Work Breakdown Structures for Engineering Projects

An Online Continuing Education Course for Engineers

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Course Contents

1 Introduction

1.1 Project Scope Definition

The project scope is all the products, services, and deliverables required to complete the project. The combination of the scope statement, work breakdown structure (WBS), and WBS dictionary is often considered the "scope baseline":

Scope baseline = Scope statement + WBS + WBS Dictionary

The scope statement should describe the general quantity and quality of work that is required in the delivery of a product, system, or facility that meets the requirements of the client and/or project sponsor. A scope statement outlines deliverables, design objectives, boundaries, exclusions, and acceptance criteria. Unfortunately, the project scope does not simply present itself and must be thought through by the project manager and/or design manager, with input from the project team and project sponsor.

Even if all the alternatives have been evaluated and selected with a clear line of sight on the design elements (which is rare), there are likely unique tasks and deliverable details that still need to be fleshed out in order to write a good scope statement.

Example questions to ask when developing a scope of work and writing a scope statement:

- How detailed should the design report be on technical requirements?
- What level of accuracy is needed for the class estimate?
- How detailed should the 3D model be?
- Should clash detection be done on a 3D model?
- How many drawings are estimated for each discipline?
- How many specification sections are estimated?
- Should the topographic survey include a boundary survey, easement search, and title search?
- Should the geotechnical report include foundation options or a single recommendation?

Flushing out these questions further develops the scope definition. A correct scope definition ensures that all the parties involved in the project (PM, design staff, subcontractors, project sponsor and champion, client staff, contractors, and regulators) understand the results and roles of a project in a common way.

Scope creep is an occurrence in which new activities, functionality, or requirements are introduced into the project without a corresponding change in time, cost, or resources.

1.2 Vulnerability of Engineering Projects

Although scope definition and scope management are important for all projects, design projects and engineering projects need even greater attention. The nature of a design project involves creativity, undecided alternatives, ever-evolving arrangements, multi-discipline teams working in different software, a need for technical precision, constructability issues, safety issues, code compliance issues, regulatory-related changes, and value engineering to keep within a client's budget. All this makes the project very susceptible to scope creep.

Unlike repetitive construction or manufacturing work, all design projects are unique. For example, a pilot project of a new plant, system, or process. This kind of individuality will keep a PM on their toes. Clients usually polish their requirements after reviewing design submittals, which demand additions or modifications. The various regulatory agencies may introduce new requirements in the project. The field conditions often change from the record documents and preliminary surveys, which impact the design arrangement. Besides that, the engineering teams work in various fields, including civil, electrical, mechanical, process, and structural, which are interdependent and rely on the elements from one another, such that if one discipline makes an equipment selection change, the other disciplines need to adjust their designs and the entire arrangement needs to be reviewed to confirm the change has been fully coordinated.

Another contributor is design iterations. Initial conceptual steps are premised on assumptions and incomplete information. Better information is developed early in the design process, which results in design changes. The battery limits shift as the design moves from what was originally assumed to what is actually needed. This process is normal in design and often not seen as a change in scope.

1.3 Gold Plating

However, in the process of progressing the design, staff may want to add features that have never been required but offer some benefit to the end user or owner. For example, a mechanical engineer can opt to add a redundant pump with associated piping, power supply, and controls. An architect can add EIFS (Exterior Insulation and Finish Systems) to a structure that was originally scoped to have plain walls. This is called gold plating, which represents good intentions but results in unapproved scope creep. Without proper approval and management, small design decisions like this add to the level of effort required, which can impact the budget and schedule. Also, it raises the construction cost estimate, which later can lead to value engineering to discover and remove the gold plating.

1.4 Work Breakdown Structures as a Tool for Managing Scope

To combat these challenges, PMs are increasingly relying on the Work Breakdown Structure (WBS) to create a hierarchical level of breakdown that divides a project into manageable and measurable activities. WBS transforms abstract objectives into physical deliverables, whereby all the elements of the design work are taken into consideration.

The WBS is a project breakdown map, indicating what will be in the project and what will not be in the project, based on the implications. It is not a substitute for a scope statement, which goes into technical details, but the two are complementary. Typically, a written scope statement is part of the initial project contract, agreement, or agreed-upon scope of work, and the WBS is made based on the scope statement. A WBS can include internal processes that are not listed in the scope statement, such as quality reviews, internal team meetings, or draft documents that are not deliverables to the client.

By breaking down the work from deliverables to work packages, one is able to organize what needs to be done to complete the project and who will perform each task. Each level of the structure is further elaborated, and the scope definition is related to schedule and cost management. An organizational chart is helpful in preparing a WBS for assignments. If the WBS has sufficient breakdown, when a design modification arises, a PM can quickly determine which tasks and staff are impacted, which ultimately helps determine if the modification is a part of the original scope of work, is gold plating, which can be eliminated, or is a change in scope that requires a change request.

1.5 Purpose of this Course

The course seeks to demonstrate why the development and utilization of a WBS is an important part of an engineering project. The goal is to help project professionals and design leaders develop a quality WBS that matches the scope statement, schedule, and budget. A main benefit of this approach is to avoid scope creep.

2 Understanding Scope Creep

Project scope varies greatly depending on the nature of the work. Engineering projects can involve the addition of a new system, building, infrastructure, digital elements, or land development. Inevitable, a change in design occurs. This could be a new feature, a regulatory change, or a new deliverable. These changes should be captured through change management and a change order or change approval. Such changes are not scope creep, as they are managed through a formal change control process.

However, gold plating, as defined previously, is an example of scope creep. Uncontrolled scope growth is where such modifications multiply without proper approval and lead to a vague conception of what the project should offer. Change occurs in every project, but the difference would be that the change is either managed or creeping.

A PM may not be able to tell at a glance if a modification should go through a formal change approval process or if it is scope creep that should be stopped. The PM should review the relevant project documents, such as the original agreed scope of work and WBS, consult with relevant coworkers, and/or consult with the project sponsor. When in doubt, the change should be listed on a change log as a potential scope change and evaluated through the formal change process.

2.1 Causes of Scope Creep

Poor scope definition during proposal and planning is the most common cause of scope creep. Key initial documents include the project charter, feasibility report, design brief, proposal, contract, and project plan. If the scope is not clear in these documents, the goals of the assigned participants may differ based on their interpretation of what is needed. This vagueness generates assumptions that would be found out at a later stage, as incompatibilities between the designs from each discipline or a construction cost estimate and schedule that is overbudget.

For example, when the project for a facility expansion does not specify upgrading the control system, engineers may program a new control system when the client would be satisfied with minor upgrades to the existing software. One way to prevent this is to have the design disciplines review and add details to the written scope statement during the proposal and planning phases. Exclusions and assumptions should be written, reviewed, and discussed. It is better to take the time early rather than later in the project when rework is required.

Failure to align the stakeholders is another common cause for scope creep. Projects have multiple stakeholders, including the project sponsor, project champion, other client staff, customers, operators, architects, engineers, construction contractors, regulators, cost estimators, procurement staff, etc. Each of them possesses their own priorities and opinions. Structured communication, including an early review of project assumptions, can clarify expectations and get any strong opinions out of the way early.

For example, a client assumes that site civil work encompasses landscaping, but the civil design team does not do landscaping design. This creates a gap in scope that will be identified at a late stage when the client reviews the design documents and comments to add landscaping. If landscaping is not listed as excluded in the assumptions in the agreed scope of work, the PM may then argue that landscaping is not normally considered civil work and thus was not in the civil scope of work. The client may disagree.

A significant factor in the extent of the scope creep is the extent of client management by the PM. Clients are in a position to dictate expectations and approve deliverables, which can creep into a position to dictate changes. For example, the owner may decide mid-way into the project that the building needs to have provisions to allow future expansion. These requests are usually based on actual benefits, but without the formal control of change, the client requests may get out of control and impact the cost and timeline of the project. The PM needs to remind all parties of the original agreed-upon scope of work and of the unintended consequences of making major design changes late in a project.

2.2 Real-World Examples of Scope Creep

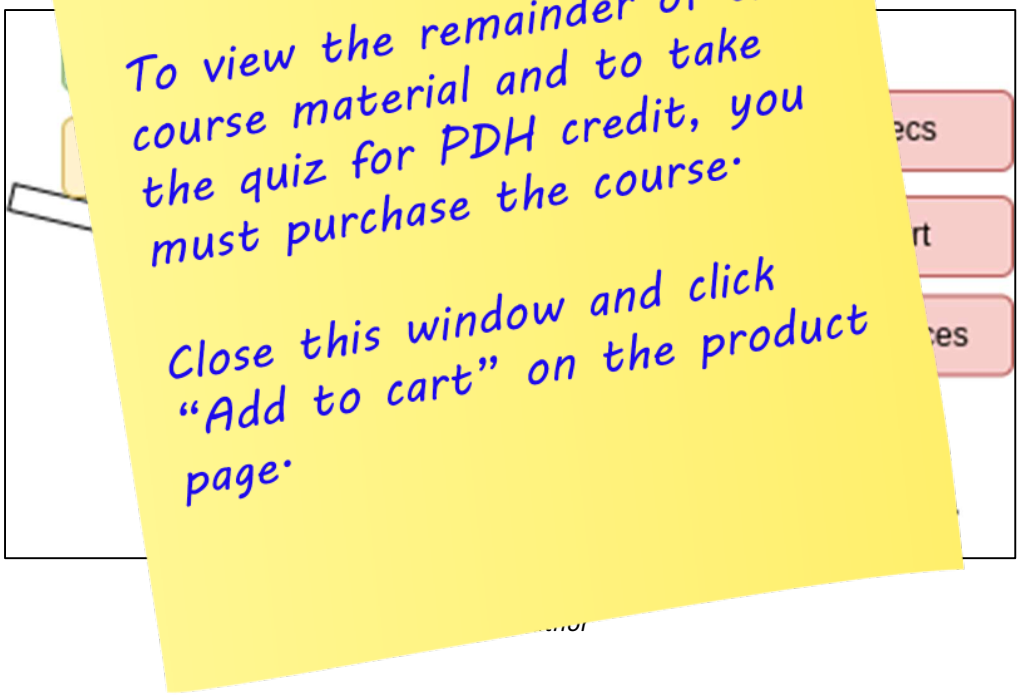
Consider the case of a wastewater treatment plant redesign with the original goal to improve the processing of sludge. New regulation requirements are introduced at the detailed design stage, with the need to have additional nutrient removal. To fulfil the attempt, the engineers must include the usage of a chemical dosing system, change the hydraulic profiles, and redesign the logic of process control. With all the validity of the reason for compliance, the additional design work adds months to the schedule,

thousands of dollars to the design schedule, and hundreds of thousands of dollars to the construction cost. This scope creep should be captured through a formal change approval process.

In another case, a manufacturing expansion project aimed at increasing production capacity suffers from midstream modifications. First, it involves the introduction of a new production line that was covered. When halfway through, the management decides to integrate a robotic packaging system to save on labor costs. Now, the mechanical and electrical design teams have to redesign layouts, revise control schematics, and change utility requirements. The result is an overbudget and a six-week unplanned postponement. Again, the scope creep should be captured through a formal change approval process.

2.3 Consequences of Scope Creep

Unchecked scope creep disturbs the delicate bal udget goals versus using effort and resources needed to how extra product specifications



Budget overrun is an obvious effect of scope creep. Additional design time, new work, and unexpected amounts of work cause costs to increase. Other types of budget problems include construction cost increase, lifecycle cost increase, return on investment decrease, and payback period increase.

Next come schedule delays. Every emerging requirement has a coordination, review, and redesign cycle across disciplines. Dependencies lead to delays, such as mechanical modifications must wait until structural engineers, drafters must update models, and procurement schedules must be updated. The