FINAL REFLECTION

{FACADE REVERSE LOGISTICS}

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When it comes to the Built Environment, several perspectives can be identified. It has been always related to the aesthetical dimension, not only providing space for people to be but also to be inspired. It must be solid and also functional. The current discourse has shifted towards these last aspect, defying the idea of a purely beautiful architecture. It is today's context — material scarcity and global warming — that has promoted the exploration of concepts such as sustainability and circularity. It was then valuable to choose such theoretical background to develop the thesis work. In the specific case for Reverse Logistics, not much literature and research have been conducted. The few authors found do mention such facts: RL has not been fully investigated— not to mention applied— due to the several variables that go into the design and construction processes.

RELATIONSHIP RESEARCH-DESIGN

The reverse logistics topic in the construction industry has the particularity of being a relatively new subject in its first steps of exploration. Given this, the research part of the current thesis project was predominant. The intention since the beginning was to use such material and apply it in a tangible methodology and eventual design exercise, as this has not been conducted in most of the previous research works. From the building technologist perspective, design can greatly facilitate the implementation of reverse logistics for facades. It is one step that makes circularity more achievable. It was my role to link the findings made in the first stages, and that I am currently still doing, to the design dimension for a proper illustration of the theory.

Figure 1 *Basic RL concept*

I have realized during the research process that design is not the only barrier preventing a proper implementation of reverse logistics, it is mostly the economic and legal aspects that block the system. This is also a good reason for the thesis to include the logistics part, in which such aspects are highlighted, even if my area of studies does not address them. Just be laying everything on the table, a discussion can be encouraged, allowing other experts to bring their knowledge and experience. The following steps are directed to start this process, input being the most valuable asset to inform the overall topic.

RELATIONSHIP TOPIC-TRACKS

Even if not immediately evident, Façade Reverse Logistics is directly intertwined with the Building Technology Master Track a sit responds to one of the most urgent needs in the construction industry: less resource consumption. The built environment is known for consuming 40% of the resources on earth due to the linear economy model being followed since the industrial revolution. As comfortable and easy as it is to construct and manufacture our products in such ways, they are the most unsustainable and irresponsible. They are leading the planet to a delicate state, a point of no return where global warming and pollution would not allow to follow the common consumerist lifestyle we are used to have. It is logic then to pose the question from the Building Technology discipline, how can our processes and design have a less negative impact in the environment? Not even that, but how can we have no impact or even a positive one when building? By applying circularity strategies, the way we design and construct would allow to close loops and use the resources to the fullest, without having any waste or consuming unnecessary energy in the process.

There is also the link "reverse logistics" has with the master program, Circular Built Environment (CBE). Circularity is a new economic model that prevents having any waste, by introducing a cradle-to-cradle approach to the current flows. Instead of having a normal forward logistics, a reverse one must be implemented to close such productive loops. The topic focuses on this specific part: what needs to happen during this stage and what strategies must be implemented to avoid products turning into waste or a downcycle process.

METHODS & PROCESS

To address this particular research, an extensive literature research was conducted as well as a series of interviews with experts from the façade industry. They gave input on how RL is perceived and how feasible it is to be applied in real practice. Such method was highly effective, as the thesis is a "one of its kind" — no previous examples were found that could serve as starting point— and it was necessary to set those foundations. The way to reflect the findings generated the idea of the framework creation. This marked the start of the design phase. Even if it is unconventional for a creative exercise to consist on more methodology creation, the proposed RL

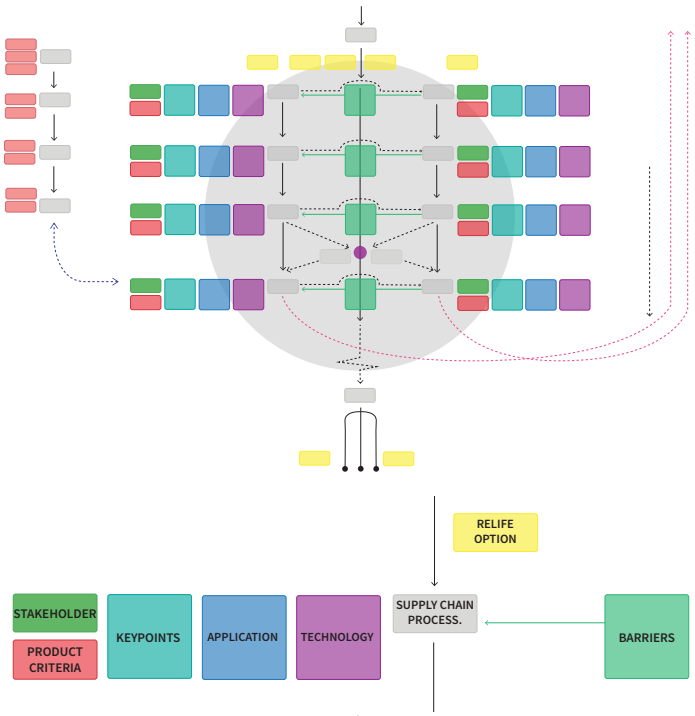

Figure 2 *Framework components*

framework paved the way for a deeper understanding of the topic and its context. Such product was complemented with the proposal of the DfRL (Design for Reverse Logistics) criteria, a concept that still needs to be explored and put to the test. Both formats were used in the Application phase to evaluate a specific product. They proved to be of good use and gave basic notions on the considerations for RL implementation. Finally, the Design Phase turned the lessons learned from the previous chapters into conceptual ideas. Brainstorming and discussion with the mentors indicated that developing ideas for the specific product being addressed was less useful than if the exercise transferred the knowledge to bigger contexts. The final design speculates on the office of the future, having RL practices at its core. It translates— at least from the designer's point of view— the criteria and requirements RL suggests.

All of the process and methods employed in the research worked well and complemented each other to result in a coherent storyline. It must be noted, however, the initial intention was to validate the results— especially the framework— in the scheduled workshops in June. The current situation (referring to the Corona pandemic) didn't allow for those workshops to happen, part of the Façade Relog event that TU Delft is organizing along with other institutions and companies. The goal is to generate knowledge and awareness in the industry to bring Reverse Logistics into the picture. The project will run for two years, and even if it was not possible to apply the framework and validate it with experts, it will be valuable to use it in the future to have input form others. This will enhance the developed methodology and make it a more informed tool.

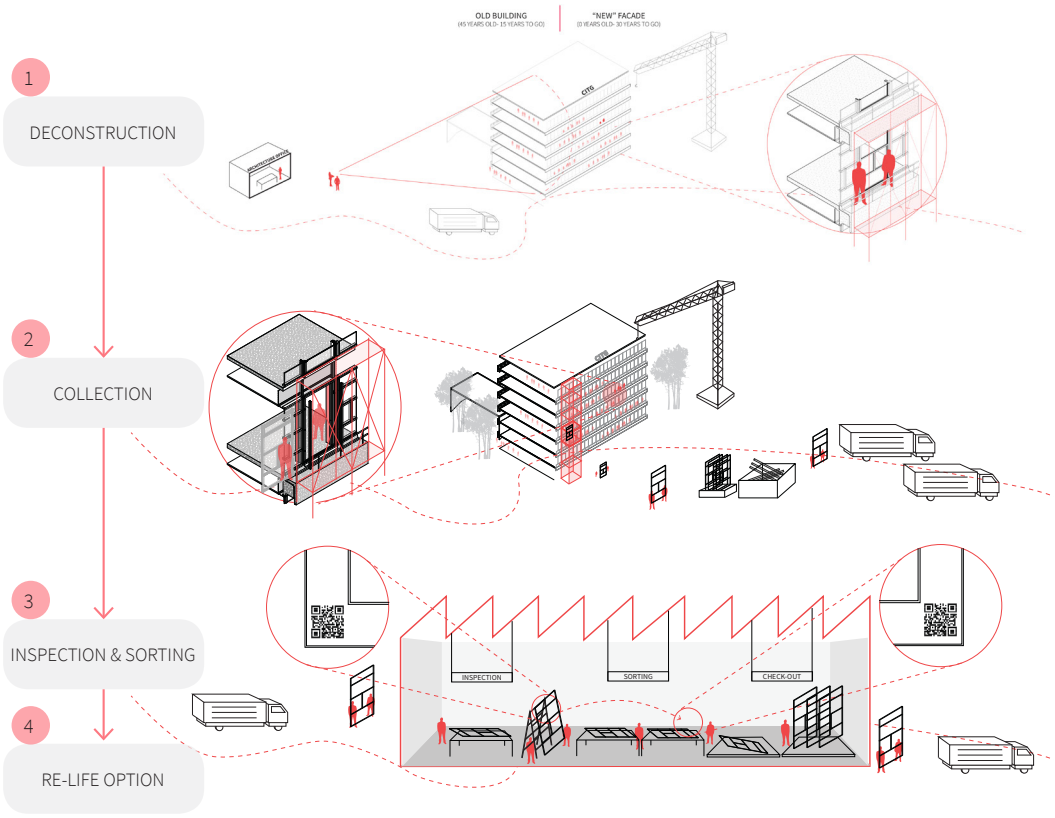

Figure 3 *Partial view of RL process*

FEEDBACK DYNAMICS

During the whole process, feedback from the mentors was highly valuable. It helped shaped the research and their insight was a great contribution. Given the author tends to maximize in content, their restraint and simplification advice helped on developing a more understandable and digestible product. Their expertise and connection to theory informed all the stages of the research and kept it up to date. Even if the Façade Relog event was not possible (whose intention was to shape the framework being developed), their input provided enough material to work with and bring cohesion to the findings and results. In this sense, I learned not only about the topic and how relevant its implementation is, but on how to present the information and tell a simple story that everyone can grasp.

DESIGN & RESEARCH RESULTS

The research methods chosen- mainly consisting on literature research and interviews- lead to an eventual design that would translate the findings into intangible/tangible products. The first was the Reverse Logistics framework that gives an overview of the necessary steps and requirements for it to be implemented. It opens the discussion and hopefully raises awareness. The DfRL criteria is also a product that proposes a way of evaluating and informing the design phase, drawing from the previously developed circularity assessments. The application of both formats is also a result in itself, as it serves to visualize how a specific product might look like when going through the developed methodology. Having such visual application will not only benefit students but also the industry to better understand their role in the new economic model. The eventual design exercise is the culmination of the research, as it brings an end to the storyline by putting into a physical product the foundations laid in the previous steps. It represents a façade system that could be compatible with other buildings based on modularity and light standardization, a much-needed strategy if buildings are to be used as material and product banks. In conclusion, because reverse logistics has not yet been adopted by common curriculum in architecture

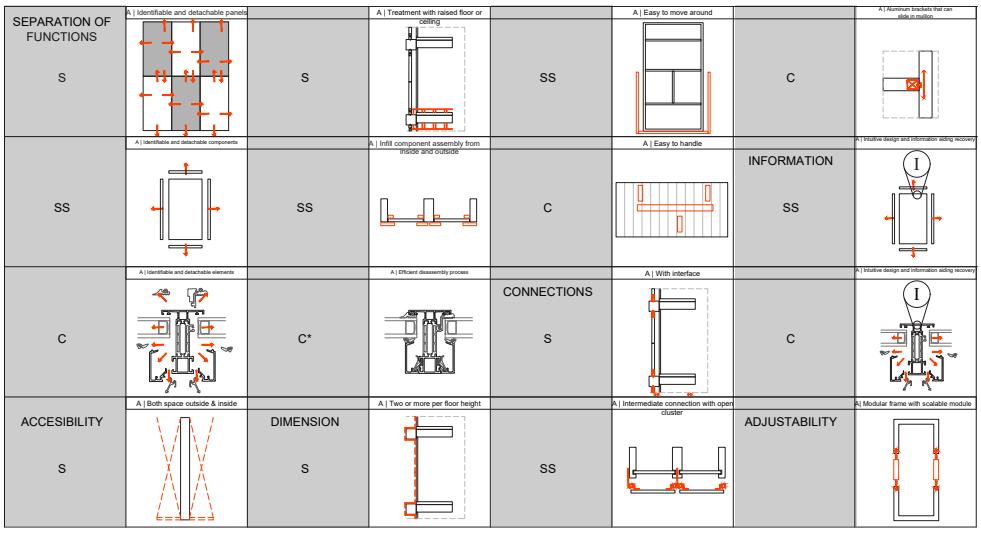

Figure 4 *DfRL synthesis*

schools or in general practice, it makes sense to first dive into the more theoretical background just described, to understand its roots and implications. It is then that it can be translated it into more digestible methodologies and designs.

ISSUES ENCOUNTERED & LIMITATIONS

Figure 5 *Design exploration*

Due to the recent exploration of the topics, the industry and governments are still having questions on how to implement reverse logistics, and if it even makes sense to do so. The main dilemma encountered was the lack of initiative taken by governments in their legislation or construction application form building offices. Because the current linear model is so comfortable, convenient, and especially economic, almost no one questions the way of doing things. The rest is considered an impassable challenge that simply cannot be faced. General education of society is also a major barrier for a proper implementation: no one wants used products; they are thought to be of less quality. Supply must be met by a corresponding demand: if remanufactured/reused products are to be produced, a market must also want to acquire them and use for a new life. Hopefully, at the end of the research, the physical design of the façade can reflect so well the reverse logistics requirements, that it can leave more than one wondering of its application in the real industry. Hopefully, the developed methodology can serve for future development of the topic and new research to come.

As for the limitations, reverse logistics is still an unfamiliar topic, it is taking its first steps in the construction industry. It being part of circularity, will be explored in the near future, especially in an era where digitalization is predominant. Due to time constraints, having a deeper understanding of the various topics surrounding RL was not possible. Topics like supply chain process, system-thinking, transportation optimization and stakeholder coordination might be among the relevant topics. The overview developed gives opportunities for others to study and analyse the unknowns highlighted throughout the research. The most relevant variables to focus-on are highlighted in the Descriptive Assessment Framework, in the Application Information Boxes. They are quantifiable factors that would be good points of reference

when analysing the different re-life scenarios. For instance, defining how much more expensive is to deconstruct than to demolish or how much preparation it needs is highly relevant. Even though some of the mentioned aspects are more abstract than others, estimations are enough to serve as initial indicators.

Besides, experimenting with physical models was not possible: first, because of the time constraint and the extensive research work, and second because of the physical confinement everyone was subject of. Having physical models would take the research to the next level, by relating the actual design of a product and how it is assembled with the reverse logistics process behind. Having a partnering company would be useful to build such model. In the case of the current research, VMRG was more information-oriented, which enriched the theoretical research. A façade supplier would be the best match for the model exploration.

Finally, having the current circumstances (referring to the Corona outbreak in 2020), the validation workshops in which the framework would be put to the test were not conducted. This is considered a major step of the process: to have direct input from industry actors, who ultimately are the intended users. Their insights might confirm the thematic organization and the ways in which the ideas can contribute to an overall theory.

NEXT STEPS

As stated in the first chapter, the current research offers a more longitudinal than transversal vision of the topic. The research gave an overview of the Reverse Logistics when applied to facades, addressing the various stages and relevant points to consider. It is due to this broadness that several of the points mentioned could be taken into different research projects and be further developed. The industry now needs hard data and evidence to apply Reverse Logistics in their supply chain. An initial Quantitative Assessment was performed in the last chapters, to suggest a way of comparing different scenarios. Exploring new calculation methods that can take into account the subtleties of each scenario would be relevant and highly useful for the industry. Even the Qualitative Assessment, substantially

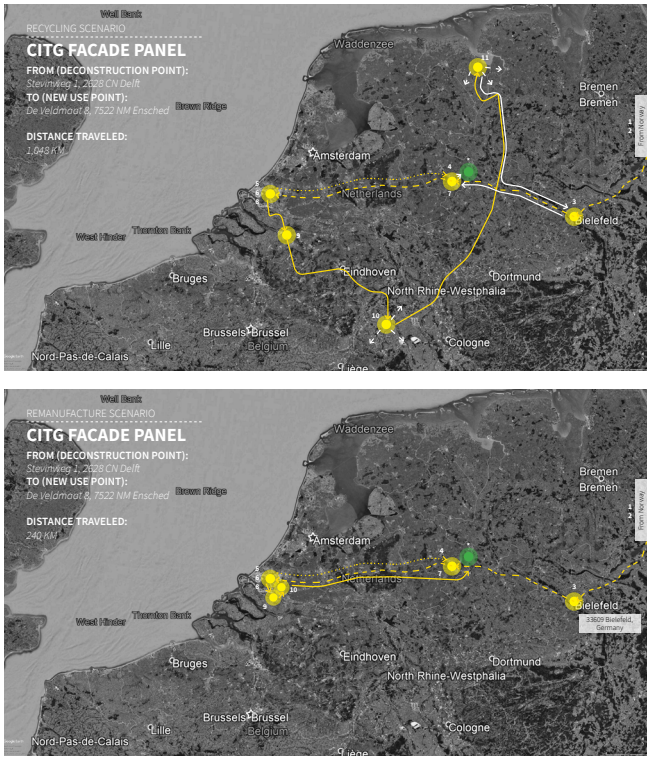

Figure 6 *Geographical assessment*

explored in the current research, is also open to transformation and feedback from other perspectives. The format should be developed to be the friendliest and most understandable to be used in the practical world.

As highlighted in various occasions, money is one of the biggest barriers. Understanding the differences in cost and how a façade being reused or remanufactured can be treated so it is still a convenient product to acquire, is vital. Analysis on financial feasibility is one of the most urgent aspects to explore, as showing the potential saving would directly speak to investors and clients. Also, calculating the environmental gains when reusing as well as the burdens that recycling represents is key to put forward the idea of closing loops more efficiently. Energy and carbon dioxide footprint are two of the indicators that can be used to bring clear references of environmental impact.

Finally, physical modelling of the developed concepts is also a subject to address, as having physical products always helps on concretizing theoretical concepts. The models should not only focus on panels that can be disassembled, but also interfaces that enable interchangeability. It is in the connections and intermediaries that recovery is assured, and such topic has not been addressed enough. Focus on who must be in charge of the coordination and creation of such interfaces must also be defined, as confusion is common in current practice when it comes to their responsibility.

RELATIONSHIP SOCIAL AND BROADER CONTEXT

Reverse logistics is one of the most relevant construction topics when it comes to the social context. It isn't without the cooperation of society that a full implementation is possible, and if it is, it will benefit the environment and society equally. Apart from the benefits highlighted in the literature research, having a fully circular built environment will ensure a more responsible practice where society's future is respected. Professionally, the topic is relevant as it is still to be applied into real practice, and it is a top priority given the current situation of material scarcity.

Having in mind an eventual transferable model to the professional world, the current project develops a framework that can be filled with information from other cases or products. It is versatile as it allows any feedback coming from different experts inside or outside the industry. When having talks with the assigned mentors, a high value was given to the development of such framework, as it organizes the topic in a simple way and serves as canvas for future explorations and findings. After validation workshops, it's value can be assessed and it can also be further refined to accommodate the different perspectives from the industry.

Besides the mentioned relationship, awareness material destined to the general public and he industry was formulated. RL demands a dissemination of information to make the public more aware and informed about the current needs. Lately, such efforts have been emerging, but non have regarding RL in the construction industry. It is concluded that a market of reused products can only be assured once society is fully conscious.

Figure 7 *Future vision*