

From Analogue to Digital Product Passports in the Furniture Industry

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Abstract: The wood industry faces challenges from multiple angles, markedly from rapidly changing market environments, policy and compliance demands, and, in general, the digitalisation of its core processes. A particularly challenging area is the transition to digitalised, cross-domain supply chain management. Thus, this paper addresses the furniture industry's transition from analogue to Digital Product Passports (DPPs) following the EC's initiative to promote circularity, foster innovative business models, and assist in sustainable product management. This paper provides a blueprint DPP for the furniture industry that explores not only what requirements can be expected from the upcoming regulations but also how existing data management practices can be adapted to meet these requirements.

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1. INTRODUCTION

In recent years, digitalisation has shown its impact on many sectors, especially when considering its potential and side effects with regard to major societal challenges such as sustainability (Lampoltshammer et al., 2021). The paradigm shift resulting from digitalisation directly impacts the operational aspects of companies and hence also redefines their market position (Busch et al., 2015). This effect becomes apparent when looking closely at the changes within internal processes, the required technical infrastructure, and the increased and changed qualification requirements for employees (Müller-Jentsch, 2007). These changed requirements redefine the efficiency and effectiveness of a business, which directly manifests in its competitiveness (Peneder et al., 2016). That being said, many businesses still struggle due to the aforementioned plethora of challenges to identify their individual perspective on the innovation potential of digitalisation in relation to the increased efforts during the transition period (Parviainen et al., 2017).

One sector that suffers from the before-described situation is the wood industry. This situation is of particular interest, as the wood industry faces challenges due to the economic decline of the sector and, hence, the increasing

pressure for innovation and new business models (Näyhä, 2020; Ranacher et al., 2023; Gallina et al., 2023). While research has demonstrated the benefits of digitalisation in the form of Industry 4.0 applications for the wood industry (Müller et al., 2019), the sector still faces a huge, untapped potential (Ranacher et al., 2023). This is particularly true for enhanced networking and on-demand services to increase customer focus and reach new customer groups (Kies et al., 2018). A domain where these aspects are of high importance is supply chain management. Here, interconnectivity and data, in general, play a crucial role (Liu et al., 2018), yet the wood industry remains within the role of slow adaptors (Figorilli et al., 2018) and faces constant challenges regarding the topic of data governance (Santos et al., 2019).

Some businesses in the wood industry, especially the furniture industry, which has a significant share in the wood industry, currently provide limited information on their products through analogue product passports (APP) or product folders, designed mostly for customers, reflecting a conventional approach to data governance. Given the limitations of analogue formats, the Digital Product Passport (DPP) proposed by the European Commission (EC) emerges as a crucial catalyst for overcoming obstacles to a circular economy and enhancing environmental sustainability in the wood industry. The DPP represents a transformative tool for various stakeholders, offering extensive benefits that transcend mere legal compliance (WBCSD and BCG, 2023). For businesses, the DPP facilitates sustainable growth through improved environmental perfor-

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mance, allows the development of new business models, and provides competitive advantages among eco-conscious consumers. Customers benefit from transparent information about product origins, promoting loyalty and enabling value-aligned purchasing decisions. Public entities gain a streamlined instrument for regulatory checks. Craftsmen and repair professionals receive detailed product handling information, while recyclers obtain critical data for eco-friendly practices. Overall, the DPP is a cornerstone for sustainability, efficiency and customer engagement across the product life-cycle.

Our paper addresses the necessary steps and challenges in the transition from APP to DPP in the wood industry using the example of furniture production. The paper is structured as follows: Section 2 presents ongoing activities concerning cross-company data sharing in the wood industry as well as the DPP. Section 3 discusses the activities using a specific use case from the furniture industry, where the transition from an APP to a digital equivalent is underway. Section 4 presents a furniture DPP blueprint, and section 5 completes the paper with conclusions and recommendations for future work.

2. DATA SHARING AND THE DPP IN THE WOOD INDUSTRY

2.1 Digitalisation Maturity in the Wood Industry

The wood industry is as diverse as its stakeholders, application areas, and resulting products. Hence, providing a comprehensive overview of all aspects of digitalisation is beyond this paper. However, the authors would like to provide a basic guideline of aspects and dimensions to be considered when analyzing digitalisation within the wood industry. For this purpose, the authors refer to the work of Ranacher et al. (2023), who differentiate, based on the work of Saam et al. (2016), three distinct levels of digitalisation that can be used to categorise development within the wood industry. Each of these levels, in turn, is divided into external digitalisation aspects, internal digitalisation aspects, and the aspect of knowledge basis. On the first maturity level, an example of external digitalisation is the website of the organisation. Internal digitalisation would refer to, e.g., Enterprise Resource Planning (ERP) systems and the knowledge basis would cover basic knowledge about digitalisation as such. On the second maturity level, the use of external social media or internet-based applications, in general, would represent external digitalisation factors, while big data analysis or cloud computing scenarios would cover internal digitalisation examples. On the third maturity level, external digitalisation would cover, e.g., business models based on digital products and services, while the internal digitalisation aspect would focus around, e.g., industry 4.0 applications. Using this maturity system, studies, e.g., Ranacher et al. (2023), have demonstrated that within the SME sector, digitalisation is embraced as a chance for an increase in value creation. However, the technological aspect is often in the foreground, and comprehensive digitalisation strategies, together with the associated competence increase, fall behind.

2.2 DPP initiatives

One of the biggest obstacles to a more circular economy and higher environmental sustainability of products is the

lack of relevant information for various actors along the value chain (Rusch et al., 2022). With the DPP, the EC aims to tackle this issue by introducing unique identifiers on products to facilitate the collection, storage and stakeholder-specific data sharing throughout their life cycle. Anchored in the Ecodesign Regulation for Sustainable Products (ESPR), the DPP aims to promote circularity, foster innovative business models, assist consumers in making sustainable choices, and aid authorities in compliance verification (European Commission, 2022). The ESPR, in turn, seeks to mitigate negative environmental impacts throughout the product life cycle, enhance the internal market's efficiency, and drive the circular economy forward. Consequently, the DPP is recognized as an enabler of the circular economy.

At the European level, a categorical differentiation is established between the *DPP system* and *DPP data*. *DPP system* concerns the question of "How?" - i.e. how a DPP must be structured in order to fulfil all requirements. In contrast, *DPP data* deals with the question of "What?" - i.e. what data is stored in the DPP. This will be defined in delegated acts under the ESPR for individual product groups. Noteworthy information encompasses recyclability, sustainability metrics, and value retention aspects such as reuse and recycling. Batteries are the first product group for which the use of a DPP will be a legal requirement as of 2027 through the recently adopted Battery Regulation (European Commission, 2020). Among other products – such as textiles, toys, electronics, tires and cosmetics – furniture regulation is highly prioritised at the European level. This paper focuses on the DPP data for furniture.

Several scientific works try to explore the potential of DPP data in various fields. Berger et al. (2023) address the data requirements for the digital battery passport in sustainable battery management. They analyse data availability and criticality for all actors in the supply chain and for both the design and end-of-life phases. Situated in the mechatronics context, Jensen et al. (2023) analyse the data needs of different stakeholders for DPPs and identify seven data clusters. The paper emphasises the differences among the stakeholders and encourages the exploration of the use of the DPP for decision-making in different industries. Reich et al. (2023) contribute to the goal definition of the DPP by circular product strategies and conclude that the DPP can enhance several R-strategies for electronics. Szaller et al. (2023) deal with quantified benefits of the DPP and show in industrial use cases how the DPP can reduce uncertainties and increase efficiency in case of re-manufacturing.

Turning our focus on the furniture DPP, several initiatives can be mentioned. *Möbelfakta* is a sustainability label for furniture. It is a general reference system open to all and conforms to the specifications delineated by ISO Standard 14024, meaning that the products meet environmental requirements set by an independent third party and get continuously tightened and that they are developed from a life cycle perspective (*Möbelfakta Sverige AB*, 2024). The Nordic Blockchain Alliance explores the potential of a DPP building on a common Nordic blockchain by drawing on knowledge sources from various North European countries focusing on the furniture, fashion and design

sectors. (Sedin, 2023). The initiative of the *Chalmers Industriteknik* focuses on furniture DPP data, specifically related to circularity (Linden, 2021).

To the best of the authors' knowledge, no scientific paper deals with the possible content of a furniture DPP. Therefore, this paper sets out to provide a first version of a blueprint for furniture DPP data requirements and thus addresses the following research question: "What kind of data does a furniture DPP have to offer to support furniture value chain actors in their sustainability-oriented product management?"

3. INTRODUCING A DPP IN THE FURNITURE INDUSTRY - A USE CASE

3.1 Overview of the Use Case

In furniture production, numerous questions arise in connection with the transition from an APP to a digital one. Traditionally, (analogue) product passports in this sector have been primarily designed for end consumers, focusing mainly on the material wood. Essential information such as the original location of the tree and the date of felling have been of particular interest to customers. The envisioned digital transformation of this product passport draws inspiration from the most advanced concepts at the European level, notably the DPP for batteries. This adaptation aims to broaden the circle of stakeholders from forest owners and foresters to sawmills, furniture manufacturers and distribution platforms through to end consumers and beyond.

3.2 Context and Scope

The furniture industry's shift towards a DPP is driven by the need for more efficient data generation, storage and retrieval processes. Currently, customer-relevant data, including production details, are accessible only upon request through conventional communication channels. The transformation of the product passport into a digital format aligns with the EC's requirements for DPPs, emphasizing not only customer-centric information but also data reflecting the product's environmental impact or containing information regarding durability, reusability, etc. The DPP's extended scope is anticipated to cover various stages of the product life-cycle, including various stakeholders, thereby facilitating strategies for repair, refurbishment, recycling and other circular economy practices.

3.3 Actors and their Roles

The stakeholder spectrum in this use case encompasses forest owners, foresters, sawmill operators, furniture manufacturers and online distribution platforms, extending up to the end consumer. Each actor plays a critical role in the furniture life cycle, from the sourcing of wood to the final product delivery. The transformation from an APP to a DPP necessitates a collaborative effort among these stakeholders to ensure accurate and timely data recording and updating. The DPP initiative seeks to provide a comprehensive, accessible and (near)real-time data repository beneficial for all involved parties, thus enhancing transparency and traceability in the furniture production process. In addition, the framework should also offer the

opportunity to consider and include other stakeholders across the entire product life cycle as well as system providers and regulatory bodies in DPP-based data service ecosystems. Figure 1 gives an overview of the stakeholders.

3.4 APP in the Furniture Industry

In the high-end furniture and wood industry, current concepts based on an APP are tailored towards consumers who are both price-conscious and place a high value on sustainability. Beyond sourcing information, additional data is collected throughout the value chain, which, although not included in the APP, can be accessed "manually" upon request. Presently, the APP serves as an ancillary service to premium furniture pieces. However, the inception of the APP has sparked a notion that user-relevant data already being gathered could be amalgamated with other value-adding information generated across the production chain. This integration could further be enhanced with sustainability indicators required by regulatory authorities, thereby enriching the data spectrum beyond the traditional scope of the APP. This evolution from an analogue to a more comprehensive DPP in the furniture industry reflects a growing interest in leveraging existing data for broader value creation and compliance with sustainability standards. By embracing the DPP, companies can not only comply with evolving EU regulations but also drive innovation, enhance sustainability and strengthen their market position. However, successful implementation will require concerted efforts across technology, collaboration, and education to overcome challenges and maximize the benefits of the DPP initiative.

4. FURNITURE DPP BLUEPRINT: SUGGESTION FOR A FURNITURE DPP

Transforming from an APP to a DPP entails a comprehensive transformation process that necessitates meticulous planning, stakeholder engagement, and technological adaptation. The following aspects have to be studied before starting with digitization and DPP introduction.

Based on existing frameworks (Kebede et al., 2023), several considerations emerge as essential in facilitating this *transition effectively* (University of Cambridge Institute for Sustainability Leadership (CISL) and the Wuppertal Institute, 2022). The necessity of a holistic and inclusive approach (Gunnarsson and Mignot, 2023) emphasizes active stakeholder involvement from manufacturers, suppliers, regulators and consumers. This engagement is crucial for gathering diverse perspectives on data requirements and ensuring that the DPP meets the varied needs of all stakeholders. To ensure efficacy and compliance, the transition must be in strict alignment with regulatory frameworks, particularly the ESPR introduced by the EU, which sets the groundwork for sustainable product life-cycle management and market access. In the use case examined in this paper, prior insights from various battery passport projects (e.g., CIRPASS) constitute the essential basis for the required data sets in relation to European regulations, which is necessary also for furniture DPP.

The initial phase of this transformation journey involves defining the essential *data sets* to be incorporated into the DPP. These data sets should encompass regulatory

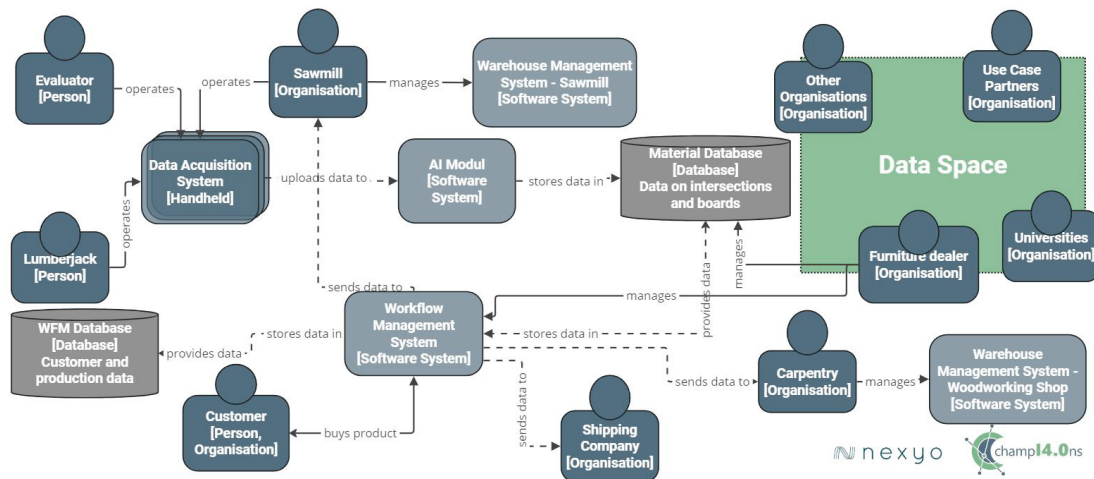


Fig. 1. Stakeholder overview

requirements, ensuring compliance with regulations regarding material composition, energy efficiency and recyclability, among others. The structured approach of the battery passport, with its emphasis on regulatory adherence and life-cycle tracking, offers a valuable blueprint for this purpose. Additionally, integrating customer-centric sustainability indicators, such as durability, reparability, and carbon footprint, will further enrich the DPP's value proposition, aligning it with consumer expectations and sustainability goals (Stratmann et al., 2023; Gunnarsson and Mignot, 2023).

The subsequent *implementation* phase focuses on establishing efficient data collection and integration mechanisms, capturing information across the product lifecycle, from manufacturing to end-of-use. Leveraging advanced technologies will automate this process, enhancing data integrity and making the DPP readily accessible to users. Providing comprehensive training and support to stakeholders, especially small and medium companies, is vital in facilitating the transition and maximizing the DPP's utility. Lastly, a commitment to continuous improvement, through regular feedback and updates, will ensure that the DPP remains adaptive to evolving regulatory landscapes, market trends and technological advancements, thereby sustaining its relevance and efficacy in promoting product sustainability and transparency.

This paper focuses on data to address the aforementioned aspects of regulations, customer information, manufacturer data, etc. The current information available in the form of an APP is summarized in Table 1 and investigated in the DPP context with the first approved DPP-related regulatory text for a particular product group, namely batteries (European Commission, 2020).

5. CONCLUSION

Professionals in the wood and furniture industry must acquire a diverse skill set to navigate the digital transformation. Key skills include digital competency, awareness of data security, technological proficiency, and ICT proficiency (CENFIM, 2019). The shift to digital processes necessitates integrating technical knowledge with cognitive, social, and behavioural competencies, emphasizing adapt-

ability to changes and a proactive mindset for continuous learning and improvement.

Technological implementation of the DPP in the furniture industry remains uncertain. Thus, it is fundamental to explore diverse technological solutions (e.g. data service ecosystems, blockchain etc.), ensure interoperability, and assess the integration of DPP into existing IT systems and business processes. Issues such as differentiated access levels for stakeholders, data security, privacy, and measures against manipulation demand a thorough investigation as part of the overarching requirement to enhance the DPP's effectiveness. Additionally, examining data verification methods, such as assurance mechanisms, is crucial for maintaining information integrity within the DPP.

As the investigated use case partner already has an APP, the question for them: "How should the already existing data management be modified to be well-prepared for the upcoming furniture regulations and DPP?"

Despite the implementation challenges, the DPP presents significant innovation potential. In concluding, the initial phase of implementing Digital Product Passports (DPPs) in the furniture industry, as detailed within this paper, underscores the paramount importance of stakeholder engagement and regulatory compliance, setting a robust foundation for sustainable product management. As a next step, a Technology Assessment remains a critical area for future exploration, vital for identifying and bridging digital capabilities essential for the seamless integration of DPPs. A further phase needs to focus on the development and pilot testing of the DPP framework. This phase is crucial for validating the proposed structure, refining data standards, and ensuring the system's adaptability and effectiveness across varied product lines within the industry. Looking ahead, the expansion of our horizon to encompass full-scale implementation, meticulous integration of supply chains, and the nurturing of consumer engagement signifies a transformative journey towards a circular economy. This trajectory not only underscores the potential of Digital Product Passports (DPPs) to revolutionize the furniture industry by enhancing sustainability and generating value for all stakeholders but also positions DPPs as a catalyst

Table 1. Information and data requirements in the analogue (APP) and digital product passport (DPP) for furniture based on the current status of the battery pass

Access	Category	Data	DPP	APP
public	(a) information specified in Part A of Annex VI	manufacturer's identification	x	x
		product category	x	x
		product identification	x	?
		manufacturing place	x	x
		manufacturing date	x	x
		weight	x	x
		capacity chemistry	-	-
		hazardous substances	x	-
		usable extinguishing agent	-	-
		critical raw materials	x	-
		chemistry	x	-
		hazardous substances	x	-
		critical raw materials	x	-
		product CO ₂	x	-
	(b) material composition			
	(f) carbon footprint differentiated per life cycle			
	(g) responsible sourcing		x	x
	(h) recycled content information		x	-
	(ha) share of renewable content		x	-
	(i) rated capacity (in Ah)		-	-
	(j) voltage, with temperature ranges		-	-
	(k) orig. power capability (W)		-	-
	(l) expected lifetime		?	-
(m) capacity threshold for exhaustion		-	-	
(n) withstand temperature		x	-	
(o) warranty period		x	x	
(p) energy efficiency		-	-	
(q) internal resistance		-	-	
(r) C-rate of relevant cycle-life test		-	-	
(s) labelling requirements	"separate collection" or more marking symbol for metal concerned	x	x	
(t) EU declaration of conformity		x	x	
(u) waste prevention and management	information on prevention	x	-	
restr. ⁱ	(a) detailed composition		x	-
	(b) component part numbers with contact details		x	x
	(c) Dismantling information	showing the location of battery cells	x	x
		disassembly sequences	x	x
		fastening techniques to be unlocked	-	-
		tools required for disassembly	x	?
		amount and layout of cells	-	-
(d) safety measures		x	-	
restr. ⁱⁱ	(a) results of test reports proving compliance		x	-
restr. ⁱⁱⁱ	(a) performance and durability parameters		-	-
	(aa) state of health of the product		-	-
	(b) status of the product		-	-
	(c) usage data		-	-
tbd	specific for furniture	water consumption	x	-
		energy consumption	x	-
		fair work conditions	x	-
		logistic data	x	-

restr.ⁱ: product model-related information accessible only to interested persons and the commission;

restr.ⁱⁱ: product model-related inform. accessible only to notified bodies, market surveillance authorities and the commission;

restr.ⁱⁱⁱ: information related to an individual product and accessible only to interested persons;

for redefining business models. Through providing comprehensive data on products, manufacturing processes, supply chains, and consumer insights, DPPs embody the capacity to fundamentally transform existing industry paradigms.

By offering diverse and extensive data on products, production processes, supply chains, and consumers, the DPP has the capacity to revolutionize existing business models. Adaptations in business models are crucial to align with

the dynamic capabilities and requirements introduced by the DPP, marking a transformative technological and ecological shift in the furniture industry.

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