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Gurzhii Anastasiia, Islam Najmul, Marella Venkata

This is a Author's accepted manuscript (AAM) version of a publication
published by Springer, Cham

in New Sustainable Horizons in Artificial Intelligence and Digital Solutions. I3E 2023. Lecture
Notes in Computer Science

DOI: 10.1007/978-3-031-50040-4_21

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Please cite the publication as follows:

Gurzhii, A., Islam, N., Marella, V. (2023). Understanding the Challenges Surrounding Decentralized Applications: An Empirical Study. In: Janssen, M., et al. New Sustainable Horizons in Artificial Intelligence and Digital Solutions. I3E 2023. Lecture Notes in Computer Science, vol 14316. Springer, Cham. https://doi.org/10.1007/978-3-031-50040-4_21

**This is a parallel published version of an original publication.
This version can differ from the original published article.**

Understanding the Challenges Surrounding Decentralized Applications: An Empirical Study

Anastasiia Gurzhii¹[0000-0003-2187-7509], Najmul Islam²[0000-0003-2236-3278] and Venkata Marella³[0000-0002-2824-3368]

^{1,2} LUT University, Lappeenranta 53850, Finland

³ Open University, Heerlen, Limburg, 6419 AT Heerlen, Netherlands

Abstract. As the Blockchain gains prominence as a disruptive technology, there has been a rapid growth in the number of decentralized applications (dApps) built on them. Despite the growing number and importance of dApps, we still know very little about the success factors surrounding such applications. While the existing research is primarily focused on the creation and development of dApps, very little research is dedicated to the challenges from dApps developers' perspective. We addressed these issues in the paper by collecting data by means of individual discussions with technical people. The purpose of this collection is to map, classify, and describe the challenges surrounding dApps to help organizations make adequate decisions regarding decentralized applications' development and promotion. We identified five dimensions of challenges and proposed a framework to describe dApps management and highlight how identified factors influence such applications' adoption.

Keywords: decentralized applications, dApps, developers, challenges.

1 Introduction

Over recent years, the growth and rapid development of information and communication technologies disrupted existing business organizations. Blockchain, hailed as one of the most disruptive technologies of recent decades, promises organizations to transform from centralized governance to a decentralized approach [1]. After Satoshi Nakamoto introduced Bitcoin in 2008, the interest in blockchain technology rapidly increased both in industry and academia [2]. The main features of blockchain that attract organizations are decentralization, immutability, and transparency [3, 46]. As blockchain-based platforms gain momentum, decentralized applications (dApps) are becoming increasingly popular nowadays.

Existing research (e.g., [4, 5, 6, 44, 45]) in dApps is mostly focused on creating decentralised applications, providing development guidelines and strategies, or discussing such applications' benefits. However, there is little empirical evidence and understanding of the existing challenges and barriers related to dApps adoption from developers' perspective and only a few studies covered this dimension [7, 8]. To fill this gap, this study aims to contribute to the literature by identifying the most common challenges in dApps. Consequently, we address the following two research questions.

RQ1. What are the common challenges surrounding existing dApps adoption from the developers' perspective?

RQ2. How those obstacles should be overcome to increase the global adoption of dApps?

In order to answer the above research questions, we collected data from 14 decentralized applications developers. We analyzed the collected data using the GIOIA method [9]. The findings suggest that the dApps ecosystem is still in its infancy and widespread adoption is limited. Our paper contributes to the literature in two main dimensions. First, we empirically identify existing challenges surrounding existing dApps development and promotion by collecting data from developers. Second, we provide a conceptual framework for dApps management [10, 11] that can guide developers during the process of blockchain-based applications creation and future promotion on the market.

The remaining part of the paper is structured as follows: in section 2, we shed light on the open blockchain platforms for dApps development and various types of decentralized applications. Section 3 focuses on the research methodology and data analysis. In section 4, we summarize our findings that include observed challenges and a framework that unites various concepts which have an impact on further dApps development, followed by the discussion in section 5. Finally, in section 6, we provide conclusions of the study along with its limitations.

2 Background

Decentralized systems are mainly used to create fault-tolerant distributed computing systems where authority can be distributed without relying on a centralized system [12]. As the first application of blockchain, Bitcoin [2] contributed to the global popularity of the technology and made the world aware of its benefits. Blockchain can be described as a distributed system and a data structure that is arranged as a continuously growing chain of blocks [13]. It is open, allowing anyone to read the information. Various blockchain platforms have been developed over the last decade and since there are many technical features required to implement blockchain technology, choosing the right blockchain platform for a particular application can be a challenge [13]. For example, scalability, security, and cheap transaction costs are the most important issues to be considered. Gariga et al [14] focused on the most popular public blockchains (e.g., Ethereum, Cardano) and their features namely cost, consistency, security, functionality, etc.

An application operating on a blockchain network is known as a decentralized application. Hence, dApps take advantage of the main blockchain characteristics: transparency, reliability, and data immutability [15]. Antal et al [16] provided a detailed guideline for dApps application architecture design and implementation steps. Among the main features of such applications is the possibility to run on a distributed network, securely store information, and substantially protect the privacy of users. Decentralized programs, like mobile apps, generally have a user-friendly interface and nowadays the UX is straightforward. The application layer only handles user registration, transactions, queries, and other routine tasks [17]. The fundamental layer is made up of smart contracts created by developers and the code is written in special programming

languages. In other words, once developers have released their software into the public domain, no one can ever change the logic of the program [18, 45]. Pure decentralization can be achieved only if all the data is stored and all processes are handled in the blockchain and a dApp must be protected by a cryptographic token. This means that data and records must be publicly available and not operate under the control of a single person or group [15]. Nevertheless, modern dApps are far away from full decentralization. Wu et al [19] described 3 types of architecture in DAPPs. The first type is a direct architecture where users interact directly with smart contracts and blockchain (e.g., NFT marketplaces). The second type of architecture has back-end services on a centralized server, and users communicate with smart contracts via the server (e.g., cryptocurrency hardware wallets). Finally, mixed architecture DApps are the combination of the previous 2 types, where users interact with smart contracts both directly and indirectly via a back-end server (e.g., GameFi domain).

At the same time, the prior literature is focused on the technical features of blockchain technology to take into consideration. The importance of providing safe management of personal clients' data creates a broad discussion about on-chain and off-chain data storage [20, 21]. On-chain storage involves storing data directly on the blockchain and has limitations such as finite capacity, scalability challenges, and increased transaction costs for large data volumes. While, off-chain storage utilizes external systems like centralized databases or cloud storage, offering scalability and efficiency advantages. Combining both storage methods is common, with critical data stored on-chain for trust and transparency, while larger or complex data is stored off-chain for scalability. Additionally, some research (e.g., [22, 23]) discusses the importance of business models in dApps. Unlike traditional centralized models, dApps leverage the decentralized nature of blockchain technology and create new models on the market that have never existed before. These applications offer diverse revenue streams, including tokenomics, subscription-based models, licensing fees, or transactional charges for accessing their services. Overall, the evolving landscape of business models in dApps showcases the potential for innovative and sustainable approaches that can disrupt traditional industries and create new economic paradigms.

3 Methodology

3.1 Data collection and participants

Our goal was to collect respondents that have development experience and can give comments from various perspectives regarding the technical side of blockchain and decentralized applications. To collect empirical data, we identified several active open groups on social networks (e.g., Twitter, Discord, and Telegram). Over there we found 14 current blockchain developers from various countries who are currently working on the creation or the decentralized applications testing. We interviewed these 14 blockchain experts. The interviews contained 3 major themes: 1. basic overview of the decentralized applications and the current situation on the market; 2. challenges associated with the development and adoption processes; 3. obstacles that hinder dApps global adoption. The background of some respondents is not only technical but additionally covers business, marketing and interface design domains.

3.2 Data analysis

To analyze the collected data and classify issues we used the Gioia method [9]. The data analysis contained three main stages. First, we repeatedly looked over the collected empirical data and assigned codes to describe various content parts. Table 1 presents the codes that were produced at this point along with the relevant data quotations. Second, we classified the linked codes to create more abstract notions, also referred to as second-order concepts. Third, we combined the second-order ideas into five broader dimensions: infrastructure, limited resources of users, limited resources of developers, mechanics of a project, and governmental regulations. Figure 1 shows the dimensions together with the related sub-dimensions. In Table 1 we present 2nd and 1st-order concepts with example quotes.

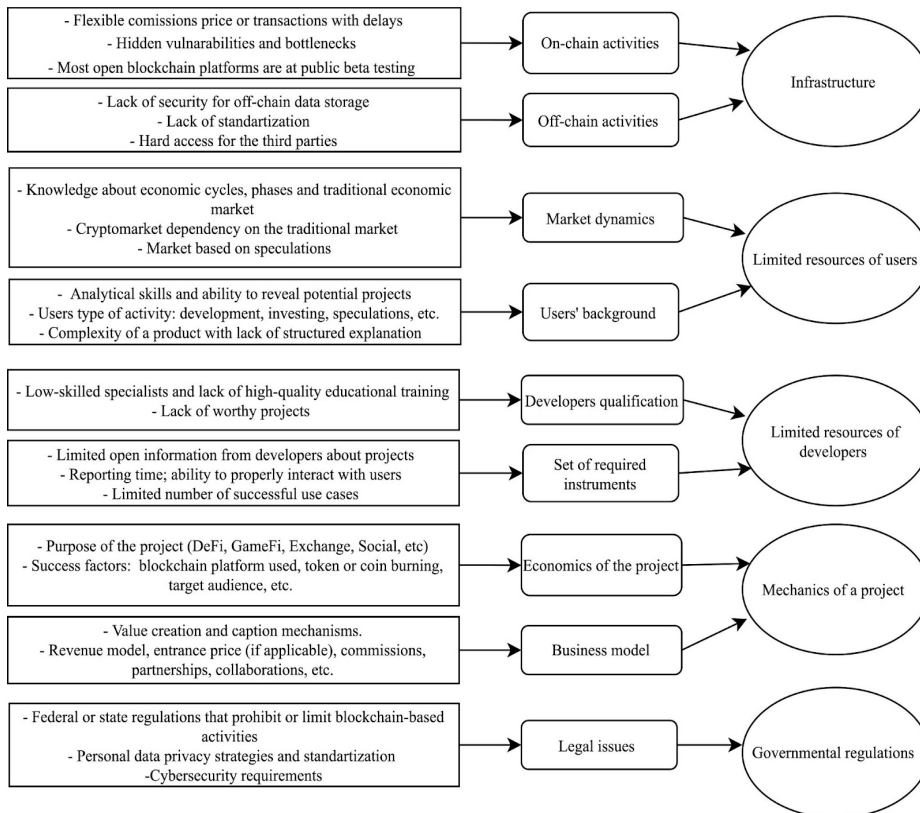


Fig. 1. Influencing factors on dApps adoption dimensions and sub-dimensions

At the same time, in Table 1 we present some quotes from experts that were extracted from the interview data and place them according to the dimensions identified earlier.

Table 1. Key concepts and associated codes with examples

2nd order concept	Example code/1st order concept	Example quote
Scalability and stability challenges	Switching off transactions for a while; more than 24 hours transactions delay.	<p><i>"It is easy to suspend transactions in various blockchains. I missed a couple of good opportunities because of those limitations"</i></p> <p><i>"The network can be easily overloaded if the number of users increases. There are still complexities to achieve a perfect scalability level"</i></p>
Absence of additional services standards; on-chain and off-chain data storage.	Personal data collection (e.g/ e-mail address, locations), payment systems connection (e.g., bank transfers or card payments)	<p><i>"I've heard a lot of stories about the data and assets leak. It happens because of smart contacts' insecurities, manipulations from dishonest teams or a targeted attack on Access Control. A developer downloaded a new job invasion that was a virus file and this resulted in a millions dollar loss of assets for users... external solutions are full of vulnerabilities"</i></p> <p><i>"I have a secured e-mail address and a phone number that is not associated with me. Transactions in blockchain are visible to everyone, while sensitive data is stored on other servers and can be compromised one day"</i></p>
Easy access for the market for everyone	Potentially scam projects, the stolen ideas, lack of experience that can make an interesting project unnoticed, focus on financial products	<p><i>"I've been on the market since 2018 and have seen too many projects. The sphere gives a lot of opportunities but, at the same time, unscrupulous developers hold most of the market"</i></p> <p><i>"Most projects do not have a normal community and developers easily make changes in the product when something goes wrong, especially at the early stage"</i></p> <p><i>"The majority of projects are just for speculations. They are created in a rush just for money and with basic on-chain analysis skills you can easily detect this"</i></p>
Traditional market economics	Dependency on the leading market (the USA), a sphere with a high risk.	<p><i>"I always support my experience with analytical reports and it's foolish to expect that during the economic crisis, everything will be smooth here" (in dApps)</i></p> <p><i>"Even though I can create a full working project, there is still a limited number of potential clients... the industry is claimed as a high-risk one and nowadays (2022-2023) it is too vivid"</i></p>
Knowledge about the market among potential users	Lack of awareness about the market, following hype projects rather than potential ones	<p><i>"I am on the market since 2018. Even though it's 2022, I still see people that say, "Hey, I got scammed, can you help me?". I understand that the level of education around blockchain is still low. I always tell people that knowledge and a "cold head" is a key to success"</i></p> <p><i>"There is a lot of information about blockchain in the internet... but the majority have too limited knowledge about the technology"</i></p>

Market share and tokenomics of the project	Projects purpose, inner mechanics, speculations on price by big players, absence of open documentation	<p><i>“From the developer’s perspective, there is still a reluctance to add explanatory text for complete beginners or some guidance for a smooth experience”.</i></p> <p><i>“Developers should create more value out of the product than they do now. The key is in the mechanism, which must work properly, avoiding chaos and dead loops.”</i></p>
Financial side and project’s viability	Ways to attract create a revenue stream, collaborations with other successful companies, strong community	<p><i>“It is very important to permanently evolve alongside the market and understand the reasons for all changes for a long-term and effective market collaboration”</i></p> <p><i>“Whitepaper is something I always follow in the first place. Of course, there are a lot of other factors that attract me to a project but well-structured open documentation gives me more trust and is proof that developers are scrupulous to details”</i></p>
Set of government-based challenges worldwide that limit dApps adoption	Unclear position about blockchain; strict limitations; lack of from authorities; no government-based programs	<p><i>“Some regulations and clear government positions can simplify things. Better than uncertainties”</i></p> <p><i>“If we want to see a global dApps adoption there should be cases from governments... People tend to follow the majority and without governments, it is likely possible in a global sense. Internet adoption is a good example”</i></p>

4 Results

From our interviews, we found that blockchain and dApps in particular are surrounded by numerous challenges. We identified 5 main categories as we discussed them next.

4.1 Infrastructure

Despite the growing number of blockchain platforms, there is still no well-functioning infrastructure for dApps. For example, it is still tough to choose the right blockchain platform: some of them have expensive transactions (e.g., Ethereum), while the new ones can cause problems when scaling dramatically, provide a lack of stability or lose popularity with essential liquidity. Due to source data, and the general principle of transparency, the public nature of dApps, an on-chain structure offers hackers a unique opportunity to find and exploit vulnerabilities that would otherwise go undetected [15]. In addition to on-chain activities that are linked with bridges between blockchains and smart contract execution results, dApps rely on off-chain infrastructure (e.g., web interface, and backend servers to index data from a blockchain used). Oracles give blockchains the ability to interact with the real world for the first time and transfer information securely from a blockchain platform to external services [24]. This opens up a huge range of new possibilities, as smart contracts can now work with data from the real world. But our experts mentioned that existing off-chain storage alternatives do not have equivalent security and immutability as on-chain data storage. It is essential to make transactions faster, not overload blockchain networks, hide some details about transactions when privacy is required (e.g., special use cases such as private data

healthcare according to legal regulations for data protection – GDPR [25]), and provide an ability to delete or modify sensitive data outside blockchain [16]. The respondents mentioned that developers solve this problem independently since there is no unified and standardized model.

There are several key issues with existing data storage [26] hard access for third parties (e.g., auditors), risk of disclosure by a malicious team member, storage of a cryptographic proof to the blockchain that the data was not modified since the last access and in frequently modified repositories processing of such keys can be burdensome, lack of uniform response time from various sources, etc. Hence, the infrastructure dimension has a huge impact on the dApps future growth and it is included in the final framework.

4.2 Limited resources for developers

Since the market is at the early stage, non-homogenous and non-regulated, there are a lot of low-skilled developers with substandard projects. Hence, most people consider it as an opportunity for speculation. Respondents mentioned that dApp projects can be classified into cutting-edge and moderate. Cutting-edge projects can improve existing ecosystems with their ideas or even ground-breaking, while moderate ones do not provide innovative ideas, use open-source data of similar projects and may quickly lose popularity. At the same time, a lot of dApps lack good open documentation or even its absence. While brochures and other marketing materials can be flashy and include obvious sales pitches, a whitepaper [27] is designed to provide convincing and factual/technical evidence that a particular proposal is a superior method of solving a problem or challenge. Experts are sure that well-written open documentation with a roadmap can be among the most important features to take into consideration before using the app and showing the qualifications of a team. The respondents mentioned a lot of important elements of good documentation and we grouped them into 6 categories: 1. The project value from customers' perspective; 2. A relevant format with FAQ, guidelines, overviews, and analysis; 3. Writing style and literacy (preferably in English); 4. Readability and attractive design; 5. Sharing in various open resources (e.g., social networks). 6. Relevant information about the team, investors and other interested parties. In the technical documentation of the project, developers describe how their platform works, talk about the protocols used in the blockchain, and what problems their project solves.

Additionally, from the technical side, the smart contracts' immutability makes dApp design particularly difficult when the experience in the sphere is limited. Developers need to plan the whole process carefully from the beginning and ensure that future applications are consistent with decentralized applications. However, lack of knowledge about smart contracts' programming languages results in failures during the execution, security, and privacy issues that attract most hackers. Smart contracts audits show various errors at different levels and according to recent research [28], 40% of smart contract developers indicated the existence of vulnerabilities in the code. Overall, a lack of good educational programs or advanced training courses leads to low educational levels and unwillingness to improve skills.

In general, we found that the project can be easily listed without a proper audit and testing. This happens due to the costly audit process for small teams and code protection

is not a paramount concern for the majority. Therefore, when the number of users grows, the load on each member of the team increases and negatively affects the project management at the company, individual and institutional levels (e.g., [10]). From the end user's perspective, dApps should not differ much from traditional applications from the usability side as well as problem resolving by the team.

4.3 Limited resources for users

Overall, respondents mentioned that most people consider all blockchain-related activities as a high-risk investment and a dependency on the traditional stock market. The main indicator of the crypto market is Bitcoin as the leading coin [29]. Currently, its correlation with stock indexes (especially S&P500 or NASDAQ) is a benchmark of market reaction. Additional factors include the exchange balance of the coin, transaction volume and the outflow of exchange capital [30]. Therefore, considering the most popular dApps categories, in the bearish market most people are less likely to use blockchain-based applications because of the market volatility, limited knowledge and concerns about the market potential. In the bullish market, the level of interest among potential users is high with fear of missing out on the high revenue and a lot of new projects emerge. Our interviewees mentioned that most new projects are gaining momentum for a short period and during our short-time analysis, we saw how some projects rose rapidly against the market and also lost their value instantly. Additionally, experts mentioned that the Defi sector offers a lot of possibilities and attracts users (e.g. P2P crypto exchange, coins staking, trading, mining, etc.). But as usual, manipulations by “big players” in every dApps category are significant which makes the whole industry more unpredictable rather than a traditional market.

At the same time, the more dApps developed, the more scams and high-risk projects emerged [1]. We noticed that a lot of users are not fully aware of blockchain technology, cannot analyse projects, and follow hype trends without a proper understanding of the inner mechanics. However, the market is dynamic and regular people are not able to follow all trends simultaneously without research. In this case, our experts strongly believe that individuals who have had unpleasant experiences with blockchain technology in the past would be hesitant to engage with any blockchain-based activities in the future, exercising an increased amount of caution.

An additional serious barrier for users is the complex procedure for account creation (e.g., wallet tools installation, data import, personal wallet creation with remembering seed phrases or private keys, gaining tokens for every particular blockchain (e.g., ETH for Ethereum) that requires knowledge and additional skills. Therefore our experts are sure that complex strategies are not very convenient for complete beginners, as most people are, while the ultimate goal of dApps should be an open, decentralized product that is available to everyone [31, 37].

4.4 DApps mechanics

Traditional apps are based on a robust business model where the companies develop them purposefully, emphasizing usability. But dApps tend to be developed by the community, lacking the essential resources (e.g., deep knowledge of the market, ability to create good project tokenomics, maintain stable transactions inside apps, collaborations with well-known and trusted brands, etc) that traditional enterprise apps

have. This means that the most popular business models are social or community-based, where success is determined by the activity of the users involved. Nevertheless, taking into consideration the GameFi sector, which holds more than half of active users [32], the business model can be described using a Ponzi scheme [33] or financial pyramid. The income system for members of the structure is created by constantly attracting funds from new members [3, 34].

Additionally, the main project token economics takes an important part in dApp mechanics. It describes the basic main features of various types of cryptocurrencies (e.g., demand or supply), studies the development mechanisms, and describes the rules that determine the development path of each currency's token [36]. The most valuable information includes token usage, launch with tokens model (inflationary or deflationary), distribution (how coins or tokens are mined, earned, and managed by the community), and supply schedule. This information can be used not only by active players but has a great impact on potential investors and speculators that may add value to the project.

4.5 Regulation Guidance

Last is regulation guidance and government involvement in the dApps market control. We revealed that countries are divided into four groups: 1. Loyal to the technology with governmental-level solutions, with low taxes (or without) on cryptocurrency transactions, with transparent laws and regulations of the industry and startups (e.g., Switzerland, Estonia, Japan, Germany, Sweden, etc.). 2. Less progressive than the first group but accept cryptocurrencies as a digital asset, have tax laws to regulate the sphere, less enthusiastic, trying to control somehow but do not prohibit any activities (e.g., Finland, France, Czech Republic, the USA, etc.). 3. Where blockchain is allowed only on the governmental level, strict regulations restrain and where regular citizens cannot easily access the market (e.g., China, Ecuador, Vietnam, Indonesia, Morocco, etc.). 4. Completely forbidden (e.g., North Macedonia, Iraq). Any uncertainties are because dApps offer significant opportunities alongside risks and concerns to regulators, investors, and financial markets. For example, because of their anonymity cryptocurrencies are widely used to make payments for criminal activities, such as money laundering, drug trafficking, and terrorist financing. Therefore, governments cannot agree on the international status of blockchain technology and blockchain-related activities. This, on the other hand, gives the industry an advantage over the developers of traditional applications.

Finally, taking into consideration low-quality projects, they can be easily identified since all transactions are stored on the blockchain [20, 21]. But experts are sure that this requires a lot of additional work such as on-chain data collection, processing, and visualization which cannot be easily done by individuals without proper knowledge. Therefore, with an absence of control and regulations, users with a lack of knowledge will suffer from information asymmetry, fraud, and self-trading (e.g., NFT collections on dApp marketplaces).

5 Discussion

5.1 Conceptual framework

Our research supplemented existing literature, and according to the collected evidence, we developed a framework that contains factors that influence the adoption of dApps. We presented the factors that affect dApps management, business models, and long-term outcomes that have direct implications for the future of dApps (Fig. 2).

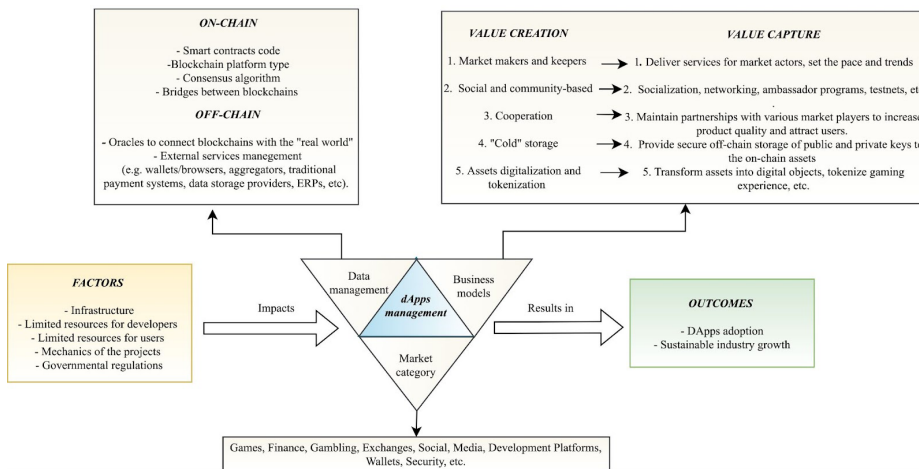


Fig. 2. Conceptual framework of dApps management

In the current study, we revealed 5 main challenges (Figure 1) that affect the future of dApps adoption. Tallon et al [35] describe such factors as antecedents and can be divided into external (e.g., regulations, infrastructure, limited resources for users) and internal (e.g., project mechanics and resources for developers). We found that all factors mentioned above have an impact on 16 market dApps categories (e.g., games, finance, wallets, etc) [37]. For example, the mechanics of the project as an economic model contains the data on how tokens are distributed, in what proportions, the total supply of circulating coins, the price of the token on the launchpad, unlocks by rounds, etc. Hence, the capitalization of the project at the start should be low, it is calculated on the basis of the total sum of the project and the main emphasis with respect to the allocation of tokens should be the dominant area from which the project will work: the reserves and liquidity for DeFi, commissions for marketplaces, rewards for GameFi, etc. Resources for developers and users are limited in all categories and impact the further experience, while regulations are essential to reduce low-quality projects.

Data management in dApps depends on the complexity of the project, and the market category depends on the dApp architecture. Mixed and indirect types are divided into on-chain and off-chain, while direct includes only on-chain that relies on smart contracts [37]. The on-chain structure is most common for all dApps where the use of multiple blockchains with bridges can reduce the load on one network and provide faster transactions [24]. As it was mentioned before, sensitive data (e.g. phone numbers,

e-mail addresses or even the customers' names) cannot be stored in blockchain. For this purpose, oracles were created to connect on-chain data with off-chain services. Some ideas from the developers' side include: *“If an oracle needs a reliable reputation, it can retrieve its data from multiple sources. In addition, when an on-chain contract makes a request, contracts are executed on several off-chain nodes as well”*. Connection with off-chain storages (external services) depends on the sphere and should be adapted according to the basic needs (e.g., traditional payment systems connection, extensions for browsers, data storage for personal clients' data). *“Among the options for how to move to blockchain is to connect existing systems with decentralized platforms. Nevertheless, there is no need to migrate the entire system to blockchain - only to identify areas where increased transaction speed, data protection and scalability are needed”*.

A lot of existing research is focused on business models in blockchain-based applications [10, 35, 38] but in the case of dApps, the data is limited. Business models that are mentioned in the current research are the basic methods that prevail in the majority of dApps. First, market makers and keepers may represent two types of dApps – innovators that set a trend in the sphere (e.g., CryptoKitties [34]) was the first blockchain-based game); and marketplaces with exchangers that act as an intermediary between market actors, systematize data, provide statistics, etc. Second, in “cold” storage value is created by connecting various blockchains to deliver completely decentralized access for users to their assets (e.g., SafePal wallet that helps to store assets and where the access can be restored only using a mnemonic phrase which is not available for any third parties). Third, the cooperation or partnership model is based on the shared experience with various projects to increase the number of active users (e.g., exchange platform Binance created a TrustWallet for “cold storage”). Nevertheless, the situation with partnerships is more ambiguous since those who are indicated in this role sometimes do not have any serious impact on the project. So, in low-grade projects, big projects (blockchains or marketplaces) can be indicated. Fourth, social and community-based as usual linked with other models and determines the success of a dApp on the market. The value is generated by active users that drive the industry forward by increasing the community size (e.g., Decentralend where users monetize their content and the project success is based on the number of active users). Fifth, assets digitalization and tokenization are linked with transferring physical property into digital objects (e.g., Brickken (Brickken, 2022) dApp offers the infrastructure required for businesses to list their assets on the market, raise money on their own through securities offerings (STOs), and run DAOs in a compliant manner).

Currently, blockchain-related projects and dApps in particular evolve faster than standardization [11]. As a result, the industry evolves without the support of any international standards organization and complies individually with the regulations of various countries. For example, in Aave [40] management mechanism can be explained as follows: first, we can see that there is a precise distribution of responsibilities in the teams (e.g., CEO, the division into marketing, development, compliance, business, etc departments) which leads to effective management where the area of responsibility corresponds to the area of employees' influence. The platform was created based on Ethereum which is among the most popular blockchains in the world and the POS consensus mechanism. Second, the project has huge and trusted investors, as well as collaborations with other successful projects from other market categories (e.g., Axie

Infinity Game [41]). Third, for a better user experience, there is an active GitHub where important updates are provided regularly, the whole documentation is provided on the website and users can easily reach the team in a live chat with any possible issues. Finally, in the ranking of Coinmarketcap [42] in 2022, the Aave token ranks among the top 50. Therefore, since its launch in 2017, the project successfully covered institutional, company, and individual layers implementing the mechanisms mentioned earlier.

Finally, outcomes refer to the main consequences that are linked with dApps development and promotion. We identified 2 of them which are linked with long-term dApps performance. Adoption of blockchain and dApps in particular have a number of influencing factors such as social, organizational, user efficiency, technology characteristics, etc [43]. Nevertheless, the research on this matter is essential in various industries, market categories, and countries as the result may vary across different domains. Sustainable industry growth leads to dApps promotion in various spheres since blockchain-based platforms can help to standardize and evaluate data, asset metrics and compliance (e.g., sustainability or ESG standards) [11]. A number of policies are needed to promote the development of blockchain-based solutions in a safe and fair manner.

5.2 Theoretical and practical implications

The paper has several theoretical contributions. First, even though there is a huge number of papers discussing challenges surrounding blockchain adoption [4, 5, 6, 7, 8, 44, 45] there is still limited feedback from the technical people's perspective surrounding dApps development and promotion. For example, Chiu and Meng [4] provided a detailed overview of a platform that can support the development of decentralized applications. Dao et al [7] focused on challenges and strategies associated with decentralized applications development. Nevertheless, we found that prior research provides a broad overview of dApps. In research, we aim to fill the mentioned gaps and narrow the findings.

Second, we found up-to-date challenges surrounding the modern and rapidly growing industry from the developer's perspective. Under these concepts, we have identified five dimensions: infrastructure, limited resources for users, limited resources for developers, mechanics of the project and regulations guidance. We divide impact factors into 3 levels to explain the most crucial ones for practitioners to support future research. Third, under the prior research, we identified that there is no clear answer to how to create successful dApps and promote them. We collected and expanded the existing knowledge using the interview data with experts.

At the same time, we can identify 2 practical implications. First, as it was mentioned before the industry is at an early stage and companies that want to create dApps, make them fully operational and attract users should consider all potential challenges and overcome the most common obstacles. To support our findings, we conducted 14 interviews with experts from different countries during the research. Future research can expand our findings by considering a more extensive set of experts from various domains and countries. Second, we provide a conceptual framework based on the collected data from the experts and future validation through the case studies may broaden the findings.

6 Conclusions

The current research on existing dApps revealed the following conclusions. First, the existing sphere of decentralized applications or dApps is gaining momentum but still is not mature enough. Most people lack knowledge about blockchain technology, and scrupulous developers use this to create low-quality projects. Second, the lack of involvement from governments and the absence of standards creates a free area for low-quality projects. The current situation allows low-budget teams to show their potential and win market share in various categories. Third, uneven progress is still progress. The deeper insight into the market reveals that there are many directions for improvement, and we found a surprisingly small group of people involved in the development process of a quality product. Fourth, the level of maturity of dApps' UX is somewhere between "hostile to users" and "developer-centric", but not "user-centric" at all. It takes years for this area to reach full maturity and there are a lot of improvements.

Among the main limitations of the study is that we did not focus on the respondents' location since some of them do not permanently reside in one country and have a different experience with regulators. Additionally, we mostly focused on challenges and gaps rather than the benefits of the adoption. Further research can be linked with data privacy and frameworks that comply with existing legal regulations, ways how to increase awareness and acceptance levels among users, and some technical features of dApps (e.g., what are the main steps of blockchain-based applications development, how to keep synchronization on-chain and off-chain, how to increase the performance of such application or focus on frameworks both for private and public solutions). Additionally, more detailed and targeted research on business models in blockchain-based applications may complement the findings and expand the conclusions of this research. The results of the current study can be validated among users from one particular country.

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