White Paper 2016-20

From 1D to 3D Projects: the Dimensional Factor in Infrastructure Project Complexity

A number of factors decide Project complexity. One of them is often underestimated – it is the effective construction dimensionality of the final infrastructure being built. While quite naturally some industries manage well by keeping it low, it explains the exceptional level of complexity of some project realisations. Full 3D project objects are the most difficult and complex to plan and build.

How to measure the project dimensionality of an infrastructure, and examples

Project dimensionality is not necessarily only a property of the final object; it is also intrinsically linked to the manner with which the final infrastructure is being built. Projects generally try to minimize the dimensionality as part of their execution plan.

- 1D or 1D+ projects are essentially linear; for 1D+ there might be some complication brought by the necessary layering of some material. Examples are railways, pipelines, tunnels and roads outside specific major crossings and bridges. Specific scheduling approaches are available (e.g. time-distance diagrams and other linear scheduling methods) and productivity is essentially measured by the unit length of works, with the need to keep the construction contributors fully utilized.
- 2D projects are projects in which components, structures and modules are essentially brought next to each other on a two-dimensional plane and tied in. Productivity will often be measured by the weight of steel, the cumulative length of welding or some length against the main dimensions. Examples include:
  - Many small oil & gas and mining plants which are essentially bi-dimensional in the way they are built and installed. Sections of the plant consist of a single module for each ground surface area. The few tall structures are generally built on the ground before being erected next to the other structures and modules,
  - Very large bridges can also be seen bi-dimensional between the vertical and the main direction dimensions,
  - Most ships are built in pre-fabricated modules that are joined together in a 2D manner in a dry-dock to form the entire hull,
  - Most modularized projects are designed to be bi-dimensional,
  - It is also the case for many floating plants or offshore jacket-based plants, where the topsides are often modules tied together on a bi-dimensional setup, and then brought on top of some supporting structure.
- 2D+ projects add the complexity of at least a single substantial layering in the vertical direction to a generally horizontal bi-dimensionality, but without the full 3D constraints related to main equipment. It is the case of:
  - complete industrial plants developments for which a substantial underground network of civil works or piping (e.g. drainage, etc) is required on top of a substantial soil preparation. The additional complexity of completing the underground networks prior to the erection of the above-ground infrastructure is a very significant constraint in project execution.
  - the conversion of tanker hulls into FPSO where works have to be sequenced to take into account all dimensions up to a certain point.
- 3D projects are projects where the built needs to take into account the third dimension intrinsically. These are often very large structures that involve the installation of different equipment in all three directions, on several layers in a very compact manner. Examples include:
  - Nuclear power plants / nuclear reactors,
  - Special highly advanced facilities like fusion reactors,
  - Large floating LNG plants, where the compactness is achieved at the expense of an additional dimension in the built, with many equipment in the hull itself and not just on the topside.

Dimensional complexity is a major factor that influences execution complexity and constraint.
It should be minimized as much as possible.

At this stage it is important to note that many 3D objects are not built according to the 3D constraint. Actually the respective projects always try to breakdown the scope according to the smallest dimensionality possible. For example conventional building construction builds the civil works in one go before ensuring water tightness and installing equipment. In that case there is no real 3D constraint on execution, but rather a 2D+ approach; in high-rise construction 1D scheduling approaches are even being used with floors being built repetitively. Many plants components are built in 2D and then brought together.

The Added Complexity of 3D Projects

The added complexity of 3D projects can readily be understood taking into account the specific constraints on project execution created by the 3D circumstance. Several levels must be considered when scheduling the built, which impacts the entire chain from Engineering to Procurement. It will also make the execution plan much less flexible and most common productivity measures irrelevant to the performance of the project.

In 2D projects, it is often possible to progress each element relatively independently from each other, and fine-tune or even change the installation sequence to fit the construction performance. This is not any more the case in 3D project where a significant additional rigidity is imposed on the execution plan, with many new constraints related to the third dimension:

Full 3D project objects are the most difficult and complex to plan and build.

- Equipment for the lower levels must be available when required, because they often can't be installed any more when the upper levels have been built; this is a major constraint in particular for long lead items on engineering and procurement,
- Civil works or structure works must consider several successive water tight closures to allow the progressive installation of weather sensitive equipment as the work progresses from one level to the other. This creates significant constraints on the work for the upper levels. Conventional civil works productivity measures are thus not fully relevant,
- Key activities such as cable pulling (often critical as they can only be performed on the completed infrastructure) become more complicated at the cable paths cover full 3 dimensions, and this situation is even more difficult when there are geographical segregation constraints such as often in the nuclear industry,
- The management of simultaneous construction operations is made more difficult by the need to avoid dangerous situations with superposed works (falling objects, water ingress etc).

Managing 3D complexity

When faced with a 3D project, the first reaction of the Project Manager should be to try to simplify the built design as much as possible from the project execution perspective, so that at least some sections of the built become 2D or 2D+ instead of 3D. It is often the case of increasing the footprint if that is possible so as to diminish compactness and superposition. It can also be possible to reduce the constraints on equipment delivery by making sure they can be installed later even if they are not ready when the relevant level is built (through the planning for larger access doors or temporary openings, sufficient cranage inside the facility etc.). The facility also needs to be split in discrete levels for which completion will drive the engineering and delivery of relevant equipment, pre-fabrication and bulk. Those levels should be made as independent from each other as possible during construction with the minimum of tie-ins. This obviously requires the project execution constraints to be brought up during the design stage.

Once maximum simplification has been achieved at design stage taking into account the particulars of the project, the Project Manager should concentrate on the execution planning to clearly take into account the constraints of 3D and try to regain as much flexibility as possible. One of the major issues is to remove constraints to be able to work around missing equipment or difficulties in one area of the facility. Splitting the facility in different horizontal zones with independent levels is an essential way to increase the potential work-front in case of an unexpected execution issue.

Summary

Dimensional complexity is a major factor that influences execution complexity and constraint. It should be minimized as much as possible. If it is not possible to avoid 3D complexity, the project should try to devise an execution plan that regains as much flexibility as possible with several potential work-fronts, while clearly establishing the priority sequencing for engineering and procurement taking into account the third dimension.

Full 3D facilities are amongst the most challenging projects and require the utmost applicable of the complex projects toolbox. 3D project characteristics should not be taken lightly.

Thanks to Gilles Zask for raising the point initially about the 3D complexity factor for nuclear powerplant projects