Hans de Heij

The Banknote Designer and the Banknote Design Manager

WHO DOES WHAT?

International Banknote Designers Association
De Nederlandsche Bank NV
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Banknote design is the work of people. But just who are these people and what is the scope of their work? This publication is the result of ongoing cooperation between De Nederlandsche Bank (DNB) and the IBD. More than 35 years of experience in the field of studying and researching the practices, techniques and approaches employed by banknote designers is embodied in this publication by Hans de Heij. The principal question asked and addressed is directly reflected in its title: The Banknote Designer and the Design Manager. Who Does What?

In recent years we have seen the emergence of a trend whereby many central banks have elected to discontinue their in-house banknote printing operations. Central banks tend to work more-and-more with independent designers, often selected via a banknote design contest or a review of formal bids for the work by a committee at the central bank. Banknotes are also becoming more complex and the number of modular component or security feature technology suppliers is increasing. Finally, banknotes are losing ground to digital payment methods. All good reasons for central banks to invest in the control of the design process of banknotes. The appointment of a banknote design manager is a first step. One of the first of this kind is Hans de Heij, appointed in 1981 as banknote design manager at DNB. The role of the design manager is broken out into three topics providing a clear and inspiring study:

› The banknote design process
› The banknote designers
› The arrival of the banknote design manager

This publication will help central banks to successfully execute their design management of future banknotes. The publication will also provide banknote designers with insight on the modern design process which becomes more and more challenging to navigate.

The present situation is illustrated and mapped, incorporating best practices in banknote design management from a range of real-life examples from the former Dutch guilder banknotes to the more recent Norwegian series.

The reader will recognise the topics as have been debated in various forms by IBD Members. While perspectives may differ, we all agree on one thing: banknote design and those talented individuals who do this work, along with those who take final decisions, is undergoing a phase of significant change.

Mark Stevenson
IBDA President
Design is a great field of work. For me it started with my design education, a multidisciplinary training in product design at the Faculty of Industrial Design Engineering at Delft University of Technology. I graduated when I was 25 years old and at the age of 27 I became design manager of the Dutch banknotes at De Nederlandsche Bank (DNB). I was proud of it, not in the least because I had the privilege to work intensively with Robert Oxenaar (1929-2017) and later with Jaap Drupsteen (born 1942), two well-known Dutch designers (figure 1). Soon I discovered that banknote design, indeed, has two domains: the design and the design management.

Experiences with Dutch banknote designers
I also discovered that banknote designers want to design and don’t want to be bothered with bureaucratic paperwork or meetings. They also have an aversion to formal design methods. I saw it as my job to take this work off their hands. I added structure to the design process of banknotes, which was appreciated by both designers. In a personal communication, Oxenaar recognised my endeavours at the occasion of finishing his entry for the euro banknote design competition in 1996: “Once again my special thanks and appreciation for the friendly, cheerful, very patient and very expert way in which you "coached" my sometimes desperate, but mostly cheerful EURO adventures. It was a real pleasure.” (letter dated 2 February 1997). Finishing his last guilder design, Drupsteen offered his compliments by stating that the Dutch banknote design process was “a textbook example of a thorough, well-organised and flexible procedure; openness to innovations and improvements was core to this process (...) leading to solutions you would otherwise never have come up with” (letter dated 28 October 1997).

While working with both designers I learned that there are different working methods. Oxenaar used to sketch the banknote in pencil and brought the drawings to every meeting, to make sure that they would be reproduced as accurately as possible, a working method characterised by a top down approach (De Heij, 2000). In contrast, Drupsteen was primarily interested in the interaction between the craftsmen of origination and his initial design. Both methods seem to be equivalent from a design management perspective - taking into account design quality, time planning and budget - and depend mainly on the preferences of the designer.

Later, I also had the privilege to work together with Robert Kalina (born 1955), the designer of the first series of euro banknotes, named “Ages and Styles of Europe”. We cooperated in particular on the euro 200, a yellow denomination representing the age of “Iron and Glass”. My personal objective was to get this banknote as yellow as possible (De Heij, 2009).

Figure 1.
Two Dutch banknote designers.
Kalina was employed by the Austrian central bank as an in-house designer. Kalina had his very own and somewhat unique way of designing a banknote. He prepared most of his work by himself using a computer station.

During my career I have met many other banknote designers and worked together with several of them, such as Inge Madlé (born 1963). All these experiences confirm that there is no such thing as a uniform banknote designer.

Experiences with the design of euro banknotes
In 1993, after twelve years - particularly enjoying myself at my work - I thought that I should go and work somewhere else. Then my manager stepped into my room and asked if he could count on me for DNB’s contribution to the design of the euro banknotes. A unique project and being in the avant-garde of banknote design, we really had to contribute something. For example, all European countries used portraits on their banknotes, except for the Netherlands. Our lobbying for an alternative to portrait designs was successful; next to the bounded theme of Ages and Styles of Europe, a free category was created. In the end, this made the road free to accept also non-portrait designs, like the selected one carrying architectural themes. Another contribution from our side was the colour scheme. However, the major achievement of the first euro banknotes is not so much the design, an average represent of the 1980s, but the fact that the euro notes were created and were ready on time. In 1998 the small European Monetary Institute (EMI) had turned into the European Central Bank (ECB) and had grown much larger. The design of the second series of euro banknotes (ES2) started in 2003. I was part of it and my ambition reached further. “Now that we all have the same banknotes”, I thought, “the Eurosystem will be able to make a major step forward in the formalisation of banknote design”. One of my suggestions was to introduce the method of a Programme of Requirements, which was a highly appreciated tool by the Dutch designers. However, I soon discovered that a structured approach to the design process was not going to happen. It wasn’t going in the direction I envisioned and I felt miserable. I went to a course: “Why don’t they just do what I say?” and there I learned that there are other ways to influence, such as publishing. The pinnacle of a publication is a thesis and this idea brought a new challenge into my life.

Thesis
The methodological underpinning of banknote design is at its infancy, at DNB and also at other central banks. When I started in 2008 with my thesis on banknote design I recognised once more the mingling of topics on design management and the design itself, when my tutors asked me questions like:

› How does the banknote design process differ from the standard design process?
› What type of designer is a banknote designer?
› What is the role of the central bank in the design process?

These are, of course, highly relevant questions and answering them broadened my scope of knowledge and experience. These few questions actually represented the introduction of too many topics in my manuscript. In a next stage I therefore skipped everything on the banknote design process, on the how, and kept the focus of my thesis on the banknote as a product, on the what. The ‘what’ became the topic of my thesis, which I defended on 7 November 2017 (De Heij, 2017). The ‘how’ is the topic of this book. An electronic version, a PDF, was published in Madrid at the “IBDA Seminar on Banknote Design for Decision Makers”, held from 20-21 June 2017. This edition is the second version of the ‘how’ and is published in print and electronically.

Within our community, an academic discussion on a model for the design management is still largely absent. As I am working for De Nederlandsche Bank, it is inevitable that there will be a bias to Dutch banknote design. The model is not meant to be a one-size-fits-all method, but a starting point from which other central banks may consider banknote design management and build their own model. It will also serve to instigate a broader discussion on the topic of banknote design management within the industry.
Of course the study on design and design management is a constantly changing and evolving phenomenon. A publication is created and not just talked about it. This book will be criticised and will never be really finished. This is a good thing and therefore other members of our community are invited to comment and to share their knowledge on the topic of banknote design management for the benefit of all actors in the banknote design process.

ABSTRACT

Worldwide there are about 250 banknote designers and - most likely - there are even fewer banknote design managers. Both designers and managers operate in a closed and technology-driven design environment, that is isolated of the mainstream discussion on design and design management techniques, due to critical day-to-day operational priorities. As a result, knowledge about their working fields is rather limited.

Banknotes have been designed for well over 350 years. In the early days, the banknote designer was a craftsman, a typographic artist, working for a printing house. The manager of the printing house was probably also the design manager. The banknote designer developed from an artisan to a graphic designer. Nowadays several specialists deliver parts of a banknote design, like a watermark, an engraving and a hologram. The ownership of the overall design lies in the hands of the modern banknote designer and this graphic designer has to initiate and coordinate many design contributions from a design and technical perspective.

As more and more central banks end their in-house printing activities, it is becoming more frequent for a banknote design manager to work for a central bank. Still, many design managers work for a banknote printing company. There is an important difference. To a printer the central bank is the end user, whereas the actual client is the public. The advocated design policy is a use-centered one, as an alternative to a technology-driven design policy. Furthermore, working for a central bank the banknote design manager may bridge the cautious organisational culture of the central bank and the necessary design culture, which involves exploring and innovating. Working together with a banknote printing organisation, the banknote designer and banknote design manager are responsible to interface not only with the end user, but also with all other project stakeholders and ultimately deliver a new banknote design.

The banknote design manager operates like a project manager and takes care of the user requirements, stakeholder interests, counterfeit prevention and the production technologies to be applied.
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Do not seek praise. Seek criticism.

Paul Arden (1940 - 2008)

CHAPTER 1

INTRODUCTION 09

THE BANKNOTE DESIGNER AND THE BANKNOTE DESIGN MANAGER. WHO DOES WHAT?
Abstract
The model presented on modern banknote design involves three key players: a banknote design manager (1), a banknote designer (2) and a contractor (3), usually a banknote printing works.

1.1 Introduction
A subject, which is rarely addressed by industry publications, is the people behind a banknote design. Banknote design is not a one-man-job. Several design professionals make their contributions, individually and collectively. The focus of such activity is usually on the banknote designer, but there are also the originators of other work such as the watermark die-cutters, the engravers and the hologram designers. A relatively new profession that has emerged in our industry is that of the banknote design manager. This professional, usually working for the central bank, acts as a professional client for banknote design and manages the design project. The banknote design manager is also responsible for the design requirements, based on user requirements.

The design manager regularly checks whether the new banknote design can be processed on the central bank’s sorting machines and by other automated cash-handling devices provided by a group of industry stakeholders known as BEMs (Banknote Equipment Manufacturers). Furthermore, the design manager organises counterfeit resistance or adversarial analysis of the new design, durability tests, health and safety tests, and cash-handling tests.

It is also critical for the design manager to ensure that the graphic subject represented on the note is depicted accurately as the design progresses through the multiple phases of origination. It is the manager’s responsibility to validate progress by regularly meeting with the subject matter experts, whose works are depicted on the banknote to maintain their approval.

The banknote designer and banknote design manager operate within a banknote design process, all having one keyword in common: ‘design’.

Dictionaries provide several definitions for the word, ‘design’, ranging from conceiving a plan in the mind, to making a drawing or pattern of something to be made or built. As a banknote is a product, design can be limited to ‘designing material products’, defined by Roozenburg and Eekels (1995) as follows:

"Design is to conceive the idea for some artefact or system and/or to express the idea in an embodiabale form."

How banknote design is interpreted by central banks is reflected well by the following definition provided by the Reserve Bank of New Zealand (2016):

"Banknote design requires very specific technical knowledge in a range of areas, including aesthetics, printing techniques, security features and banknote equipment requirements."

Furthermore, a banknote printer, Giesecke and Devrient (2016), formulates the requirements of a banknote design as follows. Banknotes must:
- Meet the aesthetic requirements of the respective currency area.
- Be easily and unambiguously recognizable and verifiable by people and machines.
- Integrate and combine security features intelligently.
- Provide the best possible counterfeit protection.
- Be durable.
- Be easy for different printers to produce identically.

However, the basic question for a central bank is: how to execute product development in case of a monopolistic supply situation? Central banks are institutions whose main task is the assurance of financial stability and functional payment systems.
A more recent task of the central bank is to practice oversight or regulatory supervision of commercial banks. These tasks make that central banks have a prudent management culture, built along hierarchical management layers, steered by procedures which are interwoven with legal and regulatory aspects. This prudent management culture may put central banks behind when it comes to keeping up with modern technical developments. When it comes to banknotes, engineers may say that central banks were - or still are - about 10 to 20 years behind on topics like spot varnishing, hybrid substrates, barcodes, QR-codes, printed holograms, taggants, digital watermarking, smart phone applications, vector graphics or user-centered design. Such inertia is recently articulated by Eagleman (2017) in response to an assignment of the ECB to improve the perception of public security features (italics by author): “(...) but the ECB rejected it on the grounds that there’s too much cultural momentum in the design of banknotes.” An unsatisfactory answer seems to be to leave things as they are.

Furthermore, central banks do not experience direct competition on the issuance of cash, although they do experience the indirect competition from digital and other alternative payment systems. If people do not like cash, they may opt for other electronic means of payments such as debit cards.

As opposed to the rather cautious management attitude of a central bank, the design of a modern banknote requires an entrepreneurial attitude and must be explorative and innovative in nature. This is the organisational culture where a banknote design manager and banknote designer fit in. Together with the contractor there are three main parties involved in a banknote design process and together they have to deliver a new banknote design.

Three Parties Model and Multi Parties Model
The interrelationship between the banknote design manager, the banknote designer and the contractor is described by the “Three Parties Model” as provided in figure 1.1, which also indicates their main tasks. Central banks may also organise their design management according to the “Multi Parties Model” as provided in figure 1.2. Instead of one contractor, the central bank’s design manager makes separate contracts with manufacturers. An example is the four parties taking care of former Dutch banknote design: central bank (1), designer (2), paper mill (3) and the printer (4) (De Heij, 2000). The argument for this construction was that DNB procured banknote paper from Van Houtum and Palm (VHP); production risks were attributed to DNB and not to the printer. Since 1945, VHP was the only Dutch banknote paper supplier up to the introduction of the euro banknotes in 2002. The organisation of the design of the Europa series, the second series

Figure 1.1
The Three Parties Model covers the interrelationship between the banknote design manager, the banknote designer and the contractor. Contributing designers are contracted by the contractor.
of euro banknotes (ES2) is also a variant of the Multi Parties Model. The European Central Bank not only orders their substrate origination, but also ordered other origination directly at a foil manufacturer or any other semi-finished product supplier. In addition to the ECB, there are more and more central banks following this method, often because they have closed, or transferred, their in-house production to private operators, like the Bank of England (in 2003), Nordic central banks like in Sweden (in 2002), Finland (in 2004), Norway (in 2007) and Denmark (in 2016). The central bank of Belgium will close their in-house printing works in 2019 and there are signs that other countries will follow suit. Unfortunately, the commercial banknote printer in the Netherlands, Joh. Enschedé, had to stop banknote printing in 2017 as it was no longer profitable.

**Copernicus Model**
When it comes to ordering a banknote design, there are two principally different situations. In the first case, the central bank gives an assignment to a banknote printer. To the printer, the central bank is the client and the bank is centre of the design process. This situation is described as "the sun around the earth" in the Copernican Model (figure 1.3a). In the other case, the situation of "the earth around the sun", a banknote design manager is working for a central bank and is committed to the end users (figure 1.3b). However, no matter how a central bank may organise the banknote design process, the participants should keep in the forefront of their minds the fact that the banknote to be designed will be used by the end users, the public and retailers. The central bank should create an optimum solution for the interaction between the users and the technology within their product, the banknote.

*Figure 1.2*
The Multi Parties Model covering the interrelationship between the banknote design manager, the banknote designer and manufacturers.
In four chapters this study presents the scope the banknote designer and the banknote design manager.

Chapter 2 starts with the design process, along with all design professionals who are operating within this framework. After a preliminary description of the 'standard design process', a detailed description of the design process of a banknote is presented. The scope of activity and responsibilities of the banknote design manager and the banknote designer are respectively defined and clarified.

Chapter 3 focuses on the banknote designer, responsible for the aesthetics and for the implementation of all design requirements. The first banknote designers were artisans, while modern banknote designers are fully-fledged graphic designers. Craftsmen may still deliver design elements to a new banknote, such as an engraving. Other specialists contributing to the banknote design will also be introduced, such as a hologram designer. This chapter ends with a description of the modern banknote designer, who is in charge of the overall design of the banknote.

Chapter 4 introduces the banknote design manager, a relatively new profession. The design manager ensures that the banknote designer successfully performs her or his primary duty - designing the banknote. Working for the central bank in most cases, the banknote design manager has a demanding, full time job, requiring a high degree of competency, polyvalence and good interpersonal/communication skills. Usually the banknote design manager operates like a project manager, responsible for resources, time planning, budget and listing of the design requirements. Furthermore, the banknote design manager assists the banknote designer in a vital part of the design process - integrating all design requirements into one landscape.

Chapter 5 presents the conclusions. The principal conclusion is that central banks should organise their banknote design projects according to the fundamentals of 'use-centered design'.
If you think good design is expensive, you should look at the cost of bad design.

Ralf Speth (1955 - ....)

CHAPTER 2

14 THE DESIGN PROCESS OF BANKNOTES
Banknotes have been designed for over 350 years. Early banknotes were printed on paper and the illustrative content was created by hand. These first banknotes were delivered to the customer within one week, whereas today, the average lead time for the delivery of modern banknotes is about two years. Although a banknote is a utility product, the design process of banknotes is similar to that of consumer products. The development of new features is not part of the design process, but an R&D-activity. When new features have to be incorporated, the design process is extended to a product development cycle.

2.1 Introduction

A modern banknote designer can be compared to an architect. At least, this is what banknote designers may answer at conferences to the question whether a banknote designer is an aesthetic artist, an engineer or an architect. Indeed, the realisation of a banknote design can be compared with the building of a house, which involves a client (central bank), an architect (banknote designer) and a construction contractor (origination by printer). Several scenarios may be identified. A client may want to design their own house, following the design proposed by a mandated architect. A customer may also order a new house from a catalogue and in such a case the client only has to reach an agreement with the construction contractor since the catalogue contains information on what the final product will look like. Finally, one may design and built one's own house. All three variants also occur when it comes to banknote design, shown in figure 2.1, ranging from full outsourcing of a new banknote design to a complete in-house activity.

When a central bank outsources the banknote design, one of the central bank's staff members must act as banknote design manager, all too often in parallel with her or his ordinary workload. In case of an in-house printing works, the central bank management leaves the design of a new banknote to this department. Smaller central banks tend to outsource the entire design process to a banknote printer, either a private printer or a foreign, state-owned printer. Larger central banks opt for printing their own banknotes in-house, either within their own central bank or by their national security printing works. The ECB does not have an in-house printing works. The ECB does have a "Directorate Banknotes" with over 50 employees, covering different disciplines within the development (as part of R&D), design, production and sorting of banknotes. Observing the background of the employees one may notice that they are often engineers, mainly selected on their knowledge and experience with banknote production techniques, like paper-making, intaglio printing and holograms, and not on the basis of consumer insights or design skills. This enforces a technology-driven approach of the design of banknotes. Furthermore, this bias will enforce discussions with the manufacturers on production issues.

Banknote design is a niche within the larger design community. According to the International Banknote Designers Association (IBDA) there are about 250 banknote designers active in over 70 countries. Worldwide there are about 180 banknote issuing authorities, indicating that not all have their own designers. Central banks seem to organise their banknote design processes in different ways. In this author's opinion, all too often the design of a banknote resembles a random walk. The final result is often disappointing and the central bank's management may say: 'We learned a lot from this design exercise and now we know how to do it. Next time we will do it right!'. Except, there is never a next time, because when the next time comes around, the pitfalls are slightly different and usually, again, not recognised (Norman, 2013).
Literature on banknote design process

There are a few publications available on the subject of the banknote design process, although not many. In the 1990s several new currencies had to be introduced in former parts of the Soviet Union, and the International Monetary Fund (IMF) was in need of more insight into banknote development. The IMF-study on the introduction of a new currency was published and included design topics (Abrams, 1995). A contemporary view of how the Bank of England perceives banknote design was prepared by Salmon (2011). Such considerations are also part of an extensive personal report on the creation of the euro banknotes by the European Central Bank (Heinonen, 2015).

Contributions to the mapping of the banknote design process have also been made by the author, like a publication on the design methodology of Dutch banknotes (De Heij, 2000), another on banknote design management (De Heij, 2004) and one more on the banknote design process (De Heij, 2010b; 2010c).

This chapter continues with the introduction of the standard design process (section 2.2), followed by a description of the banknote design process (section 2.3). The risk of delays in banknote design is minimised by an appropriate issuance strategy (section 2.4). This chapter ends with conclusions on the banknote design process (section 2.5).

2.2 Standard Design Process

At its essence, a design process is similar to the scientific method of problem solving, a method applied to discover how `things’ work in different scientific domains, like natural and social sciences (e.g. Mohan, 2007). Several well-known scientists have contributed to this scientific method, from Aristotle (384 BC–322 BC), Isaac Newton (1643–1727) to Karl Popper (1902–1994). Designers experience similar phases in their work and it seems that the main difference between a design process and the scientific method is the name given to the individual phases. For example, the scientific method includes a validation phase of the scientific model, while designers test in this phase a prototype. In case of a banknote the prototype is the validation of a full printing proof, or earlier output like a digital proof.

Roozenburg and Eekels (1997) defined the design process of a product as “the process to conceive the idea for a product and express this idea in an embodiable form”. Providing structure to a design process is a frequently covered topic and a review is provided by Foqué (2010). In addition, an overview of over 70 design methods has been published by Van Boeijen et al. (2013). Such summaries demonstrate that all design processes show a more-or-less similar structure. However, there is no agreement on a Standard Design Process. Figure 2.2 presents a standard design process, developed by the author, which is based on schemes found in literature.

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<td>Central bank</td>
<td>Central bank</td>
<td>China, India, Mexico, Morocco, Philippines, Vietnam, …</td>
</tr>
<tr>
<td></td>
<td>State owned printer</td>
<td>Brazil, Indonesia, Japan, Russia, South Korea, USA, …</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2.1

Classification of design activities by central banks.
A banknote design process follows the design phases of the Standard Design Process, which are subsequently problem description, information, analysis, design requirements, exploring solutions, prototyping and the selection of a final design. Defined in this way, the design process is a linear set of design stages, since at each gate to a new stage, there is a decision whether or not to continue from one stage to the next. At each gate, the progress is evaluated and a go/no-go decision is made. Progress in a stage-gate method goes in a single direction and is at odds with an iterative design process, a circular design process, characterised by continual refinement and continual rethinking of early decisions, indicated by the feedback arrows. Both methods can be applied. For the early design activities the iterative method usually suits best, while the stage-gate method provides a better control and is therefore more suitable for later phases of the design process. The situation is recognised in a publication by the British Design Council, proposing the Double Diamond Design Process Model (Design Council, 2005), as will be elaborated on in the following.

Fuzzy front end of design
A poor problem definition is often the cause of many problems that central banks face with their banknote designs. It is a consequence when a proper analysis of the previous design is not made. The problem is exacerbated when far-reaching decisions are made too early in the design process without adequate information being available for such decisions. The issue is made worse when knowledge of design methods is not applied.

In the best case a central bank prepares a Design Brief. A Design Brief can be quite thorough and complete or it can be a limited instruction, focusing on the main design elements, like size, colour and authenticity features. A Design Brief will be introduced in more detail in section 4.4.

The Double Diamond Design Process Model provides a solution to the problems described. This model, presented in figure 2.3, shows two diamond shapes representing respectively the activity of the problem definition and the activity of the search for the solution. Both activities first diverge and subsequently converge. Furthermore, both activities have an analytical and a synthesis phase. In the case of a banknote design process, the central bank’s banknote design manager is responsible for finding and identifying the right design problem, while the banknote designer is responsible for finding the right solution. The banknote design manager will start in the first diamond by questioning the problem of a new banknote design and will expand the scope of the problem by examining all fundamental issues, focusing on the different usage situations of banknotes. Then the model converges towards a single problem statement, for example as may be included in the design requirements listed in a Programme of Requirements (section 4.4). The banknote designer operates in the second diamond of the solution activity, also characterised by a phase of diverging before converging and delivering a proposal for a banknote design.
Agile Design Process

A modern variant of an iterative design process is an Agile Design Process. Agile means ‘lots of moving’ and the term agile in relation to design was first coined by Beck et al. (2001). An ‘agile approach’ to design projects has grown in popularity and there is plenty of modern literature available on this subject (e.g. Ratcliffe and McNeill, 2012). A fundamental characteristic of an agile design approach is that a skilled design team will make several steps at the same time, instead of one-after-the-other. For example, in traditional banknote design, the engraver may only start engraving after a clear instruction by the banknote designer and approval of the project manager. In an agile approach the engraver may make a first suggestion, based on a meeting between designer, project manager, engraver, of course agreed by the controller of the engraver’s company. Secondly, in an agile approach, there exists an element of learning and proving the design at every delivery cycle including customer feedback. Compared to the Standard Design Process, the iteration cycles within an Agile Design Process are therefore shorter. Section 4.3 elaborates on the consequences for the project management of an Agile Design Process.

Research and Development

Further insight into a banknote design process is achieved by discriminating between a design process and a product development cycle. Development projects are usually managed by the Research and Development department (R&D) while design projects are usually part of a separate design department, linked to the activities of gaining consumer insights and market research. Indeed, once more, literature describes several variants, telling that any product development cycle involves phases like development, design, prototyping and zero-production (e.g. Roozenburg and Eekels, 1995; Kumar and Phrommathed, 2005).

Coming back to the ‘R’ of ‘R&D’, there are two types of research; basic research and applied research. Usually central banks will not operate in these two research domains. For example central banks may run development projects but no research projects. This will be explained with an example of the development of a hologram within a thin foil. For a hologram monochromatic light is needed, which can be produced by a laser. The full knowledge and understanding of monochromatic light is an example of basic research. The laser is in this example the result of applied research, the systematic study and gleaning of knowledge and understanding. This clarifies that central banks may operate development projects, which may start with the findings of applied research. In the corridors of a central bank researchers may talk about research, but they mean development.

The ‘D’ of ‘R&D’ does not refer to Design, but to Development, which may include design, but is usually not part of the development.
Central banks have a poor track record in gaining user insights; banknote design is mainly technology-driven and does not follow a use-centered design approach (section 4.5). In the case of authenticity features central banks tend to focus on the reproducibility of the features and not on their usability, as will be elaborated on in section 4.6 on Use-centered design of banknotes.

2.3 Banknote design process

The previous section unveiled the Standard Design Process of any product (section 2.2). The transformation of this Standard Design Process into a banknote design process is the subject of this section. The users of a banknote are introduced first (subsection 2.3.1), followed by a description of the product development cycle of a banknote (subsection 2.3.2) and a review of the Quality Assurance process (subsection 2.3.3).

2.3.1 A banknote is a utility product

Banknotes are not a consumer product, but a utility product. Designers of utility products have to follow the adage of ‘one size fits all’. Following Norman (2013) people expect the trouble free use of ‘everyday things’ like the availability of a letterbox, clean water or public transport. Similar, they expect to use banknotes without any difficulties. When utility services are not working, people become irritated. For example newly issued banknotes that are not (yet) accepted as payment on the toll road or at the parking garage will frustrate users. Another property of a utility product is that people cannot opt for specific designs, like a trendy happy banknote or a senior model with a bigger letter type. Product availability may also be limited; in front of an ATM people may select from three different denominations, for example 10, 20 and 50 euro. Furthermore, the notes received may be second hand, already used by others. Typical for banknotes is their high proximity to the user and banknotes may even take the body’s temperature, just like a coin or a seat in public transport. Unlike most utility products, people do have an interest in banknotes because of its nearness.

Difference between user and stakeholder

Banknotes are more-and-more part of automatic processing environments, like in ATMs and payment terminals. To cope with this on-going development some central banks have developed a stakeholders’ policy, which is not similar to a design policy, as underlined in figure 2.4. In simple terms, stakeholders provide the infrastructure for the usage of banknotes, while the focus of a design policy is on the use of the banknote by the public and retailers. However, as aforementioned the interest in the banknote users tends to remain of secondary importance (section 2.2). The main users of a banknote are the public and the retailers. User groups are subdivided in subgroups. For example the public is subdivided into ‘normal sighted’ and ‘visually impaired’. Accordingly, the visually impaired are subdivided into colour blind (1), poor sighted (2) and blind (3). Investigating all users, stakeholders and their requirements is one of the main tasks of the central bank. An example is the publication on “Banknote design for the visually impaired” (De Heij, 2009). Another example is a publication by Balke (2017), listing the requirements of one the main current stakeholders, the Banknote Equipment Manufacturers (BEMs). Section 4.4 on Programme of Requirements will elaborate further on the translation of user requirements to design requirements.
Influences on banknote design
People working on a new banknote design have to keep their work confidential. In the words of a banknote designer: "Our room is pretty much like a moat" (Pentis, 2015). Internal and external factors influence the design process, captured by the scheme of the time spirit presented in figure 2.5 (De Heij, 2000). The decision to develop a new design is usually prompted by the arrival of new reproduction techniques, like photography around 1860, the breakthrough of offset printing in the 1920s, or colour copiers in the 1980’s. Such developments are described in chapter 3. Another example of the time spirit is the popularity of utility design, which achieved great importance in the Netherlands in the 1970s and 80s, in products like stamps, public telephones, public transport, road signs, coins and banknotes (Staal and Wolters, 1987). A similar time spirit prevailed in Switzerland, Denmark and the United Kingdom.

Benchmark for design period: 0.7 bn/year
Early banknotes were delivered very fast. For example, the design and delivery of the first Dutch banknotes was accomplished in six days. The notes were ordered on 2 April 1814 and issued on 8 April 1814. These banknotes were printed by Joh. Enschedé and were ordered by De Nederlandsche Bank. Joh. Enschedé was selected by DNB because they had experience with printing receipts of the Ministry of Finance, which were used for the collection of direct taxes. Joh. Enschedé remained the supplier of Dutch banknotes up to the introduction of the euro in 2002.

Such short delivery periods of one or two weeks can be explained by the relatively simple design process, the limited production techniques and the low production volumes. In contrast, the design and delivery of modern banknotes takes about two years, consisting of 18 months for the design and six months for the production. Such a time cycle was achieved by DNB at the time of the guilder banknotes, bringing an issue frequency of 0.7 bn/year (banknote/year). The first seven euro denominations achieved a slightly higher issue frequency of 0.9 bn/year. The notes were realised in the period 1996-2001 and included a design contest with 44 different entries.

Technological developments at the beginning of this millennium resulted in shorter lead-times at a banknote printing works. The lead-time to make an engraving by hand is three months, which decreased significantly for an engraving supported by digital techniques. Digital mould making at a paper mill is another example, with production time reduced from six weeks to two days through the introduction of new digital technology. Such technical achievements made in it 2011 possible to deliver six denominations for a new series of South Sudanese banknotes within eight months, a design production of 9 bn/year. Scheduling problems of central banks become visible to the outside world, as central banks increasingly communicate a release date of a new banknote design before the project is finished. Obviously it is not always the banknote printer who is responsible for the delays of the introduction of a new banknote, it can also be the central bank.

![Figure 2.5](image)
Schematic representation of the influence of the time spirit on banknote design. The design of a banknote is influenced by external factors and design factors.
2.3.2 Product development cycle of a banknote

Indeed, the design management of a new banknote is definitely not plain sailing, as evidenced by the delay of several major banknote design projects (figure 2.6). Usually, time planning is the first element to get out of control, followed by budget overruns and increased production costs. On top of that the quality of the new design may often be disappointing.

Started in 2003, the first banknote of a new series of euro banknotes, the Europa Series, should have been issued before the year 2010 (European Central Bank, 2005), but arrived four years later, in 2013. Once the first denomination was issued, other issues followed more quickly, increasing the average to 0.3 bn/year (four denominations within 14 years). Unsatisfactory, as phrased by a member of the "Banknote Committee" (Banco) of the Eurosystem: "We have all seen how ineffective the development of the current new series of euro banknotes has been. (...) It takes too long (...) and the costs are much higher" (Negueruela, 2014). Another world currency suffering from delays is the US dollar, where the new 100 dollar banknote, started somewhere around 2007 and was planned to be issued in 2010, but had to wait until 2013 because of production problems with a new feature. Long lead times were also experienced by a smaller central bank, the Swiss National Bank. The design concept of the new Swiss banknotes were published in 2006 and their issuance was realised ten years later, in 2016 (0.1 bn/year).

It is not only the time management that is problematic. There are also budget overruns, as experienced by the central bank of Australia. After five years working on the issuance of a new series of polymer banknotes at a cost of 9.3 million Australian dollars a complete restart was made in 2012 (Shand, 2012; Reserve Bank of Australia, 2012). Besides not meeting time and budget targets, central banks may face criticism on the design. In 2012 the Bank of Canada made their apologies for replacing an Asian woman on a proof print of the 100 Canadian Dollar by a more neutral looking person (Beeby, 2012; Bank of Canada, 2012). The latest Australian banknote of 5 dollar received criticism on its Australian identity, as it features Queen Elisabeth II. Euro banknotes are also criticised, for example, as "banknotes without a face" (Tett, 2016).

Furthermore, there is the general observation that authenticity features remain unnoticed by the public, as recently phrased by Eaglem an (2017), who advised the ECB on the perception of public authenticity features in euro banknotes: "Govern- ments care enormously about the security features; the populace does not. (...) There is no point spending a massive amount on security features that are noticed only by security experts."

The reasons for the delay of the four banknote models highlighted above are different, but are mainly caused by the connection of development projects to the design process, as will be discussed in more detail further on. In case of the USD 100 the delay was attributed to production problems with the wide windowed security thread. Paper became creased in the press, causing a lot of spoilage. The delays of the second series of euro banknotes were mainly caused by the introduction of new features, which were not ready on time (varnish, a machine readable feature and a transparent window in a paper based banknote). In case of the Australian banknote the delays were mainly the result of design problems. Finally, the Swiss banknote was late because of the introduction of a new type of paper ("Durasafe"). This paper is a multilayer substrate, composed of a transparent layer in the centre and two thin paper layers on both outsides.

Causes of delays
What is causing this poor track record of banknote design management? There seems to be more than one cause. The first is already mentioned, the organisation culture of certain central banks, which is quite opposite to what a banknote designer needs. Designers require an entrepreneurial attitude, the opportunity to explore and innovate, with a clear focus on the end-user.

The second cause of delay is the mismatch between development projects and the design process. What has happened is that the development of a new feature is already brought into the design, although it is not finished. This is the trigger to a highly technology-driven design process, with many
iterations and changes, bringing the central bank out of control. In many cases the central bank does not seem to understand the difference between a design process and a product development process. If the banknote designer only has to deliver a new design, there would probably not be any delay. Delays occur because innovation should be included, resulting in an extension of the design process to a product development process. It is essential to realise that the development of a new feature is neither part of the design process, nor part of the development cycle of a banknote, a topic to be introduced in the following section.

A third cause of delay is the absence of a proper set of design requirements, like a Programme of Requirements (as will be elaborated on in section 4.4). In other words, the fuzzy front end of design does not receive enough attention as stipulated in section 2.2.

Another type of delay is caused by the banknote's production process, which is a typical stacking production process, in contrast to parallel production processes.

Figure 2.6
Four examples of recent banknote design which experienced management problems. All design projects suffered from long lead times and budget overruns.
Stacking production process of banknotes

The production machines for banknotes are costly and may be compared to other capital intensive production facilities, like the aviation or semiconductor industry. Banknote production machines not only include substrate, print and finishing, but also the sorting machines of the central banks. Being capital intensive, new banknotes have to be produced within the scope of the available production machines.

The modern banknote printing process involves a combination of the following production steps: substrate (1), foil application (2), silk screen print (3), offset printing (4), intaglio printing (5), numbering (6), varnish (7) and cutting (8). The substrate can either be paper based or synthetic and today can also be a composite construction of paper and synthetic layers. A stacking process limits the possibilities to introduce alternative production methods and/or techniques. Furthermore, adding new components to a banknote in another plant can be problematic, because of additional security measures and transports, tending to be costly and time consuming. Semi-finished products added to the substrate and print provides flexibility, like specific pigments. In case of paper, special fibres and a synthetic thread may be included.

The stacking production process makes banknotes sensitive to delays. When, for example, the security thread of a banknote cannot be delivered in time, the banknote paper cannot be produced and the proof printing cannot start. And this is also true for the printing process. Number printing, for example, should be done after offset printing (unless the numbers are kept free from any other print).

The stacking production process of banknotes is also mirrored in the design process. The different layers have to be constructed one by one, respecting the different tolerances.

Design is part of product development

New features should be developed within the ‘D’ of an ‘R&D’ environment; the ‘R’ remains unused in the case of innovative banknote features (section 2.2). When development projects are part of the design process, the design process is extended to the product development cycle of a banknote, as shown in figure 2.7. The development cycle starts with the results of the development projects and therefore development projects should be ready in time to be part of this cycle, otherwise there will be delays. However, a central bank may start with the first phases of the banknote design process, while development activities are not yet completely finished. In that case, the developers should unveil the design requirements of the new feature, so that the designers may incorporate the feature in their proposals. Central bank may opt for wishful thinking on a successful ending of the development project, but when there is constant adversity, this is a risky management decision.

After the optional input of the development projects, the banknote design process starts with the phases of ‘collecting information’, ‘analysis’ and ‘Programme of Requirements’. Arrived at this stage, the Governing Board is usually asked for an official ‘go’, for example with a design contest. The banknote design process ends after a successful zero production and the mass production phase may start after an official approval. The time needed for the mass production will differ for small and large production volumes. A small central bank may order a few million banknotes every three or five years, while larger central banks may order over a billion banknotes per year. Differences in production volumes may influence the time needed for mass production, although this is basically a matter of production planning. However, the design period is similar for a small or large central bank. Although a new banknote may suffer from problems in mass production, unfinished development projects are often the main reasons for delaying the banknote design process.
Different development projects

With the introduction of the product development cycle the question about the causes of delay is moved to the development projects. Why are these not on time?

A banknote has various user functions and development projects aim for improvement of one or more of these functions. These development projects may run in one or more of the production lines as provided by figure 2.8, This scheme is named the Development and Design Framework for Banknotes or in short, the D&D Framework for Banknotes. All too often there is an interrelationship between the different development activities, indicated by the dotted line in this figure. The central bank may want to introduce a coating to prevent soiling or is in need of new detectors for their sorting machines. A central bank may also run development projects to improve the substrate production or print production, although normally, this is the responsibility of the producers. The scheme also includes the development of banknote equipment to be used by retailers, banknote automates and third party sorting organisations, manufactured by the BEMs. Development activities may also include solutions for the destruction of banknotes. Furthermore, development projects may run to facilitate the production of a banknote design and to prepare origination.

In daily practice a central bank may have a portfolio of several development activities, as is the case of the "R&D Task Force" of the Eurosystem. To fill
this portfolio with relevant development projects is a matter of an R&D strategy or more precisely, a Development strategy. The development of new features, including authentication features, should target the public and retailer. Development projects may also serve the needs of stakeholders, so that they can contribute optimally to the infrastructure of banknotes (section 2.3).

It seems to be a hurdle to central banks to formulate an adequate Development strategy. The portfolio tends to get filled with projects that aim to solve a multitude of production or detection problems.

**Featuritis**
A frequently publicised cause of delays within the design process of banknotes seems to be the development of a new authentication feature or a feature complicating the reproduction of a banknote. Banknotes carry many features. The first series of euro banknotes includes 37 authentication features, while the first banknotes carried just five features (De Heij, 2006). When a product has too many features, it will become incomprehensible and may even become unusable. Mashey (1976) coined the term creeping featurism. Incorporation of features as the direct result of new technology development is called featuritis (Norman, 2013). Banknote design is not free from ‘featuritis’. Recent examples are the banknotes from Kazakhstan (KZT 10.000, 2012) and Switzerland (CHF 50, 2016). Instead of more features, central banks should consider the need for a new feature and, if in so doing, the bank should identify and define which features can be left out (De Heij, 2010a).

In the case of new features for the BEMs (section 1.1), the central bank should make sure that banknote accepting devices have been adapted before a new banknote may be issued. The Bank of Canada was in 2004 the first to plan an additional three months for the BEMs to adapt their devices. In 2012, these stakeholders received a lead-time twice as long, six months, to recalibrate their devices. However, this planning was too optimistic and many devices were not ready to accept the new polymer 20 Canadian dollar banknote (Beeby, 2013). In 2015, the ECB planned nine months additional time before the introduction of a new euro 20 banknote.

![D&D Framework for banknotes](image-url)
Banknote production is characterised by a growing number of semi-finished products. Banknotes are also increasingly checked by detectors. Therefore, there is an increasing need for quality control, an area that has seen significant development in recent decades.

Up until the end of the 1990’s the quality inspection of new banknotes was conducted largely by human vision. When entering a printing works in the 1980s or 1990s one would see large displays to instruct the workers on the expected quality. These displays exhibited a variety of printing errors. Other printing works collected all kind of files with printing errors, usually just one set was prepared, safely locked up by the supervisor. Since these files are not very accessible and did not cover all possible defects, interpretations were often needed. Defining printing quality in such a way is never complete, because it is impossible to collect all possible misprints. Complete printed sheets were manually checked for defects, almost always by women. Although the banknotes were well-controlled, the central bank also had a basic incoming quality control. Stacks of banknotes were randomly sampled and assessed to check for spots or other defects. For this purpose register marks were obviously printed in the 1960s on Dutch banknotes (De Heij, 2008b).

First steps to Quality Assurance
Since 1880, DNB has ordered its banknote paper at VHP, in those days Van Houtum (Koeze, 2003). This was an uncommon situation, as many central banks left the procurement of the paper to the printing works. A separate set of ‘Paper Specifications’ and ‘Inspection Regulations for Paper’ was contractually required. This situation was in the 1970s the root for Quality Assurance (QA) at DNB, one of the first central banks introducing QA (figure 2.9). The acceptance of banknote paper was based on sampling methods, applying the AQL-method (Acceptable Quality Level), which defined the risks of both the supplier and the client (De Heij, 1989b).

In 1992, the quality of printed banknotes was for the first time described by DNB in a more generic way, called the Landscape Model. This model was a practical, visual instruction for all workers involved and relates allowable printing flaws to areas within the banknote. In 1995, the method was implemented for all NLG-denominations. Both the printers at the presses and the printers’ quality department used these quality control instructions. At DNB offices the same documents were used to verify the delivered notes on their printing quality. Shortly after the issuance of the euro banknotes in 2002, the European Central Bank adopted this method for the quality control of the euro banknotes and renamed it in Zoning Model.

With the introduction of the euro banknotes the market for banknote procurement became more transparent. Euro banknotes may be ordered from over ten different printing works and at least eight paper mills are able to produce the euro banknote paper. To accord with others - and with a keen eye on a future tendering process - DNB decided in 2007 to leave the banknote paper procurement to the printer.

DNB has always strived for a reliable and efficient Quality Management System (QMS). In 2007 the banknote sorting department of DNB received its first ISO 14001 certificate (environmental management system). An ISO 9001 certificate would complete DNB’s accreditation on quality management of the banknote development and production, but has a low priority.

Incoming quality inspection at DNB ended with the introduction of the euro. Instead DNB started to verify product quality at the premises of the printer, aiming for quality checks on semi-finished products at the source and on process verification. The acceptance procedure became based on batches, lots of four million banknotes. Randomly 20 banknotes are selected by the automated quality inspection system and verified on their specifications by measurement. Another 500 banknotes are randomly taken from this batch and are visually checked.
Rise of automatic banknote inspection

The banknote production process has always shown variations in substrate and print, which remained often unnoticed to the human eye, like variations in the UV- and the IR-part of the spectrum. Such variations prevent an optimal functioning of detectors used to inspect banknotes, such as the banknote payment devices, authentication devices used by retailers or by the banknote sorting machines of the central bank. In 1981, this was one of the reasons for DNB to take over the banknote design management from the printer, as will be elaborated on in detail in section 4.1.

Since the year 2000, banknotes are automatically inspected before they are issued. To serve the automated inspection of banknotes, it is important to manage the manufacturing quality of banknotes by a Quality Management Systems (QMS). This policy was in line with the policy of the ECB to set the 'Technical Specifications' for euro banknotes for the final product, often referred to as the TS, and not for plain paper sheets or progressive printing stages.

One of the last achievements is the 'inspection regulation for circulated banknotes' which is now set by the Eurosystem and is referred to as 'the framework' (European Central Bank, 2010).'
2.4 Issuance strategies

A well thought-out strategy can help to prevent problems with development projects. Two basic release strategies are indicated in figure 2.10 to issue a new series of banknotes, a simultaneous issuance strategy and a rolling issuance strategy. A simultaneous issuance strategy releases all denominations at the same moment in time. An example is the release of the euro on 1 January 2002, in these days referred to as "The Big Bang". When a rolling issuance strategy is followed, the components of a series are issued one-by-one, with a frequency defined by the central bank. Within this category, four different rolling issuance strategies are identified. The first is a successive rolling issuance strategy; the issuance pattern follows the denomination sequence from low to high or from high to low. An example from low to high is the Eurozone, where in 2013 the euro 5 was the first model issued of the Europa Series, followed by the 10, 20 and 50, and to be continued with the 100 and 200. An example from high to low is Canada, starting in 2011 with the CAD 100, followed by the 50, 20, 10 and 5.

A second strategy within the category of rolling issuance strategies is a non-successive rolling issuance strategy. An example of this strategy comes from Sweden, where the central bank released four denominations in 2015 (SEK 20, 50, 200 and 1,000) and two more in 2016 (100 and 500).

A third issuance strategy is a roof tile issuance strategy of denominations. Following this strategy, central banks react on the most counterfeited denomination(s) and replace them by another design. The frequent replacement of the denomination of 100 guilder by another design is an example of the Netherlands. Within a time span of 20 years (1972–1992) the design of this denomination changed twice, other designs of the 1970s were kept, like the NLG 10/Frans Hals. A disadvantage of this strategy is the impact it may have on the serial impression. To overcome this drawback DNB introduced a roof tile issuance strategy of denominations while maintaining a serial impression, an approach showing similarities to urban planning and architecture (De Heij, 2000) and will be discussed after the introduction of the next topic of the implementation of developments within the banknote design process.

<table>
<thead>
<tr>
<th>ISSUANCE STRATEGIES FOR A NEW SERIES OF BANKNOTES</th>
</tr>
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<tbody>
<tr>
<td>Category Subcategory Issue sequence Example</td>
</tr>
<tr>
<td>1. Simultaneous issue strategy Issue all denomination at the same date. Big Bang Introduction of the euro, 7 denominations on 1 January 2002.</td>
</tr>
<tr>
<td>2. Rolling issue strategies</td>
</tr>
<tr>
<td>2.1 Successive Different dates; one-by-one. Denominations are issued in sequential order. Introduction of Europa Series (EUR 5 in 2013, EUR 10 in 2014, EUR 20 in 2015, EUR 50 in 2017, etc.</td>
</tr>
<tr>
<td>2.2 Non-successive Different dates; one-by-one. Denominations are issued in non-sequential order. Introduction of Swedish Series (SEK 20, 50, 200 and 1,000 in 2015, 100 and 500 in 2016).</td>
</tr>
<tr>
<td>2.4 Roof tile issuance of denominations, while maintaining a serial impression Regular design releases. Denomination and design are adapted to most needed, within a serial concept. Abstract Series in the Netherlands, 1989 (NLG 25), 1992 (NLG 100), 1994 (NLG 1,000), 1997 (NLG 10).</td>
</tr>
</tbody>
</table>

Figure 2.10 Overview of several of issue strategies for a new series of banknotes.
Implementation of developments

Delays within a banknote design process can be caused by delays in feature development (subsection 2.3.2). A roof tile issuance strategy (figure 2.10) provides an answer. By running development projects parallel to the design process, the design process will not be hindered by unfinished activities. A development targeted for model i within series S may take too long. In such a case, the new technology planned will serve for banknote Si+1, so that Si will not be delayed. Si+1 can eventually be produced, as illustrated by figure 2.11. In case the new technology is not ready for Si+1 it can be moved on for Si+2. Following the principle of the roof tile issue strategy, developments are implemented when ready, which allows the central bank to adapt new banknotes to the latest views, including novel authentication features.

Maintaining a serial impression

Characteristic of a flexible issuance strategy is a spot plan. The banknote designer is first in the role of an urban planner and constructs a generic template for the components of the series, the spot plan. An example of a series design based on a spot plan is provided in figure 2.12, the original proposal for a new series of Dutch guilder banknotes by Jaap Drupsteen, submitted in 1987. Subsequently, the individual denominations are filled in, comparable with an architect filling in an urban planning with separate buildings. This issuance strategy provides the central bank flexibility to react to developments in the outside world and provides freedom to implement the latest results of development projects. Furthermore, this strategy provides central bank management an answer to the question of what banknote developers should do in between two banknote design life cycles, since a roof tile issuance strategy creates a steady, continuous workflow for all professionals involved.

Figure 2.11

Basic principle of ‘implement development when ready’. Development projects for a new banknote become part of the design process when they are ready. If they are not ready they are planned for the next design process.
Example of a spot plan

“A so-called spot plan guarantees the consistent structure of a series of banknotes not issued simultaneously (but instead in ‘roof tile’ fashion). The plan outlines the general impression to be conveyed by each model in the series without a detailed elaboration of that model. As well as involving directives for the design and position of characteristics recognized by users and machines, a spot plan also applies to design specifications. These include the type of paper, sizes, colour schemes, typography, print techniques and general suggestions for subjects.”

An experienced designer entering the field of banknote design has to learn the job. Therefore, the learning curve is another actor in the issue strategy. Because of the impact of such a learning effect it is advisable not to start a new series with the most frequently attacked denomination. In the case of the last Dutch banknote series a start was made with a low denomination (NLG 25, low 2), followed by the (NLG 100, mid 2) and a high denomination (NLG 1,000, high). According to designer Jaap Drupsteen, his fourth banknote (NLG 10, low 1) is his ‘best note’.

The serial character of the banknote series may be affected by adding new features and is a disadvantage of the roof tile issuance strategy. To mitigate this, DNB developed in the 1980s a roof tile issue strategy, while maintaining serial impression, illustrated in figure 2.13. This strategy was for the first time applied to the Abstract Series (1989-1997, figure 2.12 and 3.26). This strategy worked well, when judged by the realised design period of two years, described as follows (Bolten, 1999):

Figure 2.12
Example of a spot plan, a rough sketch design, for a series of banknotes. DNB asked in their design contest for a sketch design of a low, mid and high denomination (25, 100, 1,000) instead of a detailed proposal for six denominations (10, 25, 50, 100, 250 and 1,000). Doing so, the designers could focus more on the concept than on the production of a complete series. Seeing this spot plan, anyone will be able to have an idea of how the other denominations will look like. The designs are made by J.T.G. Drupsteen in 1987. The unit of account is represented by a grid of 25, 100 or 1,000 units, representing respectively 25, 100 or 1,000 guilder.
Division of development costs

Central banks generally lack the means to develop an innovative feature. Therefore the bank must contract an innovator. The innovator’s costs can be covered by selling the final innovation on the market. As the market for new banknote features is restricted, the central bank may encourage an innovator by funding the start-up of a development project, as illustrated in figure 2.14. Over time, there will be roughly four stages of development. The start-up (1), followed by the phases of feasibility (2), prototyping (3) and outfitting (4). Going through these four phases, the innovator will increase the probability of success; if not the project will terminate in the feasibility phase. The basic idea underlying the proposed model is that the central bank bears most of the development costs in stage one and two, and the innovator in stage three and four. Finally, in this model, the innovator becomes the owner of the developed feature and may deliver this to the bank and also to other accredited producers of security documents.

Figure 2.12
Basic principle of series development according to the ‘roof tile’ and ‘spot plan’ principle. Issue in roof tile fashion: five notes within 3.5 years. In this example the first note to be issued is the low 2, followed by mid 1, mid 2, low 1 and high.
The design of a new banknote requires a creative environment, something which is not necessarily provided by most central banks. Maintaining financial stability is the main task of a central bank and therefore central banks tend to operate within a risk-adverse corporate culture. Furthermore, banknote design may be an atypical activity; often a new series of banknotes comes along only once every 10 to 15 years.

A central bank may outsource the entire design process to a contractor or the bank may acquire an independent banknote designer and have the design originated by a printer. In both cases, a central bank needs a form of design management. When preparing the new design, the banknote design manager operates in the first diamond of The Double Diamond Model of Design. This fuzzy front end of the banknote design process is often complex and should result in a set of design requirements, preferably in the form of a proper Programme of Requirements. An ‘agile working method’ may be helpful when operating in this first diamond.

The banknote designer is mainly active in the second diamond of The Double Diamond Model of Design. As the design process of a banknote follows similar design phases as the Standard Design Process, this will not be problematic and will be recognised by any banknote design manager. A complicating factor is the banknote production process, being a stacking process, making the design process inflexible.

The main cause of the delay of new banknote designs is also discussed, being the mismatch between development projects and the design process. What can happen is that the development of a new feature is already brought into the design, although it is not finished. This is the trigger to a highly technology-driven design process, with many iterations and changes, forcing the design timeline to exceed its predicted allocation.

A flexible issuance strategy brings a solution, called a roof tile issue strategy. To maintain a serial character, this strategy can be extended to a roof tile strategy, while maintaining a serial impression.
Anyway. You are the designer. You know what to do.

From series "What not to say to a designer" (2014) by Luca Masini.

CHAPTER 3

THE BANKNOTE DESIGNER

THE BANKNOTE DESIGNER AND THE BANKNOTE DESIGN MANAGER. WHO DOES WHAT?
Today there are about 250 banknote designers with different backgrounds and skills (section 2.1). Modern banknote designers may complain that they "design in a vacuum", receiving last minute changes. Decision-making and governance is conducted over the banknote designer's head. Furthermore, there may be a lack of formal requirements. Indeed, the design process in the past was clearer and the banknote designer was the centre of the design process. There was no "Project Approval Committee" like in the case of the redesign of the US dollar banknotes or a "Project Steering Group" like in case of the euro banknotes.

Many chiefs, no Indians
Not only does the number of people on the management side increase (committees, steering groups), also the producers are increasing in number, as more and more semi-finished products are part of a banknote design. Both, managers and producers, expect the solutions from the banknote designer. To the designer a clear case of "Many chiefs, no Indians".

Designers will recognise that decision-makers may turn 180 degrees, usually when they have forgotten something or don't know an attractive solution, then they may give free rein to the designer, saying: "The designer will know and has to solve it".

This chapter will describe the development and evolution of the very first banknote designers right up to today's modern banknote designers, from typographers to graphic designers. This chapter relies on two publications, the "History of Document Security" (Schell, 2007) and "Counterfeiting and Technology" (McCabe, 2016).

Invention of paper money
First paper had to be invented before paper money could be born. The first paper, a wood-like material is invented in China, although contemporary precursors existed in the Mediterranean world (papyrus, stem of the papyrus plant) and pre-Columbian Americas (amate, bark from the ficus tree). In the year 105 AD the Chinese Ts'ai Lun used water with a mixture of fibres from the bark of trees, remnants of hemp, cloth rags and fishing nets (e.g. McCabe, 2016). The fibres were collected on a flat woven screen, allowing the water to drain through, still the basic technical principle behind the production of paper, including banknote paper. The first European paper mill was built in Fabriano, Italy, in 1276.

Coins had two major disadvantages. First, carrying large amounts was heavy and second, travelling the roads from A to B could be unsafe. These two disadvantages triggered the development of paper money, easing coin transfers, first in China and later in Europe. People deposited their coins in "proto-banks" and then used the receipts, which were like promissory notes, in making purchases. The first forms of this type of money appeared in the 2th century BC and the carrier of the imprint was not paper, but the leather from the white deer, a rare animal which only occurred in the imperial Chinese gardens. The first Chinese paper money appeared in the 7th century (e.g. Davies, 2002). During the reign of Chen-tung (980-1022), the government gave 16 merchants a monopoly on the issuance of paper money called chiiao-tzu, meaning "exchange medium" (e.g. McCabe, 2016). This paper money was the first widely distributed paper currency to reach large-scale use. The Chinese merchants were allowed to charge a three-percent fee for supplying and handling the notes.
In the year 1023, the private merchants were replaced by a governmental institute, a “Bureau of Exchange Medium”, a precursor of a central bank. None of the early Chinese paper notes have survive, but it is known that the design of these notes showed strings of coins, as the paper money had to replace large quantity of coins. Three different ‘printing plates’ were used, in case wood blocks of which the high areas were covered with respectively black, blue and red ink. The paper was made from the bark of mulberry trees.

The first bank was established in Italy in 1472, the Banca Monte dei Paschi di Siena. In 1661 Stockholm Banco was the first to issue private banknotes. In 1988, the first plastic banknote was issued in Australia, displayed in figure 3.13 (Solomon and Spurling, 2014)

First banknote designers
Typographers were the first generation of banknote designers, followed by engravers (figure 3.1). Other craftsmen also contributed to the banknote design, like watermark die-cutters and designers of line-structures. Nowadays several specialists make their contribution in optical features, like experts in holography or micro lens structures creating floating images. The modern banknote designer watches over the contributions of these professionals and is responsible for the final design quality. Modern banknote designers typically operate in the second diamond of The Double Diamond Model of Design (figure 2.3).

The banknote designer works closely with central bank’s banknote design manager, who will be introduced in chapter 4. To arrive at a printing proof, the banknote designer cooperates closely with the originator, usually the banknote printing works.

In the following sections several different type of banknote designers are introduced: typographers (section 3.2), engravers (section 3.3), specialists in line-structures (section 3.4), specialists in optically-variable authentication features (section 3.5) and full-fledged graphic designers (section 3.6). The selection of a banknote designer is one more topic being introduced (section 3.7), before the conclusions are presented on the development of banknote designers (section 3.8).
The technique of cutting characters from wood was the basis for letterpress printing in China, long before it was reinvented in the Western world. Johann Gutenberg (circa 1399-1468) invented a roller-printing press using a printing form of single wood carved letters, which could be reused (e.g. Schell, 2007, McCabe, 2016). The roller-press was probably inspired by presses used for winemaking and papermaking. Laurens Janszoon Coster (1405-1484) is believed to have contributed to this invention by grouping such letters within a frame, assembling the first printing forms. However, there is no proof that Coster has lived and some believe that he never existed.

The wood carved letters were replaced by Gutenberg by metal types and after several years of labour, in 1455, the world’s first book ever printed by movable types was ready, the Bible in Latin.

Just like the first cars were a carriage with a motor instead of a horse, the design of the first banknotes were a mirror of their predecessor, the receipts (figure 3.2). Some of the designers of receipts became the first banknote designers. The basic idea was that the letterpress printing tools were unique and could only be imitated by a die-cutter with the same qualifications as the original craftsman. Furthermore, the reproduction would take a lot of time. In the case of the first Dutch banknotes, unique characters were used, which were originally developed by Joan Fleischman for a musical notation system, but they were never used for that purpose. However, large areas were left blank and they were filled in later by hand (figure 3.2a). Clerks, employees of the bank, filled in a date, denomination and a banknote number. In the case of Dutch banknotes, the board of the DNB signed the prepared notes each Wednesday morning. When banknotes became more popular, handwriting was gradually replaced by printed elements. In 1809, the numbers on banknotes were the first of these handwritten elements to become printed (e.g. Byatt, 1994).

When ordering banknotes at a commercial printer, DNB printed, for security reasons, the banknote numbers inside their bank, which was the start of an in-house printing works. Unlike DNB, other central banks developed from these in-house printing activities to a complete printing works.

By 1840, most handwriting on banknotes was replaced by letterpress typography (figure 3.2b). This development created more work for the typographic designers, however, already within a decade most letterpress printing was replaced by gravure printing and by around 1850 the engravers took the lead in banknote design.

Banknotes printed by letterpress
James River Bank, Virginia, 1773
Netherlands, 1847

Figure 3.2
From partly handwritten to full printed banknotes.
b) Banknote issued by DNB in 1847. Texts were composed of ten different and unique fonts suitable for letterpress printing. The borders of these banknotes were printed with characters as designed by Joan Fleischman for a musical notation system.
Letterpress still part of banknote design today

Letterpress printing of banknotes was replaced by gravure or intaglio printing. However, some letterpress elements were kept, like seals, signatures and banknote numbers. These elements can still be seen today on modern banknotes. For example, seals in letterpress are present on the US dollar (figure 3.3a) and also on the Japanese yen (figure 3.3b). As signatures may change when there is a new treasurer or chief cashier, signatures can be in letterpress printing, thereby avoiding the necessity to make a complete new set of printing plates. Nowadays signatures are usually part of one of the three or four offset plates. One may question why signatures should change (De Heij, 2006; 2017), whilst others may know that signatures must change to keep currency legal tender, as legislated by national governments.

Gravure printing is more costly than letterpress printing. In troubled times, issuing authorities returned to letterpress printed banknotes, as was the case in Ireland, Belgium, France and Germany. The German emergency notes, called "Notgeld", were issued between 1914 and 1922 and became a collector’s choice because of their colourful designs. Two examples are shown in figure 3.4. One of the most characteristic elements of a banknote are the serial numbers, printed in letterpress by special numbering presses. Until the 1930’s one might find up to four printed banknote numbers on a banknote, each number covering one quarter part of the banknote. Nowadays, usually two numbers are required, one printed on the left part and one on the right part of the banknote. This requirement is prompted by the redemption rule whereby some central banks reimburse damaged banknotes. Such damaged notes might be the result of deliberately tearing a banknote in two parts and subsequently offering each half to the bank for replacement by a complete note. To prevent such abuse central banks keep a record of the numbers of damaged banknotes offered for replacement.

In the case of Dutch guilder banknotes two numbers were replaced in 1989 by one barcode (figure 3.3c). Reading just one barcode number was achieved with a higher reliability than reading two OCR-B numbers (De Heij and Van Gelder, 2006a; 2006b). Ironically the replacement of numbers with a barcode actually created work for a typographic designer. The small numbers below the barcode were, on request of DNB, designed by the well-known Dutch typographer Bram de Does (born 1934).

Figure 3.3
Some examples of letterpress printing.
a) Seal of the Department of the Treasury (1789). The seal displays a pair of scales, symbolising a balanced national budget, and a key.
b) Seal of the Governor on JPY 10,000 (first issued 1984). Japanese banknotes have two seals, one on the front and one on the reverse.
c) Barcode number on NLG 100/Little owl, issued in 1992.

Figure 3.4
Two examples of banknotes fully printed by letterpress.
a) Emergency note Lier (Belgium). 25 centienien, 1918.
b) Emergency note Bielefeld (Germany), 50 mark, printed on linen, 1922.
Glass engravers are believed to be the first engravers, cutting their decorative designs into glass vessels as early as the first century (Carron, 1993). In the European Middle Ages goldsmiths engraved metalwork. To record their work, it is thought that they made print impressions. The next step was made in Germany in the 1430s, when copper plates were engraved to produce artistic images on paper.

Instead of engraving directly in copper or steel, an engraver could also make a note design on a small sheet of gelatine. Blue chalk was then rubbed into the lines the engraver had scratched. Subsequently, the blue chalk was copied to a lithographic stone, which were always limestones. After preparing the stone the engraver worked out the details on the stone. After treating the original stone, usually four transfer stones were made, which were used for pulling impressions on a lithographic press.

The grooves are deepened areas in relief that accept and retain ink, a printing technique which is the opposite of letterpress, where the raised areas of a printing form take the ink. When the gravure is not filled with ink, the plate will deform the paper, called blind embossing or dry embossing, a technique already used for the seals on the first banknotes issued in 1661. Printed gravures appeared in 1694 on British banknotes, using a copper plate. Banknote engravers received in 1771 assistance of vignette designers, delivering a completely engraved design element showing.

**Figure 3.5**
Examples of vignette design.
- a) One dollar banknote, confederate money, Georgia (1861).
- b) Medallion of NLG 1,000/Relief border, issued in 1860. The gravure was made by Heinrich Nüsser (1822-1883), working in Düsseldorf and the printing plates were made by F.G. Wagner Junior in Berlin.
- c) Denomination numeral 20 by American Bank Note Company (ABNC).

**Figure 3.6**
Illustration of the development of banknote gravures.
- a) Eye gravure by Karl Bickel, printed by Orell Füssli for the Swiss National Bank, 1941.
- b) Modern eye gravure by KBA with high resolution using Computer to Intaglio Plate, 2010.
Britannia (e.g. Bayatt, 1994). A typical example of a banknote composed of vignette design is shown in figure 3.5a. In 1857, the Dutch central bank also ordered such a vignette, the medallion shape gravure displayed in figure 3.5b, which is a fine example of the spirit of the times (Bolten, 1999). Banknote designers could also select a vignette from a catalogue (figure 3.5c), offered by printers such as Waterlow & Sons, Bradbury Wilkinson and American Bank Note Company (e.g. Tomasko, 2012; McCabe, 2016).

One of the problems of making a gravure in copper was its transfer to another copper plate. When the original gravure is made in steel, a copper plate could be, in a very low relief, reproduced from a steel original by pressure, a technique named "Polytypag e" and developed in France in 1791 by an artist named Gingembre (McCabe, 2016). In 1793 and 1794, French banknotes, assignates, were printed using this technique.

Jacob Perkins (1766-1849) invented a method to replace copper engraving by engraving on steel and transferring the work to other steel plates, a process he called "siderography" (McCabe, 2016). The process was characterised by several hardening stages using high temperatures. Perkins also invented replaceable dies within a gravure. In 1819, he offered his inventions, including the "Transfer Press" to the Bank of England, but it took up to 1836 before the Transfer Press was adopted by the British central bank. Later gravure plates could be reproduced by chemical processes.

As copper is softer than steel, engravers still liked to make their work on copper. A solution was found in 1838 by Boris Jakobi (1801-1874). He invented a method to duplicate a copper engraving into a mother plate of steel, a technique called "electrotyping", which was applied in 1839 to produce Russian banknotes.

Another Russian inventor, Ivan Ivanovich Orlov (1861-1928), developed an indirect inking system for gravure printing, bringing a higher resolution. The first banknotes printed with Orloff technology - the v was changed in a double f - appeared in Russia in 1892 and the patent followed later (Orloff, 1898).

Portrait engraving is a specific skill and in this category Italians were well-known for their qualities, like Edoardo Chiossone (1833-1898) and Giovanni Pino (born 1945). An impression of the development of the quality of gravures is provided in figure 3.6.

Ink and banknote colours
Just like painters in the 17th century prepared their own paint, engravers prepared their own inks. An ink is composed of one or more pigments and a varnish, a vehicle to transfer the pigment.

The first inks were prepared in China, the pigments was made from carbon soot, obtained from the controlled burning of pine wood. The varnish was animal glue.

For long black was the most important ink colour, for example used for the Gutenberg Bible. Gutenberg developed his own black ink, using copper and lead. Black was also the most important ink used for early banknotes and the engravers often specified which pigments they wanted, resulting in many variants like "hard black", "soft black", "mixed black", "Frankfort black" and "ivory black" (McCabe, 2016). In the 18th century other ink colours were developed, first blueish ones, based on ferrocyanide, like the very dark "Prussian blue" and the lightest in this category, "Chinese blue".

Yellow inks were based on lead chromate, delivering inks like "Chrome yellow" and "Canary yellow". The green back of the US dollars issued in 1862 was a mixture of Chrome yellow and Prussian blue and had to protect these notes from photographic reproductions. Red inks were introduced in the 1850s, based on the red sulphide of mercury, delivering terms as "English vermilion", "Trieste vermilion", "Persian red" and "Venetian red".

Development of engravers
Until the 1820s, engravers not only produced original gravures, they also prepared the production plates for new batches (e.g. Robertson, 2005). With one copper plate 5,000 to 10,000 banknotes could be printed. Reproducing printing plates by hand could not deliver exact copies, creating dissimilar genuine banknotes, which hampered the identification of counterfeits.

Modern Engravers
Up to the year 2000, engravers were hand-engravers. The chemical etching techniques did not allow them to print a gravure up to the edge of the banknote unless using a ‘double cut' instead of a
single cut. When the Digital Revolution reached the world of the engravers, the *digital engraver* was born. These modern engravers translate an image with the help of a computer software programme into 3D ‘groove and line structure data’. The introduction of digital techniques also made it possible to print a gravure up to the edge of the banknotes. Two principal computer to intaglio plate systems exist today from technology developers JURA JSP and KBA-NotaSys S.A.

### 3.4 Specialists in line-structures

The previous sections described two craftsmen, respectively a typographer (section 3.2) and an engraver (section 3.3). The typographer used raised surfaces for printing, while the engraver used deepened relief surfaces.

Photography and lithography and are two inventions of the Industrial Revolution (1760-1840), making it possible to reproduce banknotes by photolithography. Lithography was invented in 1796 by Johann Alois Senefelder (1771-1834), after years of experimenting. Senefelder’s invention is based on the repulsion of oil and water, separating printed areas from areas to be kept free from print, making it possible to print with a flat surface, a plano graphic printing process. In 1811, a British banknote was reproduced, redrawn in oil or fat on a lithographic limestone.

The first photograph was made in 1825 by Joseph Nicéphore Niépce (1765-1833). Photography received a boost in 1839 with the arrival of the daguerreotypes, named after Louis Jacques Mandé Daguerre (1787-1851). The lithographic stone that engravers used could be illuminated with a photonegative made with a camera, which was first noticed in 1845 by Antoine Claudet (1797-1867) (e.g. Robertson, 2005).

**Development of colour printing**

The development of colour printing starts in 1710, when a German painter and graphic artist, Jacob Christoph Le Blon (1667-1741) created the first colour prints (e.g. Lilien, 1985). Le Blon used three slightly different gravures. Each gravure was printed in a transparent ink, respectively Red, Yellow and Blue, denoted by RYB. In a next exercise Le Blon added a fourth gravure, printed in black, resulting in a four colour print, using RYBK. In this abbreviation the letter K represents black. When inks are printed on top of each other, a brownish colour will usually appear, the result of *subtractive colour mixture*. Colours in a projection like a movie or on a computer screen are the result of *additive colour mixture*.

**Banknote printers adopt line artwork**

With ‘dot-printing’ becoming popular, banknote printers confirmed their expertise of being ‘line-printers’. Their argument was that the outdated technique of line-printing would disappear from the market and with that the threat of becoming reproduced. However, line-patterns in letterpress or gravure printing could only be done in one colour (figure 3.7a). These line-patterns were made as complex as possible, called *line-artwork*. Typical line artwork was prepared by a *guilloche-machine*, named after a French engineer Guillot, from whom not much more is known then his name. Guilloche-patterns were known from engravings on glass and metallic surfaces before they were applied on printing plates for banknotes. Designing guilloches necessitated a new type of craftsman, a person able to operate the settings of the guilloche-machine with its many steering wheels (figure 3.8a). The first guilloches on banknotes appeared around 1855, printed in one colour (figure 3.8b). Guilloches patterns of later date introduced solid areas, in between the line-patterns.
Basic colour principles of line - patterns

One colour

Alternating 2 colours

Alternating 3 colours

Figure 3.7
Basic principles of using colour within a line-pattern (De Heij, 2010a).
- a) Line pairs with line width (a) and an un-printed line width (b).
- b) Line pattern based on two colours.
- c) Line pattern based on three colours.

Guilloches

Guilloches designer

Guilloches on NLG 1,000 (1859)

Figure 3.8
An example of complex guilloches printed by using two printing plates.
- a) Guilloche designer at work.
- b) Guilloche line-work on the reverse of the NLG 1,000/Relief Border, issued in 1859. The nickname of this banknote was 'red back' (in Dutch: "Rode rug" of "Rooie rug").
Line artwork in two colours
Instead of printing dots, banknote printers wanted to print lines, but of course, this line-artwork should be difficult to reproduce and therefore they opted for line-patterns in two colours (figure 3.7b). For this reason, banknote printers embraced the plano graphic printing as invented by Senefelder. Lithographic printing machines were adapted in the 1920s to meet the special needs of high security printers. Instead of printing dots, these presses were able to print two lines in different colours in register, using two different flat printing plates. The lines within a guilloches-pattern could also be printed in alternating colours.

Around 1960, it became possible to print line-patterns in three colours, coming from three different printing plates in a narrow register (figure 3.7c). However, reproduction photography made it possible to reproduce this type of line artwork. As people got used to guilloches, they remained prototypical for other security documents. Even nowadays such patterns are seen applied on debit or credit cards to emphasise that people may trust these cards.

Screen decoded images
Up to the 1970s, banknotes were filled with line-patterns like guilloches. Also other line-patterns were used, as shown in the Moroccan banknote in figure 3.9a.

In the 1970s, a new type of line-patterns were developed, known as screen decoded images, images are hidden in an original print and become visible to the naked eye in a reproduction. These images can have a random character, like moiré, or can defined like the text "NIPPON" (figure 3.9d). The images are decoded by periodic phenomena like a matching screen or the sampling frequency of a copying system.

There are several variants of screen decoded images, in order of their appearance: screen traps (1), latent images (2), scan traps (3) and moiré variable colours (4). Figure 3.9 provides some examples.

1. Screen traps
Screen traps create imitated banknotes, counterfeits, with moiré fringes, as the dedicated line patterns of a screen trap will interfere with the screens applied in standard reproduction systems. Therefore, the frequencies selected for the screen traps should be similar to the frequencies used in the reproduction systems of counterfeiters, such as a screen 45 or a screen 60 dpi. Koeze (1982) found that, to be effective as moiré inducing patterns, the line width of the printed and the unprinted line in a screen trap should be exactly the same, a task which was exceedingly difficult for the banknote printer to achieve (De Heij, 2010a).

When screen traps and scan traps are printed too small, people will not notice them. That is why a large circle was printed on the background of the NLG 100/Snipe (figure 3.25c) and later also on other models of Dutch banknotes (figure 3.25b and d).

2. Latent images
A latent image is invented by Trevor Merry and Robert Hutton in 1977, both working for the American Banknote Company. The basic principle of a latent image is to create two pattern fields, a foreground and a background pattern. Both patterns have a high resolution and will therefore be seen as one element under normal observation. Reproduced with a lower resolution the pattern will no longer provide a homogenous impression to the human eye. Latent images are typically constructed in intaglio, as the ink thickness has to ‘hide’ unprinted lines.

Probably the first application of such a latent image is in a banknote of 100 intis, issued by the Bank of Peru in 1987. The Bank of Japan introduced latent images on their banknotes in 2004 (figure 3.9b). It is usually difficult to check a latent image, as it has to been seen under with a very low-angle.

3. Scan traps
Scan traps are defined as printed patterns that create aliasing effects when the feature is scanned with similar frequencies (i.e. Eigen Frequency). One of the first scan traps was SAM, an abbreviation of Screen Angle Modulation. This imaging technique is developed by Joh. Enschedé Security Solutions and is for the first time incorporated in the NLG 100/Little Owl, issued in 1993 (figure 3.26c). The SAM-pattern received a diamond shape, on the left side of the front of the note, emphasized by a frame of ‘tumbling bricks’. 
After the introduction of the Personal Computer (PC) in the 1980s the Digital Revolution continued in the years that followed. Banknote printers developed all kind of scan traps, like De La Rue. One of the first of this type of scan traps is applied on the 5,000 pesos issued in 1995 by the central bank of Colombia (figure 3.9c).

In the year 2000 the SAM-feature received a sibling in 2000, the µSAM, a self-authentication feature. The message "2YK" is modulated according to the SAM-principle and becomes visible in the NZD 10, issued in the year 2000 in New Zealand, when the decoding line screen in the transparent window is folded over it.

4. Moiré Variable Colour
Moiré Variable Colour (MVC) is introduced on the Russian Rouble banknotes in 2001 (figure 3.9c). The basic principle behind this type of pattern is the high register quality between two or three different offset printing plates. When the banknote is tilted, the MVC shows all kind of rainbow colours. A variant of MVC is offered in 2010 by Giesecke and DeVrient. Instead of lines, dots are printed in close register. Embossing is added to the feature in a second step, creating the so called 'PEAK pixel' feature.

Evaluation
Nowadays, screen decoded images are losing its value, as reproductions of line-artwork in dots, such as reproductions of screen and scan traps, are barely visible to the naked eye (e.g. Zlotnick et al., 2015).

![Screen-decoded images](image-url)

**Figure 3.9**
Examples of screen-decoded images.

- a) Banknote full of line structures. 50 franc, Morocco (1947).
- b) Latent image. Above: reverse side of YEN 10,000 (2004). Below: The word “NIPPON” appears when the note is viewed from an oblique angle.
- c) Scan trap. COP 5,000 (1995). The indicated area in the background.
- d) Moiré Variable Colour. RUB 500 (2001). The indicated band below the numeral.
Digital watermarking
In the 1980s, the Digital Revolution created a very real requirement for banknotes to be protected against digital reproduction techniques. Once more, line-patterns were used to offer part of a solution, known as a digital watermark, a term coined in 1992 by Andrew Tirkel and Charles Osborne.

A digital watermark in a banknote is based on varying the width of printed lines, lines of constant width are transformed into frayed lines. Such line patterns are associated with the thickness variations of a watermark in paper. Digital watermarking is a common technique, applied to prevent graphical products, like certificates, from being reproduced. Digital watermarking has also been introduced in banknotes as part of the Counterfeit Deterrence System or CDS, as the specific lines have to be recognised by reproduction devices. Digital watermarking was first applied in the euro banknotes, issued in 2002. While still in development, the line-patterns within the euro banknotes were re-engineered to the digital watermark specifications of the CDS. Developing line-patterns of banknotes for CDS is once more work for specialists, using dedicated software programmes. These first digital watermarks did have a side-effect. They tended to blur the original banknote (De Heij, 2010a). Software programmes were improved, aiming for a higher visual quality of the digital watermarks, as applied in the second series of euro banknotes, of which the first model is issued in 2013.

Smartphone application
In 2015, line-artwork received, again, a new role, when it was used as a basis to detect counterfeit by using a smartphone, since the lines printed in banknotes are a unique characteristic in times when most commercially-printed matter was based on dots and pixels. Just like in the 1920s, is with the arrival of offset printing and in early years 2000 as a tool to implement CDS, line-artwork proved its value.

A comprehensive overview of smartphone applications is provided by Currency News (2016). The first connection between a smartphone and a banknote was realised in in 2011 with the "EyeNote App", which made it possible to denominate banknotes, aiming at the American blind. Other apps followed, especially apps aimed at informing the public on authentication features, like the DNB's "Eurobiljet" (euro note), launched in 2011 (figure 3.10a). This app shows a virtual banknote and makes use of augmented reality. Holding the smart phone up to the light the watermark appears. In the same way, tilting the device allows for exploring all the images of the holographic foil. And, when touching the virtual tactile areas, the smartphone vibrated. Other central banks followed with similar apps, such as the Bank of England in 2015 and the Swiss National Bank in 2016.

Soon after the introduction of the Eurobiljet app, several users asked for an application which could scan and authenticate the banknote by itself. A working prototype, called "Genuine or Counterfeit" (figure 3.10b) was presented by DNB in 2014 (Van der Woude and Geusebroek, 2014) and launched in 2015 (Van der Woude, 2016). Using the characteristic line-patterns in banknotes the app makes it possible for the smartphone to determine if a banknote is genuine or fake.

![Figure 3.10](image)

The app uses the functions of a smart phone such as movement and touch. When the screen is touched, the tactile area of the banknote the phone will vibrate, simulating feel. The watermark will appear when the phone is held up to the light (look). Tilting the phone will display the holographic effects (tilt).

- a) App "EuroBiljet" launched by DNB in 2011 (developed by Visual Space, Amsterdam, in order of DNB). Symbols 'feel-look-tilt' as developed by Bureau Mijksenaar are used.
- b) App "Genuine or Counterfeit" launched by DNB in 2015 (developed by Perceptech and Visual Space, in order of DNB).
Raster and vector graphics

Digital images appear in two basic formats, raster graphics or vector graphics. Images made by a digital camera are examples of raster graphics. These image files are made up of individual colour pixels or dots. Raster graphics are saved in different image file formats, the most well-known is JPEG (Joint Photographic Experts Group). Raster graphics work best for photographs, paintings and drawings.

Vector graphics are the result of mathematical processing of shapes and are applied when crisp edges are desired, like in the case of texts and lines. Vectors are being increasingly used to display graphic images on smartphone screens (e.g. apps) and computer screens (e.g. websites).

Vector graphics are created by using professional software like Adobe Illustrator, Corel Draw, InDesign or Photoshop.

Future banknote designs may contain a mixture of raster and vector graphics, similar to a PDF (Portable Document Format) and specialists adding vector-based design elements to banknotes would be the latest example of specialists contributing to the line-work of modern banknotes. Instead of an engraved eye as shown in figure 3.6, such designers may propose an eye based on vector graphics as shown in figure 3.11a. Fürbach (2016) warns that counterfeiters may take advantage of the growing availability of vector images of banknotes on the internet (figure 3.11b).

Vector image of an eye

Vector image of an euro 10 banknote

3.5 Specialists in optical authenticity features

In 1987 the Japanese company Canon introduced the Color Laser Copier (CLC 1), the first digital colour copier using standard paper (figure 3.12). From that moment on anyone could reproduce a banknote on ordinary paper within one minute by simply pushing a button. The resolution of the print was limited, below 300 dpi. The copier did deliver some relief to the copies, quite similar to real banknotes. Central banks had to react and decided to add anti-copy features, like a highly reflective foil. Although commercially available, central banks judged a glossy foil as a good protection against colour copy machines and inkjet printers. Using a silver or gold coloured foil would increase its protective value further, as these colours were not available in colour copiers or inkjet printers.

Color Laser Copier (1987)
Add-on features
The anti-copy features, mainly glossy foils, could be incorporated without changing the existing banknote design, leading to a boost of upgraded banknotes being issued. As these features were produced outside the security paper mill and printing factory, they are categorised as add-on features, opposite to internal features (De Heij, 2010a). Add-on features are semi-finished products delivered by an external factory, like features on a roll, in a box, in a can or in bottle. An internal feature is one that can only be produced inside a secure environment in the course of the actual production process, such as a watermark the print of an or the print of an intaglio engraving.

The third generation of copy machines used smaller pigments leading to higher print resolutions (1994, Canon CLC 800). Due to these smaller pigments the embossing disappeared, to the relief of the central banks. The graphic reproduction industry developed further, focussing on resolutions and improvements of the colour gamut. Meanwhile, the development of add-on features for banknotes continued. Although there are no disruptive graphic reproduction techniques, central banks have the previous war in mind. Instead, of a technological threat, central banks now face a 'usage threat', as people opt for digital means of payments, which have a better match to their user needs. The introduction of a use-centered design policy for banknotes will bring banknotes closer to the modern user needs, as will be introduced in section 4.7.

The first banknote with a glossy foil, including holographic images, appeared on an Australian 10 dollar banknote in 1988 (figure 3.13). Once more, new specialists entered the domain of banknote design, as the design of optical authenticity features requires different skills than those of typographers (section 3.2), engravers (section 3.3) or line-work specialists (section 3.4). However, some traditional authentication features are also optical authentication features, like watermarks, already known since the early Chinese paper money (section 3.1). This subject will be further elaborated on in subsection 3.5.1. Another classic optical feature is a security thread, first applied in banknotes in the 19th century and reviewed in more detail in subsection 3.5.2.

Classification of optical features
A classification of optical authentication features is provided in figure 3.14, based on the work of Van Renesse (2005). Authentication features are split in optically invariable features and optically variable features. Many authentication features which have been introduced in the last decades are part of the subset of optically variable features, which is divided in non-iridescent and iridescent features. Iridescent features are further split in diffractive features and features based on interference.

First polymer banknote (Australia, 1988)

Figure 3.13
Australian 10 dollar polymer banknote (1988). Including an innovative security feature, being a transparent window and a new type of hologram (Pixelgram), viewable from both sides.
a) The front of the note shows the Supply, a ship from the feet which landed at Botany Bay in January 1788, with a line of immigrants and the site of the first settlement at Sydney cove in the background.
b) The reverse celebrated Aboriginal culture with designs based on work commissioned from Aboriginals artists; the main features were an Aboriginal youth, an ancient rock painting, hand stencils and a ceremonial morning stare pole.
The developments by banknote specialists in the field of optical features, from watermark die-cutters to holography experts is presented in the following subsections: watermarks (subsection 3.5.1), security threads (subsection 3.5.2), holographic features and floating images (subsection 3.5.3), and colour changing features (subsection 3.5.4).

3.5.1 Watermarks

The invention of paper has been introduced (section 3.1). Already the first Chinese paper showed a watermark. Not an image, but a faint impression, all running in one direction, known as laid lines. The stitches, running at right angles, left even fainter impressions known as chain lines. Later, dedicated images were prepared to create a watermark (figure 3.16a). Fillers are added to the paper pulp to increase the opacity of the paper and improve its printing quality by reducing the penetration or strike-through of the ink. The banknote designers have to balance these two aspects of banknote paper, the visibility of the watermark and the strike-through of the ink.

Operating Principles

The operating principle of a watermark is as follows. Light (L) is falling on a banknote and will be reflected (R), transmitted (T) and absorbed (A). In the case of reflection, there are two situations distinguished, direct reflection and diffuse reflection. Diffuse reflection is also known as incident light. In a simple formula (figure 3.15): R + T + A = 100 %

Basic principle watermark

Figure 3.14
Classification scheme of optical authenticity features based on the work of Van Renesse (2005; 2010).
OVD = Optically Variable Devices.
DOVID = Diffractive Optically Variable Image Devices.

Figure 3.15
Basic optical principle of a watermark.
Increased speed of paper machines

For many decades, Japanese watermarks showed a high quality, a high resolution, combined with a large range between the lightest and darkest elements (figure 3.16b). The Bank of Japan keeps their production method confidential. Other central banks may envy the high quality of these Japanese watermarks, which is remarkable since these central banks actually abandoned the quality of their own watermarks, which was in the past higher than today. The cause of this quality loss can be attributed to two changes in the production process since the 1960s, the speed of paper machines (1) and the introduction of double layered paper (2), which...
became necessary because of the introduction of windowed security threads (subsection 3.5.2). Finally, the fibre makeup of the substrate pulp has also changed, which had an impact on the quality. The speed of the paper machines increased from about 25 m/minute in the 1960s to over 80 m/minute in the 1980s, making watermarks less sharp. The whirling paper fibres have less time to settle. The range in which lighter and darker areas were applied was also reduced, with lighter areas in particular disappearing from the designs. In fact, this made watermarks less secure. As the watermark is only present in one of the two layers, the quality of the watermark in double-layered paper is of lower quality when compared to watermarks in single-layered banknote paper.

Although the basic watermark lost quality because of these two developments, the watermark area received new elements, like an additional single tone, lighter than any part of the shaded watermark. This technique goes back to the very first watermarks of the 13th century. With reference to its production technique, such elements are known as highlights or electrotype watermarks. However, in combination with a multi-tone watermark this was new and was first applied in Italian banknotes. The first example of a highlight in register with the multi-tone watermark, is the Little Owl issued in 1993 (figure 3.16c). Over the years, highlights developed further to pixel elements; the first proof example was produced in 2003 as an exercise for future watermarks in the euro banknotes (De Heij, 2010a). The latest developments are in the direction of high definition watermarks, portrait watermarks showing higher resolution. Future developments included registering the watermark to the print, allowing the integration of a printed element with the watermark image. Other techniques may also be brought into register with a watermark image, like micro perforations (De Heij and Stange, 2007), which would also enhance the watermark design. For long a watermark is one of the components of a banknote. However, a connection has not yet been yet been made to other production techniques, probably because of the tolerance of the watermark position to the print of +/- 3 mm.

3.5.2. Security threads

Early paper was already used to incorporate other elements than paper fibres. Silk fibres, usually red, were added to the paper and were randomly distributed, a practice started with the notes of New Jersey in 1756. Mica particles were added to the paper as early as 1764. Instead of a random spread of fibres, fibres could be localised, an invention of James M. Wilcox in 1866, called "Safety Paper" and known to date as a Wilcox strip. The Japanese are believed to be the first to insert a thread into paper in the 14th century (e.g. Clapperton, 1967). John Dickinson (1782-1860) received in 1829
a patent to insert a thread - cotton, flax or silk - in banknote paper during the paper manufacturing. Dickinson is already introduced in the previous subsection 3.5.1 as the inventor of the multi-tone watermark. The first application, a silk thread in paper, was not in a banknote, but in the legendary Penny Black stamps.

In 1844, Zenas Marshal Crane invented a distinctive banknote paper in which parallel silk threads ran lengthwise through the notes (e.g. McCabe, 2016). The number of threads corresponded with the denomination of the note, so one thread indicated a one dollar note, two threads in a two dollar note and three threads were on three dollar notes, then a common denomination. Spanish peseta banknotes incorporated a woven lane of several threads were issued by the end of the 19th century (figure 3.17a).

Several decades passed by before security threads were further developed. In 1984, the Bank of England introduced new twenty pound banknote, featuring the first windowed security thread, named ‘Stardust’. This was a glossy embedded thread coming regularly to the surface (figure 3.18b). The width of these first windowed threads was 1 mm. By the year 2000 paper makers were able to incorporate threads with a width of 4 mm, thanks to the introduction of double layered paper (subsection 3.5.1). Modern threads are as wide as 8 mm (figure 3.17b) and may be further increased in the near future. Since these threads are partially visible on the banknote’s surface, all kind of applications are on offer today, such as threads covered with holographic images, floating images or colour changing effect. Thread and foil stripe technologies may merge in the future into one product. One of the first examples is ‘Optics’, first issued in 2007, a 13 mm wide foil stripe embedded within the paper, showing a characteristic oval transparent centre (e.g. De Heij, 2010a).

### 3.5.3 Holographic and floating images

Before foil features were applied on banknotes in the late 1980s, foil applications were common in other domains, such as the automotive, post/greeting cards and luxury good packaging industries. Still foils were found a good protection against inkjet printers and colour copy machines, as these reproduction devices could not reproduce glossy, silver or gold coloured foils. Efforts were undertaken to make these commercially available foils unique, most of them aimed for adding a hologram.

**Development of printed holograms**

The first holograms date back to 1908, when Gabriel Lippmann (1845-1921) created a 3D-image using an array of lenses. Dennis Gabor (1900-1979) recorded in 1947 the first 3D-image on a 2D-surface. In the years that followed a ‘rainbow hologram’ was developed in 1969 by Stephen Benton (1941-2003), followed in 1972 by a cylindrical ‘holographic stereogram’ invented by Lloyd Cross (1934-2015).

This last invention showed, as the viewing angle shifted, fragments of a moving object in 3D and this invention became the basis for printed holograms. In 1984, the VISA credit card was the first product of security printers applying a hologram, featuring a dove flapping its wings (figure 3.18). Fringes, a type of micro-gravure, are characteristic for this first generation of holograms. Several technical developments and applications followed, such as the invention of a-symmetric fringes. The technical principles behind these and other optical authenticity features were reviewed in the first publication by Van Renesse on “Optical Document Security” (1994), a second edition followed in 1998 and a third in 2005.

**Hologram**

![Figure 3.18](image_url)

First holographic foil application on Visa Card (1984). When moving the card, the dove flies away.
Glossy add-on features on banknotes
In 1984, the VISA credit card was the first product from security printers incorporating a hologram (figure 3.18) and the first innovative glossy element on a banknote appeared in the United Kingdom, the Stardust thread already introduced in subsection 3.5.2 (figure 3.19a). A few years later, in 1988, this British innovation was outperformed by the Australian 10 dollar banknote, also already introduced (figure 3.13). The basic innovation was a polymer substrate and this new substrate technique made it possible to incorporate a transparent window with a foil patch. The patch, viewable form both sides, displayed a computer generated dot-based greyscale image. When tilted, the image turned from a positive image into a negative image, called a "Catpix grating" or "Pixelgram", OVD's invented by Robert Lee (e.g. Lee, 2006). One year later, the first printed hologram appeared as a foil patch on a paper based Austrian banknote of 5,000 schilling, shown in figure 3.19c. This computer generated hologram is based on line-structures, providing 2D-images a 3D-effect. The hologram appeared in a shiny gold coloured foil and received the trademark "Kinegram". Two months after the issuance of this innovative Austrian banknote, another innovative banknote was issued in Canada. The 50 dollar denomination of the "Birds of Canada" series received a metallic patch (figure 3.19c). This glossy element was not a foil, but a thin film layer and changed from gold to green.

A plain silver coloured foil stripe with transparent areas, called "Strap", was part of the FFR 50, issued in France in 1992 (figure 3.19d). One year later, in 1993, the Dutch applied plain foil patches on NLG-banknotes (figure 3.26c). Since these early years many banknotes have incorporated glossy foil patches and foil stripes, most of them included variants of holographic effects.

A new type of optical features is based upon floating images, created by arrays of small magnifying lenses (diameter about 30 µm) of which category the "Motion" thread was first applied in 2006 in Sweden on the SEK 1,000 (figure 3.19e). Such a thread, with a width of 5 mm, is also prominently present on the USD 100, issued in 2013 (figure 2.6). How banknote designers should design such floating images is described by the producer Crane (2013). The first foil stripes in register with other print elements appeared on Turkish banknotes in 2009. The latest Europa series also displays registered foil stripes.

A further development for paper-based banknotes was discovered by introducing transparent areas. In this category "Optics" was first, applied in 2007 in Fiji on the FJD 100 (figure 3.19f). Transparent areas have always been part of the polymer banknotes. A novelty in this category was in 2011 the introduction of very wide foil stripes, up to 25 mm, in the new Canadian banknotes issued (figure 3.19g).

The development of transparent areas in paper-based banknotes reached another height with the introduction of the euro 20 banknote in 2015 (figure 3.19h). After punching a hole in the paper, this area was covered by a foil stripe, covering the hole in the paper with a hologram, viewable from both the front and the back. An additional protective transparent stripe had to be applied on the reverse.

The Bank of England was the first to abandon foil stripes on paper based banknotes in 2013, on the GBP 50. The foil stripe was replaced by a thread with floating images. Their argument was that foil stripes received too much attention, while at the same time counterfeiters could mimic the foil stripe with almost any glittering foil.

Structural Colour
Beetle scales and gemstone opals are examples of structural colours provided by nature. A structural colour is the result of the interaction of light with a precise micro- (10^{-6} m) or nano-structures (10^{-9} m) applying very small holes in the order of the wavelength of light. These 'nano-hole arrays' create novel optical effects (e.g. Dunn et al., 2014; Harada et al., 2014). For example, a monochrome colour can be created by such nanostructures, avoiding (disturbing) rainbow effects as known from the earlier generations of holograms.
Development of add-on optical authenticity features

First optical security thread (Great Britain, 1984)

First hologram on paper (Austria, 1989)

First metallic patch (Canada, 1989)

First foil stripe (France, 1992)

Floating images in thread (Sweden, 2006)

First transparent area in paper (Fiji, 2007)

Wide foil stripe in polymer (Canada, 2012)

Window in paper covered with foil (Euro, 2015)

---

**Figure 3.19**

Impression of the development of glossy optical authenticity features.

a) First glossy elements in a banknote, the Stardust thread. Great Britain, GBP 50, issued in 1984.

b) First hologram ("Kinegram") on a paper based banknote in Austria. ATS 5,000, issued 17 October 1989.

c) First banknote with a metallic patch, Canada. CAD 50, issued 1 December 1989.


e) First banknote with floating images ("Motion"), SEK 1,000, issued in Sweden in 2005. Applied in a 3 mm wide thread.

f) First banknote with an 18 mm wide security band and a transparent area ("Optics"), FJD 100, issued in Fiji in 2007.

g) Polymer banknotes with a very wide foil stripe and large transparent areas were first issued in Canada in 2011. The first issue of this Frontier series is the CAD 100. The width of the foil is on all denominations 16 mm and the transparent area can be up to 25 mm wide.

h) EUR 20 banknote with "Portrait window", a transparent area, issued in 2015. The substrate is cotton, the width of the foil is 15 mm and the transparent area is up to 14 mm wide.
3.5.4 Colour changing features

The metallic patch introduced on Canadian banknotes in 1989 was not only a glossy element, it was also a colour changing feature (figure 3.19b). To protect their banknotes against colour copiers central banks continued to introduce new add-on optical authentication features as introduced in subsection 3.5.3 and specific inks are a relevant category. Like foil features, such inks were already commonly used in the greeting card and packaging industry, like pearl lustre inks or iridescent inks. Such inks are based on interference and should provide banknotes a glossy look, just like the foils. A specific pearl lustre ink was first applied on a Dutch banknote issued in 1993, the NLG 100/Little Owl (figure 3.20a). The designers of this banknote covered a large area, about 80 % of the surface. Later, much smaller surfaces were applied on the reverse of low euro denominations (euro 5, 10, 20), which display an iridescent band up to a width of 9 mm (figure 3.20b). The band is applied before the paper rolls are cut into sheets by an ink roller, part of an indirect gravure printing technique called rotogravure. As with foils, a drawback of these iridescent inks is that they were commercially available. By adding a specific colour change such inks became unique and became known as "Optical Variable Inks" (OVI). The first banknote with an OVI was issued in 1992 in Belgium, the BEF 10,000 (figure 3.20c). As the patent on OVI expired after 20 years, the technology was copied and applied in nail polish and other products within the cosmetic industry. To keep colour changing inks unique, OVI’s were further developed by creating pigments with a magnetic centre covered with several thin layers, which became known under the name “Spark”. In 2008, a commemorative banknote celebrating the Olympic Games appeared in China, the CNY 10, which is the first banknote incorporating Spark technology (figure 3.20d).

A disadvantage of OVIs, including Spark-versions, is the limited availability of colours.

Development of colour changing features

First iridescent surface (Netherlands, 1993)

First OVI, (Belgium 1992)

First Spark (China, 2008)

Iridescent stripe (Euro, 2002)

Figure 3.20
Some examples of the development of colour changing features.

3.6 Future specialists

This chapter on banknote designers introduced in a chronological order specialists within the field of banknote design, ranging from typographers to hologram designers. What kind of design specialisation will contribute to future banknotes? The search for new authentication features may go in the direction of intrinsic features instead of the many extrinsic features that form part of the modern banknote landscape (Koeze, 1976; De Heij, 2010a). Extrinsic banknote features are set by the choice of the applied production technique, while the intrinsic banknote features are characterised by the choice of materials. Luminescent pigments added to the paper are considered intrinsic, since whatever the size of a piece of banknote paper, the same spectral effect will appear. An example is M-feature in paper, using complex rare earth-phosphor compounds that are hard to source.

Luminescence describes any process where photons are emitted without heat being the cause, whereas fluorescence is a specific type of luminescence where a photon is initially absorbed, which causes the atom to be in an excited singlet state. As the electron falls back to the ground state, a lower-energy photon is emitted.

Instead of features based on microtechnology ($10^{-6}$ m) novel intrinsic features could be based on nanotechnology ($10^{-9}$ m). An example is the paper’s fibre structure, already present in any paper based banknote, an inseparable part of the complete banknote. At least in theory, the paper fibres could be used as variable data like a banknote number. Because intrinsic features are typically more difficult to counterfeit than extrinsic, they help to prevent composite banknotes being partly genuine and partly a reproduction. Falsifiers create such composite notes using the necessary parts of a genuine banknote to be acceptable by an automated banknote device. The other genuine part is claimed to be refunded at the central bank.

**Taggants**

Another development are taggants, specific compounds added to the banknote paper or ink. Adding specific elements to banknote paper is an old phenomenon that goes back to the fibres, planchettes and threads in early banknotes as introduced in subsection 3.5.2. However, there may be a revival of in the form of taggents. Following the classification of intrinsic and extrinsic features, there are two types of taggants, intrinsic taggants and extrinsic taggants. Examples of intrinsic taggants are customised genetic codes, which could be added to the banknote paper substrate. An examples of an extrinsic taggant is the random placement of (micro) planchettes or other particles. These developments may bring new specialists to the banknote design process, like for example, DNA-designers. Customised genetic codes can be produced by extracting DNA from an infinite selection of plants, botanic-DNA. Each banknote denomination could receive a specific DNA-code. It is even thinkable to provide each banknote with a unique code. Such DNA taggants could be introduced in banknotes as a retail feature, since to date they can only be read by specialised devices operating at rather slow transport speeds or at standstill. Instead of a DNA-code, micro magnetic codes could be applied on specific fibres which may be added to the substrate, paper or synthetic.

3.7 Banknote designer becomes a graphic designer

The previous sections looked into craftsmen and specialists contributing to a new banknote design. This section continues with a focus on the modern role of the banknote designer, the role of a fully-fledged graphic designer.

Banknote designers can be divided into free artists and designer artists, as shown in figure 3.21. Designer artists are also known as applied artists. Painters and sculptors are examples of free artists, while the designer artists are divided into designers either with a graphical background or without a graphical background. Graphic design is often referred to as ‘communication design’ or ‘visual communication’ and includes identity (logos and branding), publications (magazines, newspapers and books), advertisements, product packaging, websites and apps. Graphic design is a discipline that refers to both the process by which the communication is created and to the products which are generated. An illustrator is an artist creating
images on a 2D canvas, which are creative, showing sensitivity, imagination and often some humour.

Illustrators may deliver their work to graphic designers, although graphic designers may still be characterised as a design artists. An example of a banknote designer calling himself illustrator is Harry Eccleston (1923-2010), employed in 1958 by the Bank of England.

Central banks may invite free artists to participate in a banknote design competition. However, experience shows that such free artists lack the training and experience to design a banknote. One of these examples is the Netherlands, where two painters and one graphic designer were invited in 1965 to prepare a design for a new 5 guilder banknote (Bolten, 1999). The outcome was that the banknote designs created by the painters were less suitable to become a banknote than the designs prepared by an applied artist, in this case, a graphic designer. Since 1860, graphic designing of Dutch banknotes has been conducted on a freelance basis, like the acquisition of the medallion gravure shown in figure 3.5b. Following Bolten the Dutch banknote designers have been graphic designers since 1922. Since that date, the Bank - and not the printer - has acted as a matter of principal to secure the services exclusively of graphic designers.

With more and more specialists involved in the banknote design process, it is the task of the banknote designer to integrate all required elements in an attractive and communicative way (figure 3.22). The challenge is to create a culture where the product - and not the project - is central.

INDEPENDENT BANKNOTE DESIGNER

<table>
<thead>
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<th>Free artist</th>
<th>Graphic background</th>
<th>Non-graphical background</th>
</tr>
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<tbody>
<tr>
<td>- Painter</td>
<td>- Typographer</td>
<td>- Video creator</td>
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<tr>
<td>- Sculptor</td>
<td>- Engraver</td>
<td>- Image constructor (electronic)</td>
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<td>- ...</td>
<td>- Vignette engraver</td>
<td>- Photographer</td>
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<tr>
<td>- Illustrator</td>
<td>- Architect</td>
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</tr>
<tr>
<td>- Graphic designer</td>
<td>- User experience designers</td>
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<tr>
<td>- ...</td>
<td></td>
<td>- ...</td>
</tr>
</tbody>
</table>

Figure 3.21
Classification of banknote designers in free artists and designer artists.

Using digital equipment

Checking print out

Making corrections on interactive screen

Figure 3.22
Banknote designers use digital equipment since the 1990s.
a) Banknote designer Robert Kalina at work (circa 2000).
b) Banknote designer Inge Madlé at work (circa 2010).
3.8 Design freedom

Once an identity description is prepared and the bank has determined a selection method for a designer, a decision has to be taken on the design freedom. Ten levels of design freedom are presented in figure 3.23 (De Heij, 2012). Free artists receive the highest design freedom (10), as they are not restricted by any guidelines or client requirements. An example, a design for a euro 50 banknote, is provided in figure 3.24a.

Dutch banknote designers were free within the frame of an identity description, a design freedom classified at level 9. Multi-interpretable mottos are examples of level 8, like ‘Unity in Diversity’. The Danish designers were more restricted, as their theme was: “Danish bridges and surrounding landscapes, or details from these landscapes.” Lower design freedom is found when central banks follow an upgrade policy. The design freedom to change a signature is close to zero, indicated by level 1 (figure 3.24b).

MODEL FOR DESIGN FREEDOM OF BANKNOTE DESIGNERS

<table>
<thead>
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<th>Level</th>
<th>Policy</th>
<th>Example</th>
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</thead>
<tbody>
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<td>Completely free</td>
</tr>
<tr>
<td></td>
<td>9</td>
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<td></td>
<td>7</td>
<td>Prescribed new theme</td>
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<td></td>
<td>6</td>
<td>Prescribed new main image</td>
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<td>Keep motto</td>
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<td></td>
<td>4</td>
<td>Adapt main image</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Keep main image</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Keep lay-out</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Minor change</td>
</tr>
</tbody>
</table>

Banknote designers may receive different design assignments; from an upgrade to a completely free assignment.

Design freedom

Design freedom 10
Design freedom 3

Figure 3.24
Two examples of banknote design freedom.

b) Signatures of the Treasurer and Secretary of the Treasurer are regularly changed, as on this USD 20, first issued in 2004.
High design freedom leads to iconic designs

A successful banknote designer is Robert Oxenaar, also known by his nickname Ootje. Four of his designs are shown in figure 3.25. These designs became world famous and are judged as being iconic (e.g. Cramsie, 2010). The artistic side of Oxenaar has been highlighted as follows (Kuijpers, 2011).

"Oxenaar avoids the one-sidedness of either a formalist or a determinist approach. Indeed, the role of the banknote designer is also to step out of the technology-driven banknote design and introduce aesthetics and emotion."

After nine banknote designs, Oxenaar was succeeded by Jaap Drupsteen and his designs are shown in figure 3.26. In the 1970s Drupsteen was one of the first to experiment with video graphics. This proved to be a perfect technical background to become a banknote designer, since, like banknotes, video graphics are also created by adding up several image layers.

A recent example of architects becoming a banknote designer is Snøhetta Design, providing an innovative entry to the Norwegian design contest for a new series of kroner banknotes in 2014 (figure 3.27). These designs proved a step too far for the assessment. The Norwegian bank then decided to combine the front of this design with the front of another submission. Snøhetta’s designs became the reverse of the new Norwegian series.

**Figure 3.25**
Banknotes designs by Robert Oxenaar. Portraits (a) and House-Tree-Animal Series (b, c and d).

a) NLG 25/Sweelinck, issued in 1972
b) NLG 50/Sunflower, issued in 1982. Design together with J.J. Kruit.
c) NLG 100/Snipe, issued in 1981.
Figure 3.26
Banknote designs by Jaap Drupsteen (Abstract Series).
a) NLG 10/King fisher, issued in 1997.
b) NLG 25/Robin, issued in 1990.
c) NLG 100/Little owl, issued in 1993.
d) NLG 1,000/Lap wing, issued in 1994.
Figure 3.27
The theme “The Sea” designed by Snøhetta, participant to the Norwegian banknote design contest in 2014. The reverse of all denominations is kept black, which adds emphasis to the coloured front. Secondly, the front does not have a clear main image, but a coarse digital grid in which one may recognise a ship or an oil-drilling platform. The grid can be filled in with different printing techniques.
Banknote designers active in today’s industry can be placed into two main categories: free-lance and employed. Banknote designers with a permanent job can be found at both private and state-owned printing organisations, such as the Bureau of Engraving and Printing of the U.S. Department of the Treasury. The employer may set parameters on innovative designs, as was the case of Dutch guilder designs before the 1970s (Bolten, 1999). Banknote designs generated by in-house designers may have a repetitive character, making them easier to pass through existing production processes. On the other hand, in-house designers are knowledgeable on these production processes and on traditional banknote features. Balancing pro and cons, in-house designers may not challenge a printing works as independent designers may do.

An overview of in-house and independent designers is provided in figure 3.28. Central banks may opt for an independent designer, as was the case in Denmark, Sweden and Switzerland, a policy also practised in the Netherlands (De Heij, 2007; 2012). Independent designers have experience in different graphical products and may bring this experience to banknote design. In contrast, an in-house designer is bound to the company (e.g. Pentis, 2015).

### Banknote design competitions

One of the tasks of a banknote design manager, which is the topic of the next chapter, is to prepare the central bank’s selection procedure of a banknote designer. Figure 3.29 provides an overview. Possibly the largest design competition ever was the competition for the first euro banknotes. This design contest delivered 44 entries, prepared by 29 different designers or teams of designers (European Central Bank, 2003).
Banknote designers have evolved from typographers, to engravers to fully-fledged graphical designers. Converting a banknote design to a final printed product is not a one-man’s job. Several specialists contribute design elements, such as watermarks, engravings, line-structures, security threads, holographic and floating images, and colour changing features. Additional specialists may contribute in vector graphics or in new intrinsic features, based on nanotechnology or on DNA-technology.

The main task of the modern banknote designer is comparable to a conductor of an orchestra. The graphic designer has to accomplish a high design quality, aiming for user satisfaction. The design must be understandable and aesthetically pleasing for the public. The central bank is the client of the banknote designer and this relationship can be a major pitfall, as the designer may tend to please central bank officials, instead of keeping a keen eye on the needs of the banknote users.

### BANKNOTE DESIGN COMPETITIONS

<table>
<thead>
<tr>
<th>Category</th>
<th>Type of designers invited</th>
<th>How?</th>
<th>How many?</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>Graphic designers</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Professional applied artists</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Everyone</td>
<td>Announcement; 46 applications; selection by committee.</td>
<td>8</td>
<td>Sweden (2011)</td>
</tr>
<tr>
<td>Closed</td>
<td>Professional applied artists</td>
<td>By committee</td>
<td>12</td>
<td>Swiss (2005)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>Denmark (2006)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td>Norway (2014)</td>
</tr>
<tr>
<td></td>
<td>Graphic designers</td>
<td>By single design advisor</td>
<td>6</td>
<td>Netherlands (1987)</td>
</tr>
<tr>
<td></td>
<td>(2 young, 2 mid aged, 2 established)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Banknote designers from 14 EU countries</td>
<td>Maximum 3 designs per category; 2 categories</td>
<td>29</td>
<td>Euro 1996 (44 entries, 29 designers)</td>
</tr>
</tbody>
</table>

### 3.10 Concluding on banknote designer

"Figure 3.29
Different approaches to invite designers to a banknote design competition."
Recognizing the need is the primary condition for design.

Charles Eames (1907 - 1978)
Abstract
In the model presented the banknote design manager works for the central bank and operates as the client to both the banknote designer and to the banknote producer. The banknote design manager prepares the assignment and subsequently manages the design process. User requirements are investigated and transformed into a Programme of Requirements.

4.1 Introduction

When a central bank is considering a new banknote design, the bank must implement an organisational structure necessary to bring the relevant parties together, if this is not already in place. Following the Three Parties Model of figure 1.1 these are the central bank (1), the banknote designer (2) and the contractor (3), usually a banknote printing works. The objective of this chapter is the review of the role of the banknote design manager in the banknote design process, a role which is complementary to that of the banknote designer. The difference between the two can be understood with the Double Diamond Model of Design (figure 2.3). The work can be organised according to the two stages of this Model. For the first diamond, there are basically two organisational forms, a design committee or a banknote design manager.

A central bank may opt for a design committee when they decide to issue a new banknote design. In case of the first series of euro banknotes the theme "Ages and Styles of Europe" was proposed by the "Advisory Group on Design Theme Selection". Central banks may also opt for a committee to solve a specific problem. For example, the Bank of England relied on a "Character Advisory Committee" to nominate a female who will be featured on a new banknote design. The committee's decision is supported by the feedback of focus groups, which composition is representative for the UK society. The Bank of Canada is in search for the iconic woman which will feature one of their future banknotes and has deposited this question with an "Expert Panel". The Monetary Authority of Hong Kong relies for governance of their new banknotes on two committees; an "Artistic Review Committee" and a "Technical Review Committee". One more example is the "Project Steering Group" for new euro banknotes, already introduced in section 3.1.

Engineers
"Banknotes are essentially products with a technical performance to deliver" (European Central Bank 2004). This statement refers to an engineering approach. The U.S. Bureau of Engraving and Printing also employs engineers, along with other, often found in engineering enterprises (Newberry, 2013). In fact, many of the directors of the Bureau in the past 150 years have also been engineers. Engineers have also been working at the Dutch central bank.

Engineers at DNB
In the early 1920s, the DNB hired its first engineer, entrusting him with the management of the technical aspects of the production and issuance of guilder banknotes. Not only for the design and the production of banknotes, but also sorting and vaults. In fact this engineer was also in charge of the maintenance of the building. In 1968, hand sorting of banknotes by DNB was replaced by a mechanical sorting process. With the arrival of these banknote sorting machines the Dutch central bank recruited more engineers to add to its workforce, including paper and print specialists. In the 1980s, DNB brought banknote design under project management. The reason is explained as follows. The banknote design management of a new denomination of 50 guilder was on request from the printer, left entirely to the printer, Joh. Enschede. The design result was great, the NLG 50/Sunflower is one of Oxenaar's best designs, but the costs were significantly higher than expected and the new banknotes were rejected by DNB’ sorting machines (the intaglio line pattern, named ISARD-pattern, was printed in orange, a colour that is not visible to the red laser beam of the detector used, the Intaglio Scanning and Recognition Device or...
ISARD. Furthermore, there was no contract with the banknote designer, as the printer thought that the bank would have held the responsibility and vice versa. In response, DNB decided to take the banknote design management into their own hands. An engineering background suits best for this work, as engineering aspects are a substantial part of the development of a new banknote (Newberry, 2013). The bank selected an industrial design engineer, in case your author Hans de Heij, who was appointed in 1981. This combination of an engineer and design manager worked out well (Bolten, 1999). Since 1981, all design projects for new guilder banknotes were realised within time and budget, were innovative and were highly appreciated by the public (e.g. De Heij, 1989; 2002).

Furthermore, the production costs of the banknotes with the new design did not increase, fulfilling the target of producing the new series at a similar or lower cost than the costs of the notes to be replaced. Central bank president Duisenberg’s standard opening remark to the design team was: “What beautiful design have you made for us this time?”. Encouraged by the applause received for previous guilder note designs, the Dutch central bank always felt challenged to take a new design one step further. Such a challenge is seen as an example of the key role for the highest management; to create the appropriate conditions for the banknote design project, one of them being the support of a banknote design manager, acting as a project manager.

But why would the DNB’s board endorse proposals for new, innovative banknote designs, when it is supposed to play it safe? The answer lies in the many small steps made over the years towards a fully-fledged design methodology. Through the gradual adaptations of this process, the DNB’s board members kept a good feeling about banknote design. A design which should be brought forward and should develop itself.

**Linking Pin Model**

In order to achieve any product design, two domains are required: a *product domain* and a *process domain* illustrated by figure 4.1. Product requirements are the linking pin between both domains and therefore the model is referred to as the "Linking Pin Model". Product requirements are usually laid down in a Programme of Requirements (PoR).

Simply said, the PoR is the responsibility of the banknote design manager and the design is the responsibility of the designer (De Heij, 2000; 2010b; 2010c). The banknote design manager works for the central bank and may operate as a project manager. The main characteristic of a project is a clear beginning and a clear end, which is obviously the case with the delivery of a new banknote design. The project manager controls the project’s time planning and budget. Design models for use-centered design assist a further understanding of the usage of banknotes by the public and retailers, such as the Upid-Model, a model for user Payment Instrument Design (De Heij, 2015a; 2017).

**Figure 4.1**

The Linking Pin Model the tasks of the banknote design manager and the banknote designer. Linking pin between process and product is the Programme of Requirements (De Heij, 2010c), a tool to make a clear separation between the responsibilities of the central bank and the designer.

a) The process to come to the design is described in several separate planning topics (n), like quality, time, budget, information and organisation.

b) The product to be designed is described in the PoR, divided in several main topics (m), for example following the user functions of a banknote as described in the Model for Use-centered Design of Banknotes (section 4.6).
Key figures on Dutch project management

Project management did not only result in a high design quality of Dutch banknotes, it was also successful from a management point of view, judged by its lead-time and costs, which were according to schedule (e.g De Heij, 2000):

- Lead time two years, from start to issuance. This included testing, informing stakeholders and the launch of a publicity campaign. This lead time is not dependent on the number of banknotes to be produced.

- The banknote designer needed about 900 hours per banknote, from scratch to approval of mass production, and included meetings.

- The project management team on Dutch banknotes consisted of four people. One participant from the paper mill and the printer, the (external) graphic designer and the project manager from the Dutch central bank. On average, their work load during these two years was roughly as follows: graphic designer (25%), participant of the paper mill and printer (15%) and the project manager (75%).

- After approval of a series design by the DNB Board, a new banknote design appeared twice in a Board meeting. After approval of a sketch design, the Board approved a proof print.

- Costs of designing and proof printing a banknote were about 2 million guilder, which would be today about 2 million euro.

This chapter continues with a description of banknote design by committee (section 4.2), followed by banknote design under project management (section 4.3). User functions are transformed into design requirements, laid down in a Programme of Requirements (section 4.4). A design policy guides the central bank in its choices (section 4.5). There are four basic models to fill in a banknote design policy (section 4.6) and a use-centered design policy is the advocated one (section 4.7). A major decision is the choice for a completely new or an upgraded design (section 4.8). A task of the design manager is also to set targets to the quality of the banknote design and targets to the banknote design management (section 4.9). This chapter ends with conclusions on the roles of the banknote design manager (section 4.10).

4.2 Banknote design by committee

Utility products like a banknote are usually the responsibility of a public utility company. In this case the central bank may be considered as the utility company. When something new has to be designed, these authorities tend to establish an expert committee, usually composed of different users and stakeholders. One of the (unsaid) arguments in favour of this approach is to anticipate complaints which may be made afterwards and can therefore be countered by the statement: ‘your interests were represented within the committee’.

When there is a shortage of a certain profession, then an organisation may send a committee member who is not knowledgeable. An incident from the author’s experience is the introduction of a new member to the Design Group of the ECB in 2005. When he joined the group for the first time he introduced himself by saying: "I do not know anything about banknote design, but I am very interested in what you are doing."

"Design by committee" is considered among designers as a somewhat notorious saying. In general a committee will operate in the first stage of the Double Diamond Model of Design (figure 2.3). Instead, this work may also be organised by the banknote design manager, who may achieve better results than a committee. Committees are hindered by group dynamics and tend to settle for the lowest common denominator of what their members find acceptable. Indeed, there are several drawbacks to such an approach (De Heij, 2010c).

Drawbacks of a committee

The first drawback to be introduced is known as diffusion of responsibilities and this phenomenon was already observed by Edmund Burke (1729-1797): "All that is necessary for evil to triumph is that good men do nothing". A clear original by Burke is unknown and many variants exist. Translated to today’s practice, individuals within a group of seven or more may think: ‘Why should I be the one to answer that question?’ or ‘Why should I make that decision?’ and they may opt for the safe road of not saying or doing anything.
A second pitfall of design by committee is **planning fallacy**, the irresistible urge to give a rosy picture of how things are going: unreasonable optimism. A committee will often continue a project, even if it is not running according to expectations. 'A fault confessed is half redressed' is not an option here. Group thinking goes hand-in-hand with **plural ignorance**. If people are unsure of or unfamiliar with a subject, they tend to look towards other group members for clues. This may move the group in the wrong direction and may lead to amateurism. Furthermore, people lacking the appropriate skills might try to block innovative approaches by using far-fetched arguments or asking irrelevant questions. Instead of proper design requirements a committee will formulate general principles, like 'banknotes should maintain public confidence' and 'the banknote design should defeat current and future counterfeiting techniques'. However, a committee may have an effective role, especially in the very first phase of the design process of a new banknote, when a central bank has to determine the identity description and a theme.

### 4.3 Design under project management

To enable Americans to walk on the moon, achieved in 1969, project management was first developed by NASA (National Aeronautics and Space Administration). After this success, project management became popular in the 1970s for activities with a clear start and a clear end, as is the case for product design.

When the organisation of the design process of a new banknote is seen as a project, the banknote design manager is also the project manager. Project management is an appropriate method to organise the design process of a banknote. Managing their banknote design processes, central banks may experience major problems with time planning and budgets (subsection 2.3.2). Indeed, Norman's law of product development (2013) is also true for banknote design:

“"The day a product development process starts, it is behind schedule and above budget."

However, your author believes that the best results are achieved when the design of a new banknote is organised by the principles of project management. The project manager should stick to these principles and get the support of the hierarchical line manager to keep the project in control.

Yet, there are also drawbacks to a managed project. Project managers may experience the planning fallacy as introduced in section 4.2; projects are started easily, but are hardly ever frozen (e.g. Wysocki, 2009).

**Banknote design under project management**

Bringing banknote design under project management implies five domains to be managed: maintaining the design quality (1), keeping the project within budget (2) and within time planning (3), informing others (4) and maintaining an adequate project organisation (5) (De Heij, 1989a; 2000). A project manager is successful when the targets of all five domains are achieved. For each domain the project manager may use methodological tools, like a Programme of Requirements, a cost planning and a time planning.

All design requirements are laid down in a Programme of Requirements, reflecting user requirements and stakeholder requirements, as will be elaborated on in section 4.4.

The costs of the design project are part of the budget and budget control methods are available.

Several methods are available to implement a time planning for the design project, such as a Critical Path Method (CPM). Furthermore, the design manager is responsible for keeping all project members informed, including other relevant parties outside the project organisation, such as stakeholders.
Finally, the project manager is responsible for the organisation of the project, especially the cooperation with the other project members. The project manager is also responsible for the atmosphere in the team, ideally creating a knowledgeable, small and proud team, working on a great job.

**Project Steering Group**

Instead of a project manager for new euro banknotes, the ECB appointed a *programme manager*. In this complicated European organisation this official did not manage to make progress. In response the ECB installed a "Project Steering Group" (PSG) which took - and still takes - decisions on design proposals. The PSG is chaired by the Director Banknotes of the ECB and other members are representatives of the Eurosystem of Central Banks (ESCB). The PSG often has to settle for a compromise, bringing a committee culture to the design process of the second series of euro banknotes.

**Agile approach**

Section 2.2 introduced an *agile approach* to the banknote design process. An agile approach may also be applied to the method of project management, known as Agile Project Management (e.g. Werhnham, 2012). Within an agile approach the design process is managed in a flexible and iterative manner, taking many small steps and is seen as opposite of a *procedure oriented approach*. The methodology of project management first requires a *Project Set Up* (PSU) or a *Project Document Submission* (PDS). Instead of the preparation of such paper work, within an agile approach the participants define - and redefine - their goals from day one. Instead of a focus on the project, including time planning and budget, the focus is on the product, on the banknote. An agile team will not compromise on the design quality. An agile approach requires openness to non-hierarchical forms of leadership, a *scrum master* instead of project manager. Furthermore, each (short) design cycle will deliver customer input.

### Relation between design quality, time and costs

The strategy of DNB on banknote design at the time of the guilder was to add time (t) and money (c), in this order, until the right design quality level (Q) had been reached. In other words the quality Q is function of t and c, noted as Q (t,c) (De Heij, 2000). The quality Q was defined by fulfilling all design requirements. The aesthetic quality was considered implicitly addressed by the acquisition of one of the best Dutch graphic designers (section 3.8).

As design quality was leading the process, a first date of issue was not communicated before enough stock was built-up. The policy of De Nederlandsche Bank towards the production costs of new banknotes was that these costs should be a little lower than the production costs of the banknote model to be replaced.

Other considerations between quality, time and cost can also be made, like in case of the introduction of the euro in 2002. In this case the time (T) to accomplish the project was leading, according to T(q,c), as the design quality (q) prevailed over the costs (c). Finally, the costs (C) may be driving a design project, following C (q,t).

Delays may put pressure on the design quality of the banknotes, tempting central banks to fix the time variables, captured by T (c,q).

**Multidisciplinary design team**

Selecting a project manager, the central bank should have an eye for someone enthusiastic with experience in product development and project management, stimulating a collaborative atmosphere and able to secure adequate resources. Once recruited, the project manager will be independent and should have access to a high management level, preferably a single person, acting as the "delegated client" (Groote et. al, 1990).

The next step is that the project manager starts to compose a 'New Banknote Project Team'. This team should not be too small, nor too large. In theory, an optimal design team should exist of five to seven members (e.g. Schlick, 2009). A smaller team might affect the quantity of ideas and the group energy level, whereas a larger team might enhance group dynamics and will be harder to manage. Secondly, the design team should be a multidisciplinary team, involving different educational backgrounds and skills. Third, a multidisciplinary project team can be more powerful, when it includes different personalities, as first defined by Gerard Puccio in 2002 like a clarifier, ideator developer and implementer (e.g. Grivas and Puccio, 2011).
Once the candidates for the design team are pointed out, the project manager has to consult the line management of the central bank for approval, as employees might be needed on other jobs.

**The Norwegian organisation**
The design process of a banknote is described in figure 2.7. All stages are usually the responsibility of the project manager. For the development of their new banknote series “The Sea”, the central bank of Norway chose a different approach (Eklund, 2016). First the bank formulated internal ambitions. They would like to use their in-house competence as much as possible within their project set-up, indicated by the blue activity arrows in figure 4.2. These tasks included theme selection, a design contest and the selection of the design. The transition of the design into print was the full responsibility of the printer, indicated by the red arrows. Furthermore, the bank made active use of external advisors. This division of responsibilities was successful. Issues by the ‘blue team’ or ‘red team’ were early addressed in an open and constructive way.

Comparing committee and project management
Wrapping up, figure 4.3 summarises the characteristics of banknote design by a design team under project management and by a committee (De Heij, 2010c). Project management is preferred for any banknote design process, instead of a committee approach. The design team should be kept lean and mean to ensure a fruitful design process.

<table>
<thead>
<tr>
<th>CHARACTERISTICS OF BANKNOTE DESIGN</th>
<th>Committee</th>
<th>Project management</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Number of people involved</td>
<td>Undefined, often 5 to 25.</td>
<td>≤ 7</td>
</tr>
<tr>
<td>2. Diffusion of responsibilities</td>
<td>Diffuse. Everybody and nobody responsible.</td>
<td>Clear. Each member contributes specific knowledge or skills.</td>
</tr>
<tr>
<td>4. Plural ignorance</td>
<td>Reactive members; unfamiliar with banknote design.</td>
<td>Proactive members; knowledgeable on banknote design.</td>
</tr>
<tr>
<td>5. Planning fallacy</td>
<td>Unreasonable optimism.</td>
<td>Planning based on experience previous project.</td>
</tr>
</tbody>
</table>

Figure 4.2
Organisation scheme of the design process of the latest Norwegian banknotes. Clear division of responsibilities between the National Bank (NB) and the printer (Oberthur).

Figure 4.3
Overview of the characteristics of banknote design by committee or by project management.
4.4 Programme of Requirements

One of the main causes for a disappointing level of design quality is a lack of formal requirements (subsection 2.3.2). When clear information on the banknote to be designed is absent, the banknote designer is in a vacuum and the banknote designer may ask: What is it exactly that I have to design? Clear criteria are also necessary for the approval process of a new banknote, criteria which are also delivered by a proper Programme of Requirements.

Design brief
The start of a new design project central banks may formulate their requirements in a Design Brief. A Design Brief is intended for use by the candidate designers and describes the required deliverables, but not necessarily the aesthetics. Topics clarified in a Design Brief are the sizes, the main images and two or three authentication features, a rather incomplete document compared to a Programme of Requirements (PoR). This is a crucial observation, as the banknote design will most likely fail when all requirements are not known at the start of the design process.

However, a Design Brief may be used to select a banknote designer on their artistic merit. This artistic design is often sent to a banknote printer, where an in-house designer will ‘translate’ it to printed matter without much involvement of the original designer. This is a suboptimal situation, since the final result will deviate from the original design, which may result in a disappointed banknote designer and central bank. Bolten (1999) described that this situation was regularly the case for Dutch banknote designs prepared before 1965.

Instead of a Design Brief, a complete design instruction in the form of a ‘Programme of Requirements for a Sketch Design’ is advised (De Heij, 2008a). To get the design requirements right is the hardest part of any design process, at least according to Norman (2013). Unfortunately there is not much supporting literature on how user functions should be translated into design requirements and is therefore one of the topics of this section. The scope of a design process is well documented (e.g. Roozenburg and Eekels, 1995; Foqué, 2010; Van Boeijen et al., 2013).

The introduction of a PoR may encounter resistance, as central bank management may get the idea that the design preparations (figure 2.7) take too long and that printing should start. However, if requirements are not well thought through or absent, the end result will be disappointing.

Literature on Programme of Requirements
Asimow (1962) is credited to be the first to emphasise on a list of requirements as part of the design process. These theories were brought to further perfection by Archer (1963; 1971) and Roozenburg and Eekels (1995). There are several terms used for ‘a list of requirements’ and the most common is a ‘Programme of Requirements’. Others are ‘Product Requirements’, ‘Functional Requirements’, ‘Quality Function Deployment’, ‘Schedule of Requirements’ and ‘List of Requirements’. Roozenburg and Eekels used the term ‘Product Design Specification’.

As specifications are commonly used to describe the characteristics of the final product, the term requirements is preferred for a product that does not yet exist. Once realised, a requirement may become a specification in the product’s Technical Specifications (TS). Such technical specifications provide a nominal (production) value including the corresponding tolerances (see also subsection 2.3.3).

The design requirements of Dutch banknotes were organised by the method of a Programme of Requirements (De Heij, 1986; 2008a). Similarly, Van Renesse (1996) advocated a Programme of Requirements for security products like passports and banknotes. Later, Norman (2013) emphasised the importance of a thorough set of design requirements, as far too many project teams rush to produce requirements that later prove to be faulty. According to Norman, it is a pitfall to ask people what they need. User requirements should be developed by watching people in their natural environment.

The preparation of adequate user requirements is one of the main tasks of the banknote design manager, as will be elaborated on in section 4.7 on use-centered design of banknotes.
**First banknote design requirements**

Already in 1803, the first requirements for a new British banknote were described as “keeping the design simple in order to make the money easily recognised by the general public” (e.g. Byatt, 1994). Several years later, in 1819, the British inventor William Congreve (1772-1828) advised to design “features to be immediately recognised and understood by the most unlearned persons” (e.g. Schell, 2007).

A problem associated with banknote production in the first half of the 19th century was that genuine banknotes were not all the same. Granville Sharp (1854) proposed to make all genuine banknotes uniform, so that imitations will be instantly recognised. He also recommended the inclusion of human faces on banknotes, as forgers will experience paper distortions because of their multiple print operations, which will be noticed, especially in portraits. Sharp also proposed special black inks, like “Frankfurt Black” and “Velvety Black”, which were different from the black inks with bluish or brownish hues as used by forgers (see also section 3.3). The main critique of Sharp’s advice was that banknotes can always be imitated, as long as the authentication is performed by humans; there is no such thing as inimitability (e.g. Robertson, 2005). Sharp’s suggestions were partly used for a new banknote design of the Bank by England, issued in 1855.

**Development of PoR at the DNB**

Early design requirements were also determined by the DNB and committed to paper in 1857 (Bolten, 1999):

1) An extremely fine artistic engraving, either with a vignette or something else, by an artist who stands out for his sophisticated style.
2) An engraving produced on guilloching or die-stamping machines, which achieve a degree of fineness which the hand cannot hope to trace.
3) Typography, with its typical difficulties for hand-copyists."

These three requirements are considered to be DNB’s first Programme of Requirements for a new banknote series. Over the years the body of design instructions evolved from these few lines to a set of PoR’s in the 1990s (De Heij, 2008a). One of the basic thoughts behind these PoRs was to reduce the paperwork for the banknote designer, as explained in the author’s preface. A PoR would be the only ‘bureaucratic’ document banknote designers have to accept. The PoR went beyond Dutch Designers. Other parties involved in the design process, such as the paper makers and the printer, appreciated such a clear and detailed assignment from their client too; especially since instructions were thought through and fixed.

The watermark ‘Little Owl’ (figure 3.16c) serves as a textbook example of the synergy between a PoR and a quality design.

**Development of design requirements at ECB**

The European Central Bank reported several times on the development of requirements for new banknote designs, like in 2004 (italics are added by author):

“The focus is on the different kinds of customers and users: the general public (including the visually impaired), cashiers, vending machines, banknote processing machines, cash handlers, law enforcement authorities and the note-issuing authority itself. Each has different needs in terms of convenience, authentication, efficiency, resilience and cost, and these needs also differ for low, medium and high denomination banknotes”. Followed in 2006 by:

“Basic functional requirements for the new banknotes, including a shortlist of security features, are being established on the basis of market research and consultations with European consumer associations and the European Blind Union. The consultation process has also involved the European banking, security transport, retail and vending machine sectors, as well as the association of banknote equipment manufacturers.”

And continued in 2007 with:

“In the course of 2005, the ECB established the functional and technical requirements of different groups of banknote users through consultation and market research.”
Although efforts were undertaken to investigate user requirements, the results of this research remained unfortunately unpublished.

The design process of the second series of euro banknotes did not include a Programme of Requirements. Furthermore, unfinished development projects hindered the design process (subsection 2.3.2), which became therefore highly technology-driven, with many iterations and changes, bringing the design management out of control.

From user functions to design requirements

There are two groups to be served by a new banknote design: users and stakeholders (subsection 2.3.1). The only way to arrive at design requirements for both groups is to investigate in respectively user functions and stakeholders’ functions, a four step process as illustrated for user functions in figure 4.4 (De Heij, 2015a). Writing down the stakeholders’ requirements follows a similar methodology as for user requirements.

Starting with the user functions (1), the first stage is the identification of the functional requirements (2), defining sub functions of a product or system. The following phase is the identification of user requirements (3), based on user needs and user preferences. Finally, all collected information will have to be analysed and will lead to an instruction to the banknote designer in the form of design requirements (4). This method is also applicable in the field of banknote design as illustrated by the included example. For instance, when the central bank would like to have a new 50, the functional requirement for the user function ‘value recognition’ is ‘50’. To have a readable numeral 50 is a next step and user requirements will have to be formulated. To list user requirements, knowledge has to be gained on user needs. This knowledge is commonly obtained via literature or by performing dedicated studies. In the case of the numeral 50, typographic parameters have to be set, like the height of the numeral and the contrast to its background (e.g. De Heij, 2009). All collected information will be analysed and will lead to an instruction to the banknote designer in the form of design requirements. The role of the modern banknote designer is, as elaborated on in chapter 3, to provide an aesthetically pleasing design based on the design requirements, set by the banknote design manager of the central bank.

PoR is a set of documents

The identified design requirements are listed in a Programme of Requirements. Via a number of steps the design requirements are converted into specifications; the idea of a new banknote is brought to an embodiab le form (section 2.2). In this view a PoR is not a single document, but is expanded into a set of documents, reflecting the typical phases of the banknote design process (figure 2.7), as has been the case for the design process of the last guilder banknotes, provided in figure 4.5.

The separate documents have a similar structure. For example, all sets have the same numbering of

![Figure 4.4](image-url)
the requirements and wishes. The Technical Specifications (TS) are the end product of a set of Programmes of Requirements. Organising a PoR this way contributes to a SMART-approach of banknote design. SMART stands for Specific, Measurable, Acceptable, Relevant and Time-bound, as first formulated by Doran (1981). The future production costs of the banknotes are foreseen in the PoR Banknote Issue.

Organisation’s memory
The design expertise may have left the central bank by the time a new banknote design has to be prepared (which is one of the reasons for this study). An important function of a PoR is therefore an ‘organisation’s memory’. Once a robust PoR is available, it may be used for the development of a new ‘repeat banknote design’, assuming requirements have not changed in the years between the two note series, an assumption that will require validation.

Technical layout
After the completion of a Programme of Requirements, one of the first design activities is the preparation of a technical layout, also known as a functional layout. In this technical drawing the required attributes are recorded, including machine-readable features.

From design requirements to technical specifications

- Input from different users and stakeholders
- List of series design parameters. Include an identity policy and issuance strategy (roof tile and spot plan). Include the most relevant requirements, wishes, constraints and comments of (the next phase) of banknote design.
- QC1: check if series design matches all requirements, score the wishes. If not: change PoR Design or adapt design.
- List of all the requirements, wishes, constraints and comments
- QC2: check if design matches all requirements, score the wishes. If not: change PoR Design or adapt design.
- List all requirements for origination and proof printing. Including files/films, dies, etcetera. Reference notes.
- QC3: check if proof print matches all requirements, score the wishes. If not: change PoR Proof Print or adapt proof print.
- List all requirements and wishes for pilot production and issuance
  Typical production volume: one day production (0.5 - 1 million notes).
- QC4: check if design matches all requirements, score the wishes. If not: change PoR Issue or adapt pilot production.
- Repeat orders.

Figure 4.5
Flow diagram of four different Programmes of Requirements for a new banknote and the Technical Specifications. Repeat orders are based on a set of Technical Specifications. QC = Quality Check.
4.5 Banknote design policy

One of the tasks of the banknote design manager is to develop a banknote design policy, a subject that is seldom written about. With such a policy a central bank provides direction to the banknote designer how to fill in the design. The banknote design manager offers the proposal for endorsement to the central bank’s board. An overview of banknote design policies in the order of their first application is available and provided in figure 4.6 (De Heij, 2016a).

Historical overview of banknote design policies

The oldest banknote design policy is a ‘banknote handling’ policy (figure 4.6, row 1). Paper money was invented to offer merchants an alternative to carrying heavy coins along unsafe roads. A handling design policy is still applied, mainly to create smaller banknotes. If the size of banknotes is reduced, they fit better into wallets. When the Bank of Israel introduced their new banknote series in 1999 they stated: "They are narrower than the first NIS series, so that they do not protrude from the average size wallet, thereby reducing wear and tear." (Bank of Israel, 1999). The Swiss decreased their note height from 74 mm to 70 mm for similar reasons: "With their proportions being more ideal, the banknotes will not only give a more favourable overall impression, but wear and tear in the wallet can also be reduced." (Swiss National Bank, 2005).

In the early years of banknotes many central banks followed a ‘low volume’ design policy (figure 4.6, row 2). The denominations have similar images and are printed on the same paper. Modern examples are the Bermuda Monetary Authority (similar paper and print) and the Central Bank of Aruba (similar paper, different print).

The third design policy reviewed is an ‘emergency’ policy (figure 4.6, row 3). Emergency banknotes are prepared to be issued if the number of counterfeited banknotes is beyond control. The concept of auxiliary, substitute or fallback banknotes is similar to that of emergency banknotes. In the 19th century, DNB produced seven variants which were never issued, except for some minor volumes (Bolten, 1999).

Instead of the full production of emergency notes, central banks may prepare just a design. This was the case in the 1970s when designer Oxenaar prepared a fallback design for the denomination of 100 guilder. As a portrait was not specified, Oxenaar was free to propose an alternative theme and he chose a bird, the snipe. As counterfeits of the then current 100 guilder note kept on being accepted, the prepared design was taken into production (see figure 3.25c). The new denomination was issued in 1981 and became very successful, the word Snipe even became synonymous with 100 guilder. Although a success, the Snipe was the last Dutch emergency banknote. Since then, priority has been given to a controlled banknote design process due to the ongoing innovation in digital printing techniques. Fully prepared emergency banknotes in DNB’s vaults would probably have been outdated by the time they were needed. And the same reasoning can be applied to a fallback design. The revised policy stipulated that a new banknote should be developed within two years, including new authenticity features (section 2.5). Instead of new banknotes in their vaults, DNB wanted novel features ready for implementation within a ‘roof tile issuance strategy while maintaining a series impression’.

In the first years of the euro the European Central Bank developed two sets of emergency banknotes: the ‘Six Month Project’ and the ‘Two Year Project’, both covering three denominations (20, 50 and 100 euro). The two projects remained unused and in 2007 the Eurosystem opted for controlled planning of a new design and for features on the shelf.

The fact that ‘authenticity’ policies (figure 4.6, row 4) have always been popular, is not surprising as banknotes have endured three major technical threats of being counterfeited in large numbers. Central banks may say that it is their policy to stay one step ahead of counterfeiters, or they may say (Sharman, 2014):

"It’s about getting the balance right between something that’s difficult to counterfeit but very simple to authenticate."
In 2003, the Federal Reserve System of the United States (FRS) captured their authenticity policy with the motto: “Safer. Smarter. More Secure.”

The design policy for the second series of euro banknotes was also an authenticity policy that involved the introduction and advancement of ‘quantum leap features.’ (e.g. Heinonen, 2015).

Using banknote design as a ‘communication tool’ (figure 4.6, row 5) is a design policy applied since the 1850s that has many followers. According to the Swiss National Bank communication is the most important aspect of a banknote: “The public is doubtlessly more interested in the theme and design of new banknotes than in the security technology.” (Swiss National Bank, 2005).

A similar design policy is ‘commemorative’ banknote design (figure 4.6, row 6), which commemorates historical or recent events. Usually such banknotes are printed in limited volumes, which is appreciated by collectors and the reason why they tend to disappear from circulation. Unlike collectors, the general public are wary of unfamiliar looking coins and banknotes and usually try to get rid of these first (Van Schagen, 2007). Commemorative banknotes may also serve other purposes, for example testing new approaches such as new substrates, features, varnishes or designs.

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<table>
<thead>
<tr>
<th>Banknote design policy</th>
<th>Main focus</th>
<th>Aiming for</th>
<th>Recent examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Low volumes</td>
<td>Similar substrate</td>
<td>Similar sizes, paper tint and watermark</td>
<td>Aruba, Bermuda, Cayman Islands, East Caribbean, Tobago</td>
</tr>
<tr>
<td>3. Emergency banknote</td>
<td>Authenticity features</td>
<td>Replacement in case of large amount of counterfeits</td>
<td>NLG 100 (The Netherlands, 1981)</td>
</tr>
<tr>
<td>4. Authenticity</td>
<td>Authenticity features</td>
<td>New security features</td>
<td>Almost all central banks</td>
</tr>
<tr>
<td>5. Communication (message)</td>
<td>Main image</td>
<td>Celebration of person or nation</td>
<td>Science/arts/royalty (Great Britain, Thailand) Big Five (South Africa) Focus on message (Switzerland)</td>
</tr>
<tr>
<td>7. Durability</td>
<td>Time in circulation</td>
<td>Cost reduction, environment</td>
<td>Polymer banknotes (Australia, Canada) Hybrid papers Durable paper/varnishes</td>
</tr>
<tr>
<td>8. Low production costs</td>
<td>Paper and gravure</td>
<td>Low banknote price, high law enforcement</td>
<td>USA</td>
</tr>
<tr>
<td>11. Cash is one system</td>
<td>Coins and banknotes</td>
<td>Usability cash</td>
<td>Same image on coin and banknote designs 1994 and 2002 (Brazil)</td>
</tr>
<tr>
<td>13. Use-centered</td>
<td>Public, retailer</td>
<td>Usability, user-friendliness</td>
<td>Advocated design policy</td>
</tr>
</tbody>
</table>

---

Figure 4.6 • Overview of different banknote design policies, ranked according to their (believed) first application.
A design policy that was first applied in the 1950s is the ‘durability policy’ (figure 4.6, row 7) which aims to increase the lifespan of banknotes. Durability policies are mainly driven by efforts from central banks to reduce the cost of banknote production. There are no direct benefits for banknote user groups, except that in the end they may pay less tax.

Central banks may also try to reduce costs with a ‘low production costs policy’ (figure 4.6, row 8). The production of euro banknotes involves two additional steps compared to that of the US dollar (foil and silk screen printing) and is therefore more costly. Europeans rely more on ‘self-defending banknotes,’ while the FRS has a stronger bias towards stronger law enforcement in order to prevent counterfeiting. This bias towards law enforcement dates back to President Lincoln, in office from 1861 until 1865, who explicitly assigned the Secret Service the task of combating counterfeiting and this still holds today.

Another reason for a new series are changes in the central bank’s banknote sorting systems. Policies facilitating such changes usually concern the introduction of a ‘new feature plus detector’ (figure 4.6, row 9).

‘Value recognition’ is a design policy aiming for unambiguous identification of the note’s value (figure 4.6, row 10). Banknote designs are often sub-optimal when it comes to value recognition (De Heij, 2009). Complaints from the public about the ability to recognise the value of banknotes may trigger new banknote designs, as was the case with the E-series in the United Kingdom issued between 1990 and 1994.

Currencies with a coherent design of coins and banknotes are rare. This is remarkable, because to the public the cash is one type of payment system, referred to as a ‘cash is one system’ (figure 4.6, row 11). An example is found in Brazil (see figure 4.7).

The last two banknote design policies are the most recent and receive more attention in the following two topics: identity (figure 4.6, row 12) and the advocated design policy is a use-centered design policy (figure 4.6, row 13), focussing on all user functions of a banknote. This design policy will be introduced in section 4.7.

One of the basic requirements for any product design to be successful is having a design policy. A first step is the formulation of a banknote design policy, which starts with an identity description.

Identity description

An identity description is a short text, about half A4, which explains what kind of experiences the new banknote design should evoke (De Heij, 2012; 2015c). Examples are forward looking, exude some

Banknote design policy: cash is one system

Figure 4.7

Emphasise that coins and banknotes are both payment instruments part of one payment system, being cash. Similar image on Brazilian coin and banknote. The image is a national symbol of Brazil - Efigie da Republica - and represents a young woman wearing a crown of bay leaves in Roman style. After the proclamation of the Brazilian Republic in 1889, this image became one of the national symbols.

a) Coin issued in 2002.
b) Banknote issued in 1994.
happiness, and be dynamic. Two examples of an identity description are provided in figure 4.8, respectively for the last Dutch guilder banknote and for the euro banknotes (De Heij, 2000; European Central Bank, 2003). In case of the guilder the identity description was coupled to a high design freedom.

Instead of a description central banks downsize the required identity of new designs to a motto like "Switzerland open to the world", "My country-Belarus" or to a self-referential text like "The euro should be clearly identifiable as European".

Discussions on which female portrait should be introduced are also examples of a narrow view on an identity profile, as is presently the case in Canada, United Kingdom and the United States. People may object to an imposed identity, illustrated by reactions to the latest Australian 5 dollar banknote featuring Queen Elisabeth II, issued in 2016. Inhabitants of modern nations are self-acting citizens with personal responsibilities and therefore they may experience such traditional symbolism as directive or even as paternalistic. Forward looking symbolism offers an alternative. A first step is made by the Bank of Canada saying that Canadians (79 %) would like their new banknote designs to be meaningful for the years to come (Pollara, 2014).

4.6 Combining use and experience

The terms 'use' and 'experience' are not only encountered within the domain of User Interaction Design. Architects and artists often distinguish between use and experience when they explain their designs. The use of a building will receive more weight than its experience, at least in general terms (figure 4.9a). In the case of a painting it will be the reverse, the experience will be key, as the use of a painting is, put bluntly, 'something to hang on the wall' (figure 4.9b). An explanatory example from another field concerns the preservation of open waters in the Netherlands. Like banknotes, open waters are a commodity. The use of open waters can be defined by swimming, sailing, fishing, diving and skating, while its experience can be defined by walking close to the waterfront and looking at the associated eco-system (Stichting Toegepast Onderzoek Waterbeheer, 2014).

In the 1990s, the term experience received a boost, when Pine and Gilmore (1999) introduced the "Experience Economy", offering emotional value to a product or service by introducing the 4E's (Entertainment, Educational, Esthetic and Escapist). The attention for experience was also noticed by product designers, as customers would no longer take a functional product as a given, described as a "clear shift from object-centred to experience centred design" (Buxton, 2007). This trend is also
reflected in the titles of publications like "Emotional Design" (Norman, 2005), "Product Experience" (Schiffers and Hekkert, 2008) and "Happy Design" (e.g. Pavliscak, 2015). Creating a little smile is a common objective of use-centered design policy (e.g. Jordan, 2000); people may respond positively when a banknote elicits a little smile, which may lead to better levels of attention for the banknote.

Four basic models
Application of the variables use and experience leads to four basic models to approach a new banknote design (figure 4.10). As a new banknote design will replace an existing one, the novelties of a new banknote should be compared to its predecessor. If not much has changed, neither in use, nor in experience, the design is an upgrade (Model 1).

![Figure 4.9](image)
Architects and Artists speak about "Use and Experience".


![Figure 4.10](image)
Four basic models to approach new banknote design. Compared to the existing banknote model a new banknote design may have different settings to emphasise the use and/or experience aspects.

<table>
<thead>
<tr>
<th>BASIC MODELS OF USE AND EXPERIENCE OF BANKNOTE DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1. Customise existing design</td>
</tr>
<tr>
<td>Use</td>
</tr>
<tr>
<td>Experience</td>
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<tr>
<td>o</td>
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<tr>
<td>o</td>
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<tr>
<td></td>
</tr>
<tr>
<td>2. Emphasise use</td>
</tr>
<tr>
<td>Use</td>
</tr>
<tr>
<td>o</td>
</tr>
<tr>
<td>Experience</td>
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<tr>
<td></td>
</tr>
<tr>
<td>3. Emphasise experience</td>
</tr>
<tr>
<td>Use</td>
</tr>
<tr>
<td>o</td>
</tr>
<tr>
<td>Experience</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>4. Emphasise use and experience</td>
</tr>
<tr>
<td>Use</td>
</tr>
<tr>
<td>o</td>
</tr>
<tr>
<td>Experience</td>
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<tr>
<td></td>
</tr>
<tr>
<td>o = Maintained design policy</td>
</tr>
<tr>
<td>● = Result of new design policy</td>
</tr>
</tbody>
</table>
Examples
The replacement of the euro banknotes is an example of Model 1, as the second series kept the design quite similar to the first (figure 4.11a).

The replacement of paper-based banknotes by synthetic substrates is an example of Model 2, since the new use of the banknotes is emphasised. The main image and some of the other design elements can be kept, as in case of the transition of the Canadian banknotes to polymer (figure 4.11b). Since the first Australian polymer banknote was issued in 1988, over 35 central banks followed, including New Zealand (in 1999) and the United Kingdom (in 2016).

The third model (Model 3) represents new banknote designs that introduce new graphic designs, emphasising the user experience. The new series of Swedish banknotes is an example of this category. Historic portraits are replaced by images with more public appeal, like persons known from the cinema (figure 4.11c).

The introduction of the euro in 2002 was for the citizens of twelve countries a major change of respectively the use and the experience of what they were accustomed to. The euro was a new currency and it was a break with a portrait tradition. The introduction of the euro is an example of new banknote designs emphasising both the use and

A more recent example is the Norwegian banknote series "The Sea" (figure 4.11d). This series introduces main images from different image categories, like an animal (fish) and a building (lighthouse), which supports instant value recognition, the main user function. Furthermore, the Norwegians clearly defined and underlined their banknote identity, the main experience function.

Basic Models of Banknote Design, examples

![Basic Models of Banknote Design, examples](image)


Although the Dutch already started with the replacement of portraits in 1981, this has become a real trend since the introduction of the euro banknotes.

Figure 4.11
Four examples of basic models to approach a new banknote design.
4.7 Use-centered design of banknotes

Section 4.4 explained that the identification process of design requirements starts with the determination of the user functions. User functions of a banknote are captured by the Model for Use-centered Design of Banknotes, displayed in figure 4.12 (De Heij, 2015a; 2016b; 2017). This model identifies two groups of user functions: User Interface Functions (UIFs) and User Experience Functions (UXFs).

**User Interface Functions (UIFs)**
Searching for notes in their wallet, people are interested in their value. Also when they receive a banknote as change, people’s first interest is if the correct denominations are offered. In both situations they are in recognizing value mode (UIF 1). Subsequently, people will take the banknote, arriving at the second user function, named handling (UIF 2). When people do not trust a banknote at offer, they may want to do a self-check on its authenticity and therefore UIF 3 is checking authentication.

**Receiving a communication message** is a fourth identified user interface function, as people may be interested in the themes, images and features displayed (UIF 4).

**User Experience Functions (UXFs)**
People will have more interest in a banknote of their own than in a foreign banknote. Therefore recognizing identity is the first user experience function within the Model (UXF 1). If it is not a national banknote, people will have no interest, so is the assumption. Second, within a fraction of time, people have their judgement ready on the aesthetics. They either find the banknote beautiful or ugly. For this reason judging aesthetics is listed as UXF 2. Whether a new design looks like a valuable banknote or a cheap coupon is a matter of keeping confidence, function UXF 3. Furthermore, the main image of the new design is noticed instantly, is it a portrait, a bird or a tower? Reacting on the main image is therefore one more user experience function (UXF 4). Two upcoming user experience functions are positioned at the bottom rows. The first is expecting sustainability; people expect their banknotes to be ‘green’ (UXF 5). The latest function is linking to information technology, listed as UXF 6; people expect that a banknote can do something with information technology, like checking a banknote by using a smartphone.

**Ranking user functions**
The four UIFs were prioritised by the Dutch in the order as given in figure 4.13 (Visser and Dijkers, 2013). Together, the UIFs define the usability of the banknote, which is reported by a usability score.

**A use-centered design team**
Participants in a traditional banknote design project are the design manager of the central bank, the banknote designer and the contractor (Three Parties Model, section 1.1). One of the keys to improve future banknote designs is the involvement of the users, the public and retailers. Their needs are too often overlooked. Consequently, user requirements are not thoroughly investigated. With the public and retailers being absent from the design process, the final design results can be disappointing.

### MODEL FOR USE-CENTERED DESIGN OF BANKNOTES

<table>
<thead>
<tr>
<th>User Interface Functions (UIFs)</th>
<th>User Experience Functions (UXFs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Recognising value</td>
<td>1. Recognising identity</td>
</tr>
<tr>
<td>2. Handling</td>
<td>2. Judging aesthetics</td>
</tr>
<tr>
<td>3. Checking authenticity</td>
<td>3. Retaining confidence</td>
</tr>
<tr>
<td>4. Receiving a communication message</td>
<td>4. Connecting with main image</td>
</tr>
<tr>
<td>-</td>
<td>5. Expecting sustainability</td>
</tr>
<tr>
<td>-</td>
<td>6. Linking to information technology</td>
</tr>
</tbody>
</table>
In a use-centered design approach the presence of producers could be reduced, while other disciplines may come in. An example would be the addition of an interaction designer, a specialist on the design of user interfaces of a banknote, like value and authenticity features. Figure 4.14 describes the members of a use-centered banknote design team along the lines for a development team aiming for high usability of electronic products (Van Kuijk, 2010).

An example related to banknotes is provided by Peters et al. (2004), which describes the involvement of a skilled disabled person as a member of the development team. The aim of the project was to develop a reading device for the blind, which is also able to denominate a banknote. Figure 4.15 illustrates the organisation of such a project team and the relation with the suppliers, who are positioned in the outer ring. These suppliers are diverse in nature. They may deliver semi-finished products, perception testing or other services to ensure future user satisfaction.

A project team as described will be proactive and will invite the designer to come with a proposal in this or that direction. Such an approach encourages team collaboration. This is a more stimulating situation than the other where project members play a reactive role to the proposals of the (isolated) banknote designer.

### Table 4.1

<table>
<thead>
<tr>
<th>Relative importance of User Interface Functions of euro banknotes</th>
<th>Importance</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>UIF 1 Recognising value</td>
<td>2.6</td>
<td>7.7</td>
</tr>
<tr>
<td>UIF 2 Handling</td>
<td>1.6</td>
<td>7.1</td>
</tr>
<tr>
<td>UIF 3 Checking authenticity</td>
<td>1.7</td>
<td>5.7</td>
</tr>
<tr>
<td>UIF 4 Receiving communication message</td>
<td>0.2</td>
<td>5.2</td>
</tr>
<tr>
<td>Usability score (average of UIF 1 - 4)</td>
<td></td>
<td>6.4</td>
</tr>
</tbody>
</table>

**Figure 4.13**

Relative importance of four usage functions of a banknote to the Dutch. Respondents were asked which of these four functions of euro banknotes are most important to them (4 = high importance, 1 = low importance) and how they would rate these functions on a score from 1 to 10.

### Table 4.2

<table>
<thead>
<tr>
<th>Job title</th>
<th>Role description</th>
<th>Also known as (alias)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banknote design manager</td>
<td>Manages the banknote project (product quality, time planning, budget, information/reporting and organisation).</td>
<td>Project manager, product manager, customer-marketing manager, scrum master.</td>
</tr>
<tr>
<td>Banknote designer</td>
<td>In charge of the overall design of the banknote.</td>
<td>Graphic designer. Visual communication designer, communication designer.</td>
</tr>
<tr>
<td>Usability tester</td>
<td>Evaluates the usability of banknotes and banknote features.</td>
<td>Usability specialist, user experience specialist.</td>
</tr>
<tr>
<td>Interaction designer</td>
<td>Designs the user interface of the banknote; especially value and authenticity features.</td>
<td>User interface designer, user experience designer, visual designer.</td>
</tr>
<tr>
<td>Originator</td>
<td>Responsible for technological and production aspects.</td>
<td>Printer Development engineer. Printing works is often also the contractor for a new banknote design.</td>
</tr>
</tbody>
</table>

**Figure 4.14**

Design team roles identified as relevant for providing a banknote design with a high usability (adapted from Van Kuijk, 2010).
One more major policy topic should be addressed when it comes to banknote design, the question of creating a totally new banknote design or simply upgrading the existing design.

In general, people are not waiting for a new series of banknotes. This is demonstrated by studies done in Japan and the Netherlands (De Heij, 2010a). People have a wait-and-see attitude towards banknotes, which is explained by two psychological phenomena. First, there is the satisfice principle, a contraction of satisfy and suffice (Simon, 1956). People are satisfied with the existing banknote, which is good enough. However, they understand that counterfeiters are thwarted by new banknote design issues. According to the Matrix of Gourville (2006) banknotes are an easy sell. People will use a new banknote like the previous one, even in case of a different graphic design. According to industrial designer Raymond Loewy (1893-1986) consumers will be positive about novelties in a design, but innovations should not be taken too far and he named this the MAYA-principle, an abbreviation of Most Advanced, Yet Acceptable. New banknote designs should therefore have one foot in the past and one foot in the future, which is translated to a maximum change of the graphic design of 80%. The minimum change is set at 20%, as otherwise there is no reason to issue a new banknote.

These two values can be applied on two design variables, the technical innovations and the degree...
of renewal of the graphic design (De Heij, 2012). These two variables lead to four different design policies, represented by the ‘new/upgrade ratio’ (figure 4.16). Upgrades (20/20) are represented by the purple quadrant, an area where larger currencies like to settle, such as the Chinese yuan, the Indian rupee, the US dollar, the Japanese yen and the euro. Such upgrade designs are based upon the existing banknote design receiving one or two new authenticity features (figure 4.10, Model 1). Such redesigned banknotes fail on the primacy effect (Ebbinghaus, 1885); when a product is new, it will have a higher probability that some pieces of information will be stored in the long-term memory (De Heij, 2015b).

The orange quadrant represents technical innovative banknotes (20/80), such as the first banknote printed on polymer, technically highly innovative but, in your author’s opinion, its design was not (Model 2).

Smaller central banks tend to opt for the green quadrant (80/80), like Denmark and Switzerland and also the former Dutch guilder notes (Model 3). People will be interested in a new design, including interest for the innovative features.

Many new banknote models can be found in the blue quadrant (80/20). A new design without innovative features can be made with relatively little costs. Still such designs may be highly appreciated (Model 4).

Concluding, new banknote designs are preferred, as a new design will receive attention and will not be confused with the old model.

![Model for the New/Upgrade Ratio of Banknote Design](image)

Figure 4.16
The Model for the New/Upgrade Ratio of Banknote Design. Banknote design policies based on two variables: change of the graphic design (x-axis) and innovative technology (y-axis). Four basic design policies are represented by respectively different values for a design change and the introduction of an innovative technology. The figure 20/80 indicates respectively a design change of 20 % and an technology change of 80 %.
4.9 Targets to banknote design and banknote design management

Once the design of the new banknote has been brought to an end, it should be assessed whether the design meets the specified criteria. Furthermore, it should be assessed whether the management of the project has achieved the objectives set.

In two topics, the targets will be discussed for the banknote design and the banknote design management.

**Targets banknote design**

First, the banknote designed must meet the requirements as set in the Programme of Requirements, otherwise it should not be produced. If the new design does not meet all requirements, then, in consultation with the client, requirements should be adjusted or skipped. Within a central bank organisation, the client of the banknote design manager is one of the line managers.

Once in circulation, the users will review the new banknote design. Their assessment criteria are the same as the user functions as identified by Model for Use-centred design of Banknotes (section 4.7) and shown in figure 4.17. This figure sets targets for a number of user criteria, but not (yet) for all.

These targets are based on the studies done on measuring user satisfaction (e.g. De Heij, 2002; 2010c; 2016b).

<table>
<thead>
<tr>
<th>Model for Use-centred Design of Banknotes (Coaster Model)</th>
<th>Target</th>
<th>Realised (Euro 50, NL)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UIF</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Recognising value</td>
<td>&gt; 98 %</td>
</tr>
<tr>
<td>2</td>
<td>Handling</td>
<td>&gt; 90 % clean</td>
</tr>
<tr>
<td>3</td>
<td>Checking authenticity</td>
<td>Av. knowledge of features &gt; 3</td>
</tr>
<tr>
<td>4</td>
<td>Receiving com. message</td>
<td>( &gt; 7)</td>
</tr>
<tr>
<td>1-4</td>
<td>Usability score</td>
<td>&gt; 7</td>
</tr>
<tr>
<td><strong>UXF</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Experiencing identity</td>
<td>( &gt; 7)</td>
</tr>
<tr>
<td>2</td>
<td>Judging aesthetics</td>
<td>&gt; 70 % beautiful</td>
</tr>
<tr>
<td>3</td>
<td>Keeping confidence</td>
<td>For complete series &gt; 7</td>
</tr>
<tr>
<td>4</td>
<td>Reacting on main image</td>
<td>( &gt; 7)</td>
</tr>
<tr>
<td>5</td>
<td>Requiring sustainability</td>
<td>( &gt; 7)</td>
</tr>
<tr>
<td>6</td>
<td>Linking to IT</td>
<td>( &gt; 7)</td>
</tr>
<tr>
<td>1-6</td>
<td>Experience score</td>
<td>( &gt; 7)</td>
</tr>
</tbody>
</table>

*) Combined score for recognising and handling euro banknotes (European Commission, 2015).

Figure 4.17

Assessment of a banknote design by the Model for Use-centered Design of Banknotes. On the left the targets a central bank may set. On the right the realised values for the euro 50 (2002), measured in the Netherlands. Measurements are not available for the targets set between brackets. In general a banknote should score on a specific user function > 7 on a scale of 1 to 10.
Targets banknote design management

Except that the product needs to score sufficiently on the banknote’s user functions, in general >7 on a scale from 1 to 10, the development of the banknote should also meet the set targets on its management. Therefore, these targets should be set and known. Central banks will tend to have some criteria, but all too often these management criteria are not complete. One of the main policies is to know whether, at the end of the day, the quality of the banknote is more important than respectively the issuance date or the costs incurred (section 4.3).

Figure 4.18 provides an overview of the targets for the banknote design management.

<table>
<thead>
<tr>
<th>Planning topics, in order of priority</th>
<th>Criterion</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design quality</td>
<td>Usability score</td>
<td>&gt; 7</td>
</tr>
<tr>
<td></td>
<td>Experience score</td>
<td>&gt; 7</td>
</tr>
<tr>
<td></td>
<td>Counterfeit rate</td>
<td>&lt; 50 c/mnic (counterfeits per million notes in circulation)</td>
</tr>
<tr>
<td>Time</td>
<td>From decision date up to issuance date</td>
<td>&lt; 2 years</td>
</tr>
<tr>
<td>Costs</td>
<td>Design costs</td>
<td>&lt; 2 million euro</td>
</tr>
<tr>
<td></td>
<td>Production costs</td>
<td>Similar or lower to banknotes to be replaced.</td>
</tr>
<tr>
<td>Information</td>
<td>Inform stakeholders before issuance date</td>
<td>BEMs: 9 months</td>
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<tr>
<td></td>
<td></td>
<td>Press: 9 months</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Retailers: 3 months</td>
</tr>
<tr>
<td></td>
<td>Inform users before issuance date</td>
<td>Visually impaired: 3 months</td>
</tr>
<tr>
<td>Organisation</td>
<td>Project management</td>
<td>Management on quality, costs, time, information.</td>
</tr>
</tbody>
</table>

4.10 Concluding on banknote design manager

When it comes to banknotes, a central bank has three major tasks: the development of new banknotes (1), the production of banknotes (2) and the issue of banknotes (3). At the end of the design process there is an additional assessment task (4). A summary of these four tasks is provided in figure 4.19.

Traditionally central banks will have a chief cashier, who is responsible for the issuance of banknotes. Central banks may also have one or two employees responsible for order/procurement management of new banknotes. Dedicated staff taking care of new banknote designs may be absent. A lack of banknote design expertise explains why many central banks experience problems with the management of their banknote design projects. Such problems will be reduced with the introduction of proper banknote design management, preferable by appointing a banknote design manager. This design manager should operate within a project structure and not within a line management organisation.

The tasks of the banknote design manager are complementary to those of the banknote designer. The banknote design manager supports the banknote designer by easing the paperwork and reducing organisational meetings. The banknote designer should design and should have a minimal bureaucratic workload.
Following the Double Diamond Model of Design, the banknote’s design work falls apart into two principal activities, the phase of the problem definition and the phase of finding a solution. The banknote design manager is responsible for the problem definition and may do this work by consulting others, people from inside the project team and also others from the outside. Leading for the description of the problem definition is an activity-centred design approach, how users interact with the banknotes. To increase a better understanding of user behaviour, the design manager may order some specific investigations.

The activity of the problem definition will be finalised when the banknote design manager presents a Programme of Requirements (PoR) for a new banknote, based on the available knowledge and analysis. This (first) list of design requirements may be discussed with all parties involved.

A PoR is a helpful methodological tool to prepare a banknote design project. First, it enables a clear working programme, agreed by all involved members. Secondly, a PoR leads to shorter design periods, as the risk of having to redo the design work will be reduced. As a side-effect, project cost savings will be achieved. Finally, a PoR may lead to a higher design quality, as it will prevent ‘design mistakes’ and it will inspire the banknote designer.

<table>
<thead>
<tr>
<th>BANKNOTE DESIGN – TASKS OF CENTRAL BANK</th>
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<tr>
<td><strong>Tasks of central bank</strong></td>
</tr>
<tr>
<td>Development of new banknotes</td>
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<td>Production of banknotes</td>
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<td>Issue of banknotes</td>
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Figure 4.19
The tasks of a central bank within the banknote design process.
Once the PoR is agreed, the first diamond of the Double Diamond Model is left behind and the banknote designer may start its work. Thereafter a new task starts for the banknote design manager, the management of the design process. First the banknote designer will describe a proper structure of the banknote design process, for example following the one as presented in figure 2.7. The design manager makes sure that in the case of unfinished development projects for new features or other new production techniques, a fall-back design should be available. This fall-back design should have a high design quality, it simply does not include the originally planned new features/technologies which may eventually be introduced within two years’ time when the next banknote will be issued. The congratulations and support received for previous banknote designs will create more freedom to go in a next design a step further. A use-centered design policy is advised, asking for a use-centered design team. Instead of production people (paper makers, printers) user experts take part. The banknote design manager is also an engineer and will bring the design solutions of the banknote designer into reality. The design manager will avoid platitudes like:

*What the designer proposes is not possible; we never do it that way!*

Furthermore, the banknote design manager monitors the banknote design process using common project management tools for supervising the expected design quality, time planning, budget control, informing others and maintaining an adequate project organisation.
Always design a thing by considering it in its next larger context - a chair in a room, a room in a house, a house in an environment, an environment in a city plan.

Eliel Saarinen (1873 - 1950)
5. CONCLUSIONS

The advocated organisation of a banknote design process is the Three Parties Model. One banknote design manager represents the client, the central bank and operates together with the banknote designer and the contractor. Specific parts of the banknote design will be delivered by contributing designers, like a watermark die-cutter, a thread designer, a creator of holographic elements, a creator of floating images, a designer of line structures and an engraver.

The roles of the banknote design manager and the banknote designer are complementary. The banknote design manager represents a ‘knowledgeable client’ and sets the design requirements in the first part of the Double Diamond Model of Design. The second part of this model is the actual banknote design, the work of the banknote designer.

"Can anybody tell me what I have to design?" is a question often raised by banknote designers. The answers are provided by a Programme of Requirements, prepared by the banknote design manager of the central bank. Such a Programme should be based on user requirements and stakeholders’ requirements.

The banknote designer coordinates all the design work, up to the last colour corrections of the final proof print. The design process of banknotes is in its essence not different from any other product design processes. The design process of banknotes is sensitive to delays because:

- Design project is not well prepared by the central bank (first diamond of the Double Diamond Model of Design),
- The design process is extended to a product development cycle,
- Development projects which are not ready are included in the product development cycle.
- Banknote production is a stacking process; parallel production is not possible.

The design process can be underpinned by the Model for Use-centered Design of Banknotes. This model can also be used to assess interim and the final banknote design results by a usability and experience score.

This study concludes with Ten Golden Rules for novel banknote design:

1. Adopt the Three Parties Model to organise the design process.
2. Introduce project management; the banknote design manager is the project manager.
4. Provide an appealing identity,
5. Adopt a use-centred design policy; implement the Model for Use-centred Design of Banknotes.
6. Ad an expert in user insights to the project team.
7. Select an independent designer; aim for the best.
8. Provide the banknote designer a high design-freedom (> 8).
9. Draft a proper Programme of Requirements, based on user and stakeholder needs.
10. Invite users to test interim design results.
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ACKNOWLEDGEMENTS

This study is a by-product of my thesis “A Model for Use-centered Design of Payment Instruments Applied on Banknotes: Upid-Model” at Tilburg University. Topics on banknote design management are not part of my thesis and are presented in this book.

Originally this study aimed for a use-centered design concept of banknotes. However, without design methodology the proposals could not be underpinned. Therefore, in the second part of my thesis period I focussed on model building.

I thank my main promotor Prof. Dr. Ron Berndsen (Tilburg University and De Nederlandsche Bank). Prof. Berndsen offered in 2015 to help me to complete the thesis which I started at Delft University of Technology. I also want to thank Prof. Dr. Rik Pieters (Tilburg University) for being promotor and for his academic suggestions to make the study regarding banknotes applicable on all payment instruments.

Here I also give credit to my former PhD supervisors and co-supervisor for their interest and remarks in the first part of my thesis period (2008-2015):
- Prof. Ir. Jan Jacobs (Delft University of Technology, Faculty of Industrial Design Engineering), who accorded emeritus status in 2012,
- Prof. Dr. Frans Verstraten (University Utrecht, Faculty of Social and Behavioural Sciences), Professor of Experimental Psychology at the University of Sydney, since 2012,
- Dr. Theo Boersema (Delft University of Technology, Faculty of Industrial Design Engineering), retired 2015.

My mentor and inspirer is Dr. Ir. Peter Koeze (De Nederlandsche Bank, retired in 2004). Peter provided me in 1981 the job of banknote design manager of Dutch banknotes. Since the very first start he was an example for me in many ways, including insights in design, design management and an academic approach.

My dissertation and this book have a long lead time. During these years my wife drs. Cecilia Dijkstra kept things into perspective, which was a great support.

My manager is Mr. Jan Binnekamp, head of the Currency Policy Department at DNB. Jan made this study possible and encouraged its publication. I thank my colleagues of the Currency Policy Department for their interests and warm support.

On the side of the publisher all credit goes to Mr. Mark Stevenson, President of the International Banknote Designers Association (IBDA). Mark realised the importance of the publication for the community of banknote designers, a unique publication under the flag of IBDA. Mark ensured that the graphical layout and content of the book is entirely to my liking. Furthermore, Mark assisted me with my English.
ABOUT THE AUTHOR

Hans de Heij (1954) graduated in 1979 at the Faculty of Industrial Design Engineering of the Delft University of Technology. In 1981, he became banknote design manager of new Dutch banknotes at De Nederlandsche Bank. During the period 1981-1997 he managed the introduction of five new guilder banknotes:

- NLG 250/Lighthouse (1986),
- NLG 25/Robin (1990),
- NLG 100/Little Owl (1992),
- NLG 1000/Lap Wing (1994),

For the Eurosystem De Heij was the manager of:
- Euro design contest (1996), contribution of DNB,
- EUR 200/Iron and Glass (2002), origination and zero production,
- Design contest ES2 (2006), contribution of DNB.

The guilder banknotes received much attention, not only because of their outstanding graphic designs, but also for their technical innovations. De Heij contributed several partial design concepts to the guilder banknotes, including the technical innovations, like a printed barcode and a corresponding reader, introduced in 1990. He has a number of patents on his name.

De Heij pioneered the inclusion of public (consumer) feedback in banknote designs and he has published several articles on the subject.

De Heij also contributed to the design of the euro banknotes, like it's colour scheme. Several other suggestions were wayfinding features, tactile structures and a holographic feature with public appeal.


De Heij was member of the Paper Committee of the Banknote Printers’ Conference (1983-2006). To this committee he was respectively Secretary (1997-2000) and Chairman (2001-2004). He was member of the Materials Committee of the European Banknote Committee (2007-2014).

De Heij was instructor at the training course 'New Developments in Banknote and Currency Management' by Central Banking Publications (2006-2012). Since 2012, he is member of the committee reviewing publications for the Conferences on Optical Document Security.

On 7 November 2017 De Heij defended his thesis on "A Model for Use-centered Design of Payment Instruments Applied on Banknotes: Upid-Model" at Tilburg University (promotores: Prof. Dr. Ron Berndsen and Prof. Dr. Rik Pieters).