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Building passports and material inventories – concepts, trends, job sharing

M Buchholz¹ and T Lützkendorf¹

¹ Karlsruhe Institute of Technology, Department of Economics and Management, Centre for Real Estate, Chair for Sustainable Management of Housing and Real Estate, Kaiserstraße 12, 76131 Karlsruhe, Germany

matthias.buchholz@kit.edu

Abstract. The real estate industry is motivated to contribute to a more sustainable built environment. To meet future sustainability goals, building owners and other decision makers rely on high-quality building-related data. On the one hand, possibilities to collect, access and exchange data improve constantly due to developments in information technology. On the other hand, the task to manage data as a growing and versatile resource becomes more difficult. To overcome resulting challenges, the use of building passports, that can serve as a life cycle data repository for single buildings, can be very useful. The importance of building passports is more and more recognised within the industry, but there is an ongoing discussion about their original function. For this reason, the contribution firstly explains the origins of building passports and how the concept has evolved over time. Furthermore, the following research questions are addressed: (1) What are the main goals, functions and requirements of building passports? (2) Which current developments are related to building passports and how do specific concepts differ? (3) How can a job-sharing with other instruments like material passports be realised and what are the benefits? The research focuses on the situation in Germany considering developments on EU level.

1. Introduction

The documentation of realised buildings has a long tradition. Even today, plans, models and records of the building materials used can be found for buildings that were erected thousands or hundreds of years ago [1]. With the emergence of public administrations, it became customary to create a housing file for each building and to keep it permanently. Only in more recent times, this procedure has been questioned and partly restricted for reasons of cost. This raises questions about the goals, tasks and possibilities of documenting records of buildings.

For decades, the introduction of building passports has been discussed in Europe. The aim was and is to improve transparency in the real estate market. Purchasers should be enabled to better recognise and take into account hidden features, and owners should be motivated to improve the properties of their buildings. The introduction of energy performance certificates (EPCs) which was initialised in 2002 from the European Commission as part of the Energy Performance of Buildings Directive (EPBD) was a step in this direction [2].

Today, the need to support sustainable development in the construction and real estate industry is linked to the question of the future role of building passports.



2. The evolution of building passports

The way to store and manage building-related data has changed over time. An analysis of the historic evolution of building passports reveals several drivers that are closely connected to the conventions on how people dealt with the documentation of buildings. Moreover, current megatrends play an important role in the discussion and act as boundary conditions. A collection of relevant drivers is given in table 1 below. The transitions between the drivers are fluent.

Table 1. Drivers in the evolution of building passports

Driver	Description
Keeping of design documents	Architectural plans exist since the Middle Ages, but they usually got destroyed after the completion of a building [3]. Materials and building components could not be traced back. With the beginning of the modern age, a documentation of construction works has primarily been known for noble or ecclesiastical buildings. The nineteenth century was characterised by the industrialisation, a steep population growth and an ongoing urbanisation which led to higher and more diverse requirements on the functions of buildings. Meanwhile, legislation started to enforce the submission of certain architectural and other documents [3]. As a response to societal needs for housing, the predecessors of the modern real estate industry evolved and the coordinated design, construction and operation of buildings became more important. In the second half of the twentieth century, housing files evolved with the goal to keep design documents during the operation and use phase of a building. In Germany, this led to a discussion about suitable building passport schemes. At this stage, a building passport was not only associated with documentation goals, but also with the possibility of integrating a quality label for buildings [4]. Afterwards, this function was fulfilled by a variety of building certification systems, and it was not pursued in further building passport discussions. An official version of a building passport was formally published by the German government in 2001 [5]. It came in the form of a paper document where building owners could voluntarily fill in the most important facts on their property. In 2004, the housing file enhanced the existing building passport concept so that relevant data in the use phase and contractual information could be recorded as well [6]. Nowadays, it is common to hand a housing file to the building owner within the prefabricated construction industry. Furthermore, building passports are no longer solely used exclusively for residential buildings, but can be used and adjusted for all types of building.
Transparency in the real estate market	Historically, the supply with information in the real estate market has been perceived as poor in comparison to other markets, e.g. the stock market. Transparency as such refers to the availability of information to market participants on equal terms so that the underlying market mechanisms can be understood clearly [7]. In the real estate industry, the lack of transparency is strongly related with the growing information demand that originally derived from the perception of buildings as investment goods, and thus is a result of an increasing amount of transactions. It becomes clear that the real estate industry deals with typical information asymmetries, which can partly be explained by phenomena such as the principal-agent-theory. According to this, so-called adverse selection can occur where the agent is better informed about a product (e.g. a building) and its quality than the principal which can lead to a decline of product quality in the market. Also, moral hazard can be observed when agents try to make advantage of their surplus in knowledge [8]. At the same time, both parties often combine limited information about the building [9]. Instruments like a building passport could significantly increase transparency in this case, but there has not been a sufficient demand in times when mainly the minimisation of costs was the prior competitive factor. With the increased amount of new challenges, which mainly derive from sustainability requirements and increased expectations on the overall building quality, also the value of instruments for transparency increases.
Supporting role for management activities	Institutional real estate companies in Germany experience a fast growth since the early 2000s. These companies, that act for example as investors, property managers and landlords, are associated to be more efficient and professional in managing their building

	<p>stock compared to private landlords. This fact gains special relevance in the German rental market which is the biggest in Europe. For managing their building stock, companies strongly rely on building-related data which needs to be collected for assessing the real performance of buildings. This is also relevant for corporate real estate management. Companies benefit in many ways from a structured data and information management [10].</p>
Contribution to a sustainable development	<p>The construction, operation, use and demolition of buildings draws responsible for a high percentage of resource consumption, emission of greenhouse gases and waste production among other things. Simultaneously, the potential to reduce the negative effects on climate and environment is still huge. To move forward in the transformation to a more sustainable built environment regulatory requirements have been sharpened and enhanced steadily, e.g. in form of the EU Taxonomy as a framework for sustainable financing [11]. For the construction and real estate industry, there are various schemes and methods to assess for the environmental performance as well as for the overall future-proofness of buildings, while the demand for the relative information continuously grows. The results as well as the basic data of assessments should therefore be available to building owners, service companies and others when needed.</p>
Globalisation	<p>The real estate market consists of a nearly infinitesimal big number submarkets due to regional and building-type-related differences. The ongoing globalisation leads to a decrease of spatial, economic and cultural barriers so that market participants can act on more submarkets than before. Globalisation goes along with an increased mobility of people which has a significant effect on the real estate market as well. Especially the demand for buildings in general is fluctuating in a shorter amount of time, while development activities serve as a respond and tenants as well as ownerships change more often [12]. These dynamic developments foster the demand for building-related data.</p>
Digitalisation	<p>The digitalisation sets the frame for many new business opportunities and technical developments and thus results in challenges for data and information management. Building-related data is more and more an integral part of information systems which are developed and used for various purposes in real estate management. An information system is a socio-technical system that enables the collection, storage and dissemination of information and thus supports decision-making, coordination and analysis [13]. Trends in digitalisation of the real estate industry such as Building Information Modelling (BIM), cloud technology or blockchain have the potential to be used for building passports [14].</p>

3. Requirements and functions of building passports

A new generation of building passports aims to serve as whole life cycle repositories for single buildings and therefore plays a significant role in real estate information management. A clear vision of the functions that building passports should fulfil and of the requirements of potential users are a prerequisite for this. Some of these aspects have already been examined within studies on EU-level [15, 16]. While there still remain a couple of open questions in this manner, the following section concentrates on some of the most important requirements and functions to set the basis for the further analysis in section 4.

3.1. Requirements

According to the needs of potential users, building passports should fulfil certain requirements in order to serve their purpose. In general, there are different forms of requirements. On the one hand, user-oriented requirements tackle the practical usability of a system. This can convert for example to the design of processes or the technical implementation. On the other hand, there are thematic requirements that determine the form, structure, quality and usability of data. These data-related requirements take on a significant role in building passport development and usage. A selection of the most relevant data-related requirements is described in table 2 which have been addressed in [15, 16] for example and enhanced by the authors.

Table 2. Data-related requirements in building passports

Requirement	Explanation
Availability, Accessibility	In a building passport, whole life cycle data must be available and accessible to the user permanently.
Accuracy, Integrity, Consistency	Data accuracy and consistency should be ensured through quality control. At the same time, the integrity of data should be persecuted to make sure that the database is complete.
Validity, Updateability Traceability	Data should always be valid and up to date. It must be possible to trace back data so that a chronological timeline of the evolution of a building exists. A suitable scheme for archiving data should be implemented.
Non-redundancy	At the building passport level, data should not contain redundancies. This does not necessarily affect the physical representation of data.
Relevance, Currency	Only relevant data should be stored. This is not a strict requirement since there is no clear definition of the term building-related data and the relevance of data can vary and evolve over time.
Comprehensibility Security, Protection	Data should be easy to understand and interpret for the user. Data security must be ensured and data protection measures must be implemented if necessary.
Control, Ownership	There should be clear regulations about the ownership and administrative control of data.
Compatibility	Data should take in a form which makes it compatible to its form in other systems and instruments whenever possible.

3.2. Goals and functions

The principle of a whole life cycle data repository for building passports goes along with original goals that are rooted in the ambition to an improved data and information management for buildings in general. If these goals are met, building passports can have a variety of benefits for the individual user. Some of the main goals are...

- increase in transparency,
- improvements in the efficiency of management processes,
- higher trust in information resources and system reliability,
- decision support for strategic or operational decision-making,
- cost reductions in data management and data creation to prepare future refurbishments,
- risk mitigation in decision-making [15, 16].

These goals are closely interrelated and they are complemented by a large number of subgoals. Pursuing these subgoals can contribute to the fulfilling of several main goals while they also might depend on the specific purpose of building passport usage.

In order to serve this purpose and to meet the relative goals, a building passport is obliged to fulfil a number of functions that translate to specific tasks in practical use and that can be further specified through requirements (see section 3.1). The functions of building passports derive from the tasks of information systems such as the collection, storage, maintenance or communication/dissemination of data [13]. Therefore, the focus in this section lies on the identification of relevant data categories.

The evolution of building passports showed that different streams provoked the demand for certain building-related data. However, against the requirement of data integrity (see section 3.1) all kinds of data that is supposed to be understood as “building-related” should be considered. Since there is no precise definition of the term “building-related”, the dimensions of real estate serve as a basis to capture the relevant data. Hence, physical, economic, legislative and life cycle building characteristics should be recorded and kept through life cycle. Taking current drivers for building passports into account (see section 2.1) this leads to the following data categories that should be part of a whole life cycle repository:

- “Master data” refers to general more static information about the property location or involved actors for example.

- “Inventory data” refers to the physical or technical building characteristics such as the structure or the materials that have been used.
- “Process-oriented data” does not necessarily refer to the physical building, but it can be an important factor for management decisions, acting on a meta stage.
- “Operational data” is of dynamic nature and it covers for example economic data, legislative data or consumption data such as energy consumption or GHG emissions.

According to the abundance of potentially available data, a building passport should, among other things, prevent the loss of relevant building documentations, it can support the monitoring of performance characteristics and it plays a role for strategic decisions [15, 16]. This highlights its relevance throughout the passage of time referring to past, current and future building-related data.

4. Analysis of existing approaches for the management of building-related data

In addition to building passports, there are other information systems and related instruments that respond to the increasing demand for systematic management of building-related data. As there have been simultaneous developments and some instruments receive a new interpretation based on new features, changed demands or altered boundary conditions it seems to be more difficult to draw a clear line between the goals, tasks and contents of these instruments. Therefore, respective instruments will be analysed against the background of the functions and requirements of building passports (see section 3). A proposal for a future job-sharing approach will then be made based on the findings.

4.1. Differences between relevant instruments

The demand for supporting tools and instruments, that help actors in the real estate industry with information management, is increasingly high today. Political requirements and market competition are two of the most important pull effects for this, while technological developments and new business models, for example, can be seen as push effects that encourage the introduction and use of such tools. The combination of pull and push effects led to the development of information systems that meet the specific needs of different stakeholders. While the co-existence of different systems on the one hand supports specialisation and can lead to higher efficiency in certain tasks, on the other hand it can lead to challenges and confusion in real estate information management. Table 3 therefore first provides an overview of the most important information systems for managing building life cycle data.

Table 3. Information systems for managing building-related data

Concept	Description
Building Passport (also “Housing File” or “Digital Building Logbook”)	A building passport is a real estate information system that functions as a whole life cycle repository for building-related data and thus fulfils the information needs of various stakeholders. Building passports can include other instruments or their respective functions. There is an ongoing discussion about the goals, structure, and use of building passports while their great relevance in the future is agreed on [15, 16].
Digital Twin	Digital Twins are virtual representations of a real building and are usually developed using BIM. Following technical improvements in the past, they can be used not just for the design of buildings but for maintenance, environmental impact assessment or strategic planning for example. Learning effects via simulations and testing in digital twins can potentially be transferred to the real building [17].
Renovation Passport	Renovation passports contain a strategic roadmap for the renovation of a building and provide the necessary data. The goal is to support building owners in their decisions regarding energetic renovations [18].
Energy Performance Certificate (EPC)	EPCs are a legally binding instrument to disclose about the energetic performance of a building. EPCs usually contain an energy characteristic value, a specification of GHG emissions and an energy rating for the possibility of comparison. The digitisation of EPCs bares potentials for cost reductions and easier administration among others [19].
Computer Aided Facility Management (CAFM) System	CAFM systems aim to leverage the benefits of using information technology for the discipline of Facility Management (FM). Their function relies on the existence of various kinds of building-related data [20].

Material Passport (i.e. building related Material Inventory) Material passports serve the goal to keep data about materials installed in a building (e.g. type, amount, position) in a data repository. The respective data can represent information on a material, component, product, system or building level [21]. For a leaner and more circular way to deal with the selection, use and assessment of building materials, the framework for sustainable buildings in the EU “Level(s)” formulates indicators for the bill of quantities and the bill of materials [22]. The need of data acquisition on building materials incorporated in buildings is especially strong for the existing building stock [23]. Material passports can stand alone or be an integral part of a multifunctional system, e.g. building passport..

The question arises how and to which extent the presented instruments can fulfil the goals and requirements of a whole life cycle repository for building-related data. To answer this question, the functions and requirements described in section 3 are considered for the analysis. In more detail, a matrix consisting of some of the main data categories, that are set into relation to the main life cycle stages of a building, serves as an assisting illustration (figure 1).

		Production/ Construction	Operation and Use	Refurbishment	End of Life
Ecological aspects	Energy	<i>EPC</i>			
	CO ₂				
Technical aspects	Materials	<i>Material Passport</i>			
	Building structure				
Processural aspects	Economic	<i>Digital Twin</i>		<i>Renovation Passport</i>	Building Passport
	Legal				
	Actors				

Figure 1. Scope of selected real estate information systems

Figure 1 visualises that the selected instruments differ in their scope which is defined by the data-related and time-related axis. While building passports aim to serve as a data repository throughout the whole life cycle that covers all kinds of relevant data and information...

- material passports only cover characteristic information about building materials,
- renovation passports focus on the strategic management of renovation activities,
- EPCs contain limited information related to the energetic quality,
- CAFM Systems primarily support institutional Facility Management,
- Digital Twin applications are able to cover a wide range of data categories, but they still need structuration of data and a database environment [17].

In regard to the data-related requirements (see section 3.1), the biggest difference to buildings passports lies in the missing of data integrity while also other requirements such as traceability or compatibility of data take in a less relevant role. However, all instruments have shown long-term approval or are of significant relevance for current information needs in the industry. As there is no severe conflict in a parallel usage of these instruments, the potentials of a harmonisation of tasks and data bases can be regarded as high. This fact gains special relevance in the further development of building passport concepts in specific. The following section will explain how other instruments can contribute to the function of building passports by taking in a job-sharing perspective.

4.2. Job-sharing perspective

Independent from the specific boundary conditions, there are several success factors for an effective and efficient information management throughout the life cycle of a building. On the one hand, a good communication between actors in the real estate industry can ease the supply with relevant building-

related data. On the other hand, a targeted use of supporting instruments can be crucial. The analysis above revealed that there are overlapping as well as complementary functions of instruments. For a better harmonisation, the authors suggest to perceive a building passport as a superordinated system in which all whole life cycle building-related data is kept and thus all data that is part of other instruments as well. Data for certificates, renovation strategies or material inventories, among others, can be an integral part of building passports and also stand alone to fulfil their respective functions (see figure 2). By taking in this job-sharing perspective, consistent data only has to be represented once in the data repository while still serving various purposes. This approach goes along with the findings of the European Commission that a building passport should either be implemented as a digital gateway, where data is only linked while it is physically stored at other places, or as a physical database with all data stored at one repository [16].

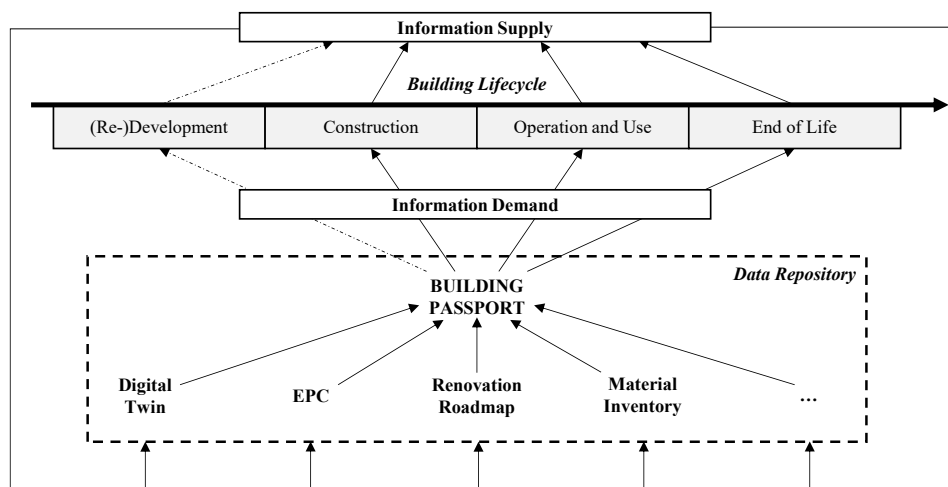


Figure 2. Building passports as superordinated information system

5. Conclusion and outlook

Actors of the real estate industry are confronted with new possibilities and new challenges in managing building-related data under the influence of current trends. The concept of building passports is an instrument which has the potential to overcome many data-related problems and therefore receives more and more attention. The European Commission is currently working on a proposal for digital building logbooks which is to be published in 2023 [16]. At the same time, various EU-funded projects from the Horizon 2027 programme incorporate the development of building passports, renovation passports or EPCs. In Germany, the new government agreed in 2021 on the development and introduction of building resource passports. Likewise, the Finnish green building council is currently developing a building passport scheme while Finland has the goal to achieve a circular economy and carbon neutrality in 2035 [24]. In addition, other instruments like material passports that address the material inventory of buildings are under development in the EU as well.

The interdisciplinary research on future-proof building passports is expected to intensify in the future. This contribution aims at supporting the clear definition of the functions and scope of the various instruments with a particular focus on building passports. Misinterpretations should be prevented due to the short timescale for the sustainable transformation of the built environment. Since there is no direct conflict between the function of the analysed systems, a suggestion was made to regard them as complementary and to integrate them into a building passport framework where a job-sharing between the instruments is possible. Coexistence of the systems is possible but mutual effects must necessarily be considered. A job-sharing approach can lead to synergies in data management that increase transparency or efficiency for example. Questions remain for the transfer of goals and requirements into specific features of applications.

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