



HONG KONG MONETARY AUTHORITY
香港金融管理局



e-HKD Pilot Programme **Phase 1 Report**

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Table of Contents

04	Foreword
06	Executive Summary
07	1 Introduction to Project e-HKD
09	2 e-HKD Pilot Programme
11	3 Case Studies: Potential Use Cases
3.1	Overview
3.2	Case Studies
	Case Study 1: Full-Fledged Payments
	Case Study 2: Programmable Payments
	Case Study 3: Offline Payments
	Case Study 4: Tokenised Deposits
	Case Study 5: Settlement Instructions for Web3
	Case Study 6: Settlement of Tokenised Assets
23	4 Evaluation
4.1	Pilot Feedback and Assessment
4.2	Technical Considerations: DLT Interoperability and Scalability
33	5 Way Forward
35	6 References
36	Appendix A: Factsheets / Supplementary Reports
37	Appendix B: Glossary

Foreword

The world has witnessed a remarkable evolution in the way we view and use money. With the advent of, to name a few examples, smartphone-driven transactions, virtual banking, and AI-driven customer servicing, our expectations on how our money should work for us have continued to rise as we require faster, more accessible, and more affordable ways of managing and using our money. Hong Kong's complex ecosystem of banks, fintech firms, and other industry participants has made remarkable strides in this regard by continuously innovating in response to ever-changing market demands and trends.

In tandem with these developments, the topic of central bank digital currencies (CBDCs) continues to permeate the central banking community, with most jurisdictions engaging in some form of work on retail CBDCs (rCBDCs). When positioned and implemented properly, an rCBDC has the potential to unlock unrealised economic value by transforming the ways we transact and the systems we transact on. However, its implementation will require conscious and careful balancing with existing systems, processes and stakeholders.

The HKMA embarked on Project e-HKD two years ago to study the case for issuing an rCBDC in Hong Kong. Given the maturity of Hong Kong's retail payment ecosystem, we opted for a use-case driven approach to explore where an e-HKD could bring additional value to consumers and businesses. The e-HKD Pilot Programme launched last year underpins the HKMA's joint efforts with the industry to experientially evaluate viable applications.

This report details our key findings and assessment from Phase 1 of the e-HKD Pilot Programme, and it represents another significant milestone for Project e-HKD. Whilst the HKMA has not decided on whether or when to introduce an e-HKD, these pilots will enrich our repository of knowledge formed under Project e-HKD and inform our future policy decisions. We also believe that our experiences and learnings will facilitate further research and discussion on rCBDCs among policy makers, the industry, and the international community.

The journey that lies ahead is an exciting and rewarding one. We have fostered a culture of continued innovation within the industry while maintaining Hong Kong's stable, long-established banking system. In this regard, the HKMA commits to ensuring this project addresses the challenges of today and the future.

Howard Lee

DEPUTY CHIEF EXECUTIVE
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Executive Summary

Central bank digital currencies (CBDCs) have gained significant traction globally, with many central banks recognising the potential of wholesale and retail CBDCs. The HKMA has been researching CBDCs as part of its “Fintech 2025” strategy, with a view to increasing Hong Kong’s readiness in issuing CBDCs.

The HKMA embarked on its retail CBDC (rCBDC) journey with Project e-HKD in 2021. As part of the three-rail approach in paving the way for the potential implementation of an rCBDC in Hong Kong, i.e. an e-HKD, the HKMA launched the e-HKD Pilot Programme in November 2022. The programme is a joint effort between the HKMA and the industry to explore and evaluate the commercial viability of potential use cases for an e-HKD.

This report follows the conclusion of Phase 1 of the programme, and discusses the key findings, learnings, and the HKMA’s assessment of the conducted pilots. Phase 1 took deep dives into potential domestic and retail use cases in six categories: full-fledged payments, programmable payments, offline payments, tokenised deposits, settlement of Web3 transactions, and settlement of tokenised assets. 16 firms from financial, payment and technology sectors were selected to participate.

While Hong Kong’s retail payment ecosystem currently provides consumers and businesses with a wide range of payment options enabled by well-established and robust financial infrastructure, the pilots under Phase 1 uncovered three areas where an e-HKD could add unique value to the current ecosystem. These are: programmability, tokenisation, and atomic settlement. An e-HKD not only has the potential to facilitate faster, more cost-efficient, and more inclusive transactions, but it could also unlock new types of economic transactions. With that said, the potential and prerequisites for realising such unique value at scale to substantiate the issuance of an e-HKD are subject to market development and further investigation. In addition, a number of inefficiencies today are the result of longstanding business norms and processes, rather than deficiencies in technology. An e-HKD, despite its potential use of new technologies, may not be the cure-all to all inefficiencies.

The HKMA has not yet reached a policy decision on whether or when to introduce an e-HKD. Careful consideration should be given to the positioning of an e-HKD, as well as the roles that the HKMA and the industry may take up in implementing and operating an e-HKD. Other factors such as policy and technical design as well as legal considerations will also need to be studied.

Phase 1 of the e-HKD Pilot Programme has provided valuable insight into the potential use cases for an e-HKD, and has also raised a number of areas for future study. The HKMA will examine the identified business and implementation issues in greater depth in the next phase of the e-HKD Pilot Programme.

1 Introduction to Project e-HKD



A selection of banknotes issued by the three note-issuing banks in Hong Kong (i.e. The Hongkong and Shanghai Banking Corporation Limited, Standard Chartered Bank (Hong Kong) Limited, and Bank of China (Hong Kong) Limited). Cash (such as the banknotes above, and \$10 notes and coins issued by the HKSAR Government) is legal tender and an accessible and reliable means of payment. A central bank digital currency – a digital version of cash – should likewise provide the same level of accessibility and reliability in the digital economy.

The Hong Kong Monetary Authority (HKMA) has been researching central bank digital currencies (CBDCs) as part of its “Fintech 2025” strategy, with a view to increasing Hong Kong’s readiness in issuing CBDCs at wholesale and retail levels and promoting financial innovation in Hong Kong.

The HKMA’s exploration of CBDCs dates back to 2017, when its initial focus was on wholesale CBDCs (wCBDCs) under Project LionRock. This project gradually expanded and evolved into Project mBridge in 2021.

Project mBridge is a joint project between the HKMA, Bank for International Settlements Innovation Hub Hong Kong Centre (BISIHC), and three other central banks. It explores the use of a wholesale, multi-CBDC, distributed ledger technology (DLT)-based platform to enable commercial participants to conduct cross-border business and international trade flows in an efficient

and low-cost manner. This project is well recognised by the international financial community, and is expected to enter a minimum viable product (MVP) phase in 2024.

On the front of retail CBDCs (rCBDCs), the HKMA embarked on its journey with Project e-HKD in 2021, and has participated actively in cross-jurisdictional projects.

The HKMA previously collaborated with BISIHC and the Hong Kong Applied Science and Technology Research Institute (ASTRI) on Project Aurum in creating a prototype two-tier CBDC system, which comprises a wholesale interbank system and a retail e-wallet system. A project report was published in October 2022.

More recently, the HKMA completed Project Sela with BISIHC and the Bank of Israel, and a report was published in September 2023.

This project was a joint rCBDC experiment with a focus on cybersecurity. It demonstrated the technical feasibility of an rCBDC architecture that could promote competition and innovation in digital payments, by allowing non-bank payment intermediaries to connect directly to the CBDC ledger of the central bank.

The HKMA also established a CBDC Expert Group in October 2023 comprising leading academics to support Hong Kong's future exploration of key policy and technical issues surrounding CBDCs, such as privacy protection, cybersecurity, and interoperability. This group facilitates collaboration between the government, industry and academia on CBDC research as well.

On Project e-HKD, the HKMA has conducted two rounds of market consultations, one on high-level technical designs, and the other on key policy and design issues¹. Respondents were generally receptive to an e-HKD, although they highlighted the need to study the commercial viability of use cases and other issues such as privacy protections and legal considerations.

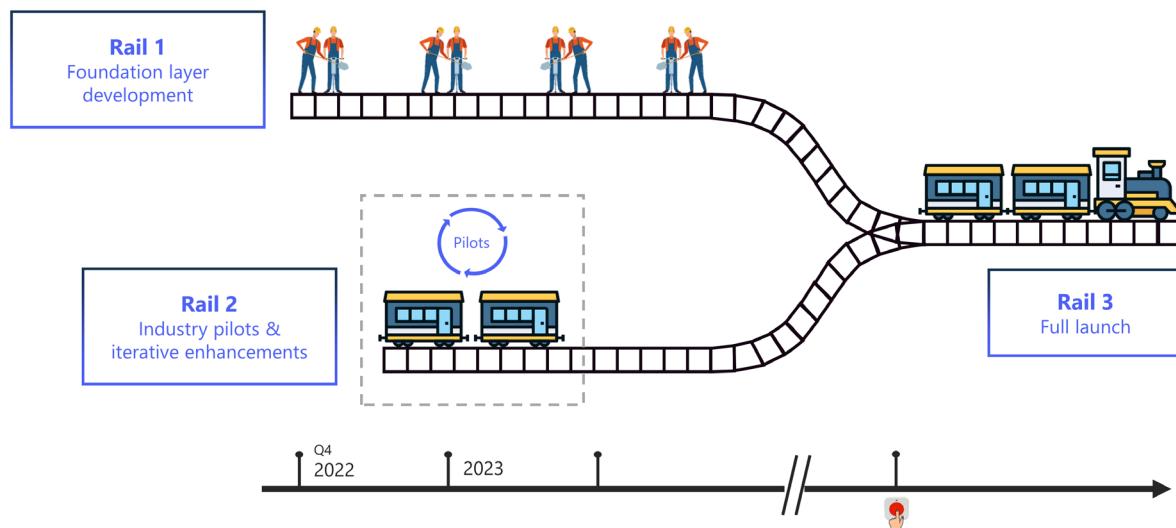
Taking into account feedback received during the market consultations, the HKMA published a position paper in September 2022² to set out its policy stance and outline a three-rail approach

for the potential implementation of an e-HKD (see Figure 1). Given the plethora of convenient retail payment options in Hong Kong, an e-HKD would need to add unique value to the current payment ecosystem, for instance, by providing new or innovative use cases. In this regard, the HKMA has adopted a use-case driven approach, and launched the e-HKD Pilot Programme as a key component of Rail 2 to explore commercially viable use cases for an e-HKD in collaboration with the industry.

This report follows the conclusion of Phase 1 of the programme, and discusses the key findings, learnings, and the HKMA's overall assessment of the conducted pilots. Phase 1 focuses on domestic and retail use cases in six categories: full-fledged payments, programmable payments, offline payments, tokenised deposits, settlement of Web3 transactions, and settlement of tokenised assets.

The HKMA has not yet reached a policy decision on whether or when to introduce an e-HKD. The lessons learnt from the programme will provide important insights that will inform the HKMA in making its decision. The HKMA remains open-minded towards the design features of an e-HKD, and will continue to follow international developments on CBDCs closely and consider feedback from different stakeholders (in particular the industry and the general public).

Figure 1 – Three-Rail Approach for the Potential Implementation of an e-HKD



¹ See "e-HKD: A Technical Perspective" (October 2021) and "e-HKD: A Policy and Design Perspective" (April 2022)

² See "e-HKD: Charting the Next Steps" (September 2022)

2 e-HKD Pilot Programme

This section discusses the HKMA's engagement with the industry under the e-HKD Pilot Programme and the launch of the e-HKD Sandbox for the development of use cases.

The HKMA launched the e-HKD Pilot Programme in November 2022 and invited industry participants to submit potential use cases for an e-HKD.

There was substantial interest and engagement from the industry. Submissions were received from both domestic and global firms, ranging from small fintech firms to large financial institutions.

Following an assessment based on pre-defined criteria (see Figure 2), the HKMA decided to focus on domestic and retail use cases in Phase 1 of the e-HKD Pilot Programme. Other use cases which were received (such as corporate use cases) may be explored in future phases of the programme.

16 firms from financial, payment and technology sectors were selected by the HKMA to participate in Phase 1. Their use cases spanned six categories, namely: full-fledged payments, programmable payments, offline payments, tokenised deposits, settlement of Web3 transactions, and settlement of tokenised assets. A commencement event was hosted on 18 May 2023 to kick-start the pilots.

For Phase 1, pilot participants were granted flexibility in determining the scope of features, technical design, and other design aspects of a hypothetical e-HKD for use in their pilots.

In this connection, participants were granted the option of using the e-HKD Sandbox. This sandbox is based on Project Aurum, and it was developed and launched by the HKMA in partnership with the Hong Kong Applied Science and Technology Research Institute (ASTRI).

It offers a technical environment to accelerate prototyping, development and testing, and is intended to enable participants to deep dive into their use cases, examine implementation and design issues relating to an e-HKD, and gain actual experience.

Participants also had the option of using the HKMA's Fintech Supervisory Sandbox (FSS). The FSS allows banks and their partnering technology firms to conduct pilot trials of their fintech initiatives involving a limited number of participating customers, without the need to achieve full compliance with the HKMA's supervisory requirements.

Whilst participants were granted flexibility by the HKMA in designing a hypothetical e-HKD for use in their pilots, their designs may not necessarily translate into the final design of an e-HKD, should it be issued. A number of relevant technical considerations are discussed in this report.

Figure 2 – Assessment Criteria for Use Cases



3 Case Studies: Potential Use Cases

Phase 1 of the e-HKD Pilot Programme took deep dives into potential use cases for an e-HKD in six categories, namely full-fledged payments, programmable payments, offline payments, tokenised deposits, settlement of Web3 transactions, and settlement of tokenised assets. This section discusses these potential use cases as proposed by pilot participants in the form of six case studies.

3.1 Overview

A total of 16 firms were selected to participate in Phase 1, conducting a total of 14 pilots across six categories (see Table 1)³. Details of each pilot may be found in the factsheets / supplementary reports prepared by pilot participants, accessible via the links in Appendix A.

Table 1 – Summary of Pilots by Category and Participant

Category	Pilot Participant(s)
(1) Full-Fledged Payments	The Hongkong and Shanghai Banking Corporation Limited
(2) Programmable Payments	Alipay Financial Services (HK) Limited ⁴ ARTA-Emali HK Limited Bank of China (Hong Kong) Limited China Construction Bank (Asia) Corporation Limited Hang Seng Bank Limited ⁴
(3) Offline Payments	Giesecke+Devrient Standard Chartered Bank (Hong Kong) Limited Industrial and Commercial Bank of China (Asia) Limited
(4) Tokenised Deposits	Hang Seng Bank Limited The Hongkong and Shanghai Banking Corporation Limited Visa Inc.
(5) Settlement of Web3 Transactions	Mastercard Asia/Pacific Pte. Ltd.
(6) Settlement of Tokenised Assets	Fubon Bank (Hong Kong) Limited Ripple Labs Inc. Boston Consulting Group HKT Payment Limited ZA Bank Limited

³ A number of pilots have evolved beyond their original category since the HKMA's announcement on 18 May 2023 and this has been reflected accordingly.

⁴ AlipayHK and Hang Seng Bank have each conducted two pilots under the category of "Programmable Payments".

3.2 Case Studies

This section discusses the potential use cases for an e-HKD as proposed by pilot participants in the form of six case studies. These pilots are neither indicative nor definitive of the functionality, architecture or positioning of an e-HKD, should it be issued. These use cases are only intended to facilitate the HKMA and the industry in evaluating the commercial viability of an e-HKD. Furthermore, neither this report nor the pilots are conclusive of any resulting roles or responsibilities that different stakeholders (such as the HKMA and the Government of the Hong Kong Special Administrative Region (HKSAR Government)) may take up in implementing and operating an e-HKD, should it be issued.

Case Study 1: Full-Fledged Payments

Physical cash is the only type of central bank money available to the general public today. An e-HKD would be a new form of central bank money and akin to a “digital cash”, preserving the same characteristics as physical cash such as negligible transaction cost and instantaneous settlement finality. An e-HKD would also serve as a full-fledged payment alternative, enabling money to be stored and transferred in a similar manner to physical cash and other electronic means of payments (such as via the Faster Payment System (FPS), credit cards, and e-wallets).

In addition to these baseline characteristics, an e-HKD could potentially enable payments to be settled in a cost and time-efficient manner by bypassing intermediaries typically involved in an electronic payment flow. Currently, merchants may not receive funds in real-time, and may also be exposed to reconciliation errors in the event of erroneous transactions. This is often due to a

lengthy payment chain and the use of net settlement for card networks and similar solutions (for instance, settling once a day at day-end).

HSBC explored in their pilot the use of a private blockchain⁵ network to transact hypothetical e-HKD between consumers and merchants, with the objective of testing instant, final settlement at a transaction level. This can remove the need for frequent liquidity management payments for settlement purposes. Through this network, both consumers and merchants would be able to bypass today’s intermediaries to enjoy a quicker and more efficient settlement process, as well as potentially lower transaction costs.

Case Study 2: Programmable Payments

Programmable payments allow conditions to be imposed to govern when and how payments should be initiated. Such conditions are typically implemented through the use of a smart contract⁶ in conjunction with application programming interfaces (APIs)⁷. Programmable payments are not new and are already used to facilitate direct debit and recurring payments. However, in their current form, they only support simple and unidirectional payments (such as bill payments⁸) which are triggered regardless of whether the underlying service has been provided.

In contrast, smart contracts enable consumers and businesses (such as merchants) to directly embed instructions into an electronic contract to initiate payments once pre-defined conditions are fulfilled. These conditions could include the amount to be paid and the frequency of payments in relation to the level of service provided. Smart contracts also allow for the multidirectional

⁵ **Blockchain** is a type of **distributed ledger technology (DLT)**. DLT refers to a technology architecture where a ledger is replicated across multiple entities, allowing records to be simultaneously accessed, validated and updated.

⁶ A **smart contract** refers to an agreement between participants where the terms, predetermined conditions and outcomes have been coded into a computer program, enabling the agreement and its associated outcomes to be automatically executed when certain conditions have been met.

⁷ An **API** is a software interface enabling two or more programs (which may be running on the same or different systems) to communicate with each other.

⁸ When a customer instructs their bank to make a recurring payment, the bank programs related conditions (such as the frequency of payments) into their own system, which then initiates the payments as specified. The resulting payments do not contain these conditions.

exchange of information on whether the said conditions have been fulfilled. This could enable the release of a payment to be automatically performed once the consumer has electronically acknowledged receipt of a service.

Programmability Concepts

“Programmable payments” are often explored by central banks in conjunction with the concept of “programmable money” for two different means of implementation. Both of these concepts fall under the umbrella of “programmability”, which generally refers to the ability of a software application or hardware device to accept and execute a set of code. However, in the context of payments and related concepts, “programmability” is considered ill-defined.

In programmable payments, the money that is transferred merely serves as a form of value. Although such payments are only initiated as a result of fulfilling certain pre-defined conditions, there are no restrictions imposed on how the money can be spent. This also means that the integrity of a payment can be compromised if there are issues like loss, fraud or errors at the point of initiation. This is in line with how physical cash and electronic payments work today, where physical and electronic controls are typically implemented to control access to money, but the money can generally be used for any purpose as long as it is in one’s possession.

In contrast, programmable money involves embedding the pre-defined conditions into the money itself, meaning that it will retain its pre-defined conditions regardless of who it is transferred to. Typically, these pre-defined conditions are used to restrict how the money can be spent. An analogy is a store-purchased voucher that can only be used on certain goods within the store, regardless of who is holding the voucher.

Whilst this characteristic of embedding in programmable money can be operationally beneficial, a programmable money may potentially undermine the public’s trust in the legal tender. Given the restrictions on how and when it can be spent, it could be considered less valuable compared to other forms of money such as physical cash. Furthermore, it may not be easily transferrable into a less restricted form of money. The topic of what constitutes programmable money as well as whether central banks should issue programmable money is a controversial one, and entails legal issues which will require further study⁹.

With this in consideration, a programmable e-HKD¹⁰ incorporating smart contract functionality could unlock new modes of business transactions between consumers and businesses, and encourage wider adoption of conditional settlements for retail payments. Conventional payment systems currently lack functionality to allow for this level of programmability at scale, particularly in the retail space. In the institutional space, escrows¹¹ enable complex transactions to be performed in accordance with pre-agreed conditions, but they entail substantial overhead and complexity since the escrow agent has to manually validate each condition and effect the resulting actions and payments.

Consumer Protections

A programmable e-HKD could improve consumer protections and promote trust between consumers and businesses by leveraging the rich functionality of smart contracts.

In Hong Kong, smaller merchants tend to prefer cash in advance for goods/services, as it benefits the merchant in terms of cash flow. However, this exposes the consumer to the risk of losing their funds, or the risk of the merchant not delivering the promised goods/services (such as in the event of bankruptcy or merchant malpractice).

⁹ Although this case study is titled “Programmable Payments”, this report does not distinguish whether a given pilot makes use of a hypothetical e-HKD as a programmable payment or a programmable money (along with any other related concepts). It also does not indicate or conclude which concept may apply to an e-HKD.

¹⁰ The term “programmable e-HKD” applies solely in the context of this report, and refers to a hypothetical e-HKD incorporating programmability features.

¹¹ An **escrow** is where a trusted agent to one or more parties to a transaction holds assets (such as funds and securities) and only releases them when conditions have been met.

In this regard, a programmable e-HKD could offer an option for consumers to make phased payments for goods/services and to safeguard their funds.

(1) **China Construction Bank (Asia) (CCB (Asia))** and (2) **Bank of China (Hong Kong)** explored in their pilots the viability of a “retail escrow” product using a hypothetical e-HKD for holding consumer prepayments towards the purchase of a good or service (see Figure 3). An e-HKD could enable escrow to be scaled as no agent is needed to manually perform validation and payment release. After the consumer has prepaid their funds, the funds can be held in escrow and disbursed automatically to the business only when the conditions have been satisfied.

This creates an incentive for the business to maintain a good level of service and build strong initial consumer trust, as they have yet to receive the funds (but they can ascertain the consumer has paid). This in turn means that in the event of a business default, the consumer is no longer exposed to the risk of losing their funds.

CCB (Asia) also explored the use of a hypothetical e-HKD for subscriptions which operate in a similar manner to prepayments where instead of an upfront prepayment, a recurring amount is disbursed to the business with the option of triggering a refund mechanism as needed.

Whilst some businesses may view escrows to be operationally intensive, willing businesses may use this to demonstrate integrity and differentiate themselves from other businesses to attract potential business (especially when the business is building initial consumer trust). However, without the benefits of advanced cash flows, merchants may have to adjust their pricing or financing models.

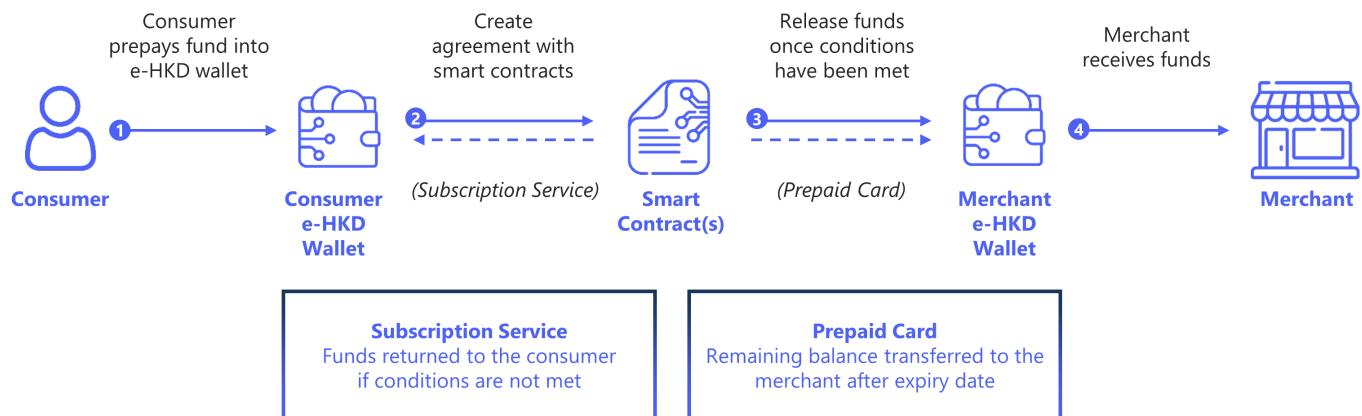
Loyalty Programmes and Targeted Spending

A programmable e-HKD could enable merchants to elevate their loyalty programmes, obtain better consumer insights, and enhance their targeted marketing spending.

The current retail payment ecosystem places the onus of building, tracking and executing programmes solely on the merchant, requiring them to either engage a service provider to integrate these services into their payment channels, or dedicate operational and technical resources to manually apply discounts and track rewards for each transaction. Larger merchants are, as a result, at an advantage as they benefit from economies of scale in terms of consumer insights, resources and tools to determine how to best deploy their programmes.

A programmable e-HKD could level the playing field for smaller merchants by providing low-cost access to similar capabilities, such as the automatic

Figure 3 – Prepayment and Subscription using e-HKD



dispensing and acceptance of rewards at the time of sale. This streamlines the consumers' experience when making payments, encouraging loyalty and repeat business whilst freeing up operational resources on the part of merchants. In addition, an e-HKD could embed useful consumer identifiers allowing merchants to better allocate targeted spending to attract their intended consumers. However, such new functionalities would require businesses to have certain technical competence in creating and maintaining the programme codes. New infrastructure may also be needed (for instance, to onboard and categorise merchants).

(1) **Hang Seng Bank**, (2) **HSBC¹²** and (3) **AlipayHK** explored in their pilots the viability of a low-cost alternative for merchants of all sizes to build and execute their loyalty programmes using a hypothetical e-HKD. Through the use of smart contracts, merchants of all sizes can offer discount and reward programmes to consumers without additional ongoing effort in managing these programmes, with the option of automatically applying discounts at the time of sale. This in turn enables merchants to dedicate resources to programme optimisation instead of execution. An e-HKD being common to financial institutions could also enable merchants to target first-time consumers more accurately and cost-effectively irrespective of the payment channel or financial institution used.

Investments

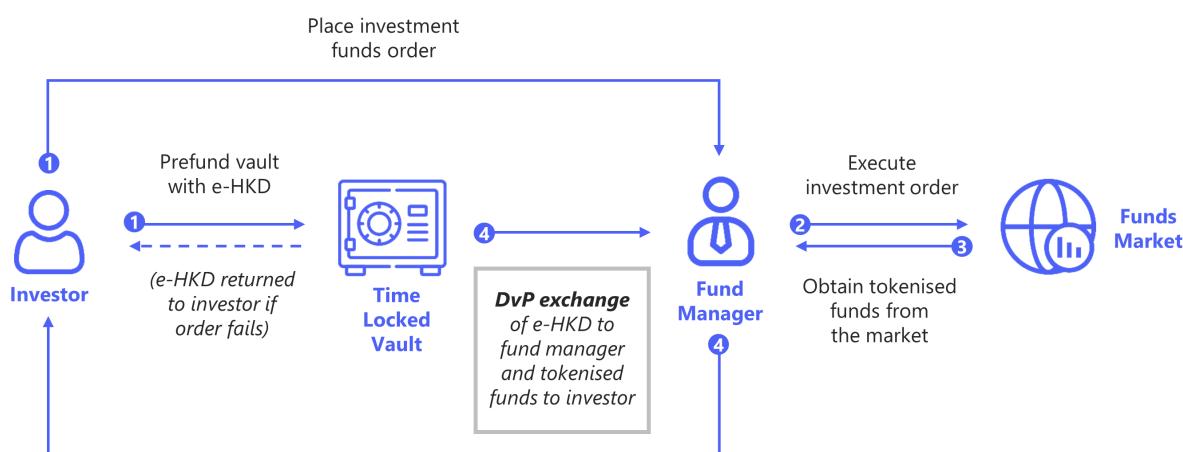
A programmable e-HKD could enable investors to enjoy a faster turnaround and a closer to real-time market price when subscribing to investment funds.

Investors typically complete a number of processes when subscribing to a fund such as checks, pre-funding, and order placement and settlement. The process today of fulfilling investment fund orders is not instantaneous, as the fund manager is only obligated to fulfil the order by day-end after receiving the investor's prefunding. As a result, pre-fulfilment steps such as obtaining a market price for the fund may not be performed instantaneously.

ARTA-Emali explored in their pilot the atomic settlement of a fund order using a hypothetical e-HKD, and the ability to integrate operational processes involving upstream and downstream investment intermediaries (for instance, placing agents, fund managers, fund administrators) in a straight-through manner through the use of smart contracts (see Figure 4). The pilot also explored the integration of investors' credentials with the smart contract using decentralised identities, in order to further streamline onboarding processes prior to the fulfilment of an order.

Shortly after an investor initiates a fund investment order, their e-HKD is escrowed in a smart contract-based vault. The e-HKD is only released to the fund manager when the fund manager delivers the tokenised funds to the investor.

Figure 4 – Fund Investment using e-HKD



¹² This is a continuation of their pilot in Case Study 1.

An e-HKD has the potential from a technical viewpoint to unlock new ways of transacting, integrating payment processes, and mitigating risk for both consumers and businesses, in turn enabling businesses to focus on product innovation rather than execution.

Under this delivery versus payment (DvP) model, the fund manager is exposed to less risk as they have the knowledge and confidence that the investor has already prefunded their order. The fund manager also has an incentive to obtain the market price and satisfy the order as quickly as possible to receive the investor's funds. This mode of straight-through atomic settlement can reduce operational overhead. The investor in turn can enjoy faster order execution and a timelier entry to the market, allowing them to potentially benefit from an extra day of interest income, say with the purchase of a tokenised bond.

Fund Ring-fencing, Government Disbursements

A programmable e-HKD could embed fund ringfencing and tracking functionality, enabling funds with designated spending conditions to be safekept, spent and tracked without requiring the funds to be confined to a single commercial payment channel. This can be of use where the issuer of a given set of funds may not have a particular affiliation with a commercial payment channel, for instance, the government in issuing subsidies, reimbursements and consumption vouchers to the public. Payment recipients would nevertheless still have their own e-HKD wallet.

There are few options today to facilitate fund ringfencing and tracking without resorting to single payment channels or dedicated agents (such as for the escrow product). One such option is to disburse the funds to stored value facility (SVF) operators, who then configure their platforms to restrict how the funds can be spent on their platforms. This is

operationally-intensive on the part of each SVF operator as they have to independently configure their platform to effect the intended use of the funds, and they will also need to reconcile the funds after it has been used by recipients.

Furthermore, merchants generally do not receive the funds in real-time via the SVF, and recipients of the funds are limited to the merchants available on the SVF that they have selected, without an easy option of switching their remaining vouchers to another platform.

(1) **AlipayHK** and (2) **Hang Seng Bank**¹³ explored in their pilots a more cost and operationally-efficient mechanism to disburse government subsidies using a hypothetical e-HKD. The government first programs the scope of distribution (such as the list of whitelisted merchants) and other relevant conditions into the smart contract, before tokenising and distributing the funds to designated parties for onward distribution to the intended subsidy recipients.

This streamlined process enables the issuer of the funds (being the government in these pilots), SVF operators (as the case may be) and merchants to lower their cost of implementation, and also enables merchants to receive funds in real-time as the smart contract configured by the government is updated in real-time when the voucher recipient spends the subsidy. This can enable both the government and subsidy recipients to enjoy greater visibility of their use of funds, whether at the programme or individual level.

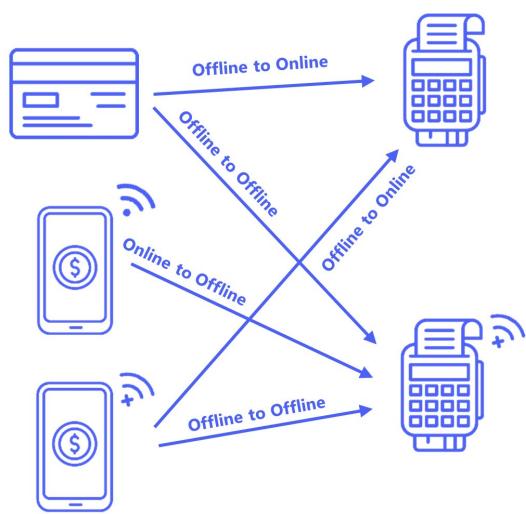
¹³ This is a continuation of their pilot in Case Study 2, Loyalty Programmes and Targeted Spending.

Case Study 3: Offline Payments

In-person transactions settled through electronic means of payments in real-time generally require network connectivity. Despite high cellular network penetration in Hong Kong, an intermittent or lack of network connectivity in some situations could prevent the use of an electronic means of payment which relies on real-time validation (such as a payment terminal supporting settlement using a credit card or mobile wallet). This can ultimately impact the customer experience and transaction. This also applies to consumer-business transactions and peer-to-peer transactions.

Similarly, whilst smartphone penetration in Hong Kong has already reached 97% as of 2022, certain segments of the population may not have access to a smartphone, or prefer to conduct transactions in-person using cash. This could be the result of ingrained behaviours, a steep learning curve, or upfront and ongoing costs. This applies equally to businesses that may be reluctant or even unable to justify electronic means of payments, given that cash already satisfies their current needs by enabling them to settle in an intuitive and resilient manner.

Figure 5 – Offline Payments



Accordingly, whilst an e-HKD could serve the role of a "digital cash" as discussed in Case Study 1, it may not be the sole solution to overcome the inertia of some consumers and merchants in adopting electronic payments. Other factors could also dilute the value proposition of an e-HKD, like charging fees to create incentives for merchant acquirers and technical service providers (involved in using and supporting an e-HKD ecosystem).

(1) **Standard Chartered Bank (SCB)** and **Giesecke+Devrient (G+D)** and (2) **ICBC (Asia)** explored in their pilots the storage and transacting of e-HKD via physical and electronic mediums for transactions between consumers and businesses across offline and online contexts (see Figure 5). A hypothetical e-HKD is stored using secure elements within smartphone wallets and physical smart cards. This can then be transacted offline using proximity-based technologies such as near-field communications (NFC)¹⁴ with safeguards against double-spending¹⁵. These offline transactions are settled with finality and funds can be used immediately in subsequent offline transactions. This is in contrast to certain payment schemes where transactions are reconciled at day-end and netted for settlement later.

In **SCB** and **G+D**'s pilot, the mediums are designed to enable secure and consecutive dual offline payments¹⁶ in persistently offline settings. This allows for funds settled offline to be immediately available for use in subsequent offline transactions, with the flexibility of allowing offline payments to be synchronised online in a seamless manner when connectivity is available.

¹⁴ NFC allows for the contactless communication between devices over short distances and is often triggered by holding the NFC reader of two devices closely together.

¹⁵ This is enabled by cryptography, software and hardware-level protections. This **asynchronous characteristic** would typically be guarded against fraudulent transactions initiated by malicious actors by assigning a digital signature to each digital wallet owner (such signature being computationally infeasible for malicious actors to replicate). Each transaction would need to be digitally signed and validated before it can be posted onto an e-HKD digital wallet or network.

¹⁶ A **dual offline payment** is when both parties to the transaction are offline.

Tokenised deposits have the potential to transform transactions in terms of visibility and execution efficacy, by enabling transacting parties to integrate separate processes, stakeholders, and data points into a unified, end-to-end flow.

Case Study 4: Tokenised Deposits

"Tokenised deposits" is a developing area relating to tokenisation¹⁷. It currently does not have a universal industry definition or standard, but is generally understood to refer to digital representations of bank deposits where money deposited with a bank is minted¹⁸ on that institution's own blockchain ledger with the backing of that financial institution's balance sheet¹⁹.

When a depositor transfers their tokenised deposits to another institution, the institution can hypothetically make an interbank transfer using a wholesale CBDC (wCBDC) to the beneficiary's financial institution on the HKMA's ledger whilst simultaneously burning the token on their own ledger. Like bank deposits today, tokenised deposits are intended to be a claim on the relevant bank and not the central banking institution.

Whilst tokenised deposits and e-HKD are conceptually separate in terms of backing, and tokenised deposits may be issued without involving an e-HKD, this case study pools these together to examine how different tokenised deposit implementations could be integrated within the same ecosystem.

Tokenised deposit payments bear many similarities to today's processes in effecting interbank transfers. Nevertheless, they can facilitate financial institutions in enabling their consumers and business users to reconcile transactions faster and with greater transparency through richer, end-to-end integration across different systems. This is in contrast to existing payment processes and systems which may not provide the same level of end-to-end integration. Financial institutions and other intermediaries may also apply additional checks on payment receipts resulting in funds not being immediately credited to say, a business.

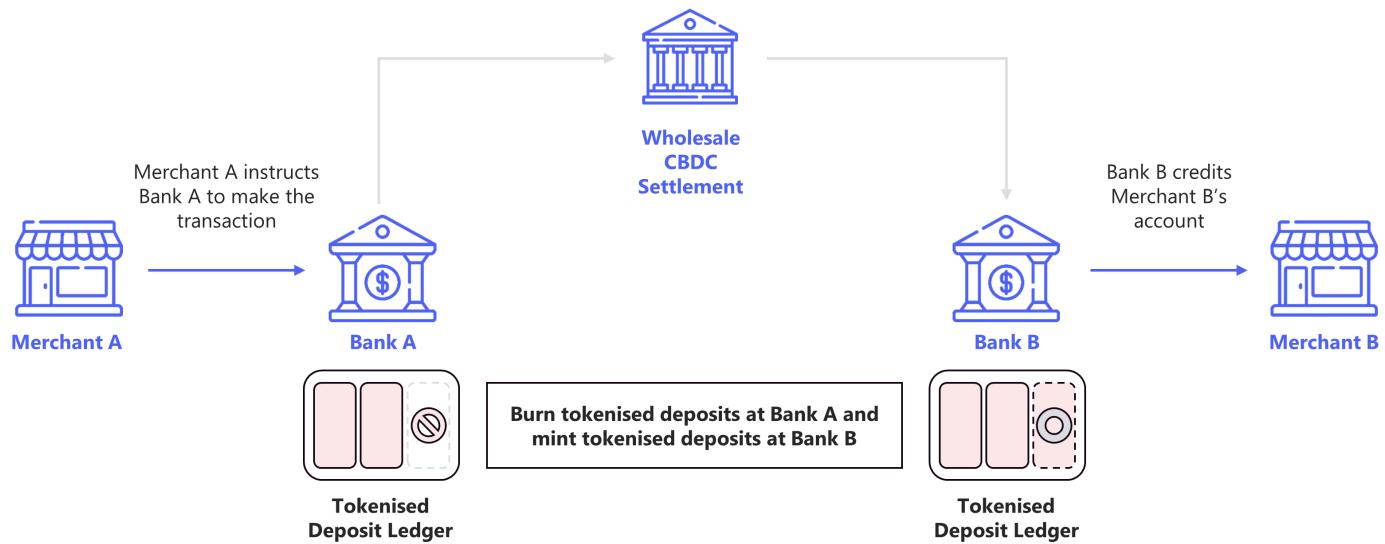
In addition, payments may not be supported post business hours or during the weekend. Transacting parties may also be required to manually track and complete costly reconciliations. As a result, transacting parties may incorporate additional processes to manage liquidity, reconcile flows based on different data sources, and prepare onward payment instructions for processing. These processes can unpredictably prolong the execution of a business transaction.

¹⁷ **Tokenisation** (in the context of blockchain technology) refers to the process of converting the ownership rights to an asset into a digital form.

¹⁸ **Minting** refers to the process of creating new tokens, whilst burning refers to the process of destroying existing ones.

¹⁹ The use of the term "**tokenised deposit**" and the characteristics described in this report in relation to a "tokenised deposit" apply solely in the context of the pilots described in this report, and are not intended to indicate or conclude what constitutes a "tokenised deposit".

Figure 6 – Tokenised Deposits with wCBDC Settlement



In a global first, **Visa** alongside **Hang Seng Bank** and **HSBC** explored in their pilot the atomicity and interoperability of on-us²⁰ and cross-chain payments across a variety of business scenarios using tokenised deposits (see Figure 6).

Where tokenised deposits are used in conjunction with a hypothetical wCBDC, transactions could potentially be settled around-the-clock and in an atomic manner from end to end. This represents an improvement compared to the limited availability of conventional payment systems²¹ and the variable number of dependencies imposed by intermediaries in further processing the transactions. This in turn improves liquidity management for the transacting parties because of reductions in settlement times and collateral usage, and enhances the overall level of transparency by allowing transacting parties to check the status of the transaction in real-time and identify pending transactions for follow-up.

The use of a global correspondent network built using distributed ledger technology (DLT) also opens the use of tokenised deposits beyond just payments. A programmable token for financial institutions to integrate into their own workflows

could also be useful for expanded intrabank use in the future such as intragroup liquidity management and accounting.

Case Study 5: Settlement Instructions for Web3

Web3 is the overarching theme for the next generation of the internet, with a focus on the concepts of decentralisation, tokenisation and blockchain-based platforms. It has led to the emergence of new types of transactions involving decentralised applications and digital assets such as non-fungible tokens (NFTs). Depending on the marketplace or exchange, many platforms may only accept “cryptocurrencies” and stablecoins which may not be readily accessible. Furthermore, off-chain funding arrangements via fiat may entail lengthy and complex processes.

In this regard, an e-HKD could act as a bridge between the conventional fiat economy and the new Web3 economy, and in turn promote the development and adoption of Web3. To facilitate this, an e-HKD could support direct integrations with decentralised applications and blockchain

²⁰ On-us refers to a payment where the initiating and receiving financial institution are the same and there is no interbank movement of funds. This is also referred to as a **book transfer**.

²¹ Excluding the FPS where retail peer-to-peer transactions are expected to be credited to the recipient in real-time.

networks, to allow for more seamless funding into and withdrawal out of Web3.

Mastercard explored in their pilot the “wrapping”²² of e-HKD for use on a non-native blockchain (see Figure 7), by simulating the purchase of physical items and the contingent exchange of NFTs (each representing a digital certificate of authenticity for the physical item) on a tokenised asset network. This network is a non-native blockchain from the perspective of the e-HKD.

The process of “wrapping” enables the value of the e-HKD to be safely used on such network by intended parties away from its native platform. In addition, the use of a smart contract also ensures that the payment is contingent on the successful delivery of the physical item.

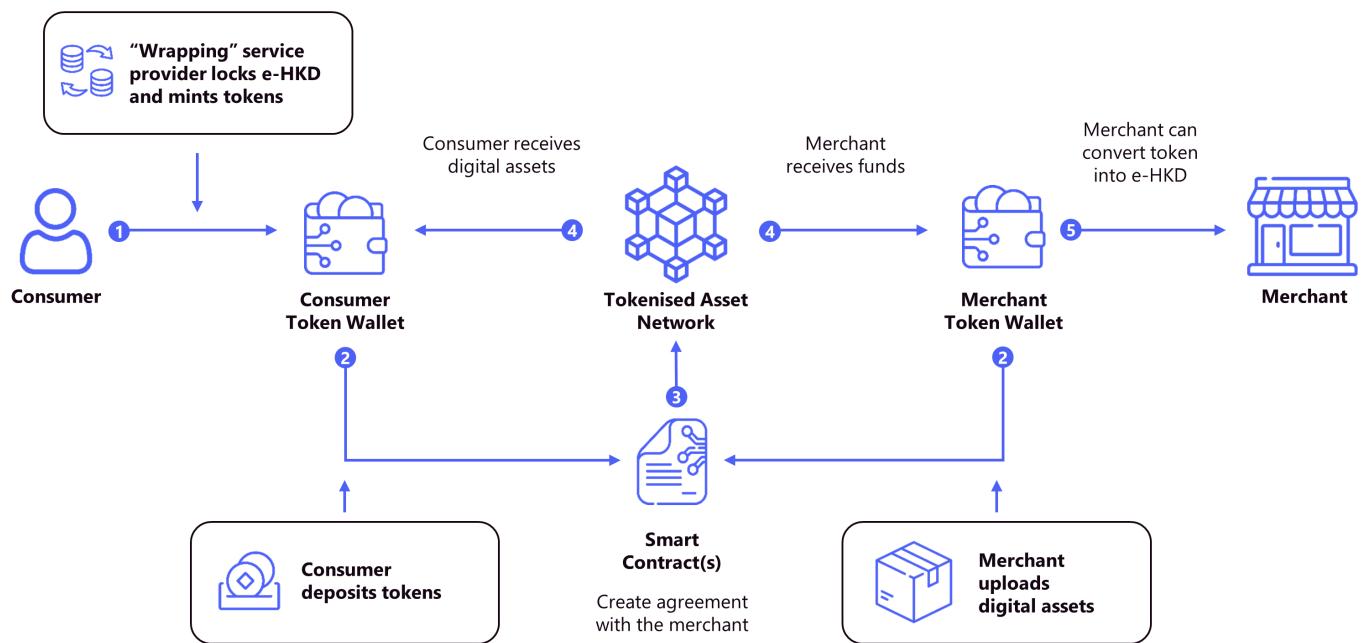
Case Study 6: Settlement of Tokenised Assets

Tokenisation has begun to make inroads into the conventional economy, with an increasing number of real world assets eligible for representation in a digital form.

Through tokenisation, asset owners may discover new buyers for their assets and be able to engage more than one buyer as a result of being able to fractionalise²³ their assets. In addition, potential buyers would have greater visibility into the details and transaction history of each asset, providing them with greater assurance and certainty. Tokenisation could also be used to represent legal rights to assets such as title deeds, although regulatory changes may be needed to facilitate this.

The market for tokenisation is still in its early stages, and there are many opportunities across asset classes which have yet to be realised. Where there is a business case, tokenisation has the potential to drive the next wave of economic activities.

Figure 7 – Settlement in Web3 using e-HKD



²² As blockchains may not always be interoperable, “wrapping” refers to the conversion process into a token for use on another blockchain. In Mastercard’s pilot, it is assumed that the e-HKD is based on blockchain architecture.

²³ **Fractionalisation** refers to the concept of dividing an asset into smaller units, where each unit represents a proportional ownership of the asset. This allows more than one person to benefit from the asset (in proportion to what they own).

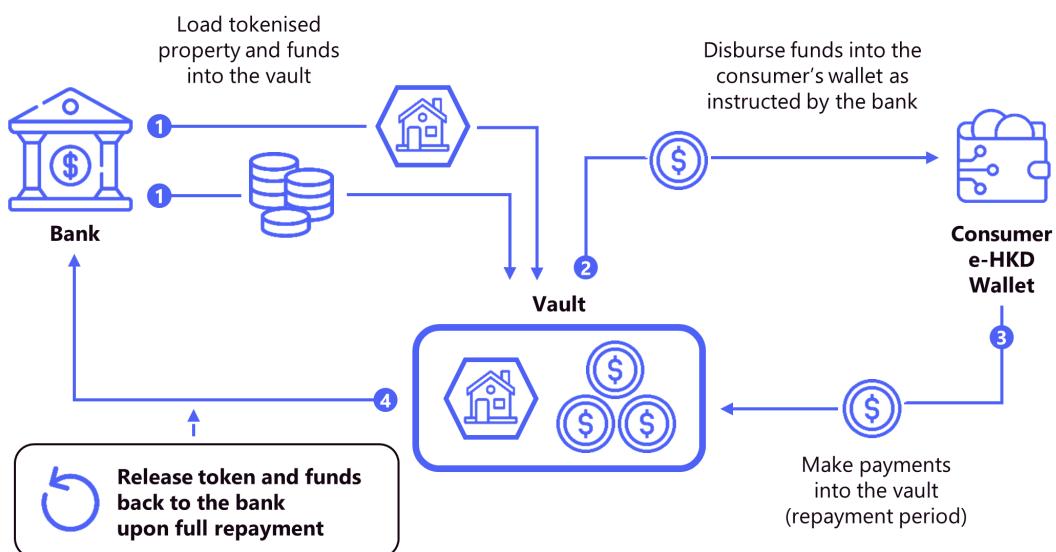
Fubon Bank and **Ripple** explored in their pilot the use of tokenised real estate assets²⁴ in granting a home equity line of credit (HELOC)²⁵ to a real estate owner using a hypothetical e-HKD (see Figure 8). When the lending protocol is triggered, property lien tokens are used as collateral by the bank in minting a residential mortgage loan, and the loan amount for drawdown is then credited to the owner in e-HKD. The process today is operationally-intensive for lenders and can span multiple systems. In this connection, the model of token-backed lending could enable lenders to provide a more efficient service to potential real estate owners to realise additional liquidity, which can in turn encourage uptake of such facilities.

In a similar vein, **BCG, HKT Payment Limited** and **ZA Bank** explored in their pilot the tokenisation of pledging rights to an asset, and the feasibility of developing a token-backed secured loan. The transaction is settled using a hypothetical e-HKD, and the funds are ringfenced for the pre-

agreed purposes. By tokenising and fractionalising such rights, borrowers may borrow from more than one lender (akin to a “retail syndication loan”²⁶) at different interest rates. Borrowers may also be able to obtain secured lending for smaller nominal amounts than if they were to borrow from a single lender. In essence, tokenisation could enable borrowers to access different lending options and terms. This could also create a market for smaller property-backed loans that banks would not typically entertain. In addition, this model of token-backed lending could apply to other asset classes, unlocking liquidity for a range of assets.

Furthermore, it is currently difficult for lenders to enforce how loan proceeds are spent after their disbursement. Given that a programmable e-HKD could facilitate ringfencing of the proceeds, lenders may be able to offer more competitive interest rates for loans issued using an e-HKD, as they would be less exposed to the risk of the loan proceeds being used for prohibited purposes.

Figure 8 – Tokenisation of Real Estate Assets



²⁴ In Fubon Bank and Ripple’s initial implementation for their pilot, the tokens represent the property liens for the real estate.

²⁵ A HELOC is a credit facility extended to a real estate owner allowing them to borrow against (or draw down from) excess equity in their property.

²⁶ Syndication loans are typical for large value institutional transactions due to the interest of multiple parties in financing the loan, but are less common in the retail space.



4 Evaluation

This section sets out the HKMA’s overall assessment of the potential use cases for an e-HKD and related technical considerations following Phase 1 of the e-HKD Pilot Programme.

4.1 Pilot Feedback and Assessment

Hong Kong’s retail payment ecosystem currently provides consumers and businesses with a wide range of means to make and receive payments, and this is enabled by well-established, well-connected and robust financial infrastructure such as the Faster Payment System (FPS). With this in consideration, an e-HKD would need to provide additional unique value to the current retail payment ecosystem to substantiate the case for its issuance, such as applications which can only be supported by an e-HKD.

There are also settlement inefficiencies today which are the result of longstanding business norms and processes, rather than deficiencies in technology. These inefficiencies will need to be addressed to realise the full potential of new technologies, and cannot be solved solely by issuing an e-HKD, despite the technical benefits that it may bring.

Based on the learnings and feedback from pilot participants, including those from users involved during the pilots, Phase 1 of the e-HKD Pilot Programme uncovered three key areas where an e-HKD could add unique value to consumers and businesses and address their evolving and future needs. These are: programmability, tokenisation, and atomic settlement.

It should, however, be noted that the realisation of such unique value in the pilots may have been made possible by the presumed existence of the relevant prerequisites, such as the readiness of other participants and supporting arrangements in the ecosystem. However, the potential for realising

such unique value at scale to substantiate the issuance of an e-HKD would very much depend on the pace of relevant developments in the retail payment ecosystem, and accordingly would be subject to further investigation.

4.1.1 Programmability

Programmability generally refers to the ability of a software application or hardware device to accept and execute a set of code. As this term is considered ill-defined in the context of payments and related concepts, the term “programmable e-HKD” is used solely in the context of this report to refer to a hypothetical e-HKD incorporating programmability features.

Wider adoption of retail conditional settlements

A programmable e-HKD could unlock new types of transactions for consumers and businesses, by facilitating the wider adoption of conditional settlements for retail transactions. This could create mutual incentives for transacting parties to complete the transaction in a timelier manner, which could be useful for certain interactions where consumers are used to paying in advance.

An e-HKD could also facilitate “open-loop system” conditional settlements, where related payment conditions can apply regardless of the means used to make the payment. This means transacting parties can benefit from conditional settlements without the limitation of having to use the same means of payment²⁷.

²⁷ In contrast, “closed-loop systems” would require transacting parties to use the same means of payment.

In the “Consumer Protections” pilots (under Case Study 2, Programmable Payments), a scalable, “retail escrow” prepayment product facilitating conditional settlements with e-HKD could incentivise businesses to provide good, consistent service from the outset to build trust with consumers, whilst providing consumers with the confidence to engage with businesses in the absence of initial trust. The business also provides the good or service with the confidence that the consumer has already made or can make payment.

In one set of surveys²⁸, 93% of consumers responded that conditional prepayments with e-HKD could alleviate their concerns of losing their money as a result of a merchant going bankrupt, whilst 70% of merchants responded that conditional prepayments with e-HKD would help build loyalty.

In the “Investments” pilots (under Case Study 2, Programmable Payments), the investor benefits from faster order fulfilment as the fund manager has an incentive to fulfil the investment fund order as soon as possible to receive the investor’s prefunding. The fund manager is also incentivised to facilitate conditional settlements as the unified process enables them to incur less operational overhead and risk.

In this connection, surveyed financial institutions²⁹ viewed that the benefits of atomic delivery versus payment settlements, and reduced settlement and counterparty risk were attractive factors supporting this mode of conditional settlements using e-HKD.

Level playing field for businesses

A programmable e-HKD has the potential to level the playing field for businesses, by allowing businesses of all sizes to integrate and automate payment-related processes, as well as to develop and provide goods or services with a greater degree of customisation and flexibility. This could benefit small businesses in particular (which may be limited by financial, operational or technical resources),

by providing them with more means to attract new consumer segments and build consumer rapport.

Furthermore, an e-HKD could facilitate “open-loop system” conditional settlements, enabling customisations to be applied regardless of the means used to make the payment. For instance, consumers would be able to spend vouchers issued by merchants without the limitation of having to use a specific e-wallet. With that said, the process of implementing programmability will likely require some technical expertise, and businesses will either need to possess this expertise themselves or partner with a financial institution or technology partner that can assist with implementation.

In the “Loyalty Programmes and Targeted Spending” pilots (under Case Study 2, Programmable Payments), a low-cost alternative using a hypothetical e-HKD could enable merchants of all sizes to build and execute their loyalty programmes. One benefit of note was the potential of an e-HKD to automate the issuance, tracking and reconciliation of vouchers and rewards. During one pilot’s testing³⁰, both consumers and merchants found the mechanism to automatically apply rewards to consumers’ transactions easy to use. Merchants also noted that its low cost and ability to implement sophisticated and frequent promotions were attractive features. In another survey, 80% of respondents³¹ had a favourable view towards programmability being a unique feature of an e-HKD, should it be issued.

Flexibility in ringfencing and tracking funds

Last but not least, a programmable e-HKD could enable the ringfencing and tracking of funds to be achieved with greater ease and less operational overhead. Instead of distributing funds to, for instance, stored value facilities (SVFs) which then configure the restrictions on their platforms, the intended use of the funds could be programmed from the outset to govern how it can be spent irrespective of the payment platform. This could also enable the funds to be used across different payment platforms, rather than being limited to a

²⁸ Survey sample: 110 consumers and 10 merchants

²⁹ Survey sample: 12 financial institutions and a small population of investors

³⁰ The pilot involved around 150 individual participants, five merchants, and 400+ transactions

³¹ The pilot involved over 150 individual participants, seven merchants, and 500+ transactions

single payment platform. In a pilot exploring the ringfencing of loan proceeds (under Case Study 6, Settlement of Tokenised Assets), around 60% of surveyed consumers showed interest in loans with ringfenced proceeds, if it came with incentives such as a lower interest rate.

Programmability at scale

Whilst programmability brings about a number of commercial merits, it will be important to consider how programmability at scale can be achieved. This refers to the process of creating an ecosystem with the necessary infrastructure so that businesses are equipped with the right incentives, resources and expertise to make the most of programmability.

It may be worthwhile to consider developing a repository of smart contract templates for common business activities. Technical frameworks, such as cross-system protocols and standards for identifying merchants, would also need to be developed in collaboration with the industry. Furthermore, a holistic review of how an e-HKD could look and feel for the average consumer would be important for consumer adoption.

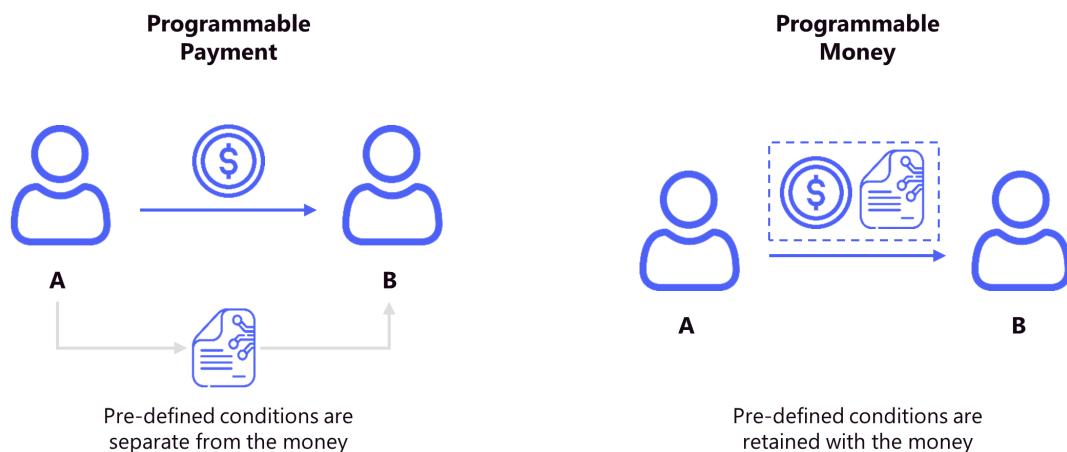
This may involve identifying and specifying core programmability functions that should be provided to consumers via, for instance, their e-wallet's smartphone application. This work could serve as a

crucial foundation to accelerate industry-wide innovation, and facilitate interoperability between different implementations of programmability in the future. Similar work could also be done in the other key areas of tokenisation and atomic settlement as discussed in later sections.

In addition, careful consideration should be given to how the concepts of programmable payments, programmable money (see Figure 9), or perhaps an extension of these concepts would apply to an e-HKD, should it be issued with programmable features. As discussed in an earlier section, an e-HKD issued as a programmable money could run the risk of undermining the public's trust in the legal tender and in turn, affect monetary and financial stability.

The question of whether and how central banks should implement certain programmability features at the time of issuing an rCBDC will also require deliberation, as different features will entail different levels of risk. For instance, an rCBDC issued as a programmable money may be more susceptible to cybersecurity risks, as it may present more mediums for external threats to inject malicious code. A delicate balance will therefore need to be struck between facilitating the industry's development of innovative products and services, and ensuring the overall safety of monetary and financial systems.

Figure 9 – Programmable Payments and Programmable Money



4.1.2 Tokenisation

Tokenisation (in the context of blockchain technology) refers to the process of converting the ownership rights to an asset into a digital form³². It has gained popularity in recent years, particularly in the space of Web3 and real world assets. When applied appropriately, tokenisation could enable asset owners to access marketplaces with increased liquidity, efficiency, and transparency compared to conventional marketplaces. Tokenisation is also used by financial institutions in minting tokenised deposits, which are generally understood to refer to digital representations of bank deposits.

Backbone for Web3 transactions

An e-HKD, were it to be “wrapped” or even issued on a blockchain, could be used to directly settle transactions relating to Web3 and tokenised real world assets. In this connection, an e-HKD could eliminate the risk of conversion losses and volatility associated with “cryptocurrencies” and stablecoins³³. This is particularly relevant in Web3, where “cryptocurrencies”, stablecoins and off-chain arrangements are typically used for marketplace transactions with no readily available option to transact, say, using a HKD. In a small-scale survey conducted with digital natives as part of the “Settlement of Web3 Transactions” case study, 65% of respondents indicated a strong interest in using rCBDCs for settling Web3 transactions.

The Government of the Hong Kong Special Administrative Region (HKSAR Government) issued a Policy Statement on Development of Virtual Assets in Hong Kong in October 2022, noting that an e-HKD could serve as a potential “backbone” and anchor to bridge legal tender and virtual assets³⁴. Nevertheless, even with these benefits in mind, businesses will still need to evaluate the

marginal cost of supporting these new types of transactions.

Central banks have also continued their study and work on potential applications for tokenisation, as the range of assets eligible for tokenisation continues to expand. In February 2023, the HKMA supported the HKSAR Government in issuing the world’s first tokenised government green bond, and published a report in August 2023 to share the experience of the issuance with a view to providing a blueprint to market participants interested in issuing tokenised bonds in Hong Kong. The report also outlined potential next steps to promote the wider use of tokenisation technology in Hong Kong’s bond market³⁵.

Wider development of token-based systems

As for tokenised real world assets, an e-HKD has the potential to enable access to increased liquidity and accelerate the development of innovative token-based systems within the industry. This could lead to more integrated and faster ways of conducting core business activities. In one pilot relating to tokenised real estate assets, a hypothetical e-HKD was shown to enable faster approval of loans and consequently real-time, around-the-clock availability, and automatic disbursement of funds. These industry-wide developments could serve as an impetus for businesses to revisit longstanding norms and processes, and address non-technical inefficiencies as part of readying their business to adopt new technologies to their full potential.

These efficiencies could also be achieved in conjunction with tokenised deposits, which have the potential to bridge different chains, systems and applications. Although tokenised deposits and e-HKD are separate concepts, private sector innovations and developments relating to an

³² It is unlikely an e-HKD would be considered a token should it be issued, given it should have the same status as a “digital cash” instead of being a digital representation of another form of money.

³³ An e-HKD being an rCBDC would observe the **singleness of money**, where each e-HKD is always equal to a HKD and the underlying exchange rate between these two forms of money remains constant. In contrast, the value of stablecoins or “cryptocurrencies” is subject to fluctuations.

³⁴ Policy Statement on Development of Virtual Assets in Hong Kong (Government of the Hong Kong Special Administrative Region, 2022)

³⁵ Report on Bond Tokenisation in Hong Kong (Hong Kong Monetary Authority, 2023)

e-HKD could be beneficial to the development of tokenised deposits and other parts of the retail payment ecosystem in Hong Kong. For instance, these innovations could serve as reference for financial institutions when designing their own mechanisms for tokenising deposits, which could help promote interoperability in the future. A wholesale CBDC (wCBDC) layer could also be established to facilitate interbank settlements.

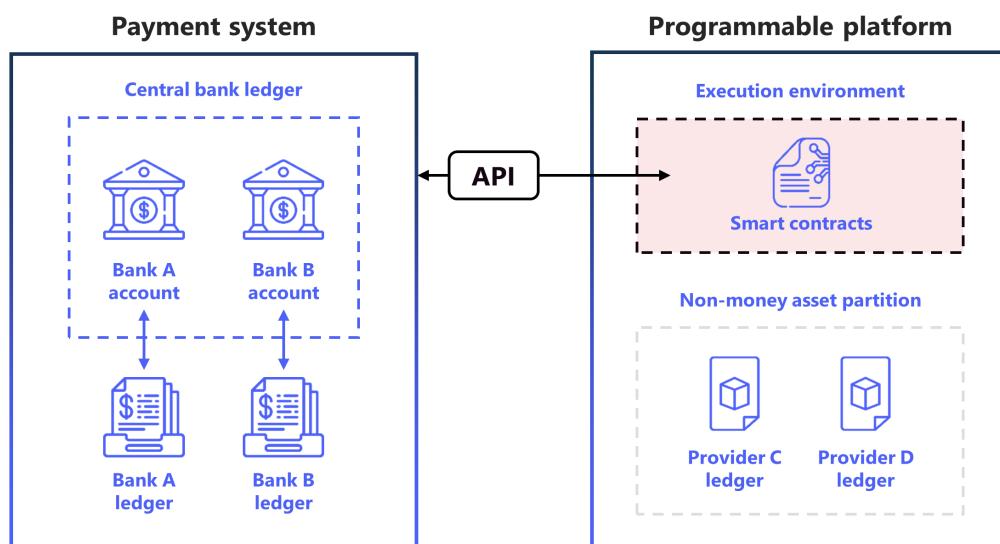
In addition, an e-HKD could be used in a “unified ledger”, a concept explored in greater detail by the Bank for International Settlements³⁶ (see Figure 10), where sequences of financial transactions can be

automated and seamlessly integrated onto a common programmable platform that combines tokenised money and tokenised assets. A unified ledger established in conjunction with tokenised deposits and a wCBDC layer could transform transactions in terms of visibility and execution efficacy, by enabling transacting parties to integrate separate processes, stakeholders and data points into a unified, end-to-end flow.

A comparison between an e-HKD, stablecoins, SVFs, and tokenised deposits is provided in Table 2 in the following pages.

Figure 10 – Models for Interoperability between Old and New Systems

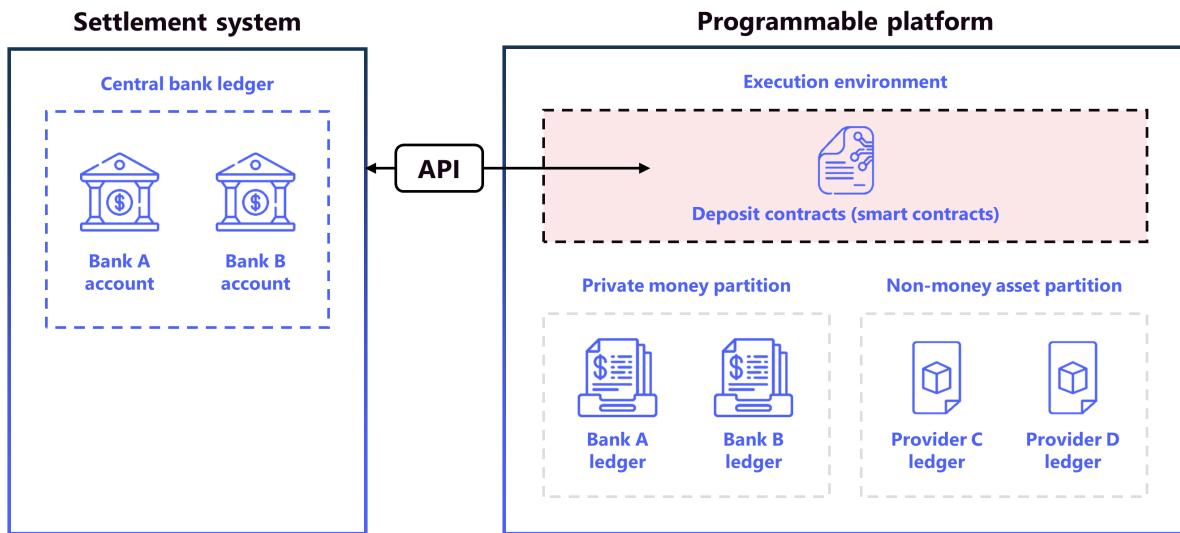
Payment messaging model



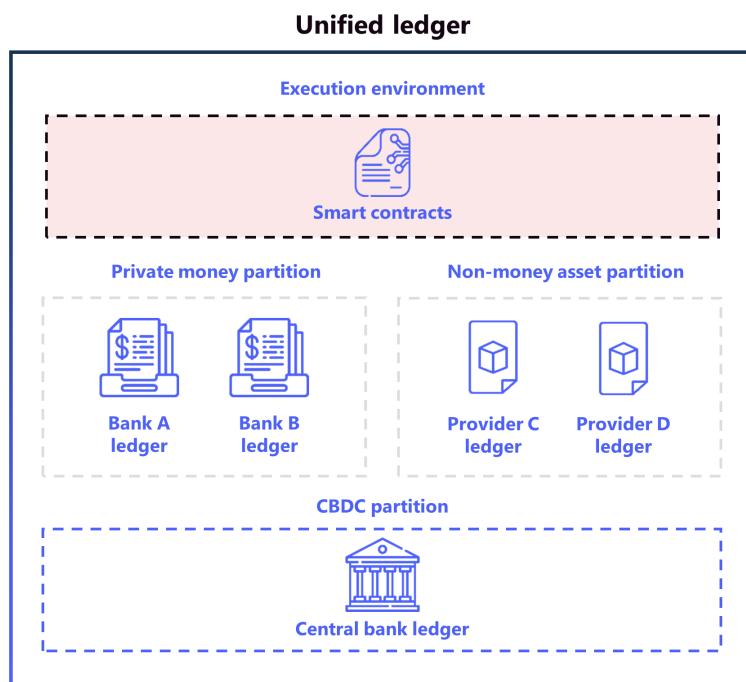
³⁶ III. Blueprint for the future monetary system: improving the old, enabling the new (Bank for International Settlements, 2023)

Figure 10 – Models for Interoperability between Old and New Systems (continued)

Private tokenised ledger model



Full-fledged unified ledger



Source: BIS

Table 2 – Comparison of e-HKD, Stablecoins, Stored Value Facilities and Tokenised Deposits

	e-HKD (rCBDC)	Stablecoins	Stored Value Facilities (SVFs)	Tokenised Deposits
Issuer	Statutory authority	Private, usually unregulated entities	Regulated entities registered with the HKMA	Authorized institutions under the Banking Ordinance
Backing	Central bank's statutory authority	Generally 100% asset-backed by fiat currencies or other cryptocurrencies	User float is fully segregated from funds of operators and protected against claims by other creditors of SVF issuers in all circumstances per supervisory requirements	Commercial bank balance sheet fulfilling the appropriate liquidity coverage ratio (LCR)
Transferability	Any other user ready to receive it	Any other user on the network	Any other user on the platform, and also to users of other FPS participants	Any other accepted user on the network ready to receive it, and within the bank's KYC/AML risk appetite
Insurance	N/A	N/A	N/A	Generally protected by the Deposit Protection Scheme, unless otherwise excluded ³⁷
Redeemability	Legal tender, exchangeable for other forms of fiat	Generally redeemable for fiat money or tradeable to other users at market rate	Redeemable for fiat money from the issuer	Repayable in fiat money

Note: The characteristics relating to an e-HKD are not indicative and do not infer that an e-HKD will be issued. In addition, the characteristics relating to stablecoins and tokenised deposits are not definitive and should not be interpreted as such, given that they do not have a clear and legal and regulatory status in Hong Kong.

³⁷ Tokenised deposits should generally be protected by the Deposit Protection Scheme unless otherwise excluded (not all deposits are protected deposits).

4.1.3 Atomic settlement

Atomic settlement refers to the ability to settle transactions and exchange assets in a simultaneous, instant and contingent manner.

Last-mile payment processing

An e-HKD could work in conjunction with the current set of financial infrastructure to enable a wider audience of consumers and businesses to enjoy the benefits of atomic settlement across a greater range of transactions. This in turn could facilitate the adoption of electronic payments. Although Hong Kong's retail payment ecosystem currently provides consumers and businesses with a wide range of means to make and receive payments, the "last mile"³⁸ of payment processing in crediting funds to businesses may not always be conducted in real-time. This can deter businesses that have to closely manage their cash flows from taking up electronic means of payments.

The pain point of "last mile" payment processing is the result of business, operational and technical factors. Whilst new technologies can facilitate the development of faster, more efficient processes, there is a crucial need for business stakeholders and intermediaries to review and align their processes and operational norms. This is necessary to realise the full potential of efficiencies granted by new technologies. These norms are typically the result of past process optimisations (such as liquidity saving arrangements), or even certain

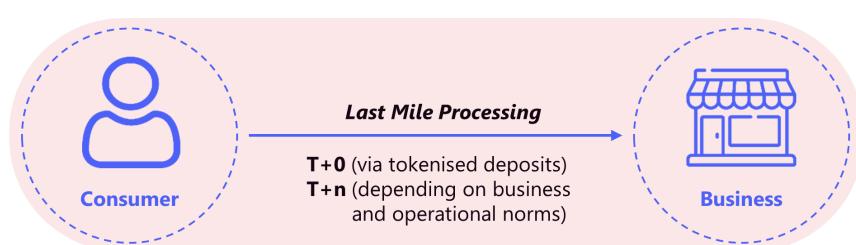
commercial interests. In this connection, new technologies could serve as an impetus for businesses to revisit longstanding norms and processes and address non-technical inefficiencies.

For instance, although the FPS enables real-time settlement for peer-to-peer transactions, external payment schemes such as credit cards may not credit funds instantaneously due to the way these schemes aggregate transactions for settlement. Financial institutions may also impose additional checks and holds on payments before crediting the funds to businesses, or process payments in batches instead of real-time.

In other words, the systems and financial infrastructure which payments are settled in may be real-time, but the intermediaries processing the payments may not be doing so in real-time. Businesses may also lack well-integrated systems and processes to support real-time settlement and reconciliation.

In addition, external payment schemes may entail a higher cost than the processing of physical cash, with processing fees subtracted by relevant intermediaries. These fees may deter businesses with thin operating margins – for example, a 3% interchange fee subtracted from a 10% margin before other costs is substantial.

Figure 11 – Last Mile Processing



³⁸ In the context of payments, the "**last mile**" refers to the final stages of the payment process where the funds are actually credited to the recipient (which may take place beyond a payment system such as the FPS).

Assuming that businesses are ready to support real-time settlements and reconciliations, the potential of an e-HKD in enabling atomic settlement can be observed in multiple pilots. In the “Full-Fledged Payments” case study, a hypothetical e-HKD powered by distributed ledger technology (DLT) not only could enable merchants to enjoy the benefits of real-time settlements with consumers (as already enabled by conventional payment systems), but it could also mitigate business inefficiencies occurring outside such systems to an extent by bypassing intermediaries typically involved in an electronic payment flow. Merchants may also enjoy lower transaction fees.

Surveyed merchants held a favourable view towards the e-HKD if it could enable intraday settlements, instead of “T+1” (a next day settlement benchmark generally expected of electronic payments) (see Figure 11). Merchants noted that this facilitated more efficient cash flow management, when say, making daily payments to suppliers.

In a similar vein, tokenised deposits could build on the current set of financial infrastructure, which already enable atomic settlements at the interbank level, and bridge settlements to achieve near-instant, more transparent and around-the-clock settlements. This assumes businesses and financial institutions are ready to support end-to-end, real-time settlements and reconciliations.

These settlements could also be conducted outside the operating hours of conventional payment systems. In comparison, last mile processing after real-time settlement in conventional payment systems took comparatively longer (measurable in hours) and were subject to fixed operating hours.

While these new means of payment could facilitate faster, more efficient settlements, it will be necessary to evaluate if the additional benefits presented could be sufficient to draw consumers and businesses from existing means of payment.

Adoption of offline payments

An e-HKD could address last mile pain points which may be amplified in offline settings, where consumers and merchants may lack perpetual access to an online network and are forced to handle settlements offline.

For instance, dual offline payments via an e-HKD could help facilitate atomic transactions across offline and online contexts, and enable an e-HKD to function as closely as possible to a “digital cash”. In a survey conducted under the “Offline Payments” case study³⁹, over 75% of consumer respondents had a favourable view towards an e-HKD incorporating offline functionality.

Should this be implemented, careful consideration should be given to the implementation of robust measures to safeguard users from the risk of fraudulent offline transactions.

³⁹ Survey sample: 32 consumers and 7 merchants. The pilot involved close to 200 individuals and more than ten merchants.

4.2 Technical Considerations: DLT Interoperability and Scalability

Whilst the focus of Phase 1 of the e-HKD Pilot Programme is on the commercial viability of potential use cases for an e-HKD, the HKMA considers it necessary to discuss DLTs, given its prevalence in the pilots under Phase 1.

DLT refers to a technology architecture where a ledger is replicated across multiple entities, allowing records to be simultaneously accessed, validated and updated. DLTs can be useful where a centralised ledger may be infeasible, such as in the absence of a central exchange or in the absence of mutual trust between transacting parties.

A DLT is neither a prerequisite for a CBDC nor an e-HKD, and the HKMA remains open-minded to both DLT or non-DLT based designs (see Figure 12). In this connection, it would be necessary to consider whether a DLT could support the intended scale, level of interoperability, and use cases without compromising performance, security or cost-effectiveness.

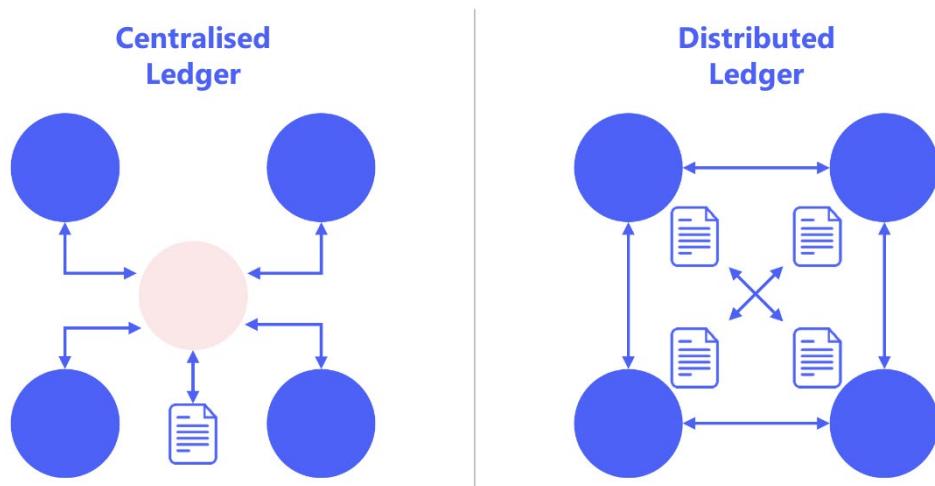
A DLT-based design could be better for future interoperability compared to a non-DLT one, as transacting entities are likely to share a common architecture. This could be useful, for instance, when integrating a wCBDC with each financial institution's tokenised deposits, where end-to-end integration and on-chain settlement are desired.

A DLT-based design could also enable easier development and study of digital currencies, as token standards relating to the issuance of DLT tokens (such as ERC20⁴⁰), DLT-related applications, documentation and academic research already exist in the public domain.

With that said, a DLT design may be less scalable in terms of transaction throughput. A non-DLT based design may also be easier and more cost-effective to run and govern as it is more aligned with today's conventional payment systems.

The HKMA will continue to examine different architectures for an rCBDC in conjunction with other collaborative work and projects with the Bank for International Settlements Innovation Hub (BISIH) and other central banks.

Figure 12 – Centralised Ledger versus Distributed Ledger



⁴⁰ Ethereum Request for Comments 20 (ERC20) is an Ethereum-based token standard proposed in 2015 that implements an API for tokens within smart contracts, enabling developers to build applications interoperable with other products and services.

5 Way Forward

This section sets out the next steps for the e-HKD Pilot Programme.

Phase 1 of the e-HKD Pilot Programme has provided valuable insights into the potential use cases of an e-HKD, and raised a number of research areas for future study.

One aspect requiring careful consideration is the positioning of an e-HKD in Hong Kong's monetary and financial systems. This includes understanding its role in facilitating new ways of transacting goods and services whilst ensuring banking, monetary and financial stability. It will also be necessary to study how an e-HKD would interoperate with conventional payment systems, and to identify areas where an e-HKD could complement the industry's own innovations such as tokenised deposits.

It is worth noting that launching an e-HKD will involve external factors beyond those covered in the pilots, given that the scale and testing environment of these pilots are substantially different from real world applications. While some of the benefits identified may remain valid for a full-scale deployment, this cannot be assumed to always be the case. Likewise, minor frictions identified during the pilots could become more apparent or even unacceptable to users in a production environment. These issues will need to be studied further before any decision is taken.

In a similar vein, it will be necessary to study how an e-HKD could compete in use cases where there are existing payment solutions, and to identify other crucial components in achieving and supporting mass adoption of an e-HKD such as the creation of a commercial network.

There is also a need to delve deeper into use cases in three key areas, namely programmability, tokenisation and atomic settlement. Continued partnership between the private and public sector will be important in establishing a way forward that ensures the commercial viability of an e-HKD. This may include establishing an optimal set of protocols, common infrastructure and policy. It will also be necessary to study distributed ledger technology (DLT) and related designs in detail given the industry's strong interest in this area.

The next phase of the e-HKD Pilot Programme will build on the success of Phase 1 and consider exploring new use cases for an e-HKD. It will also delve deeper into select pilots from Phase 1, with a view to further examining business and implementation issues identified during the pilots.

As part of its outreach, the HKMA will continue to actively engage the industry, academia and other stakeholders, as well as participate in international fora and monitor international developments on retail CBDCs. The HKMA will also continue its work under Rail 1 in laying the legal and technical foundations for an e-HKD in parallel.

Phase 1 of the e-HKD Pilot Programme has been strongly underpinned by the joint efforts, experience and talents of the pilot participants, academia and other stakeholders. The HKMA expresses its gratitude for the contributions it has received in the process, and will continue with its three-rail approach in preparing Hong Kong for the possible implementation of an e-HKD in the future.



6 References

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Appendix A: Factsheets / Supplementary Reports

Pilot Participant / Use Case	QR Code / Link	Pilot Participant / Use Case	QR Code / Link
Alipay Financial Services (HK) Limited Programmable Payments <i>Loyalty Programmes, Government Disbursements</i>	 Link	ARTA-Emali HK Limited Programmable Payments <i>Investments</i>	 Link
Bank of China (Hong Kong) Limited Programmable Payments <i>Prepayments</i>	 Link	China Construction Bank (Asia) Corporation Limited (CCB (Asia)) Programmable Payments <i>Prepayments, Subscriptions</i>	 Link
Fubon Bank (Hong Kong) Limited Ripple Labs Inc. Settlement of Tokenised Assets <i>Real Estate Asset Tokenisation</i>	 Link	Giesecke+Devrient (G+D) Standard Chartered Bank (Hong Kong) Limited (SCB) Offline Payments	 Link
Hang Seng Bank Limited Programmable Payments <i>Loyalty Programmes, Government Disbursements</i>	 Link	Hang Seng Bank Limited The Hongkong and Shanghai Banking Corporation Limited (HSBC) Visa Inc. Tokenised Deposits	 Link
The Hongkong and Shanghai Banking Corporation Limited (HSBC) Full-Fledged Payments Programmable Payments <i>Loyalty Programmes</i>	 Link	Industrial and Commercial Bank of China (Asia) Limited (ICBC (Asia)) Offline Payments	 Link
Mastercard Asia/Pacific Pte. Ltd. Settlement of Web3 Transactions	 Link	Boston Consulting Group (BCG) HKT Payment Limited ZA Bank Limited Settlement of Tokenised Assets <i>Token-Backed Secured Loan</i>	 Link

Note: Any positions or statements made in the above factsheets / supplementary reports as prepared by pilot participants do not necessarily represent the views of the HKMA. Furthermore, any characteristics described in the above factsheets / supplementary reports relating to an e-HKD are not indicative, and also do not infer that an e-HKD will be issued.

Appendix B: Glossary

Term	Definition
API	Application programming interface
ASTRI	Hong Kong Applied Science and Technology Research Institute
BIS	Bank for International Settlements
BISIH	Bank for International Settlements Innovation Hub
BISIH HKC	Bank for International Settlements Innovation Hub Hong Kong Centre
CBDC	Central Bank Digital Currency
rCBDC	Retail Central Bank Digital Currency
wCBDC	Wholesale Central Bank Digital Currency
DLT	Distributed ledger technology
DvP	Delivery versus payment
ERC20	Ethereum Request for Comments 20
FPS	Faster Payment System
FSS	Fintech Supervisory Sandbox (HKMA)
HELOC	House equity line of credit
HKD	Hong Kong dollar
HKMA	Hong Kong Monetary Authority
HKSAR	Hong Kong Special Administrative Region
NFC	Near-field communications
NFT	Non-fungible token
SVF	Stored value facility

Note: Definitions where provided are solely for indicative purposes in the context of this report, and should not be interpreted as definitive or conclusive given that they may evolve over time.

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