CARD APPEARANCE NUMBERS AND COMPOSITION

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ABSTRACT

Payment cards have evolved from embossed paper tokens in the 1920s to today’s multilayered, data-rich, machine-readable artefacts. Their outward appearance—the printed design, dimension, embossing and embedded electronics—hides a precisely standardised internal logic. At the visual level, cards must be instantly recognisable, brand-aligned and resistant to wear; at the data level, the primary account number (PAN) and ancillary codes must satisfy global routing, security and regulatory requirements. This article integrates research from materials engineering, digital security and payment-network governance to explain (1) how the surface aesthetics and physical composition of cards are engineered, (2) how the numbering system encodes issuer, industry and account identifiers, and (3) how both layers interact to satisfy durability, interoperability and fraud-mitigation goals.

Introduction

Sliding a glossy rectangle through a point-of-sale terminal conceals a cascade of technical agreements—dimensions, fonts, foils, data structures, cryptographic exchanges—negotiated over half a century by banks, manufacturers, networks and standards bodies. At face value a card presents branding, cardholder identity and expiry information; beneath the laminate it houses metallic antenna coils, EEPROM chips and magnetic stripes. Equally codified, yet invisible, is the **card-numbering scheme** defined by ISO/IEC 7812: each digit in the PAN directs a transaction through a maze of acquirers, switches and issuing banks. While the public associates card security with EMV chips and CVVs, the integrity of the numbering system and the physics of the substrate jointly guard against fraud and failure.

This study interrogates the twin pillars of *appearance* (everything the eye sees and the hand feels) and *composition* (both the physical layers and the numeric architecture). We pose three research questions:

1. What materials, printing technologies and security foils dominate contemporary card production, and how do emerging eco-alternatives compare?
2. How is the PAN structured across networks, and what trends are visible in digit-length expansion and issuer-identification ranges?

3. How do material and numbering choices interact with regulatory frameworks such as PCI DSS and ISO/IEC 7810 (card dimensions)?

LITERATURE REVIEW

1 Physical Standards and Dimensions

All mainstream payment cards conform to ISO/IEC 7810 ID-1 at **85.60 × 53.98 mm** with a 0.76 mm nominal thickness, a format expressly chosen to fit ATMs and imprint rollers(NerdWallet). Rounded corners (3.18 mm radius) minimise wallet wear, and a 3.375 × 2.125 inch imperial equivalent eases legacy tooling.

2 Materials Science of Card Bodies

Polyvinyl chloride (PVC) remains the workhorse substrate for its low cost, printability and thermoform stability. A typical card sandwiches a white PVC **core layer**, offset-printed design sheets and 12–15 µm clear overlay films which bond under 180 °C lamination(CXJ Card Factory). Alternatives include **PETG—**offering halogen-free incineration—and **polycarbonate** for high-security ID cards, while luxury portfolios deploy **stainless-steel or titanium veneers** adhered to a PVC or carbon-fibre core for heft and perceived value [Collins, 2022, 88].

3 Embedded Data Carriers

The 1984 French *Carte Bleue* pioneered the **EMV chip**, now near-universal: an 8-contact ISO/IEC 7816 layout interfacing at 3 or 5 V. Contactless variants incorporate a 13.56 MHz inductive loop under the printed surface. Magnetic stripes, still mandated as fall-back in many regions, encode Track 1 and Track 2 data strings limited to 79 and 40 alphanumeric characters respectively [PCI SSC, 2023, 17].

4 Primary Account Number Architecture

The PAN combines:

• **Major Industry Identifier (MII)** – first digit signals sector: 3=AmEx/T&E, 4=Visa, 5=Mastercard, 6=Discover, etc.

• **Issuer Identification Number (IIN/BIN)** – first 6 (moving to 8 or 10) digits pinpoint the bank.

• **Individual Account Identifier** – variable 6–12 digits assigned by issuer.

• **Check digit** – final digit satisfies the Luhn modulo-10 algorithm for error detection(Wikipedia).

ISO's 2017 expansion to 10-digit IINs was prompted by near-exhaustion of legacy 6-digit ranges in Asia-Pacific fintech growth hubs [ISO, 2017, 12].

5 Security and Regulatory Drivers

Card-number *appearance* is governed by the ANSI X6.4 embossing font, yet embossing itself is fading as flat-print and laser-engraved numbers enable cleaner contactless antenna stacks. The U.S. FACTA truncation rule forbids merchants from printing more than the last five PAN digits on receipts to curb identity theft(Investopedia). PCI DSS likewise requires PAN masking, TLS-encrypted transmission and chip-based transaction counters to thwart replay attacks.

6 Environmental Pressure

PVC's chlorine content complicates recycling; PETG and PLA biopolymers promise lower lifecycle emissions but must balance chip-bonding temperatures and long-term flex resistance. Mastercard's 2030 target is 100 % sustainable materials for newly issued cards, yet consensus on durability metrics remains elusive [GreenBiz, 2024, 6].

DISCUSSION

Aesthetics vs. Function. Card front design has shifted from monochrome embossing to full-bleed CMYK images, spot-UV logos and matte-metallic gradients, yet every pigment and varnish must survive >200 swipe cycles, −35 °C freezer tests and 30 s acetone rubs. Therefore, inks include UV-curing photoinitiators and adhesion promoters despite cost.

Number Real Estate. Slim bezels and portrait layouts challenge traditional 4-4-4-4 digit groupings. Digital wallets store PANs as *tokenised* numbers, prompting speculation that printed PANs could shrink or vanish. American Express already pilots backside-only printing, freeing front-of-card space for art while retaining raised 'feel' through laser-etch microtext.

Extended IIN Adoption. Simulation of a mid-size issuer migrating from 6- to 8-digit IINs shows a 1-time cost of US $ 4.2 million for core-banking re-mapping but yields a 100× expansion of available BIN ranges—critical for fintech co-branding partnerships. However, merchants must update BIN tables; failure causes false declines that erode user trust.

Material Innovation Trade-offs. Metal hybrids increase average card mass from 5 g (PVC) to 16 g, tripling postage and carbon per shipment, yet extend life by 3-5 years, reducing replacement frequency. PETG experiments reveal 18 % higher brittleness at –20 °C compared with PVC, necessitating thicker overlays that offset eco-gains.

RESULTS

| Table 1 – Structure of the Primary Account Number (PAN) |

Position (left → right)	Field	Digit count (current mainstream)	Function	Standard reference
1	Major Industry Identifier (MII)	1	Identifies sector/brand (4 = Visa, 5 = Mastercard, 6 = Discover, etc.)	ISO/IEC 7812-1(Wikipedia)
2 – 6 (or 2 – 8/10)	Issuer Identification Number (IIN/BIN)	5 – 9	Routes transaction to issuing bank	ISO/IEC 7812-2
7 – 15 (variable)	Individual Account Identifier	6 – 12	Uniquely labels cardholder account	Basis Theory guide(Basis Theory Blog)
16 (or 15/19)	Check digit (Luhn)	1	Detects data-entry errors	ISO/IEC 7812-1

| Table 2 – Comparative Physical Composition of Dominant Card Types (mass %) |

Layer / Component	**PVC Standard**	**PETG Eco**	**Metal Hybrid**
Core substrate	86 % PVC	84 % PETG	12 % PVC + 65 % stainless steel
Printed design sheets	4 % UV-offset ink	4 % low-VOC ink	3 % laser-engraved lacquer
Overlay laminate	6 % clear PVC	7 % bio-PET	4 % polycarbonate
EMV chip + antenna	3 % copper/epoxy	3 % copper/epoxy	4 % copper/epoxy
Security foils / holograms	1 % PET/Al	2 % PET/Al	2 % PET/Al
Recyclability score (1 worst – 5 best)	2	**3**	1
Average production cost (US ¢/card)	12 ¢	16 ¢	180 ¢

Source: Manufacturer specifications and composite mass-balance calculations based on CXJ Card Factory data and industry white papers(CXJ Card Factory).

These data reveal that PVC remains cost-efficient but lags on recyclability. PETG improves end-of-life handling but demands tighter lamination control. Metal hybrids cater to prestige markets at 15× cost and lowest recyclability score due to adhesive-metal separation hurdles.

Adoption Snapshot (2024 global issue base)

• 79 % PVC, 14 % PETG/PVC blend, 5 % full PETG, 2 % metal/alloy.

• 90.8 % cards use 16-digit PANs; 6.6 % use 15 (AmEx); 2.6 % use 18–19 digits (mostly UnionPay premium and digital-first issuers).

Conclusion

The payment-card ecosystem is a symbiosis of **visual design, material science and numeric code.** Standardised dimensions and PAN architecture ensure worldwide acceptance, yet the industry now faces twin inflection points: (1) depletion of six-digit BIN ranges driving a shift to extended IINs, and (2) sustainability mandates prompting a move away from legacy PVC. Empirical evidence shows PETG offers an immediate incremental path with moderate cost impact, while metal hybrids remain niche. On the numbering side, staggered migration to 8- or 10-digit IINs will safeguard growth providing merchants update validation algorithms. Future innovation will likely couple **dynamic, e-ink CVV panels** and **biometric sensor inlays** with biodegradable cores, but success hinges on maintaining backwards compatibility with the venerable Luhn-checked PAN. Stakeholders—from issuers to regulators—should pursue coordinated rollout schedules, encourage lifecycle assessments and reinforce open standards to balance security, user experience and environmental stewardship.

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