“Unitized Curtain Wall Systems for Truly Double-Curved Facades”

Mar Muñoz Catalina

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“Unitized Curtain Wall Systems for Truly Double-Curved Facades”

Author:

M. Muñoz Catalina
Student number: 4116194
Building Technology - International Facade Master
M.MunozCatalina@gmail.com

First mentor:

Dipl. Ing. T. Klein
Building Technology - Facade Research Group

Second mentor:

MSc Arch. M. Turrin (SBA)
Building Technology - Design Informatics

Internship mentor:

Ir. M. Molenaar (MSc)
Scheldebouw B.V. - Design and development

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This master thesis was realised in collaboration with the company Scheldebouw B.V. in the framework of an internship agreement.

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PREFACE

This research thesis is done in joint cooperation with TU Delft, through the International Facade Master at the Building Technology department, and Scheldebouw B.V., an international facade manufacturer for custom-made facades.

The aim of this research is to show the complexity of designing a double-curved facade with double-curved insulating glass and facilitate this task in practice for future designs which face these sort of challenges as well as serve as general knowledge for those doing further research in this topic.

Furthermore, I would like to thank my mentors at TU Delft Tillmann Klein and Michela Turrin for their guidance and support and the team of Scheldebouw B.V. for giving me this great opportunity. I also want to thank Mark Molenaar, my mentor during my internship at Scheldebouw who dedicated a lot of time to facilitate me all the needed information and was always available to answer my questions.

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1. ABSTRACT

With the increasing complexity in facades due to technical demands and the building performance requirements, the market has become more and more specialized in maximum prefabrication, standardization and preassembly of façade components in order to get a higher quality and minimize the work on site. Using these same principles, Scheldebouw is specialized in custom-made unitized curtain wall design for buildings in the top end of the building market.
Nowadays, among these buildings there is an increasing demand for glazed double-curved facades which are typically approached with faceted facade design solutions.

The aim of this research was to find out whether the current unitized curtain wall systems' strategies can be used for truly double-curved facades with double-curved glass and, if so, inform facade contractors (in particular: Scheldebouw B.V.) and Architects about the complexity that designing a double-curved unitized curtain wall system means and propose a concept unitized system solution for a target group among the double-curved facade scenarios.

The research strategy consisted on having three sub-fields of research: unitized systems analysis, geometry research and material research being the conclusions of these three combined in a final scenario to define the final scenario for the design development phase.

Among the double-curved building morphologies the target group chosen was the "Twisted Extruders" from which the most complex variation, "Floor-based Twisted Extruder" was selected as final scenario for the design development phase.
This scenario would, in principle, mean that double-curved insulating glass, straight+twisted or single-curved+twisted transoms and single curved+twisted mullions would have to be used.
After the material research we can assume that large double-curve insulating glass units are possible within admisible tolerances but we cannot assume that the aluiminium curtain wall profiles can be twisted with the accuracy needed for the correct performance of unitized systems.

Therefore, the design development phase focused on the design of a unitized system for the "Floor-based Twisted Extruder" using double-curved insulating glass, straight or single-curved transoms and single curved mullions. The use of non-twisted profiles led to several rotations or deviations in the cross joint (where four units meet) as well as to varying angles between the glass unit and the load-bearing curtain wall profiles.

The final system design proposal achieves solutions for these challenges using the typical unitized systems' strategies except for the varying angle between the glass unit and the aluminium curtain wall profile which is solved by placing local blocks on the external face of the profile, cut at different angles and on which a thin aluminium strip is slightly twisted in order to be parallel to the glass unit being this the surface on which the structural sealant is poured.

2. CONTEXT BACKGROUND OF GRADUATION THESIS

After studying Architecture for three years in “Universidad CEU San Pablo” in Madrid (2007-2010), my fascination about the technical aspects of the building design moved me to The Netherlands. Here I started my Master in Architecture, Urbanism and Building Sciences at Delft University of Technology following the Master Track: Building Technology (Faculty of Architecture).

By studying, researching and designing, focusing on different aspects related to building technology during my first year of the Master, the field of Facade Technology captured my attention because of the challenge that the combination of design, technique and logistics mean in the environment of a competitive market.
This lead me to choose the International Facade Master as specialisation inside the Building Technology department and, therefore, my graduation research work focuses on building envelopes.

The International Facade Master is closely related to the Facade Research Group at TU Delft and has contact with partner universities in Luzerne (Switzerland), Detmold (Germany), Bath (UK) and San Sebastián (Spain).
A very practical level is achieved by the cooperation knowledge and research exchange with the VMRG (Dutch Facade Builder Association), the KCG (Knowledge Centre of the Dutch Facade Industry).and several related facade manufacturers.

Scheldebouw-Permasteelisa Group is the company in which I chose to do my graduation project about *“Unitized Curtain Wall Systems for Truly Double-curved Facades”* (a topic proposed by them).
I believe that doing the graduation in the practical environment that Scheldebouw can offer is the best way to complete my master study getting a perspective over the facade industry.

3. SCHELDEBOUW B.V.

Scheldebouw B.V., part of the Permasteelisa Group, has a long history and a proven good reputation in the field of project management, design, fabrication and installation on site of bespoke cladding and curtain walls for buildings in the top segment of the international construction market.The product range and solutions comprises various systems, components and materials, such as active and interactive facades with ventilation, closed cavity double skin facades, sun shading systems, all types of glazing, aluminium, steel, stainless steel, copper, titanium, natural stones, prefab concrete, ceramic materials, synthetic materials etc., including various surface treatments.

The design philosophy of Scheldebouw and the Group is based on “thinking on building level” and a “holistic” approach to optimize the integration of all building components and the overall performance of the building in all aspects.
It is also directed to a maximisation of prefabrication off-site and fabrication in the factories is focussed on end-assembly. This approach results in a better control of quality and short installation times on site.

4. RESEARCH

4.1. Field of research

With the increasing complexity in facades due to technical demands and the building performance requirements, the market has become more and more specialized in maximum prefabrication, standardization and preassembly of façade components in order to get a higher quality and minimize the work on site. Using these same principles, Scheldebouw is specialized in custom-made unitized curtain wall design for buildings in the top end of the building market.
Nowadays, among these buildings, there is an increasing demand for glazed non-orthogonal buildings. There are two ways of approaching these morphologies: faceted solutions (flat glass units) or with bent glass units.

Faceted solutions, installing flat glass sheets in segmented curves, are a way to avoid complicated and expensive detailing, glass panes and framing.

Recent developments in the market make it possible to consider double curved facades with the use of bent glass for a unitized component-based system strategy.

In the glass industry, the improvement of the manufacturing accuracy is leading to each time better application to insulated glass units for which the reproducibility of the glass unit is a key issue. Coating techniques for this type of glass are also being improved to cope with the current energy saving demands for building envelopes. Also, adaptable moulds are being developed aiming for higher shape freedom added to the economic advantage that re-using the same mould supposes.
In parallel, the development of the cold-bending glass technique is using the advantages from the manufacturing of typical flat insulated glass units, facing then the challenge of controlling the stresses in the glass when bending it on site.

In the aluminium framing industry there are also hot and cold forming processes.
Cold forming processes of extruded profiles at the factory are the most common methods but there are new developments where hot bending and twisting can be done by influencing the material flow during extrusion, or by forming (rolling) right after the extrusion process (for single curved profiles). Cold bending and twisting on site is also possible for smaller deviations.

In line with the industry developments, the use of improving computational tools for geometry control and data management facilitating the communication with the different parties involved is encouraging this new way of designing and building.

A unitized curtain wall system brings higher complexity in the design phase, and the possibility of creating complex and/or irregular surfaces is limited.

The added degree of complexity that a non-orthogonal facade brings is the subject for this graduation work, aiming to be able to cope with projects with higher morphological complexity while using the exist ing strategies of the current unitized curtain wall systems.

Companies involved in the building envelopes industry, such as Scheldebouw b.v., are mainly interested in research which leads to new products in the short term. Therefore, the focus is oriented towards innovation with low risk, or what is the same, low investment. This is the reason why this research thesis has an integrated approach where the constraints for the design development are a lot narrower and specific than for a more general and futuristic approach for double curved facades which ends up being more theoretical, since it is hard to predict how the market will develop in the long term.

The question is if we can, with the current technology and strategies of unitized curtain wall systems, offer a solution for buildings designed by Architects today.

The advantage of an integrated approach, using the existing unitized systems as starting point is that the current certificates can be used and the incorporation in the market can be much faster. The research is based on the unitized systems used by Scheldebouw B.V.

4.2. Research question

Can the current unitized component-based curtain wall systems' strategies be used for double curved facades with double-curved glass?

4.3. Research sub-questions

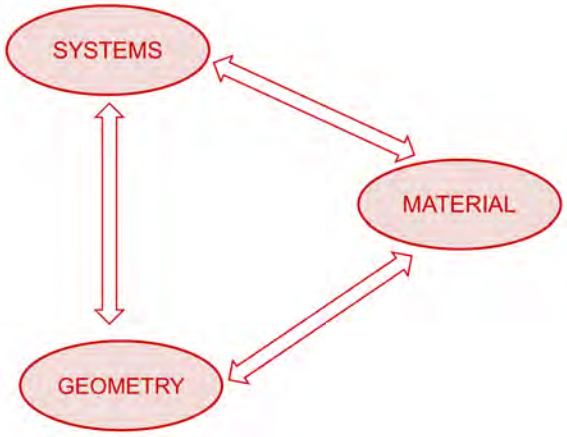
1. What is theoretically possible with bent glass and aluminium framing for non-orthogonal buildings now or in the near future and what would be the most practical type of unit to develop?

2. How do the particularities of curtain wall unitized systems interact with the double curved glass and framing possibilities?

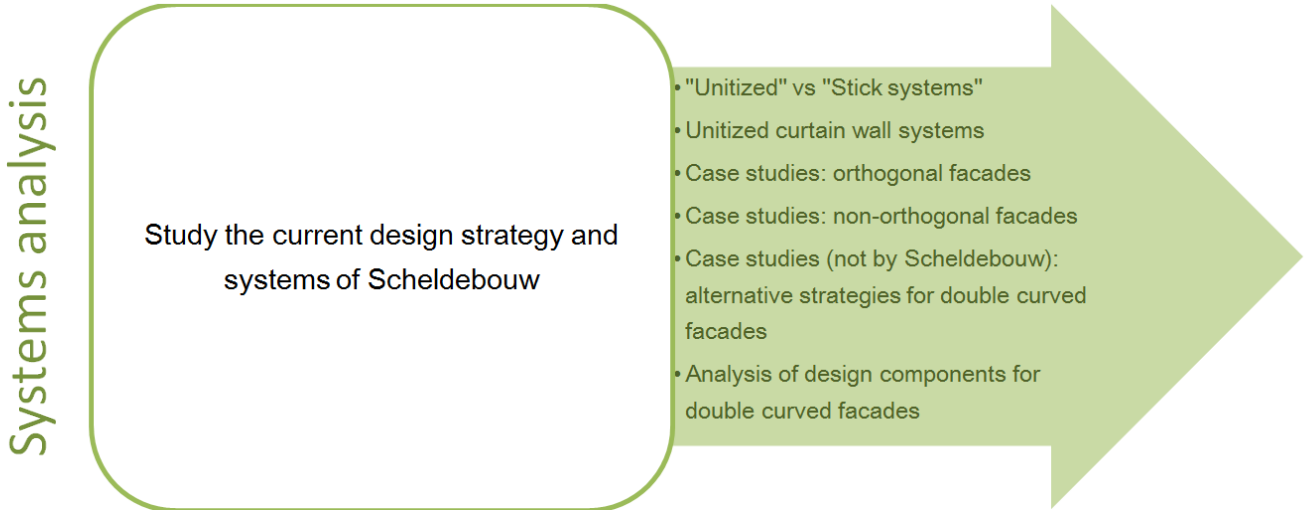
3. What are the next steps to take towards the field of unitized component-based non-orthogonal façade technology?

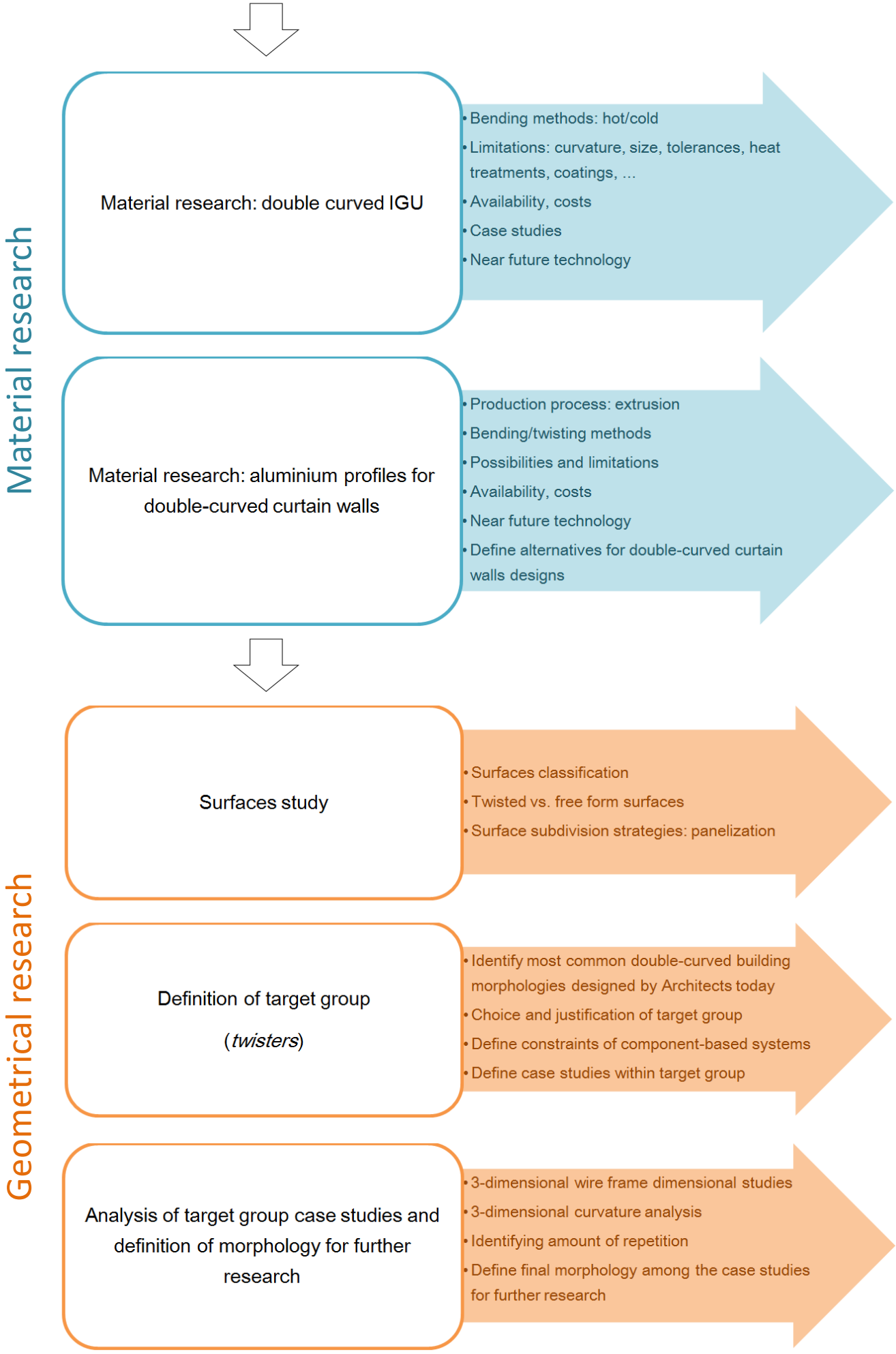
4.4. Research strategy and research method

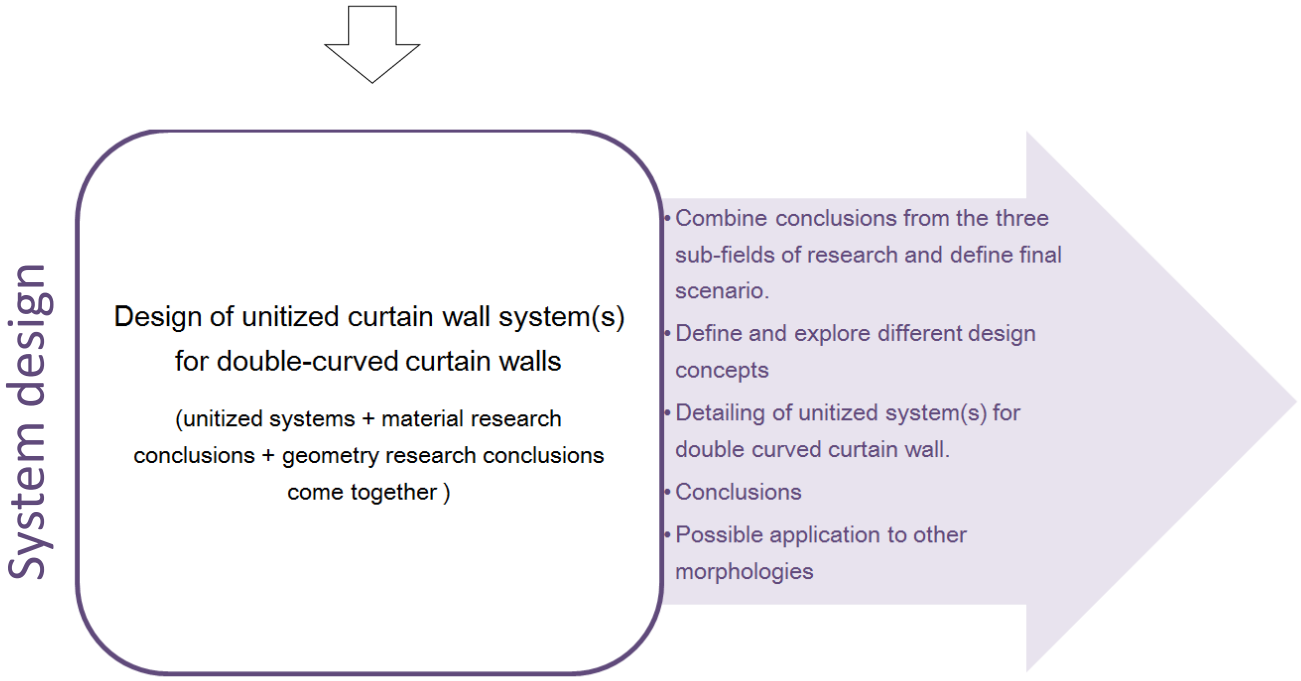
Strategy summary:
In order to design a double-curved unitized system, the research work will be divided in three sub-fields (red ovals): analysis of unitized systems, material research and geometry study.
These three fields will interact with each other narrowing the "problem" down.
The conclusions of these three blocks will be put together for the final double-curved unitized system design.



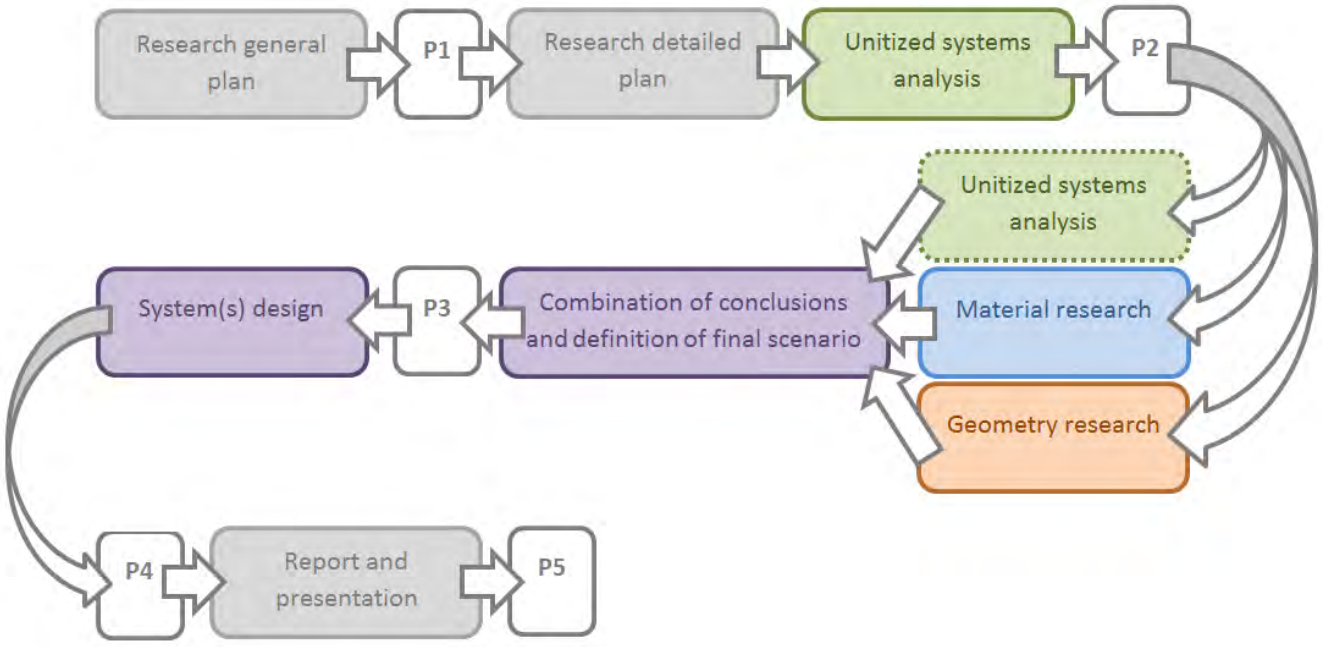
I 4.4. Research strategy general overview




Material research
Material research: double curved IGU
• Bending methods: hot/cold
• Limitations: curvature, size, tolerances, heat treatments, coatings, …
• Availability, costs
• Case studies
• Near future technology
Material research: aluminium profiles for double-curved curtain walls
• Production process: extrusion
• Bending/twisting methods
• Possibilities and limitations
• Availability, costs
• Near future technology
• Define alternatives for double-curved curtain walls designs
Geometrical research
Surfaces study
• Surfaces classification
• Twisted vs. free form surfaces
• Surface subdivision strategies: panelization
Definition of target group
(twisters)
• Identify most common double-curved building morphologies designed by Architects today
• Choice and justification of target group
• Define constraints of component-based systems
• Define case studies within target group
Analysis of target group case studies and definition of morphology for further research
• 3-dimensional wire frame dimensional studies
• 3-dimensional curvature analysis
• Identifying amount of repetition
• Define final morphology among the case studies for further research



5. PLANNING



I 5. Planning of research work

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