Institute
and Faculty
of Actuaries

An Addendum to

A Cashless Society- Benefits, Risks and Issues (Interim Paper)

by J Chan

The Rise and Rise of Quick Response Codes

January 2019

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Abstract

This paper is an addendum to the interim report, “Cashless Society- Benefits Risks and Issues”, published by the Cashless Society Working Party and sponsored by the Finance & Investment board at the IFoA, in December 2017. In the process of researching into the various aspects of a cashless society, Quick Response codes (QR codes) featured as a popular and widely adopted technology as part of the digital economy and payment system.

This paper seeks to understand the phenomenal rise of QR codes use by:

- explaining the historical development of QR codes;
- exploring the reasons why QR codes have become popular;
- highlighting QR codes in a cashless society, particularly in payment systems;
- considering issues related to the use of QR codes in payment systems.

Lastly, the various QR codes presented in the figures are ‘live’ and can be scanned with QR code readers. In doing so, we attempt to highlight the interactive, practical and robust nature of QR codes for readers of this paper.

Keywords

Quick response codes; QR codes; Cashless Society; Payment systems

Correspondence details

Justin Chan
justinchanuk@gmail.com

Ian Collier
17, Northwick Circle, Kenton, Harrow, Middlesex, HA3 0EJ
ian.collier@btinternet.com

Reading Pre-requisites

This paper supplements the “Cashless Society- Benefits Risks and Issues (Interim Paper)”, and additional papers published by the cashless society working party on the Institute and Faculty of Actuaries (IFoA) website in December 2017.

An addendum paper, “A Cashless Society – Environmental Sustainability of a Cashless Society”, has additional content regarding the environmental sustainability of QR code use.

Resource URLs
- Interim paper: https://www.actuaries.org.uk/documents/cashless-society-benefits-risks-and-issues

- Environmental Sustainability paper: http://www.actuaries.org.uk/documents/environmental-sustainability-cashless-soociety

- Cashless Society Working Party: https://www.actuaries.org.uk/practice-areas/finance-and-investment/finance-and-investment-research-working-parties/cashless-society-working-party

Introduction

In this section, we discuss the background of barcodes and QR codes, along with the reasons why QR codes are in popular use.

What are barcodes?

A barcode is an optical, machine-readable representation of data, typically in the form of parallel lines of varying width and spacing. The one-dimensional barcode that one normally finds on products was invented by Norman Joseph Woodland and Bernard Silver. They patented it in 1952 (US Patent 2,612,994) which later found popular use in supermarket checkout systems (Wikipedia n.d.).

Figure 1: Example of a one-dimensional barcode

There are also other forms of barcodes. Drobnik (2015, pp.3-16, 205-211) provides a good summary on the development of barcodes, tracing its development from the bull-eye code in 1952 up to the development of the Global Trade Item Number (GTIN) in 2009, with descriptions of both one-dimensional (eg. Code 39, Code 128) and also various two-dimensional barcodes (eg. PDF417, QR codes).

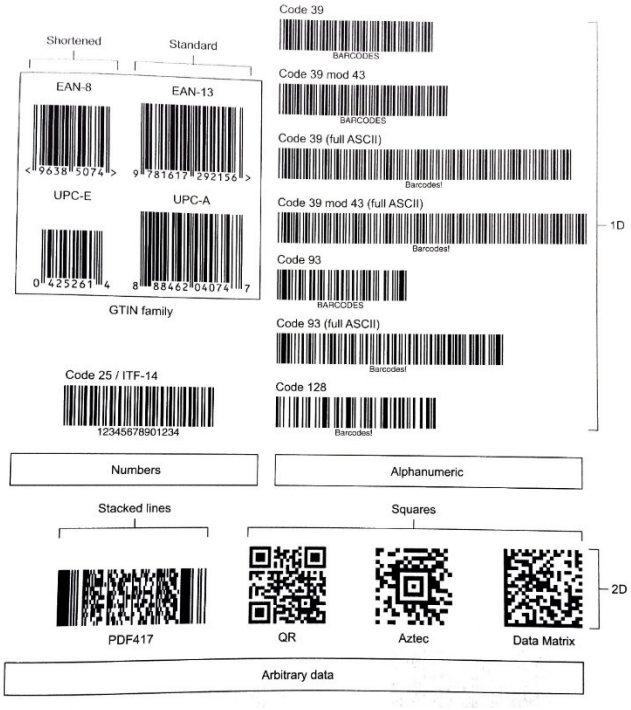

Figure 2: Various types of barcodes (Drobnik, 2015, p.7)

Quick Response Code (QR Code)

The QR code is the trademark for a type of matrix barcode first designed for the automotive industry in Japan. It consists of black squares arranged in a square grid on a white background. The required pattern is extracted from both horizontal and vertical components of the image.

Figure 3: Example of a QR code image (Wikipedia n.d.)

QR codes are commonly used in a variety of ways from payment systems to consumer advertising. A smartphone can be used as a QR code scanner, displaying the code and converting it to a useful form. QR codes can be found in many places like magazines, buses and business cards to store address, URLs and other information. They are also commonly used in cinema ticketing, coupons, packaging (ie. linking to product information) etc. (Aktas C, 2017).

Why are QR codes so popular?

1. Technological advances

The invention of the charge-coupled device (CCD) in 1969 allowed for the development of digital cameras and enabled scanning of two-dimensional barcodes, including QR codes. The inclusion of digital cameras in mobile phones allow QR codes to be widely used by the general consumer in a modern society.

2. Intellectual property and standardisation

QR codes were originally a registered trademark of Denso Wave Incorporated (a Toyota subsidiary in Japan). The company did not benefit from the patent protection rights and subsequently waived its rights to the patent in its possession (Patent No. 2,938,338) (Aktas C, 2017). QR codes can be freely used without patent restrictions.

In addition, ISO/IEC 18004:2015 provides an established standard for QR codes including symbol formats and decoding algorithms (International Standards Office, 2015). This allows for the standardisation and efficient rollout of QR codes.

3. Convenience

The convenience of QR codes' 'scan-and-go' approach removes the need to input long complicated data (eg. long URLs) manually and is useful for societies with low literacy rates. In this scenario, instead of typing a long piece of information like a web address,

https://www.actuaries.org.uk/practice-areas/finance-and-investment/finance-and-investment-research-working-parties/cashless-society-working-party, into a browser, one can use scan the QR code in Figure 4 to get to the website.

Figure 4: QR code for the Cashless Society Working Party of the IFoA website

4. Technical superiority of QR codes over one-dimension barcodes

- Stores more information

Barcodes store information in one horizontal direction whereas QR codes can store information in both horizontal and vertical directions. This allows QR codes to potentially hold hundreds of times more information in a smaller space than barcodes.

Figure 5: QR code can store data on vertical direction whilst barcodes cannot

- Readability from any direction

Reading of QR codes is also robust and can be done in any 360 degrees orientation (Mobile-QR-Codes.org, n.d). It contains “finder" patterns that allow for position detection and alignment.

Figure 6: Position Detection and Alignment Patterns within QR Codes

- Error correction

  QR codes utilizes the Reed-Solomon error-correcting codes, which are commonly used in CDs, DVDs and Blu-ray discs. The error-correcting features have error margins of between 7%-30% (Ashish, n.d.; Mobile-QR-Codes.org, n.d). QR codes are designed to be robust and will still work even if damaged.

Figure 7: Defaced QR code that can still be decoded

- Ability to be customised

  Organisations have exploited the error-correction feature by adding a logo or picture to their QR codes which still allows the intended data to be read (Ashish, n.d.). Organisations can highlight their brand logos and differentiate themselves from a sea of black and white pixels when several QR codes are placed together.

Figure 8: QR Codes on Ping An Insurance Company's website (Ping An Insurance Company, n.d.)

QR codes in a Cashless Society

QR code is gaining popularity in cashless societies around the world. They can be used to store bank account information or credit card information, and can also be specifically designed to work with particular payment provider applications. Figure 9 below features the mobile wallet payment by Singapore DBS bank – DBS Paylah!. The application links a bank customer's account to a mobile wallet on their smartphone to access various payment facilities.

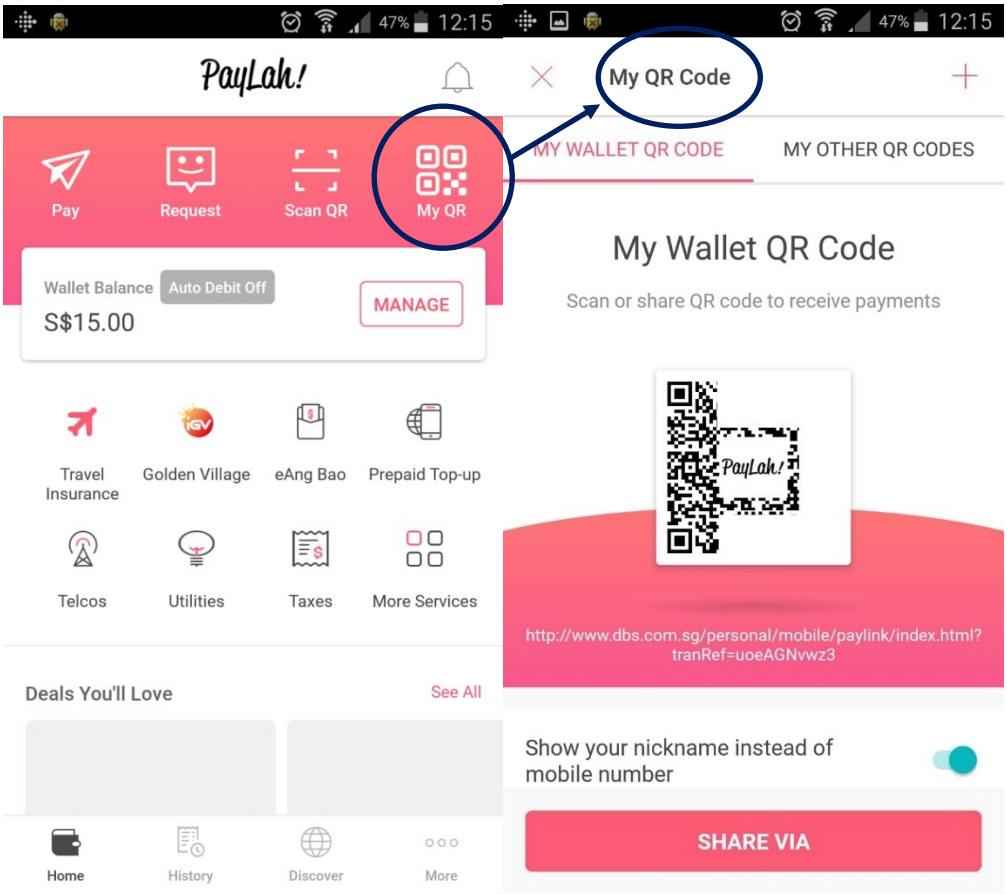

Figure 9: DBS Paylah! mobile wallet app supports QR code payments – Main screen (left), My Wallet QR Code (right, QR code redacted)

These mobile wallet applications are especially popularly in China due to the proliferation of affordable smartphones and the commercial push by large internet companies like Alipay and Tencent (Kuhn A, 2017; Better Than Cash Alliance, 2017). In a report published by Better Than Cash Alliance (2017, p7), it stated that the combined Alipay and WeChat payments have risen from less than US$81 billion in 2012 to an estimated US$2.9 trillion) in 2016 – a 20-fold increase in four years.

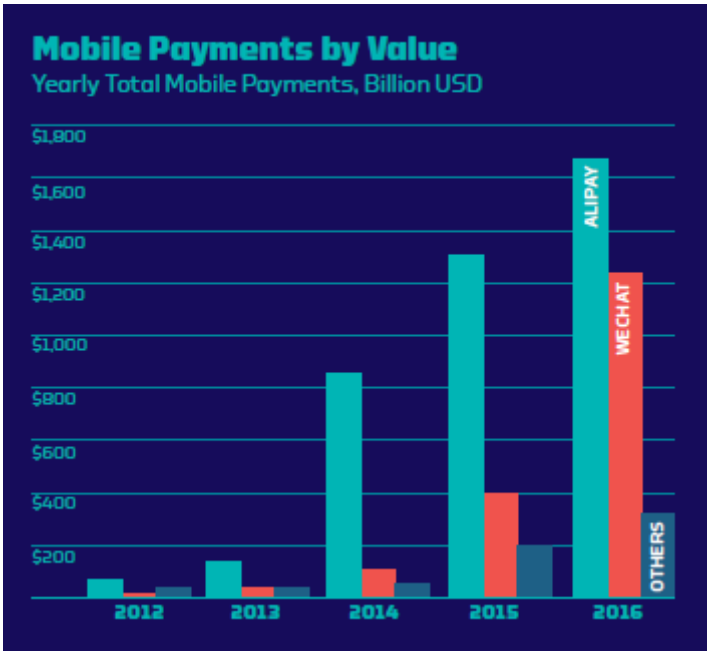

Figure 10: Mobile Payments (by Value) in China (Better Than Cash Alliance, 2017, p7)

QR code for payments received widespread support in various other countries as described below.

- In November 2012, the Czech Republic deployed QR code payments on a large scale when an open format payment information exchange was introduced and endorsed by the Czech Banking Association as the official local solution for QR payments (Wikipedia n.d.).

- In 2013, the European Payment Council (EPC) provided guidelines for the EPC QR code, enabling SCT (SEPA credit transfer) initiation within the Eurozone. SEPA refers to the Single Euro Payments Area, a payment-integration initiative of the EU for simplifying bank transfers denominated in euro (European Payments Council, 2013; Wikipedia, n.d.).

- On 20th February 2016, the Reserve Bank of India launched Bharat QR. It is a common QR code developed by major credit card companies that has the capability of accepting payment on the unified payments interface (UPI) platform (Gandhi SR, 2017; Srivats KR, 2017).

- In November 2017, Singapore endorsed a QR Code specification for electronic payments. (Monetary Authority of Singapore, 2017) This was launched in September 2018 as SGQR, a unified QR code payment label set to replace 19,000 versions of QR codes currently in use (Lim J, 2018).

- September 2018 also saw the Hong Kong Monetary Authority launched its Faster Payment System (FPS), a consolidated platform that allows fund transfer across banks and stored-value facilities providers as well as instant payments through QR codes, email addresses and mobile phone numbers. The system further allows for instant payments in renminbi in addition to the Hong Kong dollar (Woo JJ, 2018).

- In August 2018, various UK news outlets reported on a charity scheme to get people to donate to the homeless in an increasingly cashless society. The charity, Greater Change, created QR codes for rough sleepers so the public can give money using their smartphones. Donors can donate a variable amount and the system uses Stripe as payment processor, which can accept debit and credit cards. Donors can find out more about the recipient's circumstances through an online profile that appears when they scan the code (Shaw, D 2018; Owoseje, T 2018).

Figure 11: Scanning a homeless person's QR code for a cashless donation (Shaw D, 2018)

- QR Codes and Cryptocurrency

  QR codes are commonly used with cryptocurrencies, particularly those based on Bitcoin. Payment addresses, cryptographic keys and transaction information are often shared between digital wallets this way. Websites, like BTCFrog, exists to create these QR codes to enable cryptocurrency payments for merchants and users (BTCFrog, n.d).

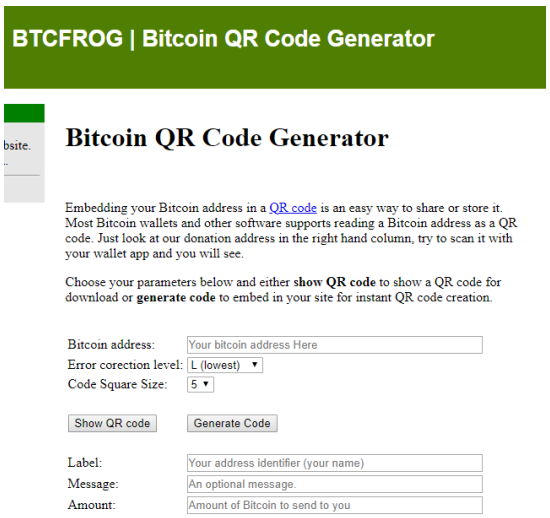

Figure 12: BTCFrog website for generating QR code (BTCFrog, n.d)

Considerations for using QR Code in payment systems

In this section, we consider various issues when using QR codes in payment systems. These include:

- security risks;
- commercial opportunities in mobile wallet;
- fragmentation of QR-code based payment systems;
- smartphone adoption;
- the role of China;
- practical considerations for environmental sustainability;
- financial exclusion.

Security risks

There are security risks involved in the use of QR codes, particularly the URL (eg. web address) being referred to. These URLs may host executable code that exploits the vulnerability of QR code readers when fetched from the internet. In addition, malicious QR codes can exploit permissive QR code reading devices which puts a user's computer content and privacy at risk (Wikipedia n.d.).

For instance, the equivalent of US$19 million was stolen in the Guangdong province of China via QR code scams. Various techniques were used like replacing legitimate codes with fake ones which were embedded with virus programmes to steal personal information. Another method involved the bike-sharing industry where scammers replaced QR codes meant to unlock bicycles with fake codes that transfer money to the scammers' bank accounts (Li T., 2017).

Peng (n.d.) describes two main points of vulnerabilities through the use of QR codes.

1. Attacks based on human interactions

   As humans are unable to decipher the information encoded in QR codes, they rely on QR code readers to decode the information. As the information in the QR code is completed obfuscated, it is possible to trick users via phishing, pharming and other social engineering techniques by putting up fake QR codes. It is also possible to exploit the weaknesses in existing QR code readers to inject harmful commands. The cited scamming cases in Guangdong was largely based on this vulnerability.

2. Automated Attacks

   Automated attacks exploit the assumption that the information in the QR codes is safe. However, QR codes can be manipulated to change its encoded information, thereby launch attacks against a particular database system or perform fraud.

Several technical measures are available to address and mitigate some of these risks. These include the use of encryption and Signed QR (SQR) codes, where QR code readers verify the source of SQR codes before launching any action. These have corresponding costs in computational and verifying sources (Peng K, n.d.).

Practical measures can also be implemented to further reduced security risks (Abas A. 2018; Li T., 2017).

- Observe for any signs of tampering with the QR code (eg. sticker on top of a menu);
- Use a secure QR code scanner that can flag malicious websites;

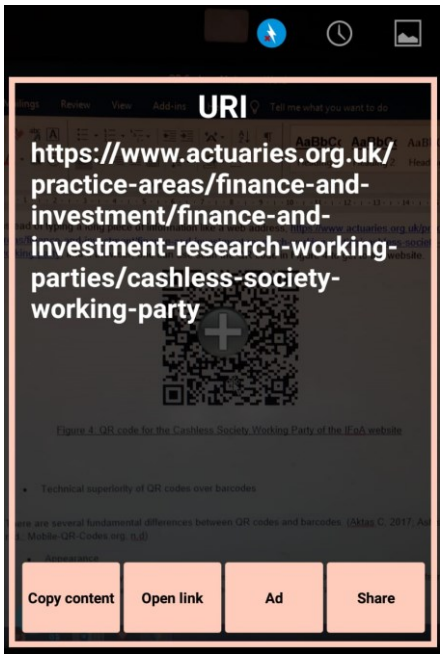

Figure 13: Screenshot of QR code reader that presents the decoded data before allowing further users action

- Do not key in any personal information after scanning the QR code;
- Regulations to adopt a 'real-name-rule' where registration is required for anyone producing a QR code;

Commercial opportunities with mobile wallets

There is a growing adoption of mobile wallet applications with QR code capabilities. Various entities can now partner with banking and fintech companies providing these wallets to offer an integrated purchasing experience to app users.

1. Commercial entities like insurance and cinema companies can allow for the purchase of their products and services within the app. (See Figure 14 for an insurance example.)

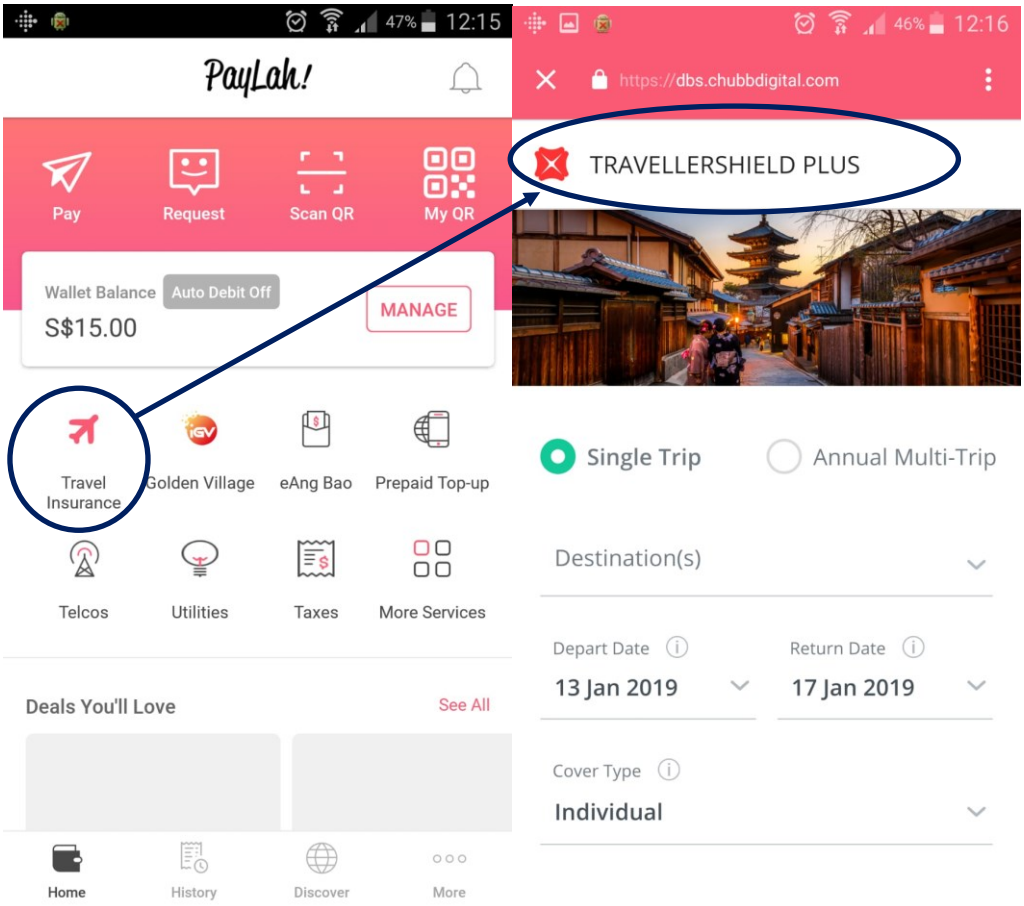

Figure 14: DBS Paylah! mobile wallet with in-app travel insurance purchase

2. Governments can allow citizens to pay taxes, fines and council fees using these apps as the identities of the payers can be verified by the bank or a trusted fintech firm.

3. Charitable organisations can accept donations through the apps. Tax deductions based on these donations can be verified and linked to the donor.

Fragmentation of QR code-based payment systems

QR code payment systems can be fragmented by competing banks and fintech companies that offer standard-compliant QR codes but incompatible underlying systems. Various countries like the Czech Republic (Wikipedia n.d.), India (Gandhi SR, 2017; Srivats KR 2017), Singapore (Lim J, 2018) and Hong Kong (Woo JJ, 2018) are adopting a unified approach which also provides a level playing field (ie. lower barrier of entry) among electronic payment providers.

Smartphone adoption

The use of QR code for payments is highly dependent on smartphone adoption. We generally see higher smartphone adoption in developed countries where consumers can afford these devices along

with suitable telecommunication infrastructure. However, the growth rate for global smartphone penetration has been decreasing in the past few years (See Figure 15). With countries like Singapore having mobile penetration rates of 149% (KPMG, 2016) (ie. likely due to each person owning multiple mobile phones) the actual number of users having smartphones may be even lower.

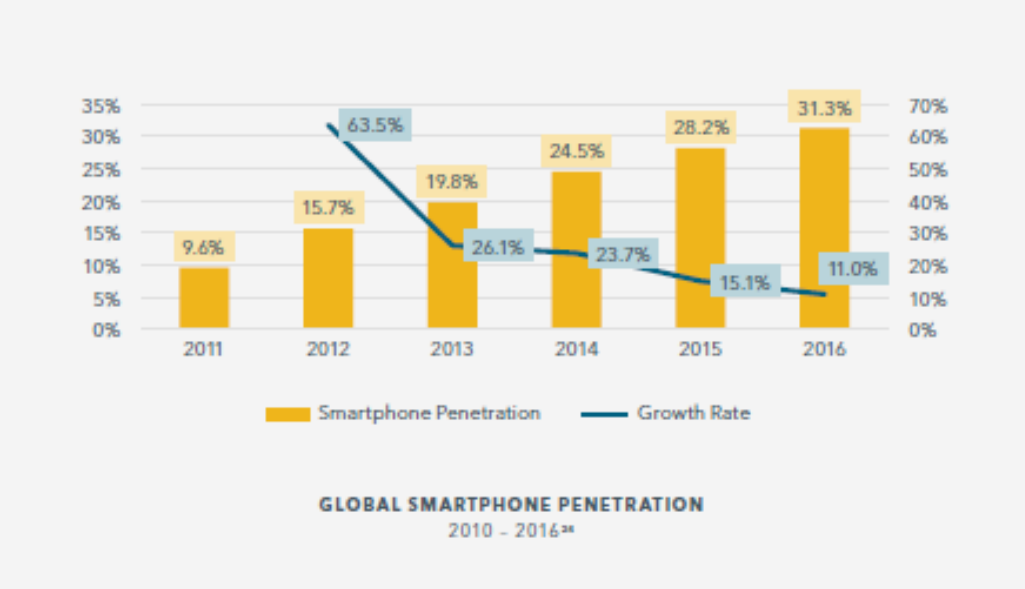

Figure 15: Global Smartphone Penetration 2011-1016 (Vocalink 2018)

With global smartphone penetration standing at 31.3% as of 2016 (Vocalink, 2018), there is potential for higher penetration, particularly in the developing economies. However, this is highly dependent on economic and infrastructure development in these countries.

For countries like China, the presence of large Chinese smartphone manufacturers and e-commerce entities like Alipay and UnionPay have driven adoption of QR code payments (UnionPay International, 2017). Other countries like those in the African sub-continent may opt for simpler forms of mobile payments using cheaper non-smartphones (eg. M-Pesa).

Role of China

China plays an important role in the adoption QR codes not only within its borders, but also worldwide.

- Chinese mobile phone manufacturers target wide segments of the global consumers with affordable smartphones including India and the African sub-continent (LiveMint, 2018; Zaagman, 2018). In fact, Chinese telecommunications company, Huawei, became the second largest smartphone manufacturer in the second quarter of 2018, beating Apple to the number two spot (Gibbs S., 2018).

- Huawei serves a large segment of the telecommunications market, overtaking Ericson as the largest telecommunications equipment manufacturer in the world (Tan J., 2018).

- Chinese commercial companies like Alipay and UnionPay are driving international adoption of their payment systems which utilizes QR codes.

- With rising Chinese wealthy and middle classes, tourists from China represents a significant spending force in the tourist sector for many countries. For instance, we observed China's credit card provider, UnionPay, launching QR code payments in six shopping malls across Singapore to cater to Chinese tourists (Wong KY, 2017; UnionPay International, 2017).

Figure 16: Display outside a 7-Eleven shop in Bangkok showing the availability of China's Alipay QR code payment system in Thailand

Practical considerations for environmental sustainability

Rochemont (2018, p21) describes QR codes as one of the most environmentally neutral means of payment. She describes two models for QR code payments.

- Model 1 – Merchant provides the QR code

In Model 1, a customer scans the QR code provided by the merchant in order to make a payment. This results in low environment impact (ie. the merchant has to simply provide a printout of the QR code) but involves more steps for the customer (ie. scanning the code, entering the amount to pay, entering security codes).

- Model 2 – Customer provides the QR code

In Mode 2, a merchant scans the QR code provided by the customer. This involves the use of an optical scanner, which increases the environmental costs due to the Point of Sales device involved.

In practice, one would see mixture of both models being applied, alongside both QR codes and one-dimensional barcodes.

Many established supermarkets and retailers have existing investments in one-dimensional barcodes as part of the Universal Product Code (UPC) for inventory and checkout purposes. Vouchers offered to their customers use the same one-dimensional barcodes, which are compatible with their existing scanning device. (See Figure 17 as an example of such voucher barcodes.)

Figure 17: Barcode voucher to redeem at a supermarket earned from AIA Weekly Vitality Challenge (AIA Vitality, 2018) (Model 2 example)

On the other hand, many small businesses, particularly those involved in services, typically transact in cash with no existing one-dimensional barcode system. This leads to Model 1 being more attractive and where QR codes can also be adopted. Merchants can simply print out the QR code from their payment systems providers for customers to scan.

Figure 18: A small restaurant business offering various QR codes for payment options linked to e-wallets (Model 1 example)

Financial exclusion

Adoption of mobile and QR code payments may be low amongst certain demographics within a cashless society.

- The elderly may be unable to afford smartphones or may not be willing to learn and make payments through QR code-based systems.

- The unbanked within a society (eg. those in the lower socioeconomic class) have no access to the mobile wallet apps offered by banks.

- Rural areas may lack sufficient telecommunications or mobile network systems to support QR code payments for the rural population.

- Foreign tourists with incompatible mobile wallets cannot make payments through the local QR code-based systems.

Conclusion

In this paper, we have explored the rise of QR codes in a cashless society. The popularity of QR codes can be attributed to:

1. technological advances;
2. intellectual property and standardisation;
3. convenience;
4. technical superiority over one-dimensional barcodes.

Several major developments in the adoption of QR codes as part of payment systems were described, including its widespread adoption in China, use for charity payments in the UK and its role in cryptocurrencies.

We further discussed the considerations for any party that wants to use QR codes as part of payments systems. These issues include security risks, commercial considerations and financial exclusion.

In writing this paper about QR codes, the Cashless Society Working Party aims to highlight how one small aspect of a digital payment systems can have a wide and deep impact for various stakeholders in a cashless society.

Acknowledgements

I would like to thank the members of the Cashless Society Working Party and reviewers from the Institute and Faculty of Actuaries in the preparation of this publication. I would also like to thank Lim Wei Jian for introducing me to DBS Paylah! and PayNow mobile apps.

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Institute
and Faculty
of Actuaries

Beijing

14F China World Office 1 · 1 Jianwai Avenue · Beijing · China 100004
Tel: +86 (10) 6535 0248

Edinburgh

Level 2 · Exchange Crescent · 7 Conference Square · Edinburgh · EH3 8RA
Tel: +44 (0) 131 240 1300 · Fax: +44 (0) 131 240 1313

Hong Kong

1803 Tower One · Lippo Centre · 89 Queensway · Hong Kong
Tel: +852 2147 9418

London (registered office)

7th Floor · Holborn Gate · 326-330 High Holborn · London · WC1V 7PP
Tel: +44 (0) 20 7632 2100 · Fax: +44 (0) 20 7632 2111

Oxford

1st Floor · Park Central · 40/41 Park End Street · Oxford · OX1 1JD
Tel: +44 (0) 1865 268 200 · Fax: +44 (0) 1865 268 211

Singapore

163 Tras Street · #07-05 Lian Huat Building · Singapore 079024
Tel: +65 6717 2955

www.actuaries.org.uk