

# STAFF MEMO

## Quality of banknotes in circulation – Norges Bank's role and monitoring system

NO. 7 | 2016

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NORGES BANK

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ISSN 1504-2596 (online)

ISBN 978-82-7553-916-6 (online)

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**STAFF MEMO**

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MONITORING SYSTEM

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After the year 2000, Norges Bank made substantial changes to its role and activities in cash operations. The aim was to increase the efficiency of the overall payment system and of cash distribution. The Bank has assumed a clearer role as wholesaler in cash distribution, and discontinued service activities better suited to the retail level. As a result, Norges Bank is now less able to influence the pattern of banknote and coin circulation.

This article explains why the quality of banknotes in circulation is important for Norges Bank in terms of performance in attaining its objectives. It then discusses the challenges regarding the quality of banknotes in circulation, and the possibility to monitor and influence quality using a concept developed and implemented by Norges Bank. Since wear is considerably less of an issue for coins, wear does not pose the same challenge in this regard. This article's focus, therefore, is on banknotes.

## 1. Norges Bank's responsibility

According to Section 1 of the Norges Bank Act, Norges Bank shall issue banknotes and coins, and promote an overall efficient payment system. Section 13 states that the Bank has the sole right to issue Norwegian banknotes and coins, and Section 14 states that banknotes and coins are legal tender in Norway. To promote an efficient payment system, Norges Bank must ensure that cash can function effectively as legal tender, and that the cash supply is distributed as efficiently as possible. Furthermore, Norges Bank must ensure that the framework under which cash is issued promotes an economically efficient division of labour between cash and other means of payment. For further discussion of Norges Bank's responsibility and organisation regarding banknotes and coins, see Eklund and Veggum (2002), Natvig and Veggum (2002), Eklund, Solberg and Veggum (2005) and Eklund, Nygård and Veggum (2010).

Norges Bank's banknote issuance responsibilities (Section 13) include the following tasks:

- *Supply*: Issuing banknotes and coins so that overall demand is met and that banknotes and coins are available to users in sufficient quantities.
- *Replacement*: Maintaining an appropriate quality level of banknotes and coins in circulation. This includes an obligation to receive worn and damaged banknotes and coins for destruction and to replace them with banknotes and coins of acceptable quality for circulation.
- *Redemption*: The obligation to redeem banknotes and coins for ten years after they have been withdrawn from circulation (cf. Section 15 of the Norges Bank Act).

In order for cash to function as an efficient means of payment, it is necessary that:

- market participants have confidence in cash

- cash has characteristics that are adapted to needs
- cash is available
- all cash processing is efficient

*Confidence* means that users can trust that the cash is genuine and functions as a generally accepted means of payment.

*Characteristics* adapted to needs mean that the range of denominations, design, technical specifications and durability enable banknotes to function effectively in different types of payment transactions, and that they are suited to various types of cash handling.

*Availability* means that the general public and businesses are assured that cash will be available without inconvenience, making it also unnecessary for them to hold large amounts of cash.

*Efficient processing* means that transport, counting, sorting, and destruction etc, are both efficient and adequate, and that there is an appropriate division of responsibility between Norges Bank and others who process cash, so that tasks are executed with the lowest possible use of resources.

## 2. Relationship between quality and efficiency

If the quality of banknotes circulating in the economy is poor, it weakens their effectiveness as a means of payment. Damaged or worn banknotes slow payment transactions and can make some security features difficult or impossible to use. This applies to both manual and automated authentication. When it becomes more difficult to determine whether banknotes are genuine or not, confidence will weaken.

Poor banknote quality also results in efficiency loss in areas besides payment transactions. Transferring, holding and handling banknotes require substantial logistics that are costly for market participants. The quality of banknotes in circulation is of considerable importance to resource use, and therefore for the efficiency of these activities. For example, worn banknotes may cause automated teller machines (ATMs) to jam, increasing the need for maintenance, and vending machines might reject banknotes that are too worn to be authenticated or handled mechanically. Similar problems will arise in cash centers that sort out unfit and counterfeit banknotes, and redistribute banknotes that are fit for recirculation. A large share of worn banknotes increases the need for resource-intensive manual processing.

It is important for Norges Bank to facilitate compliance by various market participants in order to promote overall efficiency. This implies that overall cash distribution and processing should be as cost-effective as possible, while security requirements are satisfied.

In general, as the quality of banknotes improves, these considerations will be better addressed. At the same time, a higher quality of banknotes in circulation entails higher production and destruction costs. These are costs that must also be considered. In setting quality standards for banknotes in circulation, there will have to be trade-offs between different kinds of considerations and costs.

### 3. Cash supply chain

Norges Bank is responsible for the production of banknotes and coins to meet the need for cash. Banks have accounts with Norges Bank, which is the “bankers’ bank”. Banks order cash from Norges Bank and deliver surplus cash to Norges Bank based on their need to meet customer demand. Similarly, the general public orders notes and coins, and turns over surplus cash to banks. Thus, in the area of cash distribution, Norges Bank functions as the wholesaler, supplying cash to banks, and banks function as retailers, supplying cash to the public. To a considerable extent, Norges Bank purchases services related to its responsibilities from private entities. Banknotes are currently produced by two foreign printing works (Oberthur and Giesecke & Devrient), and coins are produced by Mint of Norway. Services related to the operation of Norges Bank’s depots and the shredding of banknotes from cash processing activity are performed by NOKAS. Norges Bank defines how these services are to be performed and monitors compliance with its requirements.

The cash supply chain is illustrated in Chart 1.

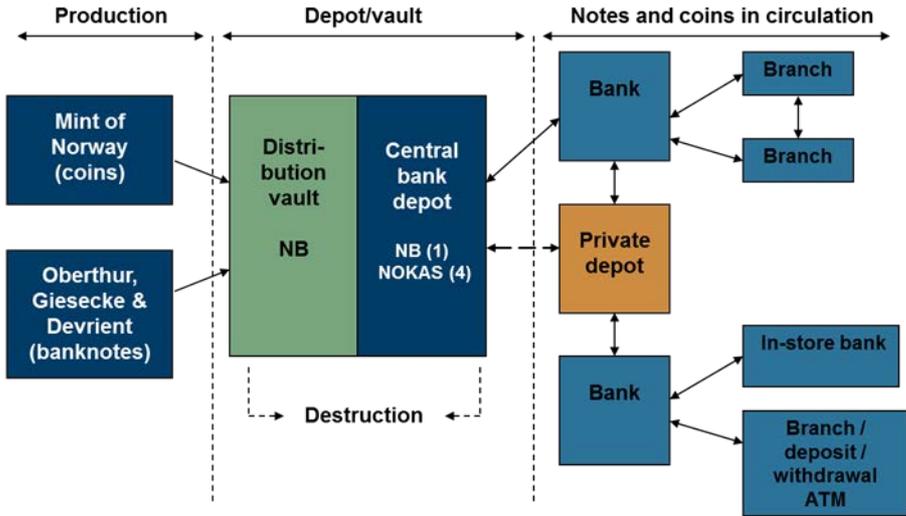


Chart1: The cash supply chain in Norway

Norges Bank performs its role as wholesaler by distributing cash to five regions via central bank depots. Banks are responsible for further distribution within the regions. Banks may exchange unfit banknotes for fit banknotes at Norges Bank. Banks can deliver their surplus holdings of fit banknotes in sealed packages to Norges Bank, which will redistribute them to other banks that require banknotes. Thus, Norges Bank performs no banknote fitness sorting.

To underpin the role of the banks, and as an incentive for efficient solutions, Norges Bank has introduced an interest compensation arrangement to make it easier for banks to establish common depots to store and redistribute cash. Under this interest

compensation arrangement, banks are paid the same amount as the interest they would receive if the stocks in such depots were deposited in Norges Bank<sup>1</sup>.

## 4. Norges Bank's measures to influence the quality of banknotes in circulation

Important factors that have an impact on the quality of banknotes in circulation are the quality and properties of new banknotes and the replacement of banknotes that are worn or damaged.

As issuer, Norges Bank is responsible for defining the properties of new banknotes in terms of printing, paper and other raw material components so that they can withstand the wear and tear of normal use. For example, banknotes should be able to circulate for a significant period before folding or tearing, and they should be resistant to soiling. Like the paper and printing, security features that make it possible to distinguish genuine banknotes from counterfeits must also withstand wear and tear. Norges Bank achieves this by providing banknote suppliers with specifications, and monitoring the compliance of delivered banknotes with these specifications.

Banknotes that circulate in the economy will inevitably be exposed to wear and tear. One condition for maintaining a certain degree of quality of banknotes in circulation is that unfit banknotes are sorted out and replaced with new banknotes or banknotes that are fit for recirculation. This necessitates the establishment of fitness sorting criteria, ie that the quality of banknotes to be removed from circulation is defined. In addition, it must be ensured that fitness sorting is actually carried out.

Norges Bank defines criteria for sorting out unfit banknotes as a minimum quality level for banknotes that may be reused, ie that may be redistributed to users. Lower quality banknotes should be removed from circulation. These criteria are published as a set of rules under the terms for deposits in Norges Bank<sup>2</sup>.

Since responsibility for fitness sorting has been defined to be outside the central bank, Norges Bank must exert control through either regulations or incentives to ensure that others perform fitness sorting in the desired manner. The central bank is able to influence fitness sorting through the conditions it places on its customers, the banks. A condition for maintaining a desired level of quality of banknotes in circulation is that the banknotes are regularly processed by machines equipped with sensors that, in addition to detecting authenticity, are also able to detect banknote damage and wear. Even in cases when fitness sorting is efficient, such processing involves substantial costs. The result may be that banknotes are recirculated without being processed, which Norges Bank seeks to counteract through the measures at its disposal.

Depending on individual banks' transactions with customers, some banks may at times have cash surpluses while others may have cash deficits. Further, the banks in one region may collectively have surpluses or deficits of cash. In the first case, redistribution among banks within a region is necessary, and is often done using private cash depots. Norges Bank is then able to manage or influence fitness sorting through the terms related to interest compensation for cash in private depots. In the

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<sup>1</sup> Private cash depots – terms for interest compensation from Norges Bank to Banks.

<sup>2</sup> Terms and conditions for banks' cash deposits in and cash withdrawals from Norges Bank.

second case, deposit or withdrawal at the central bank is necessary, and the Bank can manage fitness sorting through the terms related to deposits and withdrawals.

When banks make cash withdrawals, Norges Bank can also influence the quality of banknotes in circulation through the proportion of new to used banknotes in cash deliveries. Norges Bank does not implement measures directed at other market participants such as cash handlers, retailers or the general public.

Specific measures taken by Norges Bank to influence the quality of banknotes in circulation have been:

- Incentives and regulations for banks
  - o To make interest-bearing deposits in the central bank, the banknotes must be fitness-sorted according to Norges Bank's rules
  - o As with deposits in the central bank, to qualify for interest compensation for banknote stocks in private depots, deposited banknotes must be fitness-sorted. Unfit banknotes are to be delivered to Norges Bank and are not to be recirculated.
  - o Unfit banknotes may be replaced with fit notes free of charge at Norges Bank
- The Bank's own activities
  - o Technical specifications of new banknotes
  - o Definition of fitness sorting criteria
  - o Monitoring compliance with fitness sorting criteria
    - Random sampling of banks' deposits of fit banknotes
    - Inspection of received banknotes that are worn or damaged
    - Control of settings on cash handling machines that destroy banknotes.
  - o Proportion of new to used banknotes in deliveries to banks

## 5. New concept for monitoring the quality of banknotes in circulation

Up until 2010, Norges Bank influenced the quality of banknotes by defining criteria for sorting out unfit banknotes and for deliveries of banknotes from the central bank, without defining quality requirements for banknotes actually in circulation. This practice conforms to that of most other central banks. Moreover, the sorting criteria have been the same for all denominations. Besides lacking a clearly defined objective for the quality of banknotes in circulation, the method has the following weaknesses:

- The criteria for fitness sorting have been identical for all denominations, i.e. the method does not take into account differences in patterns of use and the length of time banknotes are in circulation before being returned for fitness sorting. Low denominations are used a lot as change and remain longer in circulation before being received by cash centres. The intermediate denominations are typical ATM banknotes, and return more frequently to the cash centres, while the highest denomination is little used in ATMs and vending machines. We currently note that the average length of time the different denominations circulate between each fitness sorting varies between three and 17 months. Differences in use result in differences in wear, but also in different fitness criteria. A denomination that is frequently used in transactions and is

in circulation for a long time should be of a higher quality when recirculated than the quality necessary for a banknote that will be returned quickly.

- The method takes insufficient account of knowledge of the actual situation with regard to the quality of banknotes in circulation. This also implies that it is difficult to correct if the actual quality of banknotes in circulation changes.

The method may be compared to attempting to maintain a steady comfortable temperature in a bathtub by regulating the temperature of the water being added to or drained from the tub without defining what a steady comfortable temperature is or measuring the actual temperature of the water.

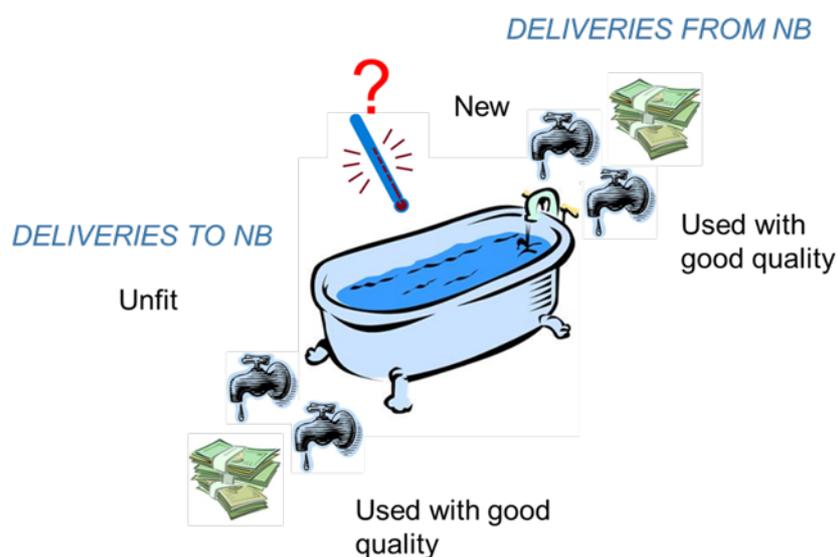
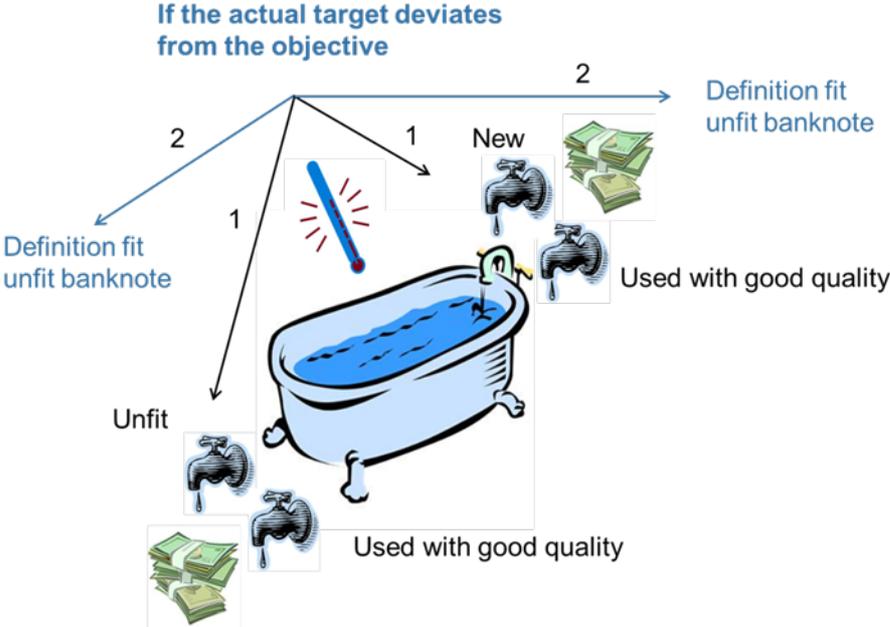


Chart 2: The problem with the earlier concept is the lack of knowledge regarding the quality of banknotes in circulation.

In view of these weaknesses, an effort was initiated to develop and implement a concept for monitoring the quality of banknotes in circulation. This has been a difficult task, and in the process, the concept has been modified somewhat, based on experience. In brief, the new concept may be described as follows:

1. Set quality objectives for banknotes in circulation for each denomination, both as an average and as an upper limit for the proportion of banknotes of very poor quality ("super unfit").
2. Measure the quality of banknotes in circulation in two sample surveys per year.
3. If measured quality deviates from set objectives, the following measures are considered:
  - a. Define and adjust separate thresholds for fit and unfit banknotes for the various denominations for use in fitness sorting. In this way, the percentage of banknotes destroyed may be increased or decreased.
  - b. Adjust the proportion of new to used banknotes in deliveries to banks.
  - c. Make changes to the technical specifications of the banknotes for each denomination.

Let us return to the image of a bathtub: the concept involves setting an objective for the temperature of the bathwater and measuring the actual temperature on an ongoing basis. If the temperature deviates from the objective, it is corrected by mixing in hot and cold water through filling and draining.



*Chart 3 The new concept. If the actual quality deviates from the objective, the taps and/or the definition of an unfit banknote are adjusted.*

**Quality objectives for banknotes in circulation**

Two quality objectives are defined for banknotes in circulation. One objective is for desired average quality in the form of a quality index and another sets an upper limit for the proportion of banknotes of very poor quality in circulation, super unfit. Both objectives are to be defined for each denomination.

The objectives are set in order to fulfil the central bank’s responsibility for ensuring that banknotes function effectively as a means of payment. Implicit in this is that banknotes must be able to be handled both manually and by machine in an appropriate manner. An important part of this is that the security features for identifying a genuine banknote must be intact. Furthermore, as for most central banks, an important consideration will be a general perception among the public that the quality of banknotes in circulation is good. Numerous factors must be addressed, and in the end, an overall assessment will have to be undertaken largely on the basis of the experience of the central bank and of other parties who use and handle banknotes. There is considerable international experience to draw on with regard to defining fitness criteria for banknotes delivered by central banks, but very little with regard to setting objectives for the quality of banknotes in circulation.

In addition to challenges posed by defining criteria and thresholds for these criteria, the following factors will have to be dealt with:

- The concept requires that the sample obtained for testing is representative for the banknotes in circulation. The current practice is to draw the sample from

banknotes received by cash centers for processing. These are primarily surplus holdings from retail trade. Normally, no fitness sorting takes place prior to delivery. Nevertheless, it may be uncertain whether the sample is representative for the banknotes in circulation.

- The sorting machine used for processing test banknotes may produce differing results depending on calibration and maintenance status. Methods have been developed to calibrate the machine, but even so, comparing results over time may be a challenge.
- Different productions of the same banknote denomination will result in minor differences in printing, which may impact test results.

### Quality index (average quality)

The quality index includes the following variables:

- Soil
- Graffiti
- Stains or extraneous ink/dye
- Holes
- Tears
- Folded corners
- Fold in the middle
- Missing corners
- Quality of security features intended for
  - general public
  - retailers
  - automated verification

For each variable, criteria are defined that indicate what is acceptable/unacceptable. For soiling, values along a scale between 1 and 16 are used, where 16 represents new banknotes and 1 represents banknotes that are very soiled. For the remaining variables, the prevalence is used. Each variable is indexed from 0 to 100, where 50 is set as the acceptable value (100 is excellent and 0 is very poor). The scale is adapted to each denomination: the value 50 for a 50-krone note indicates a lower quality than the same value for a 1000-krone note. To present the overall status and developments in quality for the particular denomination, the above information is aggregated in the form of an index where each variable has its own weight. Soiling is considered to be the most important factor explaining the perception of whether a banknote is of good or poor quality. This variable therefore has the highest weight. Table 1 below shows threshold values and weighting for each variable. Some variables are entered with a weighting of 0 because they currently do not appear to be important. If there is a desire to include these variables in compiling the index at a later date, eg because the prevalence of this type of defect is increasing, the data are already recorded.

Setup:	weight				
	NOK 50	NOK 100	NOK 200	NOK 500	NOK 1000
Soil	60	60	60	60	60
staining or extraneous ink/dye	0	0	0	0	0
Holes>40	5	5	5	5	5
Tears>30	25	25	25	25	25
Folded corners >40	10	10	10	10	10
Tape	0	0	0	0	0
UV	0	0	0	0	0
Missing corners	0	0	0	0	0
control sum	100	100	100	100	100

*Table 1: Sorting criteria and weighting*

### Super unfit

As mentioned, in addition to the quality index, a target is defined as the share of banknotes that are of very poor quality: super unfit. Even though the average value is satisfactory, there may still be a large proportion of banknotes of very poor quality.

The share of super unfit notes comprises notes with substantial

- soiling
- staining or extraneous ink/dye
- tears larger than 6 mm
- tape
- defective UV
- missing corners

The total prevalence of such notes shall not exceed 5 percent of the sample. Measurements show that very poor banknotes can be marked by the presence of numerous defects, and that there may be some correlation between the defects. This pertains especially to the two lowest denominations. Using current processing machines it is not possible to obtain data describing the correlation between defects on a banknote.

For soiling, the degree of soiling in the light areas of the note is measured according to the same scale used by the quality index. Chart 4 shows the result of a test of banknotes taken from circulation.

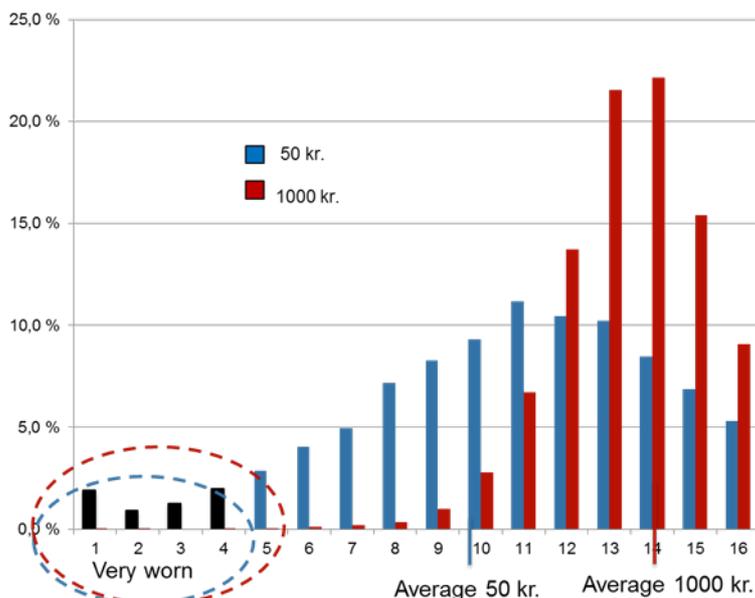


Chart 4: Banknotes in circulation by degree of soiling

The chart shows the distribution by degree of soiling for the lowest denomination (50-krone) and the highest (1000-krone). For the 50-krone notes, the quality ranges from very soiled to completely clean new banknotes, and the quality nearly follows a normal distribution. For values lower than 4, the banknotes are so soiled that they must be characterised as being of very poor quality (super unfit). The requirement for the average value is set at 10 (ie to attain a score of 50). For the 1000-krone note, the chart shows a skewed distribution, with very few banknotes with considerable soiling, and many with little soiling. For this denomination, a stricter requirement is set, with regard to both average acceptable soiling and the definition of very poor quality. The average value is set at 14 (score 50), and values lower than 5 are considered super unfit.

The objective is to maintain the share of very soiled banknotes in circulation at below 5 percent of the total number of banknotes in circulation. What is regarded as very soiled varies between denominations. Chart 5 illustrates this.

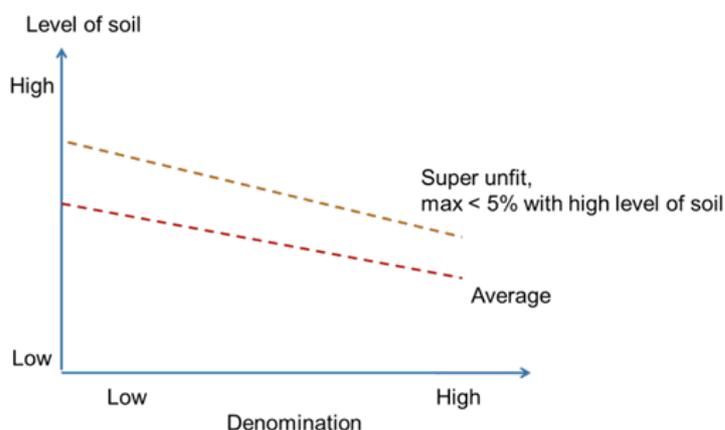


Chart 5: Objective for the level of soiling for banknotes in circulation

Table 2 shows the quality variables included in the basis for calculating the share of super unfit banknotes.

	Soil	staining or extraneous ink/dye	Tears	Tape	UV deFekt	Missing corners	correlation factor
NOK 50	<=3	all	>6mm	all	all	all	0,5
NOK 100	<=3	all	>6mm	all	all	all	0,5
NOK 200	<=3	all	>6mm	all	all	all	0,5
NOK 500	<=4	all	>6mm	all	all	all	0,5
NOK 1000	<=4	all	>6mm	all	all	all	0,5

Table 2: Quality variables for “Super unfit”

For a number of the quality variables, it is a challenge to define a value for what is to be considered very poor quality. For example, in the current guidelines for ordinary fitness sorting, area limits have been set for the size of folds. Banknotes with a fold of up to a certain size are to be sorted out and destroyed. If the fold is above this size, the note is to be flattened out and considered fit. Also for other defects, defining values is a challenge. Furthermore, it is a challenge to formulate an overall index on the basis of the individual defects. In our experience, a trial and error method has been necessary over several periods to set the values in the model.

## 6. Ongoing monitoring of the quality of banknotes in circulation using the new concept

### Measuring the quality of banknotes in circulation

Norges Bank performs measurements of the quality of banknotes in circulation based on samples obtained from the five regions mentioned above. From each region, 5000 notes of each denomination are collected twice a year. The procedure for banknote collection has been devised to reflect what is actually in circulation. Analyses using a banknote sorting machine (DLR 7000 / CPS 1200) with specially developed software provide a basis for assessing whether the quality is within the target range, which is defined as 50 +/- 10, or whether correction is necessary with the aid of the tools below.

### Adjusting the threshold between fit and unfit banknotes in fitness sorting

This threshold is defined for each denomination in a sorting guide that all banks must follow to make deposits in Norges Bank or earn interest compensation for banknotes in a private depot. Fitness sorting requirements are an important tool for attaining set objectives for the quality of banknotes in circulation. Owing to stricter requirements, the notes recirculated after fitness sorting will on average be of better quality.

The sorting guide contains the same measurement variables as the quality index, and the share of super unfit banknotes for banknotes in circulation. For all criteria except for soiling, the banknote will be defined as fit or unfit; there is no scale for these criteria. The same pertains to machine-readable security features. If a feature does not function, the banknote is defined as unfit. For soiling, the same scale is used as mentioned above: 16 is a clean new banknote, whereas 1 is a very soiled banknote.

If the banknote circulates in such a way that it quickly returns to fitness sorting after being recirculated without in essence having been used, the definition of the fit/unfit boundary will be approximately equal to the objective for the average quality of banknotes in circulation. If the banknote circulates for a long time before being returned for fitness sorting, the boundary will have to be set a lot stricter than the objective for average quality. The frequency of fitness sorting, or the average time it takes before the banknotes of a particular denomination are returned for fitness sorting, will determine how the threshold between a fit and unfit banknote will be set for fitness sorting. Chart 6 shows the share of notes in circulation for each denomination that is returned each month for fitness sorting in the years 2011-2015.

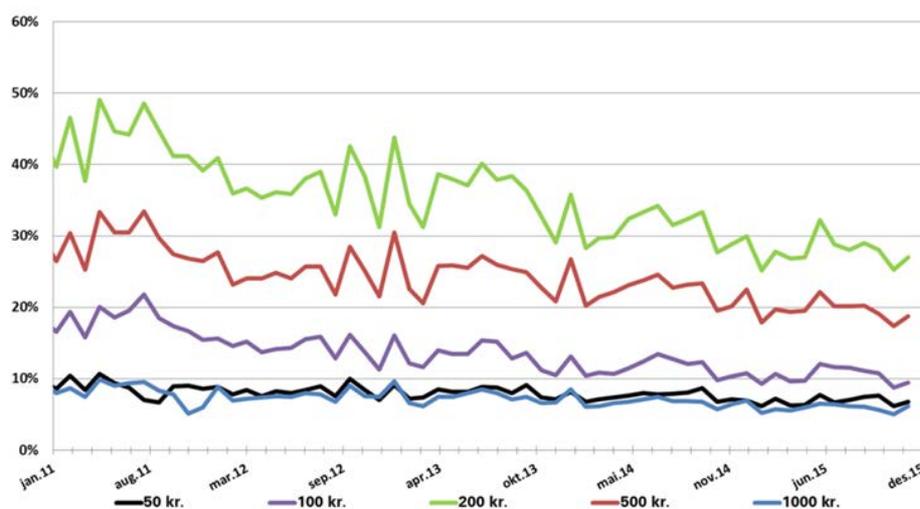


Chart 6: Share of notes in circulation fitness sorted by cash centres per month, 2011-2015

The chart shows that on average, approximately 28 percent of 200-krone notes were fitness sorted per month in 2015, which means that on average, this denomination is fitness sorted every three months. For the 50-krone note, the corresponding figure is approximately 6.9 percent or every 17.8 months. If these two denominations are to be of the same average quality, the quality of the 50-krone notes that are recirculated must be somewhat higher than for 200-krone notes. In addition to how quickly the denomination is returned for fitness sorting, the pattern of use and expectations of the public will have to be given weight. In general, expected quality will rise with the denomination's value. Furthermore, the denomination's use in vending machines and ATMs will be of importance. Chart 7 illustrates how the threshold for soiling may be set between fit and unfit banknotes. Since this threshold is largely defined on the basis of the velocity of banknote circulation for fitness sorting, the threshold may vary geographically on the basis of geographical variations in the velocity of banknote circulation.

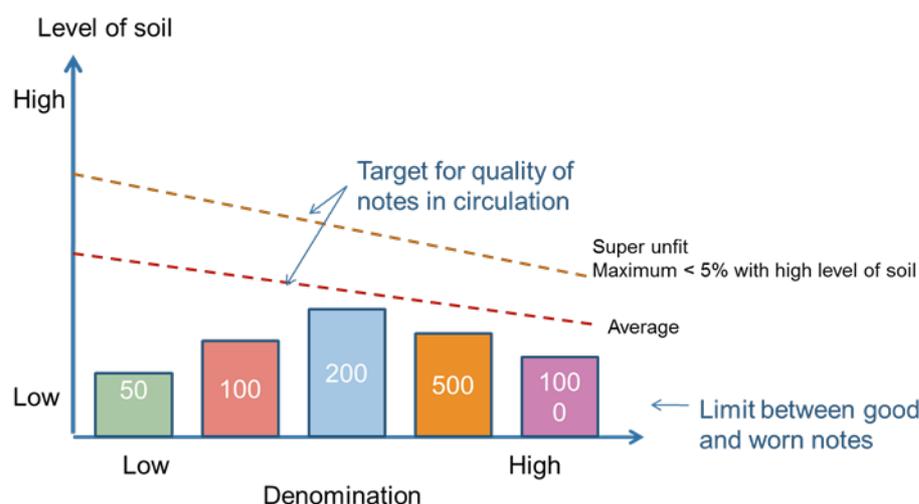


Chart 7: Levels of soiling, banknotes in circulation

### Change in the composition of new and used banknotes in deliveries to banks.

To increase the quality of banknotes in circulation for one or more denominations on a nationwide basis or in more delimited geographical areas, the share of new banknotes distributed to banks may be increased. And the opposite effect may be achieved by reducing the proportion of new banknotes. Extensive use of this tool may increase the need for redistribution among the central bank's five depots.

### Changes in banknote specifications for the particular denomination

A change in the quality of banknotes in circulation can also be attained by changing the quality of new banknotes, for some or all denominations. This is a tool that requires a long implementation time. Several years may pass between the time a specification change is implemented and the time notes with the new specification account for a considerable share of banknotes in circulation. Examples of specifications that may be changed to change the quality of a banknote are:

- Specifications of the substrate
  - type of substrate: eg cotton paper or polymer
  - for cotton paper, eg the thickness and length of fibres to make the banknote more robust to normal wear
- Surface treatment of the paper to reduce soiling
- Elements along the edge and in the corners of the banknote to reduce tears and folding of corners
- The size of the note
- Printing, both to prevent the ink from wearing and to make the banknote more robust to normal wear.

The changes that may be relevant must be assessed on the basis of information on the quality criteria that are the reason that banknotes are classified as unfit.

## 7. Summary

The quality of banknotes in circulation is important for the effectiveness of the cash system and thus important for Norges Bank's performance in attaining its objectives. Previously, Norges Bank managed banknote quality by setting a threshold for the quality to be sorted out in the surplus holdings that banks wished to deposit in the central bank or state as the basis for interest compensation in private depots. Norges Bank set these thresholds without having a defined objective for the quality of banknotes in circulation or a clear picture of the actual quality of banknotes or without knowing whether there are differences between denominations or regions that indicate that there should be different thresholds. This is generally the practice at most other central banks.

Norges Bank has developed and implemented a system in which objectives are set for the quality that banknotes in circulation should have. Random samples of banknote quality in five regions are taken twice a year, and these samples are analysed to determine the need to implement any of the measures under Norges Bank's control. The system has been in use for some time, but the plan is to adjust the concept as more experience is gained. So far, our perception is that the system provides a better measurement indicator, a sounder basis for assessing various measures for influencing the quality of banknotes in circulation and better underlying data for analyses of various issues related to the quality of banknotes in circulation than the system previously employed.

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