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Article

The “Clockwork” Model for Deployment Technology Innovations in Sports Industry Ecosystem: Holistic Approach

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Abstract: The use of technology in different aspects of the sports industry is widespread across the world, affecting sports training, performance, judging, and spectating. However, the integration, deployment, and evolution of technologies in the sports industry ecosystem are still unclear and unexplained. In this paper, we aim to build and explain the conceptual model for deployment technologies in the sports ecosystem in a holistic approach. This conceptual model is based on a literature review and theoretical synthesis, coupled with 15 qualitative unstructured interviews with high-profile sport and technology experts. Then, we formulated 4 hypotheses and confirmed them using 15 qualitative unstructured interviews with technology and sports experts. The in-depth analysis of the literature and collected data let us build the “Clockwork” Model. To better visualize and explain the development of the model of deployment technologies in the sports ecosystem, based on the analysis of theoretical and empirical data, we compare the mechanism of the model with clockwork. Technology deployment is a complicated operational process and involves the continuous sequence of consecutive elements (stages), ideally functioning as a mechanism. Together, the hypotheses underscore the symbiotic relationship between traditional sports infrastructure and technological advancements, highlighting the importance of a balanced and well-functioning ecosystem for overall success and development in the sports industry. All four hypotheses were confirmed during the second set of interviews (N = 15). Furthermore, their synthesis brought us to build and refine the “Clockwork” conceptual model, which explains, articulates, and visually demonstrates the process of how technology innovations appear and evolve in the sports ecosystem; in other words, the continuous and cyclic process of technology implementation and deployment.

Keywords: sports industry; sports ecosystem; technology; innovation; technology life cycle



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1. Introduction

The use of technology in different aspects of the sports industry is widespread across the world [1] affecting sports training, performance, judging, and spectating [2], but before a technology-based product/service is employed by a customer, it passes through the initial technology life cycle (TLC) stages. However, the integrations, deployment, and evolution of technology in the sports industry ecosystem are still unclear and unexplained. In this paper, we aim to build and explain the conceptual model for deployment technologies [3] in the sports ecosystem using a holistic approach.

Technology deployment is a complicated operational process and involves the continuous sequence of consecutive elements (stages), ideally functioning as a mechanism. However, it may refer to Project/Portfolio Management if it's a “unique and temporary” (PMPBoK) particular case to achieve specific goals, but not a management process. Accordingly, the development model may be applied to a project and/or operational activities and processes.

To better visualize and explain the development of the model of deployment technologies in the sports ecosystem, based on an analysis of theoretical and empirical data,

we compare the mechanism of the model with clockwork [4]. Clockwork pertains to the internal mechanisms of mechanical devices known as clocks, where it is alternatively referred to as the “movement”, or other systems that operate similarly. These systems rely on intricate arrangements of cogwheels, which are linked to various components or elements. In essence, clockwork involves the interconnected and precise coordination of these cogwheels to facilitate the functioning of the mechanical device.

Relationships between principal stakeholders of the technology deployment process are evolving along a three-stage continuum deployment mechanism—a journey that is reshaping how traditional and digital infrastructure is being created, developed, financed, and managed worldwide [5]. The emergence of this continuum seems to be a current trend, but one that is progressing at a varying speed in different markets, kinds of sport, particular cases, and even in different technologies and services within the case. But while the three stages can all co-exist at the same time, each has distinct features, courses, and impacts.

2. Theoretical Background

Technology is advancing at such a rapid pace that it is becoming increasingly difficult to assess the safety and efficacy of each technology before implementation [6]. Further, Nicholas [6] has found points regarding (1) complexity, (2) gradualism, and (3) the continuous nature of technology implementation and development process. However, the conceptual model reflecting all these features is missing, especially in terms of the holistic view of the sports industry ecosystem as a whole [3].

“In sport, there is a constant flow of innovation but it is unclear how the innovation occurred. This has prompted more interest in studying the environmental contexts around sport to understand the process. There are often unique intricacies of innovation in sports that require a more dynamic understanding. The sports innovation process involves the interactions and reactions between different entities. Sometimes this requires sports entities to act in a way that enables greater use of the environmental context. The sports environment is complex and needs to be analyzed in a holistic manner” [7]. “. . . in order to create a culture that enables innovation, attention has to be given to all aspects of innovation’s deployment” [8].

Furthermore, Ratten [7] has distinguished Action (leadership and management support, allocation of resources and time); Reaction (resistance to change from organizational members and stakeholders; Lack of coordination for the innovation; and Inability to access staff to channel innovation in sports technology innovation as part of the *evolutionary process*. Nilssen and Wene [9] have outlined three key active deployment measures and policies that have to be carefully crafted:

1. Coherent approaches: Measures motivated by energy policy considerations are much more acceptable when they are also in line with policies for industrial development, environmental improvement, and employment.
2. Improving feedback: Feedback helps producers to use R&D resources better. It can help both producers and consumers to learn by doing.
3. Demand-driven measures: Most consumers have little interest in energy issues per se, but would gladly accept energy-efficiency measures or renewable fuels as part of a package with features they do care about.

Considering all the points above and referring to a holistic approach, we have chosen a clockwork mechanism comparison to better visualize this model and disclose its’ nature and courses.

The Mariam Webster Dictionary ¹, definition of clockwork is as follows:

1. The inner workings of something
2. The machinery (such as springs and a train of gears) that runs a clock. Also, a similar mechanism running a mechanical device (such as a toy)
3. The precision, regularity, or absence of variation associated with a clock or clockwork, a clockwork operation —used in the phrase “like clockwork” to describe something that happens or works regularly and exactly.

The rapid uptake of new technologies by sports spectators has outpaced research in many regards, such that even basic information on users and consumers, and the level of their actual technology readiness and acceptance remains unclear. These questions may be fundamental for sports marketing and management professionals, who rely upon traditional attendance and mass media rights' revenue to support their leagues, but need to adapt the practice to incorporate the popular new digital forms of media and consumption.

For instance, XR (extended reality) is a prominent example of the new advances in technological products. Its recent growth dictates that sports managers engage with it, but how sports technological transformations are best managed, commercially ordered, and leveraged, and integrated with traditional forms of sports consumption needs to be better understood.

The important part of the theoretical framework employs the Technology Readiness Index (TRI) [10] and Technology Acceptance Model (TAM) [11] scales, with the opportunity to assess predisposition, use, and acceptance of different types of technologies in a sports consumption context, such as experiencing sports events as a spectator.

Parasuraman argues that the number of products and services based on technology is growing rapidly, however, despite this growth in quantity, these apparatuses do not bring the benefits the customers expected. Accordingly, TAM and TRI models help to measure and understand an underpinning of relations between the user and technology. The TAM model developed by Davis aimed to explain the decisive causes of general acceptance of technology [11]. It also seeks to explain user behavior when faced with various technologies and why one system can be accepted or rejected. The essential purpose of the TAM model is to provide a basis for mapping the impact of external factors on the internal individual ones such as beliefs, attitudes, and behavioral intentions. This model was formulated to measure these impacts by evaluating some fundamental variables suggested by previous research on cognitive and affective acceptance of technologies [10,11].

The TAM model is based on two main constructs linked to belief, perceived usefulness (PU), and perceived ease of use (PEOU). The TRI model developed by Parasuraman and Colby is a measuring instrument for assessing the readiness of a consumer for a technology, divided into drivers and inhibitors for the adoption of technology and are represented by optimism, innovativeness, discomfort, and insecurity. Parasuraman reinforces the importance of the constructs tested and indicates that the respondents of the research carried out were classified by scores in high, medium, or low consumption potential accordingly. Each one of these four dimensions may differ in terms of the use of high-technology products and services. Thus, the fact that an individual may be led to adopt a certain technology in a specific area (e.g., high use potential) does not imply that they will adopt it in another situation [10,11].

3. Methodology

We started with an integrative literature review [12]. It draws on the pieces of literature spanning from the sports ecosystem, customer experiences, technology acceptance, project management, operations management, optimization, technology, and innovations. We proposed a conceptual basis as a theoretical model [13] for a flare based on the results of the literature review, as well as the exploratory open-ended unstructured interviews with sports managers in a global context (N = 15). All participants (N = 30) were high-profile experts at the intersection of sports and emerging technologies with professional experience in industry of at least five years. According to the participants' preferences, we kept their identities anonymous. Once the concept had been developed, for validation, we organized an interview consultation with another group of participants (questionnaires and unstructured qualitative interviews, N = 15) to refine the concept, confirm its conceptual nature, and polish and test related hypotheses (H1–H4). These statements essentially highlight the interdependence between traditional sports infrastructure and the successful deployment and development of new technologies in the sports industry ecosystem. Further, these

confirmed hypotheses will let us advance in building the “Clockwork” Model embracing three “cogwheels” (articulated in the Findings and Discussion Section).

Hypothesis 1. *The well-managed and functioning basic traditional infrastructure is necessary for the deployment of new technologies and innovations in sports industry ecosystem.*

This suggests that a solid foundation of traditional sports infrastructure is crucial for introducing and implementing new technologies. Without a well-established base, the integration of innovative technologies may face obstacles or lack the necessary support for effective deployment.

Hypothesis 2. *Technology-based additional services and products can be successfully applied in the sports ecosystem only under the condition of well-established, managed, and functioning traditional sports infrastructure.*

Building on the first hypothesis, this statement emphasizes that the success of technology-based services and products in sports relies on the presence of a well-managed traditional sports infrastructure. The two aspects are seen as complementary, with the traditional infrastructure providing a stable platform for the integration of technological advancements.

Hypothesis 3. *Technologies in the sports ecosystem can be continuously developing if infrastructure and additional products/services are functioning well.*

The third hypothesis suggests a cyclical relationship where the continuous development of technologies in the sports ecosystem is dependent on the effective functioning of both traditional infrastructure and additional products and services. It implies that a well-functioning system facilitates ongoing technological advancements.

Hypothesis 4. *Traditional sports infrastructure develops stable and continuously under the condition of functioning of additional products/services and established sports tech ecosystem.*

In the reverse perspective, this statement asserts that the stability and continuous development of traditional sports infrastructure are contingent upon the effective functioning of additional products/services and an established sports tech ecosystem. It underscores the idea that a harmonious integration of technology supports the stability and growth of traditional sports infrastructure.

4. Findings and Discussion

Together, our four hypotheses underscore the symbiotic relationship between traditional sports infrastructure and technological advancements, highlighting the importance of a balanced and well-functioning ecosystem for overall success and development in the sports industry. All four hypotheses were confirmed during the second set of interviews (N = 15). Furthermore, their synthesis brought us to build and refine the “Clockwork” conceptual model, which, we believe, explains, articulates, and visually demonstrates the process of how technology innovations appear and evolve in the sports ecosystem, in other words, the continuous and cyclic process of technologies implementation and deployment.

4.1. “Clockwork” Model: The Evolutionary Path of SSCX Development

Three cogwheels are associated with constantly repeating three stages of technological deployment (Figure 1, Table 1). The model presents a comprehensive view of technology deployment in the sports industry ecosystem, and when viewed through the lens of the TLC, it unveils a strategic approach to innovation. The “Clockwork” Model encapsulates the continuous evolution of technologies in a holistic system, resembling the diversification and convergence phases. The interconnected elements drive each other, forming a cycle of technological development. The model’s emphasis on continuous improvement aligns

with the evolving nature of technologies in the sports industry ecosystem. Thus, the model provides a structured and cyclic approach to technology deployment in the sports industry ecosystem, aligning with different phases of TLC. The interconnected cogwheels and hypotheses highlight the importance of a well-managed traditional infrastructure as the foundation for continuous technological evolution and development.

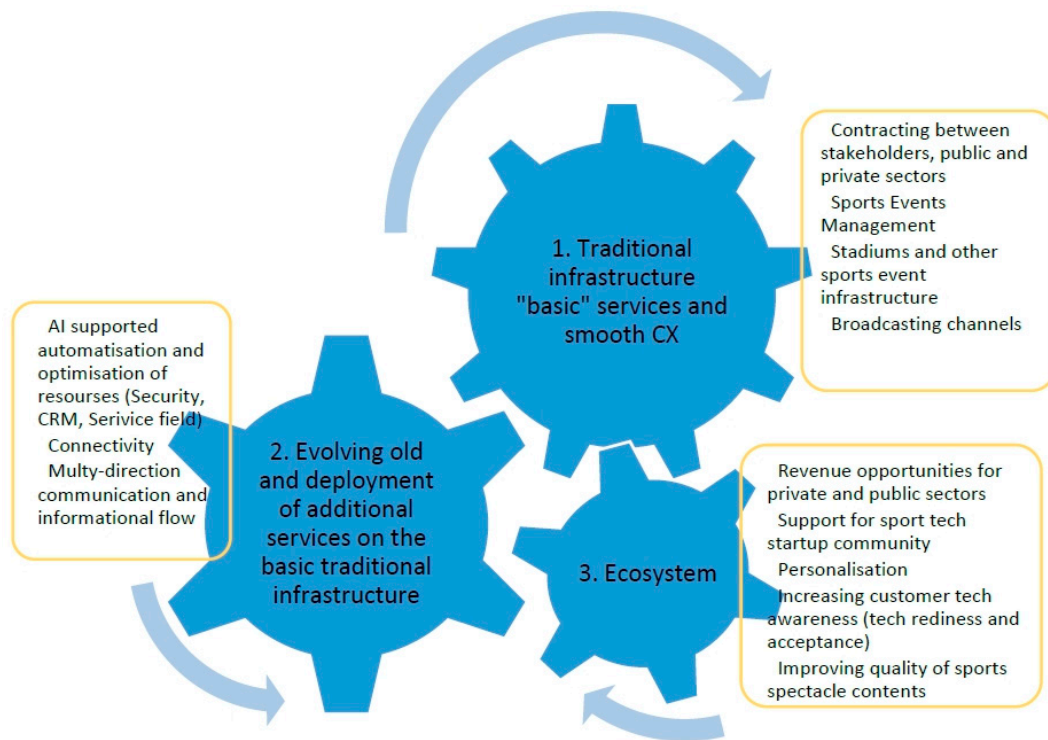


Figure 1. “Clockwork” Model of implementation, deployment, and evolution of technology innovations in the sports industry ecosystem.

Table 1. Technology Deployment Stages within the “Clockwork”.

Technologies Deployment Stage	Current Stage Contents
1. Traditional infrastructure building, maintenance, and management, in order to deliver “smooth” functioning of sports ecosystem	Contracting between public and private sectors Sports Events Management Stadiums and other sports event infrastructure Broadcasting channels
2. Development and deployment of additional services on the basis of traditional infrastructure in order to upgrade the sports ecosystem and enhance stakeholders’ experiences	AI-supported automatization and optimization of resources (Security, CRM, Service field) Connectivity Multi-direction communication and informational flow
3. Digitalized and connected ecosystem building, in order to optimize the deployment of technologies for all the stakeholders, making the best or most effective use of a situation or resource	Revenue opportunities for private and public sectors Citizens’ well-being Digital Culture Fostering: Technology Acceptance, Technology Readiness Support for sports tech-startup community Personalization Increasing customer tech awareness (tech readiness and acceptance) Improving the quality of sports spectacle contents

4.2. Cogwheel #1

Relies on traditional “classical” non-digital structures, activities, and concepts, delivering services and infrastructure, including; e.g., policies, sports events organizing, stadiums, broadcasting channels, and prerequisites for connectivity [14]. This cogwheel corresponds to the initial stage of technology adoption, emphasizing the reliance on traditional non-digital structures. It lays the foundation for the introduction and emergence of technologies in the sports industry.

This element is based on what might be regarded as fairly traditional contracting structures between public sector entities and the private sector, generally to deliver a “point implementation” of infrastructure, products, and services to deliver “smooth” stakeholders’ experiences in sport exercise, performance, evaluation, and spectating. Examples might include sports event organization, broadcasting, stadium management systems, training opportunities, public Wi-Fi, sports mobile, or systems for smart ticketing and social media.

The dynamic of the first cogwheel reflects the fact that, in the initial stages of the transfer to new technologies, public sector entities engaged the private sector and startup community to implement specific technologies or services to meet stakeholders’ expectations and needs [1]. Over time, the private sector players they engaged have also been able to suggest and recommend a wide range of other technologies and solutions that could enhance stakeholders’ experiences and increase traditional infrastructure and service functionality (Schut and Glebova, 2022). Furthermore, the stadium could be seen as a sports innovation lab [14].

In some cases, the work of this cogwheel may depend on the arrangements between stakeholders in order to integrate an innovation [15] in sports and provide a product/service, solution, or technology [1,2]. Successful deployment begins by identifying the interests of many stakeholders and bringing them together to work for accelerated dissemination of technology as well as improved performance and lower costs. Common interests of producers and consumers may be exploited by the removal of regulatory barriers, by improved communication between R&D providers and companies, by better market research to determine consumer attitudes and interests [9,16].

H1. *The well-managed and functioning basic traditional infrastructure is necessary for the deployment of new technologies and innovations in sports industry ecosystem.*

4.3. Cogwheel #2

Evolving old infrastructure and facilitating the development and deployment of additional services on the base digital and connected sports infrastructure; e.g., mobile applications, connectivity embracing mobile apps, performance analytics systems, transit payment card systems, smart ticketing, real-time analytics. Building on the traditional infrastructure, this cogwheel signifies the growth phase by evolving digitally connected sports infrastructure. It aligns with the stage of growth and more or less widespread adoption of digital services and products.

Based on the workings of the first cogwheel, the second cogwheel facilitates the development and deployment of additional products and services, multiplying the benefits and delivering the next level of ecosystem functioning and overall stakeholders’ experiences, for example, AR (augmented reality), providing exclusive footage and real-time game analytics, contactless access cards to enter the stadium, high-quality content games or news in the official app of sports club/event [2].

The second cogwheel offers stakeholders the opportunity not only to improve business performance and strategy but also to monetize expanded digital services and implemented innovations [2].

H2. *Technology-based additional services and products can be successfully applied in the sports ecosystem only under the condition of well-established, managed, and functioning sports traditional infrastructure.*

4.4. Cogwheel #3

Focuses on the development and integration of the entire digitalized holistic ecosystem in and around the sports-connected and digital infrastructure, creating new products/services, businesses, and government revenue opportunities, embracing citizens' awareness and culture of using technologies, next-level of personalization, sports associations, and communities [17]. From the TLC perspective, the third cogwheel represents the maturity phase, focusing on the development and integration of a holistic digital ecosystem. It aligns with the stage where technologies become interconnected and widely adopted in the sports industry [7,8].

The defining characteristic of this element is the development of a digital sport innovative ecosystem inside and around the digitalized innovative infrastructure, with the result that new products, services, businesses, and revenue opportunities, which are supposed to be interconnected through the Internet of Things (IoT) or "Internet of everything".

For an innovation to succeed and diffuse effectively, it needs to be relatable, relevant and well-communicated within the context of a social system [15]. Understanding the stages of diffusion and the factors that influence it can help innovators and change agents develop strategies to promote the adoption and targeted dissemination of their innovations [7]. Nevertheless, attaining a state of current service demands a foundation of infrastructure employing intelligent technologies that seamlessly blend with real-time service ecosystems [18]. This encompasses sensors and beacons, the management of extensive data sets, cloud computing, Decision Support Systems, Artificial Intelligence, and Machine Learning. These technologies, both hardware and software, actively gather and analyze information on the fly while initiating various processes in real-time. Information and Communication Technologies (ICTs) serve as catalysts within an agile ecosystem, elevating real-time service performance in alignment with the brand's distinct objectives. Thus, in sports, achieving a state of "nowness" in services involves establishing a robust infrastructure fueled by smart technologies. Just like athletes rely on cutting-edge equipment and training techniques, hardware and software technologies in sports collect and dynamically analyze information, triggering real-time processes. In this agile sports ecosystem, Information and ICTs play a pivotal role as catalysts, enhancing real-time performance based on the specific objectives and goals of the sports brand or team. It's akin to optimizing a team's strategy and performance in the ever-evolving landscape of sports through the utilization of advanced technological solutions.

H3. *Technologies in the sports ecosystem can be continuously developing if infrastructure and additional products/services are functioning well. (under conditions of Cogwheel #1 and Cogwheel #2 functioning).*

The all-round continuous evolutionary path between these three elements is depicted in Figure 1, it shows different areas of the innovative sports culture [8,15], infrastructure, and services can be at different stages at the same time, as they continue to move along the clockwork mechanism circle. However, once the continuum is established, it can trigger a virtuous and continuous cycle of technological development and deployment [9], as an evolution, with the work of the third element giving the system authorities the confidence to launch new projects based on tier one or tier two approaches, and then progress them through the continuum.

H4. *Traditional sports infrastructure develops stable and continuously under the condition of functioning of additional products/services and established sports tech ecosystem. (Cogwheel #1 can function stably and continuously by evolutionary path only under condition of functioning of Cogwheels #2 and Cogwheel #3).*

In this study, we argue that new technology deployment may be executed according to the proposed model. We have assumed, that the most probably the perfect theoretical model

does not exist, however, after researching the problem and analyzing of data, we propose the “Clockwork” Model of deployment technologies in the sports industry ecosystem as the most effective and efficient approach, in our opinion, of continuous developing, integrating and managing of new technologies in order to facilitate and holistically enhance effectiveness and efficiency of the ecosystem as a whole, functioning for all the stakeholders.

The “Clockwork” Model is a holistic system, all three elements are functioning at the same time, driving each other. Any new technology appearing in this system is supposed to make continuous evolutionary path circles, (1) evolving itself, (2) improving TRI, TA, awareness, and culture, and (3) enhancing stakeholders’ performance and experiences in various aspects: social, sensorial, behavioral, emotional, and cognitive.

We present trail running and its most recent technological evolution as an illustration of the interconnected cogwheels that build upon each other, forming an example of the “Clockwork” Model.

In France, a study by the National Institute of Youth and Popular Education indicates that running and walking engage 47% of individuals aged 15 and older, with over one-third participating regularly [19]. Another study estimates 9 to 13 million runners in France, revealing a notable surge during the COVID-19 pandemic, with 73% sustaining their engagement one year later [20]. Nature proximity significantly motivates runners, with 61% favoring rural areas, 52% forests, and 13% mountainous terrains [20]. Hence, running, particularly offroad or trail running, undeniably stands out as one of the most popular activities in France.

Cogwheel #1: Trail running requires tangible infrastructure such as hiking trails, signage, and maps. The management of these infrastructures typically falls under the purview of public entities and groups of volunteers. Responsibilities include maintaining the cleanliness and safety of the trails and installing signage. These tasks are commonly undertaken by local associations specializing in hiking, running, or forestry, as well as by municipal authorities, town administrations, and community councils [21]. A discernible trend among trail runners involves the increasing use of connected devices for route finding, orientation, and activity tracking. A recent study indicates that 86% of trail runners utilize smart devices [22]. Furthermore, digital tools are progressively being employed in the management and territorial development of this activity.

Cogwheel #2: Recognizing the emerging opportunity and heightened interest, public entities, including tourism offices and community councils, in collaboration with tour operators and other smaller private organizations, have embarked on establishing a more comprehensive outdoor tourism infrastructure. Digital devices now simplify trail-related information access through digital maps and GPS traces. Additionally, tourism details, reservations, landmarks, and ecological information are more accessible. Digital platforms also enable participation in organized activities like guided tours and running events [23]. This evolving digital infrastructure caters to the growing trail runner community, enhancing site management and development with supplementary services [22].

An exemplary Instance of this trend is the “Station de trail” mobile application, introduced in 2011 specifically for trail running enthusiasts. It provides permanently marked trails and accompanying services for those exploring landscapes through trail running. The application features freely accessible marked trails, real-time local guidance via GPS, a chronometer, session information (duration, distance, elevation gain), user reviews, points of interest, and an emergency button allowing swift GPS location transmission in case of issues. Additionally, the application offers a website for trip planning and online reservations.

Cogwheel #3: In 2022, the “Stations de trail” initiative merged with the “On Piste!” outdoor application, owned by the Rossignol Group, creating a platform offering a wider array of outdoor activities like trail running, ski touring, Nordic walking, and cycling. The aim was to design a tool that is simpler, more practical, and equipped with enhanced features to meet evolving demands. “On Piste!” functions include searching for sports destinations, geolocation, route selection, GPS guidance and tracking, participation in various challenges as a part of gamification, and tracking activities and performance. In

site management, considering how to structure the surge in trail running and hiking, the Outdoor Experts Forum in October 2022 recognized the substantial increase in enthusiasts, growing from 18 to 27 million in seven years. A noteworthy presentation introduced “Outdoorvision”, a decision support tool for territories relying on digital traces left by practitioners using connected devices.

Summarizing this example, the development of trail running is built upon a well-managed traditional infrastructure, with increasing numbers of runners utilizing designated paths. Technological innovations, like smartwatches and GPS, introduce new digital infrastructure, impacting both demand and supply. Private investors are increasingly engaging in open-access running paths [24]. Demand and supply are rapidly growing, with users benefiting from more diverse sports activities, and decision-makers leveraging big data. The mutual reinforcement of evolving demand and supply, coupled with sophisticated digital infrastructure, results in varied utilization. The digital infrastructure complements the existing traditional system, emphasizing the need for efficient functioning of both.

In the sports ecosystem, technologies are blurring the lines between the physical, digital, and biological aspects of global sports production systems. The rapid pace of technological development is profoundly impacting various facets of the sports industry, influencing how amateurs and athletes train and compete, how sporting events are organized, and the overall stakeholders’ experience. However, sports ecosystem stakeholders, including governing bodies, often find it challenging to strategically invest and implement policies to unlock that value.

To address these challenges and illuminate technology’s impact on the sports ecosystem, the World Economic Forum introduced the System Initiative on Shaping the Future of Sports Production [25]. This initiative aims to provide key insights into the transformative technologies shaping the future of production [2]. We believe that this case can be applied to the sports field, emphasizing the roles of sports organizations, businesses, and educational institutions in developing and adopting innovative technologies [26]. These insights are derived from interviews with key figures in sports operations, technology, and information management across various sports industries.

In the broader sports technology landscape, five key technologies—such as advanced training equipment, virtual reality for sports analysis, wearable technology, artificial intelligence in sports analytics, and 3D printing for customized sports gear—are transforming how athletes train, how sports products are designed and manufactured, and how fans engage with sports. These technologies impact all aspects of the sports production process, transforming the products that athletes use, the training processes, and the management of global sports supply chains. The adoption of these technologies is at different stages, with certain regions leading in technological implementation, while others are lagging behind.

Much like the global production systems, these sports technologies may not disrupt all sports industries in the same way or at the same pace. The value unlocked by these technologies varies across different sports organizations, and the readiness of sports businesses and governments to improve technical capabilities, educate the sports workforce, and ensure inclusive adoption will determine their overall impact on the sports ecosystem. Failure to invest in these technologies may hinder the long-term prospects of sports organizations. In the sports context, the convergence of these technologies prompts strategic decisions related to how value is created within sports organizations, distributed among industry players, and experienced by fans, athletes, and societies.

While technologies present valuable opportunities for enhancing athlete performance, optimizing sports products, and improving the overall sports experience [1,2], their current development pace also raises concerns about potentially exacerbating existing inequalities within the sports industry. Not every sports organization or country in existing sports ecosystems will capture the full value unlocked by these technologies to the same degree. Lagging sports organizations, including both major entities and smaller enterprises, face the highest risk of negative impacts from these technologies [27]. Many sports-focused

countries will be challenged in assisting their sports organizations, particularly smaller entities, in reaping the full benefits of these technologies.

Sports economies, heavily reliant on traditional models, may see their sources of growth diminish as technologies enable competitive sports production in higher-cost environments. The adoption of these technologies is not uniform across all sports, and their impact on citizens' active lifestyles and athletes' training and performance, both in terms of training and in competitions, necessitates the readiness of sports societies to equip their workforce with new skill sets and establish transition mechanisms to ease potential negative impacts.

Some sports organizations and countries have already embarked on significant transformations and policy initiatives, triggering a new wave of competition within the sports ecosystem. Recognizing the pivotal role of technology in the future of sports production, countries have launched programs to support the deployment of these technologies in their domestic sports organizations [28]. For sports organizations, speed becomes a defining factor in this transformative period, with the key to success lying in the ability to develop and adapt at a pace that allows them to stay ahead of the competition. Effective and enduring transformation in the sports context requires an immediate and intense focus on understanding how these technologies can create value within sports organizations and developing the culture and skills necessary to execute these changes [29]. While narrowly prescribed strategies of the Fourth Industrial Revolution may not work seamlessly for sports organizations, governments' role shifts to orchestrating comprehensive sports ecosystems that encompass research, technology, innovation, education, labor, and trade strategies [25]. Success in the future of sports production necessitates a larger framework that tracks and aligns with the evolving external sports environment.

Governments, in collaboration with sports businesses and members of the sports community, have four cross-industry and cross-technology areas of action to drive the inclusive adoption of sports technologies and foster a growing sports production system. These include coordinated efforts in research and innovation to improve technological readiness, democratizing sports technology knowledge, creating pathways to sports careers through education and skills development [29], and supporting public-private partnerships for business formation, innovation, and growth within the sports ecosystem [30].

The future of sports production poses essential questions for governments, sports organizations, and sports societies, requiring a global dialogue to shape a vision that promotes economic growth and innovation in sports inclusively and sustainably. Sports leaders will need to examine a series of "what if" questions about sources of global and local sports economic growth, innovation beyond technologies, national competitiveness in sports, importance of developing sports infrastructure, skills and opportunities for the sports workforce [29], and sustainability within the sports industry.

The process of deployment of technology innovations in the sports industry is characterized by the following features:

1. Evolutionary process [7]
2. Coherent [2]
3. Continuous [31,32]
4. Holistic [31,33]
5. Gradual [34,35]

5. Conclusions

This study has revealed a comprehensive understanding of the symbiotic relationship between traditional sports infrastructure and technological advancements in the sports industry. The four hypotheses presented in our research underscore the interdependence of these elements and emphasize the necessity of a well-balanced and functioning ecosystem for overall success and development. The "Clockwork" conceptual model that emerged from the synthesis of these hypotheses provides a visual representation of the continuous and cyclical process of technology implementation and deployment in the sports industry.

This model, consisting of three interconnected cogwheels, depicts the evolutionary path of Sports System Connectivity development, highlighting the stages of technology deployment.

Cogwheel #1 emphasizes the importance of a well-managed traditional infrastructure as the foundation for introducing new technologies. It represents the initial stage of technology adoption, relying on traditional non-digital structures and contracting between public and private sectors.

Cogwheel #2 signifies the growth phase, evolving old infrastructure into a digitally connected sports ecosystem. It focuses on the development and deployment of additional digital services and products, building upon the foundation laid by traditional infrastructure.

Cogwheel #3 represents the maturity phase, highlighting the integration of a holistic digital ecosystem. This stage involves the development of new products, services, businesses, and revenue opportunities, creating a connected and digitalized sports environment [35].

The continuous and cyclical nature of these cogwheels, as depicted in the “Clockwork” Model, reinforces the idea that the effective functioning of traditional infrastructure is crucial for the success of technology-based services and products in the sports ecosystem. Furthermore, the model emphasizes the importance of a well-managed sports tech ecosystem for the stable and continuous development of traditional sports infrastructure. Our findings suggest that the sports industry’s future lies in a harmonious integration of traditional infrastructure and innovative technologies. The “Clockwork” Model provides a strategic and structured approach to technology deployment, aligning with different phases of the TLC. As the sports industry continues to evolve, this model serves as a valuable guide for stakeholders, highlighting the interconnected elements that drive continuous technological development and deployment.

While our study provides valuable insights into the symbiotic relationship between traditional sports infrastructure and technological advancements, there are limitations and areas for future research that should be acknowledged.

6. Limitations

The findings of our study are based on a specific set of interviews, and the generalizability of the results may be limited to the context and participants involved. The rapidly evolving nature of technology may render some aspects of our study outdated over time. Continuous monitoring and updates would be necessary to capture ongoing developments. The study may not fully account for cultural and contextual variations in the implementation of technology in different regions or sports industries. The research heavily relies on qualitative data from interviews. Integrating quantitative data could provide a more comprehensive understanding of the quantitative impact of technology on the sports ecosystem.

7. Future Research Directions

Conducting longitudinal studies would allow researchers to track the evolving relationship between traditional infrastructure and technology over an extended period, providing a more comprehensive view of the dynamics involved. Exploring how cultural and contextual factors influence the adoption and impact of technology in the sports industry across different regions could provide valuable insights for a more global perspective. Integrating quantitative methods, such as surveys or data analytics, would help in quantifying the impact of technology on various aspects of the sports ecosystem, providing more concrete evidence. Comparing the effectiveness of different models or approaches to technology deployment in sports industries could highlight the best practices and contribute to the development of more efficient strategies. Future research should delve into the ethical implications of technology in sports, addressing issues such as data privacy, fan engagement, and the impact on athletes’ well-being. Given the rapid pace of technological advancement, future research should explore the integration and impact of emerging technologies, such as augmented reality, virtual reality, and artificial intelligence, in the

sports ecosystem. Further research could explore the perspectives of various stakeholders, including fans, athletes, and sports organizations, to understand their roles, concerns, and expectations in the evolving sports technology landscape.

In future projects, we are going to consider specifying the geographical scope and incorporating more diverse methodologies, such as quantitative analysis, to strengthen the empirical foundation of the findings. By addressing these limitations and exploring these future research directions, scholars can contribute to a more nuanced understanding of the complex interplay between traditional sports infrastructure and technological innovations in the ever-evolving sports industry.

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Note

¹ <https://www.merriam-webster.com/dictionary/clockwork> (Accessed on 10 February 2024)

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