Durable banknotes: an overview

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Presented by

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1. INTRODUCTION

Usually central banks have three main technical criteria for purchasing banknote paper. The banknote paper must be:
1) Secure,
2) Durable,
3) Printable.

During the last several years, central banks have taken more-and-more interest in durable banknote papers. This interest is not only from a cost point of view but cleaner notes are also more secure and more hygienic.
Durable banknote paper can be reached by using six strategies, given in more-or-less historical order:
1) Banknote paper: natural fibre blends (since 1666),
2) Banknote paper: cotton mixed with artificial fibres (since 1974),
3) Varnish the printed banknotes (since 1955),
4) Polymer or plastic substrates (since 1974/1988),
5) Traditional cotton papers with pre-print coatings (since 1997),
6) Laminated substrates (in research 2002).

In some cases strategies are combined, like e.g. varnished polymer notes.

This presentation focuses on one of the latest developments, the traditional cotton papers with pre-print coatings. As a reaction of the traditional paper makers to the polymer notes, several new cotton papers were introduced to the market since 1997. The last two years the BPC/Paper Committee invited three paper manufacturers to present their products in this field. Several central banks also reported on these subjects at the last meeting of the Pacific Rim BPC (Thailand 2001), which are incorporated into this report. Hans de Heij observed this meeting.
This paper gives an overview of the different strategies and reported results, as far as known, to increase the life of banknotes.

2. PREDOMINANT FACTORS AFFECTING CIRCULATION LIFE

Climate and culture
From the reports published on more durable banknotes it is clear that the climate is an important factor, as are prevailing public habits in handling banknotes. Three broad climatic categories are indicated in Table 1.

CLIMATE	AREA/COUNTRIES	TYPICAL NOTES
1. Mild climate	Canada, Europe, United States, …	Cotton paper
	New Zealand, Romania, …	Plastic substrate
2. Humid climate	many countries	Cotton paper (98 %) *
	Australia, Brazil, Brunei, Indonesia, Papua New Guinea, Thailand, Western Samoa, …	Plastic substrates (2 %) *
3. Hot-dry climate	Africa, Arabia, …	Cotton paper
	no examples known**	Plastic substrate

Table 1.
Overview of climate influence on banknotes. Only circulating plastic substrates are mentioned; not commemorative notes.
*) The share of plastic notes in the world's humid countries is circa 1 - 2 %. The rest is cotton paper, which is therefore the 'typical note' also in humid regions [24].
**) Kuwait issued in 1993 a commemorative polymer note of 1 Dinar.

Banknotes soil first

Reports on defect notes of two paper makers and three central bank are given in Table 2. All report the soiling level as the most predominant reason for classifying notes as defective. Mechanical defects appear later: notes get dirty first and after soiling the mechanical defects appear. Except for folded corners or dog-ears that appear already on new notes. Soiled notes are often taken out of circulation because of their soiling level, before mechanical defects appear. Since soiling is the main reason for classifying notes as unfit for circulation, soiling reduction should be the first aim in developing more durable banknotes. This is not to say that the physical condition and properties of banknotes are unimportant. In highly developed countries, the public interacts on a daily basis with machines that dispense cash or accept cash. A breakdown in the integrity of the banknote, accompanied by a loss in stiffness, can be seen on notes that are otherwise free of holes, tears, or excessive soiling. The public has an aversion to limp notes,

Defects of sorted notes	PL	Portals	DNB NL	BdlR Colombia	FRB of SF USA	Remarks
1. Soiling	81 %	60 %	70 %	80 %	64%	Including writing, dirt spots, tape, holes…
2. Folded corners (dog ears)	-	20 %	25 %			Many new notes are defect because of folded corners.
3. Mech. defects esp. tears	9 %	20 %	5 %			Before wear and tear notes are already found to be much soiled.
4. Graffiti	5 %	-	-	together 20 %	together 36%	
5. General wear and tear	4 %	-	-			
6. Damage to security elements	1 %	-	-			
Total	100 %	100 %	100 %	100 %	100%	

Table 2.
Overview of the defect types reported by Papierfabrik Louisenthal [24], Portals [25], De Nederlandsche Bank [11,14], Banco de la Republica Colombia [27] and Federal Reserve Bank of San Francisco [38].
In case of Portals figures concern: causes of note rejection after a certain time in circulation. In case of Federal Reserve Bank of San Francisco, "Soiling" applies to notes rejected for excessive soiling only, while the remaining defects contain a combination of physical defects only or physical defects plus excessive soiling.

especially when this interferes with the convenience of automated bill acceptance or dispensing. There are data that indicate a significant portion of stiffness degradation can occur prior to elevated soiling levels [38]. This indicates that the substrate itself can be important in optimising longevity even for banknotes that circulate in mild climates and sophisticated economies.

Increase paperweight for better tearing resistance
The tearing resistance is more-or-less equal proportional to the gram weight of the paper. The life of notes can be increased against wear and tear by increasing the paperweight, like e.g. done by the Bank of England for their note at the note-coin boundary, the new GBP 5.

Folded corners
To protect banknotes against folded corners - the second reason for classifying banknotes unfit - a solution is recently offered by DeLaRue/Portals. With the *Cornerstone* they presented re-enforced corners which reduces corner folding and therefor the rejects/unfit notes at the sorting machines of the central banks. There are not yet banknotes issued with this type of paper and therefor there is not much proven experience.

Note-coin boundary
Another important behavioural factor is the tendency for the public to treat the lowest denomination notes as they would coins. The Bank of England has observed those GBP 5 notes spend much of their life in the company of coins loose in the pockets of the English population. This is likely to be the case for the 5 euro note as well. In such cases, notes become unfit due to a combination of soiling and mechanical degradation.

Calculation of life
Research and reports on durable banknotes are often supplied with figures about the life of the note. A major drawback in this is that there is no uniform calculation method. Within the BPC there is an advised, standardised formula for the life L:

$$L = \frac{\text{(last year's notes in circulation)} + \text{(this year's notes in circulation)}}{\text{(this year's new notes issued)} + \text{(this year's notes withdrawn)}}$$

Prediction of life with e.g. soiling tests
The durability of paper can, only partially, be predicted by laboratory tests as given in Table 3 under Soiling and Mechanical Aspects. To arrive at a uniform soiling test, the BPC Paper Committee proposed such a test in 1997 [9]. This test is used by several laboratories, as are other artificial soiling tests such as that used by Portals [25].

Life Cycle Analysis (LCA)
Finally a remark could be made with respect to Life Cycle Analysis (LCA) of durable banknotes. In this view it is not only the life that counts, but also other process parameters. The Swiss were the first that reported on an LCA-study, analysing the environmental effects of banknote production, distribution and waste management [40]. Using natural fibre blends, recycling denim rags etceteras, could be an advantage for these kinds of papers, as was shortly discussed during the last meeting of the Paper Committee in Stockholm.

3. BANKNOTE PAPER: NATURAL FIBRE BLENDS

One of the oldest strategies to increase the life of the paper is to add other natural fibres to the cotton. A very well known natural fibre blend is the paper of the USD-notes. This paper is made of approximately 75 % cotton and 25 % flax fibres. Up to 20 % denim rags might be used in the cotton part. The reported life of the dollar notes is high, as given in Table 4. The paper manufacturer of the USD-notes is Crane. Since 1998 Crane has marketed this USD-like paper under the *Marathon* brand [38]. *Marathon* is essentially the same paper as US Currency except that the particular security features are specific to each customer. The actual circulating volumes with the *Marathon* brand are quite small compared with US Currency and there is limited performance data. But, on the other hand, the USD-paper is very well documented from the perspective of durability, press handling, printability and general circulation life expectancy.
In 2001 Orell Füssli reported in 2001 to the Paper Committee about several laboratory tests on the *Marathon* paper [23].

The last 25 years the trend has been for banknote paper to drop from their specification fibre content other than cotton. Consequently, other than US Currency (*Marathon*) virtually all banknote paper now made is 100 % cotton. One of the exceptions is the Central Bank of the Philippines that issues banknote paper using 20 % abaca - fibres from the banana plant - and 80 % cotton. In 2002 they will issue a new PHP 200 using again this type of banknote paper instead of their previous productions of 80 % cotton and 20 % flax [30].

Some well known historical natural fibre blends include the Finish banknotes with a blend of 85 % cotton and 15 % eucalyptus pulp [18]. An other example are the Canadian banknotes that used up to 25 % of recycled cotton like e.g. cotton clothes, rags into the banknote paper. For many years Dutch banknote paper consisted of approximately 85 % cotton fibres and 15 % flax. In the beginning of 1975 new tight legal regulations regarding industrial pollution were announced. Pulping of flax requires more pollution control equipment than with cotton and, in the Dutch situation, was no longer acceptable. Trials with paper of 100 % cotton were performed and were found successful. A circulation trial showed a 23 % increase of life [3].

Crane, having many years of experience with flax fibre, claims that the observed increase in circulation life was an unlikely result of having removed flax from the specification [38]. Cotton, abaca, flax, and other sources of natural fibre possess different properties that are only optimised with the correct fibre preparation strategy. Specifying a particular composition does not, in itself, assure the most durable product.

It is also important to consider specifications other than actual fibre composition such as the double fold or tear resistance. Particularly while trying to retain a vivid watermark, papermakers rarely seek to make paper any stronger than specified through these laboratory standards. Since “durability” cannot be directly measured by standard techniques used during manufacture and since it is never directly specified, this characteristic has not been optimised in most banknote paper.

4. BANKNOTE PAPER: COTTON WITH ARTIFICIAL FIBRES

Especially in the 1970s many paper mills experimented with banknote papers based on a mixed composition: blends of natural fibres like cotton and synthetic fibres. All major suppliers have experimented with synthetics right up to the present. It is difficult to complement the desired properties of natural fibre banknote paper with synthetics without undesirable consequences. This was just the case, for example with *Paressyn*, a semi-synthetic paper made by the Dutch paper mill Van Houtum & Palm. A substantial percentage of plastic fibres were added to the cotton to increase both the tensile strength and the tearing resistance. In 1974 the NLG 5 banknote was printed on this paper and issued. However, the circulation trial indicated a lower life for this type of note. The explanation was that the plastic fibres

were not fully embedded by the cotton fibres and were sticking out of the paper. These plastic fibres attracted dirt more easily because of static electricity.

Recently ArjoWiggins introduced on the market the *Diamone Reinforced* paper type. This paper includes synthetic fibres and protects both to soiling and physical damage [34].
Similar results were found in laboratory and machine made paper reported by Crane [38]. Synthetic fibres can readily enhance tear and tensile strength but achieving the desired bonding with natural fibres has not been possible. The stiff and poorly adhered synthetic fibres tend to stick up from the surface of the paper after wear.

5. VARNISH ON PRINTED BANKNOTES

The oldest known technique to increase the life is to varnish the printed notes. The first central bank that issued varnished banknotes was De Nederlandsche Bank (DNB). The varnish used was a solvent based varnish.

Solvent based varnishes
In 1955 the first NLG-notes were varnished with Ultramid Coating or UMC. This was found successful and since 1957 all the NLG-notes are varnished, except some series for the benefit of circulation trials. In 1987 DNB started with DAR-varnish - Dirt and Abrasion Resistant - and reported in 1999 that the life of the NLG-banknotes *doubled* (+ 100 %) compared to not-coated banknotes, leading to a banknote production decrease of 70 % [11, 33]. Earlier reports on varnish and circulation trials by DNB were done in 1955 [1], 1956 [2], 1975[3] and 1982 [4] and 1985 [5].
Several other central banks also have varnished their banknotes for many years, such as the Swiss Central Bank since 1971. Today there are more varnishes for banknotes available like e.g. 'TOPnote' a solvent based varnish from Giesecke & Devrient [12].

Water based varnishes
In 1993 the Swiss were the first to introduce a water-based varnish. They replaced their solvent-based varnish by a water-based varnish '850219 M' and since 2000 the Swiss notes are varnished with *Sicpa Protect.* The Swiss report that the life of banknotes in circulation increased about 20 % by using this latest varnish compared with the previous varnish (and not to unvarnished notes) [15, 23]. In 1996 De Nederlandsche Bank, issued in 1996 as a trial 100.000 NLG 50-notes with a water-based varnish DAR, the WDAR [41].

UV-coatings
New used varnish techniques are based on UV-curing varnishes. De Nederlandsche Bank issued in 1996 also NLG 50-notes with two variants of UV-coated varnishes (UV-Sigma and UV-Desotech) [41]. The Bank of England Printing Works reported trials with an UV-coated varnish from 3M, to increase the life of the GBP 5 [21]. Recently they announced to have printed 180 mln GBP 5 notes with this type of varnish, finally using a free-radical system from Sun Chemical. The Bank of England expects a 20 % longer life of this varnish.
Laboratory soiling experiments have been reported whereby the soil resistance of USD 1 notes was significantly improved by using a UV-cured post-print coating [38]. The results were comparable, or slightly better, than those for a new Australian AUS 5 note as measured by the change in brightness after soiling.

Circulation trials
The Central Bank of Malaysia started in 2001 a circulation trial on the MYR 1, were three different commercial available varnishes are used. Other central banks that recently issued varnished notes are Armenia, Dominican Republic, Latvia, Mauritania, Mongolia and Tajikistan.

6. POLYMER NOTES

The first plastic banknote was issued in 1974 in Haiti and printed on *Tyvek*, a synthetic fibre material and not a foil. It is a spun-bonded Dupont product and is used, most notably, for tear resistant mailers and house wrap. Ten years later in 1984, there was an experiment on the Island of Man with *Tyvek* 1 GBP-notes. These first plastic notes were printed on generic, white coloured substrate without windows or any other security feature. These first issues were not successful, mainly because ink failed to adhere during circulation.
The first successfully introduced polymer note was issued in 1988 by the Central Reserve Bank of Australia (1988, ASD10), printed on *Guardian,* made by Securency. Beside Guardian another substrate was offered to the market, the Canadian *DuraNote*. *DuraNote* was based on a multi-layer structure and not on a single film technique like *Guardian*. The Paper Committee reported about these two substrates to the BPC/General Meeting in Athens in September 2000 [13]. *DuraNote* is no longer marketed, since there were no banknotes issued using this type of polymer. Since 1999 DuraNote is concentrating on improved laminated substrates, just as the Canadian Domtar is researching with financing from the Canadian Government [37].
In 1999 there was a presentation from Arjo Wiggins to the Paper Committee called 'The importance of paper in banknote security', focussing on the security of cotton paper compared with polymer [10].

After Australia several other central banks also issued full series of polymer notes, all printed on the *Guardian* substrate, like New Zealand (1999-2000) and Romania (2000-2001). Other central banks issued one polymer note to gain experience, like e.g. Thailand (1997, THB 50) and Brazil (2000, BZL 10). Several central banks issued polymer notes on commemorative occasions, like e.g. Singapore (1990, SGD 50) and North Ireland (1999: GBP 5) and many others. In 2001 about 0,7 % of all the notes issued were printed on plastic [24].

According to different reports, the life of these polymer notes increased by 200 - 400 %. This life increase is not only caused by the polymer substrate, but also by the post-printed varnish used on these notes - two different types - to create a better 'grip' for e.g. the use in ATMs.
But not all central banks are convinced of the use of polymer notes. Both the central banks of Brazil and Thailand reported at the last PacificRim BPC in Bangkok that, at the moment, they would not continue to issue polymer notes. Brazil first wants to evaluate their large scale circulation trial (250 mln notes BZL 10) and said they will not order more polymer substrate before 2004. Thailand reported that 115 mln polymer notes THB 50 were issued and that they still have – for 60 mln notes – not printed polymer substrate in stock. The message communicated by the Thai was that the 50 Baht polymer experiment had failed and that no further polymer would be purchased. Preference has been given to pre-print coated paper, which is now used for all 20 and 500 Baht notes.
The central bank of Bangladesh also decided to return to cotton paper after their experiences with a 10 Taka polymer note.
On the other hand the Central Bank of New Zealand started to issue full series of polymer notes since 1999, just as Australia did in the period 1988-1996. The Reserve Bank of New Zealand reported that both the retailers as the general public strongly prefer polymer notes rather than paper notes [36].
And in 2001 the Central Bank of Romania completed the issue of the first full European polymer banknote series. The ROL 100.000 of this polymer series, a volume of 60 mln notes, was printed by Oesterreichische Banknoten- und Sicherheitsdruck and they reported about the printing of these notes at the last meeting of the Paper Committee [39]. The Central Bank of Mexico is preparing the production of a polymer note on the note-coin boundary, the 20 peso, to be issued later this year 2002 [37].

7. TRADITIONAL COTTON PAPERS WITH COATINGS

The most recent developments in banknote paper are cotton papers produced with a coating on both sides. The papers are traditional *mould* made with the particular coating being the only thing differentiating the products offered in this class.

In 2001 the BPC/Paper Committee invited two paper manufacturers to present their traditional cotton papers with coatings:
- Portals with *Platinum*,
- Papierfabrik Louisenthal with *LongLife*.

Although several banknotes printed on coated paper were issued, there is not much feedback yet from central banks on their life. The Central Bank of Colombia reported about a circulation trial done with the COP 2.000, printed on Platinum paper. The life in circulation was increased by 10-15 %. It is worth noting that the value of coated papers becomes apparent at the point where the notes start to become dirty. If, as in Colombia, the trial was concluded before this moment occurred, then the apparent benefits of the coated paper do not become evident. The Colombian national bank is doing further experiments with long life papers with a coating [26, 27].
One of the first notes issued on LongLife paper is the THB 500 issued by the Central Bank of Thailand in August 2001. Prediction of the paper makers is that this type of paper would increase the life by 100 % [24]. At the Pacific Rim conference Thailand reported back on both the Portals Platinum substrate used on the THB 20 and on Papierfabrik Louisenthal's LongLife paper used on the THB 500. This report stated that the relative life of Platinum 'of 1,95 found in the ninth month indicates that the life of durable-type banknotes is almost twice that of normal-type banknotes' [31].
It behoves the issuing authority to understand what these predictions are based on. Some researchers have used results from laboratory soiling tests to extrapolate to expected performance in the field based on an assumed direct relationship. For example, the coated papers may take twice as long to produce the same level of soiling in laboratory testing as the control papers without coating. The State Printing Works of the Czech Republic reported in 2001 tests carried out on these two coated cotton paper types and also on a third, *Diamone* from Arjo Wiggens [20, 34]. Also included in the study was *Marathon*, from Crane & Co. The Central Bank of Brazil reported at the last Pacific Rim BPC in Thailand 2001, about these durable paper types [28]. The results can be found in Table 3.

Some evidence for the paper coating policy can be found in the experience of DNB with the NLG 100/Little Owl issued in 1992. This note has a silk screen layer on the front, covering about 80 % of the surface. Although done for security reasons, this iridescent silk screen layer added an unexpected contribution to the life of the NLG 100-notes. The life of these notes increased by 280 %, from circa 3,5 years for the old NLG 100/Snipe to an average of circa 10 years for the NLG 100/Little Owl [33, 41]. It is interesting to note that the little owl notes were the first to be both screen coated while printing, and varnished after.

To complete this overview the presentation by Tumba Bruk to the BPC/Paper Committee in 2000 on 'jet cylinder mould' should also be mentioned. This is also a traditional banknote paper, but the paper has a specific internal fibre orientation and would make the paper more resistant against mechanical damages [17]. Today it is known that this invention is not used for production and has been dismantled.

8. LAMINATED SUBSTRATES

The latest developments in durable substrates are the laminated substrates, using layers of different materials to create a longer life. As already mentioned the Canadian companies DuraNote and Domtar are both concentrating on this type of laminated substrates. So far there are no banknotes issued on the basis of laminated substrates.

9. OVERVIEW

In Table 4 an overview is given of the different strategies to increase the life of banknotes and some typical examples.

	Marathon	Platinum	LongLife	Diamone	Reference/ remarks
1. MARKET/ECONOMICS					
1.1 Company	Crane	Portals	PL	AWA	
1.2 Construction	internal	coating	coating	coating	
1.3. On market since	1998	1997	1999	1999	[34]
1.4. Clients (NCBs)	≥3	> 15	> 5	> 3	[34]
1.5 Price to standard paper		> 25 %	+ 10 - 30 %	+ 15 - 25 %	[12, 22, 24, 25, 34]
1.6 Adding to price of banknote		12,5 %	~ 20 %	10 %	[24, 25, 34]
1.7 Saving on intaglio ink			15 %		[24]
1.8 …					
2. LIFE ASPECTS					
2.1 Promised increase of life		+ 25-100% [1)]	+ 100 % [2)]	+ 100 %	[12, 24, 25]
2.2 Reported increase of life		15,2-100 %	+ 100 %		[26, 31]
SOILING					
2.3 Dry soiling test		+ [3)]	++ [4)]	+	[22, 34]
2.4 Wet soiling test		+	+	++	[22, 34]
2.5 Crumpling test		++	-	+	[22, 34]
2.6 Crumpled porosity	142			+	[34]
2.7 Washing test		++	+	++	[22, 34]
2.8 Roughness smoother side	804,6	312,4	226,6	319	[28]
2.9 Roughness less sm. side	1176,9	506,1	339,4	435	[28]
2.10 Rub resistance					
2.11 Ink wear test				excellent	[34]
2. 12 …					
MECHANICAL DEFECTS					
2.11 Folding endurance MD	6.381	2.437	1.080	2.612	[28]
2.12 Folding endurance CD	5.850				
2.13 Tearing resistance MD	111,5	87,2	67,9	86	[28]
2.14 Tearing resistance CD	113,6	98,4	79,4	105	[28]
2.15 Wet tensile strength MD	5,64	6,29	9,42	5,74	[28]
2.16 Wet tensile strength CD	3,15	3,17	4,40	3,07	[28]
2.17 Dry tensile strength MD	11.4				
2.18 Dry tensile strength CD	6.5				
2.19 Stiffness					
2.20 …					
3. QUALITY					
3.1 Quality of watermark					
3.2 Cloudiness					
3.3 Whiteness	73 %	81 %	86 %	83 %	[28]
3.4 Opacity	92,4 %	93 %	95 %	93 %	[28]
3.5 Light fastness					
3.6 …					
To be continued on the next page.					

Table 3.
Overview of the 4 different durable cotton banknote paper types.

	Marathon	Platinum	LongLife	Diamone	Reference/ remarks
continuation of Table 3					
4. PRINT QUALITY					
4.1. Printability offset	good	third best	second best	best	[28]
		+	+	+	[22]
4.2. Printability intaglio	good	third best	second best	best	[22]
		+	+	+	[22]
4.3 …					

Table 3.
Overview of the 4 different more durable cotton banknote papers.
++ = excellent, + = better, ± = no difference, - = negative influence

Remarks to Table 3:
1) Dependent on circulation policy.
2) A remark is made by Papierfabrik Louisenthal: 'In this table, Marathon has the highest strength whereas LongLife is low except for higher wet resistance figures. The Marathon fibre composition can not be used for cylinder mould made watermarks, and the paper grades mentioned are thus not comparable' [24].
3) Measured 'FIRA test instrument' from Portals, soiling reduction printed notes: 30-40 %
4) Measured by Bank of Thailand, according to Grey scale for assessing staining ISO 105 A03 [PCRIM 2001].
5) Remark from Papierfabrik Louisenthal to the figures given in this Table 3: 'The LongLife samples delivered to Brazil were supplied for printability and soiling tests only, i.e. the figures given in this table are not typical of LongLife paper at all. Brazil did not give technical specifications with regard to the resistance values [24].

10. CONCLUSIONS

10.1 Soiling is the main reason for classifying banknotes from circulation unfit.
10.2 Varnish of the printed banknotes receives more-and-more interest from central banks. Life increase of 100 % are reported by e.g. the Netherlands.
10.3 The interest of central banks in polymer notes is reluctant. Recently Romania finished the issue of the third full polymer series. There are some new issues foreseen like e.g. in Mexico.
10.4 Central banks seem to move their interest to durable banknote paper. First reports from central banks indicated a longer life of this type of paper.
10.5 Research has started to *laminated* substrates, looking for combining the best of cotton and polymer substrates.
10.6 DeLaRue-Portals has presented in 2002 a solution to reduce corner folding by using re-inforced corners. This is not yet used in banknotes.
10.7 The introduction of Life Cycle Analysis (LCA) might be helpful to select the 'best' solution to increase the life of banknotes.

	Company	First or typical issue	Life in years (low face values)	Reported increase of life		References/ Remarks
				to previous	to not coated	
0. STANDARD BANKNOTE PAPER			0,6 - 2 2			[10] [25]
1. COTTON PAPER: NAT. BLENDS						
1.1 USD-notes 75/25 cot./flax, Marathon	Crane & Co	> 1996	1,8			USD 1
			2, 3, 4			USD 5, 10, 20
			9			USD 50, 100
1.2 85/15 cot./flax	VHP	NLG – old		- 23 %		To 100% cot. [3]
1.3 85/15 cot./eucalypt		FIM				Finnish notes
1.4 80/20 cot./abaca		2002:PHP 200				Several notes issued
1.5 …						
2. COTTON MIXED WITH ART. FIBRES						
2.1 Paressyn	VHP	1974: NLG 5				
2.2 Diamone Reinforced	ArjoWiggins					on market since 2002
2.3 …						
3. VARNISHED BANKNOTES						
3.1 Solvent based						
3.1.1 UMC	Joh. Enschedé	since 1953. 1957: all NLG notes		-	+ 15 %	circ. trial 1953
3.1.2 DAR	Sigma. Coatings/ Joh. Enschedé	1987: all NLG notes, 1997 circ. trial NLG 10	2	+ 14 %	+ 100 %	costs: 5 - 10 % of the note price [11, 33, 41]
3.1.3 TOPnote	Giesecke & Devrient	1999:				flexo print
3.2 Water based						
3.2.1 850219 M	Orell Füssli	1993: all CHF notes	± 2			
3.2.2 WDAR		1996: NLG 50		- 200 %	-	circ. trial [41]
3.2.3 Sicpa Protect	Orell Füssli	2000: all CHF notes		+ 20 %		
3.3 UV-cured						
3.3.1 UV-Sigma		1996: NLG 50		- 20 %	-	circ. trial [41]
3.3.2 UV-Desotech	DSM	1996: NLG 50		no change	-	circ. trial [41]
3.3.3 UV-Sun Chem.	Sun Chemical, Bank of Engl.	180 mln notes GBP 5 printed				to be issued in 2002
Table 4 is continued on the next page.						

Table 4.
Overview of the different strategies to increase the life of banknotes, including some first issues or typical samples.

	Company	First or typical issue	Life in years (low face values)	Reported increase of life		References/ Remarks
				to previous	to not coated	
4. POLYMER SUBSTRATES						
4.1 DuraNote		-	-	-	-	no issues
4.2 Guardian		1988: ASD 10		x 400 %		all notes
		1997: THB 50				not happy
		1999: NZD 20				all notes in 2000
		1999: ROL 2.000				all notes in 2001
		2000: BRL 10				250 mln made
		2002: MXM 20				to be issued in 2002
4.3 …						
5. TRADITIONAL COTTON WITH COATINGS						
5.1 Platinum	Portals Overton	THB 20, 2002		scientific data hard to get		used by 15-16 central banks s
		COP 2.000			+ 15,2 %	[27]
5.2 LongLife	Papierfabrik Louisenthal	THB 500, 2001				used by > 5 central banks [24]
5.3 Diamone	AWA					
5.4 Silk screen	Joh. Enschedé	NLG 100, 1992	10	+ 280 %	-	also varnis hed [33]
5.5 …						
6. LAMINATED SUBSTRATED						
6.1 …	Duranote					research [37]
6.2 …	Domtar					research [37]
6.3 …						

Table 4.
Overview of the different strategies to increase the life of banknotes, including some first issues or typical samples.

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