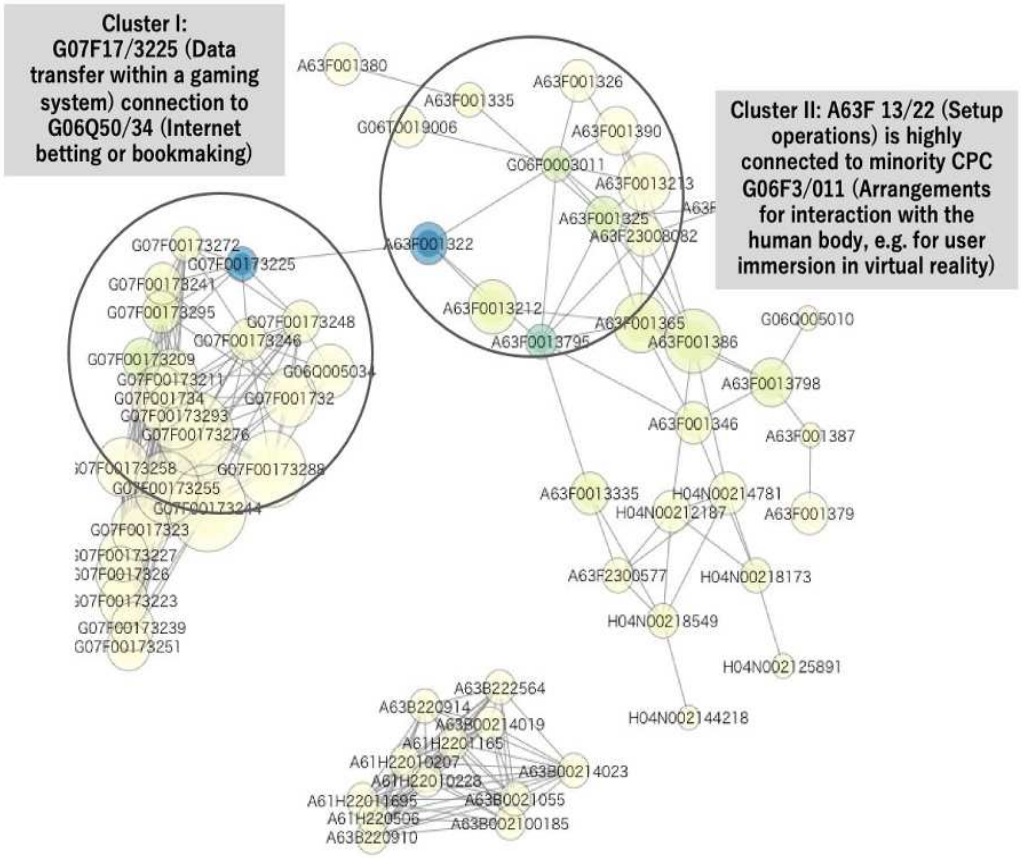


Figure 4.4 Potential relationships between e-sport's CPC codes

For instance, G07F17/3225 (data transfer within a gaming system) can be combined with TKD A63B 71/08 (body protectors for players or sportsmen) to enable a smart-protective gear with real-time performance monitoring, or immersive interactive training environments. Such cross-CPC integration highlights the potential for novel and underexplored solutions connecting digital gaming systems with physical martial arts technologies.

4.2.4 Top 5 CPCs Technology Trends: Blockchain and Information Technology/Systems

This section presents the results of the top five CPCs technology trends in blockchain and information technology/systems and recommended possible combinations for TKD. The top five CPC codes in blockchain from 2015 to 2017 showed an increased use, as shown in Figure 4.5. Among them, H04L (transmission of digital information) is identified as the primary CPC for blockchain. Our findings also identified that China and the United States are leading in blockchain patent filings, suggesting that the majority of the blockchain-related innovations are developed in these two countries. The top three assignees in blockchain's top CPCs were from Alibaba Group, IBM and Nchain Holdings, reflecting strong corporate engagement in advancing blockchain technologies.

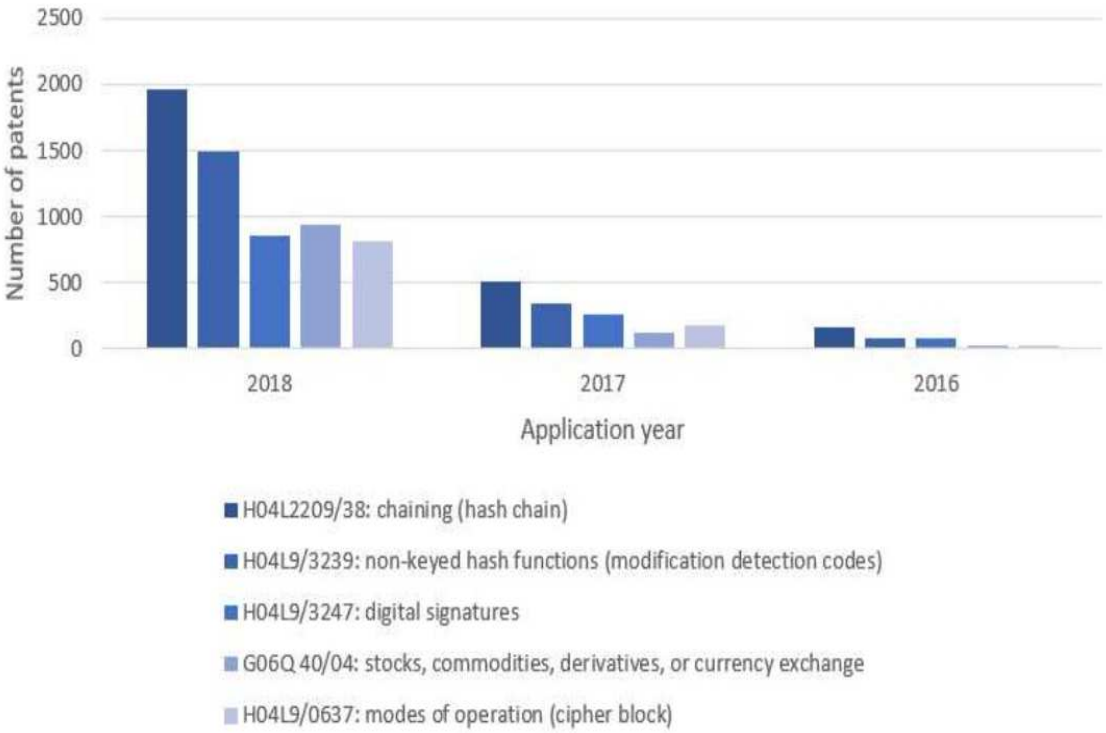


Figure 4.5 Top 5 CPC codes in Blockchain

Consequently, a new combination can be made with the CPC H04L2209/38 (chaining), which records the highest number of application numbers, and TKD CPCs in the A63B category (equipment for martial arts). For instance, the chaining technology can be used to securely store data from smart sporting TKD devices or equipment, such as headgear and body protectors. This combination can be optimized for the IoT ecosystem by providing zero transaction fees and a unique verification process, thereby reducing costs and time. By observing the CPC trends, including the increase and decrease in CPCs, the technology selection can be leveraged efficiently.

Meanwhile, Figure 4.6 highlights the leading CPC technology trends in the IT/IS sectors from 2018 to 2020. Among the top five CPCs, G06F16/29 (geographical information database) showed an upward trend in patent applications, while the others remained relatively steady or plateaued. This suggests that G06F 16/29 has gained increasing attention in recent years, indicating its growing significance in IT/IS-related innovations. A promising application area for TKD is Geographic Information Systems (GIS). GIS technology can be used to analyze the characteristics, behavioural patterns, and movements of TKD athletes, supporting precise athlete performance assessments. The next section discusses the results of the non-patent analysis, which complements the patent findings.

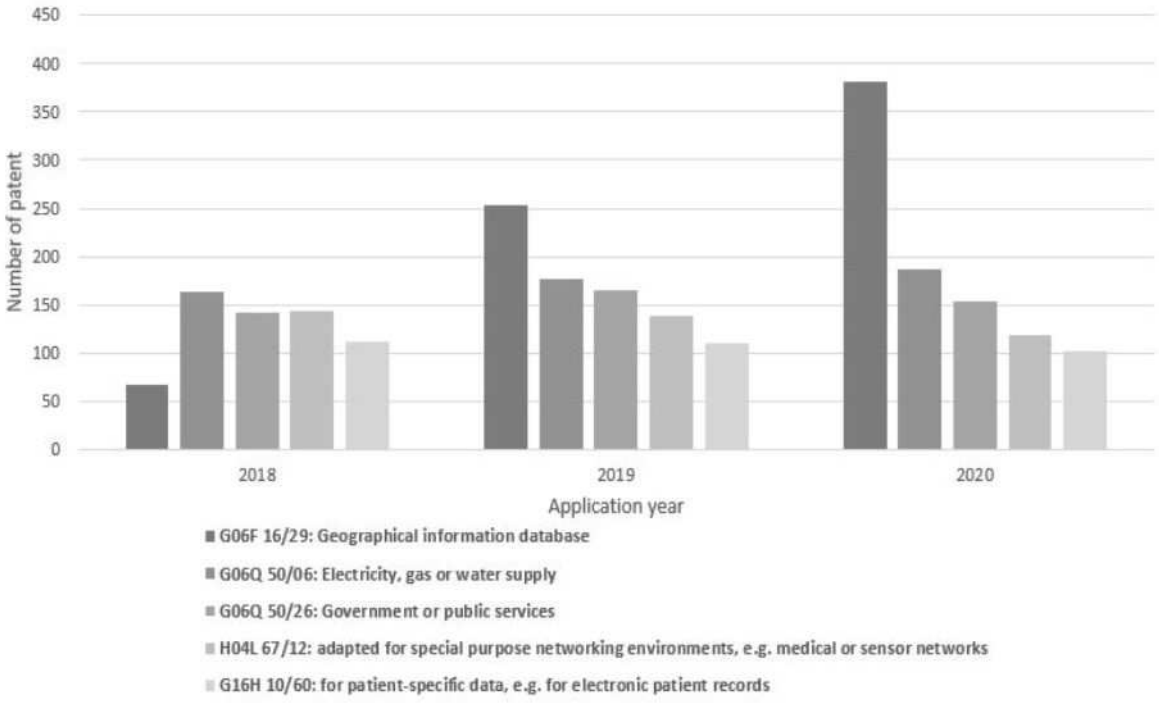


Figure 4.6 Top 5 CPC codes in IT/IS

4.3 Non-Patent Analysis Findings

In this section, the non-patent analysis findings are presented. Abstracts from journals and articles were extracted from the SCOPUS (Elsevier) database. To uncover emerging trends, the results from the patent and non-patent datasets were compared and a co-occurrence network analysis through text mining techniques was conducted.

4.3.1 Blockchain Patent vs Non-Patent

To investigate the patent and non-patent trends related to blockchain, we compared the annual publication trends and calculated the coefficient of determination (R^2) to assess the strength of the linear relationship between the two variables. The coefficient of determination (R^2) ranges from -1 to +1, where values closer to +1 indicate a strong positive correlation. An R^2 value above 0.7 is considered a strong correlation, while values between 0.5 and 0.7 suggest a moderate correlation. Values below 0.4 are indicative of a weak or no correlation. Figure 4.7 shows the number of both patent and non-patent-related documents steadily increased from 2014 to 2018.

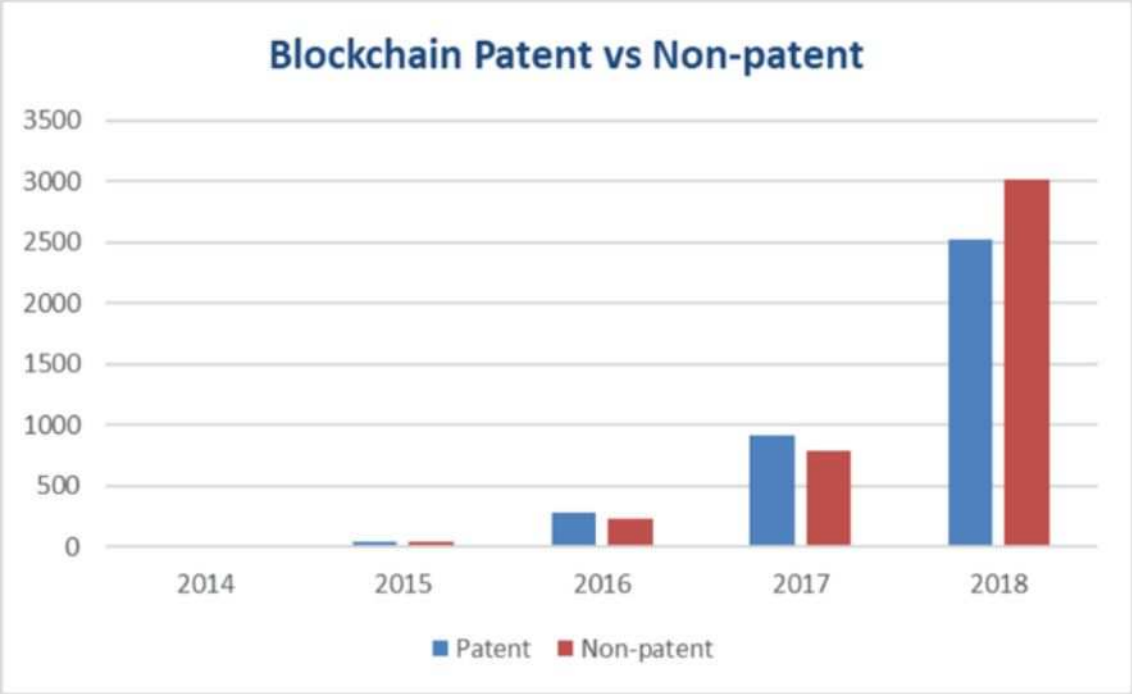


Figure 4.7 Blockchain patent vs non-patent

For blockchain-related patents and non-patents, the R2 value was 0.92, which indicates an extremely strong positive relationship are shown in Figure 4.8. This implies that blockchain technology is business-oriented because the number of patents increases with the increase in the number of journal articles. This situation differs for AI, wherein journal articles are published first, followed by patents. The following section further explores the co-occurrence network analysis on blockchain and TKD-related non-patent data to identify important keywords.

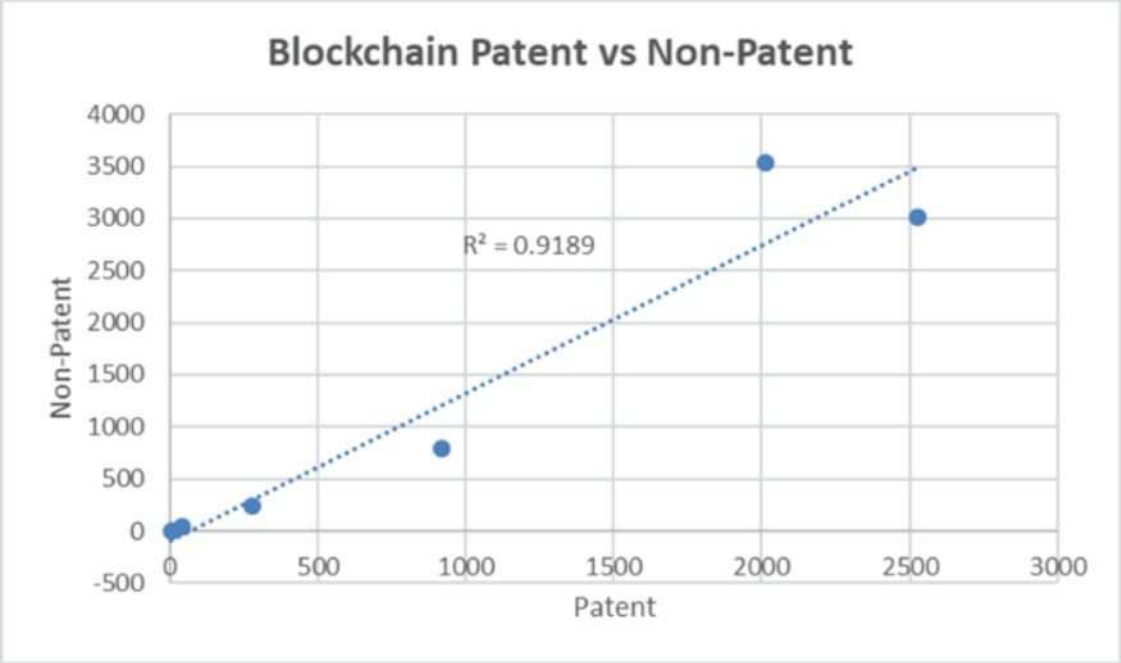


Figure 4.8 Blockchain patent vs non-patent coefficient

4.3.2 Co-Occurrence Network Analysis: Taekwondo and Martial Arts

The co-occurrence network analysis with the non-patent data was conducted to demonstrate the centrality (significance) of the particular node (concept or word). Figure 4.9 shows the co-occurrence network analysis for martial arts and TKD. In example 1, the word “athlete” has high centrality with the words “performance,” “taekwondo,” and “training.” Meanwhile, in example 2, we observed that the words “sports,” “combat,” and “athletes” are closely related to the words “rapid” and “weight loss.” This shows that combat sports have a high relationship to achieving rapid weight loss. This word-for-word co-occurrence network can help identify technology-related keywords and determine which words are closely related.

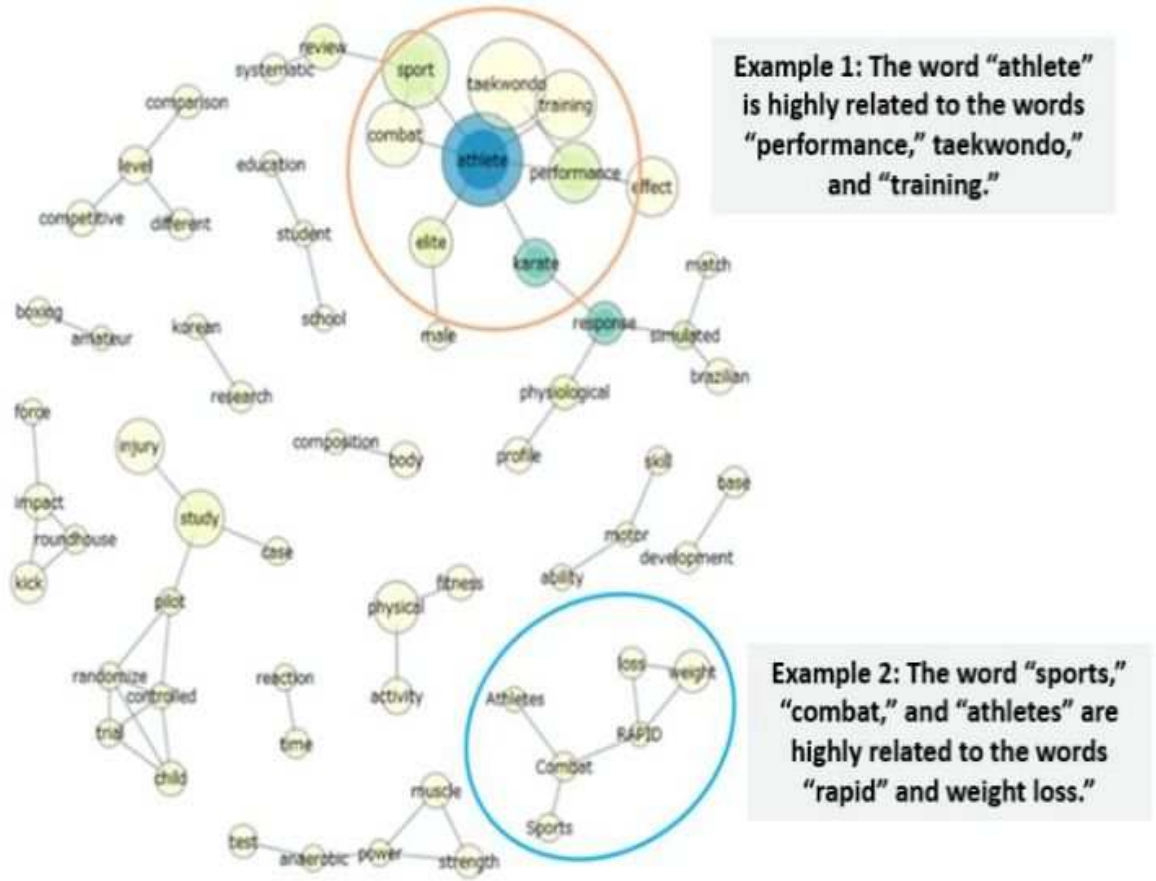


Figure 4.9 Taekwondo co-occurrence network (2006-2020)

4.3.3 Co-Occurrence Network: Blockchain and Information Technology/System

The co-occurrence network was analyzed by extracting the words in the abstracts concerning blockchains and identifying the potential relationships. An example of a word-to-word co-occurrence network analysis is shown in Figure 4.10. In example 1, the word "technology" has high centrality with words such as "chain" and "system." Meanwhile, in example 2, the word "Internet of Things" is closely related to the word "secure." IoT allows devices to send data to private blockchain ledgers for inclusion in shared transactions with tamper-resistant records. Therefore, TKD IoT devices can be highly secured by combining them with blockchain technology to send data and share transactions with tamper-resistant records.

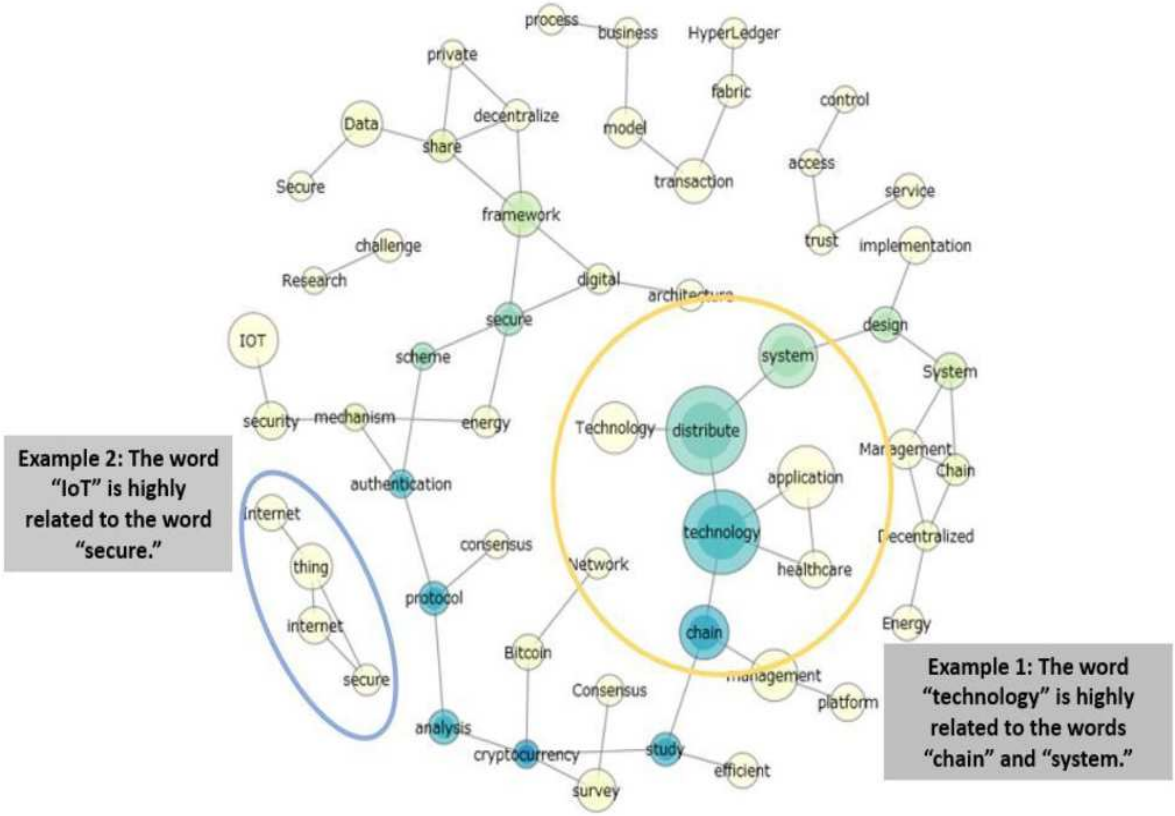


Figure 4.10 Blockchain co-occurrence network (2000-2020)

Figure 4.11 shows the co-occurrence analysis of IT/IS non-patent data. Example 1 includes words "systems" and "information," which are prominently associated. This suggests that inter-organisational information systems and information sharing between supply chain members positively impact the overall chain performance [149]. Example 2 includes the word "management," which is closely associated with the words "improve" and "quality." This implies a strong emphasis on managerial processes and quality improvement within the IT/IS applications. Therefore, in the context of TKD system innovation, it is suggested to combine the implementation of IT/IS with blockchain to improve both the organizational learning effectiveness and supply chain quality.

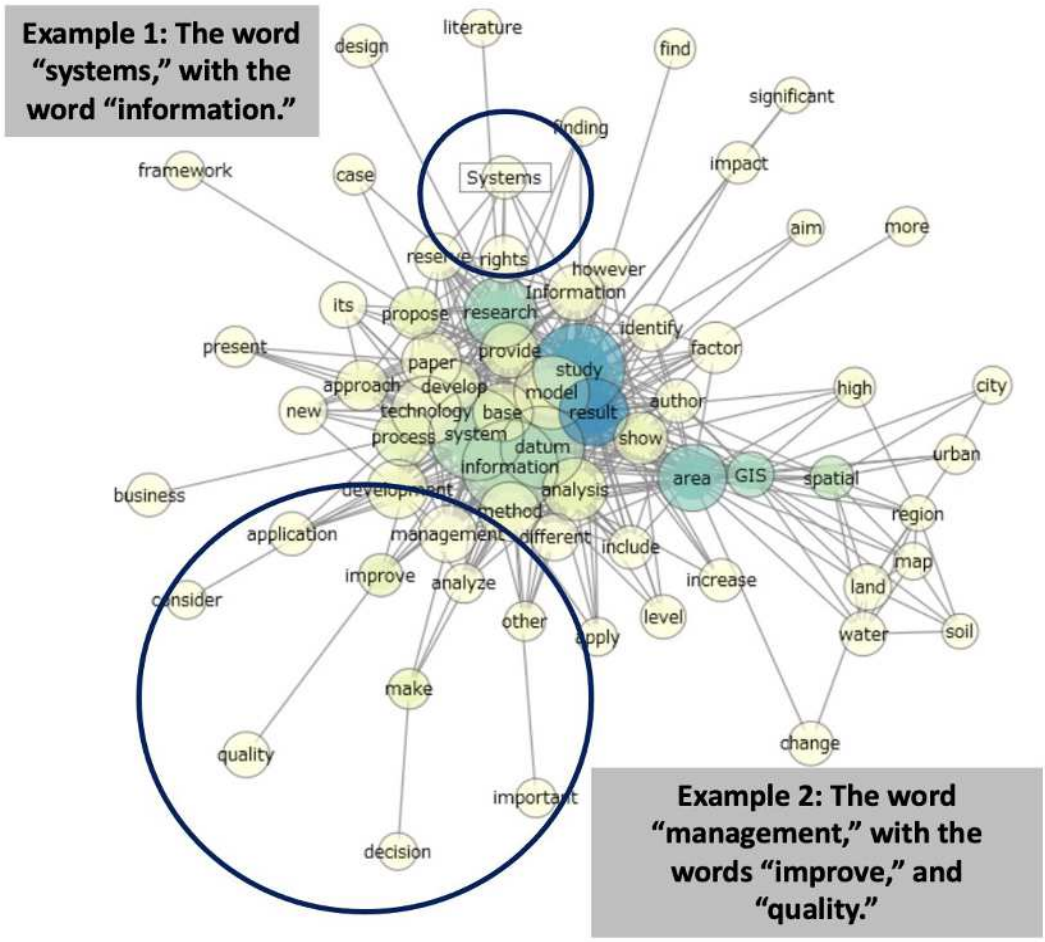


Figure 4.11 The IT/IS co-occurrence network (2020–2021)

4.4 Application and Validation

Case Study 1: Novelty Potential (Word2Vec) Analysis

4.4.1 Results of Layering Abstract Concepts and Setting the Degree of Abstraction

The novelty potential concept in collaboration with Osaka University was utilized to develop new ideas by combining sports and blockchain patent data. This method uses the Word2Vec model. A dendrogram was drawn using the distance information between the concepts found in the abstracts as shown in Figure 4.12. The horizontal axis represents the number of sentences, and the vertical axis represents the distance between concepts obtained by measuring the cosine distance. Regarding the thresholds involved in the classification of 16 abstract concepts, 0.85 was determined as the threshold after several rounds of trial and error.

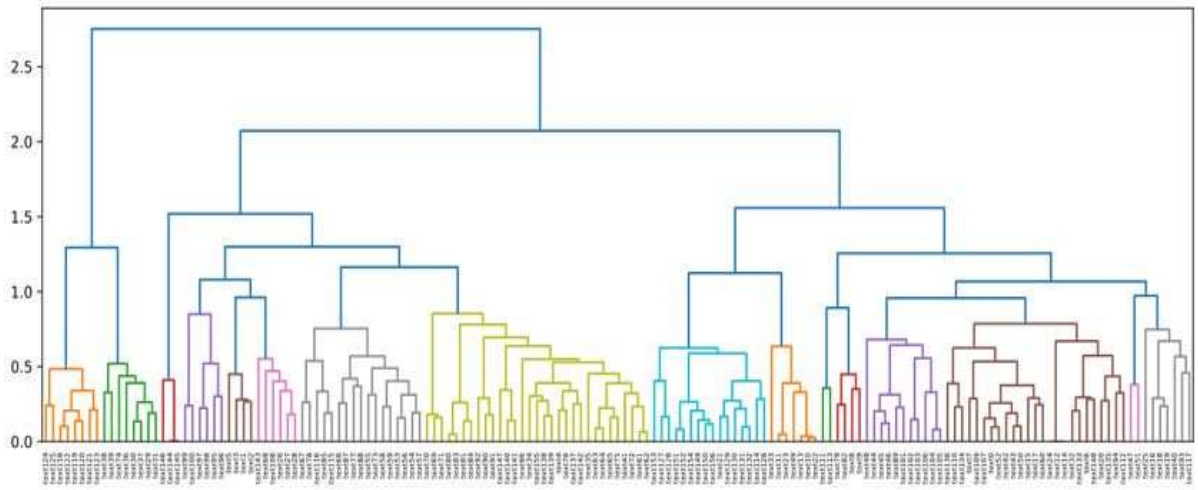


Figure 4.12 Classification of concepts by dendrogram [100]

The difficulty of verbalizing abstract concepts that collectively refer to the sentences contained in the cluster and the number of classifications of concepts was considered. In total, 16 abstract concepts were extracted and classified as shown in Table 4.2. It was difficult to form some abstract concepts independently (Concept 3, for example), and some abstract concepts included multiple technologies at the classification stage, such as Concept 7.

Table 4.2 Classification of extracted abstract concept groups

Group (G)	Description
G1	Structure of glasses
G2	Electric power (bicycle, motor, solar cell)
G3	Activity units
G4	Providing video contents
G5	Sports game broadcast and result prediction
G6	Broadcasting, authentication of personal information
G7	Motion analysis in sports, health, transaction management, chemistry etc.
G8	Communication and data storage between devices
G9	Encryption of data communication
G10	Internet of things (IoT) devices
G11	Payment and settlement
G12	Sports lottery and lottery tickets
G13	Health coin (crypto asset) platform
G14	Gambling and data communication platform
G15	Raising health awareness
G16	Artificial intelligence (AI) technology

Next, two matrices were created, novelty potential and void as shown in Figure 4.13. The novelty potential matrix measured the distance of cosine similarity. The higher the number, the further the distance; therefore, the higher the novelty potential.

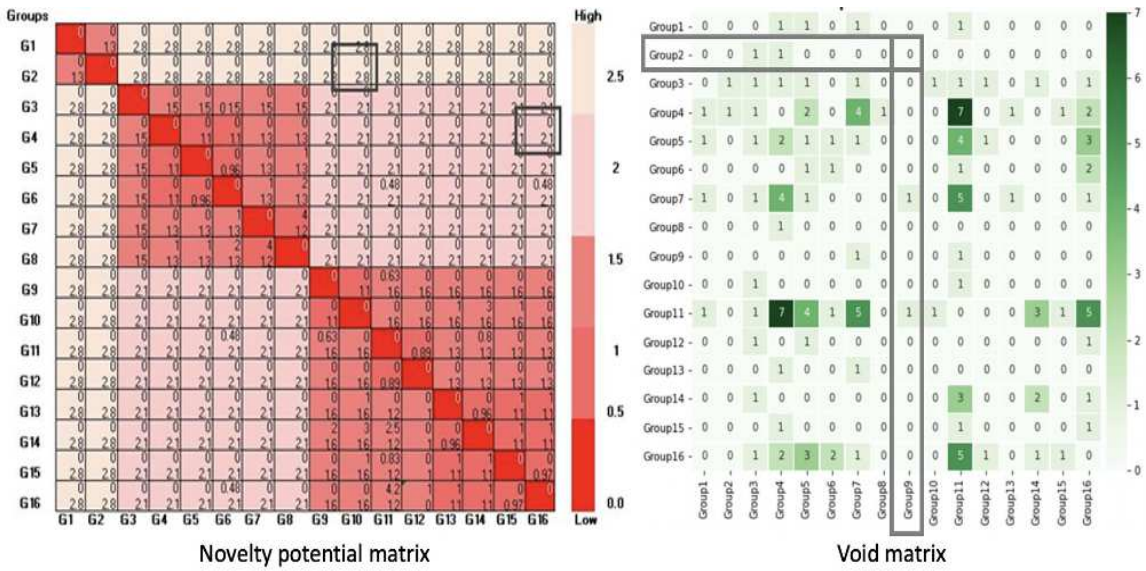


Figure 4.13 Novelty potential and void matrix

Meanwhile, the void matrix showed the count of patent numbers between the groups. Void indicates no similar patents; therefore, the combination of groups with the most voids can be new [97].

Afterward, using Equation 2,

$$\eta = \frac{Void}{Novelty\ Potential} \qquad (2)$$

a new matrix was created. η is a selection score used to evaluate how promising a concept combination is by comparing its existing patent count with its novelty potential.

η = selection score for a concept pair
Void = number of existing patents that already contain the concept combination
NP = novelty potential, or the semantic distance between the two concepts

While novelty potential measures novelty through semantic distance, the η value incorporates the "void" aspect, representing areas with limited existing patent saturation. Therefore, it helps to identify combinations with high novelty and technologically

underexplored concepts, increasing the possibility of first-mover advantage and future innovation opportunities. Therefore, a low η indicates more promising ideas; fewer patents and higher novelty, meanwhile a high η indicates less promising ideas; more patents and/or lower novelty.

Figure 4.14 shows the creation of new matrix. The upper number represents the η value, and the lower number, the novelty potential value. The minimum value of this number was found from the matrix. For η=0, the novelty potential value was weighed and its rationale clarified by quantifying its importance. The horizontal and vertical matrix presented 16 groups with different concepts, and two sets of groups were identified that form new combinations for SEs: Groups 4 and 16 (providing video content and broadcasting based on AI) and Groups 2 and 10 (using solar cells for IoT devices).

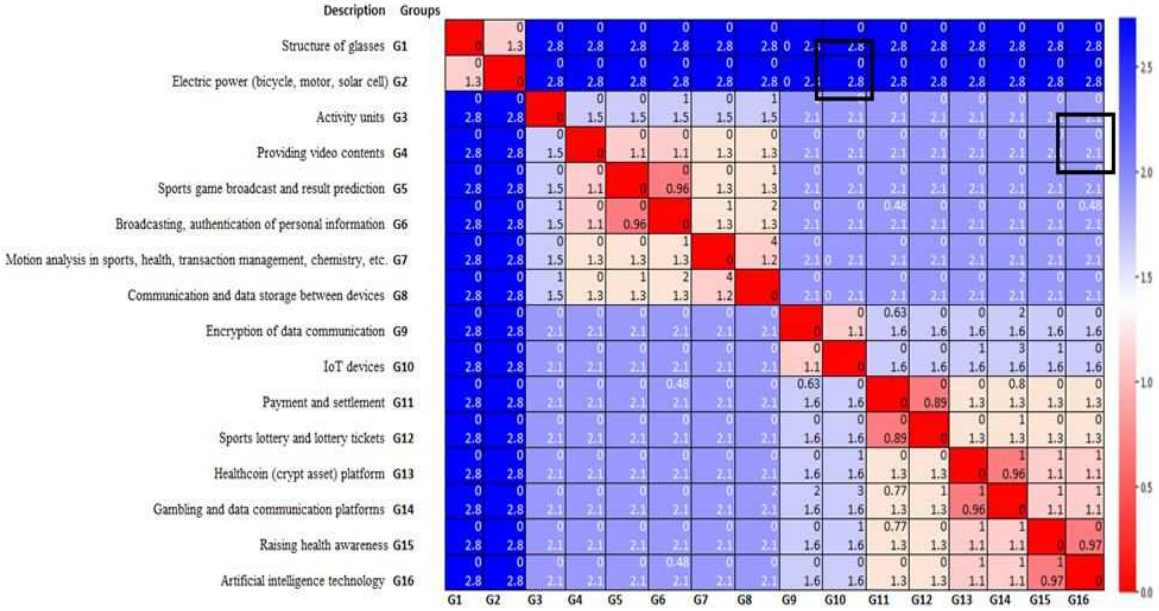


Figure 4.14 The new abstract matrix

4.4.2 Validation by Patents Trends Investigation

To verify the novelty of these groups, a patent database search was conducted using keywords "IoT," "solar cell," "AI," and "video content." Figure 4.15 shows the patent application trends of Groups 4 and 16 (AI and video content), which have gone upward in recent years. This shows that AI is becoming a powerful tool for businesses for creating advanced video content. Regarding groups 2 and 10 (using solar cells for IoT devices), the patent trend was investigated and identified that this combination caused the trend to rise from 2016 to 2018.

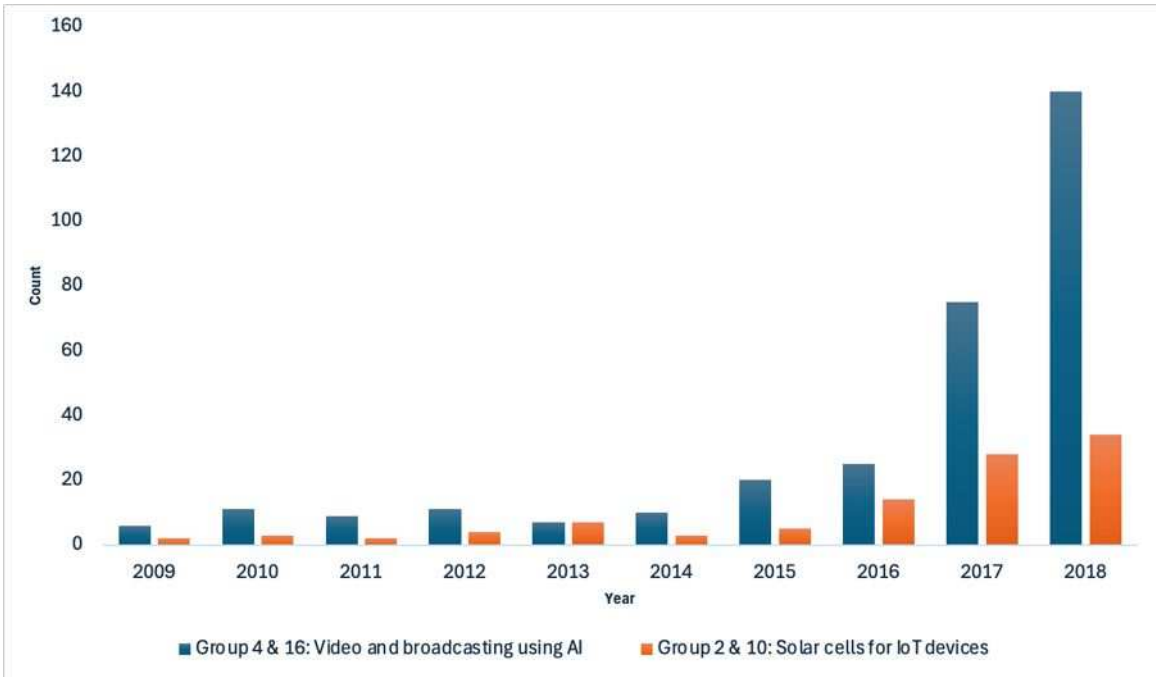


Figure 4.15 Patent application trends in Groups 4 and 16 and Groups 2 and 10

In the future, billions of IoT devices, self-powered by indoor solar cells, may provide everything from environmental information to human-to-machine and machine-to-machine communications. This could help reduce energy consumption and battery waste. Therefore, these two combinations will help SEs achieve product and service differentiation against their competitors in the market. Based on our research results, a new business idea for the SEs in the sports industry was created in the discussion section.

Case Study 2: Patent-based Design Catalogue

The result of idea generation methodologies, novelty potential/void matrix, design catalogue based on CPC codes, and Gen AI to support novel design concepts creation in the early stages of product development for TKD were presented in this section. The results were presented as follows: 1) Evaluating the novelty potential/void matrix in selecting the concept combinations, 2) Design catalogue based on CPC codes, 3) Comparison and benchmarking of novelty potential/void matrix and design catalogue ideas with LLM ideas, 4) Independent expert scoring and finally, 5) Verification with CPC codes.

4.4.3 Evaluating the Novelty Potential / Void Matrix in Selecting the Concept Combinations

This study selected the most suitable and practical approach for idea generation in TKD, utilizing the extracted data as concepts (*p-type, pm-type, m-type*, and *p-m-type*) to determine the novelty potential/void matrix concept. The objective was achieved by analyzing the contents utilizing text-mining of the co-occurrence network analysis. During this step, potential relationships of the particular node (concept or word) were identified. The four types are defined as follows:

(i) *p-type*- Data extracted as concepts for "purpose"

(ii) *m-type*- Data extracted as concepts for "means"

(iii) *pm-type*- Data extracted as pairs of "purpose" and corresponding "means" as concepts

(iv) *p-m-type*- Data extracted as separate concepts for "purpose" and "means"

Figure 4.16 presents the number of combinations of concepts between the 4 types. Based on the results, *p-type* (2080) and *pm-type* (2775) had higher overall concept combinations than *p-m-type* (1596) and *m*-type (1830), potentially indicating the superior novelty of the generated ideas. A higher number of combinations also suggested a greater diversity of concept pairings, increasing the likelihood of uncovering unique or less conventional ideas.

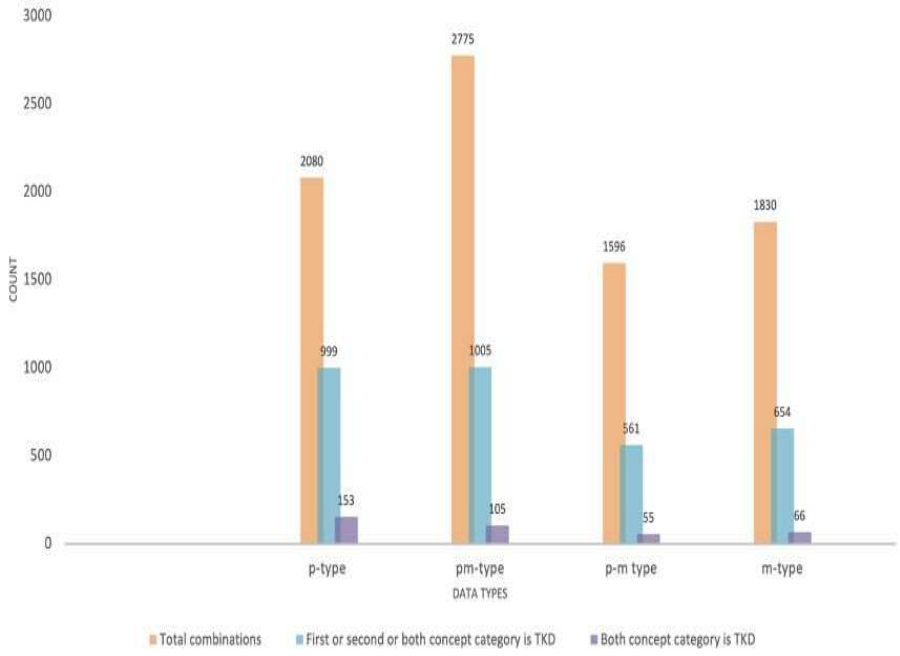


Figure 4.16 Number of combinations of concepts *(p-type, pm-type, p-m-type* and *m-type)*

An elevated purpose alignment was recorded by *p-type*, as it generated ideas focusing on a clear purpose or goal as demonstrated in Figure 4.17. For example, the cluster contained words directly applicable to TKD, such as improve, efficiency, and training, thereby supporting the selection of combinations with a strong purpose alignment and a relevant business case for performance enhancement in TKD training.

Meanwhile, Figure 4.18 illustrates the *pm-type* cluster, where purpose ("what") and means ("how") were semantically linked through existing or new methods. This supports the selection of ideas with a clear business purpose and the means to achieve it. The approach yielded words, including improve, accuracy, and real-time, which were considerably connected to words, such as feedback and video. Consequently, the idea included the purpose (to improve real-time accuracy) and means (employing a bio-feedback game device or video analysis).

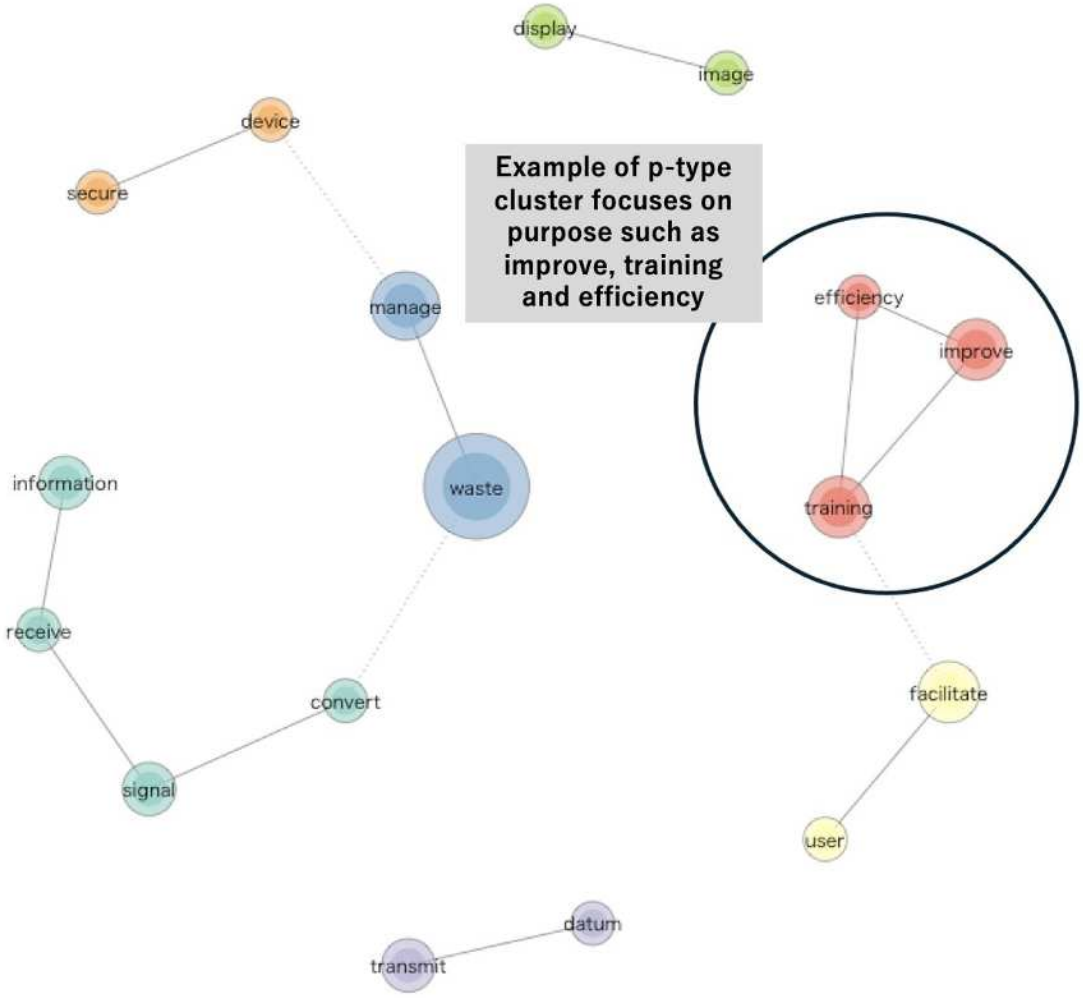


Figure 4.17 The *P-type* in the text mining

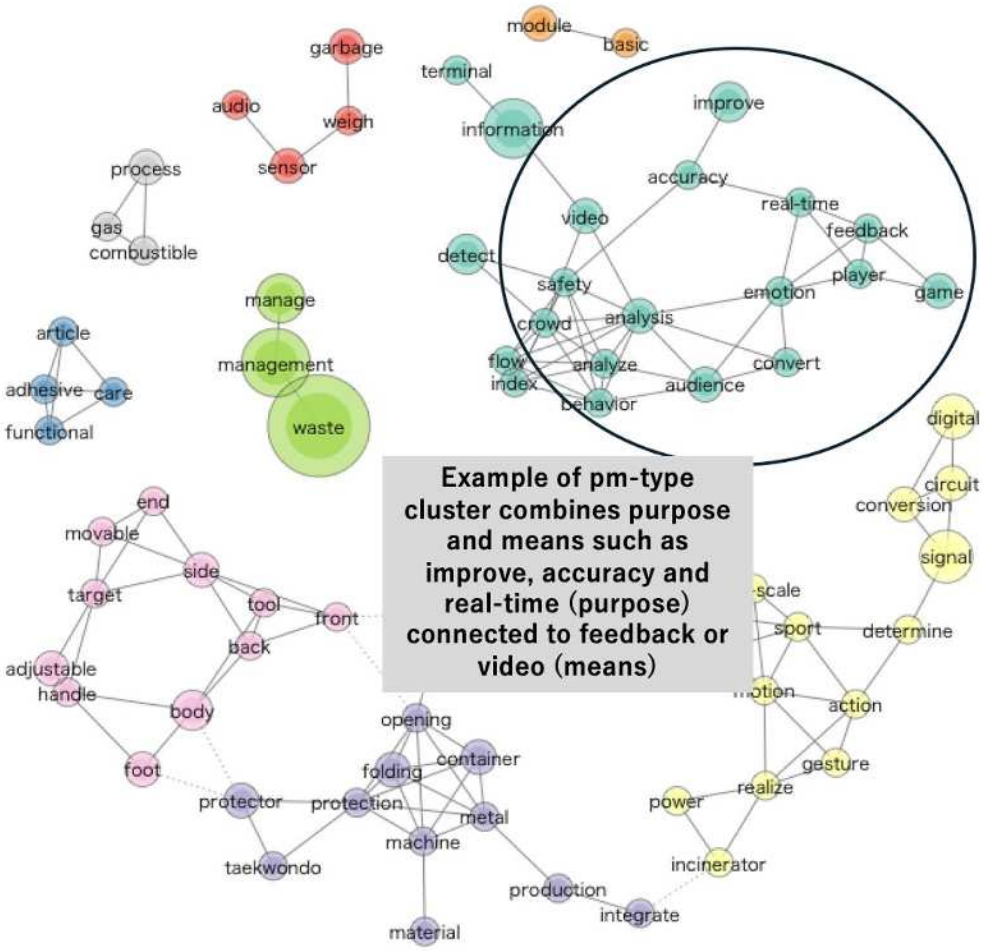


Figure 4.18 The *Pm-type* in the text mining

Figures 4.19 and 4.20 present the *p-m-type* and *m-type* ideas which might have possessed inadequate purpose alignment with business goals, rendering them less suitable for business creation. The *p-m-type* might also have resulted from disjointed ideas that were challenging to implement due to purpose and means separation. For example, a cluster presented words (enhance, user) that focus on purpose, while another cluster had words (processing, signal, circuit) focusing on means. Methods were the primary focus of the *m-type* instead of a clear purpose or goals.

An example includes a cluster with words, such as intelligent, training, and device, whereas another cluster is management and system. Consequently, the idea combination was solely based on methods, which might be technologically innovative. Nevertheless, the idea combination presented insufficient straightforward application or purpose to the TKD business creation, potentially rendering the implementation of the ideas more challenging.

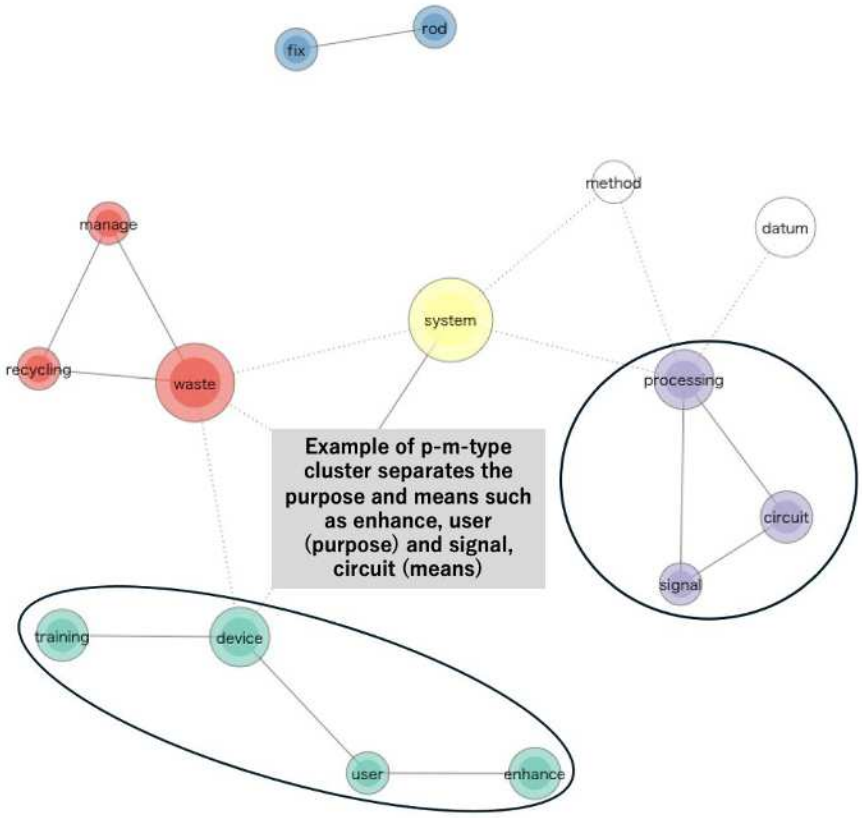


Figure 4.19 The *P-m-type* in the text mining

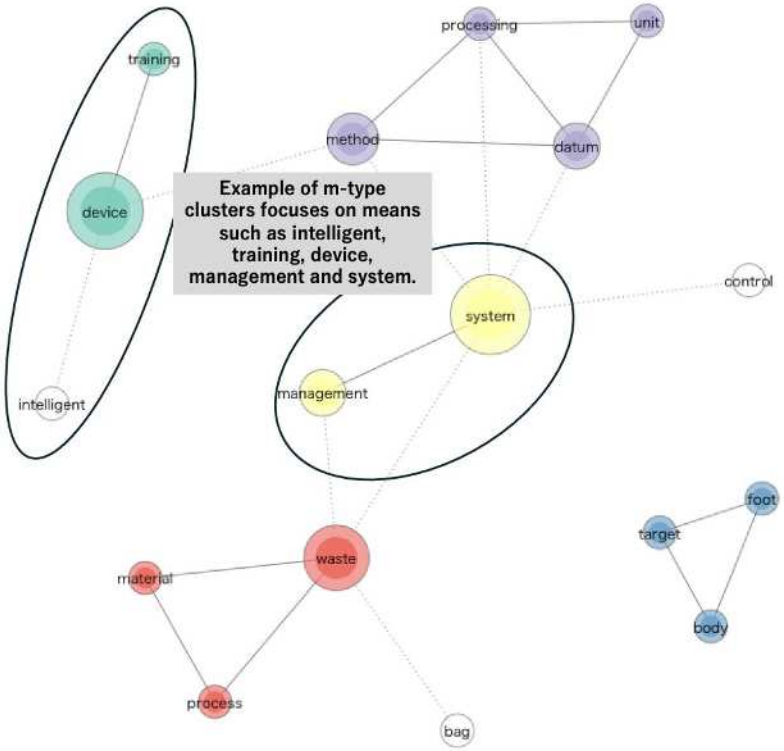


Figure 4.20 The *M-type* in the text mining

Based on the evaluations, *p-type* produced a broader and more flexible conceptual exploration opportunities. It also focused on purpose-oriented abstraction, allowing wider creative expansion before technological constraints are introduced. In contrast, while *pm-type* also generated high number of combinations, it combined purpose and means simultaneously, reducing flexibility during early-stage ideation. Hence, this study applied the extracted data as concepts for "purpose" (*p-type*) as an example for TKD. In the *p-type*, 64 clusters and representative concepts were procured, of which 18 clusters were related to the TKD category identified in the analysis of 633 TKD patents. Nonetheless, the term "taekwondo training" was deemed too general, hence excluded during assessments.

This study chose idea combinations that included one or both TKD categories to enhance their relevance to TKD business creation before sorting them by novelty potential in descending order to gain some hints. The combinations were then evaluated from the top, which indicated the highest novelty potential level. Finally, combinations with a 0 void were selected. As a result, the combination of "secures the helmet to the wearer's head (tk)" and "analyzes audience behavior (ab)", which has novelty potential and void value: (0.279574, 0) was obtained. Novelty potential represents the cosine distance between two concept vectors.

A high cosine distance (close to 1) between concepts reflects a high novelty potential. A 0.279574 novelty potential value denotes a moderate level of novelty. Conversely, void facilitates identifying areas without existing patents, revealing potential innovation gaps. Consequently, a 0 void value denotes that existing patents do not cover the combination. The following section demonstrates the application of the design catalogue, structured around CPC codes, to identify appropriate mechanisms from the selected combination of conceptual elements.

4.4.4 Design Catalogue based on Technological Trends (CPC Codes)

Post-selecting concept combinations "secure the helmet" and "analyze audience behavior", the means (solutions) were determined from the design catalogue, yielding new design concepts. Nevertheless, establishing and selecting a suitable combination of means was challenging due to the vast amount of patent information. As a solution, each design concept was classified with CPC codes in the design catalogue. The original patent information collected was also referred to ensure accuracy and consistency.

Figure 4.21 shows the top CPC codes in “secure the helmet to the wearer’s head.” Most CPC codes (sub group classified) in the “secure the helmet to the wearer’s head (tk)” were related to A63B71/00 (games or sports accessories), followed by A63B71/10 (for the head), A61F5/00 (orthopaedic methods or devices for non-surgical treatment of bones or joint and B01D53/00 (separation of gases or vapours). Other CPC codes were related to A63B group, including A63B71/06 (scoring), A63B2225/50 (wireless data transmission) and A63B2220/53 (force of an impact, e.g. blow or punch) reflect the emerging integration of sensors and protective, safety-related technologies in TKD patents.

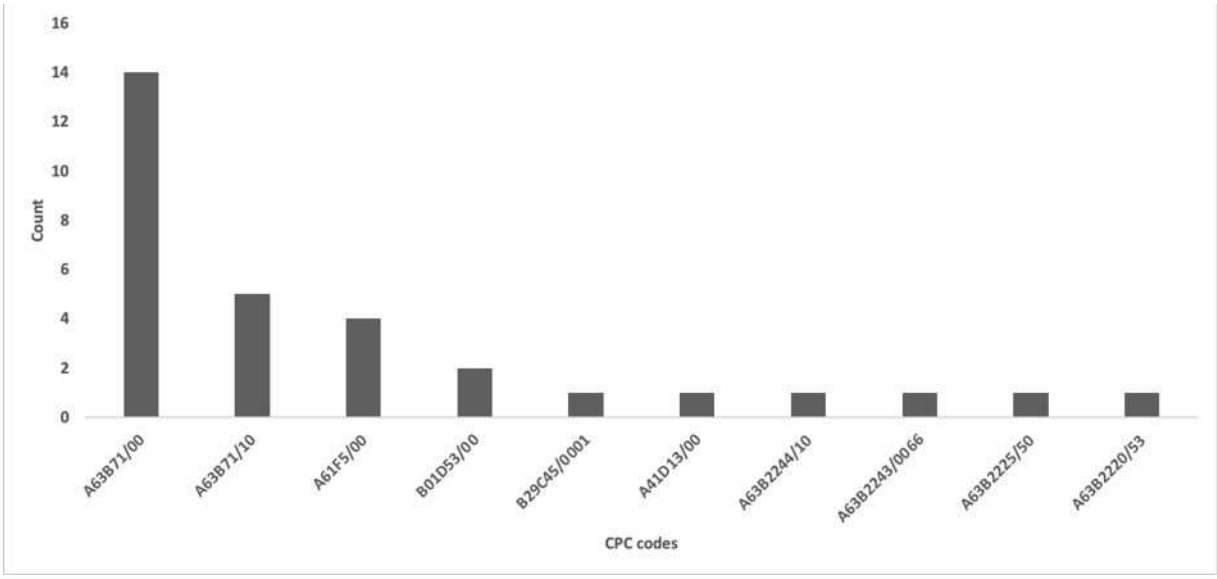


Figure 4.21 The top CPC codes in “secure the helmet to the wearer’s head”

Meanwhile, Figure 4.22 presents the top CPC codes in “analyze audience behavior,” including H04N21/00 (selective content distribution, e.g., interactive television or video on demand), followed by G06Q30/00 (commerce), A61B51/63 (by tracking eye movement, gaze and pupil change) and G06F17/00 (digital computing). The CPC codes demonstrated the importance of audience engagement, digital platforms and biometric feedback in audience behavior patents.

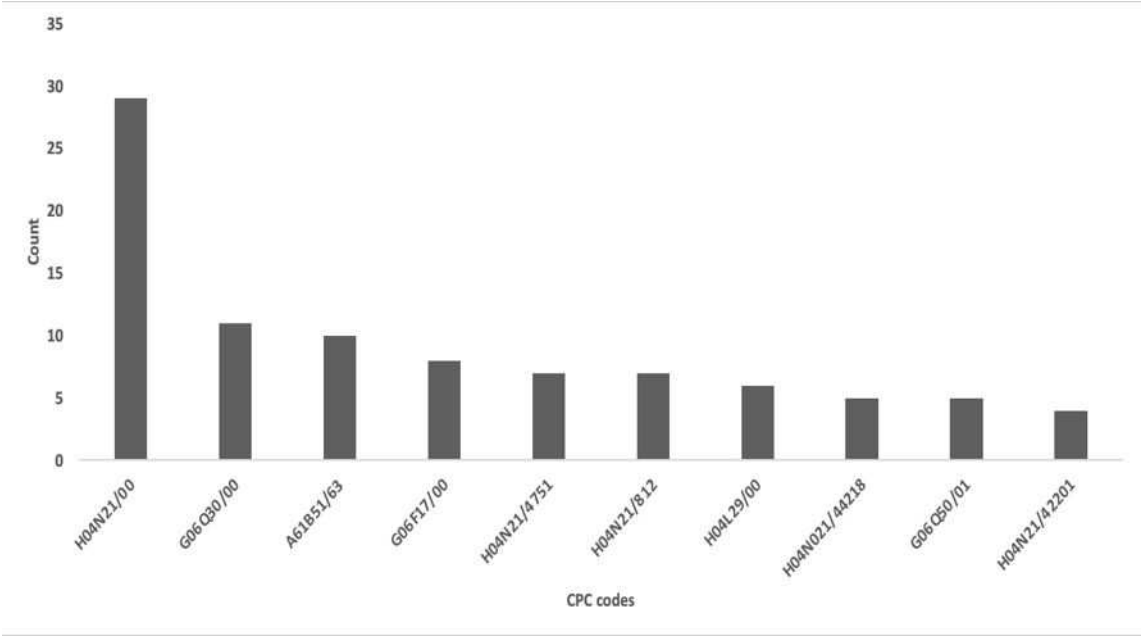
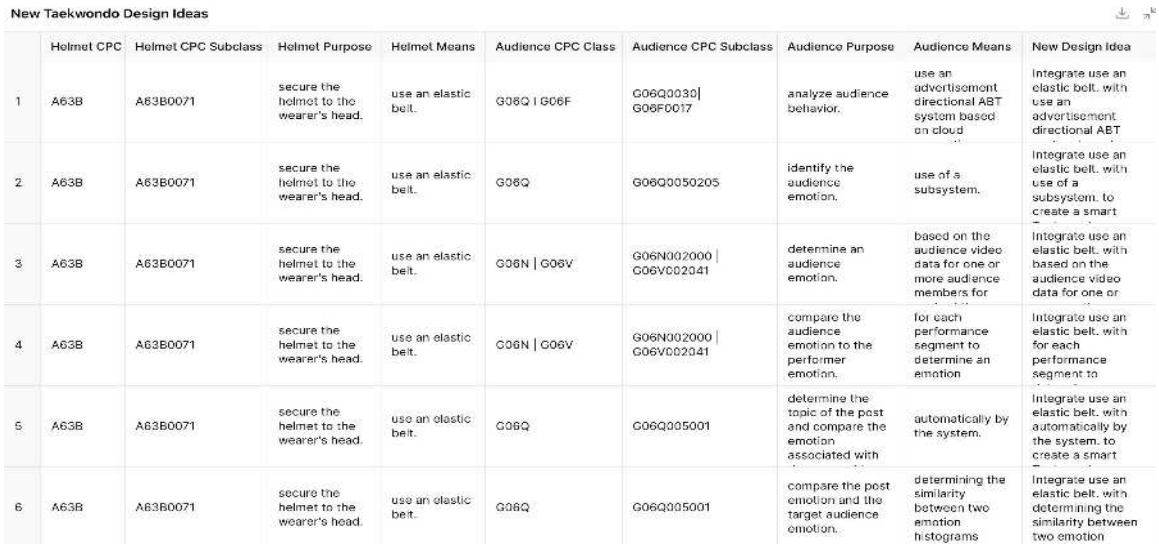


Figure 4.22 The top CPC codes in "analyze audience behavior"

This study employed ChatGPT to suggest combinations based on the technological trends (CPC codes) classified in the design catalogue by employing the role–task–format (R–T–F) prompting approach**.** ChatGPT was assigned a specific role ('expert in design concept creation using patents), provided with a task (to generate design concepts for TKD), and constrained to a specific output format (table). The structured prompting approach allowed consistent benchmarking and reproducibility across generated outputs.

An example of the prompt applied was "*You are an expert in design concept creation using patents. This is a design catalogue to generate new ideas for taekwondo based on 2 concept combinations: (secure the helmet to the wearer's head) and (analyze audience behavior). Based on the combination of CPC trends and means, please suggest a new design in table format (attach the design catalogue).*"

Figure 4.23 presents the generation of 3,969 combinations of helmet and audience behavior, systematically categorized based on CPC codes, purpose (the intended function), means (the mechanism to achieve the function) and new design ideas. The integration of the helmet and audience behavior demonstrates how different CPC-based combinations can lead to innovative design concepts. In order to address the critical challenge of reducing scoring bias and improving accuracy in TKD trainings and competitions, the A63B71/06 (scoring), G06N20/00 (machine learning), and G06V20/41 (semantic clustering) CPC code combinations were chosen in this study. Table 4.3 summarises the findings.



New Taekwondo Design Ideas

	Helmet CPC	Helmet CPC Subclass	Helmet Purpose	Helmet Means	Audience CPC Class	Audience CPC Subclass	Audience Purpose	Audience Means	New Design Idea
1	A63B	A63B0071	secure the helmet to the wearer's head.	use an elastic belt.	G06Q | G06F	G06Q0030| G06F0017	analyze audience behavior.	use an advertisement directional ABT system based on cloud	Integrate use an elastic belt. with use an advertisement directional ABT
2	A63B	A63B0071	secure the helmet to the wearer's head.	use an elastic belt.	G06Q	G06Q0050205	identify the audience emotion.	use of a subsystem.	Integrate use an elastic belt. with use of a subsystem. to create a smart
3	A63B	A63B0071	secure the helmet to the wearer's head.	use an elastic belt.	G06N | G06V	G06N002000 | G06V002041	determine an audience emotion.	based on the audience video data for one or more audience members for	Integrate use an elastic belt. with based on the audience video data for one or
4	A63B	A63B0071	secure the helmet to the wearer's head.	use an elastic belt.	G06N | G06V	G06N002000 | G06V002041	compare the audience emotion to the performer emotion.	for each performance segment to determine an emotion	Integrate use an elastic belt. with for each performance segment to
5	A63B	A63B0071	secure the helmet to the wearer's head.	use an elastic belt.	G06Q	G06Q005001	determine the topic of the post and compare the emotion associated with	automatically by the system.	Integrate use an elastic belt. with automatically by the system. to create a smart
6	A63B	A63B0071	secure the helmet to the wearer's head.	use an elastic belt.	G06Q	G06Q005001	compare the post emotion and the target audience emotion.	determining the similarity between two emotion histograms	Integrate use an elastic belt. with determining the similarity between two emotion

Figure 4.23 An example of the CPC trend combinations generated by ChatGPT

Table 4.3 The means selection based on the CPC codes (subgroup classified)

CPC codes	**CPC description**	**Design knowledge identification (ID)**	**Means (M)**
Secure the helmet to the wearer's head			
A63B71/06	-Indicating or scoring devices for games or players or for other sports activities	tk-621-7	-Employ the signal transmitted to the electronic device
Analyze audience behaviour			
G06N20/00 G06V20/41	-Machine learning -Higher-level, semantic clustering, classification or understanding of video scenes	ab-3-5 ab-3-6	-Based on the audience video data for one or more audience members -For each of the performance segments to determine an emotion accuracy score

Subsequently, ChatGPT was employed to refine the combinations, generating novel design concepts utilizing a similar prompt.

"*You are an expert in generating novel business ideas. Please generate new design ideas by combining all CPC codes and means for taekwondo in table format.*

1. CPC: A63B71/06 -Indicating or scoring devices for games or players or for other sports activities

Means: use the signal transmitted to the electronic device.

2. CPC: G06N20/00 - Machine learning

Means: based on the audience video data for one or more audience members for each performance segment.

3. CPC: G06V20/41 - Higher-level, semantic clustering, classification or understanding of video scenes

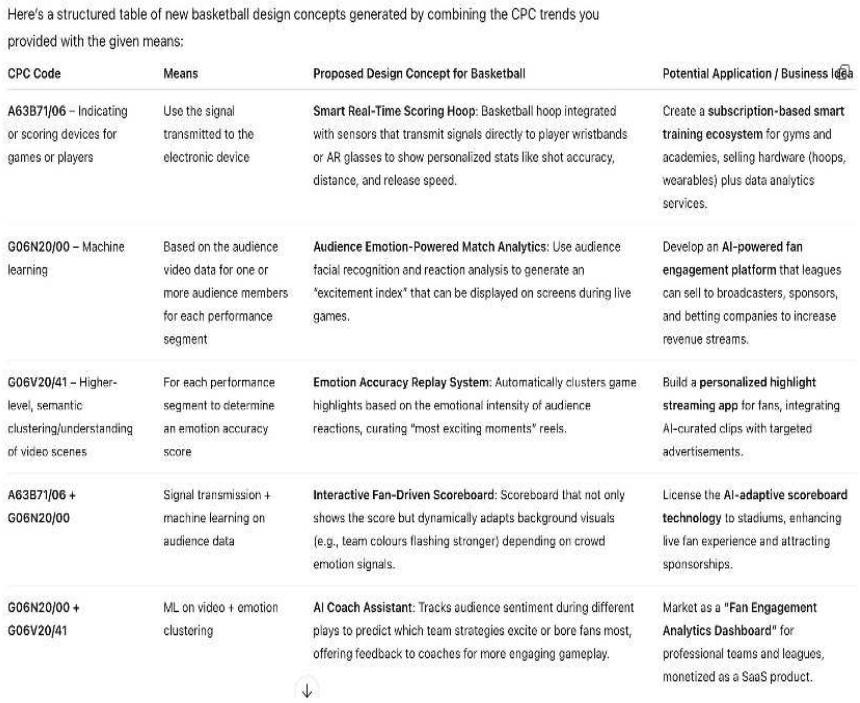
Means: for each performance segment to determine an emotion accuracy score."

Three design concepts leveraging CPC codes were obtained as shown in Figure 4.24: a smart scoring and emotion-driven system, an interactive training and evaluation platform, and a live event engagement and dynamic entertainment system.

Design Idea	CPC Codes Involved	Means/Mechanisms	Description
1. Smart Scoring & Emotion-Driven Feedback System	A63B71/06, G06N20/00, G06V20/41	- **Signal Transmission:** Sensors embedded in uniforms or gear transmit performance data. - **ML Analysis:** Cameras capture audience reactions during performance segments. - **Semantic Classification:** Video scenes are analyzed to generate emotion accuracy scores.	This system provides athletes and coaches with real-time scoring that not only reflects technical performance but also incorporates the emotional response of the audience. The resulting composite score offers a holistic view of performance, which can be used to improve both technical skills and presentation dynamics.
2. Interactive Training and Evaluation Platform	A63B71/06, G06N20/00, G06V20/41	- **Digital Scoring:** Wearable sensors feed scoring data to a central device. - **Audience/Coach Video Feedback:** Integrated cameras record sessions and capture emotional cues. - **Emotion Analytics:** ML algorithms classify video scenes for emotion accuracy.	Designed for training environments, this platform assists athletes by providing immediate, multi-dimensional feedback. The device captures both the athlete's technical performance and the emotional tone (from audience or coach expressions), helping to tailor training sessions to boost both physical and mental preparedness.
3. Live Event Engagement and Dynamic Environment System	A63B71/06, G06N20/00, G06V20/41	- **Performance Data:** Electronic devices collect and display real-time scores during competitions. - **Crowd Sentiment Analysis:** Cameras around the venue gather audience data. - **Real-Time Emotion Metrics:** Video analysis computes emotion accuracy scores that influence ambient effects.	This idea transforms live taekwondo events by linking performance metrics with real-time audience sentiment. The system dynamically adjusts elements such as lighting, sound, or digital overlays in response to the audience's emotional state, thereby creating a more immersive and interactive event experience.

Figure 4.24 The ChatGPT-generated ideas based on CPC codes and means

Figure 4.25 illustrates new design concepts generated in basketball, such as a smart real-time scoring hoop and an interactive fan-driven scoreboard, specifically using the most promising CPC code combinations identified in TKD by prompting ChatGPT. The basketball example demonstrates exploratory transferability and is not a fully generalized case, whereby it did not involve new patent data collection and novelty potential/void matrix analysis.



Here's a structured table of new basketball design concepts generated by combining the CPC trends you provided with the given means:

CPC Code	Means	Proposed Design Concept for Basketball	Potential Application / Business Idea
A63B71/06 – Indicating or scoring devices for games or players	Use the signal transmitted to the electronic device	**Smart Real-Time Scoring Hoop**: Basketball hoop integrated with sensors that transmit signals directly to player wristbands or AR glasses to show personalized stats like shot accuracy, distance, and release speed.	Create a **subscription-based smart training ecosystem** for gyms and academies, selling hardware (hoops, wearables) plus data analytics services.
G06N20/00 – Machine learning	Based on the audience video data for one or more audience members for each performance segment	**Audience Emotion-Powered Match Analytics**: Use audience facial recognition and reaction analysis to generate an "excitement index" that can be displayed on screens during live games.	Develop an **AI-powered fan engagement platform** that leagues can sell to broadcasters, sponsors, and betting companies to increase revenue streams.
G06V20/41 – Higher-level, semantic clustering/understanding of video scenes	For each performance segment to determine an emotion accuracy score	**Emotion Accuracy Replay System**: Automatically clusters game highlights based on the emotional intensity of audience reactions, curating "most exciting moments" reels.	Build a **personalized highlight streaming app** for fans, integrating AI-curated clips with targeted advertisements.
A63B71/06 + G06N20/00	Signal transmission + machine learning on audience data	**Interactive Fan-Driven Scoreboard**: Scoreboard that not only shows the score but dynamically adapts background visuals (e.g., team colours flashing stronger) depending on crowd emotion signals.	License the **AI-adaptive scoreboard technology** to stadiums, enhancing live fan experience and attracting sponsorships.
G06N20/00 + G06V20/41	ML on video + emotion clustering	**AI Coach Assistant**: Tracks audience sentiment during different plays to predict which team strategies excite or bore fans most, offering feedback to coaches for more engaging gameplay.	Market as a **"Fan Engagement Analytics Dashboard"** for professional teams and leagues, monetized as a SaaS product.

Figure 4.25 An example of ChatGPT ideas for basketball

An example of the prompt applied was *"You are an expert in generating novel business ideas. Based on the combination of CPC trends and means, please suggest new design concepts for basketball in table format."*

1. CPC: A63B71/06 -Indicating or scoring devices for games or players or for other sports activities

Means: use the signal transmitted to the electronic device.

2. CPC: G06N20/00 - Machine learning

Means: based on the audience video data for one or more audience members for each performance segment.

3. CPC: G06V20/41 - Higher-level, semantic clustering, classification or understanding of video scenes

Means: for each performance segment to determine an emotion accuracy score."

By extending the framework to basketball, it demonstrates that the methodology can generate meaningful concepts for other sports or sectors beyond TKD. The ideas were then verified by comparing them with only LLM-generated ideas evaluated by independent experts in the subsequent section.

4.4.5 Comparison of Novelty Potential / Void Matrix and Design Catalogue Ideas with LLM Models

The methods proposed in this study were compared and benchmarked by employing the novelty potential/void matrix and design catalogue against LLM models-generated ideas such as ChatGPT, Gemini and DeepSeek. The LLM models' ideas were generated by prompting *"You are an expert in design concept creation, please suggest new design concepts for martial arts such as taekwondo and potential use for other sports or sectors in table format."* The LLM ideas are presented in Figures 4.26, 4.27 and 4.28.

Design Concept	Description	Application in Taekwondo	Potential Use in Other Sports / Sectors
Smart Uniform (Dobok 2.0)	Integrate stretchable sensors and IoT into the uniform.	Track movement, force, posture, and accuracy during training or competition.	Sportswear for gymnastics, fencing, or physical therapy monitoring.
Augmented Reality Training Pods	AR-enabled environment with real-time feedback on techniques.	Practicing poomsae or sparring against virtual opponents.	Boxing, tennis, or solo football drills; military combat simulation.
Energy Absorbing Mat Systems	Smart mats with impact detection and energy absorption tech.	Injury reduction during falls or heavy kicks.	Judo, wrestling, gymnastics, elderly care facilities.
AI-Powered Sparring Assistant	An AI-driven robotic or VR sparring partner with adaptive difficulty.	Solo sparring and reaction time improvement.	Boxing, MMA, self-defense training.
Biometric Belt System	A digital black belt that lights up or changes color based on performance or heart rate.	Motivation and biofeedback for students.	Youth sports coaching, fitness gamification, or yoga belts with feedback.
Modular Taekwondo Dojang	Portable, foldable dojang setup with digital scoring and training zones.	For competitions, demos, or pop-up training.	Martial arts expos, mobile gym setups, or esports arenas.
Gamified Progress Tracker App	App using game mechanics to track belt progression, streaks, or virtual tournaments.	Engage students digitally outside of class.	Youth athletics, dance schools, or learning platforms.
Cultural Fusion Uniforms	Customizable doboks blending modern fashion with traditional Korean design.	Cultural engagement and differentiation in tournaments.	National team uniforms in the Olympics, esports jerseys, or ceremonial attire.
Eco-Friendly Gear Line	Uniforms and gear made from recycled or sustainable materials.	Appeal to environmentally conscious dojangs.	All sports gear industries, school programs, or community outreach.
Mind-Body Biofeedback Interface	Wearables that measure breathing, focus, and stres ↓ levels.	Helps students prepare mentally before sparring or testing.	Meditation apps, golf, archery, high-pressure job training.

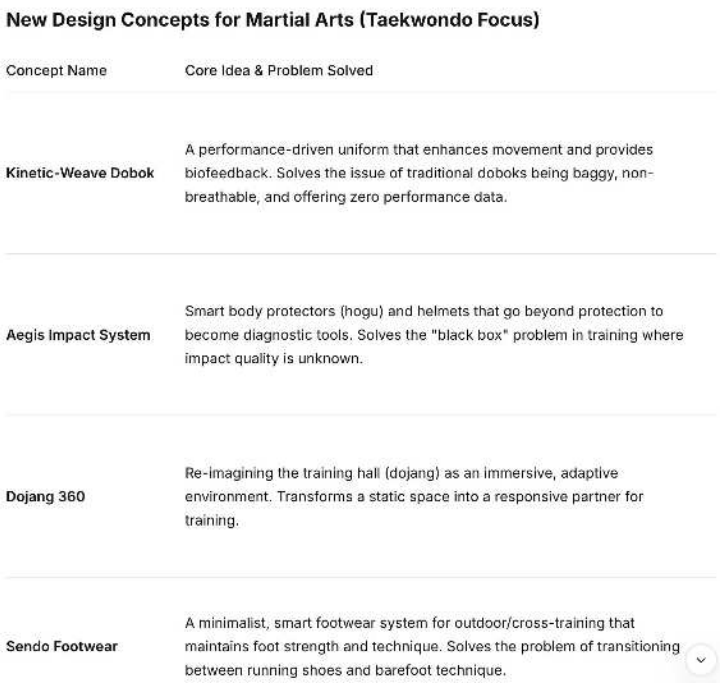
Figure 4.26 ChatGPT ideas (https://chatgpt.com/c/68b9cb97-6370-832d-addf-5aca44c7fd96)



Martial Arts Design Concepts & Applications

Concept Name	Core Idea / Description	Application in Taekwondo	Potential Use in Other Sports / Sectors
Kineti-Form™	A smart uniform (*dobok*) interwoven with micro-sensors and conductive thread that tracks movement, force, and biometrics in real-time, visualizing the data through a connected app or embedded light patterns.	1. **Training:** Provides instant haptic feedback for incorrect posture in forms (*Poomsae*). Measures kicking speed, power ($F = ma$), and rotational velocity (ω). 2. **Competition:** Automates scoring by accurately detecting contact force and location, reducing judging ambiguity. 3. **Visual Spectacle:** LED threads can illuminate on impact or trace the path of a kick, making demonstrations and competitions more engaging for audiences.	**Other Sports:** • **Golf/Baseball:** Real-time swing analysis and posture correction. • **Gymnastics/Ballet:** Monitors form, balance, and alignment, providing feedback to the athlete and coach. • **Fencing:** Integrated, wireless scoring system without cumbersome wires. **Other Sectors:** • **Physical Therapy:** Guides and tracks patient exercises, ensuring correct form and measuring progress. • **Ergonomics:** Corporate wellness programs could use this in workwear to alert employees of poor posture. • **Gaming/VR:** Acts as a full-body haptic suit for immersive virtual reality experiences.
Dynastic Weave	A modular and customizable uniform system that blends high-performance, sustainable fabrics with traditional aesthetic elements. The	1. **Personalization:** Allows students to customize their *dobok* with patterns inspired by Korean art (*Dancheong*, *Minhwa*) or their club's logo, fostering identity. 2. **Progression:** Instead of just a new belt, students could earn a new	**Other Sports:** • **Team Sports (e.g., Basketball, Soccer):** Customizable team jerseys where players can add personal or cultural motifs within a team template. • **Athleisure/Yoga:** Modular clothing that can be adapted for different styles or intensity levels. **Other Sectors:** • **Corporate Uniforms:** Allows for individual

Figure 4.27 Gemini-generated ideas (https://gemini.google.com/app/7c6ad461b6826ee5*)*



New Design Concepts for Martial Arts (Taekwondo Focus)

Concept Name	Core Idea & Problem Solved
Kinetic-Weave Dobok	A performance-driven uniform that enhances movement and provides biofeedback. Solves the issue of traditional doboks being baggy, non-breathable, and offering zero performance data.
Aegis Impact System	Smart body protectors (hogu) and helmets that go beyond protection to become diagnostic tools. Solves the "black box" problem in training where impact quality is unknown.
Dojang 360	Re-imagining the training hall (dojang) as an immersive, adaptive environment. Transforms a static space into a responsive partner for training.
Sendo Footwear	A minimalist, smart footwear system for outdoor/cross-training that maintains foot strength and technique. Solves the problem of transitioning between running shoes and barefoot technique.

Figure 4.28 DeepSeek-generated ideas (https://chat.deepseek.com/a/chat/s/481fe036-100a-4204-bdd7-9c08a01fb53c*)*

The summarized comparison of ideas is demonstrated in Table 4.4. According to the results, ChatGPT produced the highest number of ideas (10) with the most diversity such as an AI-powered sparring assistant and biometric belt system compared to Gemini and DeepSeek (4).

Table 4.4 The comparison of ideas by categories

ChatGPT	Gemini	DeepSeek	Novelty Potential/Void Matrix Idea
Digital Systems			
• AI-powered sparring assistant • Biometric belt system • Gamified progress tracker app • Mind-body biofeedback interface	None	• Aegis impact system	• Smart scoring system with an interactive emotion-driven platform
Apparel/Sportswear			
• Smart uniform (dobok 2.0) • Cultural fusion uniforms	• Kineti-form • Dynastic weave	• Kinetic-weave dobok • Sendo footwear	None
Facilities			
• Modular taekwondo dojang • Augmented reality training pods	• The AR dojang	• Dojang 360Aegis	None
Training equipment			
• Eco-friendly gear line • Energy absorbing mat systems	• Bio-tensegrity gear	None	None

However, LLM-generated ideas tended to converge on mainstream concepts such as AR dojangs and smart uniforms, indicating lower domain novelty. Additionally, the ideas were not prioritized or ranked according to structured criteria, including novelty, and were significantly dependent on the quality of the prompt. In contrast, the proposed method yielded ideas with no overlap, such as emotion-driven scoring systems, suggesting its strength in niche innovation. A more systematic evaluation in a structured, quantifiable manner is possible.

The attribute facilitates prioritizing ideas based on clear criteria, which is beneficial when involving multiple concepts. Furthermore, our proposed approach plays a critical role in overcoming the limitations of prompt engineering by providing a structured, CPC-based knowledge that reduces prompt dependency to generate distinctive, domain-specific innovations. Nevertheless, limitations, such as time-consuming, dependence on existing knowledge, including patents, and a necessity to learn the design catalogue method, remain. The advantages and weaknesses are summarized in Table 4.5.

Table 4.5 The comparison between the LLM ideas and the novelty potential / void matrix and design catalogue

	LLM ideas	**Novelty Potential/Void matrix and Design Catalogue ideas**
Advantage	• Immediate and rapid responses • Suitable for initial brainstorming	• Systematic evaluation based on novelty/void • High reproducibility and consistency • No overlapping with LLM outputs
Weakness	• Human oversight is still essential • Dependence on prompt quality • Dependence on the learning data • Not ranked in structured criteria • Overlapping outputs across models	• Time consuming • Dependence on existing knowledge, including patents • Need to learn the design catalogue method

4.4.6 Independent Expert Scoring

The novelty potential/void matrix ideas and LLM ideas were scored by independent experts. Table 4.6 presents the descriptive statistics of expert evaluations. Overall, the ideas produced a mean novelty score of 3.27 (SD =0.97), indicating moderate novelty compared to current market solutions. Feasibility was rated the highest (M=3.66, SD= 1.162), suggesting that most ideas were perceived as technically achievable. Market potential gained a mean score of 3.46 (SD=1.121).

Table 4.6 Descriptive statistics

	N	Mean	Std. Deviation
Novelty	152	3.27	0.970
Feasibility	152	3.66	1.162
Market potential	152	3.46	1.121
Group classification	19	2.58	0.902

The Kruskal-Wallis H test in Table 4.7 indicates that the novelty potential/void idea scored the highest in novelty (M=15.50) than those generated by LLM models, ChatGPT (M=8.60), Gemini (M=10.38), and DeepSeek (11.75). This suggests that the proposed methodology was more effective in generating original and unconventional ideas compared to standalone-LLM ideas. For feasibility, ChatGPT scored the highest (M=11.20), followed by Gemini (M=9.75), DeepSeek (M=8.13) and novelty potential/void (M=6.50). The proposed novelty potential/void idea ranked the lowest as it may have appeared too abstract or difficult for evaluators to visualize and implement practically.

Table 4.7 Independent experts' scoring

	Group	Mean rank	H (df=3)	p-value
Novelty	NP/Void	15.50	2.279	0.517
	ChatGPT	8.60		
	Gemini	10.38		
	DeepSeek	11.75		
Feasibility	NP/Void	6.50	1.437	0.697
	ChatGPT	11.20		
	Gemini	9.75		
	DeepSeek	8.13		
Market potential	NP/Void	8.50	0.351	0.950
	ChatGPT	10.20		
	Gemini	10.88		
	DeepSeek	9.0		

In terms of market potential, Gemini scored highest (M=10.88), followed by ChatGPT (M=10.20), DeepSeek (M=9.0) and novelty potential/void (8.50). LLMs may generate ideas closer to current market trends and customer expectations, making them appear more commercially attractive than our proposed idea. Although the differences were not statistically significant ($p>0.05$), the trend still suggests that the proposed method may offer higher novelty compared to LLM-generated ideas. This implies potential value in domains requiring original, domain-specific ideation.

Table 4.8 summarizes the top-rated ideas (score ≥4 or 5) from at least half of the evaluators across the four groups. Out of 19 ideas, 9 were rated as highly novel, including the kineti-form (8 evaluators), AR dojang (7 evaluators) and smart scoring platform (6 evaluators). A total of 12 ideas were rated as highly feasible such as the cultural fusion uniforms and eco-friendly gear line, each rated by 8 evaluators. Finally, 15 ideas were considered to have high market potential, including AR training pods and gamified progress tracker app, with 7 evaluators recognizing their potential.

Table 4.8 Top-rated ideas (score ≥4 or 5)

	Top novelty	**Top feasibility**	**Top market potential**
NP/Void (n=1)	1	0	1
ChatGPT (n=10)	3	8	6
Gemini (n=4)	2	3	4
DeepSeek (n=4)	3	1	4

Overall, the novelty potential/void idea is ranked by as one of the top-rated ideas in novelty and market potential, suggesting that it may prioritize quality and originality over quantity. Even with only one concept, the proposed method was still capable of producing ideas considered highly novel and commercially promising by evaluators. The novelty of the proposed ideas is further discussed through an analysis of CPC codes in the subsequent section of this study.

4.4.7 Verification with CPC Codes

The novelty of the ideas generated using the methods proposed in this study was verified through the investigation of CPC codes trend combination of A63B71/06 (scoring), G06N20/00 (machine learning), and G06V20/41(semantic clustering). Patent databases covering application years from 2000 to 2019 were examined. The findings are illustrated in Figure 4.29. Based on the results, an upward trend for all CPC codes was observed, particularly accelerating from 2014 onwards. The G06N20/00 demonstrated the highest number of patents and growth, reflecting the rising interest and advancements in AI technologies, such as machine learning, within the last decade.

The observations aligned with global sport innovation trends, which made AI a crucial component of technological advancements. The CPC code G06V20/41 demonstrated steady growth, specifically after 2012, highlighting the vast applications and commercialization of image-processing technology across various fields with improved sensors, cameras, and computational capabilities. Similarly, the TKD-related CPC code, A63B71/06, revealed a steady but moderate increment compared to the other two CPCs.

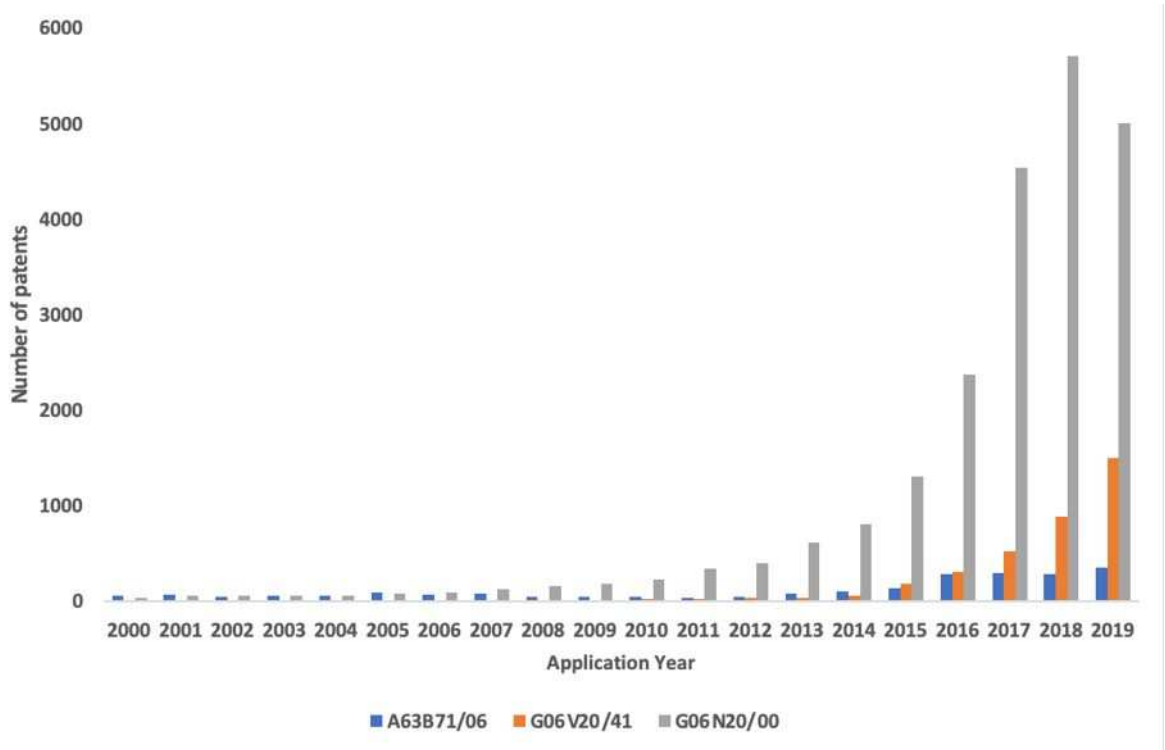


Figure 4.29 Individual CPC trends based on application year from 2000 to 2019 (A63B71/06, G06N20/00, G06V20/41)

The results suggested a consistent interest in and incremental innovation within the sports equipment industry, potentially reflecting niche technological advancements in scoring systems. Following the combination of the abovementioned CPC codes, no existing patent was identified. The information suggested that the proposed new combined ideas, which integrated AI, advanced image recognition, and scoring, might represent a novel idea. The findings from the semi-structured interviews conducted with representatives of the sports industry, SMEs and LEs, a blockchain organization and Malaysian TKD Federation and clubs are highlighted in the subsequent section.

4.5 Semi-structured Interviews

Semi-structured interviews with representatives from the sports industry, SMEs and LEs and a blockchain organization were conducted to gain insights into current business challenges and perspectives. **A**dditionally, an interview with the Malaysian TKD Federation was conducted to understand the challenges and importance of innovation. Feedback on the design catalogue as an innovation tool for idea generation was also gathered during the interviews. The respondents were provided with a list of questions they could answer freely. This study considered the responses as private opinions of the individuals and did not represent the opinions of the entire federation.

4.5.1 Business Model, Challenges and Future Plans in SMEs and LEs

Table 4.9 compares SMEs and LEs in the sports industry based on their business models, challenges, future innovation plans and potential applications to drive the company's profit. The findings indicated that LEs considered the business model innovation essential for long-term sustainability and competitiveness. SMEs, however, were found to be more complacent and reluctant to change, despite facing numerous challenges and declining profit margins, which could potentially affect long-term performance. It was deemed critical for companies to innovate their business models as new ideas could lead to the development of unique products and services. For instance, emerging competitors such as Uniqlo, a fashion brand offering sportswear products such as AIRism, are gaining popularity. If this trend continues, Uniqlo could pose a significant threat to many traditional sportswear companies.

Table 4.9 Comparison between SMEs and LE

	SMEs	LEs
Business Model	**Satisfied** -To continue using the current business model for more than 10 years. The main source of income is related to sports services & maintenance, including repairs, but limited -The martial arts industry has name recognition, and industry competition, such as karate, is not inconsequential -Currently, they are satisfied with their sales, such as in manufacturing and selling popular items for karate.	**Not satisfied** -The current business model lacks robustness in both domestic and international markets, particularly in China -Issues include poor communication between top management and challenges from the rapid growth of China's domestic industry. -Consequently, export volumes have become unstable as the amount of goods exported has become unstable, with domestic market share at 70% and overseas at 30%
Future Plans	-Might innovate business model, depending on the environment and needs -Sales decreased by 10% compared to last year due to COVID-19, when many schools and dojos were forced to close, thus losing some revenue -Plans to focus on services for customer satisfaction such as nationwide trial fitting service for high schools and increased web-sales strategy. For instance, in the Kanto area, face-to-face visit services are provided.	-Plan to innovate the business model within 6-10 years -Intend to shift expansion focus to other countries such as Vietnam, Thailand, and Indonesia instead of China -Aim to develop new products, services and technology particularly high-tech sporting goods targeting elderly population such as water-resistant swimwear and repulsion-based sporting shoes
Challenges	**i)Technology** Still relying on offline rather than online sales **ii)Intellectual property** -Many patents related to manufacturing methods; therefore, related factories are asked to take measures to avoid infringement **iii)R&D** **iv)Organizational reform** -Sales dropped more than 30% due to COVID-19. Schools and dojos could not	**i) Technology, R&D and fabrication** -No fabrication plants in Japan, hence products must be outsourced to other countries, such as Thailand and Indonesia, raising concerns about quality control **ii)Human resource** -Limited training for management and poor cultivation of human resources due to family-owned company. In contrast, larger corporations such as Asics demonstrate a better training system

	operate in March. The impact was far greater than the Great East Japan Earthquake. -Organizational reform is needed due to COVID-19. Until now, face-to-face sales were mainstream, but in the future, both web sales and telework need to be reviewed.	
Potential application for profit growth	-Big data is the most impactful, enabling SMEs to better understand consumer needs and personalize offerings. -Blockchain is a possible application to be adopted in competition scoring. Karate judges often make errors due to human eye limitations, especially in kumite. However, general adoption is questionable due to high development costs and differing opinions and styles among schools.	-The highest-rated technologies include IoT, followed by blockchain, fintech and cloud computing. Other applications ranked at less than 10% of the level of impact such as wireless devices and robots. -Human resources are considered more essential than robots in the sports domain. However, in the manufacturing sector robots remain crucial.

4.5.2 Porter's 5 Forces between SMEs and LEs

The comparison between SMEs and LEs based on Porter's 5 forces was conducted to identify the differences in the level of threats faced by each. As shown in Figure 4.30, SMEs experienced the highest level of threats from the power of buyers and the availability of alternatives. Meanwhile, LEs were more affected by the power of supplier and the threat of new entrants. Both, however, faced similar levels of threat from domestic and international competitors.

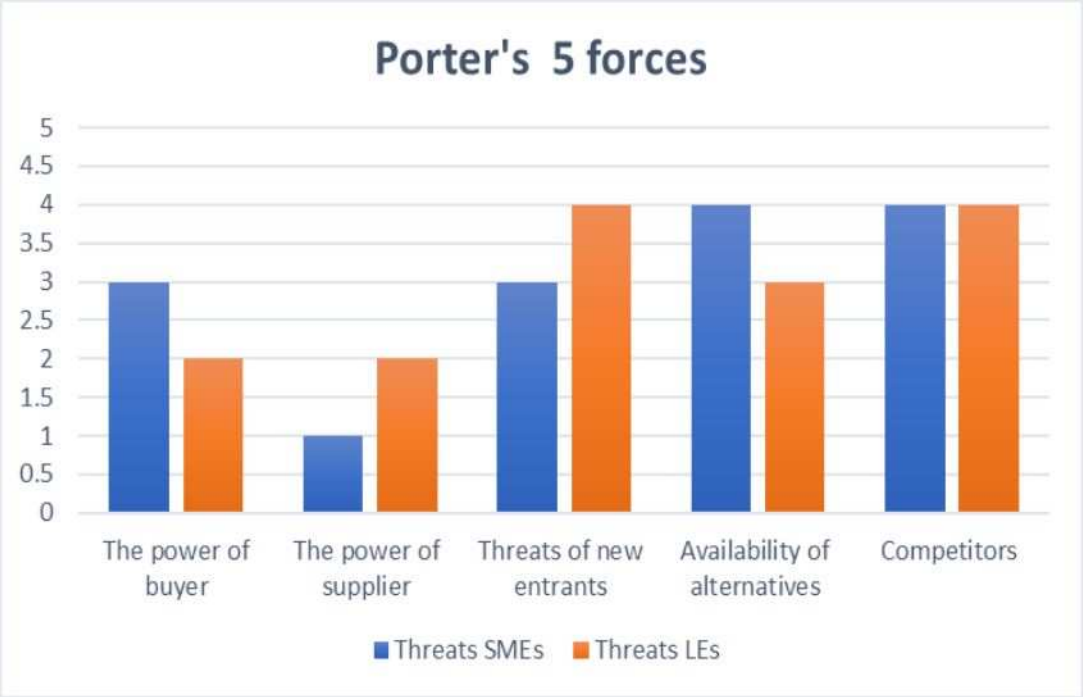


Figure 4.30 Comparison ranking of threats between SMEs and LEs

1) SMEs: Higher threat from the power of buyers and availability of alternatives

High power of buyer:

SMEs tend to have a smaller customer base compared to LEs. Their customers have a wider variety of choices for sportswear, allowing them to easily find similar products at lower prices. This results in strong buyer power, as customers can easily compare products and opt for the lowest-priced option available for similar quality

High availability of alternatives:

SMEs expressed concern that competitors from global brands such as Adidas might enter the market with superior and innovative product or service alternatives, particularly in segments such as Karate clothing, where their uniforms are 100% polyester. This could lead to loss of market share and competitive advantage for the SMEs.

2) LEs have higher: Power of suppliers and threat of new entrants

High power of suppliers:

The number of sportswear suppliers that offer similar products is large (e.g., Nike, Adidas). These suppliers offer a high degree of product differentiation mixed with fashion trends to attract consumers of all age groups. Suppliers in the athletic apparel industry often sell materials to competing companies. Larger buyers obtain lower prices from these suppliers by ordering larger quantities than smaller companies. For instance, Nike might be able to purchase

more cotton for t-shirts than smaller firms like Mizuno, thereby obtaining a substantially lower price.

High threats of new entrants:

LEs feared that the emergence of newcomers such as Uniqlo, which continues to introduce highly differentiated and unique products/services. For example, Uniqlo is a fashion brand that has been offering sportswear products such as "AIRism" which is currently gaining more popularity. If this trend continues, it may pose a substantial threat to established sportswear companies. To avoid this, LEs must innovate in terms of products and services, while enhancing a stronger branding and marketing strategy to better appeal to younger consumers.

3) Both SMEs and LEs have high threat from competitors

Both SMEs and LEs faced the same level of threats from domestic and international competitors. The main domestic competitors for SMEs include companies such as Hirota and Shureido, while international competitors come from Arazawa and Adidas. As for LEs, their main domestic competitors are Asics and Descent, while international competitors are Adidas and Nike.

4.5.3 Future Expectations in the Sports Business Industry

Some future expectations in the sports industry suggest that clear segmentation within the sporting goods industry may diminish. Instead, there will likely be a convergence where various product types are mixed across segments. However, technological areas of sporting goods may continue to exhibit some segments. Furthermore, new market entrants, such as fashion brands like Uniqlo are expected to enter the sports industry, intensifying competition. Moreover, e-sports is currently trending all over the world, though its growth may slow in Japan due to demographic factors.

Other sports, including soccer are also expected to see continued expansion in the future. In emerging markets, particularly in Asia, Africa and other developing regions, new markets in the sports industry may emerge, though development may take time. In Japan, many sports manufacturing companies operate in the same countries, including Mizuno, SSK, and Adidas. In such cases, mergers and acquisitions (M&A) may become necessary to remain competitive and ensure sustainability. Therefore, to survive in this evolving landscape, uniqueness and technological innovations are essential, particularly for SMEs. SMEs that offer unique features or adopt new technologies may sustain and grow, while maintaining long-term relationships with LEs. Otherwise, their survival may be threatened.

4.5.4 Blockchain Organization

Semi-structured interview with a representative from a blockchain organization was conducted to gain some insights and views on blockchain technology. One of the key features identified in blockchain is traceability. For instance, Japan's first comprehensive fishery product traceability system uses blockchain and IoT. With this system, consumers can purchase safer food through a transparent distribution channel that helps prevent inappropriate information leaks or illegal manipulation. Furthermore, by leveraging blockchain, companies can develop a robust social and economic system that allows them to:

(i) Manage information securely without malicious tampering,

(ii) Track history accurately, including corrections, additions, or deletions of information, with time-stamped records, and

(iii) Ensure the information is publicly verifiable by anyone.

Additionally, companies are encouraged to adopt private blockchain solutions, particularly Distributed Ledger Technology (DLT), which is emerging as a mainstream alternative to public blockchain. For instance, "Scalar DLT" developed by Scalar Inc consists of distributed Scalar DB database software and distributed Scalar DL ledger software as shown in Figure 4.31.

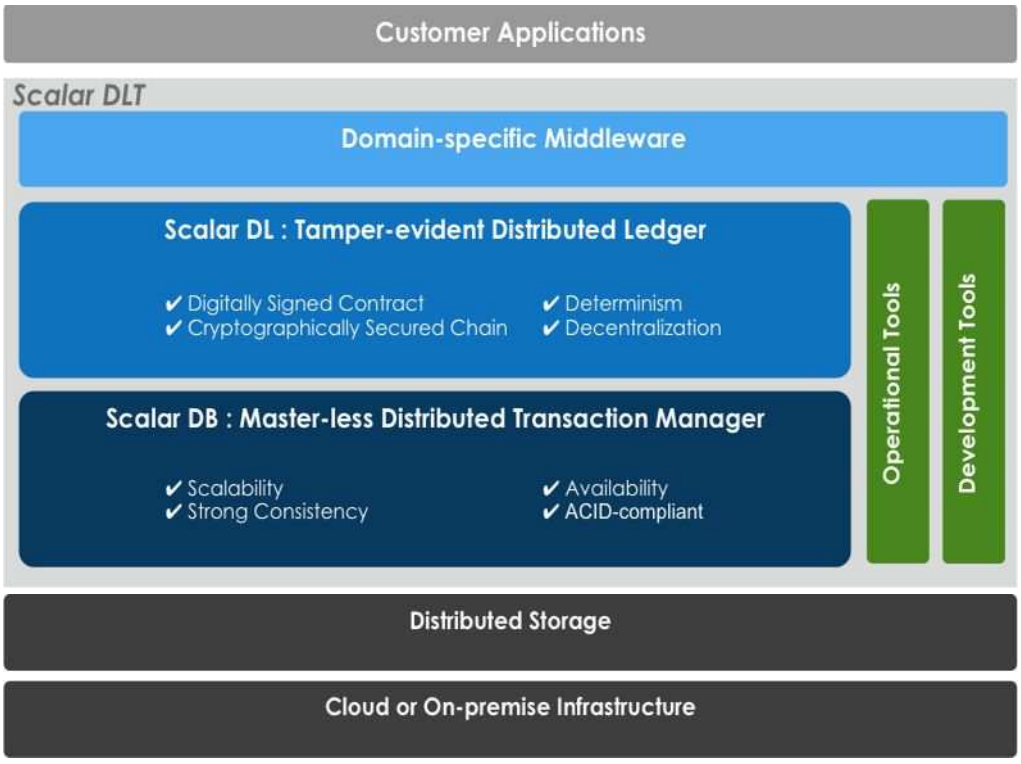


Figure 4.31 Scalar DLT (Source: https://scalar-labs.com/)

It performs a smart contract with digital signatures in the form of a distributed transaction, and outputs the execution result to multiple independent components. Furthermore, it also consists of high tamper resistance with chain management, while at the same time having high scalability, good consistency, and determinism, which was difficult to achieve with traditional blockchains. Therefore, Scalar DLT is recognized as one of the most promising blockchain solutions in the market that SMEs should investigate.

4.5.5 Importance and Challenges of Innovation for Malaysia TKD Federation

Based on the responses from the semi-structured interviews conducted in this study, innovation was considered notably vital for TKD. Novel ideas, such as adopting technology, integrating AI, leveraging digital advancements, sustainable facilities and training environments are crucial in increasing innovation and ensuring the growth and competitiveness of the federations. For instance, the electronic scoring system, protective scoring system (PSS), has improved transparency in sparring matches. Nevertheless, PSS implementation in training sessions presents challenges due to the notable costs associated with the technology. Video assistant referee (VAR) technology has recently been introduced to assist referees in enhancing decision-making accuracy, particularly in blindside scoring.

The implementation of VR is another example which enabled global remote sparring in TKD competitions. The innovation rate, innovation challenges, potential applications for profit growth and opinions on patent trends were also gathered as follows:

i) Innovation rate- Slow innovation rate, the majority of interviewees chose approximately between six to ten years to innovate as shown in Figure 4.32.
ii) Challenges to innovate-
    a) Lack of capital and high investment costs required for adopting advanced technologies
    b) Limited awareness and exposure among decision-makers, particularly within ministries or sports authorities, further hinders adoption. The lack of understanding of the benefits and effectiveness of new technologies leads to a slow rate of institutional support.
    c) Lack of a funding framework or government-led program to assist smaller clubs in technology adoption. While larger organizations may eventually invest due to necessity or competitive pressure, smaller clubs struggle to participate. In order to

foster innovation, targeted programs that allow testing of technology with selected groups, followed by government funding for broader deployment, are recommended.

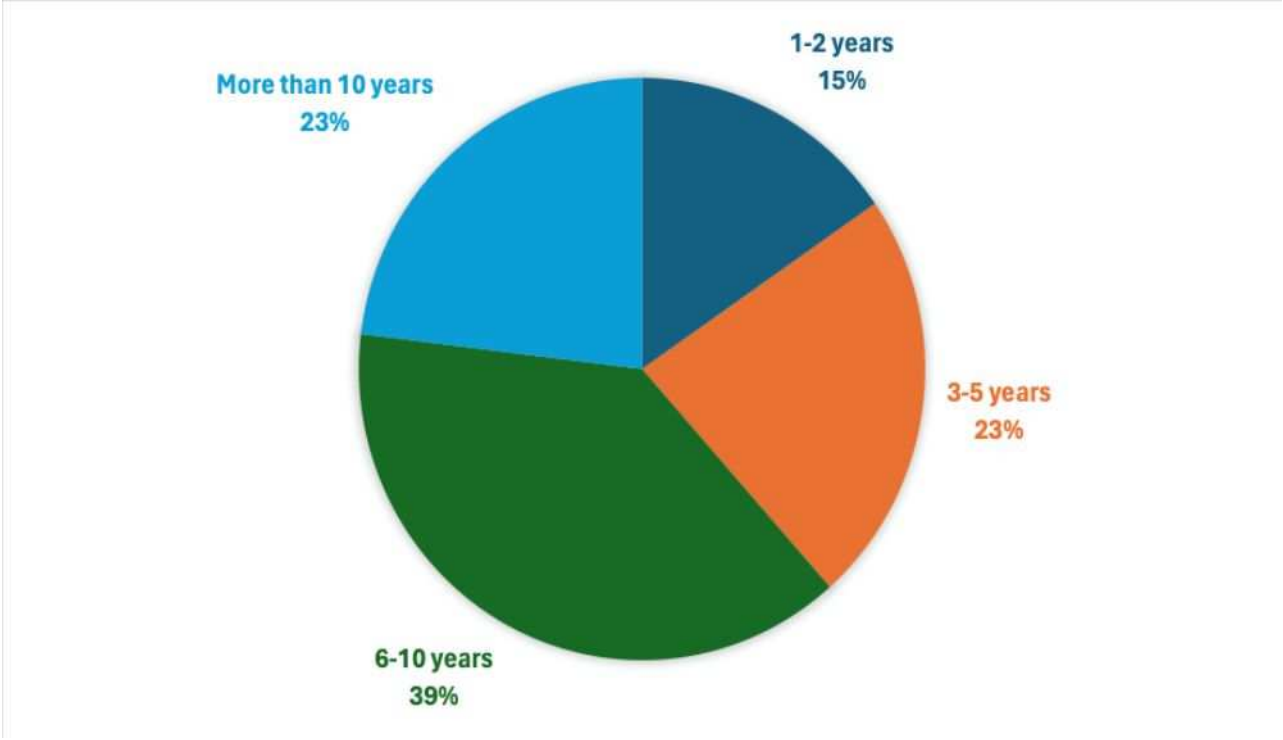


Figure 4.32 Innovation rate

iii) Potential applications for profit growth-

The most impactful applications were AI, Big Data and Internet of Things (IoT). Other applications with moderate impact are cloud computing, wearable and sensor technology, VR/AR and robotics. For instance, integrating new technologies to improve sensors for sparring and a system to record a player's journey and progress in TKD such as competitions and medal contributions, can be created.

iv) Opinions on Judo, Karate and E-sports compared to TKD patents –

Judo and Karate have a plateau trend due to being more traditional and a lack of exposure compared to esports and TKD, which are gaining more popularity. Several reasons included higher publicity, influencers' exposure and development of new technology, specifically due to the Covid-19 pandemic.

4.5.6 Design Catalogue as an Innovation Tool

The interviewees' familiarity and attitudes towards employing a design catalogue for generating ideas are summarized as follows:

(i) Usage- Not familiar, but indicated significant interest in employing a design catalogue.
(ii) Considerable importance- Realized the substantial value and potential benefits for the future of TKD in innovating and creating new systems, products, and services.
(iii) Adoption time- Slow adoption rate of the design catalogue, approximately between three and five years, might be required, unlike Korea, which is faster in embracing innovation and technologies.
(iv) Target area- New and advanced training equipment targeting safety and durability to prevent injuries, integrating smart technologies, including AI, cost reductions due to limited funding, enhancing players' experience and engagement and contribution to the SDGs as part of the United Nations (UN) efforts. For instance, a new scoring system, such as the Poomsae AI evaluation system and power test system to measure the strength of kicks and punches, can be created.
(v) Future outcomes-Main important outcomes are providing a greater strategic direction or idea generation for TKD clubs and federation and enhancing athlete training and performance. Other outcomes include the development of innovative products and services and increased revenue and funding opportunities.

4.5.7 Challenges in adopting the Design Catalogue

The principal challenges and barriers identified by the interviewees that may hinder the adoption of a design catalogue are discussed. The following are the findings:

(i) The TKD clubs and practitioners have limited financial resources for investing in new technologies and/or equipment
(ii) Insufficient comprehension or awareness of the purpose and benefits of the design catalogue
(iii) Resistance to adopting novel technologies, tools, or systems, particularly in the coaches' mindset, which still favors traditional methods
(iv) Inadequate government support concerning funding for new equipment and facilities

(v) Rigid organizational structure characterized by hierarchical layers and centralized decision-making. Any innovation efforts from local and national bodies must first obtain approval from international bodies such as World Taekwondo (WT), thereby limiting the flexibility and capability to innovate independently, particularly at the grassroots level.

(vi) Lack of institutional integration of TKD in educational settings, where TKD is not formally integrated as a core subject, unlike in some ASEAN countries such as Thailand and Vietnam. In Korea, universities offering TKD degree programs and courses. This restricts opportunities to introduce innovative tools through educational settings.

(vii) Dependence on human-AI collaboration. Despite recent technological innovations, fully relying on new technologies such as AI is not yet feasible. For instance, Poomsae scoring involves subjective elements such as presentation and emotion, which require human judgment. Consequently, AI must be complemented with human oversight to ensure accuracy and fairness.

(viii) Privacy concerns due to lack of capacity and technological expertise in managing and implementing new tools, systems and technologies.

4.5.8 Recommendations for Design Catalogue

The interviewed representatives recommended the following to enhance the usability, accessibility, and effectiveness of the design catalogue within the TKD community:

(i) A user-friendly system is required. A new tool should also be affordable, accessible, easy to use, and understandable to all practitioners, including athletes, coaches, and equipment manufacturers

(ii) The ability to address specific challenges for TKD

(iii) Should include multiple languages, such as English and the native language of a country

(iv) Customization for different training requirements and the ability to implement ideas from all levels, including grassroots, national, and elite levels

(v) Should provide innovative recommendations that provide a cheaper alternative than outsourced solutions, such as funding solutions, management and event systems that align with WT standards.

4.5.9 Future hopes for TKD

The future hopes for TKD were identified by the interviewees as follows:

(i) Structural and curriculum transformation:
   a) Structural changes in training curriculum by shifting from traditional martial arts-focused training to a sports-oriented TKD curriculum
   b) TKD as a mandatory subject in schools and universities should be introduced, following the model used in Korea
   c) Specialized TKD training centres and stadiums equipped with advanced facilities, technologies and tools should be developed similar to Korea's national training infrastructures

(ii) Digital transformation and technological advancement:
   a) Digital transformation in coaching should be implemented such as online learning, video-based coaching, and data-driven performance analysis during TKD training sessions
   b) Technological exposure among coaches and students should be encouraged to strengthen adaptability, innovation and organizational sustainability.
   c) Collaboration with esports should be increased, specifically through VR/AR applications in TKD competitions and training, continuing the initiatives launched since 2023

(iii) Governance and institutional strengthening:
   a) Government support should be strengthened by providing financial support to TKD coaches, including increasing salaries and incentives
   b) Unification and greater cooperation among various TKD groups and major federations (ITF, WTF, and MGTF) under a single governing body are essential for national development. The unification would create a more coherent structure for competitions, training and representations, ultimately enhancing Malaysia's international competitiveness in TKD.

(iv) Strategic innovation and talent development:
   a) Olympic aspirations to qualify Malaysian athletes for the 2028 Olympics and secure the nation's first Olympic gold medals
   b) Bringing innovation to grassroots levels, where the real impact should be developed and not just restricted to the elite level.

c) Organizing more inclusive tournaments for young children (ages 4 to 6) and athletes with special needs and disabilities to promote early engagement and equitable participation
d) Increasing international exposure and opportunities through cross-country training and exchanges to enhance skill development and global competitiveness.

4.6 Relationship to our research results

Table 4.10 shows the relationship of the interviews with SMEs and LEs in the sports industry, blockchain organization and the Malaysian TKD clubs and federation to our research results.

Table 4.10 Relationship to our research results

Interview results	Relationship to our research results
Sports organizations SMEs and LEs Identified and compared the business challenges, innovation needs and organizational issues	**Needs validation:** Validated the need for a structured innovation framework and informed recommendations for business model innovation, technology adoption and IP awareness
Blockchain organization Obtained expert recommendations on blockchain adoption, implementation challenges, and emerging solutions (e.g., Scalar DLT).	**Technology validation:** Recommended blockchain solutions and supported the integration of blockchain into the proposed design concepts (smart scoring system, AI video platform and wearable IoT devices)
Malaysian TKD clubs and federation Gained innovation needs and challenges, future needs, and feedback on the proposed design catalogue.	**Practical validation**: Validated the practical applicability of the patent-based design catalogue and gained recommendations based on practitioners' needs and challenges in ensuring the feasibility, relevance, and adoption in real-world TKD organizations.

CHAPTER 5

DISCUSSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter discusses the findings derived from the patent and non-patent analysis, novelty potential (word2vec), patent-based design catalogue and semi-structured interviews. It synthesizes the results to develop recommendations for strengthening business model innovation in TKD SEs and discusses the proposed design concepts generated based on the cases studies, novelty potential (word2vec) and patent-based design catalogue. Table 5.1 presents the summary of research question, results and contributions of the study.

Table 5.1 Summary of research question, results and contributions

Research Question (RQ)			
"How to create a systematic framework for generating new business ideas and novel design concepts for Taekwondo social enterprises (SEs) to support business model innovation?"			
Results			
(1) Patent and non-patent trend investigation	**(2) Novelty potential (word2vec)**	**(3) Patent-based design catalogue**	**(4) Validation: Semi-structured interviews**
Co-occurrence network analysis reveals emerging trends, technological opportunities and key relationships based on CPC codes and keywords (e.g., blockchain and IT/IS)	-Identifies novel concept combination based on novelty potential/void matrix and verifies through patent investigation, revealing upward trend. -Proposes an advanced video platform integrating AI, blockchain and	-Independent expert survey reveals no statistical significance due to potential bias; however, the observed trend indicates higher novelty -LLM comparison shows proposed method produces non overlapping ideas - CPC combination reveal no existing patent identified - Proposes a smart scoring	Provides real-world insights from industry stakeholders (SMEs and LEs, blockchain organization, TKD clubs and federation) on challenges, needs, and feedback on design catalogue

	solar-powered IoT wearables	system with an interactive emotion-driven platform	
Contributions			
-Academic: Advances understanding of technological trends and innovation gaps in TKD and sports domain. -Practical: Organizations able to identify emerging technologies and innovation opportunities	-Academic: Advances the novelty potential theory and methods into sports domain -Practical: Organizations can identify high-novelty concept combinations and generate innovative ideas	Academic: Advances structured ideation methodology and theory by integrating patent knowledge and AI-assisted design concepts -Practical: Organizations able to apply structured ideation framework integrating human-AI collaboration for innovation	-Academic: Provides empirical evidence validating the proposed framework and contributes to bridging theory and practice in sports innovation research. -Practical: Offers actionable insights and decision-making support for stakeholders

5.2 Recommendations for Strengthening Business Model Innovation for TKD Social Enterprises

Based on the interview data, LEs have a higher-level awareness of the need to face future challenges compared to SMEs. They find that innovating the business model is highly essential for the business to survive in the long run. Nevertheless, innovation is much easier for LEs, as they have more resources and capabilities than SMEs. By contrast, SMEs are more reluctant to change and innovate, possibly due to the lack of capital and resources to invest in the latest technologies. Additionally, they lack the relevant expertise and skills. This could affect long-term performance and reduce their market share as new competitors enter the market to provide better products and services, such as Uniqlo.

The Malaysian TKD federation also finds that innovation was considered notably vital in ensuring the growth and competitiveness of the federation, particularly through the integration of technologies. As competition intensifies between SMEs and LEs in POs, TKD SEs must develop their own strategies to sustain and compete in the market, particularly during the COVID-19 era. Therefore, we identified several strategies for SEs based on the challenges discussed:

(i) *Technology:* Investing in or integrating technologies such as private blockchains with IoT big data to secure transactions, lower transaction costs and connect with technology partners.

(ii) *Intellectual property (IP):* Hiring IP experts to manage IP and IP licensing and partnerships

(iii) *Organization:* Creating an open innovation ecosystem, such as seekers (companies) and solvers (experts)

(iv) Branding and marketing:

a. Collaborating and forming partnerships with athletes or celebrities for product endorsements that customers perceive to have value based on association and brand recognition;

b. Strategically collaborating with POs (SMEs or LEs), which include schools, dojos, universities, and companies

c. Developing a strong brand that is closely connected with the company's mission statement

(v) Human resources:

a. Cultivating a learning environment and educating employees on digital transformation

b. Hiring experts in R&D and technology, such as data scientists.

5.3 Suggestions on the Potential Use of Blockchain

1) Using Blockchain in the TKD Scoring System

To ensure fairness in TKD judging especially in competition scoring, a wireless scoring system for martial arts players that leaves no room for dispute needs to be put in place. For example, scoring system software such as iPS Host, developed by iCROSS, should be combined with blockchain technology from Scalar DLT. It is a tamper-resistant distributed ledger using a method called decoupled consensus, in which the contract execution phase and the tampering verification phase are separated (decoupled).

2) Combining Blockchain and the Internet of Things (IoT) for Smart Sporting Devices and Equipment

TKD smart sporting equipment such as helmet sensors, provides immediate transmission to an app that keeps track of hit count and force impact. It is possible to know when a player has experienced a hit that may have resulted in a concussion; therefore, the match can be stopped, and the player can be examined. Moreover, data retrieved from the sensors is stored in the blockchain, which provides traceability and transparency. Figure 5.1 shows the Autonomous

Decentralized Peer-to-Peer Telemetry (ADEPT), a blockchain technology that serves as a ledger of life for devices that would autonomously broadcast transactions between peers in a three-tier structure of peer devices and architecture [150].

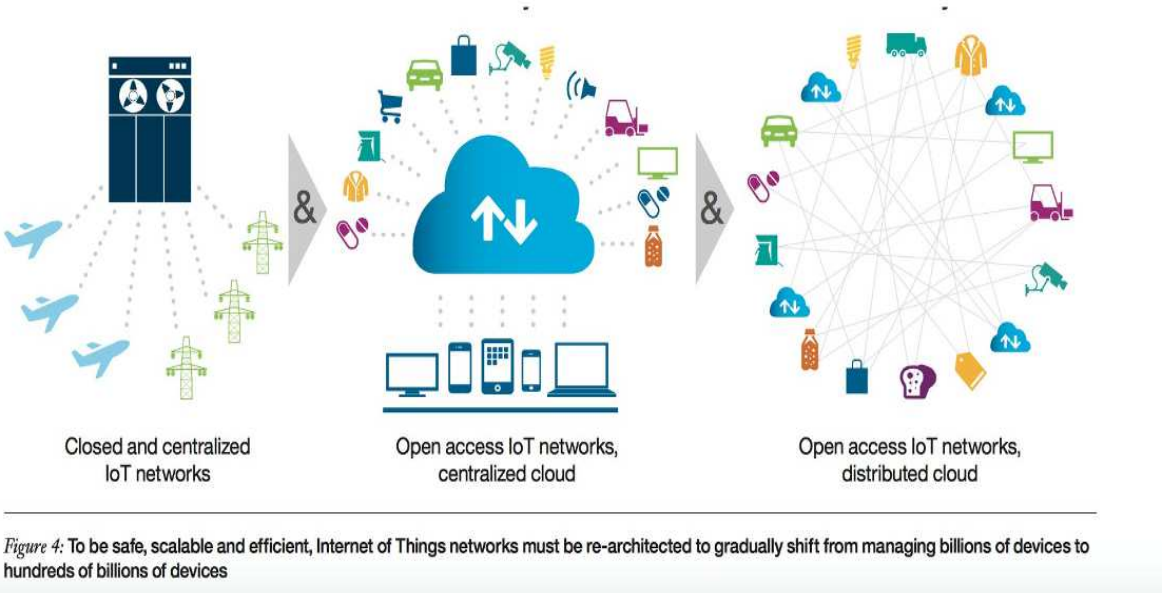


Figure 5.1 ADEPT (Source: International Business Machines Corporation (IBM))

The ADEPT concept uses blockchains as the system's foundation, securing transactions with a combination of proof-of-work and proof-of-stake. BitTorrent (file sharing), Ethereum (smart contracts), and Tele Hash (peer-to-peer messaging) were chosen by IBM and Samsung. It would serve as a ledger of existence for billions of devices that would autonomously broadcast transactions between peers in a three-tier system of peer devices and architecture. Using the Bitcoin protocol, ADEPT can be used to connect many devices at a low cost [150]. SEs can benefit from the integration of blockchain technology with smart devices to make all transactions secure and offer scalability.

3) Combining Blockchain, Internet of Things Devices, and Artificial Intelligence for an Advanced Video Platform

Blockchain can create a credible and immutable record of biometric data, while AI can analyze and generate insights from the data. By combining these technologies, a new health application platform can be created for martial arts players with strong support from the Microsoft Azure platform combined with AI. Based on the novelty potential (word2vec) results, this study created an advanced video platform based on blockchain, AI and IoT devices for the martial arts community, which includes martial arts students and trainers as demonstrated in Figure 5.2.

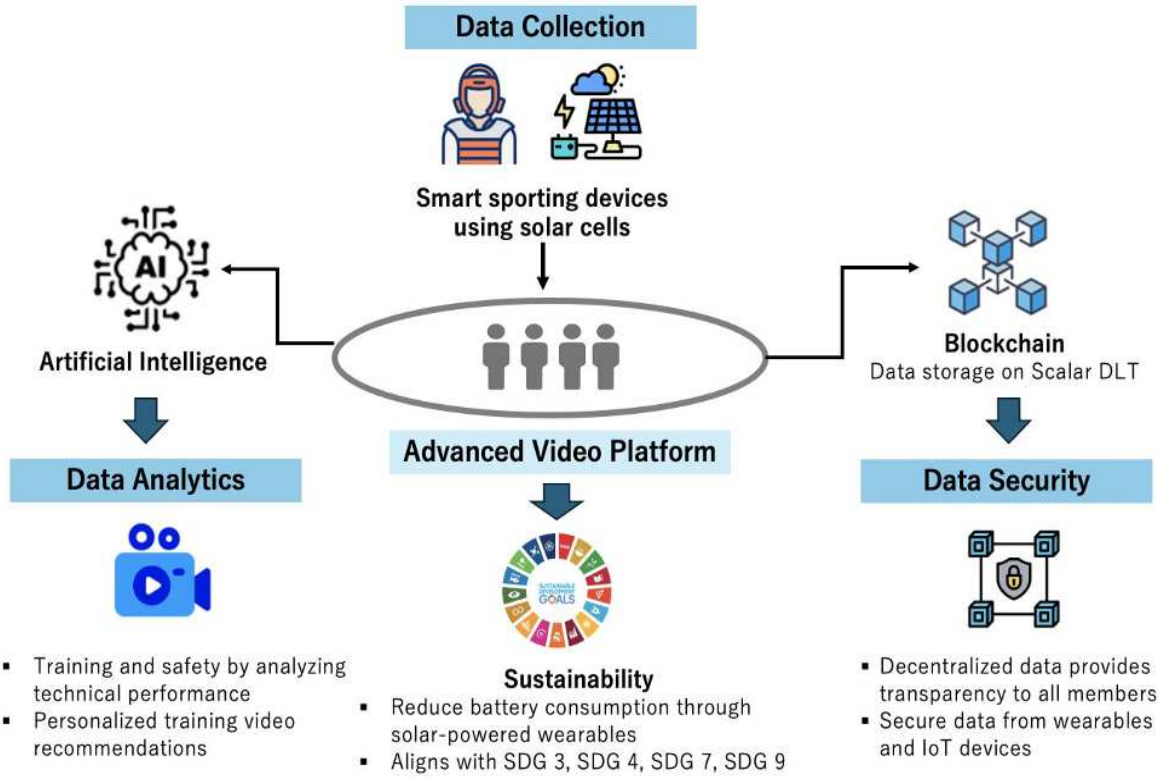


Figure 5.2 The advanced video platform framework for the martial arts community

Owing to the COVID-19 pandemic, many businesses are forced to adapt to a "new normal" involving working from home and social distancing. Therefore, it is crucial to adopt a new business model for martial arts to fit the current situation. The business plan using blockchain technology from Scalar DLT can provide a secure content platform to share data from IoT devices anywhere and anytime.

Several valuable propositions from the business idea are as follows:

(i) Blockchain-based platform

- Decentralized data, secure & transparent to all martial arts' members
- Secure data storage from smart sporting martial arts devices

(ii) Solar-powered IoT devices using solar cells

- Helps to reduce battery consumption and cost-savings
- Portable, low-maintenance devices enabling mobility

(iii) AI-generated training plans and personalised recommendations

- Analysis of the martial arts players' training performance, frequency of training and levels, as well as provision of specialized video and training plans

(iv) IoT sensors and AI

- Provide a personalized experience and help detect and monitor injury levels

(v) Sustainable Development Goals (SDG) contribution

- Lower environmental impact through sustainable energy
- Aligns with SDGs 3, 4, 7, and 9 which aim for good health and well-being, quality education, affordable and clean energy and industry, innovation, and infrastructure, respectively

5.4 Recommendations on New Design Concept Based on Patent-Based Design Catalogue

This section discusses the results of the proposed methodologies, including independent expert scoring and a new design concept for TKD SEs. Despite the statistical results yielding no significant differences ($p>0.05$), the observed trend suggested that our proposed method may offer higher novelty compared to LLM-generated ideas. The outcome may result in potential biases based on the evaluators' background, whereby they were specialists in mechanical and applied engineering rather than TKD market experts.

This may have led to the underestimation of ideas that were difficult to visualize for practical implementation. Consequently, zero-void combinations may have been perceived as emergent ideas that remain difficult for evaluators to envision in terms of practical implementation. Therefore, it is essential to consider how the evaluators' backgrounds may have influenced their assessments of novelty. Based on the results, this study proposed a new design concept for TKD SEs, a smart scoring system combined with an interactive emotion-driven platform, leveraging advanced technologies including machine learning, semantic classification, and sensor technologies. Figure 5.3 illustrates the framework for the smart scoring system and emotion-driven platform for TKD SEs.

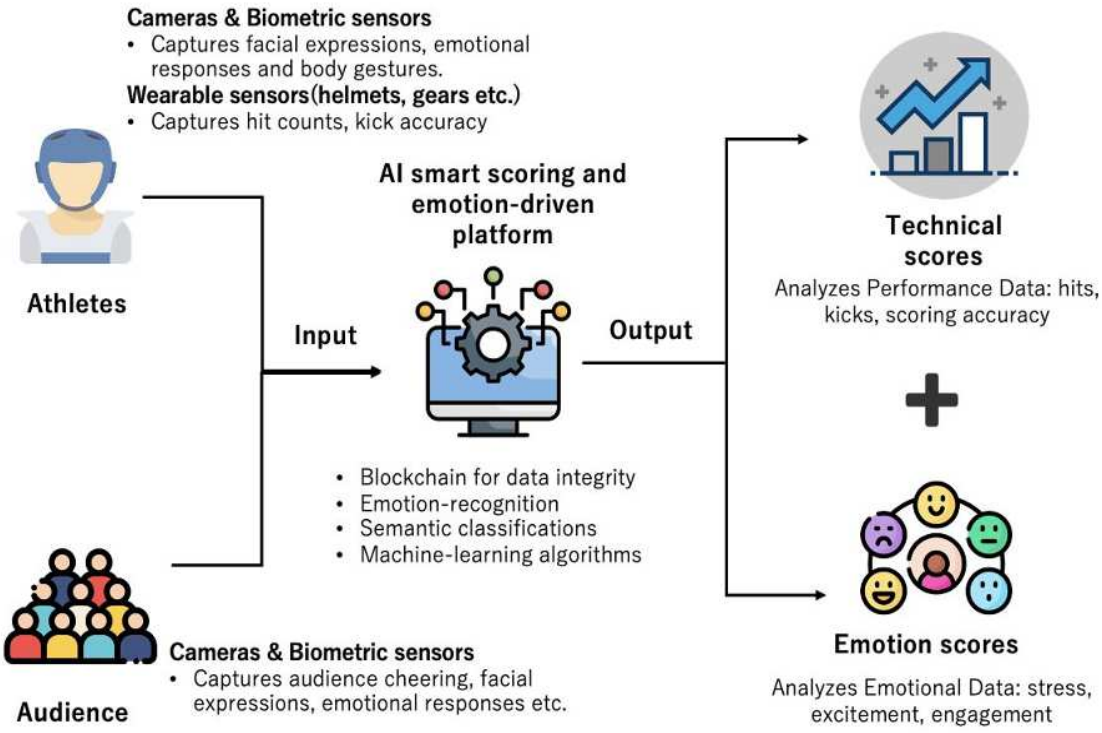


Figure 5.3 The smart scoring system and emotion-driven platform framework for TKD SEs

The system developed in this study utilizes CPC codes, such as A63B71/06 (scoring), G06N20/00 (machine learning), and G06V20/41 (semantic clustering). While existing scoring systems primarily focus on athletes' physical or technical performance, integration with emotional capabilities remains limited. Incorporating emotional aspects can provide a new engagement layer, where reactions of the audience or athletes (such as recognizing excitement or tension) can be employed to enhance feedback during training or competition.

The developed approach also leverages real-time monitoring, feedback, and decision-making, ultimately connecting multiple stakeholders, including athletes, coaches, audiences, and sponsors. For example, the TKD PSS can be combined with emotion recognition technology by collaborating with sports technology and AI companies, such as Affectiva, MoodMe, and Kick.ai. Affectiva's emotion AI technology, utilizing machine learning and computer vision, including camera sensors can be employed to analyze real-time TKD athletes' facial expressions, gestures, and body posture.

Another technology developed by MoodMe's solutions, such as Emotion Fan Cam, enables real-time capture and analysis of audience emotions, reactions, and engagement levels. The audience's emotional data streams, along with scoring results displayed during live

competitions, can significantly enhance fan engagement and provide important insights for event sponsors and organizers. Furthermore, the integration of blockchain technologies—such as Scalar DLT—with scoring system software like iPS Host has the potential to enhance fairness and minimize the risk of disputes in TKD judging. Scalar DLT employs a decoupled consensus mechanism to establish a tamper-resistant distributed ledger [23].

The platform proposed in this study also adopts a SoS approach, which is essential in integrating independent yet interconnected subsystems. Each component in the system operates independently while maintaining managerial autonomy—meaning that one module can be updated without disrupting the entire system [151]. For instance, new machine learning algorithms can be implemented into the scoring system without disrupting the emotion analysis component. This integrated approach ensures the platform is flexible and adaptable to any technological advancements or changing user requirements, thereby meeting the evolving needs of TKD SEs.

From the viewpoint of a management system [152], the platform developed in this study can serve as monitoring, decision-support and feedback, data integrity and transparency, and stakeholder engagement systems. Several valuable propositions for the new system are as follows:

(i) Enhanced scoring accuracy and objectivity- Utilizing AI-powered, real-time judging system to differentiate between scoring and non-scoring strikes in sparring competitions and recognizing correct patterns in Poomsae (forms) can reduce human error and bias

(ii) Comprehensive scoring- Integrating emotion analytics with physical performance metrics to gain improved insights

(iii) Improved athlete performance feedback- AI provides personalized training environments based on an athlete's performance and emotional data

(iv) Injury detection and prevention- Monitors and facilitates emotions and health conditions to manage fatigue levels as an injury prevention measure

(v) Increased audience and fan engagement and sponsorships- Real-time emotional analytics and interactive visualizations may enhance fan experiences, sponsorship opportunities, and event revenues

(vi) SDGs contribution- Aligns with SDGs 3, 4, 9, and 17, which aim for good health and well-being, quality education, industry, innovation, and infrastructure, and partnerships, respectively

The global market demand for the sports technology industry is experiencing significant growth. In the past five years, an 11.32% annual rate and over 2,300 new companies

have emerged [153]. An example of key players in sports technology that have revolutionized fan engagement is IBM Corporation. Their AI-powered platforms such as Watson enhance the sports viewing experience by integrating predictive analytics and real-time information [154]. Consequently, converging smart scoring systems and emotion-driven platforms in TKD aligns with the growing demand for data analytics and personalized training in sports. The methods proposed in this study and the SoS approach can support TKD SEs maintain innovation and competitiveness.

CHAPTER 6

CONCLUSIONS

6.1 Introduction

This chapter presents the summary of findings, academic and practical contributions, research limitations, and directions for future research.

6.2 Summary of Findings

This dissertation proposed a new strategy to generate business ideas and novel design concepts leveraging patent and non-patent analysis, novelty potential/void matrix, patent-based design catalogue and Gen AI, centered on TKD as a case study. Semi-structured interviews were also conducted to gain insights into challenges and to gain feedback on the design catalogue. Finally, new ideas and design concepts are recommended for TKD SEs to innovate their business model based on the proposed methodologies.

6.2.1 Patent and non-patent trends investigation

This study investigated patent and non-patent trends of TKD and other sports/technologies, including Blockchain and IT/IS, by analyzing the CPC codes and keywords through co-occurrence network analysis. The findings revealed that TKD patents showed an upward trend, compared to other martial arts, such as Judo and Karate, indicating an increase in technological and innovation potential, which is expected to increase in the future. Despite having the same trends with e-sports, there is little correlation between CPC codes, indicating a difference in core technologies and potential for new combinations to occur.

Additionally, the top 5 CPCs in Blockchain and IT/IS were identified and recommended for TKD SEs, such as CPC H04L2209/38 (chaining), and G06F16/29 (geographical information database), with TKD CPCs in the A63B category (equipment for martial arts). Blockchain technologies can be used to securely store data from smart sporting TKD devices or equipment. Meanwhile, GIS technology can be used to analyze the characteristics, behavioural patterns, and movements of TKD athletes, supporting precise athlete performance assessments.

Furthermore, results from non-patent analysis complement patent results by analysing data from academic publications, providing insights into the latest research trends. Blockchain patents and non-patents were revealed to have a strong relationship, which shows that they are more business-oriented. High centrality keywords from co-occurrence network analysis from TKD, blockchain and IT/IS abstracts were analyzed and recommended for TKD SEs. For instance, the words "IoT", "secure" and "smart contract" with "supply chain" can be implemented for IT/IS with blockchain, which improves both the organizational learning effectiveness and supply chain quality for TKD SEs. Therefore, both patent and non-patent data are critical to obtain a complete and reliable representation of the research trends.

6.2.2 Case Study 1: Novelty Potential/Void Matrix

Several new ideas were proposed and a new business idea was developed through the application of the novelty potential concept, which combined patent abstracts from sports and blockchain data. The proposed ideas include integrating blockchain into the TKD scoring system to ensure fairness in TKD judging and combining blockchain and the IoT for smart sporting devices and equipment. Finally, an advanced video content platform for martial arts players using AI, Blockchain & IoT devices was developed to support remote training amid the new normal following the COVID-19 pandemic. The platform integrates blockchain technology from Scalar DLT, which can enhance transparency and provide a secure platform to all martial arts members, while solar-powered IoT devices contribute to improving energy efficiency and cost reduction.

The novelty was then verified through patent trend analysis, which showed an upward application trend, indicating that AI in digital media and content platforms is increasingly integrated into businesses. Similarly, the growing adoption of solar cell technologies and IoT devices reflects increasing awareness of sustainability and energy-efficient solutions. The results demonstrated that the novel potential concept is effective in generating new business ideas that can provide a highly personalized customer experience and unique products and services to strengthen competitive differentiation.

6.2.3 Case Study 2: Patent-based design catalogues

The patent-based design catalogue results proposed a new strategy to generate novel design concepts for future systems. A case study on TKD utilizing idea generation methodologies, such as the novelty potential/void matrix, design catalogue employing CPC codes, and Gen AI (ChatGPT), were implemented. A highly novel design concept and logical approach was

developed, which incorporates a smart scoring system with an interactive, emotion-driven platform that integrates machine learning, semantic classification, blockchain, and sensor technologies. It provides real-time and precise scoring that reflects training performance and analyzes the emotional aspects of athletes and audiences. The platform also adopts a SoS approach, which is highly crucial in integrating independent yet interconnected subsystems.

Our approach yielded ideas with no overlap compared to LLM-based approaches, indicating its strength in niche innovation. Nevertheless, the CPC codes assessments verified the absence of similar patents, indicating potentially novel combinations and an increased potential for a first-mover advantage for TKD SEs. Finally, the responses from the semi-structured interviews with representatives of the Malaysian TKD Federation and clubs served as an initial practitioner-level validation, offering insights and feedback on the design catalogue as an innovation tool for idea generation. The proposed methods and the SoS approach can support TKD SEs in sustaining innovation and competitiveness in a rapidly evolving technology landscape.

6.2.4 Semi-structured Interviews

The results from the semi-structured interview revealed notable differences in innovation awareness and capabilities between LEs and SMEs in the sports industry. LEs demonstrated a stronger awareness of the importance of business model innovation to address future challenges and maintain long-term competitiveness, due to greater resources and capabilities. In contrast, SMEs showed relatively lower readiness to innovate, primarily due to limited financial resources, insufficient technological capabilities, and a lack of specialized skills, which reduce their ability to invest in emerging technologies and may weaken their long-term market competitiveness as new entrants introduce more advanced products and services. Nevertheless, both SMEs and LEs faced substantial competitive pressures from domestic and international competitors based on Porter's 5 analysis, which prompted the necessity for continuous innovation.

Insights from the blockchain organization emphasized the potential of blockchain technology to enhance security through immutable and time-stamped records. The growing adoption of private blockchain solutions, such as Scalar DLT, offers improved scalability, consistency, and tamper resistance compared to traditional blockchain systems. Consequently, blockchain technology can support secure and transparent digital platforms, enabling organizations and SMEs to strengthen trust, data reliability, and technology-driven innovation. Furthermore, insights from the Malaysian TKD clubs and federation highlighted the growing

importance of technological integration in sustaining the development and competitiveness of the TKD ecosystem. Innovation, particularly through digital technologies, is viewed as a critical factor for improving organizational performance and maintaining relevance in an increasingly competitive sports environment.

However, the adoption rate of innovation remains slow, due to limited financial resources and high investment costs, limited awareness and support among decision-makers. Despite these challenges, feedback on the proposed design catalogue revealed high interest among practitioners. Several challenges to adoption were identified, including rigid organizational structure and insufficient comprehension of the benefits. Additionally, recommendations were made by practitioners, including a user-friendly system and multi-language support. Finally, practitioners expressed future hopes for digital transformation initiatives, mandatory TKD curriculum and Olympic aspirations to qualify for the Olympics. The academic and practical contributions of the research are discussed in the subsequent section.

6.3 Contributions

This study provides academic and practical contributions that benefited researchers, scholars and practitioners, specifically TKD communities. Overall, the main contribution of the study is the development of a systematic AI-assisted ideation framework through human-AI collaboration, integrating novelty potential/void matrix, patent-based design catalogues and generative AI to support business and design innovation for TKD SEs. Table 6.1 shows the summary of the connection between research questions, results and contributions.

6.3.1 Academic Contributions

From an academic perspective, the research contributes to the literature on sports management, design concept generation, and management of technology (MoT) through theoretical, methodological and empirical advancements.

This study applies the novelty potential theory, which combines different abstract concepts, leading to novel design concepts. Analyzing patent documents and extracting abstract concepts may also result in the identification of unexplored high-novelty combinations. Furthermore, opportunities for innovation can be highlighted when combined with the void matrix to identify areas without existing patents. The theoretical contributions of this study include expanding the novelty potential concept beyond the engineering domain and

demonstrating its applicability to the sports industry context, specifically TKD SEs. Additionally, it also integrates multiple complementary theories, such as combinational creativity, absorptive capacity, and DT, to facilitate the generation of novel design concepts.

Second, a major methodological contribution was made by developing a new strategy for generating new ideas and novel design concepts. The framework integrated a structured and measurable approach that leveraged patent and non-patent analysis, novelty potential concept and a patent-based design catalogue using Gen AI into a single structured ideation framework. Unlike the traditional approach, which relies on AI or patent analysis independently, this innovative approach utilizes ChatGPT as an enhancement layer rather than a standalone ideation tool, improving reproducibility and reducing prompt dependency. This enables a more structured and knowledge-driven AI-assisted ideation methodology.

Finally, several empirical contributions are recognized through evidence-based comparison between the proposed framework and LLM-generated ideas through independent expert evaluation, statistical testing, patent validation, and practitioner feedback. While LLMs are effective for rapid ideation, they tend to converge toward mainstream solutions. In contrast, the proposed framework generates non-overlapping, domain-specific innovations, thereby contributing to the discourse on AI-human collaboration in design processes. This enhances the credibility and reproducibility of research on idea generation and design concept generation.

6.3.2 Practical Contributions

This study offers practical contributions to the sports industry, specifically the TKD community, including practitioners, clubs, federations and policymakers. The proposed framework offers a systematic and accessible tool for innovation that enables organizations with limited resources to generate new design concepts and ideas without relying solely on expensive R&D. Several key contributions are included as follows:

Technological strategy: The integration of patent and non-patent analysis enabled TKD SEs to identify emerging technological trends, technological gaps, and underexplored combinations. Potential relationships between CPC codes and keywords were analyzed through text mining techniques, such as co-occurrence network analysis enabled TKD SEs to identify relevant technologies for new investment, collaboration and future development. This strategy supports strategic planning for digital transformation within TKD SEs to prioritize key technology areas for long-term innovation and partnerships with technology providers and academic institutions.

Structured innovation tool: The CPC-based design catalogue acted as a structured innovation tool that facilitated the systematic generation of new business ideas and novel design concepts. By linking patent knowledge with design concept generation processes, TKD SEs are enabled to develop context-specific innovations aligned with organizational challenges and industry needs. Unlike traditional brainstorming or purely AI-generated ideas, the proposed framework offers traceability through patent validation and structured CPC classification. Additionally, the integration of Gen AI, such as ChatGPT, enhances human-AI collaboration in the ideation process.

Development of novel design concepts: The proposed novel design concepts can help TKD SEs to innovate their business model by using an AI video platform utilizing blockchain technology and solar cell-powered IoT devices, which offer a secure and decentralized platform to all martial arts members, especially during remote training. This enabled new revenue streams through digital training platforms, expanded international training opportunities and improved athlete performance. Additionally, to reduce scoring biases, a smart scoring system integrated with an emotion-driven platform is proposed. By integrating emotional capabilities, TKD SEs can introduce a new engagement layer, where reactions of the audience or athletes, such as excitement or tension, can be analyzed to enhance feedback during training or competition.

Contribution to the SDGs: The proposed concepts further contribute to the advancement of several United Nations SDGs, specifically SDGs 3, 4, 9 and 17, thereby providing several strategic advantages for TKD SEs. These advantages include revenue growth and expanded market opportunities, increased access to funding and partnerships, enhanced brand reputation as socially responsible organizations, and improved long-term organizational sustainability.

Decision-support for stakeholders: The semi-structured interviews provide valuable insights into current innovation challenges within the sports industry (SMEs and LEs) and TKD clubs and practitioners, including financial limitations, resistance to technological adoption and lack of know-how or expertise. The proposed framework, specifically the CPC-based design catalogue, demonstrates strong potential as a decision-support and idea-generation tool that can be implemented across different organizational levels, from clubs to national federations.

6.4 Research Limitations

Like any study, this study has certain limitations to its findings that should be acknowledged when interpreting the results.

First, the sample used in this study has limited generalizability as it employed a single-case study focusing only on TKD. While this enabled in-depth methodological validation, it limits the generalizability of the results. Another disadvantage is the limited technological scope and sectors. Different sports-industry SEs may operate under distinct strategic goals, institutional environments, and technological priorities, depending on the mission statement. However, this study only analyzed patents of TKD, blockchain, and IT/IS-related technological domains based on CPC codes and application years. Wider technological domains and additional sectors were not examined, which may restrict the framework's external applicability.

Second, this study utilized patent data, which may lead to potential biases from representation and geographical factors, as not all innovations are patented or publicly disclosed. Additionally, CPC codes were also relied on heavily, which are subject to potential classification inconsistencies due to human judgment. Consequently, this may have resulted in uneven granularity and coverage.

Another limitation is due to geographical representation constraints. Semi-structured interviews were conducted with a relatively small sample from Malaysia (TKD clubs and federation representatives) and Japan (SMEs, large enterprises, and a blockchain organization). Therefore, the results only reflect the perspectives of selected representatives rather than the organization as a whole. Moreover, the cultural, organizational, and technological differences in other countries, such as Korea, Europe, or North America, were not captured, which may influence innovation adoption dynamics.

Furthermore, the independent expert evaluation may have been influenced by the evaluators' disciplinary backgrounds, which may result in potential biases. Most evaluators were specialists in mechanical and applied engineering rather than TKD industry or market experts. This may have affected perceptions of novelty, feasibility, and market potential, particularly for zero-void combinations that were conceptually innovative but more difficult to visualize in practical implementation contexts. Therefore, it is important to consider how the evaluators' backgrounds may have influenced their assessments of novelty.

Additionally, reproducibility challenges are inherent in AI-assisted ideation processes. The quality and structure of prompts employed with ChatGPT directly influence the generated outputs. Although structured prompting techniques were used, variations in prompt design, model updates, or training data may affect reproducibility across time and contexts. Finally, the study is also limited to current-generation AI models whereby it does not reflect capabilities of future AI models.

6.5 Recommendations for Future Research

Several recommendations are proposed for future research based on the results and limitations to strengthen the generalizability, robustness and practical applicability of the proposed framework.

First, future research should expand the case study beyond TKD to include different sports, sectors and technologies. For instance, further investigation on slower technological innovation martial arts sectors such as Judo and Karate. Applying the proposed methodologies across different sectors, such as other martial arts or sports, emerging technologies, or educational platforms, would enable cross-sector validation and enhance the external applicability. Moreover, incorporating a wider technological scope beyond blockchain or IT/IS-related patents may also reveal additional innovation opportunities, aligned with different organizational goals. This would further strengthen the generalizability and robustness of the proposed methodologies.

Second, in order to mitigate potential biases due to reliance on patent data and CPC codes, future research should broaden its scope to include the integration of external insights, such as industry market reports, startups and scientific publications to provide a more comprehensive evaluation.

Third, the semi-structured interviews relied primarily on perspectives from selected representatives of the company, and not as a whole. Accordingly, future research should conduct in-depth interviews across multiple stakeholder groups at different hierarchical levels. This would enable deeper insights and more accurate results, thus reducing potential representation bias. Moreover, conducting international interviews with TKD practitioners from Korea, Europe, North America, and other regions would allow validation of the design catalogue's applicability across diverse cultural, technological and organizational contexts.

Fourth, comparing the design catalogue with formal TKD education systems, specifically Korean universities recognized globally for structured TKD training, could provide

valuable insights into how systematic ideation methodologies can be integrated for broader adoption in educational settings. Furthermore, multilingual adaptation of the design catalogue through other languages such as Korean, Malay and Japanese would encourage wider adoption and inclusivity across global TKD communities.

Additionally, focus on refining the design catalogue into a scalable and user-centered innovation tool for TKD SEs based on the TKD representatives' recommendations, such as an innovative, user-friendly system with the ability to address specific challenges for TKD. Finally, to explore emerging AI models (e.g., Agentic AI) to strengthen human-AI collaboration for guided ideation and design concept generation. To conclude, future research aims to further advance the integration of technology and systematic innovation methodologies to strengthen the long-term sustainability and competitiveness in TKD SEs and expand its applicability to other sectors.

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APPENDICES

APPENDIX A

QUESTIONS FOR SEMI-STRUCTURED INTERVIEW WITH SPORTS ORGANIZATIONS (LES AND SMES)

Start of Block: Consent

As part of a Management of Technology (MoT) research thesis at Yamaguchi University, this study focuses on design thinking in the sports industry and the integration of blockchain and fintech. In social sciences, questionnaires are an important tool for analysis. The information provided will be treated with strict confidentiality. We sincerely appreciate your cooperation in completing this survey.

End of Block: Consent

Respondent details:

Name:

Email:

Position:

Company:

Age:

Section 1: Business models and Challenges

1. How satisfied are you with your current business model?
   a) Very satisfied
   b) Satisfied
   c) Not very satisfied
   d) Dissatisfied
2. How long do you think you can continue your current business model as a sports equipment company?
   a) 1-2 years
   b) 3-5 years
   c) 6-10 years
   d) More than 10 years

3. Do you have plans to innovate your business model in the future?
    a) Yes
    b) No
4. If yes, in what areas do you plan to innovate?
    a) Products/services
    b) Market
    c) Distribution channels
    d) Technology
    e) Others
5. What is your company's main source of revenue?
    a) Sports equipment
    b) Sports clothing
    c) Sports shoes
    d) Sports services & maintenance
    e) Others
6. How were last year's sales compared to this year?
    a) Increase
    b) Decrease
7. By how much did sales increase or decrease?
    a) 10%
    b) 15%
    c) 30%
    d) More than 30%
8. What are your sales goals for next year and how do you plan to achieve them?
9. What measures does your company take to differentiate itself from competitors?

a) Products
b) Price
c) Technology
d) Marketing
e) Other

10. What challenges is your company currently facing?

a) Finance
b) Planning
c) Technology / Production system

d) Human resources
e) Intellectual property
f) Other

11. What challenges does your company face in order to achieve transformation and innovation?

a) Corporate policy
b) Action items
c) Organization
d) Research and development
e) Manufacturing
f) Other

12. Rate the aspects that have the greatest impact on company performance (1 = Not important at all, 4 = Very important):
    a) Product price: 1–2–3–4
    b) Product specifications: 1–2–3–4
    c) Product service: 1–2–3–4
    d) Market reform: 1–2–3–4
    e) Technology: 1–2–3–4
13. To what extent do the following threats affect your business? (1 = Not important at all, 4 = Very important)
    a) Seller power: 1–2–3–4
    b) Supplier power: 1–2–3–4
    c) New entrants: 1–2–3–4
    d) Availability of substitutes: 1–2–3–4
    e) Competitors: 1–2–3–4

Section 2: Blockchain and FinTech

14. Have you heard of FinTech and blockchain?
    a) Yes
    b) No
15. Does your company use FinTech or blockchain technology?
    a) Yes
    b) No

16. If yes, in what areas is it applied?
    a) Cost reduction
    b) Product / Service innovation
    c) Production
    d) Research & Development
    e) Other
17. What are your thoughts on the use of blockchain and FinTech in the sports industry?
18. How important are the following technologies for corporate profit?
    a) Big Data
    b) Internet of Things (IoT)
    c) Cloud Computing
    d) Blockchain
    e) FinTech
    f) Robots
    g) Wireless / Mobile devices
    h) Wearable technologies
    i) Other

Section 3: Future Expectations

19. What do you think about future trends in the global sports industry?
20. Young people today tend to move towards e-sports. How do you see the future sports market?

APPENDIX B

QUESTIONS FOR SEMI-STRUCTURED INTERVIEW WITH THE BLOCKCHAIN ORGANIZATION

Start of Block: Consent

As part of a Management of Technology (MOT) research thesis at Yamaguchi University, this study focuses on design thinking in the sports industry and the integration of blockchain and fintech. In social sciences, questionnaires are an important tool for analysis. The information provided will be treated with strict confidentiality. We sincerely appreciate your cooperation in completing this survey.

End of Block: Consent

RESPONDENT DETAILS:

Name:

Email:

Position:

Company:

Age:

Section 1: General Understanding of Blockchain

1. How does your organization define the role of blockchain in business and society?
2. What do you see as the key features or advantages of blockchain technology (e.g., traceability, transparency)?

Section 2: Applications and Benefits

3. Can you share an example of how blockchain is currently applied in Japan or your industry (e.g., food safety, supply chain, IoT integration)?
4. How does blockchain help prevent issues such as information leaks, tampering, or manipulation?
5. What kinds of business or social systems can companies build by leveraging blockchain?

Section 3: Future Outlook

6. How do you see blockchain technology evolving in the near future in Japan and globally?
7. What advice would you give to SMEs considering blockchain adoption?

APPENDIX C

QUESTIONS FOR SEMI-STRUCTURED INTERVIEW WITH THE MALAYSIAN TKD CLUBS AND FEDERATION

Start of Block: Consent

As part of my PHD research thesis in Management of Technology (MOT) at Yamaguchi University, Japan, I am conducting a study titled: **"Enhanced Systematic Idea Generation Methodologies Using Generative AI – A Case Study on Taekwondo Systems."** This research aims to develop novel design concepts for the future of TKD by applying systematic idea-generation methods, including the Novelty Potential/Void Matrix, Patent-based design catalogue and generative AI tools.

This survey aims to understand the role of innovation and challenges in TKD and to gain feedback on innovation tools such as the Design Catalogue. It consists of 15 open and closed-ended questions. Your participation will contribute significantly to the development of innovative tools tailored for the TKD community.

All information provided will be treated with strict confidentiality and used solely for academic purposes. No personally identifiable data will be shared. I would sincerely appreciate your time in completing this survey.

By participating, you agree that:

Voluntary Participation

The participation is completely voluntary and you may withdraw at any time without penalty.

Confidentiality and Data Protection

All responses will be kept strictly confidential. No personally identifiable information will be collected. Data will be stored securely and only accessed by the researcher.

Benefits and Risks

There are no foreseeable risks associated with this study. The participation will solely contribute to the advancement of innovation for TKD communities.

Consent

By selecting "I agree" below, you indicate that:

- I have read and understood the information provided
- I voluntarily agree to participate in this study

Agreement on survey participation:

( ) I agree

( ) I disagree

End of Block: Consent

RESPONDENT DETAILS:

Name:

Position:

( ) Director

( ) Committee

( ) Instructor/Coach

( ) Athletes

( ) Other:

Age:

( ) 20s

( ) 30s

( ) 40s

( ) 50s and above

Taekwondo Club's name and State:

SECTION 1: CHALLENGES AND IMPORTANCE OF INNOVATION FOR TKD

This section contains 6 questions to identify the role of innovation for TKD, including challenges, importance and possible innovation recommendations

1. How important is creating new ideas or innovation for the future of TKD?
    a) No importance
    b) Low importance
    c) Moderately important
    d) Highly important

2. If your organization would like to innovate, how long will it take?
    a) 1-2 years
    b) 3-5 years
    c) 6-10 years
    d) More than 10 years
3. Which area holds the highest priority for innovation in TKD?
    a) Training equipment
    b) Sportswear
    c) Digital systems and applications
    d) Facilities and training environment
    e) Other
4. What do you think are the main challenges to innovation in TKD?
    a) Financial constraints
    b) Lack of knowledge and expertise
    c) Resistance to adopting innovative solutions
    d) Lack of resources to new technologies/tools
    e) Organizational culture
    f) Other
5. In your opinion, what should be the primary focus when generating new ideas or innovations for TKD?
    a) Cost effectiveness
    b) Safety and durability
    c) Integration of smart technologies
    d) User experience and engagement
    e) Other
6. What kind of new improvements or innovations would you like to see in TKD? (ex, new training equipment, etc.)

SECTION 2: DESIGN CATALOGUE AS AN INNOVATIVE TOOL TO GENERATE IDEAS

This section consists of 9 questions aimed at assessing your familiarity and attitudes toward using structured idea generation tools, specifically, the design catalogue for generating innovative concepts in TKD.

7. Have you ever used structured idea generation tools such as a design catalogue?
   a) Yes
   b) No
8. How familiar are you with idea generation tools such as the design catalogue?
   a) Unfamiliar
   b) Slightly familiar
   c) Moderately familiar
   d) Very familiar
9. Will you be interested in using a design catalogue to generate new ideas?
   a) Not interested
   b) Slightly interested
   c) Moderately interested
   d) Highly interested
10. How important is a tool like the design catalogue for fostering innovation and idea generation in the future of TKD?
    a) Not important
    b) Slight important
    c) Important
    d) Highly important
11. How long is the design catalogue likely to be adopted for TKD?
    a) Less than a year
    b) 1-3 years
    c) 3-5 years
    d) More than 5 years

12. What are the main challenges in adopting an innovation tool such as the design catalogue for TKD?
    a) Limited financial resources
    b) Lack of understanding/awareness
    c) Resistance to new technologies/tools
    d) Organizational culture or barriers
    e) Others:
13. What outcomes do you expect from using the design catalogue for innovation in TKD?
    a) Increased revenue or funding opportunities
    b) Enhanced athlete training and performance
    c) Development of innovative products and services
    d) Greater strategic direction or idea generation for our organization
    e) Other
14. What recommendations do you have to improve the design catalogue as an innovation tool for TKD?

    Please share your suggestions on how the design catalogue can be enhanced. You may comment on aspects such as usability, content structure, practical applications, integration with current systems, or how it could better support innovation in Taekwondo training, equipment, or strategy.
15. What are your future aspirations for TKD in your role (e.g., as an athlete, coach etc.)

    Please share your thoughts on what you hope to see in the future of Taekwondo. For example, you may include aspirations related to innovation, training, competition, inclusivity, technology adoption, or international growth.

APPENDIX D

SURVEY QUESTIONS FOR INDEPENDENT EXPERT SCORING

Start of Block: Consent

As part of my PHD research thesis in Management of Technology (MOT) at Yamaguchi University, Japan I am conducting a study titled: **"Enhanced Systematic Idea Generation Methodologies Using Generative AI – A Case Study on Taekwondo Systems-."** This research aims to develop novel design concepts for the future of TKD by applying systematic idea-generation methods, including the Novelty Potential/Void Matrix, Patent-based design catalogue and generative AI tools. This survey aims to gain independent experts scoring of 19 ideas from LLM models and our propose method to be rated based on novelty, feasibility and market potential. Your participation will contribute significantly to the development of innovative tools tailored for the TKD community. I sincerely appreciate your time in completing this survey.

By participating, you agree that:

Voluntary Participation

The participation is completely voluntary and you may withdraw at any time without penalty.

Confidentiality and Data Protection

All responses will be kept strictly confidential. No personally identifiable information will be collected. Data will be stored securely and only accessed by the researcher.

Benefits and Risks

There are no foreseeable risks associated with this study. The participation will solely contribute to the advancement of innovation for TKD communities.

Consent

By selecting "I agree" below, you indicate that:

- I have read and understood the information provided
- I voluntarily agree to participate in this study

Agreement on survey participation:

( ) I agree

( ) I disagree

End of Block: Consent

RESPONDENT DETAILS:

Name:

Age:

( ) 20s

( ) 30s

( ) 40s

( ) 50s and above

Affiliation:

Job position:

Academic years:

( ) 1-2 years

( ) 3-5 years

( ) 6-10 years

( ) More than 10 years

SURVEY QUESTIONS:

SECTION 1: IDEAS EVALUATION BASED ON NOVELTY

Novelty: How original or unique is the idea compared to existing market and solutions?

Rating scale:

1 = Very Low (Idea is common, already in the market, or a minor variation of known solutions)

2= Low

3 = Moderate (Idea shows some originality but overlaps with existing market practices)

4 = High

5 = Very High (Idea is highly distinctive, with strong originality and minimal overlap to existing solutions)

Ideas	Description	Very low	Low	Moderate	High	Very high
1.Kinetic-Weave Dobok	A performance-driven uniform that enhances movement and provides biofeedback. Solves the issue of	1	2	3	4	5

	traditional doboks being baggy, non-breathable, and offering zero performance data.					
2.Aegis Impact System	Smart body protectors (hogu) and helmets that go beyond protection to become diagnostic tools. Solves the "black box" problem in training where impact quality is unknown.	1	2	3	4	5
3.Dojang 360	Re-imagining the training hall (dojang) as an immersive, adaptive environment. Transforms a static space into a responsive partner for training.	1	2	3	4	5
4.Sendo Footwear	A minimalist, smart footwear system for outdoor/cross-training that maintains foot strength and technique. Solves the problem of transitioning between running shoes and barefoot technique.	1	2	3	4	5
5. Smart scoring system with an interactive emotion-driven platform	A smart scoring system combined with an interactive emotion-driven platform, leveraging advanced technologies including machine learning, semantic classification, and sensor technologies. -Integrating real-time emotion analytics with physical performance metrics of players through wearable sensors (helmet, gears etc.), cameras and biometric sensors -Capturing and analysing of audience emotions, reactions, and engagement levels. The audience's emotional data	1	2	3	4	5

	streams, along with scoring results displayed during live competitions -Utilizing AI-powered, real-time judging system to differentiate between scoring and non-scoring strikes in sparring competitions and recognizing correct patterns in Poomsae (forms) can reduce human error and bias -AI provides personalized training environments based on an athlete's performance and emotional data - Monitors and facilitates emotions and health conditions to manage fatigue levels as an injury prevention measure					
6.Kineti-Form	A smart uniform (*dobok*) interwoven with micro-sensors and conductive thread that tracks movement, force, and biometrics in real-time, visualizing the data through a connected app or embedded light patterns.	1	2	3	4	5
7.Dynastic Weave	A modular and customizable uniform system that blends high-performance, sustainable fabrics with traditional aesthetic elements. The core uniform is minimalist, but practitioners can add or swap panels, trims, and emblems.	1	2	3	4	5
8.The AR Dojang	An Augmented Reality training system that projects virtual opponents, targets, and instructional overlays into the real-world training	1	2	3	4	5

	space (*dojang*) via AR glasses or a projector system.					
9.Bio-Tensegrity Gear	Training equipment (pads, shields, body armor) designed using principles of biomechanics and tensegrity structures. The gear is lightweight, flexible, and intelligently distributes impact forces away from the body.	1	2	3	4	5
10.Smart Uniform (Dobok 2.0)	Integrate stretchable sensors and IoT into the uniform.	1	2	3	4	5
11.Augmented Reality Training Pods	AR-enabled environment with real-time feedback on techniques.	1	2	3	4	5
12.Energy Absorbing Mat Systems	Smart mats with impact detection and energy absorption tech.	1	2	3	4	5
13.AI-Powered Sparring Assistant	An AI-driven robotic or VR sparring partner with adaptive difficulty.	1	2	3	4	5
14.Biometric Belt System	A digital black belt that lights up or changes color based on performance or heart rate.	1	2	3	4	5
15.Modular Taekwondo Dojang	Portable, foldable dojang setup with digital scoring and training zones.	1	2	3	4	5
16.Gamified Progress Tracker App	App using game mechanics to track belt progression, streaks, or virtual tournaments.	1	2	3	4	5
17.Cultural Fusion Uniforms	Customizable doboks blending modern fashion with traditional Korean design.	1	2	3	4	5
18.Eco-Friendly Gear Line	Uniforms and gear made from recycled or sustainable materials.	1	2	3	4	5

19.Mind-Body Biofeedback Interface	Wearables that measure breathing, focus, and stress levels.	1	2	3	4	5

SECTION 2: IDEAS EVALUATION BASED ON FEASIBILITY

Feasibility: Is it practically implementable and easy to transform into a functional product or service?

Rating scale

1 = Very Low : Unrealistic or technically infeasible with current resources/technology.

2 = Low

3 = Moderate : Achievable with effort, though requiring moderate resources or adaptation.

4 = High

5 = Very High : Highly feasible and implementable with current or near-future resources and technology.

Ideas	Description	Very low	Low	Moderate	High	Very high
1.Kinetic-Weave Dobok	A performance-driven uniform that enhances movement and provides biofeedback. Solves the issue of traditional doboks being baggy, non-breathable, and offering zero performance data.	1	2	3	4	5
2.Aegis Impact System	Smart body protectors (hogu) and helmets that go beyond protection to become diagnostic tools. Solves the "black box" problem in training where impact quality is unknown.	1	2	3	4	5
3.Dojang 360	Re-imagining the training hall (dojang) as an immersive, adaptive environment. Transforms a static space into a responsive partner for training.	1	2	3	4	5

4.Sendo Footwear	A minimalist, smart footwear system for outdoor/cross-training that maintains foot strength and technique. Solves the problem of transitioning between running shoes and barefoot technique.	1	2	3	4	5
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	- Monitors and facilitates emotions and health conditions to manage fatigue levels as an injury prevention measure					
6.Kineti-Form	A smart uniform (*dobok*) interwoven with micro-sensors and conductive thread that tracks movement, force, and biometrics in real-time, visualizing the data through a connected app or embedded light patterns.	1	2	3	4	5
7.Dynastic Weave	A modular and customizable uniform system that blends high-performance, sustainable fabrics with traditional aesthetic elements. The core uniform is minimalist, but practitioners can add or swap panels, trims, and emblems.	1	2	3	4	5
8.The AR Dojang	An Augmented Reality training system that projects virtual opponents, targets, and instructional overlays into the real-world training space (*dojang*) via AR glasses or a projector system.	1	2	3	4	5
9.Bio-Tensegrity Gear	Training equipment (pads, shields, body armor) designed using principles of biomechanics and tensegrity structures. The gear is lightweight, flexible, and intelligently distributes impact forces away from the body.	1	2	3	4	5
10.Smart Uniform (Dobok 2.0)	Integrate stretchable sensors and IoT into the uniform.	1	2	3	4	5

11.Augmented Reality Training Pods	AR-enabled environment with real-time feedback on techniques.	1	2	3	4	5
12.Energy Absorbing Mat Systems	Smart mats with impact detection and energy absorption tech.	1	2	3	4	5
13.AI-Powered Sparring Assistant	An AI-driven robotic or VR sparring partner with adaptive difficulty.	1	2	3	4	5
14.Biometric Belt System	A digital black belt that lights up or changes color based on performance or heart rate.	1	2	3	4	5
15.Modular Taekwondo Dojang	Portable, foldable dojang setup with digital scoring and training zones.	1	2	3	4	5
16.Gamified Progress Tracker App	App using game mechanics to track belt progression, streaks, or virtual tournaments.	1	2	3	4	5
17.Cultural Fusion Uniforms	Customizable doboks blending modern fashion with traditional Korean design.	1	2	3	4	5
18.Eco-Friendly Gear Line	Uniforms and gear made from recycled or sustainable materials.	1	2	3	4	5
19.Mind-Body Biofeedback Interface	Wearables that measure breathing, focus, and stress levels.	1	2	3	4	5
SECTION 3: IDEAS EVALUATION BASED ON MARKET POTENTIAL						
Market potential: What are the likelihood that the ideas will achieve adoption, scalability, and value generation in real-world settings? Rating scale: 1 = Very Low: Low chance of adoption; little to no commercial or user interest expected. 2 = Low						

3 = Moderate: Some potential for adoption; may serve a niche market but limited scalability.

4 = High

5 = Very High: Strong potential for adoption; scalable and likely to generate significant value in the market

Ideas	Description	Very low	Low	Moderate	High	Very high
1.Kinetic-Weave Dobok	A performance-driven uniform that enhances movement and provides biofeedback. Solves the issue of traditional doboks being baggy, non-breathable, and offering zero performance data.	1	2	3	4	5
2.Aegis Impact System	Smart body protectors (hogu) and helmets that go beyond protection to become diagnostic tools. Solves the "black box" problem in training where impact quality is unknown.	1	2	3	4	5
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4.Sendo Footwear	A minimalist, smart footwear system for outdoor/cross-training that maintains foot strength and technique. Solves the problem of transitioning between running shoes and barefoot technique.	1	2	3	4	5
5. Smart scoring system with an interactive emotion-driven platform	A smart scoring system combined with an interactive emotion-driven platform, leveraging advanced technologies including machine learning, semantic classification, and sensor technologies.	1	2	3	4	5

	-Integrating real-time emotion analytics with physical performance metrics of players through wearable sensors (helmet, gears etc.), cameras and biometric sensors -Capturing and analysing of audience emotions, reactions, and engagement levels. The audience's emotional data streams, along with scoring results displayed during live competitions -Utilizing AI-powered, real-time judging system to differentiate between scoring and non-scoring strikes in sparring competitions and recognizing correct patterns in Poomsae (forms) can reduce human error and bias -AI provides personalized training environments based on an athlete's performance and emotional data - Monitors and facilitates emotions and health conditions to manage fatigue levels as an injury prevention measure					
6.Kineti-Form	A smart uniform (*dobok*) interwoven with micro-sensors and conductive thread that tracks movement, force, and biometrics in real-time, visualizing the data through a connected app or embedded light patterns.	1	2	3	4	5
7.Dynastic Weave	A modular and customizable uniform system that blends high-performance,	1	2	3	4	5

	sustainable fabrics with traditional aesthetic elements. The core uniform is minimalist, but practitioners can add or swap panels, trims, and emblems.					
8.The AR Dojang	An Augmented Reality training system that projects virtual opponents, targets, and instructional overlays into the real-world training space (*dojang*) via AR glasses or a projector system.	1	2	3	4	5
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15.Modular Taekwondo Dojang	Portable, foldable dojang setup with digital scoring and training zones.	1	2	3	4	5

16.Gamified Progress Tracker App	App using game mechanics to track belt progression, streaks, or virtual tournaments.	1	2	3	4	5
17.Cultural Fusion Uniforms	Customizable doboks blending modern fashion with traditional Korean design.	1	2	3	4	5
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