Interoperability Challenges of a Digital Product Passport System

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Abstract

The Digital Product Passport (DPP), particularly its pilot digital battery passport, targets new electric vehicle and industrial batteries over 2 kWh. Its rollout across various sectors necessitates a robust technical setup, suitable procedures, and a favorable business environment to address significant challenges such as ensuring interoperability for secure data sharing, aligning with complex legal standards, and meeting a tight deadline for the development of harmonized European Norms (hEN). The DPP system faces notable challenges, including ensuring complete interoperability for secure data exchange among stakeholders, navigating complex legal and business environments to align with multiple regulations, and meeting the tight deadline for developing Harmonized European Norms by December 31, 2025. These hurdles are compounded by the need to integrate existing technical systems and accommodate future regulations and technological advances.

Keywords

Digital Product Passport System, Digital Battery Passport, Interoperability Challenges

1. Introduction

The Digital Product Passport (DPP), particularly its pilot application in the form of a digital battery passport, is set to become operational by February 18, 2027. This system is mandatory for new electric vehicle batteries, light means of transport batteries, and industrial batteries above 2 kWh. The DPP's implementation across various industrial sectors signifies a transformative approach, yet it necessitates the establishment of a technical infrastructure, procedures, and a conducive business and economic environment. [1], [2]

The DPP system's development is characterized by significant business and technological challenges[3]. These include:

- Complete Interoperability: The system must ensure secure and reliable access and exchange of sensitive data among diverse stakeholders, such as consumers, business partners, and authorities. This necessitates a comprehensive system specification that encompasses technical, organizational, and semantic interoperability, adhering to sector-specific regulations. The goal is to integrate various existing technical systems to minimize changes and operational costs.
- Complex Legal and Business Environment: The legal intricacies of aligning the DPP system with various regulations, including the ESPR, the Battery Regulation, and the standardization request, pose a substantial challenge. Future regulations and global standards further complicate the system design, necessitating a flexible and forward-looking approach to accommodate technological advancements and emerging business models.
- Tight Timeline for Standard Elaboration: The development of Harmonized European Norms (hEN) to fulfill the standardization request is constrained by a tight timeline, requiring innovative standardization approaches. The existing over-lapping and sometimes conflicting ISO standards in data access and exchange add complexity to this process. The rapid development and

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implementation of these standards, both in government and industry, are crucial for meeting the De-cember 31, 2025, deadline for technical standards agreement.

Addressing these challenges is pivotal for the successful deployment and operation of the DPP system, ensuring it meets its intended objectives and adapts to the evolving landscape of regulations and technological advancements.

2. DPP System Architecture

The primary System Architecture, as depicted in **Figure.** ***1***, is segmented into three main components oriented towards service provision: the EC Central Services, the DPP System Services distributed across different locations, and the Services provided by Third Parties.

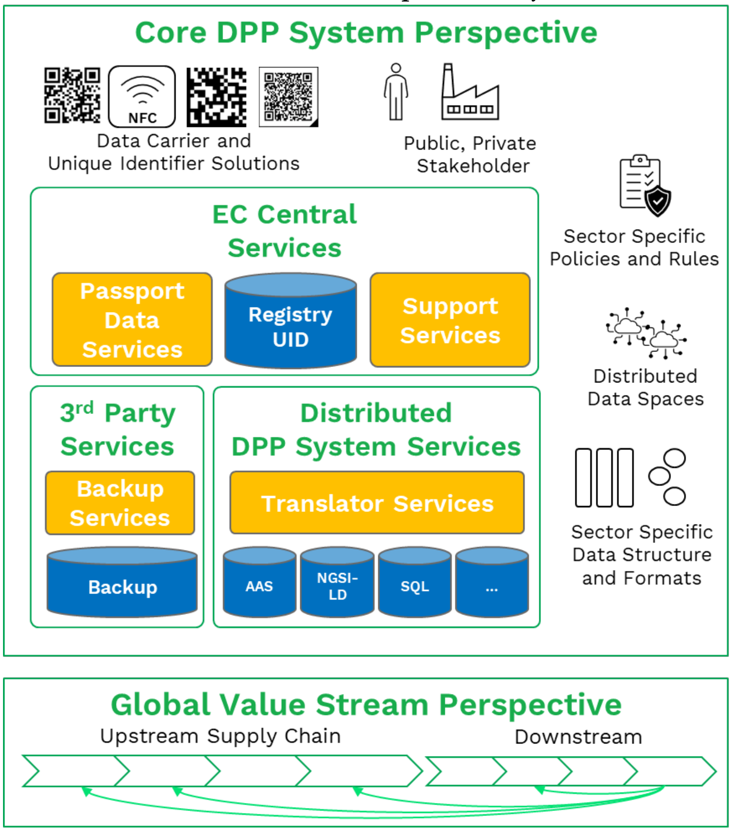

Figure. 1: DPP System Overview *[3]*

The EC Central Services fall under the responsibility of the European Commission, while the DPP System Services distributed must be set up and managed either by the Economic Operator or a designated service provider, resulting in a distributed systems approach. It is compulsory for the Services provided by Third Parties to be established by a certified, independent third-party product passport service provider, especially for data backup services, as stipulated by the current proposal for Ecodesign for Sustainable Products (ESPR) Regulation This paper aims to support the ongoing standardization process by identifying and addressing the interoperability challenges that need to be taken into account in order to define an operational systems architecture.

3. Interoperability Challenges

In the quest to develop an effective DPP System, a range of interoperability challenges emerges, each playing a crucial role in the system's functionality and adoption. The interoperability challenges identified have been pinpointed through the application of the Enterprise Interoperability Framework, as delineated in the initial section of ISO 11354-1:2011 [4]. This framework is structured around three key dimensions (see **Figure.** ***2***). The first dimension offers a systematic classification and structuring of interoperability barriers, laying out the landscape of potential challenges. The second dimension shifts focus towards addressing interoperability issues, spanning from data-centric to business-oriented perspectives. Lastly, the third dimension delves into the principal strategies for achieving interoperability, namely federated, unified, and integrated approaches. This comprehensive framework facilitates a structured examination of interoperability issues, guiding the identification and resolution of such challenges.

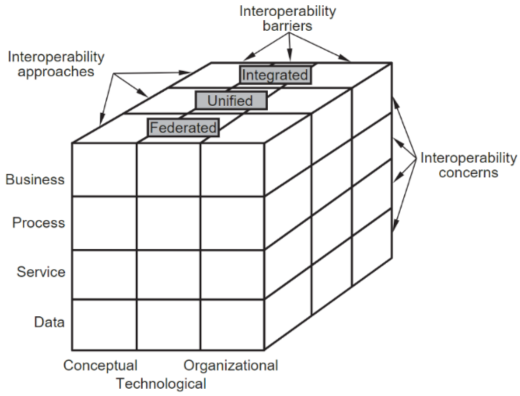

Figure. 2: Dimensions of the Enterprise Interoperability Framework [4]

One of the primary concerns is the application of different data carriers. The DPP system must seamlessly integrate various technologies such as QR codes, NFC tags, and RFID, accommodating the diverse methods used across industries. The Battery Regulation introduces QR codes as the primary means for accessing the Digital Product Passport (DPP), with provisions for adopting alternative smart labels like RFID or NFC tags through delegated acts [1]. QR codes, being two-dimensional barcodes, are capable of encoding a wide array of information in a compact form, making them suitable for diverse applications such as web URLs, text, contact information, and payment details. According to the regulation, QR codes must be visibly and indelibly affixed to the battery or its packaging, conforming to ISO/IEC standards for identity maintenance and QR code requirements [1]. These standards outline the technical and practical aspects of QR code use, including structure, data encoding, error correction, and scanning guidelines, ensuring reliability even when codes are partially damaged. Interoperability challenges with QR codes include selecting appropriate encoding modes for different data types, standardizing data interpretation, and accommodating various languages and character sets. Technological barriers involve maintaining up-to-date dynamic data, managing QR code sizes and resolutions for sufficient data capacity, and ensuring proper printing and scanning conditions.

The choice between storing a direct access URL in the QR code or incorporating offline data such as UID and basic product information presents different technical implementations and user experiences, with each approach having its pros and cons. The decision on what data to store in the QR code impacts its technical implementation and the ease of access for users, suggesting a need for clear guidelines and support for both online and offline data retrieval methods.

Unique identification forms a crucial foundation of the Digital Product Passport (DPP) system, ensuring that each object (such as a battery, its model, passport, organization, facility, or location) possesses a globally unique ID without duplication. Ideally, these unique identifiers should be generated based on the economic operator's existing schemes to minimize redundant efforts and link to central reference data. Decentralized identifiers (DIDs) are highlighted as an optimal solution for creating persistent, cost-free IDs that can be used throughout a battery's lifecycle, linking directly to service endpoints for data access. For linked data within the battery's knowledge graph, identifiers connecting data entities should be more flexibly defined to accommodate the variety of existing generation schemes (e.g., EORI numbers for businesses, GTIN for products). While the DPP supports multiple identifier systems, there's a need to define what constitutes a valid unique identifier within the DPP framework to ensure compatibility across different protocols and prevent identifier overlap or conflicts.

The DPP system is designed as a decentralized network with DPP Data Repositories managed by economic operators. This structure necessitates efficient routing mechanisms to facilitate seamless data access and exchange across various platforms, transcending organizational boundaries. To accommodate this decentralized model, it is imperative to ensure that access to the data within these repositories is maintained, considering the varying access rights of different stakeholders. Additionally, the system must guarantee consistent data access, even in scenarios where the management of a DPP Data Repository transitions to a different economic operator, thereby preserving the integrity and availability of the data across the DPP ecosystem.

Another significant challenge lies in the application of different data management technologies. The system must be versatile, capable of handling technologies ranging from domain-oriented standards or de-facto standards like NGSI-LD or AAS to cloud-based solutions and traditional databases, catering to the diverse technological preferences of stakeholders.

Ensuring secure and user-friendly access for different stakeholder groups, including manufacturers, regulators, and consumers, is vital. The system should maintain robust security standards while providing access tailored to the roles and needs of various users. Additionally, the system needs to adapt to sector-specific procedures and regulatory requirements, ensuring compliance and relevance across industries like batteries, electronics, construction and textile.

Looking ahead, the scope of the DPP system is set to expand beyond batteries, with plans to include additional sectors such as construction, textiles, and electronics. The ability to utilize data from different, sector-specific data spaces is crucial for the DPP system and emphasises once again the need for the co-existence of standards. This integration allows for compiling a more comprehensive dataset, thereby enhancing the overall value and utility of the DPP. Furthermore, the system is designed to accommodate a wide array of data types and points, enabling the interconnection between sector-specific passport data to offer a holistic view of the product lifecycle. The inclusion of these sectors will further enrich the DPP ecosystem, making batteries just the initial step towards a broader implementation of digital product passports across various industries.

A critical aspect of the DPP system is its capability to connect dynamically with products for real-time data acquisition during use and recycling phases. This connectivity is essential for gathering valuable insights into product usage, maintenance, and end-of-life processing.

Lastly, aligning the DPP system with global DPP initiatives presents a unique challenge. The system must be designed to align with various international approaches, considering different sectoral and regional initiatives. This global perspective ensures interoperability and relevance in an increasingly globalized market.

4. Conclusion and outlook

The integration of the digital battery passport as a pilot application sets a foundational model for the broader implementation of DPPs across various sectors. The road implementation and operationalisation, however, is fraught with challenges. The need for interoperability and a rapid standardisation process are immediate hurdles that require innovative solutions and collaborative efforts among all stakeholders. The complexity of these challenges underscores the importance of a robust system architecture that can integrate seamlessly with existing and future technologies. Additionally, the system's alignment with global initiatives presents a unique opportunity to set international standards for digital product passports. This global integration will ensure that the European DPP system remains relevant and interoperable on a worldwide scale, paving the way for a new era of global product traceability and sustainability standards.

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Battery Pass consortium project aims to advance the implementation of the battery passport based on requirements of the EU Battery Regulation and beyond.

Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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