BIM and Circular Design

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

BIM and Circular Design

A Aguiar, R Vonk and F Kamp

Rijnboutt bv, Moermanskkade 317, 1013 BC Amsterdam, The Netherlands

aguiar@rijnboutt.nl

ABSTRACT: Materials passport is a tool to promote circular design. BIM is an essential and powerful tool to create and manage digital information. As such, it can be used for materials passports. Which information is needed and reliable? How can we extract it from a BIM model? The current debate issues "which information is needed?" with the assumption that it will be all settled with BIM. Indeed, BIM has great potential when it comes to gain and share information, but what are the possibilities and how to maximise its potential? This paper clears the discussion by giving better understanding about BIM and circular design using the different phases of the lifecycle to get a grip on how information develops during the process. A circular economy requires a paradigm-shift: buildings as material banks. Each building will have a 'materials passport' and new buildings will be built reversible and reusable using BIM. A circular BIM model is needed and should be created with the least possible effort in order to maximise its potential on an affordable way.

Keywords: BIM, cooperation, affordability, reliability, effort

1. Introduction and context

Buildings contain a lot of materials. We need to stimulate their reuse, especially when considering that raw materials are becoming scarce and using mainly raw resources can have a great impact on the environment. The high value of reusing building components has not been adopted yet on a large scale because of several reasons, one of them being poor building information management [1 & 2]. To promote circular design, not only environmental and life cycle data is important but also information about the quality, technical specifications and measurements of the building elements. Materials passports in combination with BIM fulfill the need of information from the different stakeholders and the need to share valuable content [3].

It is preferable to use BIM tools because those are already common in the construction industry [4 & 5], it's the way suppliers deliver their specs nowadays.

2. Circular Design: design, build, in use and reuse

The idea of circular design is originated from the idea of a circular economy. That means circularity does not only affect how we design and build, but also the process of how we collaborate and make

business. This is of the utmost importance because we need to change the way we think and work in order to reach a circular economy. For instance, we need to value materials and elements at the end-of-life. Demolishing costs money and discards resources that have potential to be reused, so we should harvest our resources.

The base principles of circular design were founded by the Ellen Mc Arthur Foundation [6] and they go from a linear economy to a circular economy, starting from a technical and biological loop. For the built environment there is a third fundamental principle to expand the loop: Reversible design [7] (see figure 1). A bio based (renewable) building is just as circular as a demountable (reusable) building. Both types of buildings should have the ability to change in order to enable the use of what already is available and for as long as possible. It can be a change in function or multi usage, or an adaptation to new requirements. Depending on the circular principle there will be different key issues for design, build and reuse. Also, there are different issues according to the different circular principles. Thinking about using BIM to solve those issues, the greatest potential lies on the technical loop of Reuse.

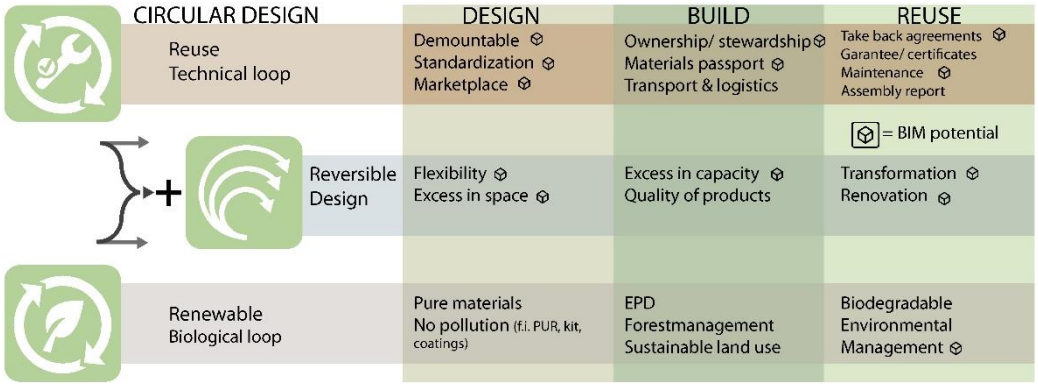

Figure 1. Different principles of circular design.

3. The power of BIM

BIM is often referred to as a 3D model where all information is stored. Around the globe BIM is gaining rapid visibility within the industry and governments are starting to demand and even mandate BIM deliverables. A material bank for buildings with information about the used materials and its specifications can be an important way to promote circular design [3]. The possibilities with BIM seem to be endless and it's being used for many different functionalities. BIM is a tool to set up (purchase) requirements, validate designs, calculate costs, for logistics and planning, energy and daylight simulations, asset management and so on. Therefore BIM stands for an activity, not an object.

3.1. Misconceptions

Many think that all information needed for the materials passport can and will be put in BIM. However, there are some misconceptions related to the use of BIM in an effective and affordable way, which we aim to clarify:

1. The core aspect of BIM is the 'I' of information, and as a gatherer of different types/sources of information, BIM is never one model. When speaking in practical terms, it is not clear what is meant when talking about BIM [8];
2. Different stakeholders are involved using BIM, all with different needs and interests which affects the type and detail of information;
3. Keep in mind how to achieve the greatest outcome with the least amount of effort (the Pareto principle, 80/20 rule [9]);
4. Too much information can lead to unreliable information or a non-feasible model.

Figure 2. Development of the model(s) from the start of the design till the end of realisation. It is important to realise that the coordination model at the end of the design phase is a static model and a new BIM model will be made in the build phase.

3.2. BIM, design model or as-built model

In order to understand BIM and its full potential, we first have to explain how BIM is used in different stages of the design process and how this results in an 'as-built' model (see figure 2). Sometimes hundreds of BIM models take part in a project, each one containing a lot of information. Early in the project, the architect starts with a BIM model. This is a 3D model that contains the basic information, starting only with spaces and later on more information is added, such as what kind of materials, walls, floors, roofs, etc. During this process, the advisors also add information with their BIM models. Both architect and advisors work out their models using their own software. These are called native models. Mutual exchange happens based on IFC files. These are uniform files, which every party involved can write and read. The IFC's are generated from the native files. As the process follows, more and more information is being added enriching the IFC models. The client establishes an IDM in which he indicates which specifications, ID's and properties should be set in an IFC. The IFC models of the architect and advisors together are called the coordination model. After mutual harmonization the provided information in this model won't be changed and so it will become a static model.

The coordination model or project information model is used by the contractor as basis to create the as-built model. The contractor is responsible for this model which is combined with the information of the sub-contractors, manufacturers and suppliers. All parties supply IFC files, which together comprise the BIM model. Here too, an IDM will be in need. All information will be available in these IFC's in order to make the building. In this BIM model the exact profile shapes, fixings, materials and such are modelled. The building is being built virtually. Reports, calculations, guarantee statements, assembly instructions are often provided separately, which will become the separate data of the project. The final as-built model is also a static model. The building will be built according to the as-built model. Nevertheless, changes can take place during the implementation. After completion, a revision of the as-built model must be made containing exactly what is built. The contractor is responsible for the revision model and makes sure it will contain reliable information of the current state of the building.

Table 1. Different models to be used for the materials passport

	Information	Reliability	Responsible
Coordination model fig. 3	General information	Reliable: should be revised and maintained	Architect
Revision As-built model fig. 4	Extremely detailed information	Perfect reliability, if maintained	Contractor
Life cycle model fig. 5	Highly detailed information: needed for maintenance purposes	Perfect reliability & maintenance	Contractor / Data manager
Circular model fig. 5	Information according to the requirements of materials passports: simplified & compact	If not maintained: reliability should be checked	Harvester (together with the Data manager)

3.3. Different BIM models possible for circular purposes

There are several options concerning what kind of BIM model can be used for the materials passport (table 1). When using a model from the design or build phase to create a materials passport, there will be some concerns about the reliability and the kind of detail present in the model, especially when the building reaches the end of life and is ready for harvesting the resources. It's not yet common to use BIM during the in use phase and most stakeholders are not familiar with using BIM for maintenance purposes yet. Here we introduce 2 additional options with different purposes: a life cycle model as a model which will be used for maintenance/management during the whole in use phase and a circular model which is adjusted to contain only the kind of information that is relevant for the materials passport.

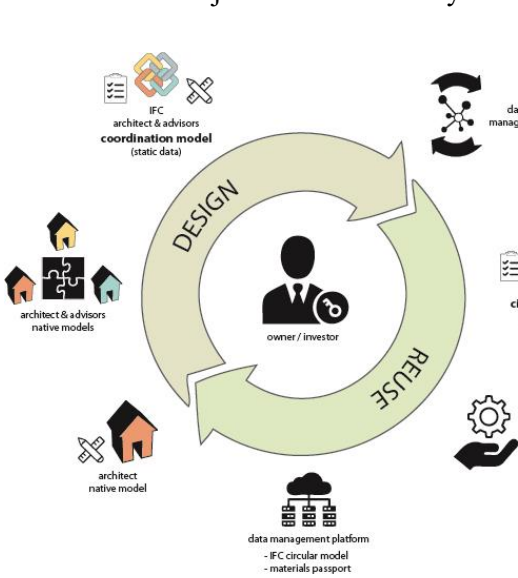

Figure 3. Coordination model as a starting point to make a circular model for the Reuse platform.

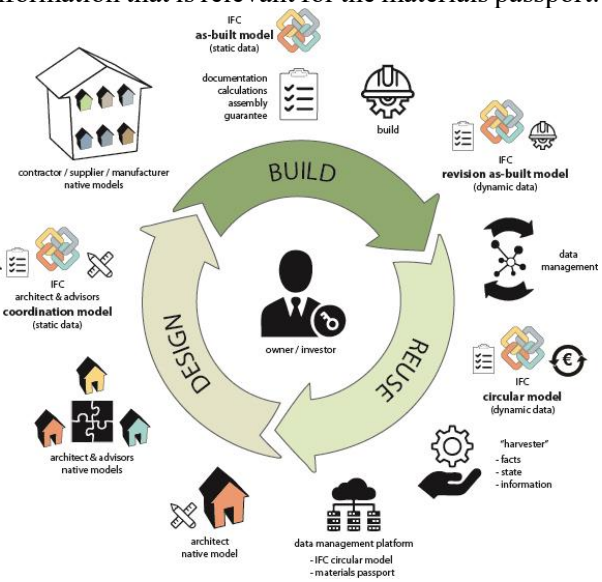

Figure 4. Revision as-built model as a starting point to make a circular model for the Reuse platform.

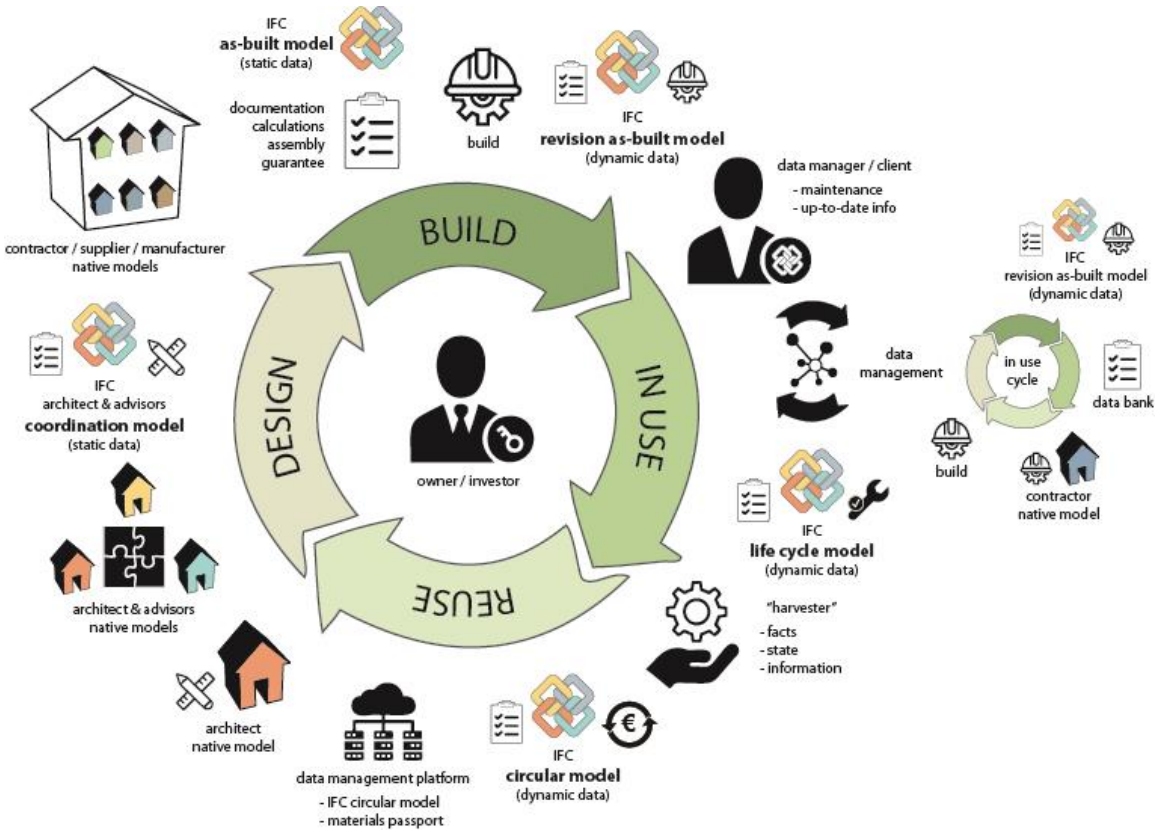

Figure 5. Life cycle model for the Reuse platform

3.4. Dynamic and static data

BIM is a good technology to bring all involved parties together during the life-cycle of a building project and share all the information among them. The consistency of all the static and dynamic data of the building is the solution to create a platform of information for the design, build, in use and reuse phases. The continuous flow of information during a BIM project needs data transfer and management in order to evaluate and predict the performance of the building and also to use it for a maintenance plan. To achieve this, it is necessary to establish the BIM data format standard, an IDM. Models at different stages can inherit component and structure data from the earlier stages, and participants of the building engineering, such as suppliers and contractors, also share data with other stakeholders. The as-build model will get more and more information which makes it more accurate and reliable. Afterwards, in the build stage, the dynamic data is used to update the BIM model so that the integrated database of the building is established. After that, the other phases can be more efficient and accurate. This process will continue during adjustments/renovations of the building. After these stages the step to a circular model is easy to make, because the information that is provided in the revision models is accurate, perfectly reliable and ready to use.

So when talking about BIM in circular design discussions, it must be clear what kind of model you mean in order to know what kind of expectations you should have about the level of detail and reliability of the information. The benefits and failures of BIM need to be measured throughout the life cycle of the building.

4. The need for effective management of data during the whole life cycle

BIM is a powerful means of sharing information. An effective data management on BIM technology can comprehensively manage information in the whole life cycle of a building. First of all, the information of the BIM model (life cycle) is parameterized, including structural geometry and physical

information, inspection information, evaluation information and maintenance history information. The main benefits rely on better communication and understanding of complex building parts which result in less failure costs. Shared data can enlarge knowledge. More knowledge makes it possible to analyse and predict certain aspects, which can improve maintenance but also improve efficient facility management. Good, preventive maintenance makes the whole process more efficient. As consequence, improved efficiency and integrated decision-making leads to cost reductions. But we must be aware that quantity doesn't mean quality. The more information is gathered, the more unreliable it can become. At the same time, it's also a fact that not everyone is open to share all their information.

As a tool that efficiently gathers important, up-to-date and accessible digital information, BIM can play an important role to validate building materials which will promote circular design as well. The only condition for having all these benefits and the best encouragement for a circular economy is that the data is accessible and reliable. To that extent, a circular model is created in advance to access all needed information in the future while a life cycle model gains both financial and circular profit out of good data management and intelligent data systems during the in use phase.

5. What is good management data

The question is: what does good data management need? The amount of information that is produced during the life cycle of a building is so extremely high that this often achieves the maximum possible capacity for the building owners' technical tools. Integrating the right project information is of great importance. In addition, the problem is that the BIM information does not yet coincide with the maintenance management program. Different information in varying formats and structures makes the exchanging process difficult. To prevent the building manager from spending a lot of time converting the information that has been supplied, a standard must be provided, which everyone can accept and follow. Research has shown that there are three possibilities for this [10]: the BIM and IFC based, the semantic web based and the information retrieval based. These different methods have their advantages and disadvantages. Good data management will have to be a combination of these three containing only their advantages. At the moment, many companies are investing on making their product information available on different platforms. This is information on RDF (resource description framework) but also IFC format. By making use of these possibilities and linking this in the IFC file, an efficient combination of data management is created. The IFC files are simplified and made more compact, links to the online database and project-specific information (own database) provide a useful data layer for the building. The information on the internet is checked by the suppliers and updated, whenever necessary, with new information. The IFC contains all the information that is needed and using links in the different elements, so the additional information can easily be found.

6. Essential models (BIM) and roles in the lifecycle process

The key aspect of using BIM models in their full potential for circularity is that they can also be used for maintenance to keep materials in a circular life cycle during the in use phase. In order to use them for maintenance, the models should be up-to-date at all times. Apart from the BIM model, which already contains a lot of information, there will also be a lot of data in other forms. We should think of warranty statements, assembly manuals, calculations, etc. (the separate data). These kinds of information are also relevant to support circular design.

A BIM model can contain a lot of information and has a high level of detail. This is exactly the strength of BIM. However, too much information could make it harder to navigate through in order to find the content we need. This is why the circular BIM model should be simplified and should only contain essential information for the specific purpose.

6.1. From destruction to reuse

Considering all the complexities related to this process, we introduce a new stakeholder, the "harvester". The harvester will be the one collecting all data, analyze it and set up a good database (see figure 6). This can be a person, but also in combination with a tool/ application/ software. When looking into how

to obtain data and the power of linking that data with IFCs, it's not BIM which is of most importance but especially the way that this data is delivered. It's important to make agreements about who delivers which information and how, where it is stored, which data is managed, and which apps can use it. The available information should not be lost, but rather be simplified, linked and compact. The harvester will convert the provided BIM model into a circular model which together with the materials passport will be placed on a data platform. The circular model clearly shows which elements (including required information for circularity) are available with the link to the materials passport (containing the required extra information). The harvester must ensure that the circular model remains up-to-date during the in use phase or determine if the circular model should only be made when the building is offered for reuse on the market.

Regardless of which model is supplied, the circular model should meet the needed requirements for the data platform to make it possible for building materials to be reused. The best way in which BIM can support this process is to consider the possibilities and benefits of the different models and use them in such a way that the least possible effort is put into preparing those models for an optimal use and by doing so, to promote circular design.

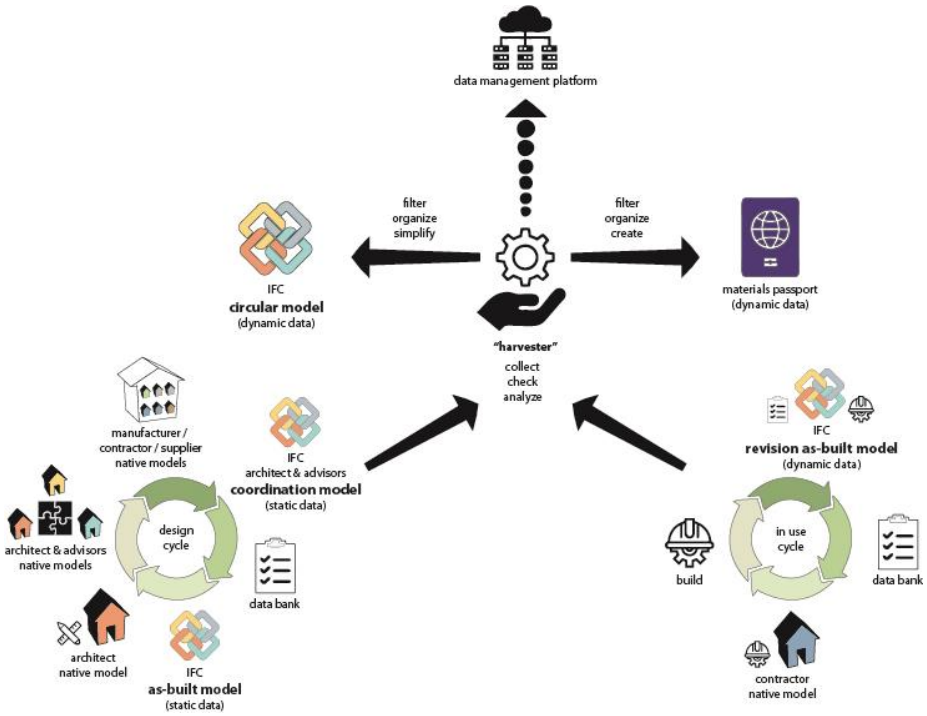

Figure 6. Overview of the different models and the importance of a harvester and data platform for circular buildings.

7. How BIM supports circular design and vice versa in an affordable way

The costs for a good BIM model have already been made in an earlier phase, in order to build a building with little to no failure costs and to make sure it is built with reliable information. This means there is already a fully functional BIM model, containing plenty of information and a database. It is a matter of linking and managing all data. It stimulates circular design with graphical information which is findable and reliable. One does not waste time searching for the right element and the accompanying information, making it highly valuable to motivate circularity.

With a clear IDM during the design phase and execution phase, there can be many advantages in creating a circular or life cycle BIM model. The more this goes together, the more benefit arises to promote circularity. Although this is already a good premise, further research must be done when it comes to IDM. The process and the stakeholders involved will determine which model has the most potential: directly making a circular model which is easy to maintain and check or a life cycle model which is good for maintenance purposes and therefore has more potential during the in use phase.

7.1. Developments

We can learn a lot from front runners like Schiphol Group, who is circulating all elements that are being used at the airport, but a lot still needs to be done and thought through. We should gain experience in using BIM together with apps for harvesting and circular design, using different models as a starting point to create a circular model. Good assessment tools can also play a big part, helping to analyse and filter which information should be added/updated to the BIM model.

We also think there will be a transition period to develop the 'life cycle model' and the 'circular model'. There will be a lot of developments involving BIM which will have influence on the effort and affordability of using BIM for circularity purposes. Block chain technology of intelligent data systems for asset management will have a positive influence on the life cycle model while developments and innovations concerning recycling technologies are more relevant for the circular model.

8. Conclusion

Circular design has a lot to gain by integrating BIM in the process. But in order to take BIM to its full potential, it is necessary to be clear on what we want to achieve with its use. The process and stakeholders involved determine what kind of BIM model promotes circular design best:

1. a life cycle model which is maintained during the in use phase and to promote circular use of the building;
2. or a circular model, made in advance, to ensure the needed information is accessible and reliable when put on a circular data platform for buildings as material banks.

Gathering and managing the information is of most importance. Agreements on how to exchange structured and relevant BIM information and clear demarcation who delivers what kind of data is needed. This leads to new tasks and stakeholders such as the one we introduce in this paper - 'the harvester' - which can be allocated to an existing stakeholder or combined with an application/tool within a circular data platform. Mutual comprehension of these tasks is needed to organize and check the gathered information. Only then, BIM can be used in an affordable and positive way for circular design.

9. References

[1] Castelein L M 2018 *Circular Contracting in the Construction sector* (TUDelft: faculty of Architecture)
[2] Adriana X. Sanchez, Keith D. Hampson and Simon Vaux, *Delivering value with BIM, a whole-of-life approach. 2016*
[3] Luscuere L M 2016 *Materials Passports: Optimising value recovery from materials* (Eindhoven: EPEA Nederland)
[4] Huurman W 2016 *Knowledgepaper: Materials passport, High-quality reuse of building elements and materials* (Delft: SBRCURnet)
[5] Slager B and Jansen G 2018 *Research conditions using Buildingmarketplaces* (Amersfoort/ Apeldoorn: Repurpose/ IMIX)
[6] Ellen MacArthur Foundation 2015 *Towards a Circular Economy: Business rationale for an accelerated transition*
[7] Durmisevic E 2018 *Potential of BAMB's Reversible Building Design Tools for the future of sustainable procurement* (Enschede: University of Twente)
[8] Finith E Jernigan Aia 2008 *Big BIM little BIM* (4Site Press)
[9] J M Juran and Pareto V 1906 *Cours d'économie politique* (Lausanne: University of Lausanne)
[10] Johannes, K., Voordijk, J. T., & Adriaanse, A. M. (2017). The use of BIM for deconstruction and reuse: Literature review and future needs. In J. Bakker, D. M. Frangopol, & K. van Breugel (Eds.), *Life-Cycle of Engineering Systems: Emphasis on Sustainable Civil Infrastructure: Proceedings of the Fifth International Symposium on Life-Cycle Engineering (IALCCE 2016), 16-19 October 2016, Delft, The Netherlands* (pp. 624-631). CRC Press.
[11] Worp A 2018 *interview 24-09-2018* (Amsterdam: Schiphol Group)