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UNIVERSITY
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Lecture 3

FNT 628

Blockchain and Cryptocurrencies

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Digital Currency

Digital Assets

- Digital assets are broadly defined as any digital representation of value which is recorded on a cryptographically secured distributed ledger or any similar technology as specified by the Secretary.
 - Digital assets include (but are not limited to):
 - Convertible virtual currency and cryptocurrency
 - Stablecoins
 - Non-fungible tokens (NFTs)
- Digital assets are not real currency (also known as “fiat”) because they are not the coin and paper money of the United States or a foreign country and are not digitally issued by a government’s central bank.
- A digital asset that has an equivalent value in real currency, or acts as a substitute for real currency, has been referred to as convertible virtual currency.
- A cryptocurrency is an example of a convertible virtual currency that can be used as payment for goods and services, digitally traded between users, and exchanged for or into real currencies or digital assets.

Digital Currency

- Digital currencies are currencies that are only accessible with computers or mobile phones because they only exist in electronic form.
- Typical digital currencies do not require intermediaries and are often the cheapest method for trading currencies.
- All cryptocurrencies are digital currencies, but not all digital currencies are cryptocurrencies.
- Some of the advantages of digital currencies are that they enable seamless transfer of value and can make transaction costs cheaper.
- Some of the disadvantages of digital currencies are that they can be volatile to trade and are susceptible to hacks.

Digital Currency

- Digital currencies do not have physical attributes and are available only in digital form.
- Transactions involving digital currencies are made using computers or electronic wallets connected to the internet or designated networks. In contrast, physical currencies, such as banknotes and minted coins, are tangible, meaning they have definite physical attributes and characteristics.
- Transactions involving such currencies are made possible only when their holders have physical possession of these currencies.
- Digital currencies have utility similar to physical currencies.
- They can be used to purchase goods and pay for services.
- They can also find restricted use among certain online communities, such as gaming sites, gambling portals, or social networks.
- Digital currencies also enable instant transactions that can be seamlessly executed across borders.
- For instance, it is possible for a person located in the United States to make payments in digital currency to a counterparty residing in Singapore, provided they are both connected to the same network.

Characteristics of Digital Currencies

- Digital currencies only exist in digital form.
- They do not have a physical equivalent.
- Digital currencies can be centralized or decentralized.
- Fiat currency, which exists in physical form, is a centralized system of production and distribution by a central bank and government agencies.
- Prominent cryptocurrencies, such as Bitcoin and Ethereum, are examples of decentralized digital currency systems.
- Digital currencies can transfer value.
- Using digital currencies requires a mental shift in the existing framework for currencies, where they are associated with sale and purchase transactions for goods and services.
- Digital currencies, however, extend the concept.
- For example, a gaming network token can extend the life of a player or provide them with extra superpowers.
- This is not a purchase or sale transaction but, instead, represents a transfer of value.

Types of Digital Currencies

- Digital currency is an overarching term that can be used to describe different types of currencies that exist in the electronic realm.
- **Broadly, there are three different types of currencies:**
 - Cryptocurrencies
 - Central Bank Digital Currencies
 - Virtual Currencies

Cryptocurrencies

- Cryptocurrencies are digital currencies that use cryptography to secure and verify transactions in a network.
- Cryptography is also used to manage and control the creation of such currencies.
- Bitcoin and Ethereum are examples of cryptocurrencies.
- Depending on the jurisdiction, cryptocurrencies may or may not be regulated.

Virtual Currencies

- Virtual currencies are unregulated digital currencies controlled by developers or a founding organization consisting of various stakeholders involved in the process.
- Virtual currencies can also be algorithmically controlled by a defined network protocol.
- An example of a virtual currency is a gaming network token whose economics is defined and controlled by developers.

Central Bank Digital Currencies

- Central Bank Digital Currencies(CBDCs) are regulated digital currencies issued by the central bank of a country.
- A CBDC can be a supplement or a replacement to traditional fiat currency.
- Unlike fiat currency, which exists in both physical and digital form, a CBDC exists purely in digital form.
- England, Sweden, and Uruguay are a few of the nations that are considering plans to launch a digital version of their native fiat currencies.
- The use of CBDCs has been suggested as a means of enhancing the speed and security of centralized payment systems, lowering the costs and dangers of handling cash, and promoting greater financial inclusion for people and companies without access to conventional banking services.
- They may also make cross-border payments easier and lessen the need for foreign exchange.
- The introduction of a U.S. CBDC presents a number of difficulties.
- For instance, for Congress to authorize the issuance of a CBDC, there must be robust privacy and security infrastructures put in place. The government must also weight the possible impacts on monetary policy and the operational management of the switch from conventional money to a CBDC.

Advantages of Digital Currencies

Fast Transfer and Transaction Times

- Because digital currencies generally exist within the same network and accomplish transfers without intermediaries, the amount of time required for transfers involving digital currencies is extremely fast.
- As payments in digital currencies are made directly between the transacting parties without the need for any intermediaries, the transactions are usually instantaneous and low-cost.
- This fares better compared to traditional payment methods that involve banks or clearing houses.
- Digital-currency-based electronic transactions also bring in the necessary record keeping and transparency in dealings.

No Physical Manufacturing Required

- Many requirements for physical currencies, such as the establishment of physical manufacturing facilities, are absent for digital currencies. Such currencies are also immune to physical defects or soiling that are present in physical currency.

Advantages of Digital Currencies

Monetary and Fiscal Policy Implementation

- Under the current currency regime, the Fed works through a series of intermediaries—banks and financial institutions—to circulate money into an economy. CBDCs can help circumvent this mechanism and enable a government agency to disburse payments directly to citizens. They also simplify the production and distribution methods by obviating the need for physical manufacturing and transportation of currency notes from one location to another.

Cheaper Transaction Costs

- Digital currencies enable direct interactions within a network. For example, a customer can pay a shopkeeper directly as long as they are situated in the same network. Even costs involving digital currency transactions between different networks are relatively cheaper as compared to those with physical or fiat currencies. By cutting out middlemen that seek economic rent from processing the transaction, digital currencies can make the overall cost of a transaction cheaper.

Advantages of Digital Currencies

Decentralized

- Digital currencies may be decentralized. This means they are not controlled by any government or financial institution. Digital currencies that are decentralized make them more resistant to government interference, censorship, and manipulation. Decentralization means true control over the digital currency is spread over a broader range of owners or users.

Privacy

- Due to the fact that transactions with digital currencies are not linked to personal data, users are given a high level of privacy and anonymity. They are therefore very helpful for those who want to protect the confidentiality of their financial dealings.

Disadvantages of Digital Currencies

Storage and Infrastructure Issues

- While they do not require physical wallets, digital currencies have their own set of requirements for storage and processing. For example, an Internet connection is necessary as are smartphones and services related to their provisioning. Online wallets with robust security are also necessary to store digital currencies.

Hacking Potential

- Their digital provenance makes digital currencies susceptible to hacking. Hackers can steal digital currencies from online wallets or change the protocol for digital currencies, making them unusable. As the numerous cases of hacks in cryptocurrencies have proved, securing digital systems and currencies is a work-in-progress.

Volatile Value

- Digital currencies used for trading can have wild price swings. For example, the decentralized nature of cryptocurrencies has resulted in a profusion of thinly capitalized digital currencies whose prices are prone to sudden changes based on investor whims.
- Other digital currencies have followed a similar price trajectory during their initial days. For example, Linden dollars used in the online game Second Life had a similarly volatile price trajectory in its early days.

Disadvantages of Digital Currencies

Limited Acceptance

- Digital currencies are still not commonly used as a means of payment by retailers and other enterprises. Because of this, using them for routine transactions may be challenging. Though digital currencies have gained in popularity, there are still limited functionalities in everyday transactions in many places.

Irreversibility

- On a digital currency network, transactions are irreversible. This means that once a transaction has been completed, it cannot be undone. In circumstances where a mistake or fraud has taken place, this may be a disadvantage.
- This is also a tremendous disadvantage for those new to the digital currency space, as there is a substantial learning curve. Because there is no central oversight area for many digital currencies, new users can't simply go to their local branch to receive help for many digital currencies.

Pros and Cons of Digital Currencies

Pros

- Faster transaction times.
- Do not require physical manufacturing.
- Lower transaction costs.
- Make it easier to implement monetary and fiscal policy.
- Offers greater privacy than other forms of currency.

Cons

- Can be difficult to store and use.
- Can be hacked.
- Can have volatile prices that result in lost value.
- May not allow for irrevocability of transactions.
- Still has limited acceptability.

Central Bank Digital Currencies Around the World

- Some major central banks around the world have begun looking issuing their own digital currencies. Some of the larger, more notable examples include the countries below.
- **China:** Since 2020, the People's Bank of China (PBOC) has been testing the digital yuan, also known as e-CNY, in a number of Chinese localities. Millions of Chinese citizens currently utilize the digital yuan, which is intended to be used for retail transactions.
- **Sweden:** Also since 2020, Sweden's Riksbank has been testing the e-krona digital currency. The e-krona is being created to complement Sweden's diminishing use of currency and to give the general public access to a safe and effective payment system.
- **EU:** A digital euro that may be issued by the European Central Bank (ECB) and used for retail transactions within the Eurozone is being investigated.
- **England:** The Bank of England is looking into the prospect of launching the "Bitcoin" cryptocurrency. The UK's payment system would be backed by a digital currency, which could also reduce the nation's dependence on cash.
- **Canada:** The Bank of Canada has been conducting research and consultations on the idea of creating a CBDC.

Future of Digital Currencies

- Cryptocurrencies like bitcoin have exploded in value, but they are largely used for speculation or to buy other speculative assets.
- Although there have been some signs of merchant adoption in countries like El Salvador, the high volatility and complexity of these currencies make them impractical for most daily applications.
- Many companies have tried to reduce volatility by introducing stablecoins, whose value is fixed to the price of fiat currency.
- This is usually done by depositing an equivalent amount of fiat, which can be used to redeem the tokens. However, stablecoin issuers such as Tether have used these deposits on more speculative investments, raising concerns that they are vulnerable to a market crash.
- Another possible application is in central bank digital currencies, which could be issued by a country's bank or monetary authority.
- These would be used and stored in online wallets, similar to cryptocurrencies, but allowing the central bank to issue and freeze tokens at will. Several countries, such as China, have proposed digital versions of their currencies.

Central Bank Digital Currency Product Development

Central Bank Digital Currency Product Development

- **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.

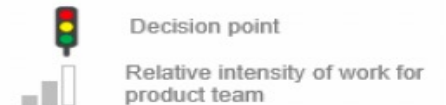
Central Bank Digital Currency Product Development

- 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.
- This methodology is not specific to any particular type or design of CBDC.
- Indeed, CBDC in this context should be understood in broad terms.

Analysis, Management, Policy Fintech Note: How Should Central Banks Explore CBDC **R&D** Fintech Note: A Guide to CBDC Product Development

	Preparation	PoC	Prototypes	Pilots	Production
Scope:	Define, Research	Lab Tests	Build	Live Tests	Launch
Objectives, Success Measures ¹	 Set			 Prove alignment	 Refine
Stakeholder Engagement ²	 Consult		 Co-create		
Risk and Impact Analysis ³					
Capacity and Readiness ⁴					 Continuous improvement
Design Features	 High level	 Tech level			 Continuous improvement
Legal, Regulatory, Financial Integrity					
Solution Capacity ⁵	 Identify 	 Test assumptions 	 Build 		 
CBDC Architecture ⁶					
Technology ⁷					
Risk Mitigation ⁸					

- 1: includes review of existing payment systems, alternative solutions.
- 2: includes users, merchants, banks, Payment Service Providers, Telco, Government services.
- 3: includes monetary policy implementation impact and financial stability risks.
- 4: includes institutional capacity, infrastructure foundations.
- 5: people, processes, technology management.
- 6: solution architecture, tech stack, standards, interoperability.
- 7: includes ledger technology, databases, platforms, wallets, cybersecurity.
- 8: cyber security, resilience.



Source: Authors

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.

The 5P Methodology

- **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	Examples of Relevant Questions
1: Preparation	<i>Research trends, monitor evolution of technology, and implications.</i>	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 risks? What capacity would be needed in each phase? What would be the business and governance impacts?
2: Proof-of-concepts	<i>Lab test assumptions and key features of a CBDC</i>	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	<i>Start to build CBDC and overall ecosystem</i>	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	<i>Live test CBDC with actual use cases, data, and stakeholders</i>	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	<i>Launch and operate CBDC and ecosystem</i>	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?

The 5P Methodology

- 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).

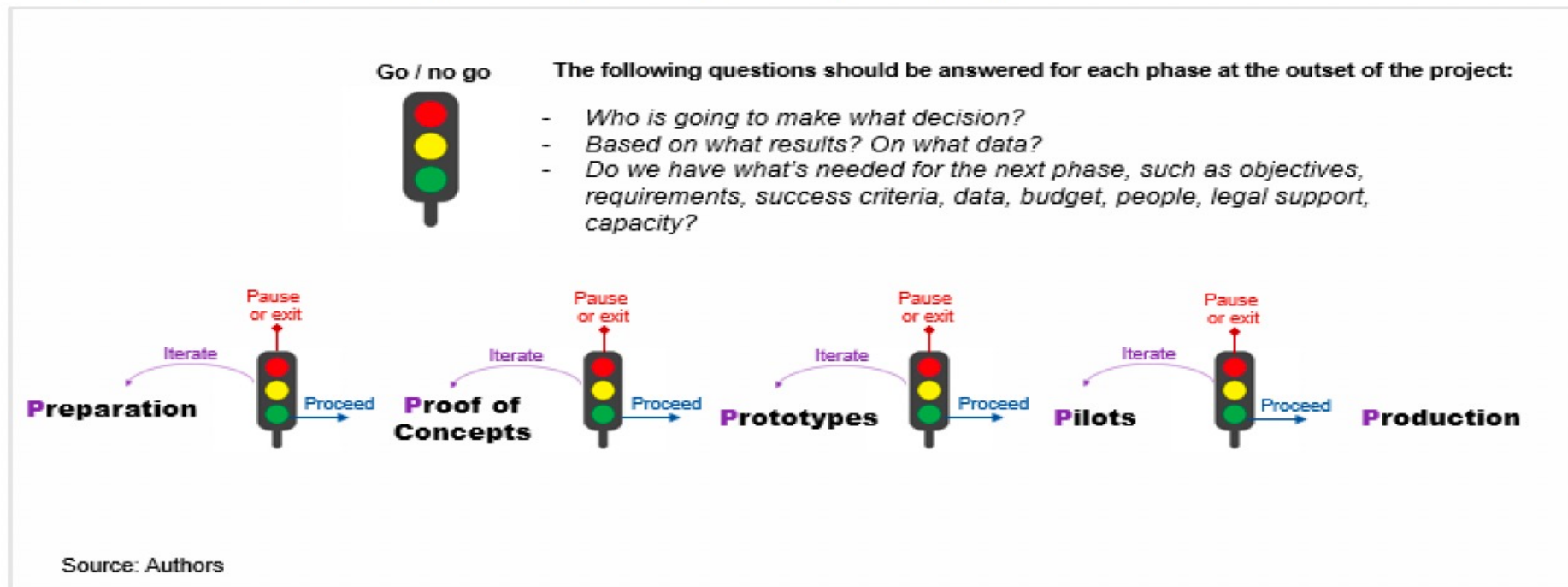
Go/No Go Checkpoints

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

Go/No Go Checkpoints

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.



Go/No Go Checkpoints

- 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 process⁴ 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 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.
- Importantly, each go/no go decision point also provides the central bank with an opportunity to 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.
- 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.

Definition of Each 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.

Definition of Each Phase

- 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 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.

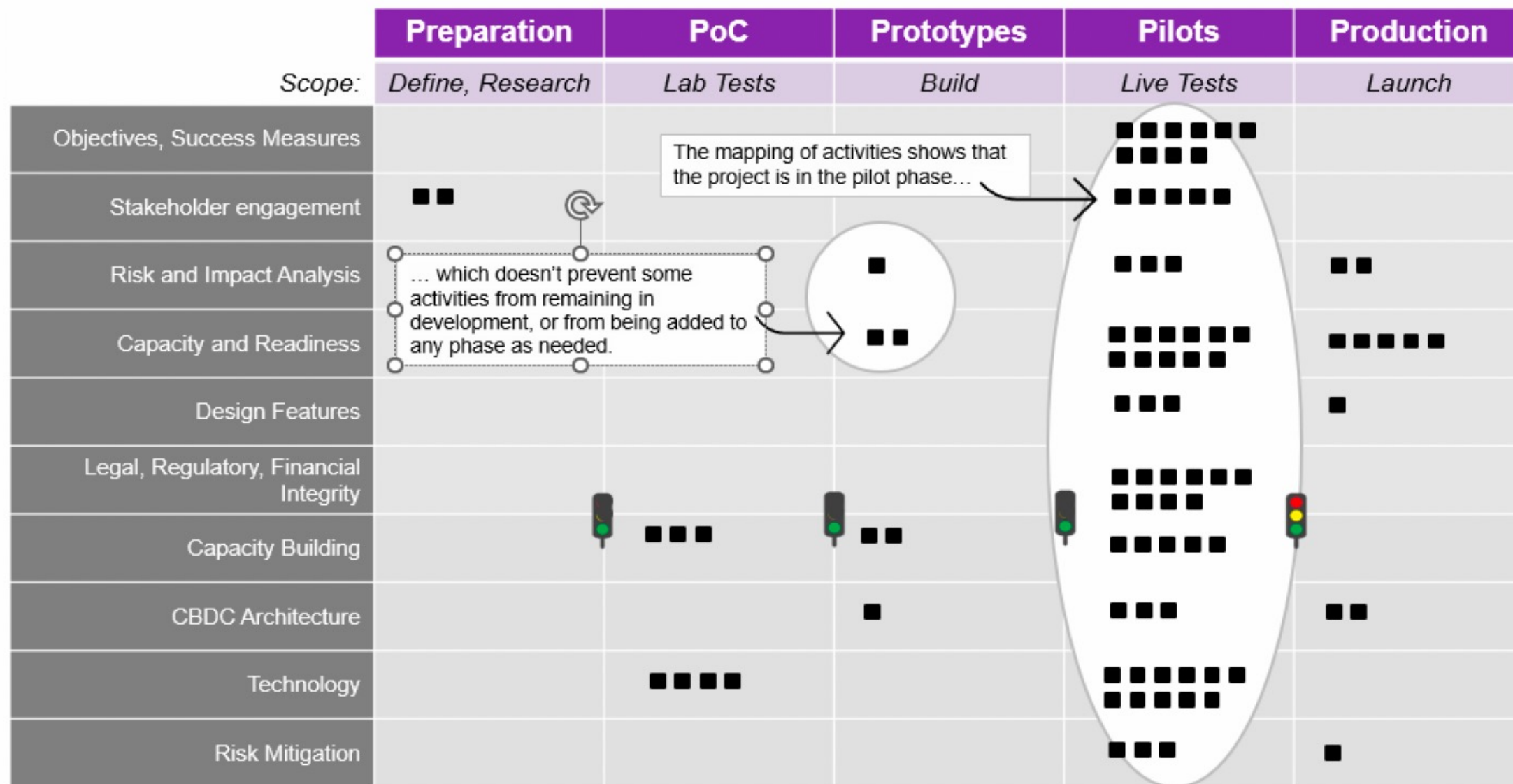
Definition of Each Phase

- 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.

Preparation Phase

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).



Source: Authors

- Conceptual representation of an element currently being treated at a given phase
- 🚦 Go/no go decision point (iterate, pause, proceed)

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

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). 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.

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.

Initial Assumptions and Conditions for Success That May Require Experimentation

- **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

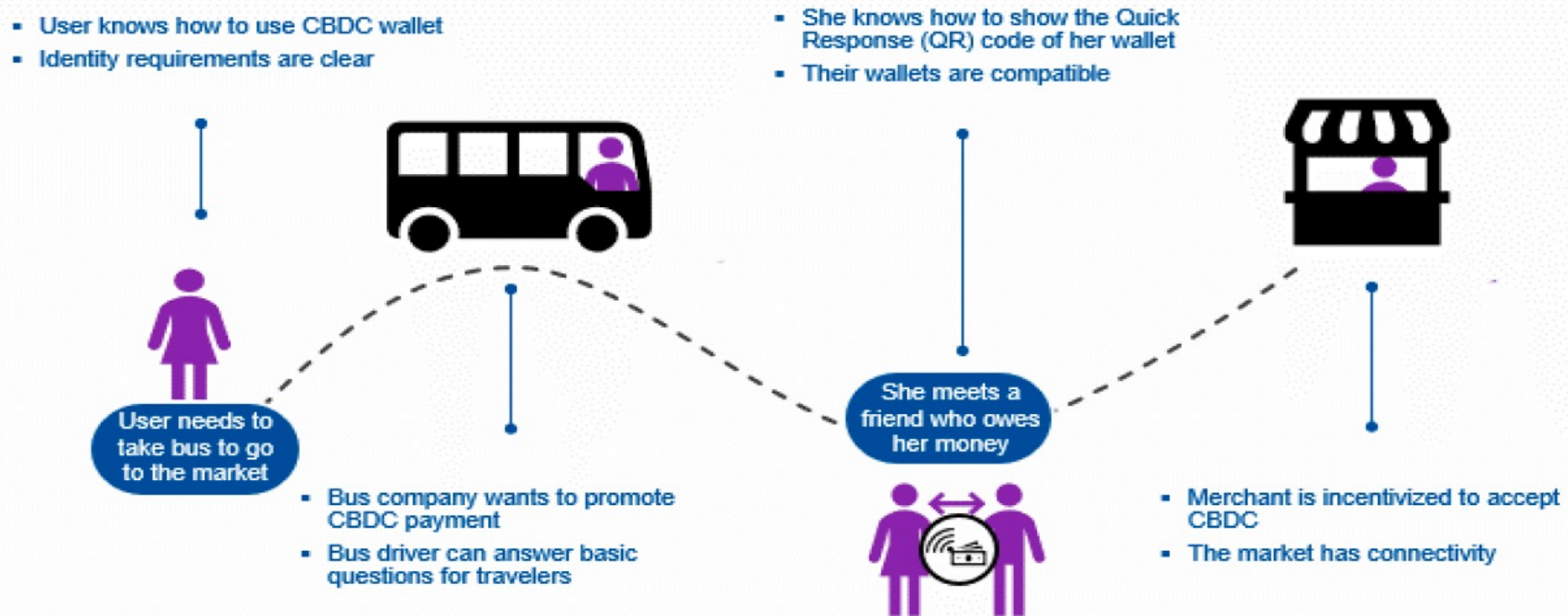
- Electricity, connectivity, affordability, phone capacity, and so on will not be a problem for the use cases in scope.
- Offline technologies can provide safe payment and are easy to use.
- Privacy and compliance can be preserved simultaneously.
- Stakeholders understand and can properly manage the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

Proving initial assumptions

- 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.

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.



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.

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.

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.

DLT versus traditional technology

- 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

Prototype Phase

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).

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).

Production Phase

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.

Production Phase

- **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.

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.

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