The Influence of Non-Standard Work Breakdown Structure on Change Orders and Cost Estimation for Sudan Oil and Gas Projects

Mohammed El Rashid

Abstract

Oil and Gas Projects in Sudan experiences an excessive numbers of change orders (CO) during the projects lifecycle, causes of these CO's are varying due to many reasons which affect directly the total cost of the project. The author argues that the major reason of the problem is due to the unavailability of standard Work Breakdown Structure (WBS) which led to ambiguous scope. This immature scope led to considerable variations and change orders claimed by the Contractors due to inaccurate project cost estimates in the first place. The author argues that adopting standard WBS can significantly reduce the number of CO per project by bridging all the gaps and tighten the scope of work. In order to arrive to the best WBS, the author establishes a comparison between the non-standard WBS (used in Sudan), the standard WBS and the multi-dimensional (i.e. OmniClass Construction Classification System OCCS, NORSOK) with a use of case study showing the variance in the cost estimation as a result of ambiguous SOW. The paper concludes that the adoption of a standardized multi-dimensional WBS could help refining the scope which help the company and contractors to have better cost estimation and consequently reduce the numbers of change orders per project.

Keywords: Change Order (CO), Work Breakdown Structure (WBS), Standardized/Non-standardized WBS, multidimensional WBS, the Fish Bone Diagram, Variance, Standard Deviation, Coefficient of Variation, Accuracy, wellhead construction WBS, Invitation to Bid (ITB).

1. Introduction

Sudan Oil and Gas Sector experiences a considerable number of change orders on each project due to many factors, the author argues that one of the major factors is the using of non-standard WBS. The author is exploring how the use of non-standard WBS will resulted in big variance in cost estimate. On the other hand the using of the Standardizes WBS will lead to a clear scope and mature cost estimation.

As per the Best Practices for Developing and Managing Capital Program Costs: "A detailed WBS as much as possible, should be used and refining as cost estimating system matures and becomes more specific and defined. The WBS ensures that no any parts of the estimate is deleted and makes it easier to make similar comparisons for systems and programs."[1]

The author argues that by adopting the Work Breakdown Structure Standardization for onshore development by selecting the best fitted one, a significant improvement can be made on projects' cost estimations and consequently reducing the Change orders for better projects performance.

2. Change Orders and reasons behind them in Sudan

The change order is written order to contractor to change part of scope, duration and or contract price. The Change order is "a unilateral written order to a contractor to modify a contractual requirement within the scope of contract and consistent with the terms of that contract. In another meanings change order is a form used to the construction contractor to change the scope of the work and contract price"[2].

"What are the causes of change orders in Oil and Gas projects in Sudan?" this question was circulated among a group of project practitioners in different types of oil and gas projects. The answers were demonstrated in the below table:

	Reason behind multiple Change order in Sudan by Project Management Team	**Summary of the Reason**
1	Lack of communication between user departments (initiator), Project Management Team (PMT) and Project Management Consultant (PMC).	Communication
2	Lack of input data from user departments (Initiator)	Scope/Design
3	Design is not performed properly with poor review from the PMT and or the PMC	Scope/Design
4	Fast track projects increase the mistakes and or omissions.	Schedule
5	Poor coordination/communication between different vendors in one project.	Communication
6	Adopting new technology with no previous knowledge or experience between PMT and PMC.	Know-how
7	No clear future plan which lead to additional requirements and incomplete scope	Scope
8	ambiguous scope from owner which resulted in ambiguous/inaccurate proposal by contractor	Scope
9	Complicated interfaces among EPC Projects	Scope
10	Un-seen factors: i.e. working inside an existing facilities	Know-How
11	Lack of reviewing of Design/Engineering documents	Scope/Design
12	Owner Supplied item affecting Engineering/Construction	Material/Resources
13	Improper contract administration and documentation during contract execution	Contract
14	Weak scope definition. Specification not updated properly according to project requirement.	Scope/Design
15	Start Engineering works prior to the final input data to expedite the project (Fast Track Projects)	Scope/Design
16	Interference of different management levels	Communications
17	Poor coordination between contractors.	Communications
18	Defective contract clauses	Contract
19	Force Major	Unforeseen
20	Resources mismanagement	Resources/Material

Table 1 : Possible Reason for Change orders as per the survey among Project managers in Sudan (source: by author)

3. Analysis for the possible reasons of change orders

With reference to Table 1, the mentioned reasons could be categorized as follows:

- Category 1: Scope/Design,
- Category 2: Communication & Know-how,
- Category 3: Material/Resources and Contract and
- Category 4: Unforeseen Condition & Others.

Then the author applied the root cause analysis (Fish Bone Diagram) and the ordinal ranking where the above mentioned causes were evaluated and ranked as follows:

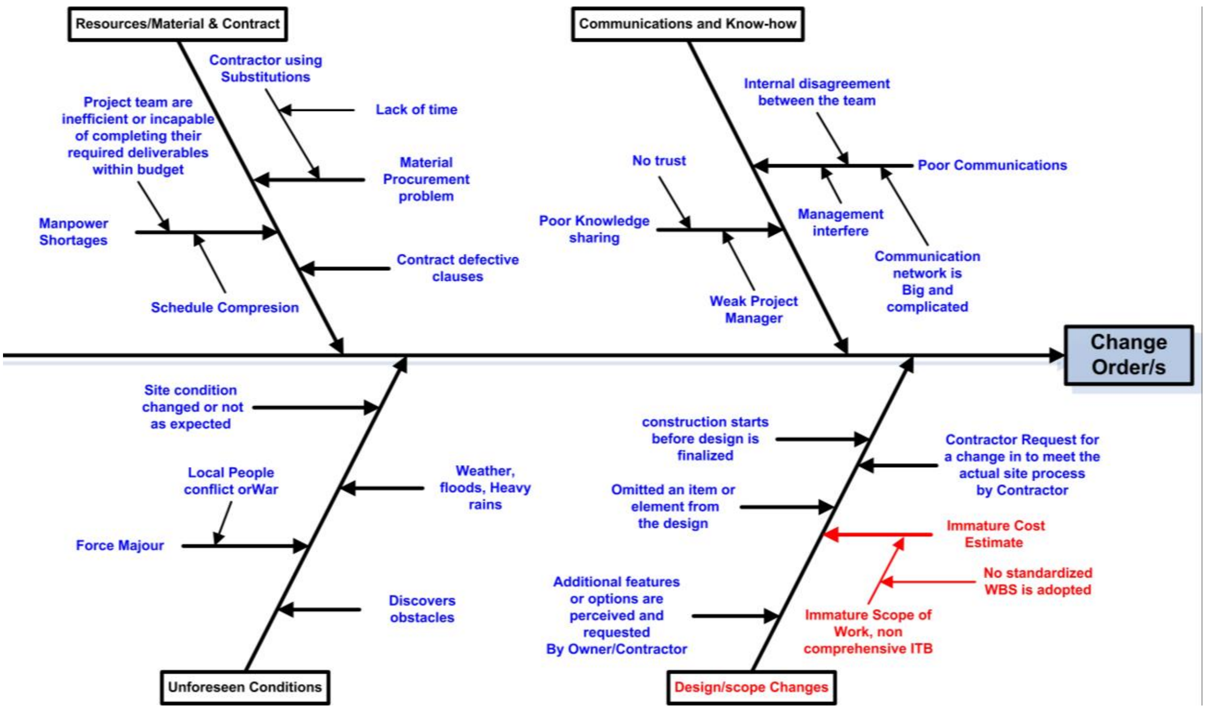

Figure 1 : Change order root cause analysis using the Fish Bone Diagram (source: by author) [3]

Furthermore, the author applied the Ordinal Ranking of change order causes attributes, as follows:

Attribute	**Rank**
A-Result of Paired Comparisons	
Scope/Design Change > Communications and Know-how	Scope/Design Change affect more than Communications and Know-how
Scope/Design Change > Unforeseen Conditions	Scope/Design Change affect more than Unforeseen Conditions
Scope/Design Change > Resources/Material & Contract	Scope/Design Change affect more than Resources/Material & Contract
Communications and Know-how > Unforeseen Conditions	Communications and Know-how affect more than Unforeseen Conditions
Resources/Material & Contract > Communications and Know-how	Resources/Material & Contract affect more than Communications and Know-how
Resources/Material & Contract > Unforeseen Conditions	Resources/Material & Contract affect more than Unforeseen Conditions
B-Attribute	**Number of Time on left > (=Ordinal Ranking)**
Scope/Design Change	3
Communications and Know-how	1
Resources/Material & Contract	2
Unforeseen Conditions	0
Rank of 3 = most important, Rank of 0 = least important	

Table 2 : Ordinal Ranking of Changer order causes attributes (source: Adapted by author from Sullivan, W, Wicks, E, & Koelling,. (2009), Engineering Economic, Fifteenth Edition.) [4]

As per the above analysis, the author argues that the major cause of change orders is the design change. Design change is resulted from the ambiguous scope in projects Invitation to Bid (ITB) Documents. Poor scope definition will lead to poor cost estimation; the same can consequently increase the contractor willingness for claiming change orders to compensate the unclear scope which could be avoided through refining a scope using a standard WBS. The following chapters briefs and compares the Standard WBS versus non-Standard WBS and its effect on the cost estimation.

4. WBS, what is it and why Standardized?

4.1 What is the WBS?

WBS is the way that the project may be divided into discrete groups by level for cost planning, programming and control purposes. In another meaning The WBS serves as a framework for defining all project work elements and their interrelationships, collecting and organizing information, developing relevant cost and revenue data, and integrating project management activities.
A WBS can either be standard by using of the various types of the Standardized WBS (i.e Norsok, CSI, OmniClass) or it can be non-standard which could be developed by individual as per their project's needs.

"A standard WBS has been defined as a "neutral work breakdown structure that can be used more than once and serves as a template for creating operative work breakdown structures, while a non-standard WBS is neither neutral nor can be used as a template for subsequent operations" [5].

4.2 Why using a WBS, The following represents reasons for using WBS

1. Very efficient project cost estimation
2. Accurately identify and organize the total project scope into manageable components.
3. Ease the assigning responsibilities tasks, allocation of resource, monitoring and control of projects.
4. By using of the WBS, the deliverables can be concrete and more precise so project team can know exactly what to be accomplished within each deliverable.

4.3 Types of Standard WBS

The following are the examples of the international accredited WBS standards. There are currently three major types of standardized WBS as follows:

- Norsok Z-014 (Three dimensional models).
- CSI's two dimensional (UniFormat/Master Format).
- OmniClass 15 dimensional model.

4.3.1 The NORSOK

NORSOK standard is a system of coding for cost, weight estimates and as-built and experience data. The SCCS consists of three coding structures individually with separate and different kind of purposes [6], as follows:

PBS	• Physical Breakdown Structure – PBS This hierarchical structure defines the Physical/Functional components of «Projects» during any phase of development. The PBS provides a coding structure, which enables any known Oil and Gas Production and processing facility configuration scheme to be coded. The structure presented in this manual is independent of project specific area/module/sub-project classification systems.

SAB	• Standard Activity Breakdown – SAB This hierarchical structure provides a timescale attribute to express when during the project lifetime, expenditures and activities occur. The structure presented in this manual is independent of Project Specific Work Breakdown Structure (WBS) or Activity Breakdown Structures (ABS). The alphabetical prefix introduces a code for use of SCCS throughout all phases of a project, from exploration through removal of facilities.
COR	• Code Of Resource – COR This hierarchical structure classifies all project resources and categorises resources according to primary, secondary and tertiary levels of resources. This hierarchical structure also termed Code of Account (COA) classifies the complete scale of resources involved in developing offshore and landbased installations

Table 3: NORSOK three coding structures (Retrieved from: https://www.scribd.com/doc/96250942/Z-014)

4.3.2 Master/UniFormat

The Construction Specification Institute (CSI) created a two dimensional model based on component (Uniformat) and Trade or subcontract (MasterFormat) and while originally designed to standardize the writing of contract documents, has proven to also work effectively as a standardized Work Breakdown Structure (WBS) and Cost Breakdown Structure (CBS) [7].

UniFormat	A publication of CSI and CSC, is a method of arranging construction information based on functional elements, or parts of a facility characterized by their functions, without regard to the materials and methods used to accomplish them. These elements are often referred to as systems or assemblies.
Master Format	A publication of CSI and CSC, is a master list of numbers and titles classified by work results. It is primarily used to organize project manuals and detailed cost information. and to relate drawing notations to specifications

Table 4: Master/UniFormat :(Retrieved from: http://www.csinet.org/FPIUF)

4.3.3 The OmniClass

OmniClass Standard is the Construction Classification System (also known as OmniClass or OCCS) [5], which developed for organizing and retrieving construction industry information. It consists of 15 hierarchical tables; they are representing the different aspects of construction information. Each of the below mentioned tables can be used independently or combined to serve a particular type of projects or subjects [8]. The 15 tables are:

Table 11	Construction Entities by Function
Table 12	Construction Entities by Form
Table 13	Spaces by Function
Table 14	Spaces by Form
Table 21	Designed Elements
Table 22	Work Results
Table 23	Products
Table 31	Phases
Table 32	Services
Table 33	Disciplines
Table 34	Organizational Roles
Table 35	Tools
Table 36	Information
Table 41	Materials
Table 49	Properties

Table 5: OmniClass Tables (Retrieved from: http://www.buildingsmartalliance.org/index.php) [9]

5. Case study for wellhead cost estimation using the non-standard WBS

A case study of Oil and Gas wellhead tie-in construction project in oil Operator Company in Sudan is considered to show the variance on the cost estimates when using the non-standard WBS, the WBS is given up to level 2 along with the case study data is shown in the below table No.6. The estimates in

Table 6 are for Level 2 WBS elements provided by three bidders; these cost estimates were compared and evaluated vs the company estimates. This data will be examined and analyzed by using the standard deviation (SD) and Coefficient of Variation (CV).

	WBS for a Well Head Tie Construction Project	Company	Bidder A	Bidder B	Bidder C
1.0	**Engineering**	$20,000	$36,514	$25,049	$35,000
	1.1 Detailed Construction Schedule				
	1.2 Detailed Field Engineering & Drawings, Work Procedures, HSE Plans, Quality Plan, etc.				
	1.3 Material reconciliation for the works				
	1.4 Other engineering Works				
2.0	**PROCUREMENT**	$90,000	$100,000	$87,670	$50,000
	2.1 Issuance of Purchase Order of Main Equipment:Prefabricated Buildings, Piles, RMUs, Transformers, MDBs, Piping Materials,				
	2.2 Submittal of Approved SPIRs, Main Equipment FAT Certificates				
	2.3 Arrival of Main Equipment at Site				
3.0	**Site Mobilisation**	$20,000	$30,000	$25,049	$31,422
	3.1 Completed manpower Mobilisation				
	3.2 Completed macheny Mobilisation				
4.0	**Civil Works**	$22,500	$18,257	$12,524	$15,711
	4.1 Completed R.O.W for Flow lines, Completed Civil Earth Work for Wellhead Facilities and Flow line				
5.0	**Complete Erection and Pre-commissioning of:**	$100,000	$91,285	$62,622	$78,554
	5.1 Flow lines,				
	5.2 Piping of Wellhead Areas,				
	5.3 Electrical & Cathodic Protection,				
	5.4 Instruments, etc.				
	5.5 Cathodic Protection System (CP)				
6.0	**Commissioning**	$35,000	$36,514	$25,049	$50,000
	6.1 Commissioning of Complete System				
	6.2 Item and Hand over to Petroenergy				
7.0	**Submission and Handing over of Final Documentation:**	$13,000	$18,257	$12,524	$15,711
	7.1 QC Documents and Certified Test Reports				

Table 6: Level 2 WBS Elements Cost Estimates for the Case-study of well head Construction, provided by the company and three bidders (source: by author)

Analysis and comparison of alternatives:

The author will consider the using of two statistical toots to measure the level of dispersion. The SD (Standard Deviation) to measure the variation in a cost estimate distribution, moreover upon the results of the SD, the CV (Coefficient of Variation) will be calculated to measure the relative dispersion, or relative risk. Those two tools will give clear indicates on the credibility of the cost estimation resulted from a non-standard WBS.

The formula of SD is as follows:

$$\sigma = \frac{\sqrt{\sum_{i=1}^{n}(x_i - \mu)^2}}{n} \qquad \text{(Equation 1)}$$

Where:

σ	=	Standard Deviation
Σ	=	Sum of
X	=	Each Value in the data set
µ	=	Mean of the all value in the data set
n	=	Number of value in the data set

The formula of CV is as follows:

$$cv = \frac{\sigma}{\mu} * 100 \qquad \text{(Equation 2)}$$

Where:

CV = Coefficient of Variation
σ = Standard Deviation
μ = Mean of the all value in the data set

The results of the (CV) analysis will have the following interpretation [10]:

- If CV is less than 16.6% then, the cost estimate will be considered reliable and acceptable.
- If CV is in the range of 16.6% to 33.3%, then, the cost estimate will have a high level of errors and ranked as Marginal.
- If CV more than 33.3% then, the cost estimate will be considered unreliable and not trustable.

Calculation:

	WBS for a Well Head Tie-in Construction Project	wt	X (n)				Mean Estimates	Standard Deviation	Coefficient of Variation
			Company USD	Bidder A USD	Bidder B USD	Bidder C USD	$\mu = \Sigma x(n)/4$	$\sigma = \sqrt{\Sigma(x-\mu)^2/4}$	$CV = \sigma/\mu\ (100)\%$
1.0	Engineering 1.1 Detailed Construction Schedule 1.2 Detailed Field Engineering & Drawings, Work Procedures, HSE Plans, Quality Plan, etc. 1.3 Material reconciliation for the works 1.4 Other engineering Works	10%	$20,000	$40,000	$15,400	$35,000	$27,600	$10,187	37%
2.0	PROCUREMENT 2.1 Issuance of Purchase Order of Main Equipment: Prefabricated Buildings, RMUs, Transformers, etc., 2.2 Main Equipment FAT Certificates 2.3 Arrival of Main Equipment at Site	35%	$90,000	$150,000	$88,000	$50,000	$94,500	$35,788	38%
3.0	Site Mobilisation 3.1 Completed manpower Mobilisation 3.2 Completed machenry Mobilisation	10%	$20,000	$30,000	$22,000	$47,000	$29,750	$10,639	36%
4.0	Civil Works 4.1 Completed survey for Flow lines, Civil Earth Work for Wellhead Facilities and Flow line	5%	$20,000	$60,000	$28,600	$23,500	$33,025	$15,871	48%
5.0	Complete Erection and Pre-commissioning of: 5.1 Flow lines, 5.2 Piping of Wellhead Areas, 5.3 Electrical & Cathodic Protection, 5.4 Instruments, etc. 5.5 Cathodic Protection System (CP)	25%	$90,000	$120,000	$66,000	$164,500	$110,125	$36,763	33%
6.0	Commissioning 6.1 Commissioning of Complete System 6.2 Item and Hand over to Petroenergy	10%	$30,000	$40,000	$33,000	$50,000	$38,250	$7,693	20%
7.0	Submission of Final Documentation: 7.1 QC Documents and Certified Test Reports	5%	$10,000	$20,000	$11,000	$23,500	$16,125	$5,770	36%
	Total - USD	100%	$280,000	$460,000	$264,000	$393,500			

Table 7: Calculations of SD and CV (source: by author)

From above calculated values of WBS elements, CV ranges between 20% and 48%. Given the previous interpretation of CV values, the following interpretation can be made:

- Since there is no value for CV less than 16.6 %., then no estimates is considered reliable.
- CVs for element (5.0) and (6.0) are 33% and 20% respectively, those values are not trusted because of high level of error associated with it and it could only be used after warning users.
- CVs for element (1.0, 2.0, 3.0, 4.0, 7.0) are higher than 33% and considered unreliable and not properly estimated.

Therefore, establishment of credible cost estimate with the use of non-standard WBS is remains a very great challenge. Since there are a lot of gaps in defining the project scope and lack of detailed WBS, accordingly there was considerable variation in project cost estimates. This estimates variations are representing the needs for a proper WBS, Selection of optimum WBS for Sudanese projects is discussed in the next chapter.

6. The optimum WBS to be adopted

In order to arrive to the optimum WBS that can be adopted by Sudanese Projects, the author uses feasible alternative analysis. The analysis identifies the selecting the suitable WBS by applying the following comparisons to a three alternatives:

1. Non-standardized WBS versus standardized WBS
2. Single dimensional WBS versus Multi-dimensional Standardized WBS
3. Which Standardized Multi-dimensional WBS to be considered?

6.1 Feasible Alternative Analysis 1: Current non-standardized WBS vs. standardized WBS

The analysis will compare the current nonstandard WBS adopted in Sudan with the available Standardized WBS (i.e Norsok, CSI Master/UniFormat, OmniClass) by using of a non-compensatory model for the multi attributes decision-making techniques, the details' descriptions of the standardized WBS were early mentioned in chapter 4. The below attributes have been selected for the analysis as follows:

- WBS Level of Details
- Complexity of the WBS
- Coding System
- Cost Definition Basis
- Scope Definition refining

Each WBS comparison of the attributes is expressed in table 8 below:

	Attributes	Non Standardized WBS (Current Sudan WBS practices)	Standardized WBS (OmniClass, Norsok,CSI/UniFormat)
1	WBS Level of Details	Poor	Very good
2	Complexity	Easy	Moderate
3	Coding System	Not unique	Unique
4	Cost Definition Basis	Different coding basis	Uniform coding basis
5	Scope Definition refining	Poor	Very good

Table 8: Ordinal Ranking of WBS attributes (source: Adapted by author from Sullivan, W, Wicks, E, & Koelling,. (2009), Engineering Economic, Fifteenth Edition.)

Attributes in table 8 were ranked in order of importance by applying paired comparison between each attribute combination. Results are shown on table 9 below:

Ordinal Ranking of Attributes		
A. Result of Paired Comparison		
1.	WBS details > Complexity	WBS details is more important than Complexity
2.	WBS details > Coding System	WBS details is more important than Coding System
3.	WBS details > Cost Definition Basis	WBS details is more important than Cost Definition Basis
4.	WBS details > Scope Definition refining	WBS details is more important than Scope Definition refining
5.	Complexity > Cost Definition	Complexity is more important than Cost Definition
6.	Complexity > Coding System	Complexity is more important than Coding System
7.	Scope Definition refining > Complexity	Scope Definition refining is more important than Complexity
8.	Scope Definition refining > Cost Definition	Scope Definition refining is more important than Cost Definition

9.	Scope Definition refining > Coding System	Scope Definition refining is more important than Coding System
10.	Cost Definition > Coding System	Cost Definition is more important than Coding System
B. Attributes		**Number of times on left of >(=Ordinal Ranking)**
1.	WBS Level of Details	4
2.	Complexity	2
3.	Coding System	0
4.	Cost Definition Basis	1
5.	Scope Definition refining	3

Table 9: Ordinal Ranking of WBS attributes (source: Adapted by author from Sullivan, W, Wicks, E, & Koelling,. (2009), Engineering Economic, Fifteenth Edition.)

Following Table 9, the ranking is ordered as follows:
WBS Level of Details > Scope Definition refining > Complexity > Cost Definition Basis
Coding System

Application of Lexicography		
Attributes	**Rank (a)**	**Alternative (b)**
WBS Level of Details	4	**Standardized WBS** > Non Standardized
Complexity	2	**Non Standardized** > **Standardized WBS**
Coding System	0	**Standardized WBS** > Non Standardized
Cost Definition Basis	1	**Standardized WBS** > Non Standardized
Scope Definition refining	3	**Standardized WBS** > Non Standardized

Table 10: Application of Lexicography (source: Adapted by author from Sullivan, W, Wicks, E, & Koelling,. (2009), Engineering Economic, Fifteenth Edition.)

Note:
a) The Rank of 4 is Most Important, where the Rank of 0 is Least Important
b) The highest ranked attribute will be selected

Considering the above ranking results, it's obvious that the standardized WBS won over the non-standardized WBS. Therefore, the optimum WBS to be adopted is the Standardized WBS which better defines and refines the scope with in-depth level of details comparing to the Non-standardized WBS. The type of standardized WBS in terms of single or multi dimension will be selected on the next analysis.

6.2 Feasible Alternative Analysis 2: Standardized Single dimensional WBS vs. Standardized Multi-dimensional WBS

As a result of the above mentioned comparison between the standardized and Non-standardized WBS, obviously the standardized WBS has taken the lead. However, the requirement of single or Multi-dimensional Standardized WBS will be evaluated in the following analysis. The comparison will be established considering the use of the Ordinal ranking analysis. The below attributes have been selected to analyze and compare WBS as follows:

- Level of work package Details
- Complexity of the WBS
- Monitoring the Project
- Level of Scope refining,
- Number of Dimensions
- Managing Interfaces

The WBS comparison of the attributes is expressed in table 11 below:

	Attributes	**Standard Single Dimension WBS**	**Standard Multi Dimensions WBS (i. e. OmniClass, Norsok)**
1	Level of work package Details	Good	V.Good
2	Complexity of the WBS	Easy	Complex
3	Monitoring the Project	Good	V.Good
4	Level of Scope refining,	Low	High
5	No of Dimensions	1	3
6	Interfaces Management	Good	V.Good

Table 11: Ordinal Ranking of WBS attributes (source: Adapted by author from Sullivan, W, Wicks, E, & Koelling,. (2009), Engineering Economic, Fifteenth Edition.)

Attributes in table 11 were ranked in order of importance by applying paired comparison between each attribute combination. Results are shown as follows:

	A. Result of Paired Comparison	
1	Level of Details > Complexity of the WBS	Level of Details is more important than Complexity of the WBS
2	Level of Details > Monitoring the Project	Level of Details is more important than Monitoring the Project
3	Level of Details > Level of Scope refining	Level of Details is more important than Level of Scope refining
4	Level of Details > No of Dimension	Level of Details is more important than No of Dimension
5	Level of Details > Interfaces Management	Level of Details is more important than Interfaces Management
6	Complexity of the WBS > Monitoring the Project	Complexity of the WBS is more important than Monitoring the Project
7	Complexity of the WBS > No of Dimensions	Complexity of the WBS is more important than No of dimensions
8	Complexity of the WBS > Interfaces Management	Complexity of the WBS is more important than Interfaces Management
9	Monitoring the Project > Interfaces Management	Monitoring the Project is more important than Interfaces Management
10	Level of Scope refining > Complexity	Level of Scope refining is more important than Complexity of the WBS
11	Level of Scope refining > No of Dimension	Level of Scope refining is more important than No of Dimension
12	Level of Scope refining > Monitoring the Project	Level of Scope refining is more important than Monitoring the Project
13	Level of Scope refining > Interfaces Management	Level of Scope refining is more important than Interfaces Management
14	No of Dimensions > Monitoring the Project	No of Dimensions is more important than Monitoring the Project
15	No of Dimensions > Interfaces Management	No of Dimensions is more important than Interfaces Management
	B. Attributes	**Number of times on left of >(=Ordinal Ranking)**
1	Level of work package Details	5
2	Complexity of the WBS	3
3	Monitoring the Project	1
4	Level of Scope refining	4
5	No of Dimensions	2
6	Interfaces Management	0

Table 12: Ordinal Ranking of WBS attributes (source: Adapted by author from Sullivan, W, Wicks, E, & Koelling,. (2009), Engineering Economic, Fifteenth Edition.)

Following Table 12, the ranking is ordered as follows:

Level of work package Details is higher than Level of Scope refining is higher than Complexity of the WBS is higher than Number of Dimensions is higher than Monitoring the Project is higher than Managing Interfaces.

Application of Lexicography		
Attributes	**Rank (a)**	**Alternative (b)**
Level of work package Details	5	**Multi dimensions** > Single Dimension
Level of Scope refining,	4	**Multi dimensions** > Single Dimension
Complexity of the WBS	3	**Single Dimension** > Multi dimensions
No of Dimensions	2	**Multi dimensions** > Single Dimension
Monitoring the Project	1	**Multi dimensions** > Single Dimension
Interfaces Management	0	**Multi dimensions** > Single Dimension

Table 13: Application of Lexicography (source: Adapted by author from Sullivan, W, Wicks, E, & Koelling,. (2009), Engineering Economic, Fifteenth Edition.)

Note:
a) The Rank of 5 = Most Important, where the Rank of 0 = Least Important
b) The highest ranked attribute is selected

Considering the above ranking results, it's obvious that the Multi-dimensional Standardized WBS won over the Single dimensional WBS. The above comparison established based on using Ordinal ranking analysis. The multidimensional WBS was found an optimum selection to be adopted for better performance in project management and cost control. These are because the multidimensional WBS is better defined and refines the scope with in-depth level of details and ease/define the possible interface and facilitate monitoring the project compared to the single dimension WBS. There are different types of multi-dimensional WBS, the selection of the best one will be considered in the next analysis.

6.3 Feasible Alternative Analysis 3: which Standardized Multi-Dimensional WBS to be considered?

This chapter will identify which multi-dimensional WBS will be selected for further adoption; the comparison will be considering the use of the Ordinal ranking analysis. The study will consider the OmniClass vs NORSOK as Standardized multidimensional WBS (detail descriptions were mentioned in chapter 4). The two models will be evaluated considering the following attributes:

- Suitable for Onshore/Offshore
- Managing project Interfaces
- No of Dimensions
- Level of work package Details
- Monitoring the Project
- Level of Scope refining

The two multi dimensions WBS are configured as follows:

6.3.1 OmniClass

(31, 33, 34, and 41) where selected as a better combination for Oil and Gas project management in Sudan, details is as follows:

Table 31 – Phases: It's represented by two terms, as follows:

Stage: A categorization of the project principal segments. For instance: Conception, Project Delivery Selection, Design, Construction Documents, Procurement, Execution, Utilization and Closure.
Phase: A portion of work that comes from sequencing the work packages in accordance with a predetermined Stage portion. Phase is considered as subordinate level of a Stage.

Table 33 – Disciplines: It's the practice areas and specialties of the participants who are responsible for carrying out the project processes and procedures.

Table 34 – Organizational Roles: Organizational Role is the functional positions which will be handled by the both individuals and group's participants who will carry out the processes and procedures during the construction life cycle.

Table 41 – Materials: Are substances used in construction/manufacture products or others. These substances could be in a shape of raw materials or refined compounds [9].

6.3.2 NORSOK Z 014

NORSOK is consisting of 3 sets of sub-coding system, interchanged complementary, which are; Physical Breakdown Structure (PBS) which defines and describes the functional and physical projects components, standard Activity Breakdown (SAB), which defines and describes the timescale during which activities occur and Code of Resources (COR), which defines the entire project resources.

Selection of the preferred alternatives

As of chapter 6.3, The WBS comparison of the attributes is expressed in table 14 below:

	Attributes	**Norsok 3D (PBS: (Physical Breakdown Structure, SAB: Standard Activity Breakdown, COR: Code Of Resources)**	**OmniClass (Table 31-Phases + Table 33 Disciplines & 34 Org. Roles + Table 41 Material)**
1	Suitable for Onshore/Offshore	Offshore	Onshore
2	Managing Projects interfaces	Good	V. Good
3	No of Dimensions	3	15
4	Level of work package Details	Excellent	Excellent
5	Level of Scope refining	Excellent	Excellent
6	Monitoring the Project	V. Good	V. Good

Table 14: Ordinal Ranking of WBS attributes (source: Adapted by author from Sullivan, W, Wicks, E, & Koelling,. (2009), Engineering Economic, Fifteenth Edition.)

Attributes in table 14 were ranked in order of importance by applying paired comparison between each attribute combination. Results are shown as follows:

	A. Result of Paired Comparison	
1.	Suitable for Onshore/Offshore > Managing Projects interfaces	Suitable for Onshore/Offshore is more important than Managing Projects interfaces
2.	Suitable for Onshore/Offshore > No of Dimensions	Suitable for Onshore/Offshore is more important than No of Dimensions
3.	Suitable for Onshore/Offshore > Level of work package Details	Suitable for Onshore/Offshore is more important than Level of work package Details
4.	Suitable for Onshore/Offshore > Level of Scope refining	Suitable for Onshore/Offshore is more important than Level of Scope refining
5.	Suitable for Onshore/Offshore > Monitoring the Project	Suitable for Onshore/Offshore is more important than Monitoring the Project

6.	Managing Projects interfaces > No of Dimensions	Managing Projects interfaces is more important than No of Dimensions
7.	Managing Projects interfaces > Level of work package Details	Managing Projects interfaces is more important than Level of work package Details
8.	Managing Projects interfaces > Level of Scope refining	Managing Projects interfaces is more important than Level of Scope refining
9.	Managing Projects interfaces > Monitoring the Project	Managing Projects interfaces is more important than Monitoring the Project
10.	No of Dimensions > Level of work package Details	No of Dimensions is more important than Level of work package Details
11.	No of Dimensions > Level of Scope refining	No of Dimensions is more important than Level of Scope refining
12.	No of Dimensions > Monitoring the Project	No of Dimensions is more important than Monitoring the Project
13.	Level of work package Details > Level of Scope refining	Level of work package Details is more important than Level of Scope refining
14.	Level of work package Details > Monitoring the Project	Level of work package Details is more important than Monitoring the Project
15.	Level of Scope refining > Monitoring the Project	Level of Scope refining is more important than Monitoring the Project
	B. Attributes	**Number of times on left of >(=Ordinal Ranking)**
1.	Suitable for Onshore/Offshore	5
2.	Managing Projects interfaces	4
3.	No of Dimensions	3
4.	Level of work package Details	2
5.	Level of Scope refining	1
6.	Monitoring the Project	0

Table 15: Ordinal Ranking of WBS attributes (source: Adapted by author from Sullivan, W, Wicks, E, & Koelling,. (2009), Engineering Economic, Fifteenth Edition.)

Following Table 15, the ranking is ordered as follows:

Suitable for Onshore/Offshore > Managing project interfaces > No of Dimensions > Level of work package Details > Level of Scope refining > Monitoring the Project

Application of Lexicography		
Attributes	**Rank (a)**	**Alternative (b)**
Suitable for Onshore/Offshore	5	OmniClass > Norsok
Managing Projects interfaces	4	OmniClass > Norsok
No of Dimensions	3	OmniClass > Norsok
Level of work package Details	2	OmniClass = Norsok
Level of Scope refining	1	OmniClass = Norsok
Monitoring the Project	0	OmniClass = Norsok

Table 16: Application of Lexicography (source: Adapted by author from Sullivan, W, Wicks, E, & Koelling,. (2009), Engineering Economic, Fifteenth Edition.)

Note:
a) The Rank of 5 = Most Important, where the Rank of 0 = Least Important
b) The highest ranked attribute is selected

Considering the above ranking results, it’s obvious that the OmniClass WBS won over the NORSOK WBS. The two multidimensional WBSs have been examined as to choose the best/optimum WBS which will serve the need of Sudan projects, the above analysis comparison established based on the using of the Ordinal ranking analysis. The OmniClass WBS was found the optimum selection, since it has the highest score. The OmniClass is suited for the onshore projects and has the highest numbers of dimensions. Therefore, it could be adapted as a standardized WBS to enhance the project performance and cost control in Sudan's projects. The OmniClass as a multidimensional WBS is better defined and refines the scope with in-depth level of details and ease/define the possible interface and facilitate monitoring the project comparing to the others. These advantages will contribute significantly in reducing the number of change orders as it will reduce the possible scope omissions or errors.

7. Conclusion

Oil and Gas Projects in Sudan experiences an excessive numbers of change orders throughout the projects lifecycle. Causes of these CO's are varying due to many reasons. These reasons are affecting directly the project's cost estimate. This paper finds that the major reason is due to the unavailability of standard Work Breakdown Structure (WBS) which led to an ambiguous scope, accordingly to considerable variations and change orders claimed by the Contractors due to inaccurate project cost estimates in the first place. The author argues that adopting standard WBS can significantly reduce the number of COs per project by bridging all the gaps and tighten the scope of work. In order to arrive to the best WBS, This paper compares the non-standard WBS (used in Sudan), the standard WBS and the multi-dimensional (i.e. OmniClass Construction Classification System OCCS, NORSOK) with a use of case study. This paper concludes that the adoption of a standardized multi-dimensional WBS will help refining the scope which led to better cost estimation and consequently reduce the numbers of change orders per project. Among the available standardized WBS, this paper recommends OmniClass WBS as a best fit to the Sudanese projects as to minimize the change orders accordingly.

About the Author

Mohammed El Rashid

Mohammed El Rashid has studied Engineering and Technology at the university of GAZIRA and MBA of Engineering Management at ALZAEIM ALAZHARI University. He proceeded to work in industrial projects where his first role was a project engineer in industrial company focusing in multi industrial and manufacturing projects. Then, he joined the booming Oil and Gas sector in the capacity of planning and project control engineer in PETROENERGY E&P Co Ltd (one of the leaded Sudanese Oil and Gas companies). He was then promoted to be the head of Projects Control in PETROENERGY.

Recently Mohammed has joined CNOOC-IRAQ (a branch of a leaded Oil and Gas Chinese Company) in the capacity of Planning and Cost Control Supervisor. Mohammed is passionate about project management with extensive demonstrable skills in planning and cost control engineering. He possesses a proven track record in Oil & Gas Industry in various capital projects as a Planner, Project Control Engineer and Head of Project control for over 14 years. He holds international credential from AACEI as a Certified Cost Professional (CCP).

Mohammed can be contacted at melrashidpe@gmail.com