Time Efficiency of Point-Of-Sale Payment Methods: Empirical Results for Cash, Cards, and Mobile Payments

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Abstract

We propose a novel approach for the time efficiency study of payment process at Point-Of-Sale (POS). A wide range of payment methods from cash and standard cards to contactless cards, RFID stickers and mobile payments (NFC and remote) was analysed. Transactions were timed by means of digital chronography of video material recorded in the biggest chain of convenience stores in Poland. Our results confirm that cash is a significantly faster payment method than traditional payment card with a magnetic stripe or EMV chip. However, the innovative payment methods, such as contactless cards and NFC mobile payments, are competitive to cash in terms of time efficiency. Contactless cards used in offline mode and without printing paper slips are the first popular electronic payment method in history faster than cash. Our results could be applied to optimise the payment process at POS as well as to develop innovative and efficient payment solutions.

Keywords: Retail Payments; Tender Time; Credit & Debit Cards; Contactless Cards; NFC; Mobile Payments.

1 Introduction

The modern retail payment market offers a wide range of payment methods which may be used at the Points-Of-Sale (POS), such as cash, cards, cheques or currently even mobile devices. Payments at physical POS have an important impact on the entire economy, as they are a daily activity of consumers. Consumer's choice of a payment method is influenced by numerous factors which *inter alia* comprise its pecuniary cost of use, convenience and certainty of acceptance [2], [9]. Individuals must have compelling reasons to change their payment habits. Otherwise they keep using means of payment they are most familiar with [3]. Consumer satisfaction from the purchase depends heavily on the time of queuing and the time of undertaking a transaction at the counter [1], [24]. As a consequence of strong competition in retail trade, aspects of payment costs, sales organisation and the length of queues have great impact on profitability of merchants business and their market success. Modelling the flow of customers and the time spent by them while paying, may result in decreasing queues which is advantageous for both merchants and consumers.

The main aim of our study was to measure the time efficiency of different payment instruments used at physical POS in Poland. The time efficiency of payment methods understood as the speed of the transaction process has been evaluated on the basis of empirical research that was conducted in the chain of convenience stores. We were willing to verify whether new payment solutions like contactless (proximity) cards, RFID stickers or mobile payments – the remote system and NFC mobile phones –

were faster in a transaction process than traditional payment methods – cash and standard debit and credit cards.

To the best of our knowledge, this is the first study in the world to gauge payment process time components of a wide range of payment methods used at POS.

2 Importance of Transaction Speed at the Check-Out

The speed of the payment transaction process is of major importance for the efficiency of a given instrument. Time of servicing a payment transaction by a seller should be treated as a part of merchants costs. Garcia-Swartz *et al.* [7], [8] label these costs as 'tender time costs'. They are a part of front-office costs and are usually translated to staffing costs at the average wage rate for shop workers [4]. Thus, the time of a transaction at the check-out constitutes an important part of merchants costs. Moreover, time spent on paying and queuing implies consumers cost. A reduction of queue lines can therefore decrease consumers costs of payment [4]. At the same time – from the merchants' viewpoint – reducing lines in shops through the shortening of the payment process may boost sales, because fewer clients will withdraw from the purchase. This element gains significance because consumers become more demanding. Research published by Barclays Bank and Populus Ltd in 2010 shows that customers are unwilling to wait in line to pay for their shopping. Two-fifths of the shoppers refuse to wait in queue for more than two minutes while two-thirds regularly abandon purchase [1]. It shall be noticed that the importance of the transaction speed varies depending on the sector – it is of key importance during mass events, in public transport or fast-food chains and less in luxury boutiques or restaurants.

In addition, speed can contribute to the market success of a new payment instrument, therefore this feature can be vital for payment providers. Studies conducted worldwide have shown that the speed of a transaction, determining time spent at the counter, is one of the most significant factors determining the choice of a payment instrument [11], [12], [13], [18], [19], [22], [23], [25]. In particular young clients negatively react on longer executing times of executing a payment [3]. This suggests that instruments requiring more effort on the consumer's part have little chance of gaining popularity.

Due to their physical and technological features, which are the most important for the presented study, payment instruments can be divided into three groups: (a) paper instruments: cash (banknotes and coins) and cheques, (b) cards: debit, credit, pre-paid and e-purses (electronic money), and (c) mobile devices working in remote schemes and proximity schemes. The usage of these instruments is much diversified across countries. However, even in countries with several decades of experience in card use, cash still remains the main form of payment. According to McKinsey [15], cash was used in 70-93% of the total number of retail transactions concluded by households in the most important western economies in 2005.

Recently many new solutions have been introduced to the market, which can become competitors of cash at physical POS. One of the most important innovations are contactless cards. Contactless payments are based on an extension of RFID

technology (Radio Frequency Identification) enabling remote reading of integrated circuits via radio waves [10]. The first application of this technology for payments took place in 1997 for the Hong Kong's public transport network [14], and first contactless payment cards for more general banking purposes, MasterCard *PayPass*, were issued in United States in 2002 [5]. In Poland, this technology was pioneered by Bank Zachodni WBK SA in December 2007. In 2011 Poland became one of the leading contactless market in Europe. Most of the contactless card are issued in traditional form, however other forms, like RFID stickers for mobile phones, wristwatches or keyfobs, are also applied to a limited extent and they operate similarly to contactless cards. The more advanced contactless mobile payment technology, i.e. NFC (Near Field Communication is an expansion of RFID technology, complimentary to contactless card; see [10]) can also work similar to a contactless payment card. However, NFC has much more features based on mobile device, and one of them is optional activation using a PIN code. Mobile NFC payments and contactless cards use the same contactless POS terminals network, what generates the synergic effect. The main obstacles for market development is a very limited number of mobile devices equipped with NFC technology. As a result, NFC mobile payments have not been commercially deployed on a large scale except Japan and South Korea.

An alternative solution, which can be used in POS transactions, are remote mobile payment systems. These systems are based mostly on universal communication through the GSM mobile network (most often through SMS or USSD sessions) or mobile Internet. The versatility of these solutions results from that the acceptance of payment is possible through an adapted POS terminal, a WEB-terminal (online payments), or a seller's handset. There are many more or less successful remote mobile payment schemes operating in the world today, a majority of which use the GSM technology and/or an installed application. Most of them are domestic systems, including Obopay and PayPal (USA), mChek and PayMate (India), M-PESA (Kenya), MoneyBox (Nigeria), and mPay (Poland) to mention the popular ones. Some of the above mentioned payment innovations could have potential in accelerating the payment process.

Several studies on the speed of payment transaction with different instruments have already been undertaken. Results of the most significant or most widely cited, are presented in Table 1. There are quite significant discrepancies in transaction times among studies due to methodology used. Klee [12], [13] in the USA and probably also the Belgian study [20] focused on the time of a payment transaction comprising ringing up items. The Dutch estimates did not include this stage. Transaction times for Netherlands are therefore shorter across all payment instruments. With the exception of the Smart Card Alliance approximate data, all other studies point out that cash is faster than traditional payment cards. According to Dutch and Belgian studies the fastest payment instrument is an electronic purse [4], [20]. Note that none of the analyses split the transaction times into stages. This subject thus requires more detailed investigation. The presented study sheds light on the duration of particular stages of payment transaction for many payment instruments, not only traditional ones but also new and innovative.

Table 1. Overview of estimates for the duration of the payment process by instrument [in seconds].

Instrument	USA[a]	Belgium[b]	Netherlands[c]	USA[d]
Cash	34.75	32	19	33.7
Credit card (traditional contact technology)	55.13	56	28	26.7
Debit Card (traditional contact technology)	50.43	39	26	
E-purse (contact microchip technology)	–	20	14	–
Contactless card (RFID technology in on-line mode)	–	–	–	12.5
Checks	77.53	–	–	–

[a] [12]: Data represent the estimated minimum time at the checkout counter for four items purchased at a supermarket (see [3]). The time for the transaction is the "ring time", which is calculated as the number of seconds between the first item crossing the scanner to the close of the cashier's drawer – the amount of time the cashier spends ringing up the transaction (see [12] for a detailed study of consumer response to time at the checkout counter).

[b] [20]: The Belgian Federation of Distributors (FEDIS) carried out a study of the time taken to pay for purchases with different payment methods - cash, electronic purses, debit cards and credit cards – in about 10 distributors. It weighted the average settlement times for the different distributors according to their turnover.

[c] [4]: The time of processing the payments is defined as the length of time between the moment the customer has been informed of the balance due and the moment the sales slip, change etc. has been handed to the customer. The time spent by a cash-register attendant ringing up individual items is not included, since in the study these activities, though necessary to complete a transaction, are not treated as payment activities. In the Cost Survey by the Nederlandsche Bank it was assumed that the duration of the payment process are typical for POS.

[d] [21]: Estimates were performed for the transactions at pharmacies based on data from American Express and CVS/pharmacy. This data should be treated only as approximate.

The Smart Card Alliance study suggests that the new contactless technology is advantageous, because proximity cards have potential to facilitate much faster transactions at POS than cash and traditional cards. Owing to the fact that the contactless technology develops quickly in the USA, many Asian countries and lately also in Europe [19], verifying the time of the payment transaction performed with proximity cards was therefore one of the goals of this research.

3   Research Methodology and Obtained Data

Empirical research was based on chronography of the purchase transaction process at cash registers with the help of video monitoring during regular work hours of shops and test transactions after closing time. In this work we will mainly focus on the results concerning duration of payment transactions at the checkout. Our research

covered all payment methods available in Poland that can be used at POS as well as new solutions that stand a great chance to become popular on the market. Thus, we have not only tested basic payment instruments but also evaluated the uncommon innovative payment methods. The final set of payment method was following: cash, traditional card with signature, traditional card with PIN code, contactless card in online and offline mode, RFID mobile sticker, NFC mobile payment with PIN code, and remote mobile payment (exampled by mPay[1]).

In order to provide full complexity of the payment process we have taken under study three modes of measurement: (1) regular flow of customers; (2) mystery client tests (testers using given payment instruments queuing among regular customers); (3) closed tests (testers only, after shop closure). In the process of a payment we investigated the time of queuing and the time of a purchase payment gauged from the moment of presenting merchandise by a client to a cashier until consummating the payment and handing out receipts. Every payment method has its own specific series of time components, although some of them may be the same – like for example the scanning of items. Nevertheless, the time components vary considerably among payment methods. In the case of cash we have: scanning of items, taking out and counting money by a consumer, taking money by a shop assistant, giving back the change with receipts, whereas in case of a payment card verified by PIN we can observe the following stages: scanning of items, card preparation by the consumer, terminal activation and card handling by the cashier, entering the PIN code on a PIN-pad by the consumer, slip printing and handing it out to the consumer. Every time a given stage had to be precisely defined and measured.

The empirical data for the study was gathered between the 19th and the 21st of November 2009 in Torun, a Polish city, in a number of convenience stores. More than 30 people were directly engaged in the process (testers, pollsters, organisers and technical support). 3,728 different transactions and tens of thousands of particular time elements for all analysed payment instruments were observed.

After the completion of the process of tests and recording the video, the chronography stage began. The team of IT specialists developed a dedicated computer program Chrono-Metrics which facilitated measurement of all transactions and its time components based on the recorded video material. 95 qualified trainees took part in measurement which lasted for more than 2 months. Each transaction in every shop was on average measured by 5 people in order to minimize errors. Eventually the set of raw data was collected and, after controlling errors, average times of transactions of payment instrument were calculated. During this process the average starting and ending time points for all stages of the payment were determined (see Fig. 2 and Fig. 3).

One has to be aware of the limitations of the study, that presents results typical for transactions in the Fast Moving Consumer Goods sector. Therefore it is advised to carefully make generalizations of the results for other sectors.

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[1] mPay is a remote mobile payment system based on telecommunication connections in GSM standard – text USSD or voice IVR. It can be used on any mobile phone without having to install additional software. A transaction is performed by entering text codes on the mobile. mPay mainly works as an electronic purse and payments can be made to merchants as well as to any mobile phone user.

4 Empirical Results

The obtained results confirmed the dominance of cash in retail POS transactions in Poland. In the regular flow of customers, 94.3% of transactions were made in cash and 5.7% with standard payment debit and credit cards. All the other payment methods could only be examined during mystery and closed clients' tests. Nevertheless it was confirmed that the structure of POS payments in convenience stores was roughly identical with the structure of payment estimated for all sorts of shops in Poland [16], [18].

The detailed empirical data gathered in the process of chronography allow to conduct an analysis of all time components of the purchase payment process using multiple variable dimensions. In this paper, we decided to concentrate on the comparison of the time process of payments using three approaches which have very important practical value (Fig. 1). The first takes the perspective of a consumer, the second of a merchant and the third is a 'pure' payment process (without non-payment components of the purchase transaction). From the consumer perspective, the transaction starts with the preparation of a payment instrument or with passing items to the salesperson and ends with the moment when the consumer walks away from the counter. In the view of a consumer, the whole time devoted by him to the execution of a payment is important. The chart below (Fig. 1 on the left side) demonstrates the times of payment transactions for different payment methods from the consumer viewpoint. The second chart (Fig. 1 in the middle) presents the merchant perspective – from the moment of a beginning of items' scanning (customer service) to handing out receipts to the customer. For the merchant, the full time of a salesperson's activity is important. The third chart (Fig. 1 on the right side) exhibits the 'pure' payment process, which begins with the preparation of a payment instrument and ends with handing out receipts to the customer. The summary statistics for the duration of a purchase transaction by payment methods are presented in Table 2.

It is evident that for all payment instruments the duration of a transaction is the shortest in the third approach. In the merchant perspective approach, times of transactions are a bit longer. They are the longest from the consumer perspective. The differences arise from the fact that moments of start and stop are not the same. It should, however, be kept in mind that the different stages of a transaction process can overlap. For instance, the customer usually starts preparing the payment instrument while items are still being scanned. Therefore it cannot be stated, as other studies suggest (e.g. [4]), that the pure payment process excludes completely the time of ringing up items.
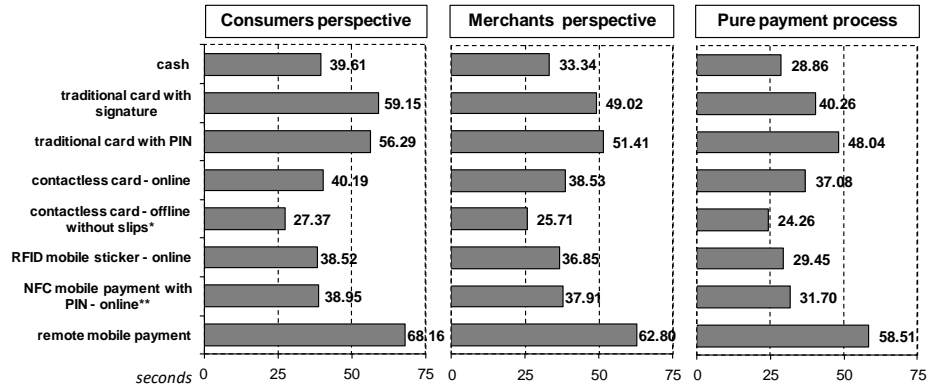
Fig. 1. Average duration of a purchase transaction by payment methods [in seconds].
* Due to the lack of a sufficient number of observations for contactless cards in an offline mode without printing paper slips, the time for this payment method was estimated on the basis of simulation procedure. ** By analogy to contactless cards, the NFC mobile payment with PIN in offline mode and without slips printed would be shorter by about 13 seconds.

The merchant perspective approach is the most methodologically comparable to the study by E. Klee [12]. The length of time of the transaction in her work was evaluated on the basis of scanner data, containing the records of a store register receipt with a time stamp, as well as information on the number of items bought, the value of the sale, the number of the store and the payment type used, etc. The results calculated for purchases of four items [3] are comparable to the results presented in our work, as the typical basket of goods acquired in the examined stores consisted of three items. In fact, our results for the merchant perspective (Fig. 1 in the middle) and Klee's results (see Table 1) for the duration of cash and traditional card transactions are very similar.

A first interesting empirical result (Fig. 1) is that in convenience stores cash still stands out as faster than traditional cards (either confirmed by PIN or with signature). The cash payment is especially short from the perspective of a merchant and in the pure payment process. Usage of traditional contact cards increases the time spent by a consumer at the counter by about 50%. Such a significant difference in duration of a payment transaction (about 20 seconds) may also have an effect on the queue when most clients decide to pay with their traditional cards.

From the consumer perspective (Fig. 1), payment by cash and contactless card in online mode (as well as by other RFID instruments) are equally fast[2]. As far as the merchant perspective is concerned, cash payment takes marginally less time. However, when used in online mode contactless cards do not exploit their full technological advantage. In fact, when using contactless cards in offline mode with abandoning slip printing, it appears that transaction with a contactless card lasts significantly less than cash transaction (on average 12.3 seconds less in the customer perspective). Thus it seems that declarations of card issuers that usage of contactless

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[2] Differences in the average duration of transaction between cash, contactless card (online mode), RFID mobile sticker and NFC mobile payment with PIN (Fig. 1) are statistically insignificant from the consumer perspective (see Appendix).

cards may shorten queues in shops are true (see Table 1). The possibility of cutting down the time of a transaction arises from two sources. The application of offline mode instead of online mode for card payments generates average time savings of 6.61 seconds. Offline transactions are recommended by payment organisations for contactless cards, and since 2010 most such cards issued in Poland are offline mode enabled. Polish merchants are accustomed to regulations requiring the printing of two paper slips for card transactions. However, we estimated that printing them lasts on average 6.2 seconds. Consequently, changes of payment organisation rulebooks, which allow not to print paper slips for low value payments, might lead to a further speeding up of contactless card payments. Therefore, we observe a technological breakthrough, because for the first time in history an electronic payment instrument that turns out more time-efficient at the POS than cash, is being issued on a mass scale.

Interesting conclusions pertain to proximity mobile payment such as RFID stickers or NFC which undoubtedly are time efficient (Fig. 1). Some clients can even pay more quickly with their mobile phones than with contactless cards taken out of wallets. These contactless solutions are technologically mature and based on international standards. They gained quite a big popularity in some countries, especially in Japan and the USA [6]. These factors greatly increase the probability of their further development. Popularisation of remote type mobile payments at POS transactions seems to be more difficult. Such payments are characterized by a wider functionality than proximity type mobile payments because apart from POS payments they can be used for transactions on the Internet, for bill payments, parking meters or purchase of tickets in a mass transit communication system. However, due to a considerable number of remote mobile payment systems operating in the world, they are not compatible with each other [17]. This is one of the reasons why they have not become common.

An additional barrier for market success of remote mobile payments is a necessity for consumers to type some information on the phone's keypad and this might be time consuming. Indeed, the Polish domestic remote mobile payment system proved to be the slowest payment method out of the analysed (Fig. 1). Nevertheless it must be emphasised that remote mobile payments were only slightly slower than payments with traditional cards and there are potential ways that – if properly implemented – may successfully speed up the transaction process (e.g. by predefined codes).

In order to assess the reasons for differences in transaction time and to find bottlenecks that slow down the process, a more detailed analysis is needed. The process of payment was divided into several stages, which were measured separately using the video chronography method (see Chapter 4). Each stage of the transaction is processed by either a consumer, salesperson or with the use of a technical device. The set of stages differs for every payment method (Fig. 2 and Fig. 3). For each stage the moment of its beginning and completion is marked. It is crucial to notice that many activities related to the payment process can be undertaken at the same time, by the client, salesperson or processed by the information system, which shortens the duration of transaction.

Table 2. Summary statistics for the duration of a purchase transaction, by payment method [in seconds].

| Payment instrument	Mean	Median	Minimum	Maximum	Standard Deviation	Sample size
The consumer perspective						
cash	39.61	33.32	4.75	244.35	25.35	2577
traditional card with signature	59.15	49.93	28.01	216.40	36.41	30
traditional card with PIN	56.29	48.30	29.21	155.18	22.43	186
contactless card - online	40.19	37.06	21.84	134.73	12.54	146
RFID mobile sticker	38.52	37.43	29.61	52.35	4.84	26
NFC mobile payment with PIN	38.95	39.01	32.64	43.75	3.06	14
remote mobile payment	68.16	58.76	38.26	165.64	28.44	52
The merchant perspective						
cash	33.34	27.59	5.35	192.26	20.73	2577
traditional card with signature	49.02	40.72	24.21	200.43	32.67	30
traditional card with PIN	51.41	44.48	16.71	150.81	19.96	186
contactless card - online	38.53	35.95	21.00	130.13	11.63	146
RFID mobile sticker	36.85	36.26	28.51	49.54	4.38	26
NFC mobile payment with PIN	37.91	38.01	31.97	42.18	2.85	14
remote mobile payment	62.80	54.82	36.29	152.69	24.05	52
The 'pure' payment process						
cash	28.86	25.24	2.82	158.59	16.08	2577
traditional card with signature	40.26	36.26	21.60	75.89	13.96	30
traditional card with PIN	48.04	41.60	15.39	140.03	19.95	186
contactless card - online	37.08	30.95	14.66	128.11	14.64	146
RFID mobile sticker	29.45	28.70	22.34	35.73	3.49	26
NFC mobile payment with PIN	31.70	30.75	24.58	36.16	2.95	14
remote mobile payment	56.51	50.31	33.49	146.46	22.41	52
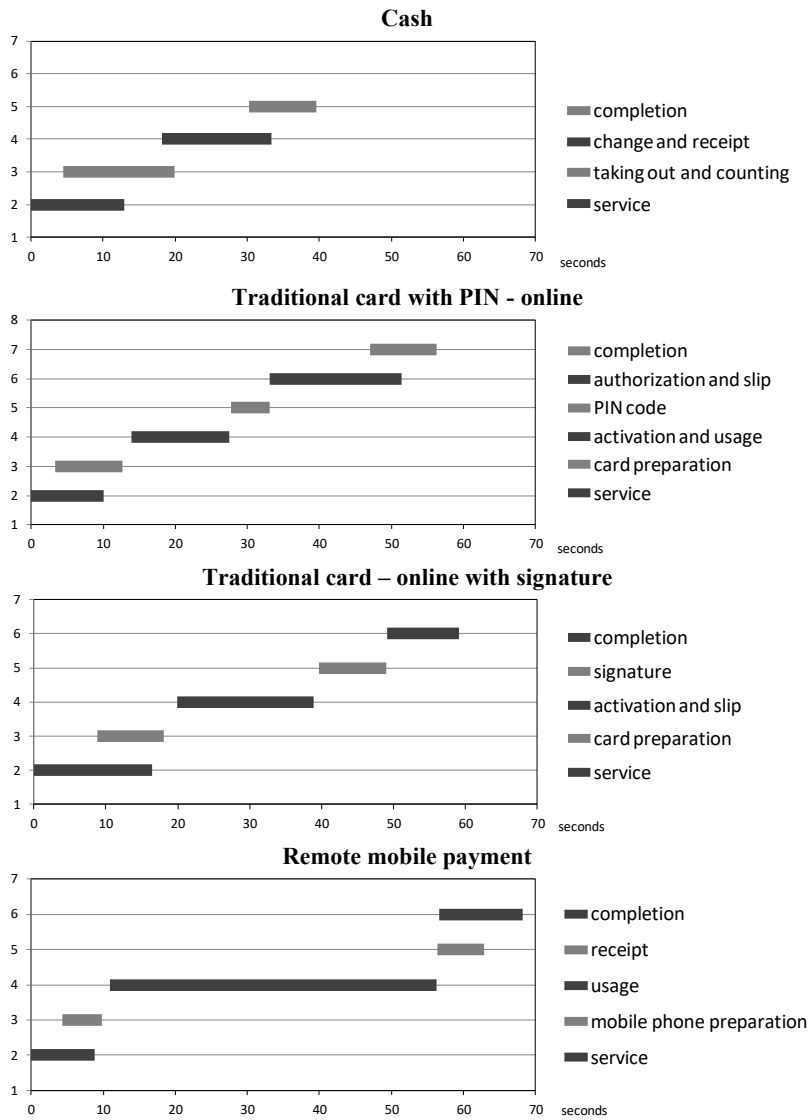
Fig. 2. The stages of the payment process (I).

The first payment method analyzed was cash (Fig. 2). The stage that delays the payment process of cash is handing over the change and receipt. Although taking out and counting money by the client also lasts long, it mostly runs at the same time as the service, which is the process of charging for the purchased items by the salesperson. When we compare cash payment with slower transactions by traditional

card with PIN code, a first important observation is the long duration of: terminal activation, entering the PIN code, the authorization and printing the slip. Due to the fact that those stages are performed one after another by the salesperson and the client, and with the use of a payment terminal, it is impossible to run them parallel, which extends the whole transaction. Where the traditional payment card with the signature is concerned, those middle stages are shortened, because there is no pause for entering the PIN code (the stage lasts constantly from the terminal's activation through the online client's bank account authorization until the printing of the slips). However, at the end the client is involved in signing the slip, which takes more time than the process of entering the PIN code. Moreover, the signing process does not let consumer to prepare to leave the counter with the purchased goods. As a result, sign-based transactions last a little bit longer than transactions with a PIN code.

When contactless cards are considered, the payment process runs in an entirely different way than with traditional payment cards. The stages of terminal activation and tapping the contactless card are extremely short. For contactless cards in online mode, the longest stages are authorization and printing of the two slips. Those stages can radically be shortened when the offline mode is used (Fig. 3). Despite the fact that consumers are satisfied from using contactless cards in offline as well as online mode, it seems that from an economic point of view in order to shorten the payment process using offline mode is reasonable.

The results of our study also enable a comparison between contactless cards and NFC mobile payments (Fig. 3). The NFC payment method requires an activation of payment functions with the use of a PIN code before the transaction can be made. We observed that users take out their mobile phone much faster than their payment card. At the same time, entering the PIN code before using a mobile phone at the terminal, does not extend the time of a transaction, because users enter this code while waiting for the activation of the terminal by the salesperson. In conclusion, the NFC mobile payments are as time effective as those where contactless cards are used.

The situation is different for the remote mobile payments model. In the study, we examined one system operating in Poland branded mPay (Fig. 2). In this case the stage of using the payment instrument lasts fairly long. The system requires the payee to enter certain codes on the mobile phone related to the type of transaction, number of the store and the amount to be paid. Authorizing is done by a PIN number. The remote mobile payment system tested turned out to be the slowest payment method of all, even though the difference between that payment method and the traditional payment card with PIN code was rather small. There are also psychological disadvantages: the consumer, while using this method, is watched by the salesperson and other impatient clients waiting in the queue. This was the reason why users taking part in tests evaluated the remote mobile payments lower than the cards in terms of satisfaction.
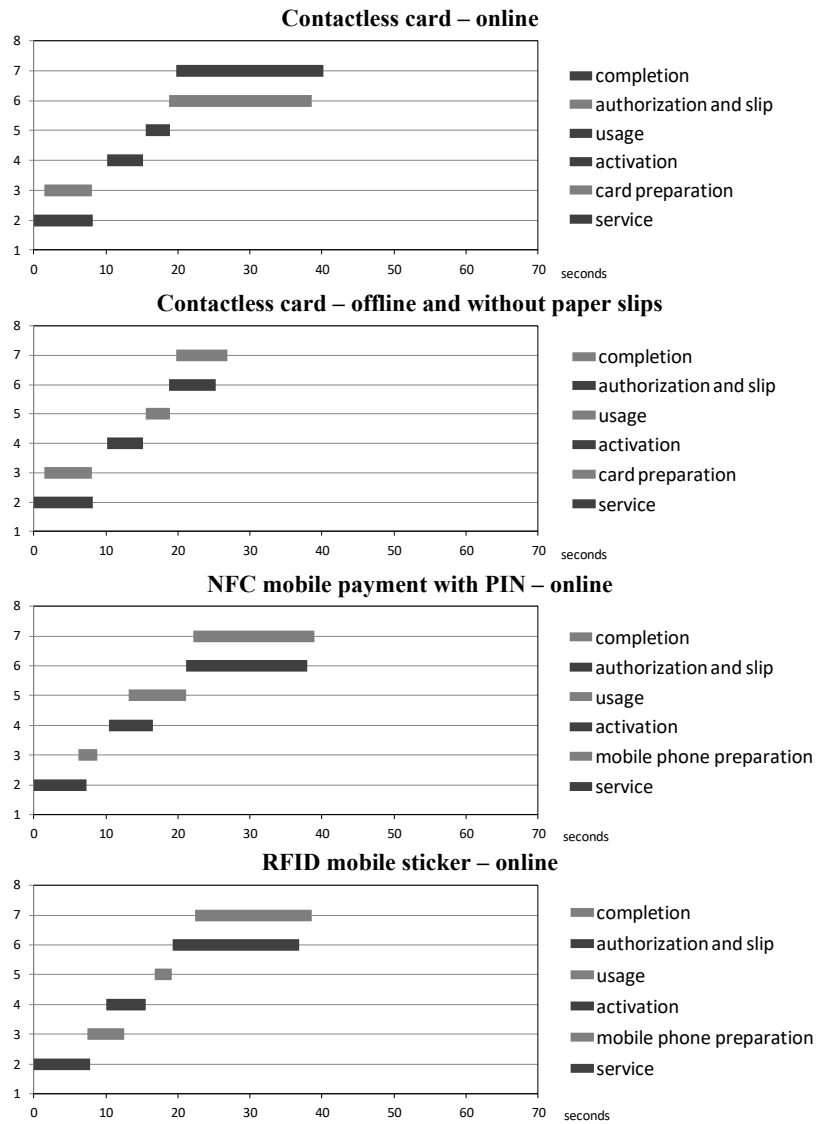
Fig. 3. The stages of the payment process (II).

5 Summary and Conclusions

The presented results provide novel insights into the important problem of the time efficiency of payment methods at physical POS. It has also revealed that, until recently, cash was the fastest payment method available at POS. As the results of the earlier studies in the other countries show, speed of a transaction is one of the most significant factors determining the choice of a payment instrument by consumer. Therefore, the time efficiency of cash, proved in our study, is probably one of the reasons why people use it so often. Traditional payment cards equipped with a magnetic stripe or EMV chip are much slower. The average time difference between cash and cards is fairly large, about 20 seconds, and amounts to half of the entire duration of a cash payment transaction. It suggests that frequent use of traditional cards by customers lengthens queues and may cause cost increases for merchants, with additional work for cashiers and risk of losing sales.

Moreover, our results have also allowed verifying the time efficiency of new payment solutions, which are expected to revolutionise the payment market. The most widely known were the contactless cards promoted by payment organisations MasterCard and Visa. It turned out that thanks to the innovative contactless technology, in terms of transaction speed, such payment instruments are likely to become true competitors of cash. Contactless cards and other types of payments devices – mobile stickers and NFC mobile payments – were almost as fast as cash, even despite processing in an online mode and with printing paper slips. After removal of these restrictions and operating in offline mode, transactions with contactless cards can be even quicker than cash. This may be considered a technological breakthrough in the evolution of the means of payment. For the first time in history, an electronic payment instrument, being issued on a mass scale, turns out to be more time efficient at POS than cash. Furthermore, the speed and convenience of contactless payments make them attractive for merchants and customers in low-value payments.

It seems that the development of proximity mobile payment, including NFC payment with PIN code, can be expected. These payment solutions have proved to be highly time efficient and were well received by consumers during the study. However, because of limited availability of mobile phones equipped with NFC technology, the RFID mobile stickers and other contactless payment gadgets have the potential to be part of the first wave of the contactless payment revolution. The time efficiency together with the strong support from the side of international payment card organisations suggest that the dynamic development of contactless mobile payments around the world is highly probable. In contrast, remote mobile payment schemes are rather slow in POS purchases. The execution of transactions in text mode seems to be a major barrier to their application at physical POS. Due to a lower time efficiency, it seems that remote mobile payments, at the current stage of their development, should rather be directed to other payment market segments (e.g. e-commerce, remittance, bill payments, public transport), where their additional functionality may be fully used.

The results presented in the paper are important from a scientific, policy as well as a business viewpoint. The data enable not only to assess the average time of a purchase transaction but also to determine the influence of payment methods on the

queuing time and costs borne by merchants. The results of the study allow also to asses consumers' costs of queuing and finally more precise estimation of the general social costs of payment methods. The comparison of many payment instruments gives valuable knowledge that can be useful in preparing strategies for promoting efficient payment instruments among consumers and merchants, e.g. by central banks or public authorities, therefore they are important for policy reasons. Moreover, the results may be especially important for companies introducing new payment solutions to the market.

The detailed timing study of payment process will allow in the future to build an accurate model of the whole payment process covering customer and salesperson activities, and including other factors such as: the type of terminal or a number of items purchased. We also plan to use the obtained data for modelling the process of queue formation and reduction, as well as for the simulation of functioning of the newly designed payment instruments. It would also be very interesting to extend the study on the other types of POS.

Acknowledgements

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Appendix

The results of verification for equality of two expected values of transaction durations for compared payment methods.

Payment methods	Perspective	traditional card with signature	traditional card with PIN	contactless card - online	RFID mobile sticker	NFC mobile payment with PIN	remote mobile payment
cash	C	-2.926***	-9.579***	-0.482	1.023	0.698	-7.032***
	M	-7.629***	-11.78***	-4.984***	-3.712***	-5.307***	-8.793***
	P	-4.479***	-12.17***	-5.344***	-0.276	-3.361***	-9.074***
traditional card with signature	C		0.417	2.817***	3.071***	3.015***	-1.159
	M		-0.977	4.650***	5.517***	5.117***	-3.619***
	P		-2.281**	1.707*	4.281***	3.239***	-4.189***
traditional card with PIN	C			8.226***	9.296***	9.369***	-2.728***
	M			7.240***	8.461***	8.064***	-3.197***
	P			6.066***	11.148***	9.233***	-2.952***
contactless card	C				1.186	0.936	-6.731***
	M				1.300	0.508	-7.009***
	P				4.659***	2.648***	-6.492***
RFID mobile sticker	C					-0.343	7.169***
	M					-0.918	-7.551***
	P					-2.538**	-8.842***
NFC mobile payment with PIN	C						7.114***
	M						-7.294***
	P						-7.947***

Notes: "C" stands for "Consumer perspective", "M" stands for "Merchant perspective" and "P" stands for "Pure payment process". *, **, *** denote statistical significance at 10%, 5% and 1%, respectively.