Project Value Delivery | Large, Complex Project Leadership White Paper Series

White Paper 2024-05

Benefits and Limitations of Project Modularity – Towards a Trend of Facilities Built of Smaller Components produced in Series

Modularity and the series effect are key success factors for large industrial projects. They improve performance, reliability, reducing the likelihood of dramatic failures. This concept is discussed in the book 'How Big Things Get Done' by Bent Flyvbjerg and Dan Gardner. It is leading to significant business model transformations in some industries. In this White Paper, we explore the advantages, drawbacks and limitations of this approach.

Advantages of modular projects

Modular projects offer better control of fabrication and construction since modules can often be erected off-site in a more controlled or easier accessible environment. This improves initial fabrication productivity, although it may be offset by the delays and complication of logistics to site and final hook-up. For more details about the benefits of modularisation, refer to our Expert Paper 2016-21 'How to Efficiently Engineer the Onshore Facilities: Standardized Modularisation

Additional advantages of standardisation

Standardisation allows for the application of a series effect to a number of similar modules, equipment, or components. It comes on top of modularisation when a single project can be developed as a set of smaller, similar modules (e.g. battery storage facility, solar farm, wind farm, etc.), or when standardisation is possible across a number of similar projects (e.g. standardisation of subsea hardware for oil & gas, modules for floating gas plants, sister ships, etc.). In addition to savings on engineering (engineer once, produce multiple), standardisation allows for significant series effects and learning curves for construction and commissioning, possibly at the expense of less precise adaptation to the needs of each module usage and thus less optimised use of equipment and material. In a single industry, standardisation and continuous improvement may significantly decrease the cost of each module over time (supposing that production is effectively in series with sufficient continuity).

There is a definite trend that industrial facilities will be designed to be increasingly modular. When possible, the combination of modularisation and standardisation can be a major driver of project performance

Advantages of projects involving number of standard modules

Statistics tend to show that projects involving a number of standard modules tend to be more reliable in terms of estimating and to diverge less from the average when encountering a problem.

In addition, facilities involving several smaller modules in parallel instead of a single process route generally have higher operating reliability. This is because smaller modules in parallel make it possible to shut down some modules for maintenance without shutting down the entire facility, reducing the risk that generic design or maintenance flaws could spread to the entire facility.

Industry Transformations Towards Modularisation and Standardisation

Recognising the benefits of building large projects or programmes out of standardised modules produced in large series, several industries are seeking to adopt this model.

The renewable energy sector has dramatically lowered its power production cost over the years thanks to this strategy. Initiatives are being taken in various areas to benefit from this approach, such as standardised and factory-manufactured Small Modular Reactors in the nuclear industry to replace larger power stations, modularisation and standardisation / configuration of oil & gas or chemical plant processes or key equipment, work on standard platforms for railway rolling stock and automotive, work on standardisation for aerospace cabin layout etc.

Upcoming trends

We believe there may be further developments in the future regarding the design of process plants. These plants are often designed traditionally with one single process route dealing with the full material flow.

However, this often implies significant scalability issues from demonstration tests done on pilot plants. It may be less risky (against possibly a higher Capex and construction cost) to envisage a series production of pilot-plant size modules that would be installed in parallel instead. This would considerably reduce scalability risks and provide additional operational flexibility with several material streams running parallel with slightly different parameters. This also reduce process feed homogenisation requirements as an input to the process, as each parallel process could be tuned to a specific feed characteristics.

In cases of very sensitive processes, we see plants being built with a number of trains in parallel (typically 3 to 6) using equipment of a proven size built in small series. We expect that this trend could continue into design concepts using a large number of process trains in series (>10) of smaller capacity.

Drawbacks of modular and standardised modules projects

Beyond the obvious advantages of such approaches, there are still some drawbacks to be considered and carefully assessed in view of the particular circumstances of the project.

Drawbacks of modularity

Standardisation allows for the application of a series effect to a number of similar modules, equipment, or components. It is a major driver of cost and schedule performance.

Modularity requires the logistics constraints associated with moving the modules to their final resting place to be considered. The constraints includes limits to size and weight of the modules, and generally also introduce a need for extra structural material to make the modules transportable and able to resist the constraints of transportation. The lay-out of equipment is also affected and may be sub-optimised. Special transportation equipment may need to be produced or adapted, and transportation pathways may need to be adapted by removing obstructions and increasing load capacity. The final site of the facility needs to be sufficiently large to allow module storage and integration, and may need adequate access for extra-size modules. Waterfront sites with quay unloading facilities, or offshore structures, tend to be advantaged in that respect.

Modules generally need to be delivered in the right sequence for assembly, which may lead to late modules being transported unfinished and then they get finished on final location. This is generally a recipe for disastrous productivity and should be avoided. Hence modularity requires very good schedule management and convergence planning to ensure that final assembly can happen without hiccups, with fully completed and if possible tested modules.

Drawbacks of standardisation

Series effect is good as long as the unit estimate is adequate and the learning curve effect prediction is accurate. Standardisation requires a high level of estimating and cost control. Otherwise, any unexpected deviation is simply multiplied by the number of items produced in the series. This can lead to huge variances in both time and schedule for the project, as have been observed in a number of instances (e.g. offshore wind farms with issues on foundations or installation times, overly optimistic estimate of the learning curve on projects etc.).

Having an effective learning curve also generally implies some centralisation of production, which may not be ideal from a geographical perspective and may lead to substantial transportation hurdles and cost. In cases where production needs to be split geographically between locations because of capacity issue or to adapt to local requirements, specific effort is needed to ensure that the learning curve is preserved as much as possible.

Standardisation generally comes with an upfront investment or effort which is then amortised on the series, and assumptions on the size of the actual series is an important consideration to ensure that development costs are actually compensated.

Also, standardisation is coupled with the risk of generic failures, i.e. one element failure may require taking out of service or retrofit the entire series for upgrade, which can have a significant operational impact. Hence, there needs to be a strong after sales follow-up to ensure that generic events are anticipated to avoid disastrous stoppage of the entire series.

Summary

We believe that it is a definite trend that industrial facilities will be designed to be increasingly modular, which has the benefit of avoiding excessive process scalability concerns. When possible, the combination of modularisation and standardisation can be a major driver of project performance and project delivery reliability.

However, this approach is not always applicable or cost-effective and also comes with drawbacks that need to be carefully considered in view of the circumstances of the project. Furthermore, the multiplicative nature of series projects can create significant variances in case of poor estimating of time and cost for the individual item.

Modularisation and standardisation are a trend that requires higher level of reliability and quality of the project management processes, and greater maturity of the organisation, in all aspects of project management and industrialisation. This needs to be taken seriously upfront to be successful in these modern industrial approaches.