Arquitetura e Sustentabilidade

Modelo de otimização do projeto sustentável: Desmontagem e Adaptabilidade

Architecture and Sustainability

Sustainable Design Optimization Model: Disassembly and Adaptability

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Resumo Alargado

Extended Abstract

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Abstract

The present dissertation' beginning was supported on the premise that sustainability and the green and digital transition, accompanied by the development of the circular economy, catalyse the evolution of contemporary construction, namely, the emerging theme of Design for Disassembly and Adaptability (DfD/A).

From this symbiosis between technology and sustainability, arises the potential to combine technological tools, such as BIM, with the act of designing, allowing to reach levels of superior quality and materialize solutions that, until a few decades ago, didn't have the means to overcome the distance between theory and practice. Thus, focusing on DfD/A, the concepts that preceded this practice and led to the writing of ISO 20887:2020 are analysed.

The implementation of DfD/A 'principles may not be felt if there aren't mechanisms that compare and evaluate this practice with the usual construction scenarios. Therefore, it's proposed the creation of a model that evaluates the capacity of buildings and elements, to be disassembled, reused, or adapted, after the first useful life, based on the principles set out by ISO 20887:2020.

Finally, the Sustainable Design Optimization Model: Disassembly and Adaptability (MOPS-DA) seeks to provide an assessment framework that assists in the design process based in the DfD/A principles. This tool was applied to two Case Studies, demonstrating, firstly, that a building with a construction that follows the DfD/A' principles, has a higher degree of circularity than a reinforced concrete construction and, secondly, that there are new solutions and several possibilities for the model' evolution.

Key Words:

Sustainability
Circularity
BIM
Architecture
Disassembly
Adaptability

1. Introduction

1.1. The Pillars of DfD/A

In 2020, the ISO 20887:2020' publication, stablished all the DESIGN FOR DISASSEMBLY AND ADAPTABILITY (DFD/A)' standard definitions, removing prominence from the definitions suggested in the past.

However, throughout history there were four main pillars that provided the base for the emergence of this concept, and whose advances have come to play a significant role in the growing acceptance and implementation of DfD/A, and of the respective ISO: 1) Sustainable Development; 2) Sustainable Architecture; 3) Circular Economy; and 4) Twin Transition (Green and Digital Transition).

Supported by new software and new ways to perceive the impact that the construction sector has in the environment, these four pillars have helped to develop several frameworks that aim to evaluate the circularity and sustainability on projects, and guide the architects, engineers, and any interested entity, to build accordingly to the sustainable architecture practices. And, although these developments have resulted in tools that evaluate and certificate the sustainability in a project, none of the existing frameworks - such as LiderA, SB ToolPT, Code for Sustainable Homes, BREAM, LEED, One Click LCA, etc.-, has begun to explore the analysis of waste and durability of materials. And, consequently, none of these frameworks offers a guide to evaluate and analyse the disassembly and the adaptability of a project.

1.2. The Concept of DfD/A

Currently, the use of traditional construction methods that do not consider future disassembly or adaptability still occupies a significant percentage on the new constructions. As such, if the construction sector continues to encourage a construction without circular concerns, scenarios like demolition, or buildings that have components and materials not so easily reused/recycled will continue to contribute for the increase of the waste deposited in landfills.

Thus, the incorporation of DESIGN FOR DISASSEMBLY AND ADAPTABILITY (DFD/A) throughout the planning and designing process brings a perspective of total resources, contributing to the end of life of assets (disassembly, reuse, recycling, etc.) and to reduce costs spent on building maintenance (repairs, replacements, or renovations) (ISO 20887:2020, 2020).

Design for Disassembly (DfD) is a growing topic in the AECO sector, as it is a practice focused on end-of-life management of buildings and for presenting innovative solutions to reduce the loss of resources, materials, and energy, as well as to reducing the polluting impact of this sector (O'Grady et al., 2021). This way, the complementarity between the principles of Design for Adaptability (DfA) - versatility, convertibility, and expandability-, and the principles of DfD – ease of access to components and services; independence; avoidance of unnecessary treatments and finishes; supporting re-use (circular economy) business model; simplicity; standardization; and safety of disassembly – can help prevent the total demolition of buildings and reuse a major part of its constituents.

1.3. Objectives

Nowadays, the study and theorization of new sustainable architecture solutions is increasingly developed. However, many practical applications are not yet found to support the theory already developed, making its expression very scarce.

Therefore, it is proposed to develop a process of research for references, standards and investigations that would help to answer the main questions proposed for this Thesis: "MAY THERE BE A MODEL THAT ALLOWS THE EVALUATION OF DESIGN FOR DISASSEMBLY AND ADAPTABILITY IN A PROJECT?" and "WHAT CONTRIBUTION CAN A TOOL LIKE MOPS-DA ADD IN THE TRANSITION BETWEEN THE THEORY AND PRACTICE OF SUSTAINABLE ARCHITECTURE?" – with regard to sustainable architecture and DfD/A.

In response to the first question, it is proposed the development of the Sustainable Design Optimization Model: Disassembly and Adaptability (MOPS-DA), which will consist of a framework where any project can be evaluated based on the DfD/A principals and on a classification system that will be applied based on the level of compliance with these same principles.

Secondly, the results obtained from the MOPS-DA appliance to two national study cases, and by taking advantage of the potential of BIM in the context of project simulation and optimization, it will be possible to obtain answers to the second question, and raise interrogations and future developments of the model and the implementation of DfD/A.

2. Methods

After a clarification of the various themes that stimulated the progress of the DfD/A, and a survey of the State of the Art on the subject, all the principles set out in ISO 20887:2020, characterizing the DESIGN FOR DISASSEMBLY AND DESIGN FOR ADAPTABILITY, are explained, in order to clarify the main theme of this dissertation and understand the premises that will precede the model that will be developed.

In the model elaboration phase, based on ISO 20887:2020, the set of principles inherent to the DfD/A is analysed, and the forms of measurement for each of them are developed. While developing the model, it is understood that it will be easier to divide the framework in two parts, as suggested by Dams et. at (2021): The principles regarding to the building (Tab.1) and the principles regarding to the elements of the building (Tab.2).

2.1. Evaluation Criteria

Following the methodology of the model, and based on the ISO in question, it was proposed the development of a scope of levels that can guarantee a consistent evaluation of the DfD/A principles. Thus, the evaluation criteria will receive a final evaluation between the minimum level, 0 (not sustainable) and the maximum level, 5 (sustainable). Level 0 is the most negative rating and level 5 is the most positive rating. Expecting that the assignment of levels, to the analysed buildings, will require both a qualitative and quantitative assessment, each level will correspond to a percentage range or a Yes-No answer according to Annex C of ISO 20887:2020.

Based on the analysis of previous frameworks and studies, it was concluded that the definition of percentage intervals depends on the exploration of considerations such as the materials used, the assessment of the asset's life cycle, the circularity of the asset' elements, the life expectancy of the project or it's durability, the connections, the standardization, the reuse of elements, the foundations, the use of BIM software, etc.

Consequently, the analysis of the design principles for Adaptability and the design principles for Disassembly will be the main support for the decision making on the assignment of levels to each parameter to be evaluated.

2.2. The Model

Once the criteria and principles to be included in the Sustainable Design Optimization Model: Disassembly and Adaptability (MOPS-DA) have been formalized, it will be possible to evaluate any building and analyse Case Studies, already built or in the design phase.

Thus, it is expected that the analysis of the Case Studies will corroborate the ideology that a model can support architects, engineers, builders, or any other entity interested in building DfD/A projects, to help building a bridge between the theory and practice.

Tab. 1 MOPS-DA: Building Level

	Parameters				Criteria	Building 1
Building	Adaptability	Versatility			% of available space	
		Convertibility				
		Vertical Expansibility (without significant changes to foundations)			% of possible growth of floors (in height)	
		Horizontal Expandability			% of additional area available	
	Disassembly	Design Simplicity	Number of parts per element		0 (> 5 parts) – 5 (1 part)	
			Standardization and modular construction	Similar Dimensions	0 (very variable, usually made to measure) – 5 (minimum or zero variation and modular)	
				Variation of components		
				Connections		
		Security and health	Use of toxic or synthetic chemicals		0 (high toxicity) – 5 (no toxicity)	
			Ease of access to connections for safe disassembly		0 (inaccessible) – 5 (accessible with safe distances)	
		Independence	Element independence degree	Parallel assembly/disassembly application instead of sequence	0 (low, sequential order, assembly hierarchy) – 5 (high, parallel order, independent)	
				Hierarchy		
	Available Information	Disassembly plan with specifications included in the drawings			0 (no plan) – 5 (clear and comprehensive plan, easy to understand and follow)	
		Disassembly Sequence Information			0 (non-existent) – 5 (easy to follow, complete)	
		Clarity of plans			0 (incomplete, unclear) – 5 (complete and clear)	
		Use of BIM software to store and organize information			0 (no BIM model or any database) – 5 (BIM model with several built-in dimensions and complete database)	
Total						

Tab. 2 MOPS-DA: Element Level

	Parameters		Criteria	Elem. A	Elem. B	Elem. C
Element	Material Information	Suppliers	0 (no information) – 5 (complete information)			
		Production Site				
		Potential for Donor Building				
		Reused or Recycled Material	% of the element			
		Reuse costs / restorations / cleanings	0 (N/A or extensive) – 5 (non-existent)			
		Full Life Cycle Assessment (LCA) with End-of-Life Scenario	0 (LCA without information or non-existent) – 5 (LCA complete)			
		Complete and Available Environmental Product Declaration (EPD)	0 (non-existent EPD) – 5 (complete and available EPD)			
	Finishes and Treatments	Chemical Coatings	0 (Yes) – 5 (No)			
		Finishes with synthetic chemicals and resins				
	Reversible Connections		0 (Cannot be reversible) – 5 (Easily reversible)			
	Circular Construction	Ability to reuse elements without restoration or modifications	% of element that can be reused			
		Ability to recycle elements without undergoing degradation	% of element that can be recycled			
	Standardization	Standard Dimensions	0 (very variable, usually made to measure) – 5 (minimum or zero variation and modular)			
		Modularity				
		Interoperability	0 (Not flexible when used in another context or in connection with other components) – 5 (Very flexible when used in another context or in connection with other components)			
	Durability	Number of previous useful lives	0 (virgin material) – 5 (≥5 previous uses)			
		Average duration of previous useful lives	0 (0 years) - 1 (10 years), 2 (20 years), …, 5 (≥50 years)			
		Expected duration for current useful life				
Total						

3. Results and Discussion

3.1. Case study analysis

In the stage of the model testing, two national Case Studies are applied to the previously developed model (MOPS-DA) – two buildings designed by Casais Group, one located in Guimarães and the other in Oeiras. Given the role of DESIGN FOR DISASSEMBLY AND ADAPTABILITY (DfD/A) in the model in question, both analysis followed the same logic and will be complemented by the State of the Art on the subject.

3.2. Case Study One - Hotel Unit of the B&B Hotels Group

Fig. 1 Construction of CE 1 (Grupo Casais, 2021)

Located in Guimarães, this Casais Group project, Case Study 1 (CE 1), corresponds to the first hybrid construction building in the Iberian Peninsula. Given the diversity of programs – hotel, multifamily housing, and commerce – the different floors of the project reveal different characteristics, depending on their uses (Grupo Casais, 2021): the first two floors, -1 and 0 (garage and commercial area), have the entire structure in reinforced concrete. Meanwhile, floors 1 to 4 (hotel and apartments) are built on a hybrid wood-steel-reinforced concrete structure, also called CREE, which significantly reduces the building's footprint in the atmosphere.

3.3. Case Study Two - B&B Hotel Lisbon Oeiras

The second Case Study (CE 2), also a recent project by Casais Group, introduces a 3-star hotel, located in Oeiras, called B&B – Hotel Lisbon Oeiras.

With a structure mostly built in reinforced concrete and masonry walls, the project presents a construction system traditionally used in the Portuguese contemporary architecture. However, buildings with a constructive system based on reinforced concrete have been increasingly moving away from the sustainable and circular architecture, making this building an ideal case study for raising questions about the present and the future of construction.

Fig. 2 Construction of CE 2 (Autor)

3.4. Result of visual format and rating scale

As previously explained, the MOPS-DA consists of two analysis' scales: 1) the analysis of the building and 2) the analysis of the elements and components used in the building. Thus, the model criteria were developed to consider the possibility of the building being adapted or extended, during the design and planning phases, or after them.

In both Case Studies, the same evaluation criteria were applied and as expected, the scores varied according to the construction system. Based on the principles of ISO 20887:2020, it was possible to confirm that the evaluation method developed can analyse the circularity of each of the buildings and predict their impact on the environment. It is important to mention that this study does not analyse additional sustainable measures to construction such as the application of solar panels, seeking to focus on the sustainability of the building.

3.5. Comparison of the two case studies

MOPS-DA is designed to analyse LCA considerations, end-of-life scenarios, the potential to reuse materials or elements, and provide a numerical sum of all parameters evaluated, as a result of the level of circularity of each evaluated project, according to ISO 20887:2020.

After analysing the results of the two Case Studies – one with a reinforced concrete-based construction system, and another that corresponds to the principles of disassemble and adaptable architecture – the results obtained showed that reinforced concrete architecture does not approach the minimum values that are considered sustainable. This being a common practice in Portugal, the impacts are significantly negative on the CO_2 footprint in the atmosphere.

During the evaluation, CE 1 obtained results above expectations, both in the scale of the building and in the scale of the elements, demonstrating the high potential of the CREE system, not only in the significant reduction of the environmental impact, but also in the innovation and excellence of this type of construction. Therefore, the adaptability of the construction associated with the support of BIM, where all the information related to the project is stored and the standardization of the elements, reinforce the sustainability and circularity of the solutions that comply with the DfD/A principles. On another hand, the evaluation of CE 2, tended to a lower score, given that a large percentage of the structure is made of reinforced concrete.

Thus, during the parallel analysis of CE 1 and CE 2, several determining elements emerged in the score that both obtained: 1) By using plasterboard walls and reversible connections, both CE 1 and CE 2 offer a good prospect of convertibility of the interior space, without compromising the exterior limit of the buildings; 2) The elements that make up the hybrid construction system of CE 1 are documented with drawings and detailed information, allowing their future disassembly; 3) While the reinforced concrete structure of the CE 2 has to be assembled in a hierarchical way, the elements of the structure of the CE 1 building can be assembled in parallel and subsequently dismantled, if necessary; 4) Most of the CE 1 elements are modular and prefabricated, while the CE 2 elements have to be created in-situ; 5) The wood and steel applied in CE 1 can be reused, which makes the project more circular in relation to reinforced concrete construction; 6) Both projects are developed in BIM, allowing easier access to information in future interventions.

Both case studies are recent projects, so the analysis were carried out based on the first useful life, that is, for the first 50 years of the building.

However, given the CE 1 solution, which meets all the functional and mechanical requirements that the CE 2 solution offers, and still significantly surpasses the sustainability and circularity of the second solution, it is expected that the discrepancy between the scores of the two Case Studies will highlight the improvements that the implementation of sustainable practices in architecture, such as DfD/A, can bring to the future of the construction sector.

4. Conclusions

This dissertation arises from the desire to find critical answers to the gap between the theory and practice of the DESIGN FOR DISASSEMBLY AND ADAPTABILITY (DFD/A).

As a discipline in constant metamorphosis, architecture is now undergoing a circular and sustainable transformation, in which DfD/A plays a key role.
When analysing ISO 20887:2020, it is understood that there is no evaluation method that allows this practice to be evaluated in any building. Thus, the first question arises: CAN THERE BE A MODEL THAT ALLOWS THE EVALUATION OF DESIGN FOR DISASSEMBLY AND ADAPTABILITY IN A PROJECT? The research conducted in this dissertation, based on the scientific material available on DfD/A, answers the previous question by proposing a project analysis framework that could become a tool to support the designer's decision-making: the SUSTAINABLE DESIGN OPTIMIZATION MODEL - DISASSEMBLY AND ADAPTABILITY (MOPS-DA). The Case Studies analysed by this method prove that the better the compliance with the principles evaluated in this model, the better its evaluation and the better its circularity and sustainability. Consequently, by evaluating projects by levels, it will be possible to understand how developed the project is, regarding the application of DfD/A principles and how it will impact the environment. Subsequently, the development of the MOPS-DA made it possible to deepen its relevance as a working tool that may help to build according to the DfD/A principles and, therefore, in a more sustainable way. Thus, a second question arises: WHAT CONTRIBUTION CAN A TOOL LIKE MOPS-DA ADD IN THE TRANSITION BETWEEN THE THEORY AND PRACTICE OF SUSTAINABLE ARCHITECTURE?
By having a tool that guides the creation of a DfD/A project, the architect can more easily design according to the Disassembly and Adaptability premises, materializing the principles set out in ISO 20887:2020. Thus, it will be possible to start a new generation of buildings that are more circular and that will be designed from scratch to have more than a useful life.

By developing a model that allows the assessment of DfD/A in a project, it can serve as a support tool for the project, to contribute to the development of sustainable architecture.
The creation of a new tool allowed to question whether the available tools until now were being fully explored. For example, the development of MOPS-DA clarified the fact that it was possible to develop new BIM parameters that could be included in the modelled objects, characterize their DfD/A level, and based on the developed framework, evaluate their disassembly and their adaptability.
Through the positive results, which were obtained in the analysis of the case studies, it is understood that sustainable and circular construction systems, such as CREE, which

complies with the principles of DfD/A, equal all the valences of a reinforced concrete constructive system, and still offer new valences that come to respond to the current needs of society and the planet – A cleaner, greener, and more circular architecture.

In this thesis, the development of the model was catalysed by the knowledge of two areas: Sustainable development and technological development. In this way, the evolution of MOPS-DA will have consequences in both areas of study, ending up taking advantage of their intersection. And, although BIM was not used to the extent that it was intended, due to the impossibility of accessing the BIM model of the projects, this same factor allowed reflection on the questions:

WHAT IS THE ROLE OF DIGITAL IN PURSUING A SUSTAINABLE PRACTICE?

Although it wasn't a fully answered question by this dissertation, the study of programs and models that analyse aspects related to the carbon footprint of an asset, at the LCA level, raises the hypothesis of transferring the knowledge of DfD/A to the development of a program, compatible with BIM software, and from which it would be possible to extract life cycle assessments through the model.

WOULD IT BE POSSIBLE TO PUT MORE OBJECTIVITY IN BIM?

Future studies could focus on the creation of a BIM parameter, which would assess the disassembly and adaptability of elements and projects, through the respective BIM models. Thus, by transferring the knowledge developed in the construction of the MOPS-DA, to a BIM software, it would be possible to develop and assess, in a more objective way, projects according to the DfD/A principles.

5. References

DAMS, B., MASKELL, D., SHEA, A., ALLEN, S., DRIESSER, M., KRETSCHMANN, T., WALKER, P., EMMITT, S. (2021). A Circular Construction Evaluation Framework To Promote Designing For Disassembly And Adaptability. Journal Of Cleaner Production, 316.

GRUPO CASAIS. (2021). Memória Descritiva e Justificativa do B&B Guimarães. Departamento Técnico Grupo Casais.

ISO 20887:2020. (2020). Sustainability in buildings and civil engineering works-Design for disassembly and adaptability-Principles. ISO Standards.

O'GRADY, T.; MINUNNO, R.; CHONG, H. Y.; MORRISON, G. M. (2021). Design For Disassembly, Deconstruction And Resilience: A Circular Economy Index For The Built Environment. Resources, Conservation And Recycling, 175.