THE NEW ARCHITECTURE OF GLOBAL FINANCE

An In-Depth Analysis of Central Bank Digital Currencies and Blockchain-Based Cross-Border Payments

Report By

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TABLE OF CONTENTS

TABLES

ABBREVIATIONS

Abbreviation	Expansion
AML	Anti-Money Laundering
AMM	Automated Market Makers
API	Application Programming Interface
BFT	Byzantine Fault Tolerance
BIS	Bank for International Settlements
CBDC	Central Bank Digital Currency
CBRT / TCMB	Central Bank of the Republic of Türkiye
CFT	Combating the Financing of Terrorism
CNY	Chinese Yuan (Renminbi; currency code)
dApps	Decentralized Applications
DDoS	Distributed Denial-of-Service
DeFi	Decentralized Finance
DLT	Distributed Ledger Technology
DoS	Denial-of-Service
DPoS	Delegated Proof of Stake
DR	Disaster Recovery
DvP	Delivery vs. Payment
ECB	European Central Bank
EU	European Union
EUR	Euro (currency code)
FATF	Financial Action Task Force
FMI	Financial Market Infrastructures
FX	Foreign Exchange
G20	Group of Twenty
G7	Group of Seven
GDP	Gross Domestic Product
HSM	Hardware Security Module
IIF	Institute of International Finance

IMF	International Monetary Fund
IoT	Internet of Things
ISO	International Organization for Standardization
KPI	Key Performance Indicator
KYC	Know Your Customer
MoU	Memorandum of Understanding
MVP	Minimum Viable Product
PBFT	Practical Byzantine Fault Tolerance
PII	Personally Identifiable Information
PoC	Proof of Concept
PoS	Proof of Stake
PoW	Proof of Work
PQC	Post-Quantum Cryptography
PvP	Payment vs. Payment
rCBDC	Retail CBDC
RPO	Recovery Point Objective
RTGS	Real-Time Gross Settlement
RTO	Recovery Time Objective
RTO/RPO	Recovery Time Objective / Recovery Point Objective
SBOM	Software Bill of Materials
SLA	Service Level Agreement
SME	Small and Medium Sized Enterprises
SWIFT	Society for Worldwide Interbank Financial Telecommunication
TDT	Organization of Turkic States
TPS	Transactions Per Second
UAE	United Arab Emirates
US	United States
USD	United States Dollar (currency code)
VASP	Virtual Asset Service Provider
VRF	Verifiable Random Function
wCBDC	Wholesale CBDC

EXECUTIVE SUMMARY

Global financial systems are approaching a significant paradigm shift, catalyzed by accelerated research and development efforts on Central Bank Digital Currencies (CBDC). The current correspondent banking model for cross-border payments harbors persistent inefficiencies, including high transaction costs, slow settlement times (typically T+2), and operational opacity [1], [2]. Distributed Ledger Technology (DLT) presents a revolutionary solution to these frictions by providing a common infrastructure that enables secure, automated, and near-instantaneous value transfers [3]. This report seeks to demonstrate that global monetary authorities have made CBDC development a priority to remedy long-standing inefficiencies. As of the first quarter of 2025, 134 countries, representing 98% of the Global GDP, are actively engaged in CBDC initiatives. Notably, all G20 members are participating, and 13 of them (including Brazil, Japan, India, and Türkiye) have entered the advanced pilot phase [4].

Pioneering international collaborations define the technical and operational contours of this emerging architecture. The mBridge project, which has reached the Minimum Viable Product (MVP) stage, has convened the central banks of China, Hong Kong, Thailand, the United Arab Emirates, and Saudi Arabia on a single platform to promote local currency payments. In parallel, the Agora Project, bringing together seven major central banks, including the Federal Reserve and the ECB, and over forty private financial institutions, is exploring a “unified ledger” that integrates tokenized central bank money and commercial bank deposits, providing a more holistic vision for a programmable financial future. Completed initiatives, such as Project Dunbar, and Project Mariana, have demonstrated the technical feasibility of multiple CBDC platforms while exposing critical challenges in governance, regulatory harmonization, and legal interoperability.

While the overarching concept is simple, adopting this change is complex. Key challenges include harmonizing heterogeneous national legal frameworks; complying with global AML/CFT (Anti-Money Laundering and Combating the Financing of Terrorism) standards, such as the FATF “Travel Rule,” without compromising user privacy; and mitigating cybersecurity risks, including emerging threats such as quantum computing. Furthermore, developing these platforms has profound geopolitical implications: competition among digital currencies may foster new international blocs and shift the global balance of economic power. Türkiye, which is piloting the Digital Turkish Lira project and participates as an observer in Project mBridge, is well-positioned to translate these global developments into concrete gains. A carefully scoped wholesale CBDC strategy can (i) lower cross-border transaction costs for Turkish exporters and importers, (ii) deepen financial integration with priority trade partners through safer settlement mechanisms (e.g., PvP), and (iii) strengthen monetary sovereignty by offering a credible public alternative to private stablecoin-based settlement rails. To realize these benefits, Türkiye will need to pair technical experimentation with a clear governance model, legal certainty on settlement finality and liability, and a privacy-preserving compliance architecture that can meet FATF expectations without creating systemic data vulnerabilities.

Data note (scope and cut-off): The global figures reported in this Executive Summary reflect the analytical cut-off date used throughout this report (Q1 2025). CBDC initiatives evolve rapidly; therefore, these statistics should be interpreted as directional and time-stamped rather than as a real-time count. Where necessary, readers should consult official central bank communications and established public trackers for the most recent program statuses. The prevailing trend clearly favors Wholesale CBDC (wCBDC), which offers a strong, compelling value proposition, particularly for optimizing large-volume cross-border payments and interbank settlements [5].

Global Key Takeaways

- wCBDC architectures are converging on three core design constraints: interoperability, governance, and compliance-by-design.
- mBridge demonstrates operational maturation (MVP) and corridor-based settlement as a realistic near-term pathway.
- Agora pushes the frontier toward a unified ledger vision that integrates tokenized central bank money with tokenized deposits.
- Interoperability is not only technical (messaging, APIs) but also legal (finality, data rules) and institutional (decision rights).

Policy Options for Türkiye in the Near-term

Prioritize 1–2 high-value corridors for a controlled pilot (based on trade volume, FX frictions, partner readiness) and define measurable KPIs.

Move from observer to deeper technical participation in a selected multilateral track (e.g., mBridge) with a clear governance and liability model.

Adopt a privacy-preserving compliance architecture (tiered access + limits + selective disclosure) to avoid creating 'PII honeypots.

Publish a phased, execution-ready roadmap that covers legal, technical, and institutional dependencies, with clearly defined deliverables, owners, and interdependencies.

The strategic choices made today about common standards, interoperability, and governance will determine whether the future of money is open and integrated or fragmented and inefficient.

INTRODUCTION

The architecture of global finance rests upon the seamless movement of capital across borders. The underlying mechanisms driving this flow are deeply embedded in financial culture. While habits formed around existing systems often diminish the appetite for change, these mechanisms are characterized by entrenched inefficiencies [2], [6], [7]. The current cross-border payments paradigm, largely reliant on the correspondent banking model, remains defined by high costs, lengthy settlement times, often lasting several days, operational complexities, and a fundamental lack of transparency. These friction points constitute a critical economic barrier, imposing disproportionate burdens on small and medium-sized enterprises (SMEs) and preventing emerging market economies from fully participating in global trade [1], [7], [8].

Table 1: Quantifiable Deficiencies of the Correspondent Banking Model

High Costs	Transactions often pass through multiple intermediary banks, each adding fees, leading to significant cumulative costs that act as a barrier to global trade.
Delayed Settlement	The standard settlement time is often T+2 (trade date plus two days) or longer, trapping liquidity that could be used more productively and increasing risk.
Operational Opacity	A lack of a shared view of a transaction's status leads to complex and costly reconciliation processes and a poor user experience.
Counterparty Risk	The delay between the legs of a transaction (e.g., in foreign exchange) creates settlement risk, where one party pays out but does not receive the corresponding funds.

In this context, a technological catalyst has emerged with the potential to restructure these legacy systems fundamentally: Distributed Ledger Technology (DLT) [1]. DLT and its most well-known application, blockchain, represent a shift away from the silo-based, hierarchical databases of the past towards shared, synchronized ledgers [9], enabling cryptographically secure and verifiable transfers of value between parties without the need for a central intermediary [10].

This technological evolution has led institutions to take concrete actions [3]. Central banks worldwide are actively exploring CBDCs to ensure that sovereign money remains a stabilizing anchor in the digital economy [3], [11]. While initial discussions encompassed a broad range of possibilities, the focus has gradually shifted toward more structured, pragmatic approaches [3]. Central banks increasingly prioritize wholesale CBDCs (wCBDCs) due to their potential to transform large-volume cross-border asset transfers [12]. This trend is confirmed by the recent increase in global CBDC pilot projects and research initiatives [5].

This report provides a comprehensive, multi-layered analysis of CBDC-based cross-border payment systems, examining their technological, economic, regulatory, and geopolitical dimensions. Its objective is to provide a definitive resource for policymakers, financial strategists, and technologists navigating this complex and rapidly evolving domain. The analysis is structured in five sections. Part I establishes the foundational technologies and concepts of these new systems. Part II thoroughly examines the CBDC paradigm, outlining its classifications and architectural principles. Part III delves into the frontier of global finance, analyzing the key international CBDC projects actively reshaping cross-border trade. Part IV critically assesses the formidable legal, technical, and geopolitical challenges on the path to adoption. Finally, Part V considers the strategic implications of this transformation, including a focused case study on the Digital Turkish Lira project.

Analytical approach and benchmarking criteria: This report evaluates CBDC-based cross-border settlement architectures through a multi-criteria lens. The objective is not to rank initiatives by publicity or scale, but to assess design choices and implementation readiness against the minimum requirements of a public, resilient, and interoperable wholesale settlement infrastructure.

Table 2: Evaluation Framework and Benchmarking Criteria for Cross-Border CBDC Arrangements

Criterion	What 'Good' Looks Like	Typical Failure Mode	Evidence to look for
Cross-border functionality (PvP / DvP / FX)	Atomic settlement options, liquidity management, clear corridor design.	Partial settlement, operational workarounds, unclear FX/PvP logic.	Demonstrated PvP/DvP prototypes, corridor KPIs, participant onboarding rules.
Interoperability & Standards	ISO 20022 alignment, API specs, identity/compliance interoperability, migration path.	Ad-hoc interfaces, bespoke messaging, high integration burden on banks.	Documented message/API standards, interlinking model, integration playbooks.
Governance & Decision rights	Clear operating model, shared control rules, escalation paths, change management.	Ambiguous ownership, unclear liability, slow dispute resolution.	Governance charter, committee structures, voting/consensus rules, operator roles.

Legal & Regulatory Certainty	Finality, liability allocation, dispute resolution, data protection, AML/CFT compliance model.	Jurisdictional fragmentation, legal gaps, compliance contradictions.	Legal opinions, MoUs, rulebooks, compliance architecture description.
Operational resilience & cybersecurity	Threat model, controls, incident response, key management, crypto agility.	PII honeypots, weak key management, single points of failure.	Security controls list, audit approach, DR testing, PQC/crypto-agility plan.
Adoption & ecosystem viability	Incentives for banks/FMIs/firms, clear value proposition, measurable KPIs, phased scale-up.	Pilot-to-production gap, weak incentives, unclear success criteria.	KPI dashboard, incentive mechanisms, stakeholder commitments, roadmap with owners.

PART I

FOUNDATIONAL TECHNOLOGIES AND CONCEPTS

A solid grasp of the underlying technologies that enable CBDC-based systems is essential for comprehensively understanding the transition to these new networks. This section examines the fundamental components of blockchain and distributed ledger technology, clarifies key terminology, and outlines the governance and consensus mechanisms that define them.

Section 1: The Evolution of Distributed Ledger Technology

The development of blockchain technology can be understood as a progression through three distinct evolutionary stages, each expanding its capabilities and potential applications far beyond its origins as a digital currency platform.

Blockchain 1.0: Currency

The genesis of blockchain technology began with the 2008 publication of the Bitcoin whitepaper by the pseudonymous Satoshi Nakamoto [13], [14]. This first iteration introduced the world to a decentralized digital currency operating on a peer-to-peer network. Its primary innovation was conducting secure, transparent transactions without a trusted third-party intermediary like a bank. The defining features of this stage were the distributed ledger, cryptographic security, and a novel consensus mechanism, Proof of Work, that solved the "double spending" problem for digital assets.

Blockchain 2.0: Smart Contracts

The emergence of Ethereum triggered a second wave in blockchain's evolution. With Ethereum, blockchain moved beyond being a mere ledger to become a programmable financial infrastructure, powered by a general-purpose virtual machine for deploying and executing applications. The introduction of smart contracts enabled the automation of complex, multi-step agreements and conditional transactions, thereby expanding the scope of blockchain technology across sectors such as decentralized finance (DeFi), real estate, supply chain management, and healthcare [13], [14].

Blockchain 3.0: Decentralized Applications and Interoperability

The ongoing third phase of blockchain evolution addresses the fundamental limitations of previous generations, often referred to as the "blockchain trilemma," such as the difficulty of simultaneously achieving scalability, security, and decentralization. Innovations of this era include the development of more efficient consensus algorithms (e.g., Proof of Stake), Layer-2 scaling solutions, sidechains, and cross-chain protocols designed to enable different blockchain networks to communicate and transact seamlessly. The aim of Blockchain 3.0 is to establish the infrastructure for large-scale, complex, and interoperable decentralized applications (dApps) capable of enabling mainstream adoption [13], [15], [16].

Clarifying the Lexicon: Distributed vs. Decentralized

In discussions about blockchain, the terms "distributed" and "decentralized" are often used interchangeably, yet they describe distinct structural characteristics. A distributed system refers to how its components are physically or geographically organized. In such a system, data processing is distributed across multiple nodes (computers) in different locations, increasing resilience and reducing the risk of a single point of failure. However, a central authority can still exert control over these distributed components. Decentralization, by contrast, concerns how authority and control are shared. In a decentralized system, there is no single point of control; decision-making, governance, and rule enforcement are distributed among network participants, often through automated consensus mechanisms. This distinction is crucial to understanding how CBDC systems are designed. Decentralization exists along a spectrum: at one end lies a fully centralized system operated by a single entity; at the other, a permissionless network where authority is widely and openly distributed among participants. A technology can be highly distributed yet remain centralized in its governance. In fact, building a centralized system using distributed ledger technology is possible and often desirable, given its alignment with existing regulatory frameworks. Large CBDC projects such as mBridge and Agora operate on permissioned DLTs, controlled by a consortium of central banks and approved institutions [5], [17], [18], [19]. This design choice deliberately trades off the censorship resistance of public blockchains to ensure the robustness, performance, and regulatory compliance required for financial market infrastructure [18].

Section 2: Governance and Access Models in Blockchain Networks

The governance structure of a blockchain network is defined by its access model, which determines who can participate, validate transactions, and view the ledger. Three models illustrate trade-offs among openness, control, and efficiency [20], [21], [22], [23].

Public (Permissionless) Networks. Public networks, such as Bitcoin and Ethereum, impose no restrictions on participation. Anyone can join the network by running a node, participating in the consensus process to validate transactions, and viewing the entire ledger history. This model provides the highest levels of decentralization, censorship resistance, and transparency. However, these advantages come with lower transaction speeds, higher energy consumption (in the case of Proof of Work), and challenges in maintaining data privacy due to the public availability of all transaction data [24], [25].

Private (Permissioned) Networks: Participation is restricted and requires explicit authorization from a central administrator or owner. Typically, a single organization determines who can join the network, defines access rights, and sets the rules of participation. This model provides higher transaction throughput, robust data privacy guarantees, and flexible governance structures. However, it remains inherently centralized and lacks the transparency and democratic governance characteristics of public networks. Financial institutions often employ private blockchains for internal proofs of concept (PoCs) and to experiment with the technology in a controlled environment [26], [27].

Consortium Networks: Consortium networks represent a hybrid approach where authority is shared among a pre-selected group of organizations. This model is neither fully public nor controlled by a single entity. Instead, the consortium collectively defines the network's rules and operational parameters. This architecture has emerged as the dominant model for wCBDC projects. A shared governance structure among multiple central banks provides a convenient, controlled, secure, and high-performance environment for interbank and cross-border financial payment systems [28], [29].

Table 3: Comparison of Blockchain Network Access Models

	Public Networks	Private Networks	Consortium Networks
Pros	Open and democratic governance; High decentralization; Strong resilience against cyberattacks [24], [25].	High data privacy, Flexible architecture, High transaction speed, Low energy consumption [26], [27].	Offers a wide range of solutions that can be tailored to balance needs for security, speed, decentralization, and data privacy [28], [29].
Cons	It can be monitored and audited by anyone, and it has high energy usage, low transaction speed, and difficulties in ensuring data privacy [24], [25] .	Centralized and anti-democratic governance; Closed to public oversight [26], [27].	Difficulty in achieving ideal system design; Performance and security challenges arising from complex structures [28], [29].

Source: Adapted from [24], [25], [26], [27], [28], [29]

Section 3: The Mechanics of Trust: A Review of Consensus Algorithms

Consensus algorithms form the fundamental protocols that allow a distributed network of computers to reach consensus on the state of a ledger. This process guarantees its integrity and consistency without a central authority. Such algorithms serve as the mathematical "constitution" of blockchain systems, systematically enforcing protocol rules through automated and impartial mechanisms. Choosing an appropriate consensus algorithm is a critical design consideration that reflects priorities regarding security, throughput, latency, energy efficiency, and the desired level of decentralization [16], [30].

Proof of Work (PoW)

Introduced with Bitcoin, *Proof of Work* was the first consensus algorithm to solve the Byzantine Generals' Problem in a permissionless setting. In a PoW system, network participants, known as "miners," compete to solve computationally complex puzzles. The first valid solution adds the next block of transactions to the chain and receives a block reward plus transaction fees. The network security scales with the cumulative hash rate: mounting a successful attack would require controlling a majority (51%) of the network’s hash power for a sustained period. This undertaking typically demands prohibitively significant capital outlays relative to expected gains. While highly secure, PoW is energy-intensive and offers lower transaction throughput and higher latency than alternative designs [31], [32], [33].

Proof of Stake (PoS)

Proof of Stake emerged as a more energy-efficient alternative to PoW. Instead of relying on computational power, PoS selects block validators by staking or locking the network's native asset as collateral. Stake-weighted, randomized selection (e.g., via VRF across epochs/slots) determines who proposes and attests to the next block. The greater a validator’s effective stake, the higher their probability of being chosen to produce a block and earn rewards, typically transaction fees plus protocol issuance. By removing hash-intensive work, PoS dramatically reduces energy consumption and enables lower latency and faster finality. To deter misbehavior and long-range/nothing-at-stake attacks, PoS protocols implement slashing: validators that violate consensus rules can have a portion or all their stake slashed and may be ejected from the validator set [34], [35].

Delegated Proof of Stake (DPoS)

Delegated Proof of Stake (DPoS) is a variant of PoS designed to improve throughput and scalability. Within the DPoS framework, token holders elect a limited set of "delegates" or "witnesses," who produce and validate blocks typically on a rotating schedule. The system achieves significantly higher efficiency and lower latency by concentrating block production among a selected group. This performance, however, comes with a trade-off: a lower degree of decentralization, as authority becomes concentrated in a relatively small validator set. To mitigate governance risks such as voter apathy or collusion, many DPoS systems pair elections with staking incentives and penalties (slashing) for misbehavior, though implementations vary across networks [36], [37].

Practical Byzantine Fault Tolerance (PBFT)

PBFT is a consensus protocol tailored for permissioned systems with identified validators communicating over authenticated channels. It involves no mining or staking. Instead, validators execute a multi-phase message exchange (pre-prepare/prepare/commit) to reach an agreement [38]. A decision is considered final when it is confirmed by at least two-thirds (2/3) of the nodes. This ensures the system remains secure and consistent even if one-third (1/3) of the nodes are faulty or malicious. PBFT provides high throughput and low-latency transaction finality, making it well-suited to the high-performance requirements of financial market infrastructures (FMI). However, the communication overhead increases significantly with the number of nodes, making it effective in smaller consortium networks [28], [30].

The choice of consensus mechanism directly reflects a project's design priorities. The high performance and fast finalization required for payment systems designed as alternatives to existing Real-Time Gross Settlement (RTGS) systems have been the biggest obstacle for heavy-duty algorithms like Bitcoin's PoW to compete with credit card infrastructures that have achieved very high transaction volumes (TPS). Consequently, permissioned DLT platforms used in finance almost invariably adopt variants of PBFT or other non-mining-based protocols designed explicitly for interbank settlements operating in a high-trust and regulatory environment [38], [39], [40].

PART II

CENTRAL BANK DIGITAL CURRENCIES: A NEW MONETARY PARADIGM

Building on the technological foundations of DLT, central banks are actively shaping money's future. This section proceeds from general principles to specific applications of CBDCs, providing a formal definition, a synopsis of existing global initiatives, and a detailed analysis of the critical architectural choices facing monetary authorities.

Section 4: Defining and Classifying CBDCs

A Central Bank Digital Currency is formally defined as a digital form of a country's fiat currency that is a direct liability of the central bank. This distinguishes it fundamentally from other forms of digital money. Unlike commercial bank deposits, which are liabilities of private financial institutions, a CBDC represents a direct claim on the central bank, making it the safest digital asset available to the holder. It also differs from cryptocurrencies like Bitcoin, which are privately issued and not backed by a sovereign authority [41], [42], [43].

The Global CBDC Landscape (Q1 2025)

- The exploration of CBDCs has become a global phenomenon, with central banks moving from initial research to active development and piloting [3]. As of early 2025, the landscape is characterized by widespread engagement and accelerating progress [4]:
- 134 countries and currency unions, collectively representing 98% of global GDP, are now exploring CBDCs. This has increased dramatically from 35 countries in May 2020, and of these, 66 countries are considered to be in an advanced exploration phase, meaning they are in a development, pilot, or launch stage. Every G20 country is actively exploring a CBDC, with 19 of them in advanced stages. Thirteen G20 nations, including Brazil, Japan, India, Russia, and Türkiye, have active pilot programs [4].
- Despite this widespread activity, only three countries have fully launched a retail CBDC: The Bahamas (Sand Dollar), Jamaica (Jam-Dex), and Nigeria (eNaira). Also, China (e-CNY) has a pilot program that has expanded to cover 26 cities across 17 provinces, processing a cumulative transaction volume of 14.2 trillion yuan (approx. $2 trillion) by the end of September 2025 [44]. These projects have so far experienced slow uptake, facing challenges related to public education, merchant participation, and a lack of clear incentives for intermediaries [1], [5].

The Wholesale vs. Retail Dichotomy

CBDC projects are broadly classified into two primary types based on their intended users and purpose [45]:

Wholesale CBDC (wCBDC)

wCBDC is designed for limited use by financial institutions and for clearing high-value transactions in financial markets, such as interbank payments, securities, and foreign exchange trading [46], [47].

Retail CBDC (rCBDC):

rCBDC is a digital currency that functions as the digital equivalent of physical cash, available for use by the public, individuals, and businesses for everyday payments and transactions; in some jurisdictions, it may carry legal-tender status subject to legislation [11], [46], [47].

The Decisive Pivot to Wholesale

A significant, decisive trend in the CBDC field is the accelerating focus on wholesale rather than retail applications. This pragmatic shift clearly assesses where problems are most acute and solutions are most applicable [5], [43], [48]. While high-profile retail projects such as the digital euro continue cautiously with no launch expected before the end of 2025 and subsequent milestones dependent on EU legislation, work on wCBDCs is advancing with greater urgency and momentum [5], [49]. BIS’s 2023 survey reports a sharp uptick in wholesale CBDC experiments and pilots, particularly in advanced economies. It concludes that over the next six years, a central bank is more likely to issue a wholesale CBDC than a retail CBDC [5]. This shift is a rational response to on-the-ground realities. The financial community broadly acknowledges the high costs, slow speeds, and risks in cross-border payments as a clear, compelling use case for CBDCs, especially [46], [50], [51]. Conversely, in jurisdictions with already efficient retail payment systems, the value proposition of rCBDCs is less pronounced, and early launches have struggled to gain traction due to public-education gaps, limited merchant acceptance, and weak intermediary incentives [11], [49]. Furthermore, implementing wCBDC involves a smaller, more manageable, and technically sophisticated group of participants (banks and financial institutions), thereby significantly reducing implementation complexity and risk. Therefore, central banks are pragmatically allocating resources to the area where the needs are greatest, and the implementation path is clearest: the wholesale market [10], [42].

Section 5: Architectural Design Principles of CBDC Systems

Developing a CBDC requires central banks to make fundamental design decisions determining the system's features, capabilities, and impact on the broader financial ecosystem. These decisions encompass key components such as infrastructure selection, access model, and distribution model.

Table 4: CBDC Architecture Trade-offs and Wholesale Preferences

	Options	wCBDC Preference & Rationale
Infrastructure	Centralized Database vs. Distributed Ledger Technology (DLT)	DLT: Offers inherent resilience, transparency, and auditability crucial for multi-party, cross-border systems where shared governance is essential.
Access Model	Account-Based vs. Token-Based	Token-based: Analogous to bearer instruments, allowing for simpler transfer of value and forming the basis for programmable "unified ledgers" that can handle various tokenized assets.
Distribution	Single-Tier vs. Two-Tier	Two-tier: Preserves the existing structure of the monetary system, leveraging the private sector's expertise and infrastructure for customer-facing services while the central bank maintains the core ledger.

Section 6: The Power of Programmability: Smart Contracts in CBDC Ecosystems

Integrating smart contracts elevates a CBDC from a simple payment instrument into a programmable financial platform, unlocking capabilities far beyond those of traditional payment systems. This programmability is widely regarded as the defining feature of token-based DLT systems and a primary driver of their exploration for financial use cases [52].

Automated and Conditional Transactions

Smart contracts automate complex financial agreements. Transactions can be programmed to execute automatically only when certain pre-defined conditions are met. This capability is transformative for processes involving significant risk and manual intervention. For example, in securities settlement, a smart contract can ensure Delivery vs. Payment (DvP), where the transfer of a tokenized security and the corresponding payment in wCBDC co-occur as a single, atomic transaction, eliminating settlement risk [8], [53], [54]. Similarly, in foreign exchange, it can enable atomic Payment vs. Payment (PvP) settlement [55].

Integration with the Real Economy

The true power of programmability is realized when payments are linked to real-world events and data. Smart contracts can be designed to interact with external data sources, including Internet of Things (IoT) sensors, to automate commercial workflows. This allows the payment step of a transaction to be integrated with the commercial logic, creating a payment structure integrated with commercial reality that is not possible in today's isolated systems [52].

Table 5: Smart Contract Use Cases

Use Case	Description
Automated DvP Settlement	A smart contract enforces Delivery-versus-Payment (DvP) by ensuring the simultaneous, atomic exchange of a tokenized security for wCBDC; delivery and payment occur in one atomic transaction, eliminating settlement risk.
Supply Chain Payments	Upon verifiable confirmation (e.g., IoT sensors) that goods have arrived, payment to the supplier is automatically released, reducing human error and delays.
Parametric Insurance	An insurance policy encoded as a smart contract automatically triggers payment based on verifiable external data, such as weather information, eliminating the lengthy claims process.

In traditional systems, the critical link between transaction information and the payment itself is often a human, which introduces the potential for error, delay, and fraud. The BIS's blueprint for a future monetary system is explicitly built on the concept of a "programmable platform." Projects like Agora aim to "enable new forms of settlement and pave the way for transaction types not feasible today" through smart contracts. Therefore, the key innovation of a wCBDC ecosystem is not merely faster payment infrastructure, but also the establishment of a new financial market infrastructure in which complex, multi-party workflows can be automated with cryptographic certainty, delivering a radical reduction in operational risk and costs [19], [56], [57].

PART III

THE FRONTIER OF GLOBAL FINANCE: WCBDS IN CROSS-BORDER TRADE

This section moves to the heart of the analysis, synthesizing the findings from major international wCBDC projects to construct a comprehensive picture of the future of global settlements. Examining these collaborative efforts makes it possible to discern the emerging architecture of a new, more efficient, interconnected financial world.

Section 7: Reimagining International Settlements: The wCBDC Value Proposition

wCBDC platforms are being designed to directly address the core frictions of the legacy correspondent banking system. Their value proposition is built on speed, efficiency, and risk reduction.

Practical Selection Criteria for Pilot Corridor Prioritization

- Trade relevance: bilateral trade volume and concentration in strategic sectors (e.g., energy, machinery, agri-food).
- FX frictions: current cost/time of settlement, reliance on intermediary correspondent chains, and documented pain points for SMEs.
- Partner readiness: central bank engagement level (research/pilot), legal openness to data-sharing arrangements, and governance compatibility.
- Risk profile: sanctions exposure, capital-flow sensitivity, and operational risk tolerance under stress scenarios.
- Liquidity & market structure: availability of FX liquidity, feasibility of PvP settlement, and integration with domestic FMIs.
- Minimum viable scope: start with a narrow set of participants (selected banks/FMIs) and expand only after KPI thresholds are met.

Cost Reduction: By establishing direct payment corridors between financial institutions across countries, wCBDC platforms can eliminate multiple layers of intermediaries. Each intermediary in the current system adds a fee, cumulatively making cross-border payments expensive. A flatter, more direct network significantly reduces these costs [58].

Speed and Availability: Processing traditional cross-border payments can take two or more business days (T+2) . wCBDC platforms running on DLT are designed to operate 24/7/365 and can move the paradigm from T+2 days to T+0 seconds, enabling near-instant payment processing.

This improvement also frees up liquidity that would otherwise be tied up in the payment process [50], [59], [60].

Settlement Risk Mitigation: The current system carries significant payment risks, notably Herstatt risk, where one party pays in its currency but does not receive the counter currency. wCBDC platforms enable Payment-for-Payment (PvP) payments through smart contracts, eliminating this critical risk by ensuring that the exchange of two currencies occurs simultaneously or not at all [61], [62], [63].

Transparency and Traceability: These platforms provide a single source of truth for all participants by providing a shared, immutable ledger. This structure increases transparency, simplifies transaction monitoring and reconciliation, and can facilitate compliance with regulations such as Anti-Money Laundering (AML) and Combating the Financing of Terrorism (CFT) [17], [50].

Facilitating Local Currency Trade: A key strategic advantage is facilitating trade directly in local currencies. A significant portion of international trade is invoiced and settled in a third-party vehicle currency, most often the US dollar. This exposes businesses in other countries to foreign exchange (FX) risk. This exposes businesses in other countries to foreign exchange (FX) risk. wCBDC platforms, for example, enable the direct exchange of Turkish lira and Indonesian rupiah, reducing dependence on the dollar and mitigating exchange rate volatility for businesses [17], [18].

Table 6: Comparison of the wCBDC Value Proposition

Dimension	Problem Addressed	Mechanism	Expected Outcome
Cost Reduction	Multi-layer Correspondent chains	Direct corridors	Lower transaction Costs
Speed & Availability	Delays (T+2)	Real-time DLT Settlement	Instant (T+0) Payments
Risk Mitigation	Herstatt Risk	Atomic PvP settlement	No Partial Settlements
Transparency	Fragmented Ledgers	Shared immutable DLT	Compliance & Auditability
Local Currency Trade	Dollar Dominance	Direct FX corridors	Reduced FX Risk & Dollar Reliance

Section 8: Global Collaboration in Action: An Analysis of Key wCBDC Projects

The theoretical benefits of wCBDCs are being tested in a series of ambitious, collaborative projects led by the BIS and central banks worldwide. These experiments are crucial for identifying practical challenges and refining the designs of future financial market infrastructures [3], [56].

Project mBridge

- Participants: A collaboration between the BIS Innovation Hub and the central banks of China, Hong Kong, Thailand, and the United Arab Emirates (UAE) [17], [18]. In 2024, the Saudi Central Bank joined as a full participant. The Central Bank of the Republic of Türkiye (TCMB) is one of over two dozen observing members [64].

- Status: The project reached the Minimum Viable Product (MVP) stage in mid-2024. This is a significant milestone, indicating that the platform has moved beyond a proof-of-concept and is being developed into a production-ready system for use by commercial banks in the participating jurisdictions [17].

- Technology and concept: mBridge utilizes a custom-built DLT platform, the "mBridge Ledger," specifically designed to host multiple CBDCs. It enables participating commercial banks to conduct peer-to-peer payments and foreign exchange transactions in real time, using central bank money on a common platform [17], [18].

- Core Objective: The project's primary goals are to address the key pain points of cross-border payments, high costs, slow speeds, and operational complexity, and to promote greater use of local currencies in international trade, which is a clear strategic priority for its core participants [17], [18].

Project Agora

- Participants: An exceptionally ambitious public-private partnership, Project Agora brings together seven of the world's most influential central banks, the Bank of France (for the Eurosystem), Bank of Japan, Bank of Korea, Bank of Mexico, Swiss National Bank, Bank of England, and the Federal Reserve Bank of New York, with the BIS. It also includes over 40 private-sector firms, convened by the Institute of International Finance (IIF), spanning central global banks (Citi, HSBC, Deutsche Bank) and financial market infrastructures (FMIs) such as SWIFT, Visa, and Mastercard [19], [57].

- Concept: Agora's vision is to explore a "unified ledger" that seamlessly integrates tokenized commercial bank deposits with tokenized wCBDC on a single, programmable financial platform. This architecture maintains the two-tier monetary system but tokenizes both tiers (central bank money and commercial bank money) on a common infrastructure [57]. This design preserves the critical distinction between central bank money (risk-free) and commercial bank money (carrying counterparty risk), while enabling both to operate on shared infrastructure.

- Significance: Compared with mBridge, Agora articulates a more holistic vision, not merely interlinking different wCBDCs, but also establishing a foundational layer where public and private tokenized money can coexist and interact via smart contracts [19]. This feature could position Agora as a reliable and regulatory-compliant alternative to stablecoins [57].

Project Dunbar (Completed in 2022)

- Participants: A collaboration between the BIS Innovation Hub and the central banks of Australia, Malaysia, Singapore, and South Africa [65].
- Key Findings: Project Dunbar successfully developed and tested two prototypes on different DLT platforms (Corda and Partior), proving the technical viability of a shared platform for multiple CBDCs. The project played a crucial role in identifying critical non-technical challenges, particularly in establishing governance frameworks, defining access controls (i.e., determining which entities should be permitted to hold and transact with which foreign CBDCs), and navigating the complexities of harmonizing regulations across different jurisdictions [65], [66], [67].
- Legacy: Dunbar's insights into the role of governance and shared control mechanisms have provided a crucial foundation for the design of more complex projects, such as mBridge and Agora [65], [66], [67].

Project Mariana (Completed in 2023)

- Participants: A joint project between the BIS Innovation Hub and the central banks of France, Singapore, and Switzerland [68].
- Innovation: Project Mariana was a pioneering experiment that tested the use of concepts from Decentralized Finance (DeFi), specifically Automated Market Makers (AMMs), for the cross-border trading and settlement of wCBDCs. The experiment used hypothetical wCBDCs on a public blockchain testnet [68], [69].
- Significance: AMMs utilize liquidity pools and algorithms to facilitate automated, transparent price discovery and trading, unlike the traditional FX market structure, which relies on bilateral relationships and order books. Mariana successfully demonstrated that creating decentralized FX markets using wCBDCs is technically feasible, potentially leading to more efficient, transparent, and accessible markets. It was a groundbreaking exploration of how protocols from the nascent DeFi space could be safely adapted for future financial market infrastructures [68], [69], [70].

Table 7: Comparative Overview of Key wCBDC Projects

Project Name	Lead Institutes	Key Participants	Status	Core Concept/ Technology	Key Objectives /Findings	Sources
mBridge	BIS Innovation Hub	China, Hong Kong, Thailand, UAE, Saudi Arabia (Central Banks)	MVP Reached (2024)	Multi-wCBDC common platform on a custom DLT ("mBridge Ledger")	Reduce cross-border payment frictions; Promote the use of local currencies in trade.	[17], [18], [64]
Agora	BIS Innovation Hub, IIF	7 Central Banks (G7-level), >40 Private Firms (Banks, FMIs)	Design Phase (2024-2025)	"Unified Ledger" integrating tokenized wCBDC and tokenized commercial bank deposits	Explore a new programmable core financial platform; Overcome structural inefficiencies in cross-border payments.	[19], [57]
Dunbar	BIS Innovation Hub	Australia, Malaysia, Singapore, South Africa (Central Banks)	Completed (2022)	Multi-wCBDC common platform on Corda and Partior DLTs	Proved technical viability; Identified critical governance, access, and regulation challenges.	[65], [67]
Mariana	BIS Innovation Hub	France, Singapore, Switzerland	Completed (2023)	DeFi-inspired Automated Market Makers (AMMs) on a public blockchain testnet	Tested the feasibility of decentralized FX markets for wCBDCs; Explored novel technology for interbank settlement.	[68], [69], [70]

Section 9: Models for Global Interoperability

The primary aim of these projects is to create a globally interconnected payment system. The BIS has identified three primary models for achieving interoperability between different CBDC systems, each representing a different level of integration and cooperation [51].

Benchmark synthesis of the collective outputs of the leading projects:

- Maturity pathway: initiatives progress from proof-of-concept to MVP once governance, onboarding, and rulebooks become as important as code.
- Architecture convergence: permissioned DLT is the practical default for wholesale settlement, with APIs and standardized messaging reducing integration costs.
- Governance is the binding constraint: technical feasibility is increasingly proven; cross-jurisdictional decision rights and liability remain the hardest problems.
- Compliance-by-design is non-negotiable: AML/CFT expectations shape data architecture, identity layers, and operational controls from the outset.
- Tokenization trajectory: the frontier is shifting from ‘CBDC-only’ to integrated platforms (CBDC + tokenized deposits + tokenized assets), enabling programmable settlement.

Model 1: Compatibility

The first model requires a relatively low level of integration. Each jurisdiction operates its independent CBDC system while agreeing on a common set of technical standards, protocols, and legal frameworks. This may include using the same messaging format (such as ISO 20022), data standards, and API specifications. Compatibility reduces the operational burden on financial institutions required to interface with multiple systems; however, it does not establish a direct connection among them [71], [72], [73].

Model 2: Interlinking

This model establishes direct connections between disparate CBDC systems. These connections can be established in various ways: Dual Connections, where two systems are directly connected; the Hub-and-Spoke model, where multiple systems are connected to a central hub; or the Single Access Point, a standardized interface for inter-system payments. Project Icebreaker, a collaboration among Israel, Norway, and Sweden, explored the hub-and-spoke model and is a prime example of this approach [29] [71], [72], [73], [74].

Model 3: Single System

This is the most integrated model, where multiple central banks agree to issue their own CBDCs on a single, common technical platform. This common platform serves as the core infrastructure for all participating countries, hosting multiple currencies and facilitating transactions between them. This model has the potential to be the most efficient model because it eliminates the need for reconciliation between different systems. However, it is the most difficult to implement, requiring deep collaboration on technical design, operations, and, most importantly, governance [71], [72], [73], [74]. The Dunbar and mBridge projects explore this single system model [18], [65], [67].

Table 8: Interoperability Models for CBDC Systems

Model	Description	Advantages	Disadvantages	Project Examples
Compatibility	CBDC systems use common standards but remain separate.	Easiest and least costly to implement; Preserves full national autonomy.	Offers limited efficiency gains; Does not solve core settlement frictions.	SWIFT GPI (Global Payments Innovation)
Interlinking	Separate CBDC systems are connected via technical links or hubs.	Balances national autonomy with improved cross-border functionality.	It can become complex to manage as links increase.	Project Icebreaker
Single System	Multiple CBDCs are issued and transacted on a shared platform.	Highest potential for efficiency, speed, and cost reduction; Eliminates reconciliation needs.	Most complex to govern; Requires deep international cooperation and trust.	Project Dunbar, Project mBridge.

Sources: Adapted through [18], [51], [65], [67], [71], [72], [73], [74], [75] Governance blueprint (minimum viable operating model): Interoperability models (interlinking or a single common system) require an explicit governance layer to define decision rights, operational accountability, and dispute resolution. The blueprint below can be adapted as a public baseline for multi-jurisdictional wCBDC arrangements.

Table 9: Minimum Viable Governance Blueprint for Multi-Jurisdictional wCBDC Platforms

Governance layer	**Key roles**	**Core decisions / outputs**
Strategic Council (Participating CBs)	Central banks, finance ministries (as appropriate), policy observers.	Membership criteria; corridor scope; monetary/legal red lines; escalation paths.
Platform Operator / Technical Secretariat	Day-to-day operations team, change-management function, technical standards lead.	Release management; uptime/SLA; incident response; API/message versioning.
Compliance & Data Governance Committee	CB compliance units, AML authorities, data protection leads.	Tiered access rules; data minimization/retention; auditability standards; cross-border information sharing.
Risk & Resilience Function	Security leads, operational risk leads, independent assurance.	Threat model; control baselines; DR testing; crypto-agility roadmap; third-party risk controls.
Dispute Resolution & Arbitration Forum	Neutral forum (or designated seat), legal representatives of participants.	Liability allocation; settlement finality disputes; smart contract incidents; jurisdictional conflicts.

PART IV

NAVIGATING THE LABYRINTH: CHALLENGES AND STRATEGIC CONSIDERATIONS

Despite the immense potential of wCBDC systems, their path to widespread adoption is fraught with significant legal, technical, economic, and geopolitical challenges. Overcoming these hurdles will require unprecedented international cooperation and careful, nuanced policy design.

Risk register: The table below consolidates the highest-impact risk categories for wCBDC development. It is designed for public readability while remaining operationally meaningful.

Table 10: Illustrative Risk Register for wCBDC Programs

Risk	Where it shows up	Likelihood	Impact	Mitigation	Owner
Jurisdictional or legal fragmentation	Cross-border finality, data rules, currency controls	Medium	High	MoUs; harmonized rulebook; legal opinions per corridor	CB legal + participating FMIs
PII 'honeypot' from Travel Rule implementation	Identity/PII sharing across intermediaries	Medium	High	Tiered KYC; selective disclosure; minimization/retention limits; security audits	Compliance + data governance
Cyberattack on nodes/keys	Participant nodes, key custody, operator stack	High	High	HSMs; key rotation; segmentation; monitoring; red-team exercises; DR drills	Security leads
Smart contract bug / logic failure	Programmable settlement workflows	Medium	High	Formal verification where feasible; staged rollout; kill-switch governance; independent audit	Operator + oversight council
Liquidity stress / FX volatility amplification	24/7 settlement during stress	Medium	Medium-High	Limits; circuit breakers; liquidity facilities; corridor throttling	CB policy + operator
Vendor / supply-chain compromise	DLT stack, cloud/HSM providers, integrators	Medium	High	Third-party risk program; SBOM; contractual controls; continuous assurance	Operator + procurement/security

Section 10: The Regulatory and Legal Gauntlet

Creating a unified financial system spanning multiple sovereign jurisdictions faces the complex reality of jurisdictional fragmentation. Each country's legal framework governs financial transactions, data privacy, and currency controls, creating a significant obstacle to seamless cross-border transactions [76].

AML/CFT Compliance and the FATF "Travel Rule"

A primary challenge is ensuring compliance with global Anti-Money Laundering (AML) and Countering the Financing of Terrorism (CFT) standards. The Financial Action Task Force (FATF) sets these standards, and its Recommendation 15, updated to cover virtual assets, is particularly relevant. It mandates that Virtual Asset Service Providers (VASPs), a category that would include intermediaries in a CBDC system, must collect, hold, and transmit information about the originator and beneficiary of a transaction, a requirement known as the "Travel Rule" [77], [78], [79]. While straightforward in the traditional banking system, where ledgers are private, applying this rule to blockchain-based systems creates a profound "privacy paradox". Blockchain addresses are pseudonymous, but their transaction history is public and immutable [26], [80]. Practical design options to reconcile AML/CFT expectations with privacy: The goal is to satisfy compliance requirements while avoiding architecture choices that centralize sensitive personal data or expose transaction histories through linkability.

Table 11: Design Options for Privacy-Preserving Compliance in wCBDC (AML/CFT)

Option	Core mechanism	Pros	Trade-offs / risks
Tiered access + limits	Low-risk wallets/participants with lower KYC; higher tiers require stronger due diligence; transaction/value limits and velocity controls.	Fast adoption for legitimate low-risk use; reduces compliance burden for small users/firms.	Requires careful calibration; may not fit all cross-border wholesale cases without strong participant controls.
Selective disclosure (privacy-preserving compliance)	Identity and attributes are disclosed only when legally required (e.g., threshold, suspicion trigger), using cryptographic proofs or controlled reveal.	Minimizes PII exposure; avoids broad linkage of identity to public transaction history.	Complexity; performance overhead; requires robust governance on trigger conditions and audits.
Intermediary-based compliance (two-tier operating model)	Banks/FMIs perform KYC/AML; CBDC platform enforces rule compliance via attestations rather than raw PII transfer.	Aligns with existing supervision; keeps sensitive data with regulated entities; reduces 'honeypot' risk.	Requires standardized attestation formats; still needs cross-jurisdiction legal agreements for information sharing.

Minimum data governance controls that are applicable in any context;

- Data Minimization: Share only what is strictly required for compliance (avoid full identity address payloads by default).
- Retention Limits: Define time-bound retention and deletion rules aligned with legal requirements and audit needs.
- Access Controls and Logging: Role-based access, immutable audit logs, and periodic access reviews across all intermediaries.
- Breach Containment: Encryption at rest and in transit, segmentation, incident playbooks, and mandatory disclosure procedures.
- Cross-border Sharing Agreements: Specify the legal basis, permitted uses, and dispute mechanisms for shared compliance information.

The Travel Rule effectively links a real-world identity to this public ledger by requiring the transmission of personally identifiable information (PII), such as names and physical addresses, alongside a transaction. This creates an unprecedented security risk: a "honeypot" of data that, if breached, would expose a person's identity, entire transaction history, and current holdings to malicious actors. This level of data vulnerability is far greater than that in the traditional financial system. Therefore, designing a CBDC system that is both fully compliant with FATF standards and vigorously protects privacy is an extraordinary technical and political challenge [78], [79], [80], [81][77].

Liability and Dispute Resolution

Establishing clear lines of responsibility in a decentralized or multi-jurisdictional system is critical. Which entity is liable if a transaction fails due to a technical glitch, a software bug in a smart contract, or a fraudulent act? Which country's laws apply? The lack of international legal frameworks for resolving disputes in a DLT-based cross-border context creates legal uncertainty and can increase systemic risk [60], [76], [82], [83]. For countries like Turkey, which serve as bridges between different economic blocs, this uncertainty poses both risks and opportunities. A country that positions itself as a trusted center for international arbitration in digital asset disputes can gain a significant strategic advantage in the new financial architecture [9].

Legal certainty checklist (public, corridor-ready):

- Settlement finality: Define when a transfer is final and irrevocable on the platform (and how this maps to domestic law).
- Liability allocation: Specify responsibility for node failure, operator fault, participant error, and smart contract malfunction.
- Jurisdiction and applicable law: Identify governing law per corridor, including conflicts-of-law handling.
- Dispute pathway: Set escalation steps, timelines, and arbitration/tribunal arrangements (including evidence standards).
- Data protection alignment: Define controller/processor roles, lawful basis for processing, and cross-border transfer safeguards.

- Operational rulebook: Publish participant obligations (onboarding, KYC/AML responsibilities, reporting, sanctions screening).

Section 11: Technical and Operational Hurdles

Beyond the legal complexities, significant technical and operational barriers must be surmounted.

Scalability and Performance: While permissioned DLTs are significantly faster than their public counterparts, they must still prove their ability to handle the immense transaction volumes of global trade and finance without performance degradation. Systems like Visa can process over 65,000 transactions per second (TPS), a benchmark many DLT platforms still strive to meet reliably at scale. CBDC pilots like Project Helvetia [84] and Project Jura [85] have explored scaling solutions, but these technologies remain nascent and have not yet been proven at a global, production-level scale [84], [85].

Integration with Legacy Systems: The global financial system runs on a vast, heterogeneous network of legacy infrastructure. Integrating new DLT-based platforms with the existing core banking systems, payment gateways, and FMI software of thousands of institutions worldwide is an immense and costly undertaking. While countries like Türkiye have demonstrated strong capabilities in modernizing their domestic payment infrastructure with systems like FAST, preparing the entire banking sector for full CBDC integration will require substantial investment in technology, expertise, and time [9].

Cybersecurity and Quantum Threats: CBDC platforms, as critical national and international infrastructure, will be high-value targets for sophisticated cyberattacks. An IMF report from 2024 highlights that the financial sector is already the most frequently targeted industry, and CBDCs could amplify these risks [86]. An emerging and particularly concerning threat is the development of quantum computers. A powerful quantum computer could theoretically break the public-key cryptography that secures virtually all digital communications and financial transactions today, including those on blockchain networks. Recognizing this future threat, the BIS has begun to explore quantum-safe cryptography. Project Tourbillon, for instance, successfully implemented and tested quantum-resistant cryptographic signatures. However, the project also found that current quantum-safe algorithms come with significant performance costs, increasing payment processing times by a factor of five in their prototype. This highlights a critical trade-off and a vital area for future research and development [87].

Threat Model and Minimum Control Set:

Threat classes: (1) participant node compromise, (2) insider abuse, (3) key theft/custody failure, (4) denial-of-service, (5) consensus/ledger integrity fault, (6) supply-chain compromise.

Controls (minimum):

- Key management: HSM-backed keys, rotation policies, multi-party controls for privileged operations, and break-glass procedures.

- Network security: Segmentation, allow-listing, DDoS protection, and secure API gateways for participant connectivity.
- Monitoring and response: Centralized logging, anomaly detection, incident response playbooks, and periodic red-team exercises.
- Resilience: Tested backup/restore, disaster recovery objectives (RTO/RPO), and regular continuity drills with participants.
- Change management: Controlled releases, configuration baselines, and independent security assurance for significant upgrades.
- Crypto-agility (quantum readiness): Adopt an explicit migration plan that enables algorithm swaps without platform redesign; maintain an inventory of cryptographic dependencies and test PQC-capable alternatives in controlled environments before production adoption.

Section 12: Macro-Financial and Geopolitical Implications

The introduction of CBDCs has the potential to reshape payment systems and broader monetary and geopolitical landscapes [86].

Monetary Policy and Financial Stability

Even in a wholesale model, the widespread adoption of CBDCs could significantly affect the banking system. The appeal of holding central bank money creates a risk of "disintermediation," which could lead to deposits being withdrawn from commercial banks. This could shrink banks' balance sheets and reduce their capacity to create credit, potentially negatively impacting economic growth [86], [88], [89]. Furthermore, the ability to move considerable amounts of money instantly and seamlessly (24/7) across borders could increase the volatility of capital flows, particularly during periods of financial stress, making it more difficult for central banks to manage economies [86].

Türkiye has two operational scenarios to stress-test design choices in this process:

Scenario 1 - For trade settlement efficiency: If a pilot corridor reduces settlement time from days to near-real time, exporters' working-capital needs fall and payment-risk exposure declines. To capture this benefit, the pilot should track (i) average settlement time, (ii) fee reduction vs. correspondent baseline, and (iii) liquidity locked during settlement.

Mitigation/Enablers: Clear PvP logic, corridor-level liquidity tools, and integration with domestic FMIs and bank treasury workflows.

Scenario 2 - For stress-period volatility: 24/7 cross-border transferability can amplify outflows during market stress. The platform should therefore include policy-controllable safeguards.

Mitigation tools: Corridor throttles; tiered transaction limits; time-bound circuit breakers; enhanced monitoring; and pre-agreed liquidity backstops for critical participants.

The Privacy-Transparency Dilemma: Lessons from Project Tourbillon

The tension between the need for regulatory transparency and the public's demand for privacy is one of the most contentious issues in the CBDC debate. Project Tourbillon, conducted by the BIS Innovation Hub's Swiss Centre, was a landmark experiment designed to explore this trade-off directly. The project developed and tested two distinct CBDC prototypes to assess different architectural approaches to 'payer anonymity'. Using cryptographic techniques such as blind signatures, these prototypes demonstrated that a consumer's identity can remain anonymous from all parties, including the merchant, banks, and the central bank. However, the merchant's identity is known to their bank to ensure AML/CFT compliance. The central bank can see transaction amounts at an aggregate level but has no access to personal data [87], [88], [90], [91], [92].

Project Tourbillon proved that a high degree of privacy is technologically feasible. However, it also demonstrated that this comes with trade-offs in terms of system complexity, performance, and security. The project's key contribution is shifting the debate from *whether* privacy is possible to *how much* privacy society and its regulators are willing to accept, and what technical and institutional safeguards are necessary to achieve that balance [87].

The Geopolitics of Digital Currency

Developing wCBDC platforms is inseparable from 21st-century geopolitical competition [93]. For many countries participating in projects like mBridge, a primary strategic driver is the creation of alternative payment corridors that reduce reliance on the US dollar and on Western-controlled financial infrastructure such as SWIFT [64], [94]. This is perceived as a way to enhance monetary sovereignty and build resilience against the potential use of economic sanctions [93], [94]. This dynamic could lead to competing digital currency blocs, with, for example, a China-led mBridge platform operating in parallel to a Western-led Agora platform. Such a development could further fragment the global financial system, create new spheres of economic influence, and shape future trade patterns, capital flows, and international power [93]. The race to build these platforms is not merely a technical competition; it is a core element of modern economic statecraft.

PART V

THE PATH FORWARD: ADOPTION, INCENTIVES, AND A CASE STUDY FOR TÜRKIYE

A successful transition from pilot projects in the experimental phase to vibrant and functional wCBDC ecosystems will depend on strategic incentives, strong public-private partnerships, and full alignment with national economic objectives [95].

Section 13: Fostering Adoption and Building Viable Ecosystems

Moving beyond the proof-of-concept phase requires creating a compelling value proposition for all stakeholders. This involves a multi-pronged incentive strategy [96], [97].

Economic Incentives

The most direct incentive is a demonstrable reduction in transaction costs and settlement times. By making cross-border trade cheaper and faster, wCBDC platforms have the ability to give participating businesses and financial institutions a competitive advantage [98], [99].

Technical Incentives

Providing open and standardized Application Programming Interfaces (APIs) can foster a vibrant ecosystem of innovation. This enables private-sector FinTech firms and developers to create new, value-added services on top of the core wCBDC infrastructure, resulting in innovative products and business models [100], [101].

Regulatory Incentives

Streamlining compliance processes can be a powerful driver of adoption. If smart contracts can automate certain regulatory checks (e.g., KYC/AML verification), this could significantly reduce the compliance burden for financial institutions, making the platform more attractive [97], [102], [103].

Pilot Design Success Metrics and Exit Criteria:

- Efficiency KPIs: Settlement time (p50/p95), cost per transaction vs. baseline, reconciliation effort, and error/exception rate.
- Risk KPIs: Failed/rolled-back settlement rate, liquidity locked duration, PvP/DvP success rate, and incident frequency.

- Adoption KPIs: Number of participating banks/FMIs, active corporates, transaction volume growth, and retention.
- Compliance KPIs: Time to complete required checks, false-positive rate in screening, and audit log completeness.
- Exit Criteria move from pilot to scaled rollout: Predefined thresholds over a sustained period (e.g., 3–6 months), plus a successful DR drill and an independent security review.

Crucially, building these ecosystems cannot be the sole purview of central banks. Deep public-private partnerships are essential. Projects like Agora, which involve over 40 private sector firms from the outset, exemplify this collaborative approach. By including commercial banks, financial market infrastructures (FMIs), and technology providers in the design phase, central banks can ensure that the resulting platform meets the real-world needs of its future users and is built for successful integration and adoption [19], [57].

Stakeholder Engagement Plan by Operational Perspective:

- Core participants: Select a small set of commercial banks, an FMI (where relevant), and priority corporate users per corridor.
- Governance cadence: Establish a weekly technical working group, a monthly risk/compliance committee, and a quarterly steering council.
- Integration playbook: Publish onboarding requirements, API/message specs, test environments, and certification steps for participants.
- Transparency: Define what will be publicly reported (KPIs, uptime, incident summaries) versus confidential operational details.
- Feedback loop: Structured feedback from banks/corporates on usability and treasury integration; incorporate into release roadmap.

Section 14: Case Study: The Digital Turkish Lira and Strategic Reputation

Türkiye's pursuit of a Central Bank Digital Currency (CBDC) should be interpreted not merely as a new financial technology investment; it should be construed as an effort to strategically position itself in a period of restructuring of the global monetary architecture. While the Digital Turkish Lira Project serves as the institutional backbone of this effort, this report examines Turkey's own CBDC platform as a multifaceted turning point, encompassing enhanced competitiveness, deeper financial integration, strengthened monetary sovereignty, the promotion of the Turkish lira, and geo-strategic positioning. This framework is based on a broader state capacity option for Türkiye, which prioritizes economic prosperity and strategic resilience over "Technological Innovation" [104], [105].

Türkiye – design decision matrix (high-level). The matrix below consolidates key architecture choices into a single view, enabling clear communication of scope and trade-offs for public audiences.

Table 12: Türkiye – wCBDC Design Decision Matrix (High-Level)

Decision area	Recommended baseline (public report)	Rationale	Open questions for Phase-2
Primary use case (wCBDC focus)	Cross-border wholesale settlement for trade finance corridors; PvP where feasible.	Targets highest frictions and smallest participant set; aligns with global trend toward wholesale.	Which 1–2 corridors first; what sector mix; which FMIs involved?
Interoperability model	Start with interlinking / hub approach; keep single-system as long-term option.	Limits governance burden initially; enables staged learning before deep integration.	Hub operator role; legal basis for interlinking; message/API versioning.
Compliance architecture	Two-tier compliance: regulated intermediaries perform KYC/AML; platform enforces rules via attestations + limits.	Reduces PII centralization; leverages existing supervisory perimeter.	Selective disclosure triggers; audit model; cross-border information-sharing agreements.
Data governance	Minimize shared PII; strict retention; immutable audit logs; access control with periodic review.	Avoids honeypot risk; supports accountability for public release.	Controller/processor roles; data transfer safeguards; breach reporting.
Operational resilience	Threat-model-driven controls; DR drills; independent security assurance before scale-up.	Critical infrastructure requires demonstrable readiness.	RTO/RPO targets; testing cadence; third-party assurance scope.
Participation strategy	Move from observer to deeper technical participation in one multilateral track (e.g., mBridge) once prerequisites met.	Accelerates learning and interoperability while managing risk.	Membership criteria; domestic system integration timeline; legal commitments.

Conceptually, CBDC refers to a country's responsibility to issue its own digital currency through its Central Bank. Current designs distinguish between retail (rCBDC) and wholesale (wCBDC) access models; wCBDC is available only to financial institutions and corresponds to the infrastructure layer used for interbank settlement, securities clearing, and cross-border payments. Considering Türkiye's current objectives, this "wholesale" design, which could affect foreign trade finance and international payment corridors, plays a critical role, particularly in rebuilding tax algorithms [104], [106].

Türkiye has been actively engaged in CBDC research and development, positioning itself to play a significant role in the new digital financial landscape. The Central Bank of the Republic of Türkiye (CBRT-TCMB) initiated its Digital Turkish Lira Project in 2022 and successfully executed its first pilot payment transactions by the end of that year. The project's first phase was completed in late 2023, with ongoing work in Phase 2 focusing on the legal, economic, and security dimensions of the potential rollout [9]. Türkiye's strategic positioning is further highlighted by its observer status in Project mBridge, which provides a front-row seat to the development of one of the world's most advanced multi-wCBDC platforms [64], [94].

This strategic choice should be viewed directly in relation to the structural problems of the current cross-border payment system. The multilayered nature of the correspondent banking network generates high transaction costs, low speed, a lack of transparency, and counterparty risk. In contrast, the average global remittance cost of around 6.35% represents a significant welfare loss, particularly for emerging markets. This report argues that the "pre-funding" requirement, which forces banks to hold idle liquidity in foreign-currency nostro accounts, creates capital inefficiency, resulting in billions of dollars in opportunity costs for countries with high foreign trade volumes, such as Türkiye [2], [60], [107].

At this point, two technical mechanisms emerge, promising the competitiveness of wCBDC. The first is the latency and cost burden incurred by the traditional SWIFT-based model, which essentially relies on a messaging infrastructure and clears or settles through a chain of correspondent banks. The second is the "atomic swap" and payment-versus-payment (PvP) approach. This simultaneous payment and delivery offer direct speed and cost advantages to Turkish exporters by reducing reliance on expensive, slow trade-financing instruments such as letters of credit. Such an increase in efficiency could also indirectly contribute to expanding the export base by enhancing the micro-export capacity of SMEs [3], [56], [103], [104], [108].

Türkiye's geopolitical and digital infrastructure goals are closely linked to financial integration. This report, while considering the increasing strategic importance of the Middle Corridor, recognizes that the slow pace of financial reconciliation may hamper the speed of logistics flows. Therefore, the Council of Central Banks within the Organization of Turkic States and the 2024 Bishkek Consensus will provide the institutional basis for closer cooperation among member countries in payment systems and financial technologies. In this context, transforming wCBDC into a "payment layer" within the TDT, supporting trade in local currencies and digital customs processes, will strengthen the vision of a regional economic bloc [109], [110], [111].

Türkiye's aim of simultaneous integration with the EU and Asia should also be part of this framework. While the need for compatibility and interoperability with the wholesale version of the Digital Euro is paramount in the EU, the adoption of the ISO 20022 standard is seen as a critical technical threshold. In Asia, Project mBridge's demonstration that cross-border payments can be made through central banks without the need for correspondent banks serves as a firm reference for Türkiye's efforts to align with similar multi-CBDC architectures [17], [18], [112].

From a monetary sovereignty perspective, the risk that centralized global payment networks could be used as foreign policy tools is decisive. In this report, recalling the discussion of the "weaponization of interdependence," we predict that a domestic wCBDC infrastructure could serve as a strategic "insurance" for Türkiye, given its alternative and censorship-resistant corridor capacity. When considering data sovereignty and cyber resilience within this framework, it is posited that a domestic CBDC would establish the essential conditions conducive to more systematic tax justice and, consequently, enhancements in social welfare [113], [114], [115], [116].

In terms of promoting the Turkish lira, wCBDC's PvP mechanism, which technically facilitates local-currency settlement, enables the Central Bank to be a more effective actor in monetary markets. In a structure where the USD and EUR weights expose companies to exchange rate risk and convertibility costs, simultaneous swaps between Digital TRY and other digital currencies can both reduce costs and limit dollarization pressures. Thus, we anticipate that the proliferation of stablecoins increases the risk of "digital dollarization," and that a secure, programmable Digital Turkish Lira, as a public alternative, could help maintain monetary policy effectiveness [17], [18], [94], [116], [117].

The implementation of this vision is already becoming apparent in the Central Bank of the Republic of Türkiye's (CBRT) two-phase Digital Turkish Lira roadmap. Phase 1 tested basic payments and identity verification, while Phase 2 expanded smart payments, offline scenarios, and interoperability efforts with stakeholders such as Aselsan, Havelsan, and TÜBİTAK. The six strategic objectives we consider here are grouped under four main pillars: economic efficiency, regional leadership, national security, and financial innovation. Therefore, Türkiye's wCBDC project can be considered a capacity-building initiative that can expand both economic and geopolitical maneuverability in the new monetary order, evolving into multipolar and regional CBDC blocs [9], [104], [106], [110], [118], [119], [120].

Consequently, for Türkiye, a wCBDC platform is more than just a technological upgrade; it is a strategic tool that could help accomplish several key national objectives.

- **Enhancing Competitiveness:** By drastically reducing the time and cost of cross-border payments, a wCBDC system can provide a direct competitive advantage to Türkiye's vital export and import sectors [64], [94], [121].
- **Deepening Financial Integration:** The platform can be used to establish stronger, more efficient financial connections with key trading partners in Europe, Asia, and the Middle East, as well as with the Turkic States, thereby fostering a more integrated economic bloc[28], [110].
- **Increasing Monetary Sovereignty:** Developing a secure and efficient payment alternative to the SWIFT network could provide Türkiye alternative payment channels, enhancing economic resilience and reducing dependence on any single infrastructure provider.[114], [115], [116].
- **Promoting the Turkish Lira:** A wCBDC platform would facilitate trade settled directly in Turkish Lira with partner nations, reducing the economy's reliance on foreign currencies and mitigating exchange rate risks for Turkish businesses [9], [18], [117].
- **Geostrategic Positioning:** Leveraging its unique geographic position as a bridge between continents, Türkiye can aim to become a central node in the emerging network of digital trade corridors, solidifying its role as a key player in regional and global commerce [9], [12], [48], [109], [115].

Table 13: Proposed wCBDC Adoption Timeline for Türkiye

Phase	Key Activities	2026 Q3	2026 Q4	2027 Q1	2027 Q2	2027 Q3	2027 Q4	2028 Q1
Technical Assessment	Evaluate DLT platforms, conduct domestic pilots with commercial banks, and develop API standards.	■	■	■				
Regulatory Alignment	Draft primary and secondary legislation for Digital Lira, align with FATF standards, and establish a legal framework for smart contracts.			■	■	■		
mBridge Membership	Transition from observer to full participant in Project mBridge and integrate domestic systems with the mBridge Ledger.						■	■

Roadmap enhancement (execution-ready): Table 8 provides the high-level timeline. Table 14 below adds concrete deliverables, dependencies, and accountable owners to make the plan implementable and monitorable.

Table 14: Execution-Ready Roadmap for Türkiye's wCBDC Program (Phases, Deliverables, Dependencies, Owners, Gates)

Phase	Deliverables (what is produced)	Key dependencies	Owner(s)	Gate to next phase
Technical assessment	DLT platform shortlist; testnet environment; API/message spec v1; participant onboarding kit.	ISO 20022 mapping; participant bank readiness; secure key custody design.	CBRT/TCMB + selected banks + operator team	Successful end-to-end testnet settlement + basic DR drill
Regulatory alignment	Draft rulebook; settlement finality definition; liability allocation; data governance policy; compliance operating model.	Coordination with AML authority and data protection requirements; corridor MoU draft.	CBRT/TCMB + regulators + legal taskforce	Legal sign-off for pilot corridor + auditability requirements met
mBridge participation (example)	Technical integration plan; node requirements; corridor scope proposal; governance participation plan.	Membership criteria; bilateral/multilateral agreements; operational readiness.	CBRT/TCMB + participating banks	Approved corridor scope + successful interoperability test

CONCLUSIVE THOUGHTS

Central Bank Digital Currencies (CBDCs) have transitioned from merely theoretical concepts to active areas of experimentation. The evidence examined in this report suggests that wholesale CBDC (wCBDC) platforms stand as highly credible options for the modernization of cross-border settlement processes. These platforms, constructed upon distributed ledger technology (DLT) and supported by carefully designed access protocols and governance frameworks, have the potential to mitigate longstanding frictions inherent in correspondent banking systems. Such frictions include settlement delays, reconciliation complexities, opaque fee structures, and the encumbrance of liquidity within pre-funded nostro/vostro accounts. Furthermore, the programmability features enabled by smart contracts significantly enhance their utility by supporting atomic delivery-versus-payment (DvP) and payment-versus-payment (PvP) mechanisms. These features facilitate automated compliance procedures and pave the way for innovative end-to-end transaction workflows within financial market infrastructures.

However, the report reminds us that technical feasibility is just the beginning; true success requires vision, determination, and the will to go beyond mere possibility. Interoperability continues to serve as the fundamental constraint for scaling initiatives beyond pilot projects. Progress is contingent upon the establishment of standardized protocols for messaging and data exchange (with practical adoption of ISO 20022 where appropriate), the implementation of robust identity and access management systems, and governance frameworks capable of coordinating rule-setting, system upgrades, and dispute resolution across different jurisdictions. In operational terms, interoperability is not centered on a single interface but comprises a spectrum of models discussed in the report, including harmonized distributed ledger technology (DLT) platforms, interconnected ledgers, and shared settlement layers. These models aim to balance national sovereignty with the facilitation of cross-border coordination. Absent credible governance mechanisms for these interfaces, the advantages of widespread central bank digital currency (wCBDC) architectures are restricted to closed networks.

The operational risk surface expands in parallel. The transition from proofs-of-concept to production-grade systems requires demonstrable scalability, resilient integration with legacy RTGS and payment rails, and defense-in-depth cybersecurity. Platform design must anticipate sophisticated availability attacks (including denial-of-service and DDoS threats), strengthen cryptographic key management and hardware security module (HSM) practices, and incorporate clear recovery objectives (RTO/RPO) supported by tested disaster recovery (DR) procedures and service level agreements (SLAs). Moreover, as quantum risk matures, post-quantum cryptography (PQC) planning and crypto-agility become prudential requirements rather than optional enhancements. Supply-chain assurance, including software bill of materials (SBOM) practices and third-party risk controls, is equally central to maintaining trust.

Macro-financial and geopolitical dynamics fundamentally influence all design decisions. The pursuit of competing strategic objectives such as efficiency, monetary sovereignty, sanctions exposure, data localization, and network leadership, heightens the risk of a fragmented ecosystem composed of non-interoperable systems. The most probable failure mode is not a technological malfunction but rather the breakdown of coordination, resulting in a landscape of 'digital islands' that perpetuate existing frictions in new technical forms and potentially reinforce regional blocs. Preventing this scenario requires unprecedented international cooperation on standards, governance, and legal interoperability, coupled with deliberate architectural strategies that enable modular participation while avoiding the concentration of political control in a single authority.

Within this global re-architecting effort, the Digital Turkish Lira should be regarded as an investment in state capacity rather than merely a technological upgrade. For Türkiye, its strategic significance derives from integrating domestic resilience, such as ensuring payment continuity, enabling programmable control, and establishing a trusted infrastructure with external connectivity that facilitates trade settlement and trade corridor diversification. A practical approach involves prioritizing use cases for wCBDC that deliver clear public benefits, such as interbank and trade-related settlement, peer-to-peer (PvP) mechanisms that mitigate foreign exchange (FX) settlement risk, and targeted corridor pilots with selected partners, before large-scale deployment. Adhering to international technical standards, including ISO 20022 compatibility where appropriate, and exploring multi-CBDC architectures, as exemplified by initiatives like mBridge, can enhance flexibility, reduce reliance on single corridors, and support regional leadership objectives outlined in the report, including the potential development of platforms within the Organization of Turkic States.

In conclusion, wCBDCs should be regarded as institutional innovations specifically facilitated by technological advancements. Their advantages are contingent not only on the design of the ledger but also significantly on governance frameworks, standardization processes, and the credibility of implementation strategies. The forthcoming period will be crucial: Central Banks that adopt a disciplined approach to experimentation, develop interoperable architectures by design, foster ecosystem development through open APIs and stakeholder incentives, and form strategic coalitions will be optimally positioned to realize efficiency gains while maintaining monetary sovereignty, ensuring financial stability, and upholding public trust.

SCOPE NOTE

This report provides a comprehensive assessment of Central Bank Digital Currencies (CBDCs) and wholesale CBDCs (wCBDCs), grounded in the current literature and publicly available primary sources. To preserve the strategic character of the analysis, selected areas remain open to further deepening in subsequent revisions; this includes sharpening the conceptual distinction between Project mBridge's bridging, or interlinking, approach and Project Agora's unified-ledger approach; presenting quantitative evidence on the privacy, compliance, and performance trade-offs more visibly and in a more measurable manner, particularly with respect to how quantum-safe cryptographic design choices affect throughput and latency; articulating the strategic relevance of contemporary geostrategic vectors such as the Turkic States Organization Council of Central Banks within the Türkiye-focused assessment through a clearer policy frame; and expanding the Digital Turkish Lira Phase 2 themes of offline payments and programmability with the technical and governance details needed to strengthen implementation readiness. This report does not represent the official view of any institution, because project statuses and regulatory frameworks may evolve, readers are advised to consult the relevant primary sources alongside this analysis. This document is intended for analytical and policy-design purposes and should be read together with official project and regulatory update.

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