Fundamental Characteristics and Concept of Material Passports

Ioana Miu
University of Twente
Enschede the Netherlands
i.miu@student.utwente.nl

ABSTRACT

Material Passports are majorly influencing the future of economy by providing a solution for the raw material crises. The goal of this research is defining the fundamental characteristics of material passports in order to have a clear overview of their role into the current economy. The actual demand for raw materials does not match the supply which concludes in a need for improving the factors supporting a circular economy, such as material passports. Due to the innovative matter of material passports, a clear definition and a characterization of the topic are lacking in the scientific literature. For that reason, we pose the central research question: "What are the fundamental characteristics which define the concept of material passports?". Both the alliable scientific researches and grey literature will be consulted in order to formulate a clear definition of the "material passports" and to create a structured classification of its concepts. The key impact of this research is to increase the understanding and the awareness about research passports in order to further positively affect the economy.

Keywords

Material passports, Resources passports, Circular economy, Life cycle analysis and Raw material scarcity.

1. INTRODUCTION

The current volume of available raw materials cannot match the current production demand. The rapid increase in resource scarcity is due to the rise in demand for raw materials, which emphasizes the importance of approaching a new strategy for preventing the termination of natural resources (Mathieux, Ardente, & Bobba, 2017, p. 12). This context accentuates the importance of a circular economy and the necessity of implementing reusing and recycling as general mindsets within the main industries (Mathieux, Ardente, & Bobba, 2017, p. 48). In order to facilitate the exchange and reuse of raw materials, a few projects and companies have created material passport documents. Material Passports state the material content of the products and describing how the stated materials can be reused, redesigned or recycled at the end of product life cycle. Material Passports are a strategy that aims in addition to increase the reuse rate of raw materials, also to redesign the current manufacturing market (Damen, 2012).

Material Passports can redefine the Product Life Cycle and transform the production industry into a Circular Economy. The improvement of information systems can play an essential role in defining the purpose and the form of Material Passports. The need of a structure system of Material Passports is at utmost importance for the economy and the environment.

The key motivation for this research is the current global crisis of raw materials. However, the more precise reason for conducting this research is explaining how Material Passports can improve the current situation by diminishing the raw materials crisis.

Unfortunately, the current knowledge about Material Passports is limited while the provided definitions are ambiguous. All these factors provide motivation for conducting a focused research on the concept of Material Passports and their characteristics.

That leads to pose the central research question: " What are the fundamental characteristics which define the concept of Material Passports?"

2. RELATED WORK

Since the main research topic refers to a very innovative approach of Circular Economy expressed through Material Passports, the literature is quite limited. However, during the last few years more and more research has been implemented and more information has been collected. During the initial phase the focus will be placed on literature reviews as a source of information. With the aim of collecting reliable impartial information, this research will analyze both the few scientific researches and the grey literature focused on Material Passports, Product Passports and Resource Passports.

2.1 Scientific research

The first scientific research about Material Passports was published in 2012 by Maayke Damen (Damen, 2012). Even though more information has been gathered afterwards and more papers have been written about the topic, the research of Maayke Damen is still the key scientific paper of the topic (Damen, 2012). This paper assesses both the possible content and format of a resource passport and how can such documents impact the current economy and help the transition to a circular economy. Another important scientific research related to the topic is BIM-Based Passports (MP) as on optimization tool for increasing the recyclability of buildings. (Honic, Kovacic, & Rechberger, 2019, p. 327-334). However, this paper focuses more on one specific industry where Material Passports can be used. A few of such industry specific scientific reports can be very useful for defining the

32th Twente Student Conference on IT, Jan. 31st, 2020, Enschede, The Netherlands.

fundamental characteristics of Material Passports across industries.

2.2 Grey literature

Since most of the Materials Passports available at the moment where created for industrial purposes by production companies, a lot of grey literature has been created for the subject. This type of information will be used for this research since it brings a more accurate practical image of how Material Passports, Product Passports and Resource Passports are viewed by production industry nowadays and how they are used in a real-life situation.
A few projects have aimed to increase the public awareness about Material Passports and their role in the current economy. Some of these projects consists in website that explain the concept of Material Passports to the public. A few examples of these most popular platforms, both in English and Dutch are: Bamb 2020 (Mulhall, Braungart, & Hansen, 2016) and Platform 23 (Platform CB'23, n.d.).

3. METODOLOGY

The principal type of research used in order to analyze the selected topic and to answer the central research question is Observational Research (Webster & Watson, 2002). This type of correlative research perfectly matches the given topic since it implies the examination of the knowledge about the subject. The research is divided into three main parts:

The first part aims to analyze the existing documentation about the topic. This part may seem similar to literature review, since in essence, it consists of consulting the current available literature and extract reliable information.

The second part focuses on making use of the information collected in the first phase. During this phase the information collected will be structured based on its relevance to the research topic. Organizing the information collected is a necessary step for obtaining a structured result. This step aims to select the description given to Material Passports and pick the most relevant characteristics found within the collected information.

Step three will focus on answering the central question of the research by designing a concept augmented matrix which clearly distinguishes the main characteristics of Material Passports and formulate a more visually clear description of what a material passport consists of. Moreover, another aim to be achieved during this step is a clearer definition for the concepts behind the term "Material Passports". Since the novelty of the topic, distinct terminology is being analyzed.

The methodology of research consists of collecting appropriate documentation to the topic. The central source of information is digitally collected from the scientific search engine: Scopus. The origin of the documents ensures their academic content. The focused selection of keywords used for the preliminary research consist of: "Material Passports", "Product Passports" and "Resource Passports". Each one of the three searches were restricted by the same criteria:

- Document type: "article", "conference paper", "review"

- Language: "English"

- Keywords: "circular economy", "life cycle", "environmental impact", "passport data", "sustainable development", "recycling potential"

From the documents resulting from the search, the selection of relevant studies was filtered without bias based on the following criteria:

• Ensuring that the journal addresses a subject relevant for the research by offering information related to a type of product documentation

• Assessing the credential of the journal publisher by only allowed ISI -based journals

• Determine whether the quality and relevance of the journal is in line with the research

• Apprise the general acceptance rate of the report and its general impact

• Studies a material documentation which is not only a description of the product content, but also includes a sustainable plan for the end of the product life cycle

• Containing an actual framework/ model that appears to be a material documentation

• Containing an actual decryption/definition of the material documentation studied

After collecting all the relevant information, the findings were structured in a way that helped construct an appropriate answer for the central research question. In addition to the sources found from the research, each study selected had its own references analyzed, from which an even large potential of sources is developed. Both primary sources and sources obtain though Snowbowl sampling technique are considered in this research.

Defining the characteristics of a material passports is a key step for creating a concept augmented matrix describing the most important features of a material passport (Verdinelli & Scagnoli, 2013, p. 12). Matrices are tables based on a "cross-classification of two or more dimensions, variables, or concepts of relevance to the topic or topics of interest" (Lofland et al., 2006, p. 214). There multiple types of matrices based on their relevance and their dimension, so the exact design of matrix will be decided after the information will be collected and classified (Verdinelli & Scagnoli, 2013, p. 15).

4. RESULTS

4.1 Analyzing the descriptions of the used terms and formulating a general definition of material passports

This section provides an analysis of how each of the selected sources defines the concept of Material Passport. In some of the sources distinct terms are used, such as "Passports", "Product Passport", "Resource Passport", "Environmental Product Declaration" and even "Sustainable Management implemented in Product Design". Despite the difference in terminology, all these of a concept seem to describe the same or very similar concepts. For this reason, all documents are clearly evaluated; both the terminology used and the provided definition in the paper are presented and structured in the first table (see Table 1). The table contains three main categories. The first category is "Terminology used" which provides the exact term used in the paper to describe a concept similar to or equivalent to a "material passport". The second column quotes the exact description associated in the paper with the concept. The last column shows the name of the authors of the study.

Furthermore, this research analyzes the correlations and differences between the distinct terms by their descriptions. The aims of this chapter provide more clarity in relation to the definition and description of Material Passports and also state

whether any of the other used terms are synonyms with Material Passport and can have the same definition.

This section is structured as follows. Firstly, all studied concepts are presented (see Table 1). The results show whether the term analysis refer to similar or equivalent concepts. In the situations where the concepts described are distinct from each other, the differences are presented.

Table 1. Descriptions of the given material documentation presented in the study

	Terminology used	Definition/Description provided	Authors
1	"Material Passport"	"A Material Passport is a qualitative and quantitative documentation of the materials composition of a building, displaying materials embedded in buildings as well as showing their recycling potential and environmental impact." (Honic, Kovacic, & Rechberger, 2019, p. 2)	M Honic, I Kovacic, H Rechberger
2	"Product Passport"	**"**focus exclusively on hosting product details, but none suggest connecting this data to a cross-industry information ecosystem to facilitate circular exchanges." (Sauter & Witjes, 2018, p. 1)	E Sauter, M Witjes
3	"Passport"	"they are the fundament of the characterization of a given accession. They provide, furthermore, the legal background for the use of an accession." (Colomsee et al., 2011, p. 1)	C. Colmsee, E. R Joachim Keller, C. Zanke, A. Senula, T. Funke, . . . O. Scholz
4	"Material Passport"	"In general, materials passports are a digital dataset of a specific building, providing a detailed inventory of all the materials, components and products used in a building, as well as detailed information about quantities, qualities, dimensions, and locations of all materials." (Heisel & Rau-Oberhuber, 2019, p. 2)	F. Heisel, S. Rau-Oberhuber
5	"Passport"	"Curators of collections use passport data to group accessions, to understand the diversity within the collection, to make core collections and to identify potential redundancies and gaps in collections (Greene 2001; Hazekamp 2002; SGRP 2010). Good quality passport data allow linkages between genebank data and other, often external, data sources." (Thormann, Gaisberger, Mattei, Snook, & Arnaud, 2012, p. 642)	I. Thormann, H. Gaisberger, F. Mattei, L. Snook, E. Arnaud.
6	"Environmental Product Declarations"	"A Type III EPD is a set of quantified environmental data consisting of pre-set categories of parameters based on Life Cycle Assessment (LCA) according to the ISO 14040 series of standards, with at least a minimum set of parameters for each product group (DG Environment, 2002)" (Manzini, Noci, Ostinelli, & Pizzurno, 2006, p. 119)	R. Manzini, G. Noci, M. Ostinelli, E. Pizzurno
7	"Sustainable Management implemented in Product Design"	"EPA recommends careful industrial and product design as a strategy to reduce the consumption of virgin materials. Sustainable life-cycle management and reuse of materials can help "to fulfil our human needs and prosper while using less material, reducing toxics and recovering more (US EPA 2009)" (Koehler, Peck, & Bakker, 2011, p.15)	A.R. Koehler, D. Peck, C. A. Bakker
8	"Environmental Product Declarations"	"The original aim was to provide final consumers with environmental product information by presenting unweighted life cycle inventory data. Over the years, the view on what later	M. Bogeskär, A. Carter,

		became known as Environmental Product Declarations Type III (orEPDs) changed, and today the common opinion is that it is probably too early to convey sophisticated environmental information directly to final consumers but that it could be useful in the business-to-business market." (Bogeskär et al., 2002, p. 13)	C. O. Nevén, R. Nuij, E. Schmincke, H. K. Stranddorf
9	"Environmental Product Declarations"	"It is designed to foster the development of ecological and healthy building. In this validated declaration, all relevant environmental data are disclosed." (Bossenmayer, 2011)	H. J. Bossenmayer
10	"SmartTags"	"SmartTags composed of functional ink can measure parameters of the physical environment, capturing more data than possible in the moment with current technology without using expensive tracking and monitoring mechanisms." (Gligoric et al., 2019, p. 23)	N. Gligoric, S. Krco, L. Hakola, K. Vehmas, K. Moessner, … R. Van Kranenburg

4.2 Analyzing the characteristics uses and designing a selecting the common ones

The second section provides the analysis of the most common characteristics material documentation of a product that appear in the papers studied. The term characteristics refers to the main elements found in the composition of the product documentation. The characteristics presented in the table selected in accordance to their relevance to the topic and their universal applicability. The characteristics found in the study that product specific, not considered in this table due to their lack of influence in creating a standardize passport purpose.

The most important characteristics found in the study are: "Product type/ description", "Product resource composition", "Product location", "Product recycling potential", "Production/collection date", "Separability", "Quality", "Disassembly instructions and disposal" and "Current status". In the following paragraph the signification of each term is explained for a better understanding of the categorization process (see Table 2).

The "Product type/ description" explains what the product is, what is the purpose of the product and what are the features and benefits of the product. This characteristic appeared as one of the most common in the study since it coves very basic information of the product.

The "Product resource composition" refers, depending on the product to the quantity of the product, the amount of materials used during production, the quantity of materials remaining in the final product. Moreover, this aspect can also cover the amount of resources used during production and during the product life cycle.

The "Product location" names the location from where the product originates. The meaning is context dependent because it could refer either to the place where it was collected , produced or built. The accuracy of the location varies depending on the situation, it can be as exact as an actual address or as generic as the continent name.

The "Product recycling potential" This characteristic describes the recycling potential of the product and proposes the most appropriate ways to recycle the product in the most environmentally efficient way.

The "Production/collection date" The date of the product refers to the exact time the product was collected, built or manufactured.

The "Separability" is a very important part since sometimes the resource composition is not enough for defining the recyclability potential of a product. Knowing the form of the elements used and their ability to separate from the other elements forming the product is very important.

The "Quality" describes the level of quality that defines the product and whether the production focus was placed on the quality of the product.

The "Disassembly instructions and disposal" explains how the product can be taken apart and how the parts that can no longer be recycled can be disposed in the best way possible.

The "Current status" offers a characterization of the current state of the product. This applies to both products that have changes occurring in the material documentation father along their lifecycle. It also relates to the products that use "SmartTags" as a way of continuously having updated information about the product current status. (Gligoric et al., 2019, p. 23).

Table 2. Characteristics of the given material documentation presented in the study

	Product type/description	Product resource composition	Product location	Product recycling potential	Production/collection date	Separability	Quality	Disassembly instructions & disposal	Current status
"Material Passport" (Honic, Kovacic, & Rechberger, 2019, p. 2)	X			X		X	X	X	
"Product Passport" (Sauter & Witjes, 2018, p. 1)		X	X	X				X	
"Passport" (Colomsee et al., 2011, p. 4)	X		X		X				
"Material Passport" (Heisel & Rau-Oberhuber, 2019, p. 3)	X	X	X	X					
"Passport" (Thormann, Gaisberger, Mattei, Snook, & Arnaud, 2012, p. 639)	X			X	X				
"Environmental Product Declarations" (Manzini, Noci, Ostinelli, & Pizzurno, 2006, p. 119)			X	X	X				
"Sustainable Management implemented in Product Design" (Koehler, Peck, & Bakker, 2011)	X	X		X					
"Environmental Product Declarations" (Bogeskär et al., 2002, p. 13)	X	X		X					
"Environmental Product Declarations" (Bossenmayer, 2011)	X	X	X	X	X		X	X	
"SmartTags" (Gligoric et al., 2019, p. 23)	X	X		X		X	X		X

4.3 A standardized model for Material Passports

This section aims to use the information obtained in the previous two sections and uses it in order to create a more standardize model of material passports. Even though most studies analyzed use very similar descriptions and have quite common characteristics, the fragments provide from passports show very distinct frameworks. For this reason, the following template of "Material Passports" proposed as an alternative way of exposing the results previously found. Furthermore, this proposed fretwork aims to contain all the basial information that should be present in any version of "Material Passports" (see Figure 1).

The main template includes three pages. The first page provides the name of document and the principal goal aimed to be reached through this type of documents "Material Passport for a circular economy". Also, on the first page, the name of the product will be stated. Most studies analyzed did not mention the name of the product as a characteristic. The name of the product is to be considered a basic information so most studies did not categories it as a characteristic. Also, the name of the company/organization offering the product is another basic information that should be included in the title page of any product document (see Figure 1).

The second page aims to reinforce the knowledge about the document type and the purpose of such document. As all studies researched underlined the importance of a circular economy for a more sustainable environment, the first section of the proposed "Material Passport" focuses on the importance of a circular economy. The following section describes what a

"Material Passport" is and the last section explains what is the purpose of such a document. This first page can be structure

as preset information that does not modify along with the different products (see Figure 1).

The third page contains separate sections for each characteristic found important in the examples studied. The sections presented here will be completed with unique content according to the specific product described. In addition to these basic sections, each passport can contain additional information, however none of the sections mention should be removed. The characteristics selected aimed to have the proper level of universality, so that they can be applicable in any situations. Data such a document type, composition, location, recycling potential and disposal instructions are broad topics that apply to any type of material product (see Figure 1).

Figure 1. Standardize Model of Material Passport

5. DISUSSION

5.1 The relation between distinct environmental marital documentation for products

The aim of the first two sections of results was to provide more structured information about what defines a document as a Material Passport, what are its main characteristics, and what are the differences in description between "Material Passports", "Passports", "Product Passport", "Resource Passport", "Sustainable Management implemented in Product Design", "Environmental Product Declaration", "Sustainable Management Documentation". Sometimes the same terminology is used in more studies, however distinct descriptions were defining the terminology. Even though each study provides its own definitions, most of the differences are related to the author's formulation choice and not to the actual description meaning (see Figure 2). Based on the explanation used for each term it appears that "Material Passports", "Passports", "Product Passport", "Resource Passport" refer to the same typology of documents (see Figure 2).

The passport type documents appear to have definitions focused on the classification properties of the document. They claim to provide a more structured way of describing the product type or analyzing the composition used in producing that particular type of product. Moreover, the passport type of documents seems to already have quite a defining structure and similarity patterns. Passport type of documents placees the focus on the raw materials used during production as a strategy of forming a define recycling plan. The benefit of this type of document is the high level of product information comprised. They emphasize the way the content of a product can affect its life cycle.

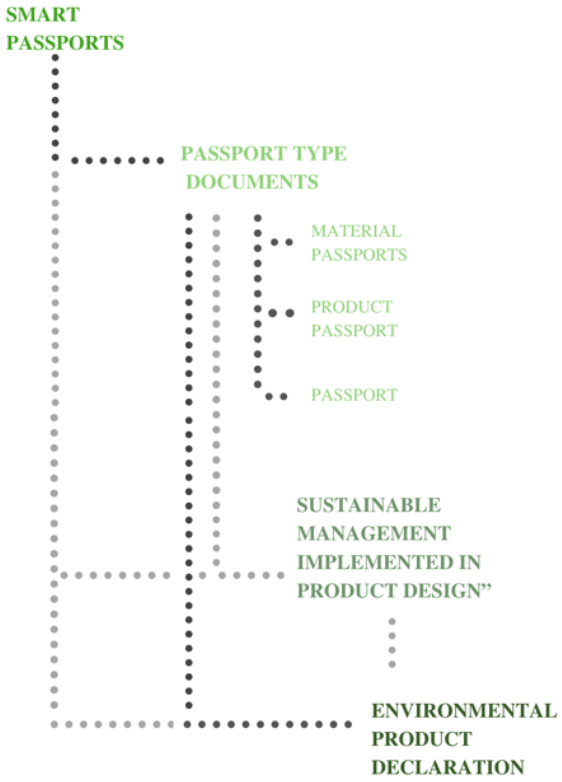
"Environmental Product Declarations" appear to focus on the environmental properties of the product, and only provide the content information that is relevant for the reuse, recyclability and disposal of the product. Although the passports type of documents and the declaration types appear to have related characteristics and overall to contain similar information, the difference is made by the principal purpose of the document in relation to the product life cycle.

Passport types documents focus on the beginning of product life cycle, more specifically on the type of resources used during production and the material component of the product. As the same time, they present this information as basic data needed for planning the end of product life cycle, so the maximum recycling potential of each product is reached. Since the most important features of "Passports" are found at the beginning of product life cycle, most passport type documents

need to be created before or during the production of a product. Designing the passport in a further stage of the product life cycle can negatively affect the accuracy of the production information.

On the other hand, environment declaration types of documents establish the end of the product life cycle as the main point of interest. They focus on the best option of recycling or disposing the product and provide the relevant production and material composition information. The aim of such documents is not to list all the elements of the product, but to provide an appropriate recycling method for the product. Due to the focus on the end of product life cycle, "Environmental Product Declaration", unlike "Passports", can be developed at any time of the product life cycle.

Figure 2: The relation between the environmental documentation for products studied



"Sustainable Management implemented in Product Design" is a type of product documentation that takes place before the actual product life cycle begins. This study presenting "Sustainable Management implemented in Product Design" acknowledges the raw material scarcity and uses it as a main focus element. This study focuses on the goal of designing sustainable products so that when they reach the end of their life cycle there will already be a plan in explaining the best methods of recycling or disposing the product when they reach the end of their life cycle. The study manages to state all the benefits of having a sustainable thinking during the design stage. However, it promotes a plan of action rather than a product documentation.

Based on its description, the concept of "SmartTags" integrates the idea of material passports into a more digitalized concept. In the study "SmartTags: IoT Product Passport for Circular Economy Based on Printed Sensors and Unique Item-Level Identifiers", the authors discuss the idea of creating QR Code based labels that can digitally provide the Material Passport of a product. Moreover, the benefits of the digital context are also the ability to continuously introduce new data about the changes occurred to the product and new information about the current product stage. The concept of "SmartTags" aims to improve the current state of passports, as the authors mention in the study "The benefit of product lifecycle and data exchange is the ability to collect a set of information beyond available data (i.e., components and materials that product contains), enhancing the level of details about the product passport including when it is being used, how, and by who; environmental conditions, etc. (Gligoric et al., 2019, p. 23).". There are numerous studies similar to this one and all aim to use the emerging technologies in order to increasing the accessibility of passport types documents. This concept is generally found under the name of "SmartPassports" and describes material type documents that have technological additions, such as QR codes, NPC, DNA spray, etc. These novel inclusions increase the accuracy, accessibility and overall effectiveness of material type documents.

5.2 The chronology of evolution in environmental marital documentation for products

One of the most relevant observation made during this research is how the age of the study analyzed affects its type and accuracy. Placing the studies analyzed based on their publishing year, shoes a clear chronology between the environmental documentation for products (see Table 3). Moreover, for a better visualization of the context, an actual timeline was created (see Figure 3). This observation supports the idea of evolving thousands a circular economy and strengthens the reliability of the discoveries made before. It provides and explanation that aligns with the results of this research. Fortunately, promptly with the increasing focus of resource scarcity and disposal restrictions, the accuracy of product documentation has been positively impacted. It can be observed that the latest studies presented in the search seem to be an improved version of the older ones. It appears that the aim is to bring a more powerful impact thoroughworts the goal of creating a circular economy.

Table 3: Chronological table of environmental documentation for products

Publishing year of study	Environment documentation type
2002	"**Environmental Product Declarations**" (Bogeskär et al., 2002, p. 13)
2006	"**Environmental Product Declarations**" (Manzini, Noci, Ostinelli, & Pizzurno, 2006, p. 119)
2011	"**Environmental Product Declarations**" (Bossenmayer, 2011)
2011	"**Sustainable Management implemented in Product Design**" (Koehler, Peck, & Bakker, 2011)
2012	"**Passport**" (Colomsee et al., 2012, p. 4)
2012	"**Passport**" (Thormann, Gaisberger, Mattei, Snook, & Arnaud, 2012, p. 639)
2018	"**Product Passport**" (Sauter & Witjes, 2018, p. 1)
2019	"**Material Passport**" (Honic, Kovacic, & Rechberger, 2019, p. 2)
2019	"**Material Passport**" (Heisel & Rau-Oberhuber, 2019, p. 3)

2019	"**SmartTags**" (Gligoric et al., 2019, p. 23)

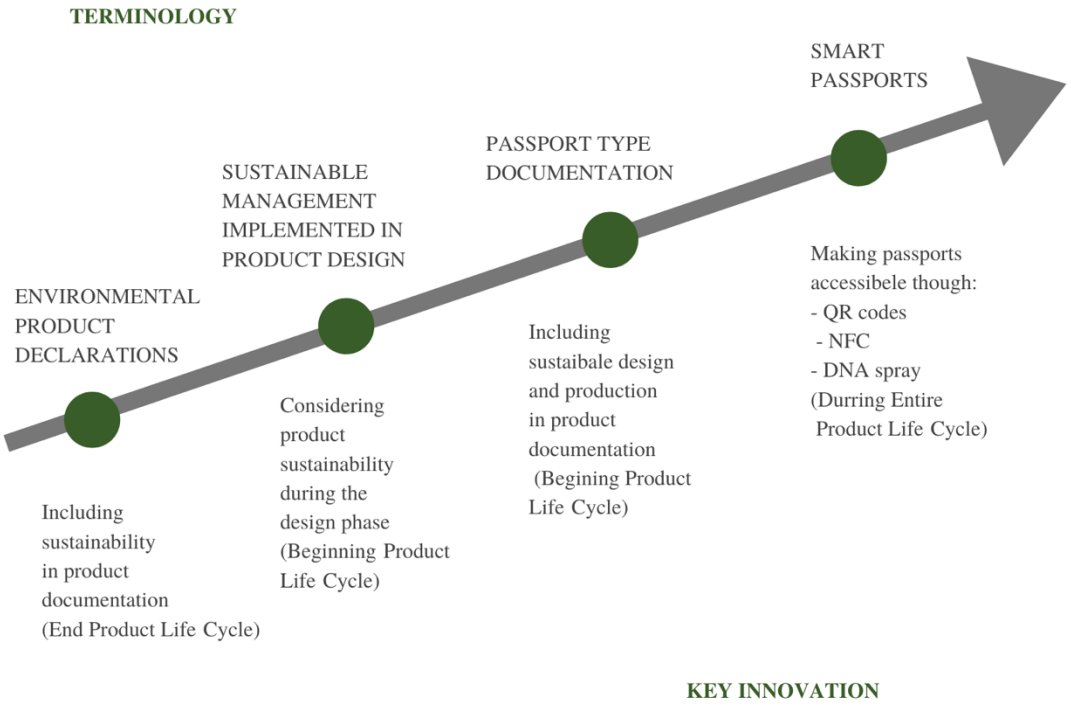
"Environmental Product Declarations" appear to be a quite a mature topic and they seems to provide a solution of improving the recyclability degree of already existent products. As stated in the one of the descriptions of an environmental declaration, "The original aim was to provide final consumers with environmental product information by presenting unweighted life cycle inventory data." (Bogeskär et al., 2002, p. 13). Preparing the end customer with a strategy of recycling the product can create a very powerful impact over the circularity level of the economy. This type of strategy finds the best option for the existing products and can be implemented to any product in the market.

While the resource scarcity crisis started emphasizing the importance of designing and manufacturing a product in relation to its recyclability and disposal strategies has become a focus. In 2009 US EPA provides a very relevant advice "EPA recommends careful industrial and product design as a strategy to reduce the consumption of virgin materials. Sustainable life-cycle management and reuse of materials can help "to fulfil our human needs and prosper while using less material, reducing toxics and recovering more (US EPA 2009)". Studies like this inferenced the product documentation and encourage that more focus should be placed at the beginning the product life cycle. Design and production become main influencing factors of product's sustainability properties.

Based on the studies analyzed, passport type of documents appears to be the following step towards a circular economy after environmental declarations. This type of document cannot apply to all products available currently in the market. However, it provides an improved option for all the products found in design or manufacturing phase. The definition of "Material Passports" provided by M. Hoinic, I. Kovacic and H. Rechberher appears to be the most accurate and inclusive one. This description states that "A Material Passport is a qualitative and quantitative documentation of the materials composition of a building, displaying materials embedded in buildings as well as showing their recycling potential and environmental impact (Honic, Kovacic, & Rechberger, 2019, p. 2)." Considering the particularities used in the context of buildings, this shows how the information collected during manufacturing phase provides insights advantageous for the end of product lifecycle. In a more universal way this description can become a very appropriate alternative for the definition of not only "Material Passports", but for all type of passport documents. This definition can be rephrased as follows: "A passport type product document is a quantitative and qualitative documentation of the (raw) material composition of a product, displaying the list of materials embedded in the particular product as well as showing how the content affect the recyclability and environmental impact of the product".

According to the timeline derivate from the studies, "SmartTags" appear to be the latest innovation in the product documentation. "SmartTags" comprise all the information a material passport contains and in addition provide a technological approach which maintains the information up to date. In addition, they cast the relevant information about the current state of the product and provide unlimited information accessibility. This technology adopts digital material passports and uses QR code labels in order to provide the best accessibility to the information (Gligoric et al., 2019, p. 23).

Figure 3. Visual timeline of evolution in environmental marital documentation for products



The downside of universally available material passports is manifested in the context of protecting the product information from the competitors. Even though having all information about the product available has many environmental benefits, the companies might be reticent to implementing it. In the context of the current oversaturated market, the uniqueness of a product becomes harder and harder to maintain. Protecting the sensitive information about a product in a competitive market context is the goal of many companies and is one of the major obstacles in the way of largely implementing product documentation methods. While "Environmental Product Declarations" and "Material Passports" appear to maintain a high level of privacy, "SmartTags" promote the opposite.

The implications of these observations have offered a clearer perspective over the impact of the current raw material scarcity over the product documentation. Moreover, it shows the large variety of documents that have been developed to accelerate the progress towards a circular economy.

The generality of the results is limited by the reliability of the study sample. While considering all existing the documentation about the topic would not have been possible in the context of the current research, the focus is placed on a sample of studies. The methodological choices for forming the sample studies selection are presented in the Methodology chapter.

The results presented are nevertheless valid due to the accuracy used in source selection and to the impartial approach of collecting information.

Further studies should consider the lack of clear terminology and universally acknowledge definitions of the subject. Moreover, the current interest in circular economy places an additional focus on the topics which results with a continuous progress and a continuous increase in resources. The latest discoveries might provide closer insides into the topics so further studies will offer a more updated perspective of the topic. A deeper investigation related to the progressive timeline observation would be extremely relevant for explaining the impact of raw material crisis in relation to product documentation.

6. CONCLUSION

This research aimed to provide a clear view on the meaning of material passports and their characteristics. By analyzing the studies available studies and presenting district product documentation options, the information needed in order to form a structured standardize model of a "Material Passports" was gather and such a framework was presented.

This research also managed to provide a more precise correlation of terms. As previously discussed, the terms "Material Passport", "Product Passport", "Resource Passport" and "Passport" refer to the same typology of documentation. They focus on the beginning of product life cycle and have material composition as principal information. Moreover, a general definition of passport type documentations has been formulates based on the findings. "A passport type product document is a quantitative and qualitative documentation of the (raw) material composition of a product, displaying the list of materials embedded in the particular product as well as showing how the content affect the recyclability and environmental impact of the product". In contrast, the documents of type "Environmental Product Declarations" appear to place more importance on the end of the product life cycle as they focus mainly on recyclability and disposal.

Based on the findings of this research all products should possess a "Material Passports" during the manufacturing phase. For the products already available in the market or closer to the end of the life cycle an "Environmental Product Declaration" should be computed. The products found before or during manufacturing phase should be classified though a "Material Passport". However, further research is needed to determine how can the efficiency of these document be even further improved.

Returning to the problem statement, this research managed to better analyze the definition of "Material Passports" and to provide a structure of the characteristics defining this type of document. Moreover, all the data gathered from the studies was used in designing a conceptual framework of a "Material Passport".

7. REFERENCES

Bogeskär, M.,Carter, A.,Nevén, C. O.,Nuij, R.,Schmincke, E., & Stranddorf, H. K. (2002). *Evaluation of Environmental Product Declaration Schemes*. European Commission DG Environment.

Bossenmayer, H. J.(2011). Environmental Product Declaration according to ISO 14025. *Institut Bauen und Umwelt e.V.*

Colmsee, C., Joachim Keller, E. R., Zanke, C., Senula, A., Funke, T., Oppermann, M., . . . Scholz, U. (2012). The garlic and shallot core collection image database of IPK presenting two vegetatively maintained crops in the federal ex situ genebank for agricultural and horticultural crops at gatersleben, germany. *Genetic Resources and Crop Evolution, 59*(7), 1407-1415. doi:10.1007/s10722-011-9768-4

Gligoric, N., Krco, S., Hakola, L., Vehmas, K., De, S., Moessner, K., … Van Kranenburg, R. (2019). SmartTags: IoT Product Passport for Circular Economy Based on Printed Sensors and Unique Item-Level Identifiers. *Sensors*, *19*(3), 586. doi:10.3390/s19030586

Damen, M. A. (2012). A resources passport for a circular economy (Master's thesis, University of Utrecht, Utrecht, Netherlands). Retrieved from https://dspace.library.uu.nl/handle/1874/257741

Heisel, F., & Rau-Oberhuber, S. (2019). Calculation and evaluation of circularity indicators for the built environment using the case studies of UMAR and madaster. *Journal of Cleaner Production*, 243 doi:10.1016/j.jclepro.2019.118482

Honic, M., Kovacic, I., & Rechberger, H. (2019).Concept for a BIM-based Material Passpor for buildings. IOP Conference Series: Earth and Environmental Science, 225, 012073. doi:10.1088/1755-1315/225/1/012073

Honic, M., Kovacic, I., & Rechberger, H. (2019). BIM- Based passports (MP) as on optimization tool for increasing the recyclability of buildings. Applied Mechanincs and Materials, 887, 327-334.

Koehler, A. R.,Peck, D., & Bakker, C. A. (2011). *Materials Scarcity: A New Agenda For Industrial Design Engineering*.Delft, Netherlands: Knowledge Collaboration & Learning for Sustainable Innovation.

Luscuere, L. M. (2016). Materials Passports: Optimising value recovery from materials. ICE Publishing, 170(1).

Lofland, J., Snow, D., Anderson, L., & Lofland, L. (2006). Analyzing social settings. A guide to qualitative observation and analysis. Belmont, CA: Wadsworth/Thomson Learning.

Manzini, R., Noci, G., Ostinelli, M., & Pizzurno, E. (2006). Assessing environmental product declaration opportunities: a reference framework. *Business Strategy and the Environment*, *15*(2), 118-134. doi:10.1002/bse.453

Mathieux, F., Ardente, F., & Bobba, S. (2017). Critical raw materials and the circular economy. Retrieved from Publications Office of the European Union website: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC108710/jrc108710-pdf-21-12-2017_final.pdf

Mulhall, D., Braungart, M., & Hansen, K. (2016, February 5). Buildings As Material Banks (BAMB2020).

Retrieved December 1, 2019, from https://www.bamb2020.eu

Platform CB'23. (n.d.). Portal Platform CB'23.

Retrieved December 1, 2019, from https://platformcb23.nl

Verdinelli, S., & Scagnoli, N. I. (2013). Data Display in Qualitative Research. *International Journal of Qualitative Methods*, 12(1), 359-381. doi:10.1177/160940691301200117

Sauter, E., & Witjes, M. (2018). Linked Spital Data for a Circular Economy. CEUR Workshop Proceedings .Colmsee, C., Joachim Keller, E. R., Zanke, C., Senula, A., Funke, T., Oppermann, M., . . . Scholz, U. (2012). The garlic and shallot core collection image database of IPK presenting two vegetatively maintained crops in the federal ex situ genebank for agricultural and horticultural crops at gatersleben, germany. *Genetic Resources and Crop Evolution*, 59(7), 1407-1415. doi:10.1007/s10722-011-9768-4

Thormann, I., Gaisberger, H., Mattei, F., Snook, L., & Arnaud, E. (2012). Digitization and online availability of original collecting mission data to improve data quality and enhance the conservation and use of plant genetic resources. *Genetic Resources and Crop Evolution*, 59(5), 635-644. doi:10.1007/s10722-012-9804-z

Webster, J., & Watson, R. (2002). Analyzing the past to prepare for the future: writing a literature review. MIS, 26.