Summary

Continuous innovation is very important to stay competitive in today's world. Automotive manufacturers are an excellent example of this evolution when looking to new vehicle concepts. But also behind the scene, they have to be innovative in order to be able to keep up this progression. Aerodynamics has a large influence on the total performance of the car, and therefore fulfils a very important role in this innovation story. Aerodynamics is absolutely not straightforward which makes it on the one hand difficult to deal with and to estimate it influences, but on the other hand, this creates an improvement potential. Today's passenger cars are already aerodynamically optimised to a fairly large extent, meaning improvements become rather marginal. To be able to keep this tendency of improving in the future, the aerodynamic design process has to be adapted.

The focus of this work will be on the reduction of the air resistance of cars, which has a large influence on its top speed and fuel consumption. Especially the latter is very important today and will even gain more importance for future cars. Earlier research has shown that 70% of the reduction of the air resistance and the corresponding C_x value is done during the preliminary aerodynamic design phase. This phase is characterised by a high design freedom and a low level of detail of the corresponding design. Due to this, this early phase invites for shape optimisation of the basic aerodynamic shape having much more potential to achieve a lower C_x value. At the end of this phase, all fundamental parameters, dimensions etc. that define the final car will be fixed in order to begin the further detailed design during which detail optimisation is only possible anymore. This fundamental difference between the early phase and subsequent detailed design is responsible for their difference in influence on the final achieved C_x value and reduction. In order to achieve a successful aerodynamic design in terms of air resistance, the importance of that early design phase cannot be underestimated.

To prevent aerodynamic improvements from stagnating, this preliminary design phase has to be fully exploited. Those preliminary phase can be split into three specific sub phases, namely the initial phase, preliminary studies and concept phase. In the first, the high level targets of the car design will be determined, which the final design should comply with. After this, as much as possible information and knowledge about the design has to be gathered during the so called preliminary studies. This knowledge will be used to formulate thoughtful concepts for the subsequent concept phase where they will be assessed and developed further until one final design concept remains which should comply with all the earlier defined high level targets. The quality of the information and knowledge gathered during those preliminary studies is therefore critical for a comprehensive final design. This is valid for the whole aerodynamic design and by extension also the total car design. But as already said, this work focuses on the design of the car exterior in terms of C_x value.

It was observed in this work that the current situation has potential for improvement. More specifically, it was noticed that the aerodynamic department is occupied mainly with detail optimisation instead of the more favourable shape optimisation during those preliminary studies. The reason for this is due to a combination of their minor influence on the car exterior design compared to the aesthetics department and the current process flow during those studies. This current process flow is very inefficient and contains too much time-consuming and repetitive manual work. This combined with the short timespan of those preliminary studies lead to a limitation of the gathered knowledge of the car exterior design that is investigated. This is the main reason why the aerodynamicists are currently doing mainly detail instead of shape optimisation. For the latter, more investigations of higher quality (higher order) are required, which

the current inefficient process flow does not allow for. Therefore, the aerodynamicists are limited to detail optimisation because of this, which is explained more into detail in this work.

Thus, adapting the current process flow to allow the aerodynamic department to do shape instead of detail optimisation was found to be the main solution to improve and further reduce the C_x value and prevent it from stagnating in the future. The current process flow of those preliminary studies was analysed in this work and a suggested methodology that could accomplish those improvements was formulated based on this. The main difference of this methodology compared to the current situation is the implemented closed-loop instead of the open-loop modelling of the aerodynamic behaviour during those preliminary studies. This requires a fully automated process flow, which is missing in the current situation. In order to be able to also work out this suggested methodology to a fully working process flow, an automated generation of the geometric variants have to provided. This was achieved by developing a parametric geometry model capable of instantly delivering the required geometric variant without human interaction. The parametric model is an approximation of the real car exterior geometry, but its accuracy was proved with relevant CFD simulations. The closed-loop surrogate modelling is realised by using a MATLAB-based toolbox, called SuMo-toolbox, which is implemented in the software framework of the developed methodology. A secure shell connection between this software framework in MATLAB and the Linux machine, on which the simulations are done, assures a stable and fully automated process flow. After this working out of the presented methodology, a reality-based use-case was done to estimate its potential for improvements compared to the current situation. Promising results were already obtained which also confirm the promised theoretical improvements in praxis. Also conclusions and recommendations for future work or alternative implementations and extensions of this methodology are formulated in this work.

This work was meant as an initial step and incentive to apply this methodology in the current industry. Before this could be possible, further research and work has to be done to make it practically implementable. This new process flow means a drastic change of the current one. It is typical for large companies to be unwilling to take this step. But if this methodology could be further developed so that it could fulfil its supposed role, namely improving and further reducing the C_x value of cars, it will become an important tool in the (near) future for manufacturers to become or stay ahead of their competitors. Certainly in today's world of increasingly strict economics, its role cannot be underestimated.