Advanced Work Packaging in capital projects: a standardized model for EPC Contractors

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Abstract

The international context in which the major EPC Contractors operate is going through a period of profound transformation. The increasing complexity of the plants, the increasing costs of labor, the increasingly binding contractual requirements, have forced companies around the world to adapt to these market laws and raise the level of competitiveness through targeted business strategies. The main EP&C realities, a national leader in the Oil & Gas sector, are constantly moving towards new process management techniques. The following work fits into this context by analyzing and deepening the process of breaking down the scope of work into the so-called Work Packages according to the Advanced Work Packaging methodology. AWP envisages a prioritization of the work, initially agreed between the various disciplines, with the ultimate aim of increasing performance in terms of time, cost, quality and alignment of the three macro-phases: Engineering, Procurement, and Construction. After thorough research on the previous bibliography, we analyzed the current process of management and decomposition of the scope of work. The result is an AWP application model, which, through modifications to the current management processes, provides a quantitative calculation tool to assess the amount of construction work related to a plant. The proposal is also extended to the engineering and procurement phase. This completely standardized process has general validity and has been demonstrated through the application of two main projects. In the final part, the procedure was extended to all the types of systems made by Tecnimont, further demonstrating the extreme versatility of the methodology.

Keywords: project management, EPC projects, construction, advanced work packaging

1. Introduction

In the next decade, capital projects in Oil and Gas sector are expected to continue increasing in size and complexity, but despite a stronger capability in project management is required still a significant amount of project failures continues to occur. Especially on larger projects such as mega-projects (i.e., projects costing more than 1 billion US$), the frequency of project failures is alarming. According to Independent Project Analysis (Merrow, 2012) four out of every five oil & gas megaprojects that IPA studied were characterized as failures[1]. Additionally, it was further commented by IPA that even in other project sectors (including minerals, petrochemicals, and power), projects suffered a failure rate of approximately 50%. Smaller projects are not immune to surprisingly high project failure related to meeting their objectives. Citing an example for smaller project failures, an IPA study found that over one-third of all site-based projects studied failed to meet objectives. These small site-based projects are characterized as projects costing less than 10 million US$ (Pellegrino, 2018) Bentley (2015) proposes a more detailed description of the Construction Industry time effectiveness' data. In particular, they have taken into account all the possible situations which would lead to a waste of time, seen as all the activities which take some time and do not lead to any added value. Furthermore, recent research performed by the Construction Industry Institute has highlighted the poor execution performance in the industrial project sector, where almost 70% of projects exceeded 10% variation from expected cost and schedule values (CII, 2012). This poor performance is inescapably tied to the lack of reliability of the planning process (Gibson et al., 2002), which is not able to offer reliable estimates and to manage the increasing complexity of industrial projects (Bosch-Rekveldt et al., 2011).

Thus, in the increasingly competitive global environments, many organizations recognize that effective use of corporate knowledge could help to improve their performance and consequently provides competitive advantages over their competitors (Wang, 2016). In the context of knowledge management, many researchers try to find ways to improve the construction industry focusing on various issues. Past and current projects have failed to deliver the desired outcomes through lost time, reworks, design errors, construction inefficiencies, and life cycle performance failures. Reliable construction plans are vital for efficient and effective collaboration across design, procurement, and construction to reduce schedule delay and cost overruns (Dawood and Sriprasert, 2006).

2. The rise of the improvement techniques

Lean construction is a new approach to design construction systems to facilitate material and information flow, therefore minimizing waste of materials, time, and effort in order to generate the maximum possible amount of value. Compared with the traditional 'push- driven' approach, the main objective of a 'pull-driven' method is to produce finished products as optimally as possible in terms of quality, time and cost, so as to satisfy customer demand (Tommelein, 1998).

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[1] *Failure* in this context means a broader concept that includes the partial achievement of the scope of work, delays, cost overrun, lack of material on site, differences between the work performed and delivered and the customer's expectations, claims, etc.

Three types of planning methods had been developed to implement the pull concept into the construction industry:

1. The **Last Planner System** (LPS), developed by Ballard and Howell, which is a production planning system designed to produce predictable workflow and *Petrochemical Complex* learning in programming, design, construction, and commissioning of projects (Ballard, 2000). According to Winch (2006), LPS is an important innovation and anecdotal evidence of the use of lean construction. However, Winch (2006) has also argued that when using LPS, there is a lack of attention paid to the theory of constraints and its project-specific application in the critical chain.

2. The **Workface Planning** (WFP), developed by Constructions Owners Association of Alberta (COAA), which is the process of organizing and delivering all elements necessary before work is started to enable craft persons to perform quality work in a safe, effective and efficient manner (Slootman, 2007).

3. The **Advanced Work Packaging** (**AWP**) developed by a joint venture between the Construction Industry Institute (CII) and the COAA, which aims to align Engineering, Procurement and Construction with the sequencing needs of site installation and turnover to operations (Hamdi, 2013; Developing and evaluating a framework of total constraint management for improving workflow in liquefied natural gas construction, Wang, 2016).

Among the most common project planning concepts, work-packaging has been extensively used and recommended within the Project Management theory to divide the scope of work into manageable units for execution. AWP is a more complete work packaging system that actually still includes the WFP as one of its main three phases. However, it covers both the construction and the initial early stages of the project and allows a system to have more control over the breakdown of the project through its life cycle (Hamdi, 2013). The key deliverable of AWP is the emission of Work Packages, vertically (different levels) and horizontally (multidisciplinary) differentiated.

2.1 The Construction Industry Institute

The Construction Industry Institute is a research institute comprised of over 100 construction-related organizations including owners, general contractors, specialty contractors, engineering/design firms and suppliers. The CII was chartered in 1983 at the University of Texas, Austin. The motivation for the institute's formation was the Construction Industry Cost Effectiveness (CICE) project, a 5-year study of the U.S. construction industry and its problems. The CICE study specifically recommended that an organization be created to take a leadership role in construction research with the purpose of improving the competitive position of the U.S. construction industry in the global market (Jortberg 1998).

Despite the progress made in the development of scheduling techniques and tools, the industrial construction sector is frequently characterized by informal and unstructured procedures during the initial planning stages. This results in planning deliverables that are scarcely aligned across the different business divisions and poorly structured to support field operations (Ponticelli, 2015). Advanced Work Packaging (AWP) methodology consists in an enhanced project breakdown structure that prescribes an organized planning approach, aiming at the alignment between construction, engineering, and procurement disciplines since the preliminary planning phase.

AWP is a deliberate and disciplined integrated approach for improving project performance and predictability through the project life cycle. The AWP process supplements normal good project management planning and execution practices. The focus of the AWP process is to identify recommended execution activities, from engineering through to construction, that deliver constraint-free executable Installation Work Packages (IWPs) that align with the sequence of construction.

The AWP process incorporates the full project life cycle, starting in early project setup and continuing with activities through to project start-up and turnover. The success of AWP is highly dependent on the alignment and coordination between the project's owner, contractors, and their various discipline leads involved in the planning, engineering, project controls and execution of the work scope, down to the work front.

The early interactive project planning establishes the necessary coordination between the engineering, construction, and system turnover teams for the development of Engineering Work Packages (EWPs) and Construction Work Packages (CWPs). These packages are matured and broken into Installation Work Packages (IWPs) through deliberate and disciplined planning and execution. Management of the IWPs in the field is commonly referred to Workface Planning[2] (WFP).

An overview of the CII-recommended AWP process is graphically presented in **Figure 1**. The AWP process incorporates a full project life cycle approach to maximize project execution benefits. The AWP process is explained by the three stages as developed by CII Research Team 272 and summarized as outlined in CII's Advanced Work Packaging: Design through Workface Execution publication (October 2013). The project life cycle stages are defined generically to highlight generally accepted stage divisions. The AWP process covers the activities from project definition through system turnover/start-up and commissioning. Each of the stages is to build upon activities completed from the previous stage.

[2] Workface Planning (WFP) is the term initially defined by the Construction Owners Association of Alberta (COAA). The initial WFP focus was on field installation of the work packs. The desire to improve the process led to efforts in the front end of projects and the designation of EWPs and CWPs. Earlier publications and currently some owners and contractors still refer to WFP as an overall term for AWP. The CII and COAA endorsed usage between AWP and WFP is shown in Figure 1.

Figure 1 - Advanced Work Packaging integration and influence within project processes (up) and project phases (down)

Stage I, Preliminary Planning/Design, incorporates activities necessary for work packaging.

Stage II, Detailed Engineering, builds off the plans from Stage I. Stage II supports the development of the sequence of construction (i.e., the path of construction), aligning engineering deliverables with construction requirements.

Stage III, Construction bares the fruit in the form of IWPs from the detailed planning and coordination in the previous stages.

2.2 Essential Nomenclature

When the AWP process is successfully implemented, the benefits of AWP can significantly outweigh the cost to implement. The positive results from AWP implementation[3] can vary in degree; in fact, when implementing the AWP process, these results can be influenced by the utilization of project management processes, resource availability and skills, and the organizational capabilities of the parties. The benefits noted have been recognized on both larger and smaller projects. To maximize the benefits from AWP, the project team should execute AWP by starting the process early during project definition, extending into the planning and engineering phases, and continuing through construction.

Prior of going into the detailed description of the processes involved, it is important to give a basic description for a few key words strictly connected to AWP philosophy starting from the Plant, which is the physical representation of the entire project (or, sometimes, a part of it). A

[3] Reduced cost through improved labor productivity and reduced rework, improved overall project predictability for cost and schedule, Better alignment among stakeholders from planning through construction, better than normal craft retention due to improved morale, improved up-front planning, improved foreman field time availability, improved housekeeping/site cleanliness, etc.

plant is a combination of facilities that form a unique process, and it is normally identified by the process of operation and a specific geographic region. As a further plant subdivision, it is possible to introduce the concepts of Inside Battery Limits (ISBL) or Outside Battery Limits (OSBL). The Construction Work Area (CWA) is a geographical division of work that shall be defined by the Construction department. It includes all disciplines, with the exception of cables and roads that are also divided into work areas, but across the entire project. Each CWA has boundaries defined by the logical association of work and becomes one activity on the Level 2 Schedule (Insight-AWP, 2017).

In other terms, the concept of CWA is very close to the one of PBS (Product Breakdown Structure, which in the EP&C environment has the variant of Plant Breakdown Structure). In fact, the CWA might even be seen as its evolution. In particular, the PBS has usually been introduced as a lower level of the project's WBS, being a spatial division of the plant on a 2D perspective and performed by the layout department. The PBS is valid horizontally within the project's disciplines (that means it is equal for all of them), and it stands as the basis for the Engineering document geographical reference. The idea of CWA brings this concept to two higher levels of detail[4]. At first (1), it evolves the idea of multidisciplinary division, since the level of granularity of a single CWA shall be decided at the very first stages of a project (together with all the parties involved, above all Engineering, Procurement and Construction departments) as the **lower level possible** of the multidisciplinary area. In other words, a CWA shall "contain" all the required works of each single discipline (e.g. Civil works, Piping works, Mechanical works, etc.) except for cables and roads which, due to their own nature, are also contained within certain areas which though do not correspond to the CWA level of granularity. Secondly (2), the name CWA usually leads to misunderstandings. In fact, a CWA should not be confined on the 2D level, as one might think, but it should split the plant up into 3D "volumes" rather than 2D "areas" when it is needed. This idea comes from the different needs of construction activities, which cannot always be confined on the 2D level and therefore need to operate on 3D volumes, according to the single work's specific logic.

The very first important moment in the AWP realization is set by the definition of the *Path of Construction (PoC)*. The **PoC** is the articulation of the optimal construction sequence based upon the release of CWPs along with the setting of major equipment and modules. It starts during Front-End Engineering and Design (FEED) with the designation of CWAs on the project plot plan and the general flow of work fronts, which typically follows the setting of major equipment and the heavy-lift plan. The initial PoC, developed to facilitate the Interactive Planning Sessions, need only contain CWPs for foundations, steel, pipe, major equipment, and any long-lead items. These are the disciplines that have the longest development cycles (critical path for engineering and procurement). The other disciplines can be scheduled before and after these activities without affecting the start of construction (Insight-AWP, 2017). In other terms, the PoC is a **process of prioritization**[5], both for the high level (CWA definition) and for the low level (CWP definition) of the project's lifecycle. An important milestone of the PoC

[4] Although we have figured out that the new definition of the "common multidisciplinary level" has been widely addressed in literature, the 3D definition of the CWA is more a hypothetical further development rather than a reality: it would require a specific effort in order to study its actual feasibility, above all for its elemental connection with the development of the 3D Model.
[5] For this reason, it would be more appropriate to talk of AWP as a "***priority-driven***" process, rather than a "***construction-driven process***", as it is usually described.

generation is that the contribution of all the involved parties is needed: this usually takes place, at the beginning of the project, with the first constructability workshop[6].

The first bricks of the theory are the Construction Work Package for sure; a CWP is a single discipline portion of a CWA that defines a logical division of construction work with less than 40,000 work-hours[7]. It should include a budget and schedule with monitoring of actual performance. The scope of work, coming from the WBS, is such that it does not overlap CWPs one with the other. The CWP is a **single level 3 activity[8]** on the project schedule and is the downstream product of a single EWP and PWP when is ready for construction. The EWP is an engineering deliverable of a single discipline that is used to develop a CWP and defines the scope of Work, drawings, vendor data, Bill of Materials and specifications, in both PDF and electronic 3D model files. EWPs are developed sequentially to satisfy elements of the Path of Construction, which will facilitate sequential procurement and the execution of CWPs. A single EWP is represented in the schedule as a single level 3 activity. Instead, a PWP is a procurement deliverable that contains all of the materials required to satisfy a single CWP. Typically, it refers to a single discipline. For instance, in the case of steel and pipe, the PWP becomes a discrete fabrication package that is expected to be manufactured and delivered as a distinct group of components.

3. Research questions

In the first part, the concept of Advanced Work Packaging as a best practice recognized by the CII was introduced, defining what is a best practice, and justifying the reason why AWP is an interesting technique to deal with widespread problems in the EP&C world. As already anticipated, the WFP (which we remember belongs to AWP as its last phase) is a technique already extensively analyzed, most likely because it has to do with on-site works where all the design problems come out leading to reworks and loss in efficiency (time-money-quality losses): for this reason, research has focused mainly on WFP so far.

Everything that precedes WFP should have as its purpose the preparation of the work in view of the WFP itself. WFP techniques are applicable regardless of the work package concept, which however leads to process optimization if used: this because, in a few words, it makes the

[6] *Constructability workshops*: The Constructability Workshop is a formal Work session (eventually with Client, if appropriate) where the major constructability issues and proposed solutions are discussed for implementation. The Workshop is previously approved by Project Manager and officially notified to the Client (if applicable).
[7] From literature, we found out that generally a CWP shall have a time reference within the range 10,000/40,000 SMh.
[8] The Level 3 of the Planning and Control Schedule represents the lowest level of breakdown by phase, by discipline, by Planning Group (by area and/or by system where the Project is as a whole). In other words, the Level 3 schedule is the scheduling level used to monitor all activities to be performed within the project execution.

construction phase more easily manageable/controllable by expanding it in micro phases of approximately the same duration on schedule.

Up to this point, some fundamental questions have arisen during the research, which we tried to answer by the application of the model to practical cases. In fact, is it correct to take for granted the duration of a CWP equal to 40,000 SMh or would it be more reasonable to ask whether these CWPs should have a variable size based on some characteristic factors, such as the size of the project? Once the standard dimensions of a CWP are selected, would it be possible to define a proper logic in order to quantitatively assess the number of CWPs (discipline by discipline) within a plant?

As previously discussed, a CWP is nowadays seen as a disciplined construction activity, 40,000 SMh time reference. We wonder though if it makes sense to give a standard value to this entity, or if it shall be adjusted according to the case we are dealing with. In fact, taking into account that in the literature the cases analyzed were more or less of the same dimension, their implementation schedule is indicative of the same duration and density, and so it is justified have as an indication that specific duration for a CWP. In this study, we will analyze plants of different sizes and complexity, and through a backward approach, we will understand and define the goodness of these hypotheses. In a second moment, we will try to move from the qualitative to the quantitative perspective, trying to set up a generalizable tool for evaluating the number of CWP with respect to a project. We will try to further implement this approach in order to set up a list of standard rules for the CWAs and CWPs assessment.

Secondly, does it make sense to define the EWP at the same time as deliverables (documents) and as activities (single activity on the third-level schedule)? According to an eventual new definition of EWP, which would be the correlation between EWPs, documents, and CWPs? If this definition fails, we wondered in our analysis how the two entities could stand out in a new way. As far as the description of EWP concerns, the definition tends to be simplistic. Literature talks about EWPs as the set of documents (deliverable) in which a CWP should be fed within the order it to be performed. The widespread idea of articles defines an EWP as an engineering deliverable, considered as a group of documents, as an upstream requirement for the CWP realization. However, this definition is restrictive, in our opinion, because it reduces an EWP to just a deliverable rather than to an engineering aim to realize a given list of *Issued For Construction* documents, which actually are the deliverable. Our purpose is therefore to introduce a new concept, called Document Package, corresponding to the current idea of EWP, which we will also call *Old* EWP. Moreover, we wish to demonstrate that two different DPs might share a document, or even more. For a logical sequence of what has just been said, we want to demonstrate finally that the EWP deliverable will not coincide necessarily with a Document Package.

4. The Planning Group

The *PMBOK 6th edition* (PMI, 2017) defines the Planning (Process) Groups as "those processes performed to establish the total scope of the effort, define and refine the objectives, and develop the course of action required to attain those objectives. The planning processes develop the project management plan and the project documents that will be used to carry out the project. As more project information or characteristics are gathered and understood, additional planning may be required".

The Planning Groups are the basic concept in order to introduce the Advanced Work Packaging practices. In particular, as we already said, the Planning Group shall correspond, with a relation 1 to 1 (both for the Home-Office-Engineering and for Site-Activities-Construction), to the activities which belong to the Level 3 Project Control Schedule. The PCS is the schedule used for monitoring the project's progress.

For this reason, the WBS follows a disaggregation logic on levels that coincide with the scheduling ones. Using this approach, the WBS activities of level 3 (Planning Groups) will correspond to the activities on the Project Control Schedule.

AWP techniques rely upon the Level 3 schedule, whose activities should also correspond (according to the literature) to **Work Packages**, with a ratio 1 to 1. This means that the level 3 schedule is the milestone of the AWP technique. What will fall into the level 3 schedule (and the practice itself of how to do it) is a fundamental point for and EP&C company in order to impact on productivity through the AWP.

In the last years, very few studies have been conducted on how to quantitatively and effectively define a Work Package. This entity has always been described in the literature as the "leaves of the WBS tree". This idea, though, is not properly detailed and does not leave any possibility of standardization of the Work Packaging process, which would be the foundation for the effective application of the AWP procedures. In order for a Work Package to be univocally defined, it has to have both a qualitative description and some quantitative boundaries. Since (as one may easily understand from its own name Advanced Work Packaging) the work package is the very core of the AWP, the first target is to figure out what a Work Package can be.

In Project Management literature, the Work Package is thought to be an ensemble of activities at the lowest level of the project's WBS. Very few definitions have been given for distinguishing a Work Package according to the type of activities it deals with. Caron (2009) defined a Construction Work Package (that is, an ensemble of construction activities) as the cross-section between the type of activity and the area where they have to be performed.

After the analysis on the work packaging process for CWP, on which the work dwells in the next paragraph, there will be other sections dedicated to the EWP and PWP: although similar to the CWP from the conceptual point of view, they require radically different definitions from the practical point of view, given their intrinsically different nature.

Based on the previous definition, a CWP is defined as the intersection between all the construction activities required on a specific area and the construction area itself (**Figure 2**). In order to elaborate on a general approach, the following principles have to be defined:

- Activity level to be considered,
- Construction Area definition.

Again, at this point, we referred as a standard to what has been already discussed and accepted in literature: the level 3 schedule. As we have explained before, the level 3 schedule contains a series of activities, both referred to Home Office Services and to Site Activities. Of course, for the Construction Work Package, we considered the latter. The site activities of level 3 WBS coincide with what is known as **Construction Planning Groups**.

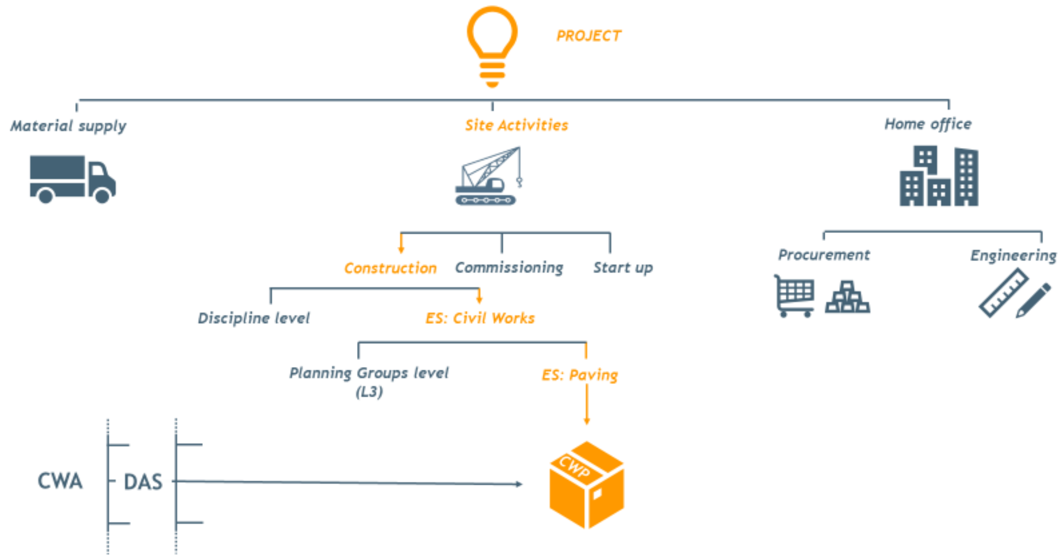


Figure 1 - Standard WBS structure and CWP creation from activities and Discipline Areas

The PGs are hierarchically structured with a parent-child structure on different levels, reflecting the progressive increase in the degree of detail of the information available on the project. For this reason, and to standardize the planning process, the Project Control department makes a standard Planning Group list available on 4 different levels. At each level, there will be an increasing degree of information about the activities of the Planning Group considered.

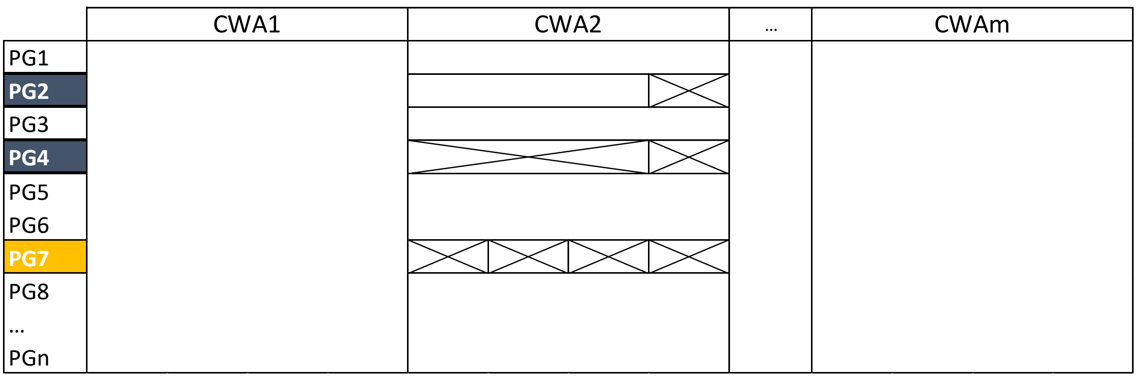
From the Advanced Work Packaging literature, the idea of area breakdown structure is fundamental, from the plant up to the lower levels. The first output of the process is the generation of construction work areas, a geographical division of work that shall be defined by the Construction department, which shall include all disciplines, except for cables and roads. Each CWA has boundaries defined by the logical association of work and becomes one activity on the Level 2 Schedule (Insight-AWP, 2017). Both PBS and CWA are a planimetric disaggregation of the plant, but there is a substantial difference between the two. The first is a disaggregation with a contractual value made by the engineering unit. Instead, the second is the result of a preliminary agreement mediated and guided by construction and supported by the engineering. The outputs of this work are areas that geographically reflect the needs construction will bring forward its work with. For what we have just said, the CWA will incorporate a series of different construction activities (or, Planning Groups). Each of them, though, will work within a CWA with different geographical construction logics. The idea, as we will see in practice terms later on in the text, is to create a CWA further subdivision by discipline wise, which we have called for this purpose Discipline Area Subdivision (DAS).

For what we have discussed previously, each group of activity representing a PG might assume different geographical logics and, at the limit, it would need a different Key Plan for each Planning Group philosophy. This would lead to an effort of engineering not sustainable and not reasonable: for this reason, we have thought to be acceptable to consider the aggregate levels of planning groups, referring to their family (or discipline) creating a Key Plot Plan for each of them. Each PG which belongs to that discipline will refer to that Key Plot Plan, or, with our nomenclature proposal, to these DAS. Each DAS, therefore, shall aim to be the 2D top representation of a single CWP.

For this reason, the CWAs decision should be carried out together, and therefore an **initial constructability workshop** with the cooperation of Engineering, Procurement, and Construction main figures is recommended. Right after the CWAs definition, further constructability meetings shall be appointed to properly define the DAS discipline-wise. This is the best way to start the project trying to align construction needs with engineering and procurement ones since its very first steps. The meaning of constructability has been given by the Construction Industry Institute: it is "the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives".

Under this perspective, the DAS dimension reflects the CWPs ones[9], as already explained in the previous paragraph. Having reached this point, it is possible to generate a graphical 2D representation of the cross-correlation process between PG and CWA from which the CWPs are born. From this matrix representation, it is possible, as well as qualitatively defining them, to quantify them, have a numerical estimate of the CWP and therefore of the total hours, both on the single area and on the whole plant. Even though the table might seem simplistic (**figure 3**), it has a dramatic practical impact. In fact, it is hidden in this new concept the following set of elements:

- the Plot Plan division in CWA, which has been numbered in general as *m*;
- a standard list of PG, which has been numbered in general as *n*;
- a CWP is defined as an "X" on this matrix, at the intersection of CWA and PG;
- two different Planning Groups which belong to the same discipline (blue example) reflect the same DAS division (which translates into the matrix with the same length for the cells under the same CWA along the row), whilst a PG which belongs to another discipline (yellow example) reflects another DAS division of the same CWA on the Plot Plan;
- it is not given that all the PGs of the same discipline (blue example) generate CWPs in all the relative DAS; in other words, this behavior means that the list of activities is standard, but it is not given that all the activities are performed in all the areas of the plant.



[9] Not in a strict sense: a CWP might be extended in 3D (work on volumes), for instance for the erection works, while a DAS is just a top-view (area), representing just the CWP projection on the Plot Plan.

Figure 3 - CWP matrix concept

At this point it is fundamental finally trying to exploit all the theory that has been produced so far for a real project: we had the possibility of doing that on two different projects. The first is the *Middle East Plastic Complex Industry* Project, which has been awarded by one of the main Italian EPC Companies in 2015. This project was used as a test bench to build and calibrate the application model. Therefore, our approach to the project has been the following:

- We have tried to simulate the first Path of Construction based on the plot plans;
- We have compared what we have figured out to what has been actually done, in order to understand the differences between the current standards and those of AWP;
- We have verified the feasibility of our proposal thanks to internal surveys to head of departments;
- After the validation of CWAs and PoC, we have again tried to simulate a possible DAS/CWP segregation for each discipline;
- Again, we have verified the feasibility through internal surveys;

Under this point of view, our critical analysis about the Middle East Project has been evolving as if it was a What-If analysis, meaning that, step by step, we had tried to figure out the possible AWP implementation strategies with the changes that it would have led to the standard way of performing the engineering processes.

5. Preliminary results from case studies implementation

Summarizing the progress made on this project, we started from the results obtained up to the definition of an operative framework for the possible implementation of Advanced Work Packaging in practice. Soon after we have applied the model to the *America Project* that was at its very first design stages taking into consideration only a few modifications functional to the logical scheme.

5.1 Middle East Project Case Study

Middle East Project is one of the Middle East's largest petrochemical projects in the growing business of the Middle East oil industry. The details about the contract are the following:

- Scope of Work: EPC (Commissioning and Performance Test included)
- Plant: 1 PP Unit x 300 Kilo Ton/Annual + 2 PE Units x 440 KTA
- FEED: from another Engineering Company
- Contract price/type: Lump Sum Turnkey (LSTK) + Reimbursable

Being the FEED design coming from another engineering company, the "philosophy" has been changed the layout, during the Engineering Detailed Design analysis (**Figure 4**). This happened because there was the need to make the planimetry as much homogeneous as possible for improving the design as well as constructability. These changes have been approved during the standard constructability workshop in order to align the Engineering, Procurement, and Construction: in other words, we can say that it was a first rough and involuntary approach to AWP methodology. It happens often that it is not always possible to satisfy the client's expectations about the plant, for technological or feasibility reasons.

For what concerns zones (1) and (2), there is no chance to change them, because they represent the "skeleton" of the plant and therefore need to be present before any other part. The same cannot be stated for the process units, though. In particular, we have thought that there is no need to keep together, for the construction logics, two areas just because they look like the same (or are even equal).

The construction phase shall be prioritized such as it will proceed at its maximum productivity rate. Thus, we have thought it would result much easier to prioritize the construction activities at the center of the plant, keeping the possibility to the construction crews to access the site to both sides and leaving the other areas for a second moment.

Figure 4 shows graphically how the prioritization process for Middle East Project was reformulated. At this point, we needed to focus on a specific part of the plant in order to figure out how to start thinking in AWP mode. For this purpose, we decided not to focus on the area (1) or (2), because not multidisciplinary enough to properly understand the interaction between different site activities. We considered the blue area numbered (3), which is the PP process area. This choice comes from a series of considerations, like:

- completeness of disciplines: it contains a process pipe rack in its center, two process zones at its lateral sides with the presence of mechanical equipment and steel structures;
- availability of documents of a different type: within the whole plant, the WBS area AA170 (PP purification) was the one with more granular and structured documents with respect to the 4 main disciplines. This helped us in understanding the difference of philosophy between these disciplines;
- smaller, easier to be managed.

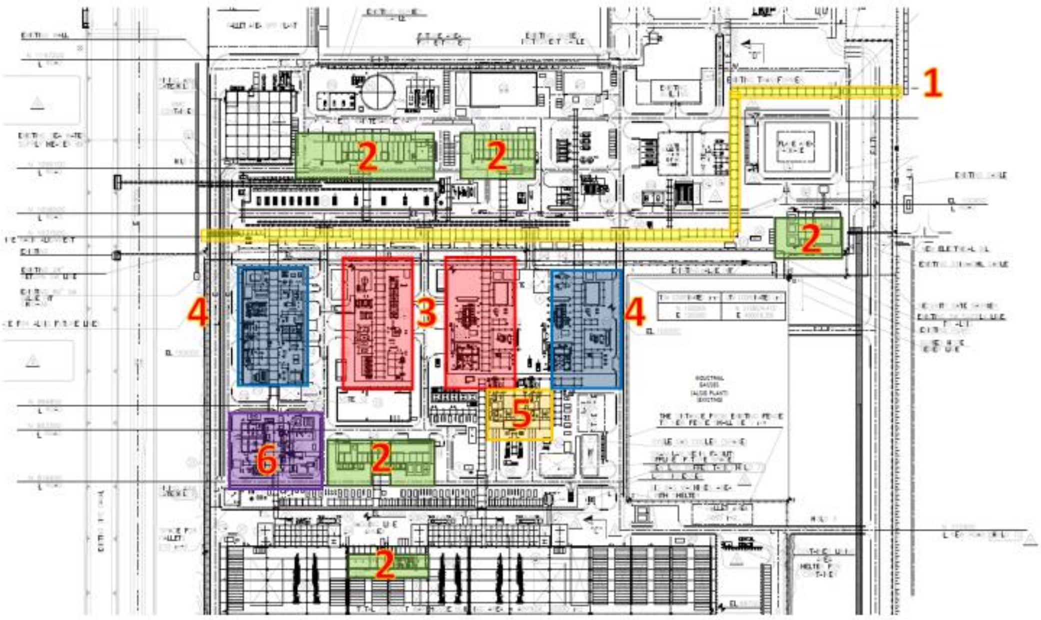


Figure 4 - Middle East Project PoC

As we already noted, thanks to the Middle East Project we have developed a pattern for AWP processes application, that has finally been accepted by the customer of the project and that we have successfully applied to the operative project of the AWP: the America Project.

5.2 America Project Case Study

In the following section, we are going to present our application of the developed concepts to the America Project. The technical specifications about products and related production processes will be left out because they the same ones of the Middle East Project (production of PE and PP). Following a similar approach to the project previously discussed, the first phases will concern the analysis of the PoC and the CWA that represent a novelty. The definition of the PoC and the CWA from the very beginning in AWP perspective is one of the key phases and we tried to set up a construction-driven approach to be applied on engineering and procurement works.

At this point, the CWP matrix it is discussed, i.e. a matrix with all the CWPs necessary to realize the purpose of the contractual work (contractual WBS). These CWPs will not be just a proposal, but real entities that will then be the input for the Workface Planning on the field during the construction phase.

We have therefore demonstrated the possibility that the same document can belong to several distinct Document Packages, and that therefore a Document Package is intrinsically different from an Engineering Work Package (and even from its deliverable). The complex is located on approximately 3,400 acres along the Houston Ship Channel, it is comprised of four manufacturing sites, employing a workforce of approximately 7,000 men, the America Project area sites are highly integrated which makes the plants and products more efficient. A few facts on facilities:

- The Refinery has the capability to process up to 584,000 barrels of crude oil per day.
- The America Project Olefins Plant, which began operations in 1979, is one of the largest ethylene plants in the world.
- The America Project Technology & Engineering Complex has been on-site since the 1920s. It has produced innovative technology, such as the lithium-ion battery separator film and numerous plastics light-weighting technologies that help make our vehicles more fuel-efficient.

The projects had undergone construction of a multibillion-dollar ethane cracker; the cracker will have a capacity of up to 1.5 million tons per year and will provide ethylene feedstock for downstream chemical processing, including processing at two new 650,000 tons-per-year high-performance polyethylene lines.

Even in this case, the prioritization process comes from a series of considerations about constructability but not limited to it: an efficient PoC comes from the mutual work of Engineering, Procurement and Construction stakeholders together. The America Project doesn’t have started the construction activities, yet. This is a great advantage because we can set properly, with the cooperation of the Construction Department, the right *prioritization sequence*.

In **Figure 5** colored areas are the most important ones that deserve the highest level of attention. For instance, in a light yellow, we can see the interconnecting pipe rack, whose function is in fact to connect the process units between them, which has been rated as (1) in terms of construction order. Two small Electric Substations are highlighted in yellow, even if they belong to other areas, they have the fundamental task of distributing electric energy among the whole plant. At areas (2), (3) and (4) we can find all the Process Units, that are prioritized according to commissioning needs (process point of view): in this way it is possible to start the production even though the plant has not reached 100% of construction work completion. Furthermore, it happens almost always that the process units contain long lead item and they are the densest in terms of work-hour in order to be completed.

Finally, we find (5) and (6) which represent the Utilities Area, which might be considered of secondary importance, even because thanks to their geographical position are easily reachable by the construction crews. The considerations just mentioned above have been approved by the project team during a series of meetings and personal interviews carried out. Considering that the America Project is part of a bigger Complex, its dimensions make the PoC easier and less constrained than other cases and from the constructability point of view.

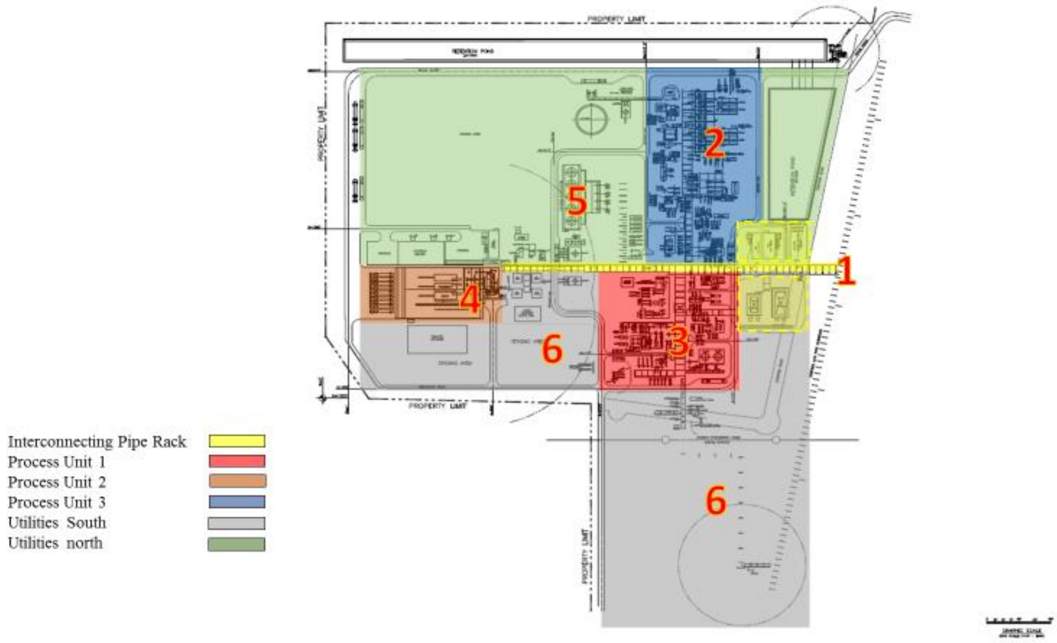


Figure 5 - America Project's PoC

The large working areas are chosen with the supervision of the Construction Department and accordingly with the construction sequence defined at the beginning of the project, following all constructability rules that help the connection between the Engineering and the Construction phases. In this case, the constructability meeting has been made with an AWP point of view taking account the constraints and the feasibility of the

For the definition of CWA itself, a CWA is a part of the plant where the construction works have to be embedded, with the exception of cable and roads works. It is, therefore, logical to assign a CWA to each part of the plant with can be isolated from the others with a processual logic: the result of this analysis, performed in collaboration of process department experts, is the set of reference CWA. Our proposal coming from the Middle East project, to segregate the main interconnecting pipe rack from other process areas and utilities have been largely accepted and adopted.

In a second step, therefore, we were provided with this new list of Planning Group and we have taken it as an input for the next steps of our work regarding America Project. This new set of PGs is not just the result of a theoretical exercise, but it can be actually considered as the real list on which CWPs will be connected to documents. This accurate set of PGs has been fundamental for our purposes to quantitatively generate a number of CWPs for the America Project.

Our idea of the CWP matrix has been presented before were we have anticipated that the complete list of planning groups was subjected to a work of intrinsic modernization in AWP view. For this reason, we assumed that this CWP matrix could be considered as a dense matrix, in the sense that any list of crossed planning groups with the respective division in CWA could generate at the limit a full matrix of CWP. This CWP matrix will give the model a validity also at a quantitative level, as well as qualitative from the point of view of the change in the management of processes according to AWP: through the CWP matrix it will be possible to know the order of magnitude of the CWP of the plant, both globally and partially, by isolating a specific area, a discipline or both (CWP of the same PG that point to the same CWA). The next figure represents an extract of the total CWP matrix generated for the America Project. In this image, we have reported an example, for the Piping and Civil disciplines, where quantitatively we are going to count the number of CWP with respect to a specific area (CWA-L). It will be sufficient to repeat the same route on the other areas to obtain the total number of the plant's CWPs.

In the first line we have included the list of CWAs, and, in **Figure 6** we have highlighted the L area as a reference for our example. We have then divided this CWA into the respective Piping Areas L11, L12, etc., and the Civil DAS (corresponding to the blue, pink and green colored macro-columns). Analyzing the respective lines to each of the PCs, we inserted an "X" (corresponding to a CWP) in case the activities of the PG were actually carried out on this area; if these activities are not carried out on the specific area, the respective box is left blank.

Proceeding in this way, we quantitatively identified, in the L area, a number of 41 CWP for civil works and 174 CWP for the Piping works, in total 215 CWP to which will be added the CWP concerning the electrical and instrumental disciplines that we considered, as it would not add anything for the purpose of demonstration. The reliability of the resulting CWP number resides upon the ability of understanding if an activity is effectively needed in a certain area or not.

	L								
PLANNING GROUP_DESCRIPTION	L11	L13	L14	L16	L18	PL21	L12	L17	L15
CIVIL WORKS - CONCRETE - FOUNDATION - CAST IN SITU			x			x		x	
CIVIL WORKS - CONCRETE - FOUNDATION - PRECAST PREFABRICATION			x			x		x	
CIVIL WORKS - CONCRETE - FOUNDATION - PRECAST INSTALLATION			x			x		x	
CIVIL WORKS - CONCRETE - ELEVATION - CAST IN SITU								x	
CIVIL WORKS - CONCRETE - ELEVATION - PRECAST PREFABRICATION								x	
CIVIL WORKS - CONCRETE - ELEVATION - PRECAST INSTALLATION								x	
PAINTING WORKS - STEEL STRUCTURES - PRIMER					x				
PAINTING WORKS - STEEL STRUCTURES - FINISHING					x				
PAINTING WORKS - PIPING - PRIMER					x	x			
PAINTING WORKS - PIPING - FINISHING					x	x			
PAINTING WORKS - EQUIPMENT - PRIMER	x	x	x	x					
PAINTING WORKS - EQUIPMENT - FINISHING	x	x	x	x					

Figure 6 - CWP Matrix application example

6. Discussion: from the Document analysis to the Document package

Up to now, the concept of CWP has been adapted to the corporate environment following the indications of the literature, which had already reached a good level of detail. As far as CWPs concern, their very nature prevents their reciprocal overlap: they are distinguishable from real geographic boundaries. The same conclusion cannot be done for the EWPs, according to the literature definition. In fact, an EWP was defined as the set of documents, needed for the construction crews to perform a CWP. Each CWP has, according to literature, its own EWP. Again, according to literature, each the Work Package level shall be the one of Level 3 Project Control Schedule: both CWPs and EWPs are single activity at this level.

From the previous two sentences, though, it comes out an inconsistency from the Deliverable List document analysis performed on this project. According to this approach, in fact, considering a document needed by 2 different CWPs, it would be linked to 2 different EWPs as well. Therefore, if those EWPs are 2 different activities on the Level 3 schedule, they would lead to errors in the accounting of engineering work-hour, and misunderstandings in the scope of work assignment. The proposal is, therefore, to abandon the idea of EWP as a “set of documents”, which actually constitutes only its deliverable: the proposed concept considers the EWP as a level 3 engineering set of activities, which have as deliverable a certain number of documents[10] which feed CWPs in a general way, but not necessarily equal to the set of documents needed by a single CWP. The set of documents needed by a CWP to be performed on the field will take the name of *Document Package*. All these efforts were done for the willing of differentiating the concept of deliverable (document) from the relative engineering activity; with the final aim of simplifying the management of the schedule, avoiding bottlenecks and duplication of the scope of the work and a better understanding of the methodology.

We have explained the validity of our idea about the new definition of Engineering Work Package, as the effort of engineering for producing a certain number of deliverables such that it can be considered a single activity on the level 3 schedule. The logical consequence of what we have said is that the relationship between the new EWPs and DPs will be, in general m to n, with m not necessarily equal to n.

[10] All the IFC drawings, Vendor data, etc. together with their predecessors.

Error! Reference source not found.**s 7 and 8** explain graphically some of the possible situations we could deal with. This is one of the simplest cases, having considered just two entities for each kind.

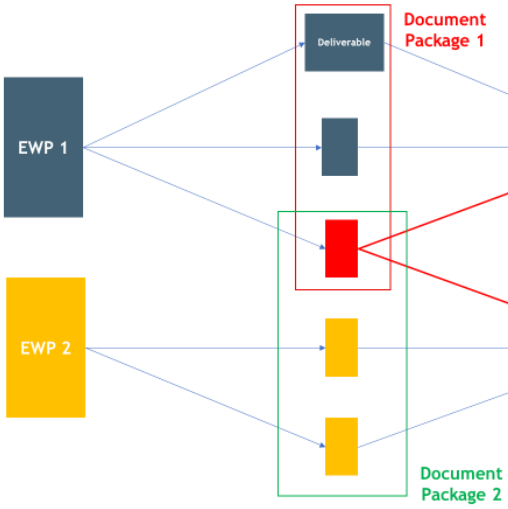


Figure 7 – EWP-Document Package-CWP old relationship

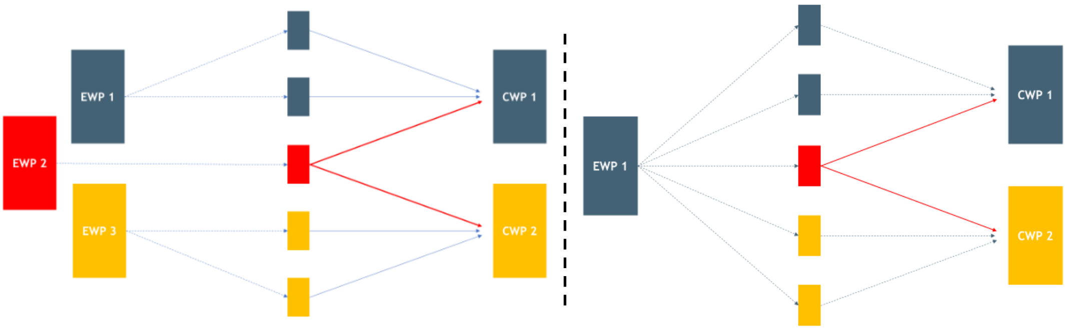


Figure 8 - EWP-DP-CWP new possible network case analysis

According to construction activities prioritization, critical Document Packages shall be prioritized, and, on a consequence, EWPs shall be prioritized using the same approach. At this point, it would be interesting to understand, how to integrate a package-wise approach for the Procurement supply chain management, according to the new definition of PWP and Material Package we have provided.

7. Conclusions

Summarizing the progress made on this project, we started from the results obtained through the analysis of the Middle East Project. This evaluation led us to the definition of an operative framework for the possible implementation of Information Management techniques aimed at

Advanced Work Packaging. As we approached this new project, we obviously had to take into consideration some modifications necessary to the functioning of the logical scheme, which after small changes in shape was not affected in its main structure and therefore standardized. In addition, we have benefited from the evolving business situation, as the America Project was the first ever to adopt AWP concepts. For this reason, the definition of the areas starting from the Plot Plan was immediately preparatory to the methodology and allowed us to identify (through the concept of DAS introduced by us) a finite number of CWP (only for piping and civil, relative to CWA L). This number, although it could take on a slightly different value during the development of detailed engineering, is anyway nevertheless a solid base for the AWP analysis of the project. We also had the opportunity to effectively identify the EWPs related to these CWPs.

So, answering to the initial research question it came up that there is no reason to think about a CWP as a standard package of 40,000 SMh, but it shall be fit-for-purpose with respect to the project's size. The CWP-Matrix model is a new tool for counting CWPs transversally within a project (whole plant, or isolating a single discipline, or isolating a single area, or isolating both of them). It is worth pointing out that in literature the idea that the CWP is just the amount of working hours (for each kind of discipline, one discipline at a time) having as deliverable the construction of a complete portion of the plant, is already commonly known: the CWP must not be confused with the respective deliverable, or rather a real structure erected on site. So, the CWPs is a separate and independent portion of the scope of the total work, relative to the branching of the WBS concerning on-site activities.

Answering to the second research question regarding EWP, it has been demonstrated that the current common definition is incoherent. So, an EWP has been re-defined as a set of engineering activities producing a deliverable, while we refer to the set of documents which feed the CWP as a Document Package. We have demonstrated that the numerical relationship between these entities is not linear, but it has to be considered in its broad sense. The new definition of EWP allows an evaluation of the progress of the different package engineering activities. In fact, according to the old definition, the work in progress of the engineering activities linked to the realization of CWPs and the work in progress of the relative Document Package would coincide. According to the new meaning, engineering activities would be monitored through independent packages that cannot be overlapped from the point of view of the respective deliverables. In other words, according to the old definition, it is not possible to connect to the final deliverables (IFC documents) all the upstream flow of work necessary to achieve these deliverables.

Finally, we can conclude that Advanced Work Packaging favors the Contractor with respect to the subcontractors, who can be entrusted with pre-established and easily monitored portions of work. The extreme of this concept leads to the micro-EPC philosophy, which leaves the possibility of sub-contracting not the whole scope of work endorsed within the plant, but each of its single portions to different subcontractors. This idea, as bold as it is innovative, would have considerable economic benefits deriving from the increase in the degree of freedom coming from an increased number of tenders.

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