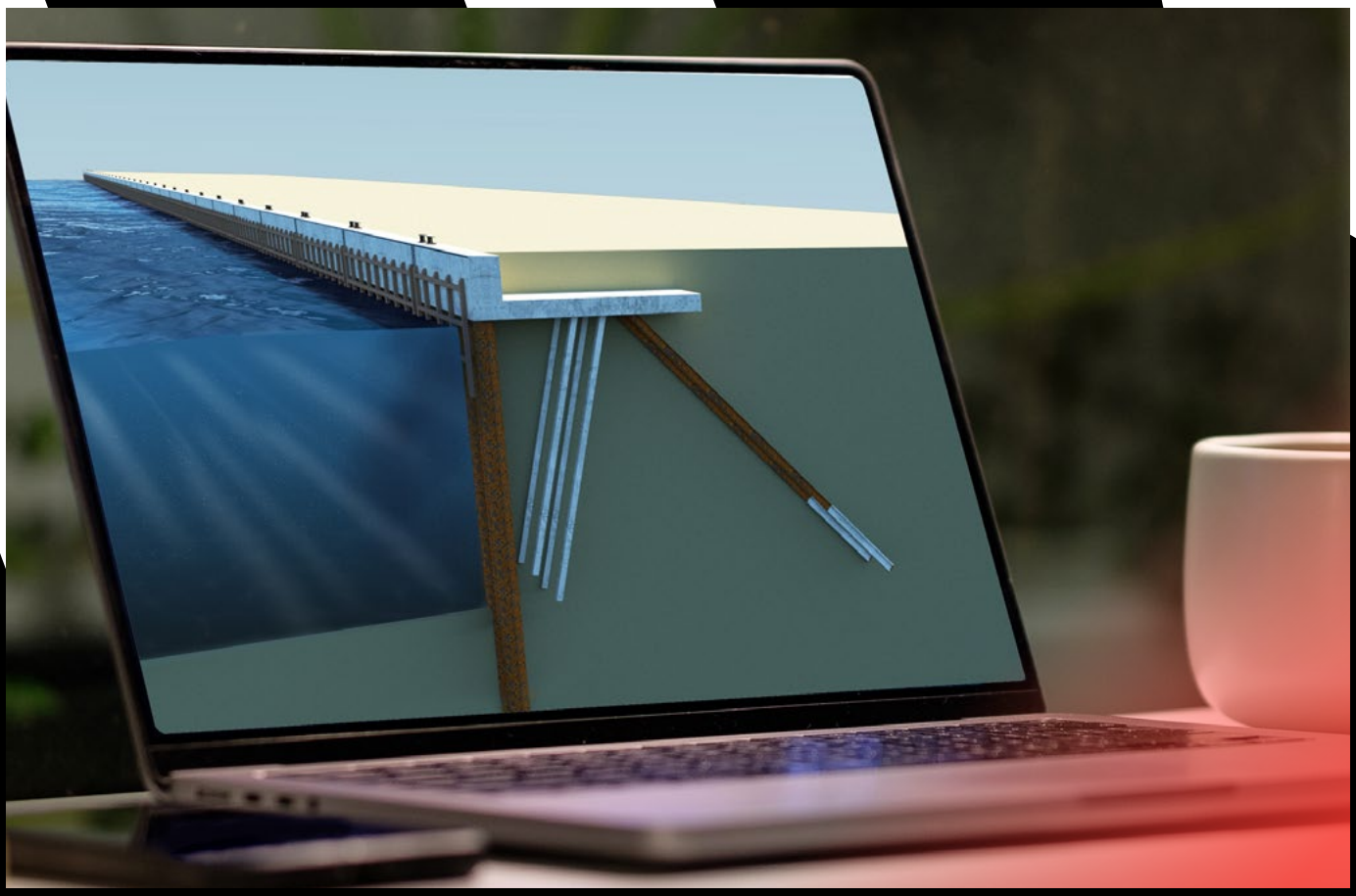
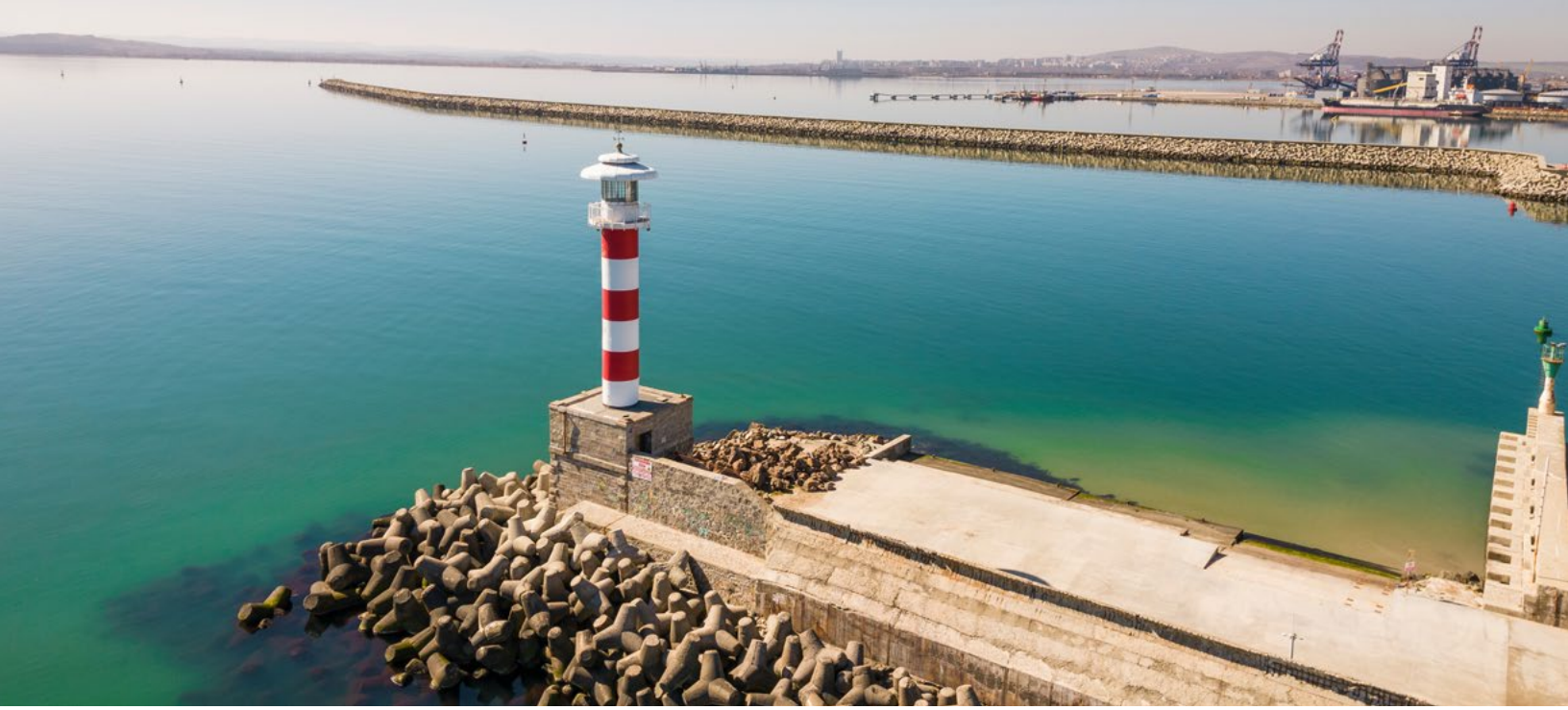


GENERATIVE DESIGN ADVANCES MARITIME INFRASTRUCTURE

Addressing complex challenges and creating cost-efficient and sustainable designs

Dennis van Heeren
Designer, Maritime
Netherlands

James Melvill
Associate, Maritime
South Africa



How is digitalization advancing project goals?

James Melvill: Digitalization of the design process helps to reduce risk and errors by ensuring that the latest design data is available to be used in the following design works. Having access to the latest design geometry from the 3D model or results from the latest analysis, will ensure that work can be done right the first time. This reduces the need for rework. Assumptions can be more accurate, and the design can progress at a faster pace, thus reducing project timelines.

Digitalization of the design process is a key enabler of parametric and generative design—the ability to change design parameters to influence the design and then optimize the design by generating many options and testing their effectiveness.

What other benefits is generative design bringing today?

James Melvill: Generative design helps to refine the design toward the selected solution more quickly. Traditionally, an engineer would make an assumption about the design, complete the calculations and then repeat this process until the design was optimized. Generative design uses automation to allow many more options to be evaluated, and the best one can then be chosen in less time than before. This can even lead to a completely different solution from that expected by the engineer.

Dennis van Heeren: Generative design is especially useful as the engineering design process usually consists of many iterations. Engineers examine the local conditions and determine the client goals to establish a complete picture of the design problem. That information is then used to iterate through different design options and make changes until all design standards and goals are met. Traditionally, these design iterations have consisted mainly of manual tasks, which, in practice, means that only a small number of options can be examined within the available time and budget. Given the limited number of options considered, it makes sense to question how well the outcome is suited to solve the design problem and meet all client goals.

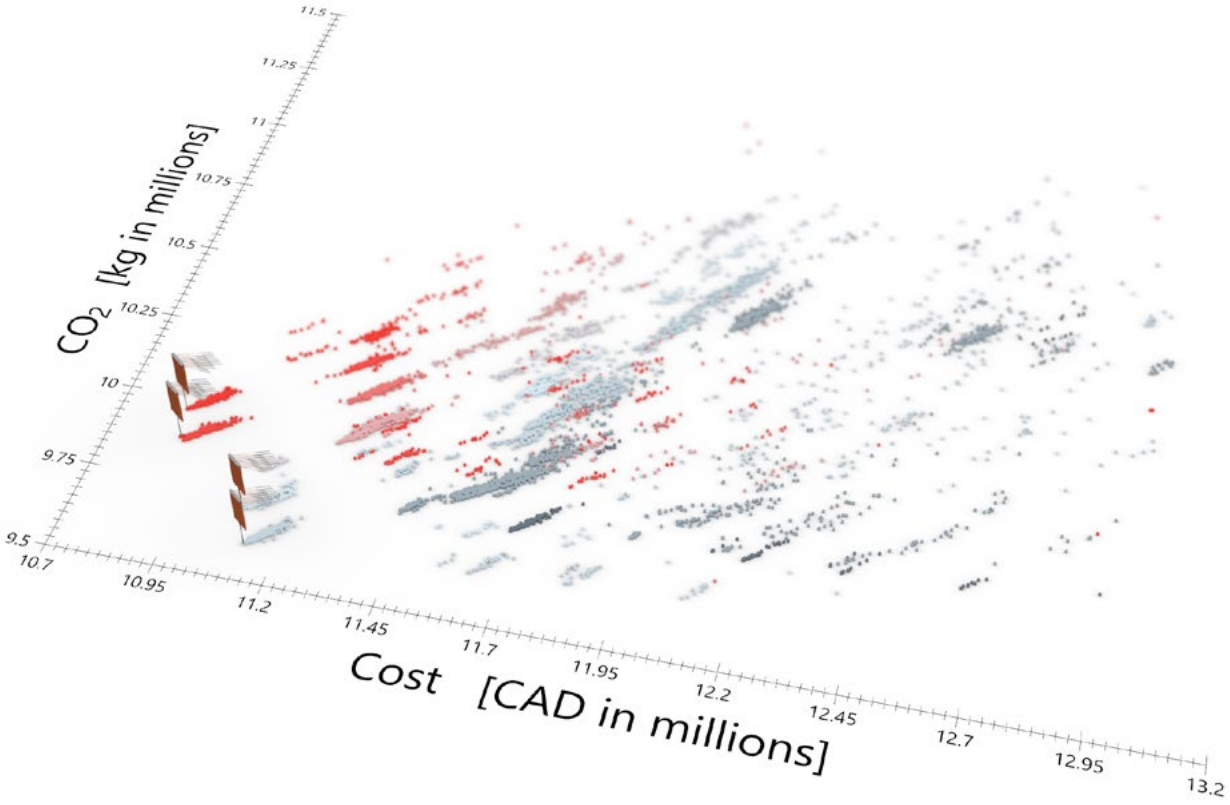


Figure 1 – This image presents the scores of the evaluated options for two design goals—cost efficiency (Canadian dollar) and CO2 emissions reduction—in a so-called pareto plot, showing the best-scoring options in the bottom left of the graph. This display allows designers and/or stakeholders to get visual insight into the trade-off between different design goals when picking the final option.

Generative design is speeding up the design process, increasing both efficiency and quality by taking out the repetitive manual tasks as much as possible. This capability allows the engineers to focus more on creative thinking and integration with other design disciplines; it also frees up resources to dive deeper into the unique aspects of the design challenges, such as complex connections and corners.

At the same time, generative design can benefit our clients by providing more insight into the relationships between the design options and different, possibly conflicting design goals, allowing the client to trade-off between these goals. The large number of iterations and design options evaluated using generative design can add more weight to the choice for a best design option, knowing that it is picked out of thousands of lesser options.

In this way, the generative design process uses the best capabilities of both digital and humans. The engineer sets up a parametric model based on the design problem and incorporates a scoring mechanism that measures the design goals for a design option. The computer, leveraging artificial intelligence, then uses an algorithm to generate and optimize solutions in this model using the performance of the options to find the best possible solutions. The engineer can analyze the data and pick the most preferred design option, present the possibilities to the client and other project stakeholders to choose from or change the input of the model and run more iterations in search of even better options.

In a world that is trying to deal with an increasingly extreme climate, generative design allows engineers to minimize the embodied carbon impact of the designs we create for the future.

James Melvill: Overall, generative design enables engineers to better address complex design challenges and create more cost-efficient and sustainable designs, goals that are increasingly prioritized by client organizations.

Can you explore how WSP engineering teams are applying generative design in maritime projects?

Dennis van Heeren: Given the nature of the method, generative design is best applied in the early stages of a project when client requirements are laid down and the direction of the solution is not yet determined. Looking at the maritime sector, it is at this stage that port authorities ask our advice on the solution direction and the investments that go with realizing their projects.

The generative design tool for quay walls we created fits right in that picture. After filling in the requirements and local conditions in the model, the tool will start optimizing, performing structural analysis, and code and feasibility checks on every option as well as calculating the impact. During that process, the tool will choose optimal components and dimensions along the way to the best solution. This allows us to advise better and also adjust to changes in the requirements faster during the process.

But optimization can also be interesting in the later stages of a project, where the general solution is defined, the contractor is in charge of the final design, and the details can still be improved—especially when looking at large projects and quantities like the replacement of sheet piling along a stretch of canal. Every kilogram of steel per metre that can be saved at that stage will make a difference on the budget and environmental impact. Using generative design, enables the engineer to divide the structure into more sections based on local ground conditions then optimize every section in a fraction of the time it takes to do this traditionally, saving both money and resources.

James Melvill: Generative design is also enabling improved modelling. We have started to use generative design for the design of offshore intake and outfall pipelines, allowing us to model the intake screens more effectively. We are looking to use these tools to further our ability to create concept design models for breakwater and revetment structures.

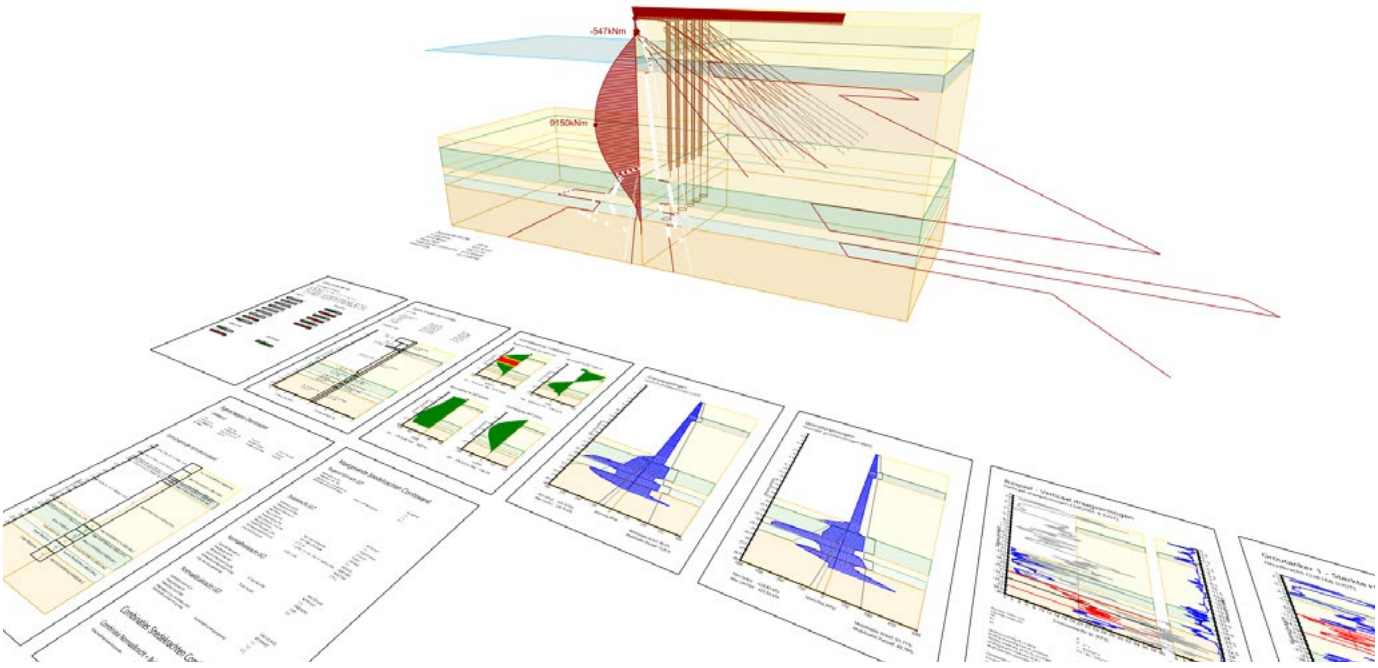


Figure 2 – In the generative design process for maritime infrastructure, options are entered into a structural finite element model, which performs code checks before considering the design goals—such as cost efficiency and embodied carbon reduction—so that only safe and stable options are taken into account.

What steps are needed to increase application of generative design in maritime and other sectors?

Dennis van Heeren: There are two limiting factors in applying generative design at the moment—adaptation and computing power. Firstly, it takes time for the people and industry to adopt the digital way of working. This involves investments to create the models, writing computer code and getting engineers trained to work in this new way.

Secondly, it takes a good amount of computing power to perform finite element calculations quickly. When applied in generative design, that can mean the calculation time per iteration becomes so long that the method is no longer feasible. So, the higher the computing power the better. Innovations in the field of processing power and cloud computing can take the method to the next level, enabling complex calculations to be done faster and in parallel so that generative design can become mainstream.

James Melvill: The fragmentation of design software and modelling software adds to the challenge to embrace generative design. There is significant effort required to reliably and consistently transfer data from one model to another for use and then transfer the results back in the same manner. The software industry is responding to this challenge. The speed of software development also creates a challenge; a solution that takes months to create for a specific purpose can become outdated or irrelevant with the next update. Another issue is promised functionality that does not meet expectations when delivered; overpromising can delay the development of a workaround.

The speed with which generative design has developed requires comparable training to make sure the skills of engineers keep pace to maximize the capabilities of digital engineering.

Contacts

Dennis van Heeren
Designer, Maritime
Netherlands
dennis.vanheeren@wsp.com

James Melvill
Associate, Maritime
South Africa
james.melvill@wsp.com

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