A Guide to Central Bank Digital Currency Product Development

5P Methodology and Research and Development

Herve Tourpe, Ashley Lannquist, and Gabriel Soderberg

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Glossary

CBDC ..... ….. central bank digital currency

DevSecOps……developments, security, operations

DLT..... ….. distributed ledger technology

PoC ..... proof-of-concept

R&D ..... research and development

RFP..... request for proposal

TOR ..... terms of reference

Introduction

The progress of central bank digital currency (CBDC) projects around the world is increasing the need for an appropriate project management methodology. This is especially true for the initial phases of research and development. A CBDC-specific project management methodology would establish a common terminology and offer guidance to development teams on best practices for addressing the complex requirements and risks associated with CBDC.

CBDCs have several specific characteristics: they are meant for the public, they are largely experimental, and their impact can be either beneficial or damaging—this latter feature means they require careful experimentation and significant international and private sector coordination. A common project management approach would take into account the various motivations for initiating CBDC research, which range from exploring the potential of emerging technologies to building the necessary capabilities in preparation for a potential CBDC issuance.

This paper introduces the 5P methodology, which draws from a variety of sources and experiences to help manage CBDC research, experimentation, development, and, when required, operation.[1] This methodology is not specific to any particular type or design of CBDC. Indeed, CBDC in this context should be understood in broad terms. The paper also offers recommendations to help development teams address the requirements and queries put forth by the policy management team. The activities of the policy management team are covered in a companion paper, "How Should Central Banks Explore CBDC: A Dynamic Decision-Making Framework" (Soderberg and others 2023). These two papers complement each other, covering distinct yet interconnected aspects of a CBDC product. The companion paper focuses on policy management, exploring the motivations and considering the essential economic, legal, and technological factors leading up to issuance; this paper uses this important input and employs the 5P methodology to guide the research and development team toward the successful execution of the CBDC project.

It is worth noting that both papers have been organized based on the 5P phases. This approach has been adopted to emphasize the unique characteristics of each phase and to offer a comprehensive understanding of the tasks and activities that are expected to be carried out during each phase (Figure 1).

The methodology and project management elements covered in this paper are not meant to be a prescriptive guide that can be applied the same way in all countries. The motivations, situations, and desired design of CBDC will vary depending on country context. Central banks have their unique experience, capacity, and resources, so there is no "one size fits all" approach. Nevertheless, sound principles of project management have been drawn into this work from various industries, from car manufacturers to software development, and from current CBDC experiences in various jurisdictions.

[1] The current literature on project management for CBDC is limited. Some papers, however, have stressed the need for such CBDC methodology. See Kiff and others (2020), World Economic Forum (2020), and Salinas (2023).

I. The 5P Methodology

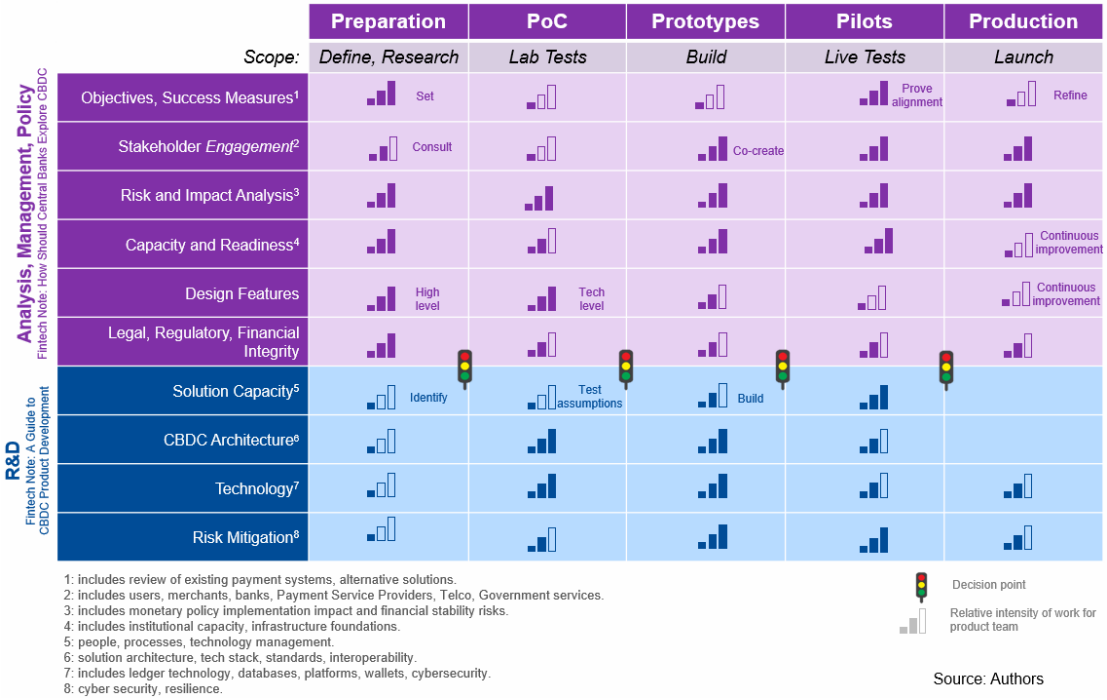
Overview of the Five Phases

Large projects, whether digital or not, often follow a well-established sequence of research, experimentation, development, testing, and operations phases. This linear approach works relatively well when the goals of the project are clear; proven technology is readily available; and a wide range of experience is offered by technology providers, consulting firms, and former clients. However, when a project is continuously evolving or when the value is unproven, as is often the case for CBDC, these steps are still necessary but are difficult to follow in a linear process. Given the highly experimental nature of CBDC and the number of unresolved questions, an iterative and flexible approach is necessary to understand and prove the feasibility, benefits, risks, and implications at every step (Table 1).

This section introduces the 5P methodology, consisting of five phases: preparation, proof-of-concept, prototypes, pilots, and production. These phases provide wholesale or retail CBDC development teams with the necessary tools and techniques to effectively manage the technology exploration and research of a CBDC during phases 1 and 2. They also facilitate coordination for the development, testing, and potential production of a CBDC in phases 3, 4, and 5. By adopting this structured approach, teams can delay costly or final decisions related to technology design and platforms until they have gathered the necessary information to make informed choices.

Figure 1. Roadmap of Activities Involved in a CBDC Project

The figure outlines in blue how the technology-related activities and the work involved in research and development are connected to the broader analysis (in purple) throughout the five phases of the 5P methodology. The former is explored in this paper, while the latter is covered in the IMF's paper "How Should Central Banks Explore CBDC: A Dynamic Decision-Making Framework" (Soderberg and others 2023). The figure also depicts the relative intensity of work for each activity, typically observed in central banks throughout the CBDC journey.



A tailored CBDC project management approach can bring greater clarity in the terminology used to describe various stages of CBDC projects across jurisdictions. For instance, terms such as pilots, prototypes, and proof-of-concepts are often used interchangeably and to refer to different things, which makes it challenging to compare and exchange knowledge effectively across jurisdictions. Furthermore, the absence of established best practices specific to CBDC management creates challenges for project managers who are faced with the task of navigating uncharted territory. This paper outlines a map for central bank project teams that establishes a common language that can alleviate confusion and that documents how technology questions can be effectively managed through the 5P methodology.

Table 1. The Five Phases of CBDC Project Management

This table outlines how each phase of a CBDC project has a specific scope. It provides examples of questions that a technology research team would typically try to answer. The work is chiefly informed and validated by the analytical and policy activities described in the IMF paper "How Should Central Banks Explore CBDC: A Dynamic Decision-Making Framework" (Soderberg and others 2023).

Phases	Scope[2]	Examples of Relevant Questions
1: Preparation	***Research** trends, monitor evolution of technology, and implications.*	What do emerging technologies and new solutions offer? How do they work? What architectures are emerging for CBDC, and what are the tradeoffs? What are the technology-related

[2] The scope covers all topics relevant to a successful CBDC, including legal, policy, opportunities, capacity, and technology. This paper covers the aspects relevant to the research and development of the CBDC.

		risks? What capacity would be needed in each phase? What would be the business and governance impacts?
2: Proof-of-concepts	***Lab test** assumptions and key features of a CBDC*	What assumptions need to be validated or invalidated? How to test the various architectures and design elements? What technologies would support the requirements, and how do they work?
3: Prototypes	***Start to build** CBDC and overall ecosystem*	How to integrate all the key elements of the architecture and the CBDC technology stack? What people, skills, processes are required to secure and support the CBDC platform?
4: Pilots	***Live test** CBDC with actual use cases, data, and stakeholders*	Now that the CBDC system (or a portion) is assembled, does it work as expected in real conditions? How to test risk mitigation? What are the system's maintenance requirements and what is the best way to meet them? Were the assumptions about adoption correct?
5: Production	***Launch and operate** CBDC and ecosystem*	Are adoption and mitigating risks properly promoted? How to monitor, test, and implement innovative developments in the industry to benefit the CBDC? How to maintain operational stability and security?

While the phases are presented in a sequential order, it is important to note that the experimental nature of CBDC projects necessitates iterative cycles within each phase. In fact, iterations can even occur across phases, as some activities and questions may necessitate going back a few phases before moving forward. This means that research, development, testing, and other activities can occur concurrently and be revisited as new information emerges. This is consistent with traditional large projects in the industry, where research and development (R&D) activities are often conducted in parallel with development, security improvements, and operations (also known as DevSecOps).[3]

Go/No Go Checkpoints

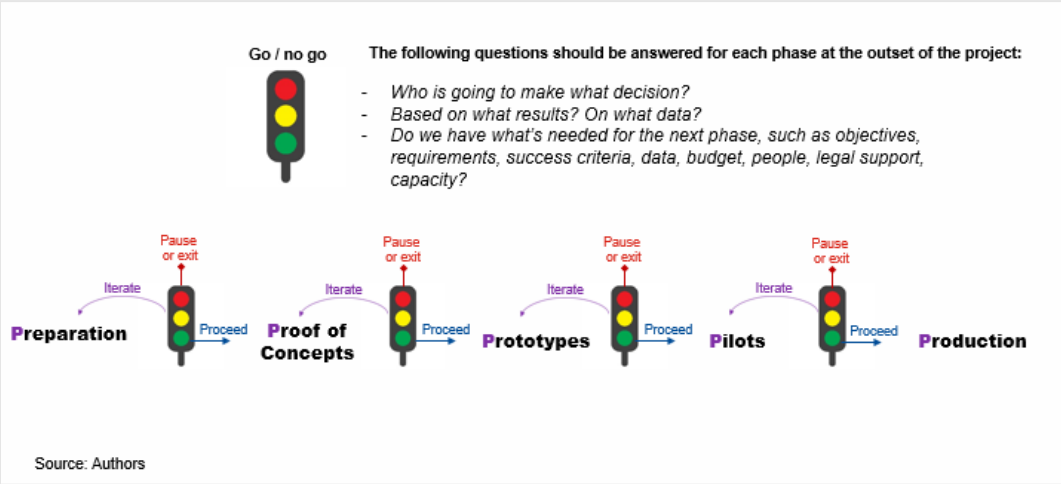
A crucial aspect of the 5P methodology is the proper definition of the conditions for transitioning between phases, known as "go/no go" processes or stage gates in project management (Figure 2). At the intersection of each phase, the central bank has four options: (1) stay in the same phase and iterate to continue learning or building, (2) move forward to the next phase, (3) move forward with some elements that are ready but stay in the same phase for some other unresolved question, or (4) pause or stop the project. The go/no go checkpoint is a crucial activity that ensures that all the central bank's authorities, team members, and stakeholders agree on current progress, lessons learned, and next steps. The criteria for moving from one phase to the next, as well as who should be involved in these decisions, should be agreed as early as feasible, ideally at the start of the project, and regularly updated as new findings and information emerge. This includes the identification and collection of relevant data, information, participants, and resources. As the global research on CBDC and experiences progresses, these criteria will continue to evolve. In general, the central bank should clearly communicate their

[3] DevSecOps is short for development, security, and operations. It is an approach that automates the integration of security at every phase of the software development life cycle, from initial design through integration, testing, deployment, and software delivery. See Bird (2016).

decisions and their rationales to the public so that decisions such as stopping the project would not be perceived as policy failures.

Figure 2. The Go/No Go Decision Points

All phases need predetermined go/no go governance to decide whether to iterate to the same phase, proceed fully to the next phase, proceed partially, or stop the project.



Because each phase is expected to go through several iterations, the go/no go process is also an opportunity to change course if necessary. Contrary to a more linear process, such as a Waterfall process (Box 5), iterative project management allows an organization to rapidly adapt to new data, new inputs, or unanticipated events. Most technology companies today use some sort of iterative and incremental development process[4] to ensure that their digital products can easily respond to change. The go/no go decision is therefore the equivalent of what developers call "sprint retrospectives" (Martinelli and Milosevic 2016) in which the team reviews the lessons learned from the current iteration and decides on possible changes to incorporate into future phases. For example, one iteration of the proof-of-concept phase could reveal that the technology for offline access to the CBDC does not work as expected or might not be mature enough for the targeted use case. During the go/no go review, the decision group[5] could decide either to abandon this use case and move forward to the next phase or to proceed with a new iteration and explore a different solution that they otherwise would not have considered, such as access via SMS/USSD (Short Message Service/Unstructured Supplementary Service Data) when voice coverage is available.[6] Importantly, each go/no go decision point also provides the central bank with an opportunity to

[4] Popular iterative processes include Agile project management and Scrum methodology. Companies often customize these methods to their own needs and culture. See Naybour (2020) and Gillis, Torode, and Pratt (2023).

[5] The decision group will vary across the process. While the go/no go decision may involve only a small number of people to move from phase 1 to phase 2, much higher-level decision makers, possibly at the government level, would be involved to decide to move to a development, pilot, or production phase.

[6] SMS (Short Message Service) and USSD (Unstructured Supplementary Service Data) are technologies often used with mobile money services such as M-Pesa. It enables transactions over a simple voice plan using 2G or 3G. While this does not address the "offline scenario," it does offer a solution wherever the internet is not available or not affordable. Nigeria employs this technology for the eNaira; see Central Bank of Nigeria (2022).

consult with its partners, including the government and stakeholders, to determine whether sufficient lessons have been learned and whether it is warranted to continue with the CBDC project.

Definition of Each Phase

The 5P methodology value lies in its structured and adaptable approach to managing a CBDC project. It provides guidance for linking goals and key questions to specific activities and for promoting coordination among participants. This section provides a general definition of each phase. Subsequent sections delve into the specific implications for the R&D teams.

The **preparation phase** is crucial for laying the groundwork and identifying key questions related to CBDC. Depending on the scope of the project, this phase can involve assessing the potential and risks of specific technologies or taking a more strategic approach to identify policy goals and legal, technological, and monetary implications of CBDC. During this stage, a technological exploration typically looks at a set of technologies and use cases that will be tested in the next phases. For a broader scope, the goal would be to establish the rationale for CBDC, including its policy goals, feasibility, benefits, drawbacks, risks, and success criteria.[7] In all cases, the preparation phase involves an initial assessment of capacity, feasibility, and risks, as well as motivation and market condition, based on consumers' behaviors, habits, and culture. All the while, some assumptions may be made explicitly or implicitly on many domains, including technical feasibility, regulatory compliance, acceptability by all stakeholders and users, or costs. Such assumptions need to be explored further during the next phase.

The **proof-of-concept phase** (PoC) aims to validate or invalidate assumptions about the CBDC and the conditions for success, such as those related to policy objectives, user motivations, technology options and maturity, as well as legal, financial, and technological questions. While the term proof-of-concept often evokes the test of a specific technology, it should be noted that concepts can be proven or understood using other low-cost activities. This includes surveys, Design Thinking workshops, interviews, hackathons, market consultations, innovation challenges, and customized demonstrations. After a few iterations of this phase, the central bank will acquire enough knowledge and clarity to make the decision to pause the project, proceed with more research, or move on to developing some elements of the CBDC system.

The **prototype phase** encompasses most of the development of the CBDC solution (or at least for some use cases). The 5P methodology promotes a development-through-prototypes approach to ensure continuous alignment with the central bank's objectives. This phase starts with translating the knowledge acquired in the previous phases into requirements for the development team. This will allow them to engage with solution providers, such as via an open request for proposal (RFP) process. Following an iterative process, the most suitable partners are tested and selected, while the central bank and other stakeholders start building the initial capacity in personnel, governance, regulation, and technology. This

[7] The IMF Fintech Note "How Should Central Banks Explore CBDC: A Dynamic Decision-Making Framework" explores questions related to the research phases; see Soderberg and others (2023).

phase culminates in the development of a working "product"[8] ready to be tested in a few low-risk settings. A working prototype should involve representation from stakeholders (Box 3), including a representative panel of users. The results will inform the decision to pause the project, continue researching and developing new aspects of the CBDC, or proceed to the pilot phase for advanced testing.

The **pilot phase** is a quasi-production stage of the CBDC journey: the final or near-final product is developed for some use cases. It then requires real-life testing to inform a potential go-live decision. A pilot involves all stakeholders for the targeted use cases, including intermediaries, merchants, and selected users, in low-risk environments. The development team assesses the operational readiness of the proposed solution. Key factors such as scalability, resilience, maintenance, risk management, as well as user experience, adoption, and user support, are tested in real conditions. The pilot phase also aims to ensure that the proposed solution aligns with the policy objectives. The likelihood for adoption is also studied, and a solid marketing and communication strategy is typically developed at this stage. Additionally, the pilot provides an opportunity to simulate and test various events, such as outages and high usage, before the product is officially launched. Conducting different iterations of this phase can allow new use cases, scenarios, or participants to be added and tested progressively. If the pilot results continue to demonstrate the feasibility, readiness, resilience, and value of CBDC, the jurisdiction is on solid ground to discuss the potential to "go live" to the production phase.

The **production phase** is the start of the ongoing management of the CBDC product. The operations and continuous development and maintenance of the product should be approached in a way that ensures its resilience, flexibility, and ongoing innovation. A robust user support process should be in place and its efficiency continuously monitored.

[8] CBDC product management is a broader concept than a CBDC project. It encompasses the entire life cycle of a CBDC, from strategic direction and conception to its upgrades, or replacement. For more on product management, see the companion paper "How Should Central Banks Explore CBDC" (Soderberg and others 2023).

II. How Development Teams Explore Technology and Develop CBDCs

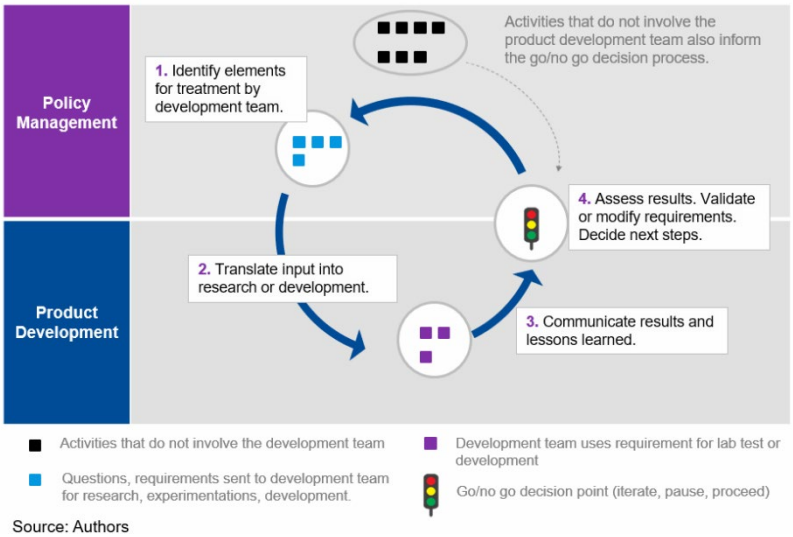
The Development Team and the Policy Management Team

The CBDC development team can originate from different departments within the central bank. Projects may start as technology-centric research, in which case the information technology unit may be in the lead, at least originally. Or they may be managed by a business unit, such as the payment or banking operations, in close collaboration with other functions within the central bank. Alternatively, the team in charge of technology R&D can be part of a higher-level entity that oversees the larger CBDC initiative (Box 1). Regardless of their function at the central bank, we refer to this team as the "development team." In the context of this paper, the team's lead, or project manager, refers to the person coordinating R&D throughout the phases of the project. The project manager and the composition of the team will change throughout the life cycle of the project.

The development team collaborates closely with the policy management team, which oversees the objectives, policies, and risks related to the CBDC project (Figure 1, purple rows, and Figure 3). The CBDC management team actively engages with the development team by posing pertinent questions and providing specific requirements to guide the development process.

Figure 3. Interdependence of Requirements and Development

The graph illustrates the correlation between the activities carried out by the policy management team and the development team (which is the focus of this paper).



Source: Authors

The two teams work collaboratively to navigate and advance through the 5P phases, with the aim of progressively minimizing uncertainties, risks, and options and simultaneously enhancing the capacity to develop a CBDC solution that aligns with the central bank's objectives.

Preparation Phase

Organizing the team

At the beginning of many CBDC projects, typically only a limited number of staff, if any, are fully dedicated to the project. An important responsibility of the project manager is therefore to identify the key functions and competencies that an R&D project would require. These resources may already exist within the central bank, in which case project managers may work to secure their availability for specific phases or iterations of the project. In instances of competency gaps, project leaders will need to devise a plan to hire the necessary resources, develop them internally, or collaborate with external partners. It is important to note that during the initial iterations of the preparation phase, the project managers should focus primarily on identifying these requirements. Prematurely building capacity without sufficient support or evidence creates risks.

Box 1. Country Example—Morocco

Bank Al-Maghrib established a CBDC Committee in 2021, comprising representatives from relevant internal entities and chaired by the central bank's director general. The committee is responsible for examining issues related to CBDC and other digital assets and oversees four Working Groups:

- Working Group 1 explores the potential role of a CBDC in the national payment landscape.
- Working Group 2 focuses on the micro- and macroeconomic study and analysis of the contributions, impacts, and risks.
- Working Group 3 addresses the legal and regulatory framework.
- Working Group 4 oversees the technological and organizational aspects and conducts R&D. In this paper, such a group is referred to as "the development team."

In addition, three subgroups are responsible for topics related to financial integrity, design options, and stakeholder engagement.

Source: Conversations with country authorities.

Conducting initial research

During the preparation phase, development teams typically conduct comprehensive research on lessons learned from other institutions and central banks. Sources of knowledge include the IMF's CBDC Handbook series, the work of the Bank for International Settlements Innovation Hub (2023), and papers released by central banks.[9] Thorough research significantly informs the subsequent hands-on activities carried out during the proof-of-concept phase.

[9] News aggregator websites such as https://kiffmeister.com/ or https://www.finextra.com/latest-news?keyword=cbdc monitor key publications on CBDC.

The research conducted during CBDC projects should not be restricted solely to CBDC solutions. It is important to adopt a mindset of *"falling in love with the problem, not the solution*" (Levine 2023) By examining other countries' experiences and non-CBDC options within the domestic context, the development team can better identify early on other potential solutions they might work with. Such solutions may effectively replace certain aspects of the CBDC (such as a fast payment system) or be conditional on the success of a CBDC use case (such as the role of digital identity for financial inclusion). Broadening the scope of the initial research may also allow the development team to uncover previously unidentified stakeholders or potential partners and enable them to facilitate collaboration and stakeholder engagement early on.[10]

Preparing to manage the project

A high-level terms of reference (TOR) document and project plan can be crucial communication and alignment tools. TOR and project plans are already best practices for seasoned project managers. The iterative process that guides the preparation phase, as well as all the subsequent phases, progressively clarifies key goals, gaps, and risks, enabling the development team to document the TOR and develop an initial high-level project plan. The TOR and the project plan can be structured around the 5P framework, outlining the team's objectives, scope, deliverables, and initial timeline as well as the roles and responsibilities of team members for each phase. It can also include initial thoughts about the go/no go decision process between each phase.

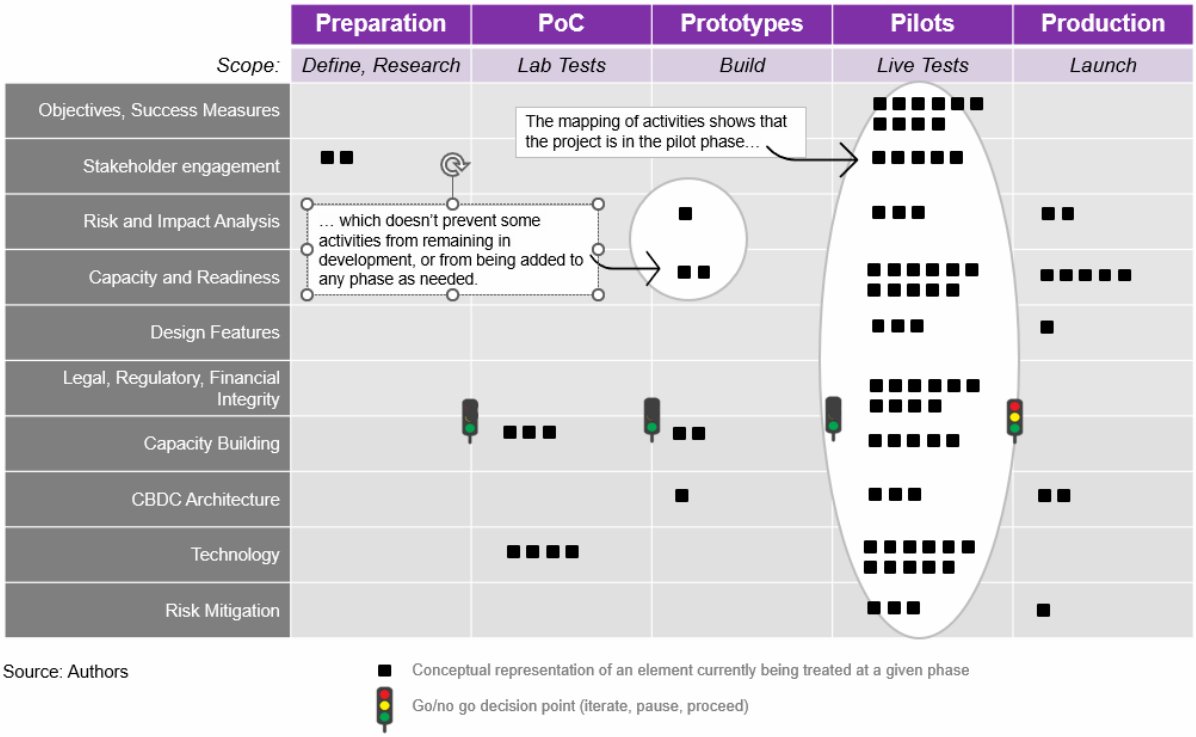
To ensure ongoing alignment and informed decision making, it is important to document the project's work through the TOR and regularly communicate progress to the policy management team throughout the project. This helps keep all team members and stakeholders on the same page and promotes transparency and effective communication. The TOR and project plan also serve as valuable reference points throughout the project, providing a clear road map and guiding the team toward successful CBDC implementation.

Managing a CBDC project can be complex, as certain questions may lag behind while others progress at a faster pace or arise at different stages over time. Therefore, the project manager must maintain a cohesive plan with a comprehensive map of key activities to track progress to facilitate clear communication with the policy management team. With diligent management, the project manager can navigate the intricacies of the CBDC project and ensure its successful execution (Figure 4).

Figure 4. Tracking Activities on the 5P Map

An important role of the project manager is to properly track and communicate the status of all activities, whether they are part of the core project (in the "pilot" phase in the example here), are already implemented in production (for instance, a cloud environment may already exist at the central bank), or lag behind in a preceding phase. This example shows that the project is in the pilot phase, although some activities can be performed in other phases.

[10] For more information about stakeholder engagement, see IMF Fintech Note "How Should Central Banks Explore CBDC: A Dynamic Decision-Making Framework" (Soderberg and others 2023).



Examples of activities

The knowledge sought during this phase can be acquired in many ways. Central banks may already have processes or practices in place or preexisting research that will inform the preparation phase. Table 2 provides examples of activities that may be useful.

Table 2. Examples of Activities for Phase 1

Tools and Activities	Key Advantages
Design Thinking sessions (see Lewrick and others 2020)	Design Thinking workshops are especially useful at the start of a project and could align various stakeholders around the goal. Examples of relevant exercises include (1) system mapping to understand the market, relationships, upstream and downstream movements, hubs, and bridges; (2) root-cause analysis and abstraction laddering to identify clustered issues, define and prioritize them, and map them to corresponding design solutions; and (3) envisioning what success looks like and setting preliminary key performance indicators and road maps
Stakeholder focus groups, surveys, ethnographic studies and interviews	These tools help to better understand motivations, gaps, capabilities, and habits of various consumers and stakeholders on both supply and demand sides. Identify type of users and behavioral patterns.
International experience	Research other countries' experience, engage with peer central banks, and hold bilateral knowledge-sharing sessions.
National information	Research existing reports, analysis, and data on relevant topics for the jurisdiction (such as financial inclusion context, financial market competition, and market structures)
White papers, consultation papers, and other reports	A central bank white paper, or other reports that document the goals of the central bank and how CBDC could achieve them, would be a crucial input to the work of the development team.

Proof-of-Concept Phase

The term "concept" in this paper refers to a particular question or inquiry related to the CBDC solution; the question requires experimentation to gain a deeper understanding of the role of technology. This definition can include inquiries about technology, adoption by stakeholders and users, internal governance, assumptions about the condition for success of particular use cases (Figure 5), or elements that contribute to the necessary capacity, architecture, or risk mitigation. As the development team iterates through several PoCs, they also garner important observations for later stages of the project, including the internal capabilities and resources that a larger project would require.

Planning and execution of low-cost activities

The project manager's primary goal in this phase is to organize the assessment and the understanding of key questions related to CBDC solutions; this can be done with rapid, low-cost activities. A PoC typically takes days or weeks, not months, to organize and execute.[11] The purpose is to acquire knowledge rather than select components of the final solution. The insights gained through multiple iterations of the PoC will significantly contribute to informing the subsequent prototype phase, which aims to build the actual CBDC solution.

A PoC is often understood to involve small-scale technology experiments to gauge the potential or the maturity of a specific technology. For instance, the Bank of Japan has been running a series of PoCs since 2020 to study various aspect of the CBDC, including the role of distributed ledger technology, or the mechanisms to preserve privacy (Bank of Japan 2023). The Bank of Israel also ran a PoC to better understand the potential of certain technology choices for CBDC (Bank of Israel 2022). In all cases, the scope of the PoC was tightly targeted, and the goal was to rapidly test technical feasibility and understand how a specific technology could play a role for CBDC.

PoCs are not limited solely to developing or testing small-scale technology in a lab or experimental environment. Questions, assumptions, or success factors to explore and validate use cases, value to the market, and consumers' reactions can also be explored with many other types of activities. Table 6 highlights other mechanisms and activities development teams can use in their experiments. For example, customized demonstrations by solution providers can offer quick insights into industry capabilities. Engaging with technology actors and stakeholders through hackathons or innovation challenges can inform the CBDC project about previously unidentified opportunities and stakeholders. In essence, a PoC should not be limited to testing a specific technology; it should encompass a broader approach that fosters experimentation and learning.

[11] It is generally recommended to keep the scope of a PoC very narrow to "learn fast and often." When a PoC is takes too long, it is usually possible to break the effort into several smaller elements that can be tested independently.

Box 2. Country Example—LIFT Innovation Challenge in Brazil

A PoC is not limited to internal technology experiments. The Central Bank of Brazil's LIFT Innovation Challenge aimed to discover opportunities for innovative business models and use cases for CBDC in Brazil. This challenge involved the participation of private-sector entities such as banks, payment institutions, and fintech companies, who developed and designed minimum viable products targeting specific activities and challenges identified by the central bank. Throughout the process, central bank staff provided input and guidance while also gaining insights into novel approaches and potential opportunities for CBDC in the country. Proposed use cases related to a potential digital real that have been selected for further exploration include offline payments, trading of real estate and digital financial assets, rural financing based on programmable money, decentralized finance for small business, and an e-commerce parcel delivery solution.

Central Bank of Brazil, LIFT Challenge Real Digital. https://www.bcb.gov.br/site/liftchallenge/en

Proving initial assumptions

Validating initial assumptions made during the preceding phase is another key objective of the PoC phase. Assumptions can be explicit or implicit in any project. Identifying them clearly and explicitly allows the development team to determine the appropriate activities to validate or invalidate them (Table 3). Building a CBDC based on unrealistic and untested assumptions is likely to hinder its success.

It is important to note that assumptions continue to be made throughout the entire life cycle of a CBDC project. Therefore, it is essential to integrate the practice of continuously identifying such assumptions and establish processes to test them as they arise. By adopting this approach, the development team can maintain a proactive stance in addressing potential risks and ensuring that the CBDC project remains rooted on solid working hypotheses.

Box 3. Country Example—Involving Stakeholders in Peru

The Central Bank of Peru is using the 5P methodology to systematically identify and validate questions and assumptions relevant for a successful implementation of a CBDC. A market consultation was conducted via a questionnaire in March 2023, which followed the issuance of a white paper on CBDC. Potential CBDC stakeholders from the banking sector, fintech, and technology firms were then invited to participate in a two-day Design Thinking workshop (see Table 6) in collaboration with the IMF. The workshop resulted in the identification of the conditions for a successful adoption of CBDC in Peru, both by stakeholders and users, and provided substantial input to the proof-of-concept phase. Such conditions included the role of the central bank in enabling realistic business models; the involvement of a wider list of participants; the recognition of regional differences in terms of use cases, stakeholders, and preferences; and the role of digital identity.

Central Bank of Peru, CBDC Project. https://www.bcrp.gob.pe/payments-system/cbdc-project.html

Table 3. Examples of Initial Assumptions and Conditions for Success That May Require Experimentation

Examples of assumptions that need to be validated or invalidated during the proof-of-concept, addressed during the prototype and measured later during the pilot phase.

Examples of Assumptions
▪ Electricity, connectivity, affordability, phone capacity, and so on will not be a problem for the use cases in scope. ▪ Offline technologies can provide safe payment and are easy to use. ▪ Privacy and compliance can be preserved simultaneously. ▪ Stakeholders understand and can properly manage the risks such as those related to cyberattacks, fraud, of identity theft. ▪ Interoperability with existing payment systems is feasible and does not affect scalability.

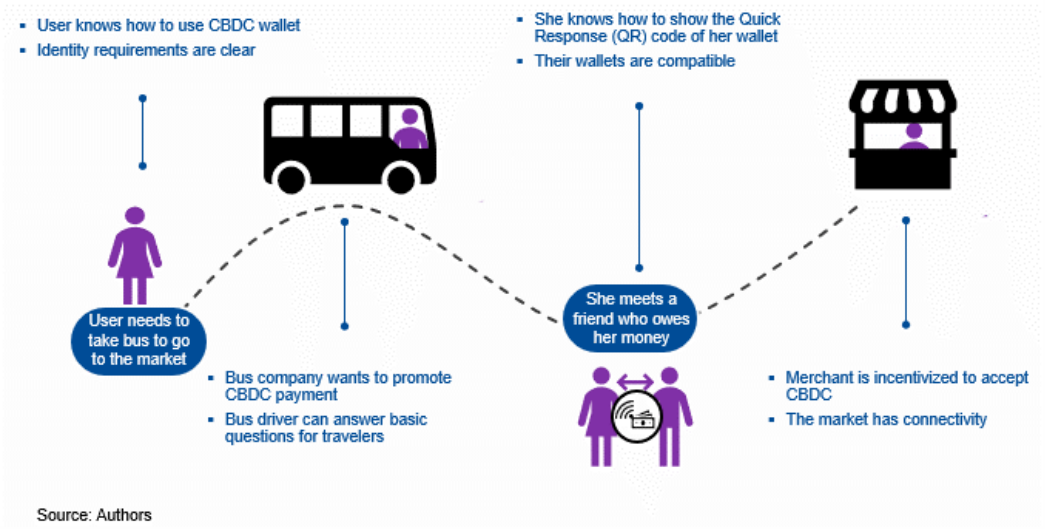
Source: Authors

For example, during the preparation phase, a use case might have been considered that allows individuals to use CBDC for traveling to the city and paying for groceries. In the PoC phase, the project manager would need to analyze the use case in detail and collaborate with the team to make certain assumptions more explicit. Figure 5 illustrates how examining the user's journey uncovers assumptions and success factors related to people, processes, technology, and the readiness of all stakeholders involved. The project manager would use this information to organize activities to test the various assumptions with relevant stakeholders to identify gaps. For instance, to fulfill certain “know your customer” obligations, the use case may reveal the need to collaborate with government agencies in charge of deployment of a national digital identity. Or the transport company may need to be involved to assess the requirements to interoperate with the bus payment system.[12]

Figure 5. Use Case Example—Traveling to the Market in the City

This figure illustrates a use case for a retail CBDC. At each stage of the user’s journey, assumptions can be identified regarding the conditions for a successful experience.

[12] For more information about stakeholders, see IMF Fintech Note “How Should Central Banks Explore CBDC: A Dynamic Decision-Making Framework” (Soderberg and others 2023).



Source: Authors

Understanding the cost structure of a CBDC

Due to the limited global experience with live CBDC implementations and the diverse approaches taken in researching and developing CBDC ecosystems, there is currently insufficient evidence to determine the direct cost of developing and implementing a CBDC in a specific country. However, as with most large-scale projects that require high resilience, it is expected that the highest costs in CBDC implementation will be associated with managing personnel and digital risks. Costs can vary widely across jurisdictions. A 2022 study by the IMF showed that central banks were employing 10 to 300 staff on CBDC work (Soderberg 2022). Risks encompass areas such as cybersecurity, data protection, and ensuring the integrity and reliability of the CBDC system. Implementing robust security measures, establishing effective risk management frameworks, and ensuring compliance with regulatory requirements are all essential factors that can significantly affect the cost structure of a CBDC project. Table 4 shows the standard items that influence the cost at each phase of a CBDC project.

The team may also investigate the potential cost savings involved with reducing the need to produce, manage, use, and secure cash. There again, while studies have looked at the cost to produce and manage cash,[13] there is currently insufficient evidence to provide a general formula for calculating the cost savings achieved through the introduction of a CBDC.

Table 4. Examples of Cost Structure in Different Phases of the Project

Preparation and Proof-of-Concept Phases	Prototype Phase	Pilot and Production Phase
▪ Small- to medium-size team ▪ Consultants	▪ Core CBDC team (including information technology,	▪ Full-scale production team

[13] Because it is difficult to estimate the total cost of producing, managing, and using cash, comparison across countries is not easily feasible. Krüger and Seitz (2014) estimated that the cost of managing cash ranges between 0.2 and 0.7 percent of GDP for selected advanced economies, although these figures are not really comparable due to differences in methodologies and assumptions.

▪ Technology providers ▪ Workshops, hackathon ▪ Market research, conferences	payment, banking, supervision, legal) ▪ Software development (internal and vendors), platform acquisition, licenses ▪ Network infrastructure setup ▪ Cybersecurity	▪ Full-scale research and development team ▪ Data security ▪ Security audits, testing ▪ Compliance assessment ▪ Training ▪ Ongoing maintenance and operation (such as systems monitoring, upgrades) ▪ User support, customer services ▪ Onboarding cost of new users and participants ▪ Ongoing fees for vendor involvement

Understanding the elements involved in a CBDC architecture

The project manager, in collaboration with the development team and other stakeholders, is responsible for exploring and evaluating different architectural options for a CBDC, given the policy objectives, analysis, and nontechnical requirements provided during the preparation phase (Figure 1, purple rows). The research performed by the team in the previous phase should be updated to consider the most recent requirements. The project manager and the team can facilitate discussions, workshops, or activities, such as those listed in Table 6, to understand the advantages, disadvantages, and implications of various architectural models. These architectural considerations encompass a range of factors such as centralized versus distributed functions; token-based, account-based, and bearer instrument approaches; offline operations; interoperability design options; and the environmental impact of different architectures (Agur and others 2023; Amazon Web Services 2021).

Assessing technology options

Technical feasibility of technology options is also assessed during the PoC phase. This task entails conducting initial evaluations to gauge the scalability, security, privacy, interoperability, and performance aspects of potential design and technology options (Box 4). For instance, the team may simulate different load conditions to assess the scalability of different CBDC architecture, ensuring it can handle peak transaction volumes relevant for the jurisdiction without compromising performance. The results may evolve as the project includes new features, integration points, or data, and the development team must continually evaluate and iterate on their findings.

Box 4. Country Example—Hong Kong Monetary Authority e-HKD

In 2021, the Hong Kong Monetary Authority began project e-HKD to research the feasibility, benefits, and risks of a potential Hong Kong dollar retail CBDC. As part of this work, it conducted initial technology research that it published in the report "e-HKD: A technical perspective." While a technical experiment was not involved, the work explored the technology requirements, options, and feasibility for the Hong Kong dollar. For instance, it studied technologies to enable two-tiered distribution of retail CBDC with privacy-preserving transaction traceability. Additionally, the Hong Kong Monetary Authority published responses to this report in a 2022 publication.

Hong Kong Monetary Authority—"e-HKD: A Technical Perspective." https://www.hkma.gov.hk/media/eng/doc/key-functions/financial-infrastructure/e-HKD_A_technical_perspective.pdf

Answering the question: DLT versus traditional technology

When deciding between a private, permissioned distributed ledger technology (DLT) and traditional database architecture for the CBDC, project managers should carefully consider various factors. These factors include the policy objectives, use cases, regulatory context, stakeholders' readiness, risk assessment, and technology-specific requirements, such as scalability, resilience, or programmability. The choice of technology and technology partners should align with these considerations. In weighing the options, the team will assess the pros and cons of each approach by conducting PoCs that will provide important knowledge on these questions.

A public version of DLT, as used by Bitcoin and other cryptocurrencies, is not suitable for a CBDC because of concerns about control, privacy, scalability, and finality. However, central banks are exploring some of the technology features that DLT offers in the context of a permissioned, private version that is controlled entirely by the operator. For instance, DLT technology natively supports distributed programs called smart contracts, and it can be used to allow varying degrees of centralized control by the central bank. Both centralized databases and DLT-based platforms, if properly designed, can provide enhanced resilience, alternative governance structures, and programmability through transparent software code.

Central banks may investigate whether traditional, centralized database environments (that is, non-DLT solutions) may be sufficient in their context. Such architectures typically already have robust security measures in place, and most central banks have significant internal competencies to tackle issues such as scalability or access control. However, highly centralized models may place a heavier burden on the central bank as the administering authority. If a permissioned, private DLT-based platform is chosen, the central bank must determine access to the ledger and the respective roles of the parties involved. Some central banks are also investigating a hybrid approach, whereby some parts of the system leverage traditional technologies, while the distribution is performed with a DLT system.

However, there is no generic answer regarding the optimal choice for a particular central bank. Each central bank should consider what technology is more relevant to their environment, based on their appetite to explore more innovative technologies and the limits and benefits of each design in their specific context. Table 5 presents considerations that can influence the attractiveness of one technology over another.

Table 5. Top Five Relative Advantages of Centralized Databases versus DLT

Advantages of Centralized Databases	Advantages of DLT (if implemented properly)
▪ Competencies more readily available for technology, security, and vendor relationship ▪ Better control of privacy ▪ Easier to scale ▪ Easier to upgrade ▪ Large available product base built on top	▪ More resilient by design if no single point of failure is introduced. ▪ Offers new governance options ▪ Central bank does not have to hold any private data ▪ Could increase compatibility with DLT-based tokenized financial assets ▪ Innovative domain, with new solutions emerging from decentralized finance

Note: DLT = distributed ledger technology. Source: Authors

Engaging with technology providers and partners

To reduce operational risks, central banks must have technology expertise to complement the expertise of technology vendors. The PoC phase consists of rapid, low-cost tests and is not intended for selecting a final technology solution or long-term technology partner. This responsibility should be reserved for the subsequent prototype phase or later. While collaboration with technology providers can expedite the learning process during the PoC, three risks must be managed effectively: First, avoid creating the expectation that the PoC partnership guarantees that the technology partner will be selected for the subsequent prototype phase. Second, consult with the central bank's procurement officers to help prevent any situation where a partner involved in the PoC might receive preferential treatment or an unfair advantage that may render them ineligible for a future bidding process. Third, ensure the technology choices remain flexible until the final designs for the CBDC are determined; the technology used in the PoC (or even prototype or pilot) phase should not be locked in. This risk can be managed by clearly separating the goals of the PoC phase (that is, developing in-house knowledge, identifying options, conducting initial feasibility tests) from the prototype goals (that is, progressively developing a CBDC solution through a series of prototypes).

Mitigating risks

Another role of the development team at this phase consists of testing approaches, processes, technology, design choices, or other elements that could mitigate the technology-related risks identified during the preparation phase. While it is too early in the project life cycle to implement such measures, this phase aids in understanding the steps to protect against cyberattacks and the capabilities needed to mitigate, protect privacy, and manage operational risks (Agur and others 2023; Amazon Web Services 2021). This is a vast topic that will be further developed in an upcoming IMF paper (see also Fanti and others 2022).

Illustrative activities

There are many ways to acquire the knowledge sought during this phase. Central banks may already have processes or practices in place, or preexisting research that will inform the PoC phase. The

following table provides examples of activities that may be useful, but it is not an exhaustive list. Project managers should consider these activities as illustrative of the type of work that is relevant for this phase. Key characteristics of these activities include their ability to facilitate collaboration with relevant stakeholders, their low cost, and their relatively short timeline of typically less than a few months.

Table 6. Examples of Activities for the PoC Phase

Tools and Activities	Key Advantages
Exploring concepts, assumptions, and conditions of success with representatives of **users and central bank functions**	
Design Thinking sessions	Assumption mapping and prioritization tools are used to identify beliefs and biases and plan ways to test them; develop design principles and draft user experience concepts (not limited to technology and user interface); understand expectations, priorities, challenges.
Stakeholders focus groups, surveys, ethnographic studies	Ability to validate assumptions on value proposition, anticipated consumption patterns and use cases, pain points, resistance, expectations, and other topics such as privacy, trust, and security. Use of behavioral models such as COM-B and others.
Mock-ups (low-cost simulation of products)	Use of "low-fidelity" interfaces, which are simulations that aid in understanding how users would interact with the future product. This activity is typically done in coordination with designers and solution providers and aims to make testing and assumptions validating more concrete.
Exploring concepts, assumptions, and conditions of success with **stakeholders**	
Risk scenario analysis (ISACA 2009)	Ability to identify risks and potential mitigation solutions
Lean Validation Board (Cooper, Vlaskovits, and Ries 2016)	Use of this Design Thinking tool helps identify the solution hypotheses and determine the core assumptions.
Exploring concepts, assumptions, and conditions of success with **solution providers**	
Small-scale technology proof-of-concept	Understanding of what technologies, designs, capacity, labor, costs, and other factors are involved in a very specific question (such as digital wallet, offline payment, scalability, privacy, exchange of data among service providers, and smart contracts)
Request for information, market consultation	Identification of vendors' capabilities, interests, and suggestions.
Workshops and demos	Understanding of technology and platforms potential; assessment of stakeholders' willingness and readiness to embark on more resource-intensive phases, and so on.
Hackathons, design jams, design sprints	Discovery of market ideas, possible vendors, innovation potential, risks and challenges, and so on. Development of relationship with the innovation ecosystem and positioning of the central bank as a player in that sector.
Innovation challenge, incubator program, accelerator program	Ability to expose a specific question of the project to the industry to discover how different actors may address it. Compared to a technology proof-of-concept, which tends to focus on one aspect of a *solution* (for example, testing how smart contracts work), a challenge event typically looks at a *problem* statement (for example, How might we deliver a delightful end-to-end user experience to low-income population previously digitally excluded?). The deliverables of a challenge can range from basic mock-ups to full-blown demos.

Note: COM-B refers to a framework known as the capability, opportunity, motivation–behavior model. It is used to analyze and understand human behavior by examining three key factors: capability (the

individual's ability or skills), opportunity (the external factors that enable or hinder the behavior), and motivation (the driving forces behind the behavior).

Prototype Phase

Once the concepts have been thoroughly understood, the assumptions and success criteria firmly established, and the decision to move forward taken, the prototype phase can start. This phase focuses on developing the CBDC ecosystem or its constituent elements while simultaneously building the operational capabilities. While central banks are not yet committed to issuing a CBDC during this stage, the prototype phase aligns with the traditional development stage in information technology projects. As a result, central banks can draw on their own experience and from industry best practices for large-scale projects that are in line with their organizational culture and specific environment (Box 5).

Box 5. Development Methodologies for Digital Projects

The five phases of the 5P methodology are highly iterative to promote rapid learning and progressive building of capacity and solutions. The development team can also use other established development best practices to further inform their work during each phase:

Agile is an adaptive iterative approach in which requirements and solutions evolve through collaboration between cross-functional teams. Agile development is popular for its flexibility and ability to adapt to changing requirements. As such, Agile is particularly useful for the preparation and PoC phases of the project (Beck and others 2001). Agile methodology should also be considered for the development and pilot phases of the project, although some challenges may exist (for example, procurement processes may have detailed functional and operational requirements that an Agile methodology may not yet have identified).

Waterfall is a traditional linear and sequential software development methodology introduced in the 1950s. It is popular in the banking sector. Waterfall methodology requires high certainty early on, which is typically not available in a CBDC project. A blend of Waterfall with Agile best practices offers a more adaptable approach suited for the prototype, pilot, and production phases.

DevSecOps integrates security into the entire software development process to promote collaboration between the development, security, and operations teams for efficient delivery of secure software. Because security is crucial in CBDC projects, adopting DevSecOps or a similar methodology is important during the production phase to continuously improve security and deliver updates efficiently (Wilson 2020).

Test-driven development is an approach that involves writing automated tests before writing the code to ensure that the code will meet the requirements and perform as intended. Test-driven development is typically used by developers during the prototype phase and fine-tuned during the pilot phase (Beck 2002).

Building internal capacity

Up to this point in the project, central banks usually allocate limited resources to the initial exploration of the CBDC concept. The prototype phase requires increasing the resources assigned to the project, including personnel, change management, governance, and technology, to support the development of the CBDC solution. Based on the insights gained in the preceding phases, the project manager should understand the skills and expertise that are needed for this phase. This entails identifying the key roles required for a successful development of a CBDC solution as well as their level of involvement (1) within the core team, (2) across the central bank, and (3) outside the central bank (Box 6).[14]

- **Core team** (within the CBDC development team) includes project manager; technical architects; developers to code key functions of the CBDC, including via smart contracts; cybersecurity

[14] The IMF provides capacity development assistance, which countries have used to assess such needs; see IMF (2023).

specialists to protect against cyberthreats and protect data; business analysts to translate business requirements into functional specifications for the CBDC; user experience designers; quality assurance analysts to test and validate the CBDC system; data analysts to help track key performance indicators, transactions, and user behavior; and change management specialists, who manage the organizational and operational changes associated with implementing the CBDC.

- **Team that functions within the central bank** includes policy experts, compliance officers and legal counsel who ensure that the CBDC implementation of policies and regulations is in line with the central bank's objectives; financial analysts, monetary policy experts who advise on the development of technology-based measures regarding the economic impact and financial implications of the CBDC; payment system experts, who study the CBDC's interoperability with the existing payment system and infrastructure; and communications specialists, who handle internal and external communications regarding the CBDC project.
- **Team that functions outside of the central bank** includes technology vendors and partners; payment service providers, who collaborate with the core team and enable interoperability between CBDC and existing payment systems; financial institutions that participate in testing, integration, and adoption of the CBDC within their operations; and government agencies, in particular the ministries of finance, to work on scenarios involving the government's use of CBDC.

Box 6. Country Example—National Bank of Kazakhstan Digital Tenge

The Digital Tenge project is a multiphase effort that seeks to implement a retail CBDC in Kazakhstan by 2025. As part of this effort, after preparatory research, the central bank developed and tested a prototype platform in 2021. The prototype explored the feasibility, challenges, and opportunities of a basic retail CBDC distributed through commercial banks. It tested opportunities for key life cycle scenarios: issuance, distribution, purchase, and transfers. In 2022, the central bank continued research with a decision-making framework report, and it tested a more sophisticated platform with limited users and merchants.

National Bank of Kazakhstan: https://nationalbank.kz/en/page/cifrovoy-tenge-pilotnyy-proekt

Potential role of technology partners

Theoretically, central banks face a choice between two approaches for CBDC development: acquiring commercial solutions from external vendors and developing the solution internally. Acquiring a technology solution can save time and resources, but it exposes the central bank to the challenge of potential vendor lock-in. Reliance on a single vendor for ongoing support and updates may restrict the central bank's flexibility in the long run. Smaller countries with limited capacities should also be cautious of vendor companies that promise turnkey solutions that may not adequately meet their specific needs. Conversely, building a CBDC solution internally offers greater control and customization, but central banks often lack the specialized expertise required for large-scale technology projects, especially retail products.

As discussed earlier, to reduce operational risks, central banks must have technological expertise to complement that of potential technology partners. In practice, a CBDC project encompasses multiple technology components (see Annex II) and involves collaboration with many solution providers. Some of

these components may already be owned by the central bank, such as existing cybersecurity measures or cloud vendors. Therefore, central banks may choose to develop certain elements of the CBDC ecosystem in house while collaborating with external solution providers for other components.

During the early stage of the prototype, the central bank is typically not yet in a position to select one final solution or set of partners. One approach to address this issue is to identify a limited number of solution providers through an RFP.[15] The RFP can be offered to more than one solution provider; these providers can then compete based on their ability to offer the most suitable, secure, and scalable CBDC platform, based on the requirements established in the RFP.

The development phase of a CBDC project follows the iterative approach of the 5P methodology, ensuring gradual progress toward the selection of potential partners and the development of the solution—at least for the targeted use cases. Throughout this phase, the central bank and stakeholders gain a deeper understanding of the associated risks, necessary resources, and required capabilities to transition to the pilot phase.

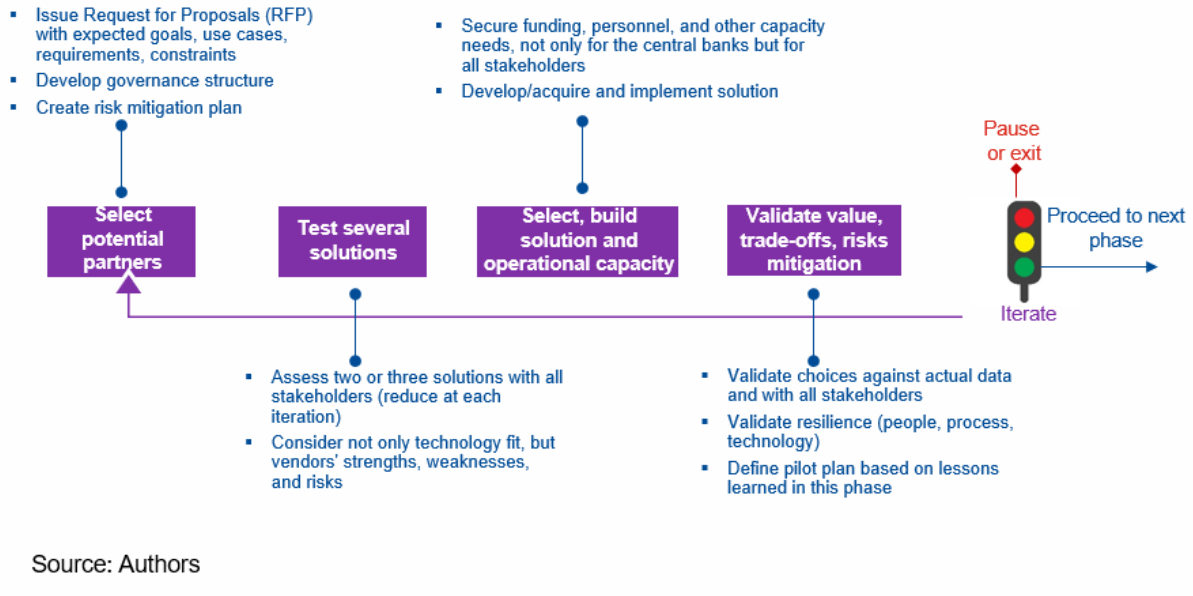
Typical steps

Central banks may draw on their own experience and work practices to manage this phase effectively. While the previous phases of the 5P framework were relatively unique to a CBDC project, this phase and the next ones are more familiar to any project manager in charge of large, mission-critical projects. Box 5 describes some of the popular categories of development methodologies, which central banks often use. Likewise, Figure 6 provides an example of a prototyping phase. Regardless of the process used, the development team can typically consider that (1) the prototype phase starts with the selection of several potential technology and implementation partners and gradually eliminates the least appropriate ones; (2) the relevance of each partner should be evaluated against the use cases, risks, and key performance indicators identified in the previous phase; and (3) the central banks work with all relevant and available stakeholders[16] to iteratively build capacity, knowledge, and operational readiness that, by the end of the prototype phase, would allow them to run a pilot with real users if a decision is made to move forward. If an alternative option to a CBDC is pursued (based on a go/no go decision), it should be clear how such an option would address underlying pain points for all use cases.

[15] A request for proposal (RFP) is a business document that describes the project. It includes most of the information collected in the previous phases, including the goals, risks, stakeholders, conditions for success, key performance indicators, and results of proof of concepts. The RFP aims to solicit bids from qualified contractors to complete a prototype, typically for one or several well-documented use cases. See also Diamond (2015).

[16] Not all key stakeholders may be willing, available, or able to participate in the prototyping process. To mitigate these risks, it may be necessary to avoid use cases that rely heavily on the participation of these stakeholders or to identify alternative options that minimize the impact of their nonparticipation.

Figure 6. Prototype Phase—Example of Possible Steps



Source: Authors

Pilot Phase

Objectives of the pilot phase

The term "pilot" carries various meanings across industries, and among central banks this situation leads to challenges in comparing CBDC projects and exchanging knowledge. To address this inconsistency, the 5P methodology provides a specific definition for the pilot phase in the context of CBDC projects. In this methodology, the pilot phase refers to the preproduction stage, when the CBDC solution has been chosen, is largely implemented, and undergoes testing with real data and actual stakeholders. The focus during this phase is on finalizing the necessary capacity, onboarding stakeholders, testing all aspects of the CBDC solution, and providing quality assurance.

Piloting is usually done through iterative steps to validate readiness for production. Each iteration sets specific goals; checks readiness of all stakeholders, including the central bank; and tests operational readiness for specific use cases (such as a CBDC wallet for public transport).

Deploying the system to a testing environment

The previous phase culminated with the selection of the final technology providers and partners. It led to a CBDC solution that can now be deployed in a dedicated test environment. This test environment closely replicates the characteristics of a potential production environment, providing an accurate representation of how the CBDC would function if the decision is made to proceed.

During the pilot phase, the CBDC solution undergoes rigorous testing and evaluation within the test environment. Multiple iterations are carried out to validate its performance, functionality, and compatibility with existing financial infrastructure. This phase allows the development team to identify any potential issues, fine-tune the solution, and make necessary improvements to ensure its effectiveness and

reliability. In short, the pilot phase provides quality assurance and validation that the product is ready for production.

As the pilot phase progresses, the focus shifts toward testing the CBDC solution in the actual production environment, even before the decision is made to actually issue the CBDC. For instance, to validate its readiness for real-world implementation and measure the benefits with real-life data, the People's Bank of China tested the potential of smart contracts[17] with the e-CNY in use cases such as prepaid fund management and government subsidies. Indeed, ensuring the CBDC's ability to handle transaction volumes, maintain system stability, and adhere to stringent security standards is paramount at this phase of the project. This information will be instrumental for the go/no go decision process.

Validation through real-world testing of stakeholders, data, and resilience

The most important role of the project team in this phase is to conduct comprehensive testing with real-world stakeholders, data, and simulated negative events. This testing allows the team to assess the CBDC solution's performance, reliability, and resilience. Testing with stakeholders, such as financial institutions and end users, provides important feedback to refine the CBDC system.

Realistic data are needed to simulate various usage scenarios and transaction volumes, enabling assessment of scalability, throughput, and response time. Although such tests were already performed during the prototype phase and were used to help select the solution, they have to be conducted again once the full solution is in place. Performance metrics, such as transaction processing speed and response time under stress, are analyzed to identify bottlenecks, optimize system components, and ensure a seamless user experience.

Simulating risk events, such as cyberattacks or system outages, is crucial. This exercise should not simply be theoretical. For instance, the team could intentionally sever the connection to the ledger to test the central bank's and stakeholders' readiness to respond to such events or to test the business continuity plan to switch to a backup system.

Identified issues or weaknesses are then addressed before moving into the production environment. These tests help instill confidence in the successful deployment of the CBDC.

Optimizing user experience

During the pilot phase, one of the key objectives for the development team is to ensure the optimal user experience of the CBDC (Box 7). The user experience is not limited to the interface or the application used by the CBDC user.[18] It involves the entire experience, encompassing aspects such as trust, ease of use, security, accessibility, and cultural considerations. It also involves the ability for users to easily find support when problems arise. Even if the user experience has been developed by a third

[17] Smart contracts are self-executing code with specific business or legal rules that automatically execute without the need for intermediary or additional manual control. Regarding this usage, see People's Bank of China (2021).

[18] The term "users" is not limited to "end users" but also includes any person, including the central bank and commercial banks staff, who interacts with any element of the digital chain that enables the CBDC.

party, such as a commercial bank or fintech firm, its effectiveness must be validated. A poorly designed user experience can have negative implications for the CBDC's adoption and success, so this testing phase is crucial for the development team. To do this testing, the development team engages in an iterative process that involves observing how users interact with the system and then gathering feedback. The aim is to evaluate the CBDC's user-friendliness, intuitiveness, and security. The team also focuses on validating accessibility for all segments of the population, including individuals with disabilities or low literacy levels.

Box 7. Country Example—Uruguay's e-Peso

The Central Bank of Uruguay developed the "e-Peso" CBDC and worked closely with a user experience design team to optimize its usability. The development team conducted usability tests, incorporated user feedback, and refined the e-Peso's interface to ensure a seamless and intuitive experience for users. The report "Seven Lessons from the e-Peso Pilot Plan: The Possibility of a Central Bank Digital Currency" (Sarmiento 2022) found some areas for improvement, such as communication and availability on all mobile devices.

See "Seven Lessons from the e-Peso Pilot Plan: The Possibility of a Central Bank Digital Currency." https://www.bcu.gub.uy/Sistema-de-Pagos/Documents/Vigilancia/Libros/CBDC%20march2022.pdf

An adequate user experience is a visual reflection of the design principles identified in previous phases, and it should translate the core behavioral findings from Design Thinking sessions, behavioral studies, and other sources into features and functionalities of the CBDC's interface. A good user experience will address considerations such as value proposition, habits, and cultural aspects that will increase the CBDC desirability and trust by users and hence will increase the likelihood of adoption (Box 8).

Testing of user experience in the pilot phase is critical to validate not only the user interface concept but the entire design approach. At this stage the testing is broad enough to provide higher certainty of decisions made yet provides a good opportunity for change if the concepts are not tested well.

Box 8. Country Example—People's Bank of China e-CNY

The People's Bank of China began researching digital fiat currency in 2014. In 2016, the People's Bank of China established its Digital Currency Institute, which developed the first-generation prototype of digital fiat currency. In 2017, it began to work with the private sector to develop and test its digital fiat currency system. As the high-level design, functionality, and testing have basically been completed, the PBoC launched the e-CNY pilot in late 2019. The e-CNY is currently available in pilot regions and was made available to foreign visitors within the venues of the 2022 Winter Olympics in Beijing. The People's Bank of China is paying close attention to the CBDC during piloting so that it operates in a steady, safe, convenient, and effective manner. It continues to expand test scenarios and applications in the pilot regions and to analyze the e-CNY's implications for monetary policy, financial markets, and financial stability. The People's Bank of China aims to study the pilot's results over time to improve the e-CNY. As of March 2023, almost 20 million stores had accepted e-CNY payments, and users had made roughly 750 million e-CNY transactions (totaling about RMB 900 billion value) in the 17 provinces and municipalities participating in the pilot (People's Bank of China 2022).

The e-CNY is developed by the People's Bank of China.
http://www.pbc.gov.cn/en/3688110/3688172/4157443/4293696/2021071614584691871.pdf

Production Phase

Should the decision be made to officially launch the CBDC, the project team takes responsibility for establishing critical operational functions. In this regard, the CBDC project should adopt best practices used in large-scale, high-risk projects. The examples here illustrate some common activities necessary for the successful operation, maintenance, and evolution of a launched CBDC.

Monitoring systems and ensuring cyber-resilience

The CBDC team assumes the critical task of continuously monitoring the CBDC system to detect and mitigate any potential cyberthreats or security breaches. They implement robust security measures, conduct regular security audits, and promptly respond to any security incidents. Protecting the integrity and confidentiality of the CBDC system and its data is one of the most critical tasks of the operational teams. This topic will be covered in a forthcoming IMF paper in the context of a CBDC Handbook.

Providing incident response and recovery

In the event of a security incident or system disruption, the team is responsible for initiating an effective incident response plan. This situation has been thoroughly tested during the pilot phase. It is important to coordinate with relevant stakeholders, investigate the incident, and take appropriate actions to contain and recover rapidly from the incident with minimal impact.

Doing maintenance and upgrades

The team continues to oversee the maintenance and smooth operation of the entire CBDC system. Just as with any other mission-critical and high-risk system, the team performs regular maintenance tasks,

applies software patches and updates, and proactively addresses any technical issues or performance bottlenecks that may arise (see section on key performance indicators in the companion paper). Additionally, the team assesses emerging technologies and market trends to identify opportunities for system upgrades and enhancements to improve security, user experience, and new use cases.

Additionally, it is important to assemble a dedicated team at this stage of the project to engage in ongoing research and development activities. This precaution ensures that the CBDC system remains at the forefront of technological advancements and emerging trends in the digital payment landscape. The team explores emerging technologies that have the potential to enhance the CBDC system's security, scalability, efficiency, and functionality. This team could work in close coordination with a DevSecOps team (Box 5).

The CBDC teams' ongoing efforts are vital for the system's continued success, user satisfaction, and resilience in the face of evolving threats and technological advancements.

III. Conclusion

The development of CBDCs is an evolving process, and best practices have yet to be established for properly managing such an innovative but uncertain project. Practical experiences show that CBDCs require a more systematic approach to research, development, and implementation.

This paper serves as a companion document to the IMF Fintech Note "How Should Central Banks Explore CBDC: A Dynamic Decision-Making Framework." While the latter aims to guide policy decisions and objective choices, this paper focuses on assisting project managers in translating those choices into experimentation and development activities.

The paper introduces the 5P methodology, which proposes a shared terminology and coordinated approach to managing CBDC projects. This methodology provides a structured framework for managing CBDC development from research and development to implementation, while also allowing for flexibility to accommodate varying country contexts. By adopting the 5P methodology, central banks can effectively manage the inherent risks associated with CBDC projects and ensure the achievement of their intended objectives. The future success of CBDCs depends on the adoption of a prudent and iterative approach, and the 5P methodology serves as a valuable tool to facilitate this process.

Annex I. Country Examples

Annex Table 1.1 presents examples of country work that can be categorized into each phase of the 5P methodology. It is not an exhaustive list. Examples are chosen for their ability to reflect the criteria of each of the 5Ps and in some cases may not be the central bank's latest work on the topic.

Annex Table 1.1. Country Examples

	Publications and Relevant Work
Phase 1: Preparation	
European Central Bank (ECB)	• 2021 Public Consultation As one component of its investigation phase for a digital euro, the ECB's public consultation gathered valuable data about the interests of end users regarding CBDC design and development plans. Since this report, the ECB has continued its outreach to external stakeholders and consultations with various Eurosystem committees.
Bank of England (BOE)	• Consultation Paper and Technology Working Paper As part of its research and exploration effort for the digital pound, the BOE first published a discussion paper on CBDC in March 2020, inviting feedback on its "platform model." In February 2023, it released a follow-up consultation paper and technology working paper describing its research and priorities in detail and inviting feedback on the policy and technology aspects of a potential digital pound. The paper was coauthored with His Majesty's Treasury. • External Expert Groups The BOE also convenes two ongoing expert groups to provide input and industry insight to its CBDC research. The CBDC Technology Forum provides insight on technology issues while the CBDC Engagement Forum provides insight on policy issues.
Bank of Thailand	• "The Way Forward for Retail Central Bank Digital Currency in Thailand" The report explores the use cases, value proposition including cost-benefit analysis, and key considerations of a potential retail CBDC in Thailand. The findings helped inform the central bank's approach toward retail CBDC.
Denmark's National bank	• Analysis report: "Central Bank Digital Currency in Denmark?" The report investigates the value proposition and use cases of retail CBDC in Denmark, concluding that the benefits do not outweigh the risks and challenges it presents.
De Nederlandsche Bank	• "What Triggers Consumer Adoption of CBDC?" The report describes survey research investigating individuals' preferences for the potential use of retail CBDC in the Netherlands. The survey data are used to inform the prospects and design for CBDC in the country.
Sweden's Riksbank	• "Petition to the Riksdag: The State's Role on the Payment Market" The document describes a petition from Sweden's central bank to its legislature to review critical issues pertinent before potential CBDC development, including the concept of legal tender and the role of the state in payments.
Hong Kong Monetary Authority	• "e-HKD: A Policy and Design Perspective" The paper describes key policy issues for an e-HKD retail CBDC in Hong Kong, highlighting both opportunities and challenges. It also explores issuance

	mechanisms, interoperability with other payment systems, privacy and data protection, and legal considerations.
Central Bank of Eswatini	• Initial Digital Lilangeni Design Paper The report describes the design characteristics of a potential retail CBDC in Eswatini. The central bank began initial exploration in 2021; in addition to this report, the preparatory phase included a November 2022 stakeholder forum. The central bank is now beginning technical experimentations.
Phase 2: Proof-of-Concepts	
Central Bank of Brazil	• LIFT Innovation Challenge The challenge seeks to promote and identify opportunities related to CBDC use cases and technical feasibility for a potential CBDC issued in Brazil. Participants develop and present minimum viable products to the central bank and public. The focus is on exploring new business models and use case ideas for CBDC.
Monetary Authority of Singapore (MAS)	• Global CBDC Challenge The technology-focused challenge was intended to help the MAS identify technical possibilities and challenges related to retail CBDC intended to increase payment efficiency and support financial inclusion and digitalization. Participants presented proof-of-concepts to a panel of judges.
Bank of Japan (BOJ)	• Proof-of-concept phases 1 and 2 The BOJ's phase 1 experiment tested the feasibility of "CBDC ledger" design alternatives for performing basic operations of a CBDC life cycle and the technology challenges and trade-offs involved. The phase 2 experiment studied the technical feasibility of additional basic functions, such as holding and transaction limits, interest paid on holdings, scheduled and batched remittances, and connections with external systems. The BOJ is commencing what it calls a "pilot phase" in 2023 now that PoCs are complete.
Hong Kong Monetary Authority	• e-HKD Pilot Programme Launched in May 2023, the e-HKD Pilot Programme hosts 12 private-sector finance and technology firms to develop use cases in six categories that could apply to CBDC in the future: full-fledged payments, programmable payments, settlement of tokenized assets, offline payments, tokenized deposits, and settlement of web3 transactions. The projects will add to knowledge about opportunities, implementation, and design issues of a potential e-HKD. • e-HKD technical white paper While a technical experiment was not involved, the 2021 e-HKD technical white paper explored technology architectures and options for a Hong Kong dollar retail CBDC. For instance, it studied solutions that would enable two-tiered distribution systems for retail CBDC with privacy-preserving transaction traceability. The work builds on past studies by other central banks, the private sector, and Project Aurum with the HKMA, BIS Innovation Hub Hong Kong Centre, and the Hong Kong Applied Science and Technology Research Institute.
Central Bank of Hungary (MNB)	• CBDC—an opportunity to support digital financial inclusion: Digital Student Safe in Hungary MNB launched a retail CBDC project with a special focus on financial inclusion and education ("Digital Student Safe Project"). In this project, adults and children can register, the latter with parental approval. A dedicated mobile application can be downloaded by any citizen. The legal form of the CBDC is electronic money issued by the central bank of Hungary; the registered users have a direct claim on central

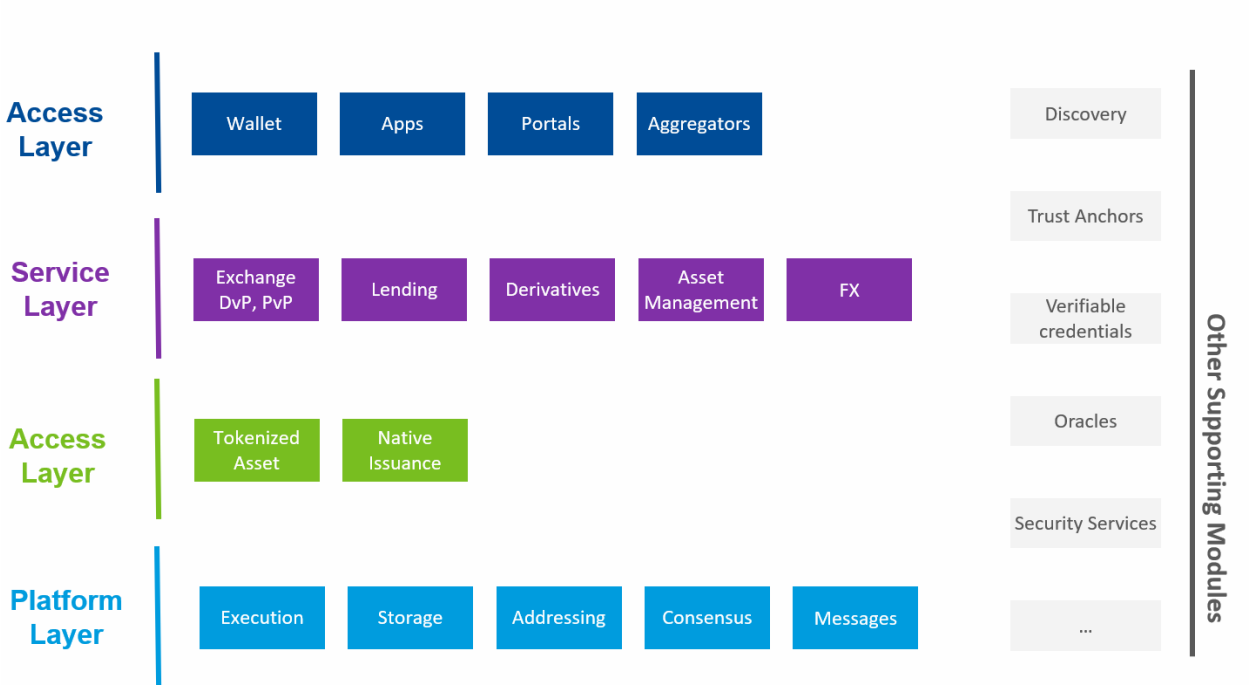
	bank liability. MNB is operating and managing all the e-money accounts. Users can top up their balance digitally from their commercial bank accounts, and they can also transfer their balance to any Hungarian bank accounts.
Phase 3: Prototype	
Banque de France	• Experimentation with wholesale CBDC The French central bank conducted a set of experiments exploring how multiple aspects of wholesale CBDC technical infrastructure can be feasibly implemented; they also looked into the associated possibilities and trade-offs.
National Bank of Kazakhstan (NBK)	• Digital Tenge Project 2021 tests After initial preparatory research for a Digital Tenge, the NBK developed a prototype platform in 2021 that explored the feasibility, challenges, and opportunities of retail CBDC distributed through commercial banks. It tested opportunities for key life cycle scenarios: issuance, distribution, purchase, and transfers. In 2022, the NBK continued research with a decision-making framework report, and it tested a more sophisticated technical platform.
ECB	• Digital euro prototyping To inform its investigation into a digital euro, the ECB conducted technical prototyping of various use cases and design possibilities from 2022 to 2023. The outcomes inform how CBDC could be technically implemented and integrated within the European payments landscape. It experimented with a back-end settlement engine and user interfaces for e-commerce and Peer to Peer (P2P) online and offline payments.
ECB and Bank of Japan	• Project Stella Phase 4 Project Stella consists of four phases of technical experimentation for a distributed ledger technology (DLT)-based CBDC that occurred from 2016 to 2020. As an example, Phase 4 explores how confidentiality (through privacy-enhancing techniques) and auditability can be achieved in a DLT environment.
BIS Innovation Hub Singapore and four central banks	• Project Dunbar Project Dunbar developed prototypes using DLT to test a multi-CBDC platform. It identified challenges related to access, governance, and regulations, and it proposed design approaches to address the challenges. It then demonstrated technical feasibility of those design approaches.
Phase 4: Pilot	
Digital Currency Institute of the People's Bank of China	• e-CNY The e-CNY was launched in late 2019 as the world's first CBDC pilot by a major economy. The pilot is currently open to specific regions and was made available to foreign visitors within the venues of the 2022 Winter Olympics in Beijing. The pilot regions have since been gradually enlarged, and more products and functions have been developed such as out-of-power payment, smart contracts, and accessibility payments.
Eastern Caribbean Central Bank (ECCB)	• DCash The ECCB launched its pilot retail CBDC in 2021 and has gradually widened availability to all eight member countries of the monetary union. The central bank continues to expand functionalities as it studies the successes and challenges of the implementation to inform the final deployment, which is expected to go live in 2023.
Bank of Ghana	• e-Cedi The e-Cedi is a pilot retail CBDC in Ghana. It is available in limited regions to test its capabilities and design for offering a secure and robust payment infrastructure that

	enables financial inclusion. Key aspects of the pilot include testing offline functionality and assessing user and merchant interest and adoption.
Central Bank of Uruguay	• e-Peso The e-Peso retail CBDC pilot ran in Uruguay in 2017–18. After the pilot's close, the central bank evaluated the results. It is not clear whether experimentation will restart.
Bank for International Settlements Innovation Hub Hong Kong Centre, the Hong Kong Monetary Authority, the Bank of Thailand, the People's Bank of China, and the Central Bank of the United Arab Emirates	• Project mBridge Project mBridge began as a prototype of multicurrency CBDCs that demonstrated the potential of using wholesale CBDC and DLT for delivering real-time, cheap, and safe cross-border payments and settlements. In 2022, a pilot was conducted involving $22 million of payment and foreign exchange Payment vs. Payment (PvP) transactions with 20 commercial banks transacting on behalf of corporate clients.
Reserve Bank of India	• Digital Rupee The Digital Rupee retail CBDC pilot was launched in December 2022 in four Indian cities and with four commercial banks who distribute the CBDC. Additional cities and commercial banks are being added in phases. The pilot intends to test functionalities of the CBDC with the given architecture and technology design, from creation to usage in real time. Knowledge gained will inform future pilots that will test additional features and applications. Users can transact with individuals and merchants using digital wallets, offered by the participating banks, on their mobile phones.
Phase 5: Production	
Central Bank of the Bahamas	• Sand Dollar The Sand Dollar was launched in October 2020. It aims to support domestic payment efficiency, improve financial inclusion, and strengthen defense against illicit payment activity. It is issued by the central bank through authorized financial institutions.
Central Bank of Nigeria (CBN)	• eNaira The CBN launched the eNaira in October 2021, with goals to increase financial inclusion, facilitate remittances, and support efficient domestic payments. It follows a phased rollout, gradually expanding in availability and features, including access to the underbanked and offline payment functionality.
Bank of Jamaica (BOJ)	• JAM-DEX In 2022, the BOJ started a phased rollout of its retail CBDC after experiments and trials in 2021. It aims to reduce cash storage and management costs and help modernize the national retail payments infrastructure.

Annex II. Reference Model for Interoperable Digital Asset Networks

Annex Figure 2.1 highlights the various technology components typically involved in a digital asset ecosystem, such as a CBDC environment (see Monetary Authority of Singapore 2023). Central banks will typically have to deal with numerous technology providers, each providing or supporting an element of the CBDC ecosystem.

Annex Figure 2.1. Technology layers and components involved in a digital asset ecosystem



Sources: Monetary Authority of Singapore; and IMF staff.

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