

# CONSTRAINT MANAGEMENT

July 2022

## INTRODUCTION

An important part of the early design stages is the layout design of the vessel. During conceptual and preliminary design the most important layout decisions are made. While initially the designer is seemingly 'free' to create the layout of the vessel according to his or her priorities, there often are a lot of requirements that influence the placement of the various ship compartments. These requirements can for example be the ship-owner's requirements, various regulations or classification societies rules.

In order to come to an satisfactory design it is important that all these requirements are met, which can be quite a challenge when they each pull the design in different directions. In case of conflicting requirements a compromise has to be reached. The constraints themselves have to be weighed against each other, or a constraint has to be reevaluated in order to come to a satisfactory design.

In the classical ship design approach first a preliminary design is made and only then the design is tested against most of the requirements. Subsequently the design is revised and adjustments are made to comply with the requirements. Using constraint management to actively monitor constraints during the design of the vessel changes this process. Requirements that are not met and conflicting constraints can be identified, and thus dealt with, earlier in the design process, when there is more design freedom to deal with these issues. This change in the design process also means that the result of the concept design phase is already a feasible solution. The differences between these design processes are presented below.

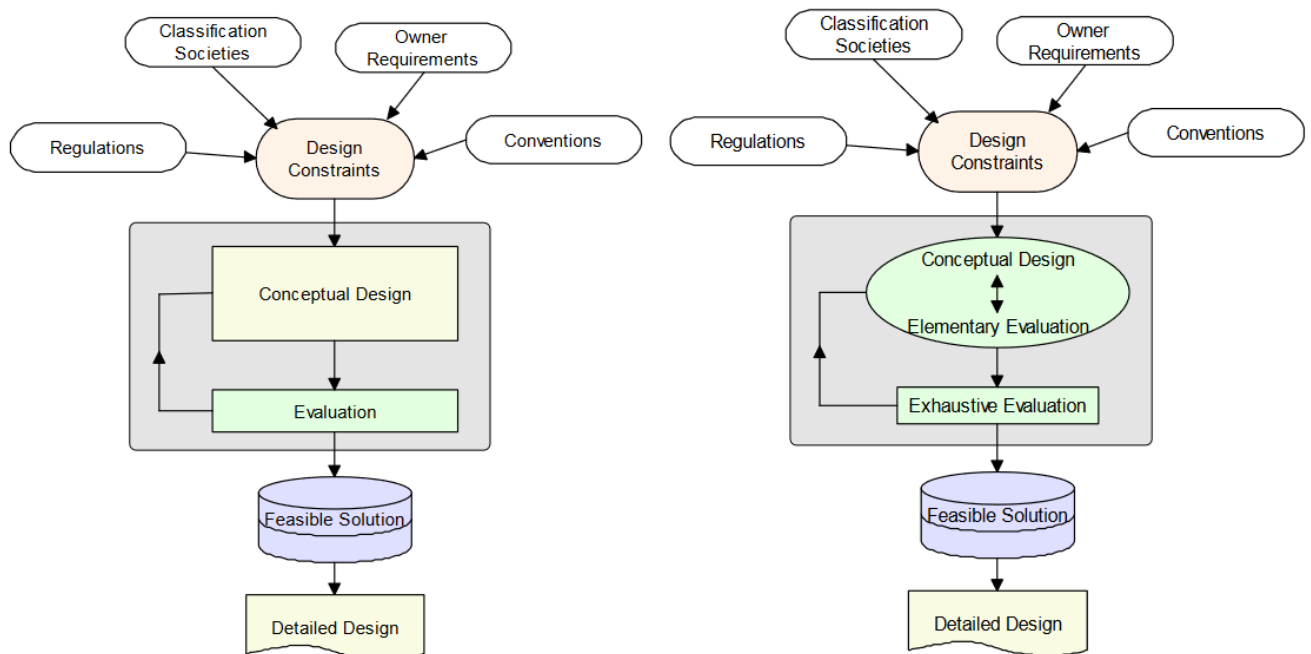


Figure 1: On the left is the conventional design process, on the right the design process using constraint management.<sup>1</sup>

<sup>1</sup> De Konigh, 'A Feasibility Study into Constraint Management in Ship Layout Design, 2010, Technical University Delft.

The following paragraphs will first describe the formulation of constraints in ship layout design. Then constraint evaluation is described. Finally, a short description of how constraint management is implemented in PIAS Layout is presented.

## CONSTRAINT DEFINITION

Requirements must be *specific* in order to be meaningful. While an owner might say that they want their vessel to be able to transport as much cargo as possible, this requirement will be translated to a numerical value that can be contractually agreed to. Similarly, while the intention for a regulation might be to make sure that a vessel is safe when the hull is damaged, this results in (among others) a requirement of a minimum amount of watertight bulkheads which can be checked by the classification society.

The specific formulation of requirements mean that constraints can be categorized by two distinct properties, that we call *groups* and *types*. The *group* the constraint belongs to says something about how the constraints relates to the geometry of the vessel. Four different groups are identified:

- Amount (e.g. number of bulkheads)
- Position (e.g. tanktop position)
- Area (e.g. engine room area)
- Volume (e.g. cargo space volume)

The second property of a constraint is its *type*. This type conveys the meaning of the numerical value(s) of the constraint. Five types are identified:

- Minimum (at least..)
- Maximum (at most...)
- Minmax (in between boundaries)
- inv\_minmax (outside boundaries)
- Exact value

Using the properties of *groups* and *types* all the constraints can be formulated in a consistent manner that a constraint management program can understand. These constraints can be neatly organized in a constraint table:

Constraint	Group	Type	Lower boundary	Upper boundary
Engine room surface area	Area	Minimum	40 m <sup>2</sup>	-
Tanktop height	Position	Minmax	0.6 m	1.2 m

Etc.

## HANDLING CONSTRAINTS / CONSTRAINT EVALUATION

With a consistent way to describe constraints defined, they can now be applied to a model and evaluated. While ideally the design would already meet all the constraints that are formulated, the reality of ship design is that is almost never the case. So the next step after the constraint evaluation is changing the vessel to better satisfy any constraints that were violated. This process of changing the design in a specific way can be automated, as it can be seen as constraint satisfaction problem, which is a special case of constraint optimization problems. More information about this can be found [here](#)<sup>2</sup>.

As the various constraints all require different things from the vessel, finding the right design compromise that satisfies all the constraints can be a challenge. An important detail to discuss here is the relative importance of the various constraints. Often, not all the constraints are equally important, or they influence the design changes unequally and should thusly be weighted differently.

<sup>2</sup> [www.sarc.nl/images/publications/background\\_newlay.pdf](http://www.sarc.nl/images/publications/background_newlay.pdf)

Since the relative importance of the constraint is dependent not only on the specific constraint itself, but is also relative to the other active constraints in the model, the assigning of the relative importance to the active constraints is best left to the user, in order to push the design in the direction that they desire.

## CONSTRAINT MANAGEMENT IN PIAS LAYOUT

Using the methodology laid out in this paper, SARC has developed a constraint management feature for our Layout module. Constraint management is an important step in automating a part of the design process, while leaving the designer firmly in the captain's seat. This is a great stepping stone for future developments.

It is important to note that we have restricted ourselves to address the constraint problem as far as it can be included in a processing time that allows interactivity. Currently, only constraints that deal with plane positions, areas and compartment volumes are considered. Using the physical planes feature of Layout to define the compartments, the constraint manager can reposition all these physical planes in order to comply with position, area and volume constraints.

Constraints can be defined in a constraint table, linked to a physical plane or compartment in the model, and in a constraint equalizer floating window the user can experiment with changing the relative importance of the constraints to find a design that suits their requirements.

More detail about the background of constraint management can be found [here](#). For the working of the PIAS implementation of this feature we refer to the [Layout section of the PIAS manual](#)<sup>3</sup>.

By adopting the described workflow the design process is improved by assuring the feasibility of the design in an earlier stage. The constraint management feature supports the designer, who stays fully in control of the design.

For further information, a demonstration or a quotation for this feature the various ways to reach SARC are presented on the contact page of our [website](#)<sup>4</sup>.



<sup>3</sup> <http://www.sarc.nl/images/manuals/pias/htmlEN/layout.html>

<sup>4</sup> <https://www.sarc.nl/contact/>