Best Tested and Proven Practices for Hospital Construction: Standardized Multidimensional WBS/CBS Coding Structures[1]

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ABSTRACT

From small organisations to large, health projects are growing rapidly with the current situation related to the Covid-19 Pandemic[2].

Efficient project management is increasingly more important to reach the objective while not wasting cost and time. An essential control element, the Work Breakdown Structure (WBS), has proven to be a tool to monitor and plan for projects. The WBS decomposes the project to manageable components. This helps the project team to execute the project in a more efficient way, properly estimate the schedule and cost, efficiently allocate and assign resources, and track the project progress and performance. This will lead to the success of the managed projects.

Through this case study, we will see the different models of WBS will be explored, including a multidimensional breakdown structure. The technical paper will also propose, based on comparison and evidence, the multidimensional breakdown structure for hospital projects to adopt to achieve project success.

Key Words: WBS, CBS, Multidimensional WBS, Hospitals, Coding Structures, Integrated Systems, Project Management Classification[3]

INTRODUCTION

" Clearly, organisations globally continue to find it difficult to deliver projects that meet all objectives around the iron triangle of time, cost and scope, along with achieving stakeholder satisfaction"[4]. The work breakdown structure (WBS)[5], in programme and project management terms is a deliverable-oriented decomposition of a programme or project into its smaller components. The WBS is the key deliverable that organises everything into manageable tasks and is perhaps the most important mechanism to understanding how on a programme of the

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[2] (2020, August 29). WHO Coronavirus Disease (COVID-19) Dashboard. https://covid19.who.int/
[3] W22_Creating a standard multidimensional WBS/CBS coding structures for hospital construction. (2020, October 18). Danilo Arba Blog. https://www.daniloarba.com/post/w22_creating-a-standard-multidimensional-wbs-cbs-coding-structures-for-hospital-construction
[4] The Future of Project Management: Global Outlook 2019. (, 2019). KPMG.com.au AIPM.com.au IPMA.worls.
[5] WBS structure. (n.d.). Planning Planet | dedicated to Project Controls. Https://www.planningplanet.com/wiki/422403/wbs-structure

scale and complexity of the reconstruction and construction detailed in the State-to-State contracts between France and Peru[6].

To correctly deliver such complicated projects in a fast-track environment, the WBS must be integrated with an array of hierarchical breakdown structures that the PMO can adopt to organise and present the activities.

- CBS (Cost Breakdown Structure)[7]
- RBS (Responsibility Breakdown Structure)
- CBS (Contract Breakdown Structure)[8]
- RBS (Risk Breakdown Structure)[9]

A great issue for the construction industry has been the integration of cost and schedule control systems, both for researchers and practitioners. In any case, the real-world implementation of this promising concept has not been popular enough to maximise the gains that this combination offers. The overhead effort is probably the main barrier to collect and maintain detailed data.

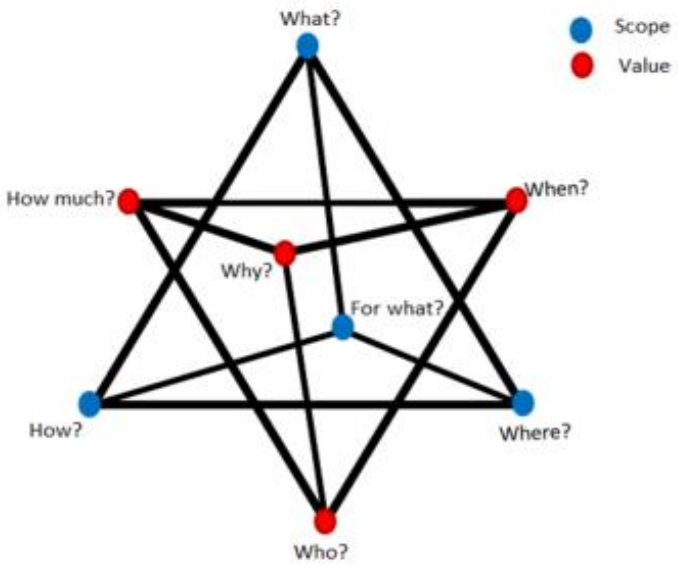

Fig.01: 8 questions to be answered if asked by our stakeholders[10]

[6] Mace celebrates pan American success in Lima and secures new role in Peru. (n.d.). Mace. https://www.macegroup.com/media-centre/190730-mace-celebrates-pan-american-success-in-lima-and-secures-new-role-in-peru
[7] COST breakdown | meaning in the Cambridge English dictionary. (n.d.). Cambridge Dictionary | English Dictionary, Translations & Thesaurus. https://dictionary.cambridge.org/dictionary/english/cost-breakdown
[8] Contract work breakdown structure. (2008, January 15). Project Management Knowledge - Simply explained by a PMI-certified Project Manager. https://project-management-knowledge.com/definitions/c/contract-work-breakdown-structure/
[9] Risk breakdown structure. (2008, September 12). Wikipedia, the free encyclopedia. Retrieved September 30, 2020, from https://en.wikipedia.org/wiki/Risk_breakdown_structure
[10] 08.3.3.7 Additional Schedule Coding Structures. Guild of project controls compendium and reference (Car). (n.d.). Planning Planet | dedicated to Project Controls. https://www.planningplanet.com/guild/gpccar/define-estimates-purpose-and-scope-of-work

This paper aims to propose a multidimensional breakdown structure integrated with our other breakdown structures that optimises the overhead effort while still allowing us to control schedule, cost and validate our estimate that needs to be done prior to the tender issue, with a Turnkey[11] based on the FIDIC Silver Book[12].

Although we have many different specifications and standard structures, like RS Means that uses CSI's Master and Uniformat[13], Omniclass[14] and Norsok Z-014[15] among others, while many companies develop their own standards that are deeply interconnected with their accounting systems.

Cost, schedule, and quality are three major measures for construction project performance assessment. Among these three measures, cost and schedule are objective and quantitative, while quality is somewhat subjective and qualitative. In addition, cost and scheduling are closely interrelated because they share a lot of common data in their controlling processes. Therefore, integrating cost and schedule control functions provides an effective tool for monitoring the construction process.

However, the excessive management demands of collecting and maintaining detailed data have been highlighted by previous research as the major barrier to utilising this concept over a quarter of a century[16]. Advance information technology is a definite solution and a driving force for the recent increasing interest in integrated cost and schedule control worldwide. Besides utilising information technology, optimising management methods can be another driving force that can result in reducing the amount of required data. Management requirements, even in a project, may vary depending on the characteristics of a work package. However, most research efforts have not addressed this issue in detail, especially various ways of work breakdown structure (WBS) usage as a solution for integrated cost and schedule control.

In this context, this paper will elaborate a solution to guarantee the best solution for the two hospital projects and allow the PMO to deliver to the required specifications.

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[11]key contract | definizione, significato - Che Cosa E turnkey contract nel dizionario Inglese - Cambridge dictionary. (n.d.). Cambridge Dictionary | English Dictionary, Translations & Thesaurus. https://dictionary.cambridge.org/it/dizionario/inglese/turnkey-contract
[12] FIDIC silver book | FIDIC 2017. (n.d.). Welcome to ICE Virtual Library. https://www.icevirtuallibrary.com/doi/book/10.1680/fsb.64362
[13] MasterFormat® - Construction specifications institute. (n.d.). Construction Specifications Institute. https://www.csiresources.org/standards/masterformat
[14] OmniClass® - Construction specifications institute. (n.d.). Construction Specifications Institute. https://www.csiresources.org/standards/omniclass
[15] NORSOK - Z-014 - Standard cost coding system (SCCS) | Engineering360. (n.d.). Engineering Standards - International Design & Technical Standards | Engineering360. https://standards.globalspec.com/std/9966210/z-014
[16] Rasdorf, W. J., and Abudayyeh, O. Y. (1991). "Cost- and schedule control integration: issues and needs." J. Constr. Eng. Manage.

Cost and schedule are closely interrelated in terms of sharing common data for performance assessments. In an analysis of practical construction data forms for separate cost control and schedule control, it has been found and detected[17] Many redundancies in the forms that eventually require repeated manipulations of the same data for different purposes. Also, its common and demonstrable of the numerous possible key-in errors that might occur during the redundant data entry process, especially in a context of reduced workforce availability. Thus, integrating these two different control functions provides not only meaningful project information but also improves the efficiency of control processes and the possibility to ensure that our revised estimate is accurate.

The results of a case study[18] Revealed that the most important business functions, in terms of contribution to the integration, include cost control, design, estimating, and schedule control, where 100 means the exact average and median with which others can be compared. The higher contribution scores of cost control and schedule control indicate that the relative effectiveness for overall systems integration can be better achieved by data from these two business functions.

Using standard classifications significantly enhances the reusability of historical data for estimating purposes as well, that for further confidence we will explore gold equivalency on our estimate, as this is part of the scope of works of the PMO team. As now we have set-up what we are proposing to do, this sets the stage for this paper that will produce and try to respond to the following question:

1. Develop the actual integrated system of our integrated WBS/CBS based on the results of our previous analysis and technical paper.[19]

A case study is analysed in this paper to examine the proposed concept. Practical implications are outlined, as well.

METHODOLOGY

Step 1

The eight dimensions model developed by Moine is basically based on the famous theory of Lisi[20]: The unified theory of universe3. The theory was developed by a young scientist called Garrett Lisi, who presents in this theory an 8-dimensional model of elementary particles which

[17] Rasdorf, W. J., and Abudayyeh, O. Y. (1991). "Cost- and schedule control integration: issues and needs ." J. Constr. Eng. Manage.
[18] Jung, Y., and Gibson, G. E. (1999). “Planning for computer integrated construction.” J. Comput. Civ. Eng. 13(4), 217–225.
[19] MULTIDIMENSIONAL PROJECT BREAKDOWN STRUCTURES TO ENSURE EFFICIENT DELIVERY OF HOSPITAL CONSTRUCTION. (n.d.). PM World Library | A Global Resource for Continuous Learning in PPM. https://pmworldlibrary.net/authors/danilo-arba/
[20] Has a surfer discovered the theory of everything? (2007, November 26). HowStuffWorks. https://science.howstuffworks.com/science-vs-myth/everyday-myths/theory-of-everything3.htm

can answer all the big questions of the universe. Lisi said: "All fields of the standard model and gravity are unified as an E8 principal bundle connection"3. This claim can have a positive effect on WBS by assuming that the tasks (the lowest component of multidimensional WBS) can have common fractals repeated from bottom to upper level building up a full project. The repeated fractal here is the star tetrahedron shape shown below which has the eight questions:

What, Where, How, When, Who, Why, How much and For What.

The answers to these questions can be derived from a multidimensional database, and they are the same questions repeated for each component in each level of the project and program. One note about the Lisi theory is that it is not yet completed nor finalised.

Toward WBS standardisation, construction industry started using a Building Information Modeling since the last decade. Building Information Modeling is the process of creating and developing virtual design and construction, illustrating the whole project's life cycle. Hence, the Building Information Model (BIM) –produced by the building information modelling process – is a 3D digital representation of the building components and functional characteristics using consistent types of data and information. The BIM helped the construction industry to come over serious challenges like the increasing demand of labours versus the hourly cost.

However, one of the main issues that have been sorted out by BIM is scheduling. BIM can be used for scheduling and cost estimates; in fact, 4D BIM is a schedule integrated BIM where you can see multiple dimensions of Gantt schedule and instance drawings.5

Illustrating the whole life cycle of an IT project is very useful in achieving the project. In the early 2000s, almost most of the biggest countries with the biggest construction projects has adopted BIM. However, this tool is still shy in the IT field; the BIM, along with WBS, can build a very powerful multidimensional schedule. Imagine what useful information the project managers, project team and informed parties can get when WBS is used to build BIM – along with other information. One for instance and as mentioned previously is the multidimensional schedule. What WBS offers for BIM is a standard WBS codification.

BIM is out of this paper scope; however, continuing with WBS and specifically what called 3D WBS (multidimensional) model. Other than the ordinary "flat" WBSs which are currently used in IT projects, 3D WBS shapes a cube out of many tree structure types crossed each other and gives six faces or sides of views, how we see the project from 6 different perspectives. A 3D WBS combines activities, zones and products so standardisation can be generated from activities vs products for any product line. The zones, however, will be different from project to another.IT projects are still without a known standard codification system and didn't publish any multidimensional model for WBS. The other business fields have been running projects successfully for their projects with standardisation, and in order to build one, we need first to find the most appropriate model.

There are many types of tree structure as follows:

1. ZBS (Zone Breakdown Structure) or GBS (Geographical Breakdown Structure)
2. PBS (Product Breakdown Structure)
3. SBS (Systems Breakdown Structure) or FBS (Functional Breakdown Structure)
4. ABS (Activity Breakdown Structure)
5. OBS (Organization Breakdown Structure)
6. RBS (Resources or Risks Breakdown Structure)
7. CWBS (Contract Work Breakdown Structure)
8. Etc.

In health projects, the manager is mostly used to ZBS, PBS and ABS.

A. The term Zone Breakdown Structure (ZBS) refers to the tree structure of areas, sites or the geographical parts of the project generally. For IT projects, the ZBS can be:

   a. Functional
   b. Physical
   c. Environmental

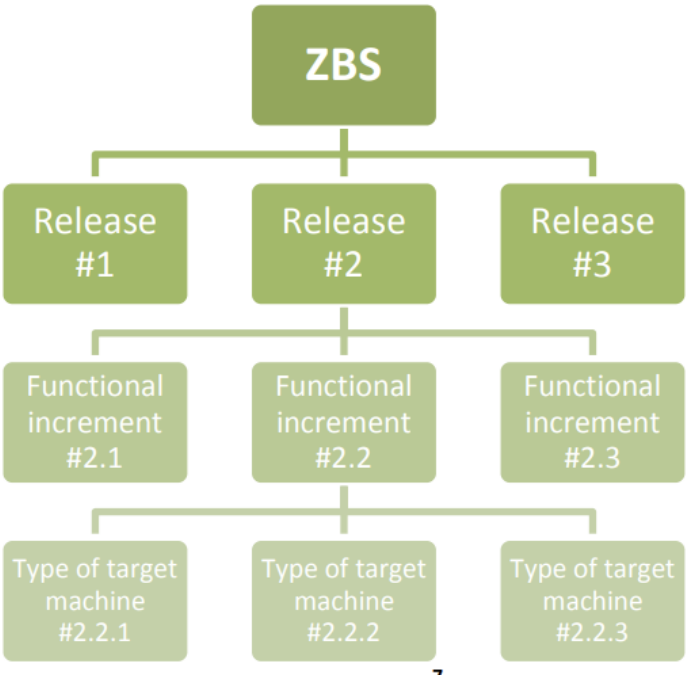

Fig 02: Typical Zone Breakdown Structure

B. The product breakdown structure breaks the project into physical elements, products, systems or sub-systems. The system or the software usually is divided into multiple applications, programs that together they form the final system. Each one of those programs and small modules forms a release or, what developers like to call, version of a system.

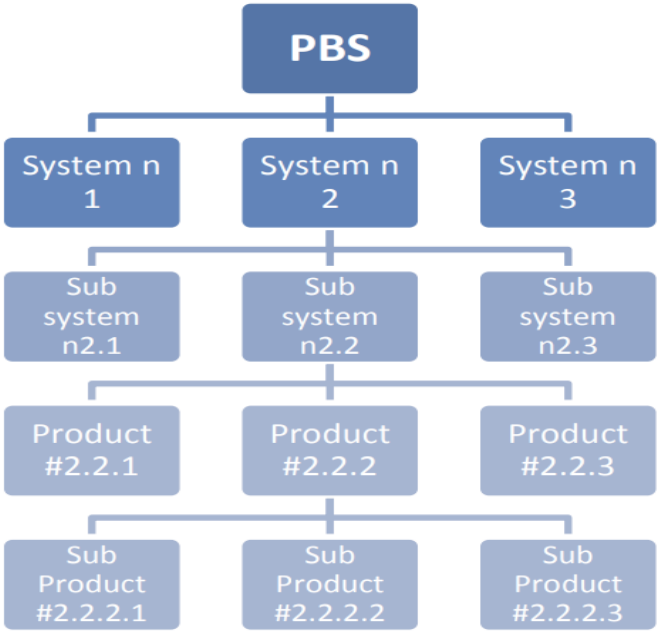

Fig 03: Typical Product Breakdown Structure

C. PBS is part of system breakdown structure (SBS); some called it Function Breakdown Structure. Figure 2 explains how the product is part of a system.

D. Activity breakdown structure is the hierarchy of activities, phases and sub-activities. The activities are linked together to form processes. Activities are not tasks rather than actions that can be described with verbs.

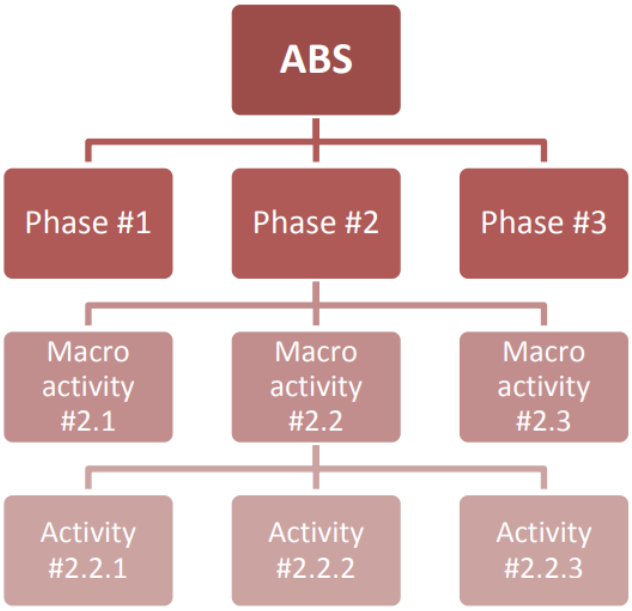

Fig 04: Typical Activity Breakdown Structure

E. The OBS displays organisational relationships and then uses them for assigning work to resources in a project, the OBS allows complex projects to be broken down, providing a more organised representation of the work to be completed.

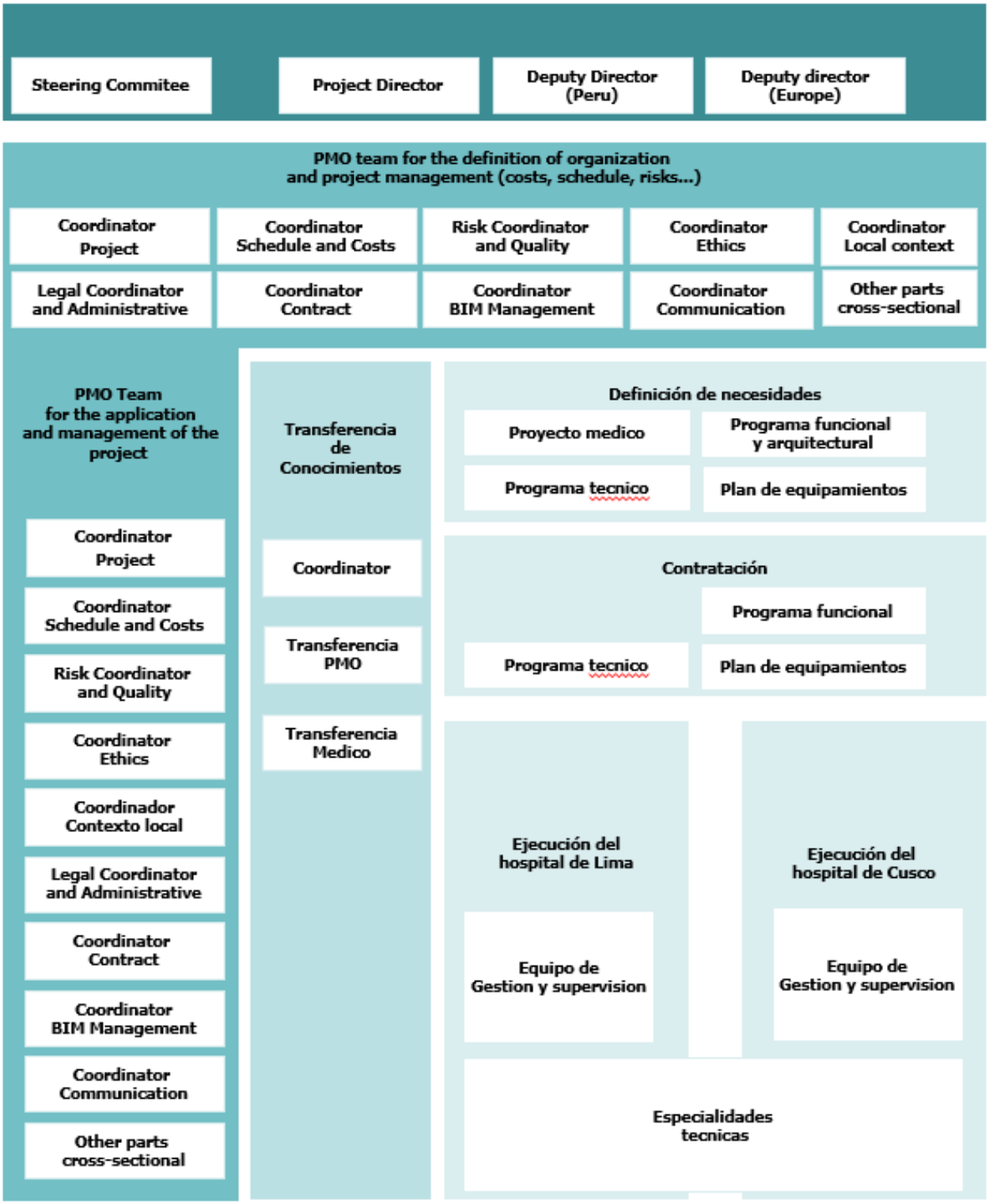

Fig 05: Typical Organizational Breakdown Structure

F. The resource breakdown structure makes reference to a specific hierarchal structure that is created to illustrate and demonstrate the totality of the resources that currently exist to the project team, and presenting this information in an organised fashion for easy recollection by all of those who may need it.

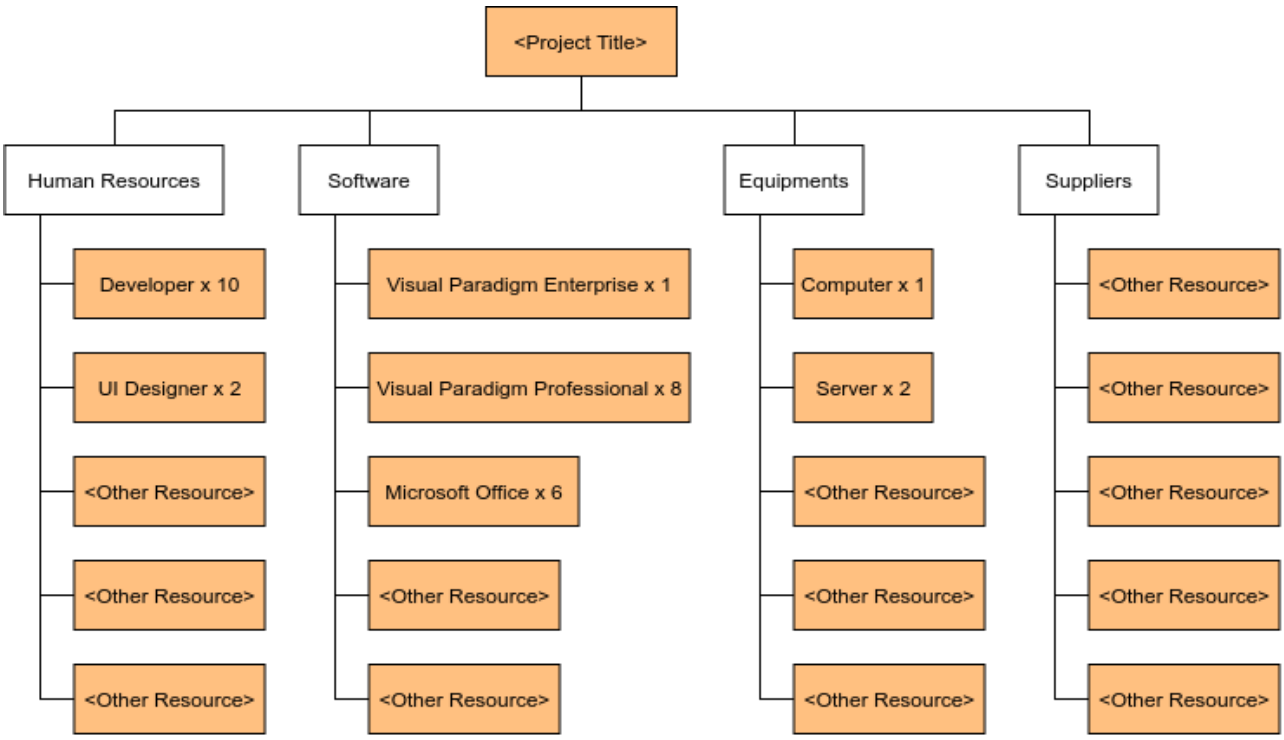

Fig 06: Typical Resource Breakdown Structure

G. By using the term contract work breakdown structure, we are referring to a particular piece of the work breakdown structure that has been linked with an individual project that has been produced and is at the moment being maintained by the seller in is a process of attempting to deliver a subproject or project component to the buyer.

H. Multidimensional breakdown structure

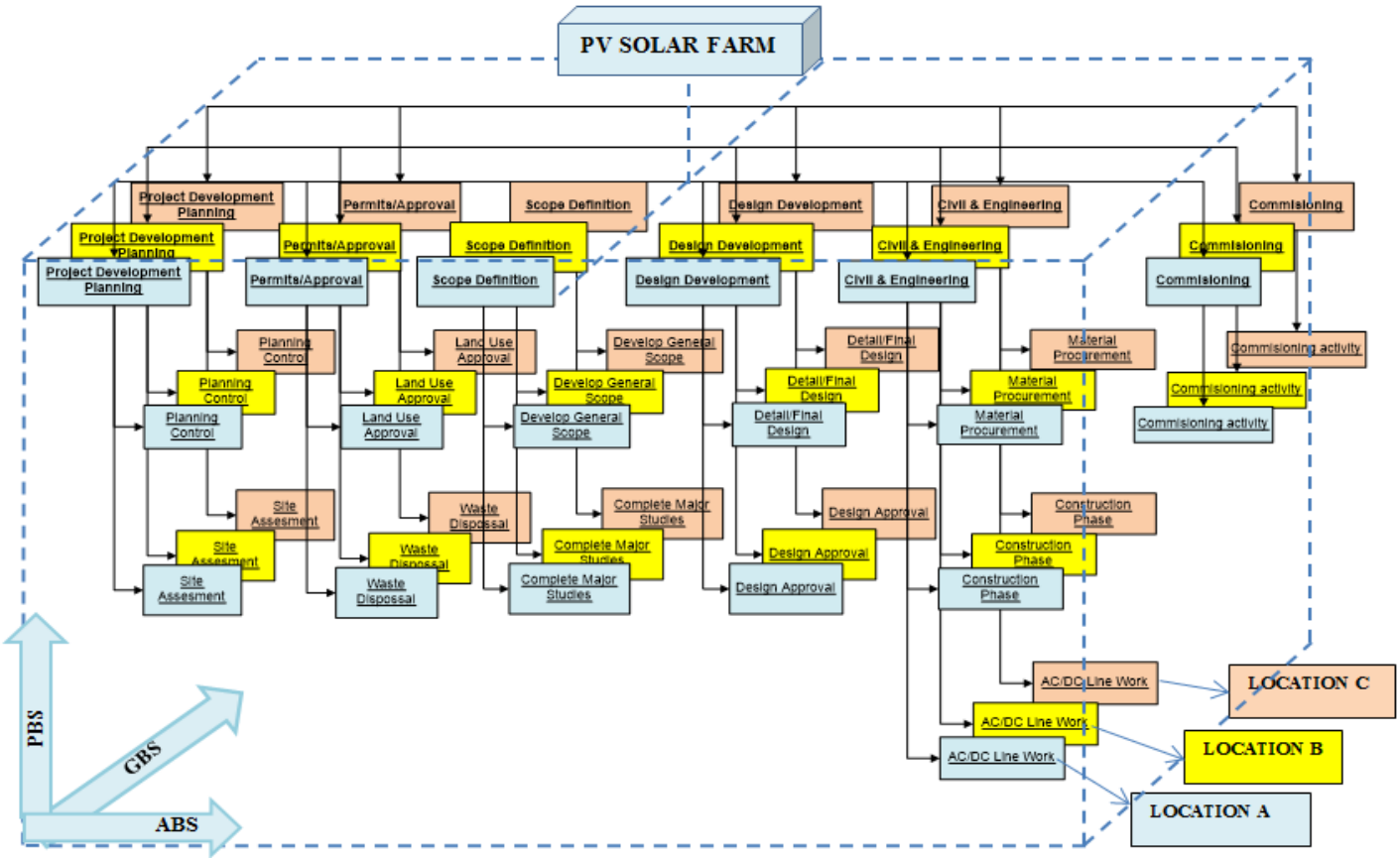

Fig 07: Solar Farm Multidimensional Breakdown Structure[21]

Step 2

New Hospital or completion of Hospital Construction are divided into several areas of work (ZBS), namely hospital contract area and then fields. In each area there is a product (PBS) that will be delivered in the form of the type of product hotel construction, namely preliminary works, civil works, completion of civil works, MEP works, Medical Equipment & Furnishing, commissioning. Each product has several activities to be composed as ABS. The following table shows the available WBS option. Option 1 and option 2 is the WBS used in the hospital building process.

[21] W4_WIRA_3D (Three dimensional) work breakdown structure for the photovoltaic solar farm project. (2014, May 21). TOPAZ SMART. https://topazsmartd.wordpress.com/2014/05/21/w4_wira_3d-three-dimensional-work-breakdown-structure-for-photovoltaic-solar-farm-project/

OPTION	TYPE	WBS LEVEL		
		Level 1	Level 2	Level 3
1	2D	Area (ZBS)	Product (PBS)	Activities (ABS)
2	2D	Product (PBS)	Area (ZBS)	Activities (ABS)
3	MULTIDIMENSIONAL	Product (PBS) X-Axis	Activities (ABS) Y-Axis	Area (ZBS) Z-Axis

Figure 8: Options, 2D and multidimensional breakdown structure[22]

The above figure shows the various possibilities that we have to create our breakdown structure; we will review two different 2D structures and a multidimensional structure. In our project, we are expecting to assign both the projects to one contractor, but we need to take in consideration the possibility that we could choose two different contractors we need to ensure flexible roll-up of cost and schedule, divided by the two projects, to ensure visibility for project reporting and analysis, including cost and schedule.

Step 3

In the following figure, WBS level 1 is ZBS and level 2 in PBS. In each of PBS, there will be related activities (ABS), which forms the WBS Level.

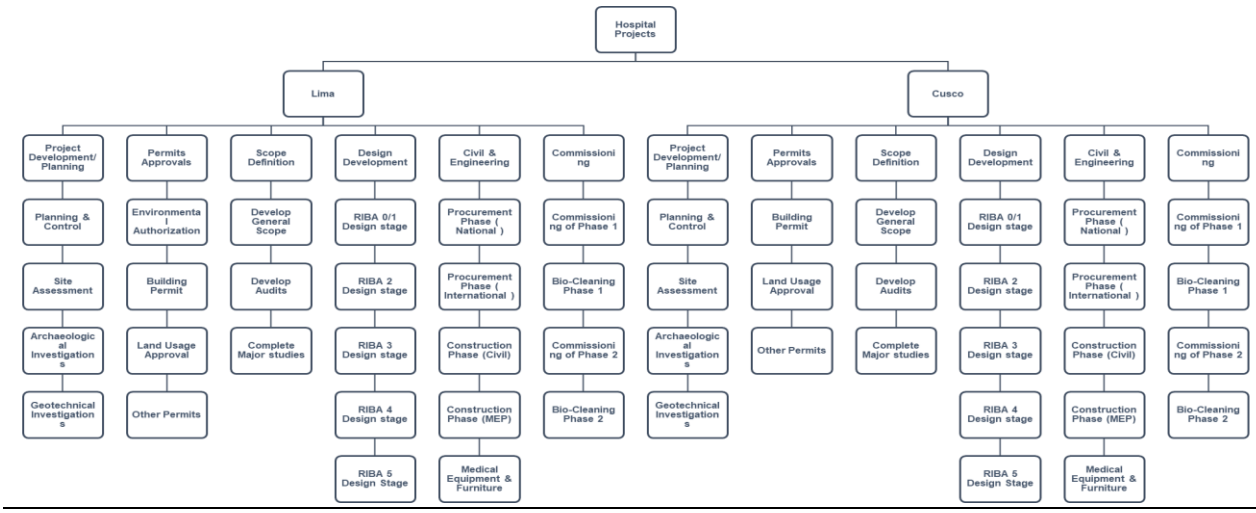

Figure 9: Option 1, 2D breakdown structure of project hospitals[23]

In the following figure, WBS level 1 is PBS, and level 2 is ZBS. In each of ZBS, there will be related activities (ABS), which forms WBS Level 3.

[22] Options, 2D and multidimensional breakdown structure, by Author
[23] Option 1, 2D breakdown structure for the project hospitals, by Author

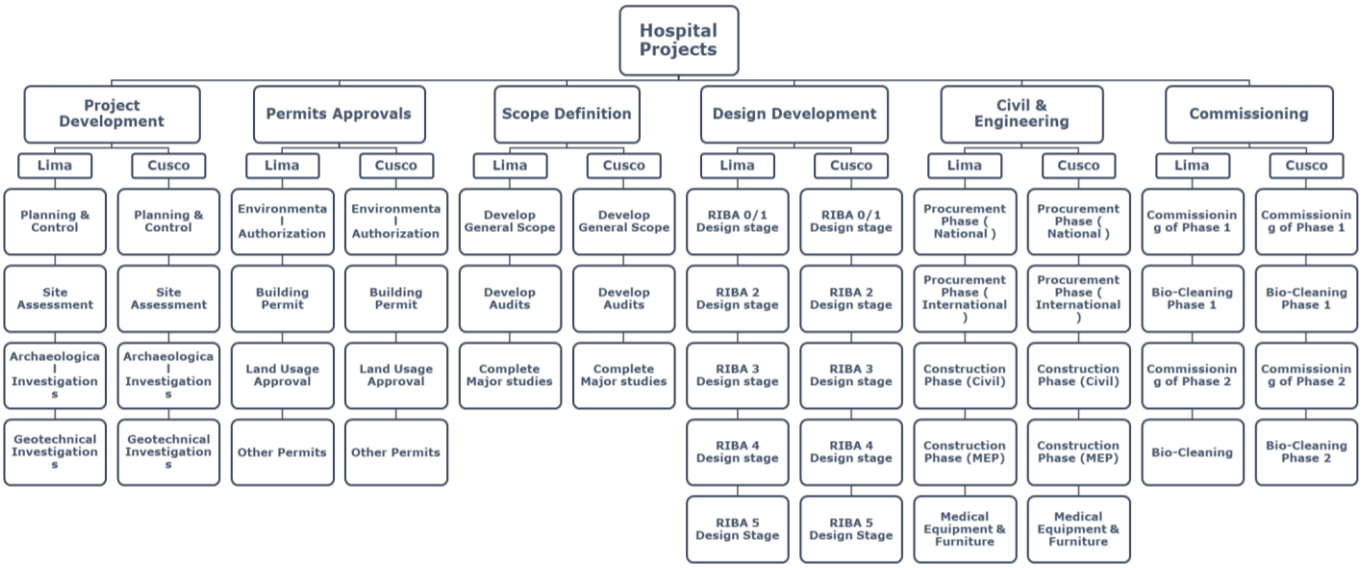

Figure 10: Option 2, 2D breakdown structure for project hospitals[24]

In the following figure, the multidimensional 3D WBS model is shown, where PBS as X-axis, ABS as Y-Axis and ZBS as Z-Axis. In this model, we can visualise the good type as a 2D model of 1 location (PBS and ABS) and then applied to the same in the third dimension for another contract area within the project scope of work (ZBS).

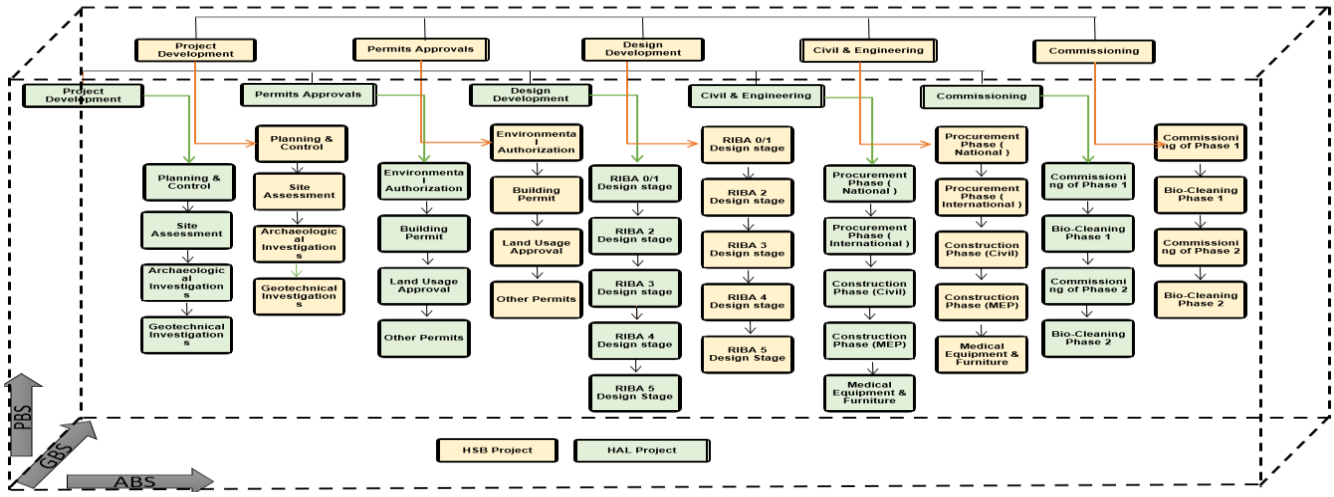

Figure 11: Option 3, Multidimensional breakdown structure[25]

Step 4

As previously discussed, we need to ensure that the full scope of the projects is included in our breakdown structures and that we have flexibility in terms of managing time, scope and cost for

[24] Option 2, 2D breakdown structure, by Author
[25] Option 3, Multidimensional breakdown structure, by Author

the two projects in case we assign the projects to different contractors or if we change the contract type.

Now that we have analysed the different solution, we can compare the different solution in the following table:

OPTION	ADVANTAGE	DISADVANTAGE
1	Productivity analysis possible by contract area	Not able to roll-up schedule and cost by product and activities
	Possibility of roll-up of schedule and cost by product	Difficult to track progress for activities and procurement and desing
	Easier to produce project report by contract or area of works	
2	Possibility of roll-up of schedule and cost by product	No roll-up available for each contract
	Easier to control Design and Procurement that focus on each contract	More complicated to produce automated reports for each contract
3	Flexibility in rolling-up the WBS for the different projects	Needs more work up-front on the coding structure
	Ease of preparing reports for the different projects in case of different contractors both for cost and schedule	
	Easier to control Design and Procurement that focus on each contract	

Figure 12: Advantages and disadvantages of the different options[26]

Clearly option 3, the multidimensional breakdown structure is the best meet the criteria. The multidimensional breakdown structure model is suitable for the construction of the new hospital and also for the completion of the second hospital because there will be a similar PBS and ABS in a lot of a number of contract area (ZBS). So, Option 3 could be used for the development of multidimensional structure for the construction of the two hospitals.

FINDINGS

Step 5

As we can see we have no shortage of project breakdown structures, see WBS, CBS, CWBS which are "flat filed" or better known as 2-D coding structures, but can we ensure we do not miss anything with this type of structures based on overall scope and values? The best solution is shown in the previous steps is using a standardized multidimensional coding structure, WBS/CBS, that will help to ensure that scope is not missed by using the WBS/CBS as a checklist. Better scope definition should lead to:

1. More accurate, precise, and reliable cost and duration estimates
2. Fewer claims and change orders

[26] Advantages and disadvantages of the different options, by Author

This is fundamental to ensure timely completion of two projects that are in the spotlight, and hugely needed by the population, and that the estimates done during the first stages of the PMO are reliable and can ensure proper use of the financial resources of the government.

The final proposal to the client was as follows, from Omniclass, as suggested and modified by the author to comply with all the requirements, the general structure as per table 11, Entities by function.

As said, we will start from Table 11 – Entities by function, and we selected the ones that are relevant to this project and added the ones highlighted in green, as this are necessary to cover the full scope.

	A	B	C	D
1	2012 DRAFT OmniClass Table 11 - Construction Entities by Function (modified by Committee action February 26, 2013)			
2	Number	Level 1	Level 2	Level 3
47	11-13 00 00	Public Service Facility		
108	11-14 00 00	Cultural Facility		
122	11-15 00 00	Recreation Facility		
185	11-16 00 00	Housing Facility		
213	11-17 00 00	Retail Facility		
249	11-21 00 00	Health Care Facility		
250	11-21 12 00		Hospital	
251	11-21 12 11			General Acute Care Hospital
252	11-21 12 15			Small Primary Care Hospital
253	11-21 12 19			Critical Access Hospital
254	11-21 12 23			Freestanding Urgent Care Facility
255	11-21 12 27			Freestanding Cancer Treatment Facility
256	11-21 12 31			Rehabilitation Hospital
257	11-21 12 34			Tuberculosis Facitlity
258	11-21 15 00		Outpatient Care Facility	
269	11-21 17 00		Medical Office Building (MOB)	
270	11-21 22 00		Ambulatory Care Facility	
273	11-21 25 00		Residential Health Care Facility	
278	11-21 32 00		Mental, Behavioral Care Facility	
281	11-21 35 00		Maternity Facility	
282	11-21 38 00		Animal Healthcare Facility	
283	11-21 42 00		Dental Facility	
284	11-21 45 00		Medical Center	
285	11-21 48 00		Medical Warehouse	
286	11-21 52 00		Ambulance Shelter	
287	11-21 55 00		Death Facility	
292	11-23 00 00	Hospitality Facility		
305	11-25 00 00	Lodging Facility		
324	11-27 00 00	Office Facility		
360	11-29 00 00	Research Facility		
406	11-35 00 00	Production Facility		
465	11-37 00 00	Storage Facility		
509	11-41 00 00	Water Infrastructure Facility		
545	11-42 00 00	Energy Infrastructure Facility		
588	11-43 00 00	Waste Infrastructure Facility		
605	11-44 00 00	Information Infrastructure Facility		
621	11-51 00 00	Transportation Facility		
706	11-90 00 00	Mixed-Use Facility		
708	11-95 00 00	Land		
752	End of Table 11			

Figure 13: Selected Structure as Selected Structure as per Table 11 of Omniclass, modified by author [27]

[27] Selected Structure as Selected Structure as per Table 11 of Omniclass, modified by author

Most of the elements in the next figure will be used, while some will be delated as it's of no use in the construction of our hospitals like Museums or Recreation Spaces, some will be detailed extensively like Healthcare, laboratory will be extensively used. This is needed so that we will be able not only to code this structure to be used for 3D to 6D BIM but will allow proper exchange data because the coding structures are set up in such a way that enables the cost and productivity information to "roll up" and "roll down" as needed for control and reporting reasons.

1	**Table 13**	**Spaces by Function**
2	OmniClass Number	Level 1 Title
3	13-11 00 00	Space Planning Types
9	13-13 00 00	Void Areas
13	13-15 00 00	Wall Spaces
16	13-17 00 00	Encroachment Spaces
19	13-21 00 00	Parking Spaces
29	13-23 00 00	Facility Service Spaces
94	13-25 00 00	Circulation Spaces
120	13-31 00 00	Education and Training Spaces
143	13-33 00 00	Recreation Spaces
202	13-35 00 00	Government Spaces
223	13-37 00 00	Artistic Spaces
256	13-41 00 00	Museum Spaces
258	13-45 00 00	Library Spaces
261	13-47 00 00	Spiritual Spaces
288	13-49 00 00	Environmentally Controlled Spaces
313	13-51 00 00	Healthcare Spaces
750	13-53 00 00	Laboratory Spaces
769	13-55 00 00	Commerce Activity Spaces
817	13-57 00 00	Service Activity Spaces
852	13-59 00 00	Production, Fabrication, and Maintenance Spaces
867	13-61 00 00	Protective Spaces
889	13-63 00 00	Storage Spaces
941	13-67 00 00	Alternate Workplace
947	13-69 00 00	Building Associated Spaces

Figure 14: Selected Structure as per Table 13 of Omniclass part 2, by author[28]

Once we arrive at the Table 22 of Omniclass we need to remember some of the characteristics of this project that will drive which information the PMO is expecting from the chosen contractor. Considering that we have chosen a Silver Book Fidic Contract Turnkey the level of

[28] Selected Structure as per Table 13 of Omniclass part 2, by author

supervision from the PMO will be "high-level" and based on the control that the contractor will follow and comply with the requirements of the contract and not with a day-by-day onsite control by the PMO. Also, the contractor will have the freedom to choose the design of the hospital, if it complies with the requirements set by the PMO, including construction methodologies and others, this means that we will only provide a high-level detail of Table 22 and the contractor will define based on his design and construction methodologies which items to choose or integrate from the Table 22 of Omniclass, as a reference the PMO has provided the following:

1	Table 22	Work Results
165	22-02 00 00	Existing Conditions
342	22-03 00 00	Concrete
502	22-04 00 00	Masonry
609	22-05 00 00	Metals
716	22-06 00 00	Wood, Plastics, and Composites
880	22-07 00 00	Thermal and Moisture Protection
1149	22-08 00 00	Openings
1461	22-09 00 00	Finishes
1773	22-10 00 00	Specialties
2029	22-11 00 00	Equipment
2306	22-12 00 00	Furnishings
2566	22-13 00 00	Special Construction
2721	22-14 00 00	Conveying Equipment
2819	22-21 00 00	Fire Suppression
2888	22-22 00 00	Plumbing
3149	22-23 00 00	Heating, Ventilating, and Air-Conditioning (HVAC)
3497	22-25 00 00	Integrated Automation
3575	22-26 00 00	Electrical
3764	22-27 00 00	Communications
3931	22-28 00 00	Electronic Safety and Security
4052	22-31 00 00	Earthwork
4333	22-32 00 00	Exterior Improvements
4596	22-33 00 00	Utilities
4915	22-34 00 00	Transportation
5108	22-35 00 00	Waterway and Marine Construction
5290	22-40 00 00	Process Integration
5586	22-41 00 00	Material Processing and Handling Equipment
5934	22-42 00 00	Process Heating, Cooling, and Drying Equipment
6012	22-43 00 00	Process Gas and Liquid Handling, Purification, and Storage Equipment
6201	22-44 00 00	Pollution and Waste Control Equipment
6362	22-45 00 00	Industry-Specific Manufacturing Equipment
6427	22-46 00 00	Water and Wastewater Equipment
6682	22-48 00 00	Electrical Power Generation

Figure 15: Selected Structure for the Hospitals construction as per Table 22 of Omniclass, by author[29]

We are going to use this list from table 22 as a checklist to ensure that all information/scope has been included and that nothing has been missed, thus creating issues later on in the project in the scoping and specification documents.

[29] Selected Structure for the Hospitals construction as per Table 22 of Omniclass, by author

If we ensure this is done Table 22, using the Table as a checklist, will support in minimizing the possible number of change orders due to items that have been missed and that should have been included in the first instance.

2012 DRAFT OmniClass Table 31 - Phases		
Number	Level 1 Title	Definition
31-30 00 00	Criteria Definition Phase	Phase to create and refine schematic diagrams of the basic project elements - substructure, shell, interiors, equipment, services, equipment and furnishings, special construction and demolition, and building sitework - that fully establish project spatial and element criteria as the Basis of Design.
31-40 00 00	Design Phase	Phase in which project team establishes means of satisfying project Basis of Design requirements with technical solutions, evaluates alternatives through value analysis or similar processes, and completes initial documentation - Drawings and specified Work Results - for the designed project.
31-50 00 00	Coordination Phase	Phase that bridges the design effort with implementation by integrating constructability and feasibility evaluations of the design in order to further develop spaces, elements, products, and materials necessary for the procurement and execution of the Work irrespective of the method of delivery.
31-60 00 00	Implementation Phase	Phase to implement the coordinated design through construction planning, prefabrication, and field execution characterized by constructor 'means and methods,' and Basis of Construction strategies, controlled by quality assurance and control protocols.
31-70 00 00	Handover Phase	Phase to evaluate the completed Work through testing, inspection, and commissioning activities, including for any Owner-furnished equipment, to ensure that design/performance criteria are met while conforming to applicable codes and standards, and transfer project knowledge from the design/construction team to the Owner/facility management team via demonstrations, training, and documentation.
31-90 00 00	Closure Phase	Phase which includes facility closure, preparation for unknown future use, demolition in whole or part, foreclosure, sale, or similar dispensation initiated by the decision that the facility no longer meets the needs of the Owner and cannot be feasibly reconfigured for continued use by that Owner.

Figure 16: Selected Structure for the Hospital construction as per Table 31 of Omniclass, by author[30]

As we are using a relational or object-oriented database and because multi-dimensional WBS/CBS structures are set up as relational or object oriented, we can do the following:

- Filter, Sort and Organize in any combination or permutation that we can use to better control and communicate to the client and other stakeholders.
- Filter, sort and show the scope of the hospitals, both for time and cost information using 4 different dimensions
- Considering this is a relational or object-oriented database, we can sort and order them using any combination of the 4 sorts that our stakeholders want to see.

[30] Selected Structure for the Hospital construction as per Table 31 of Omniclass, by author

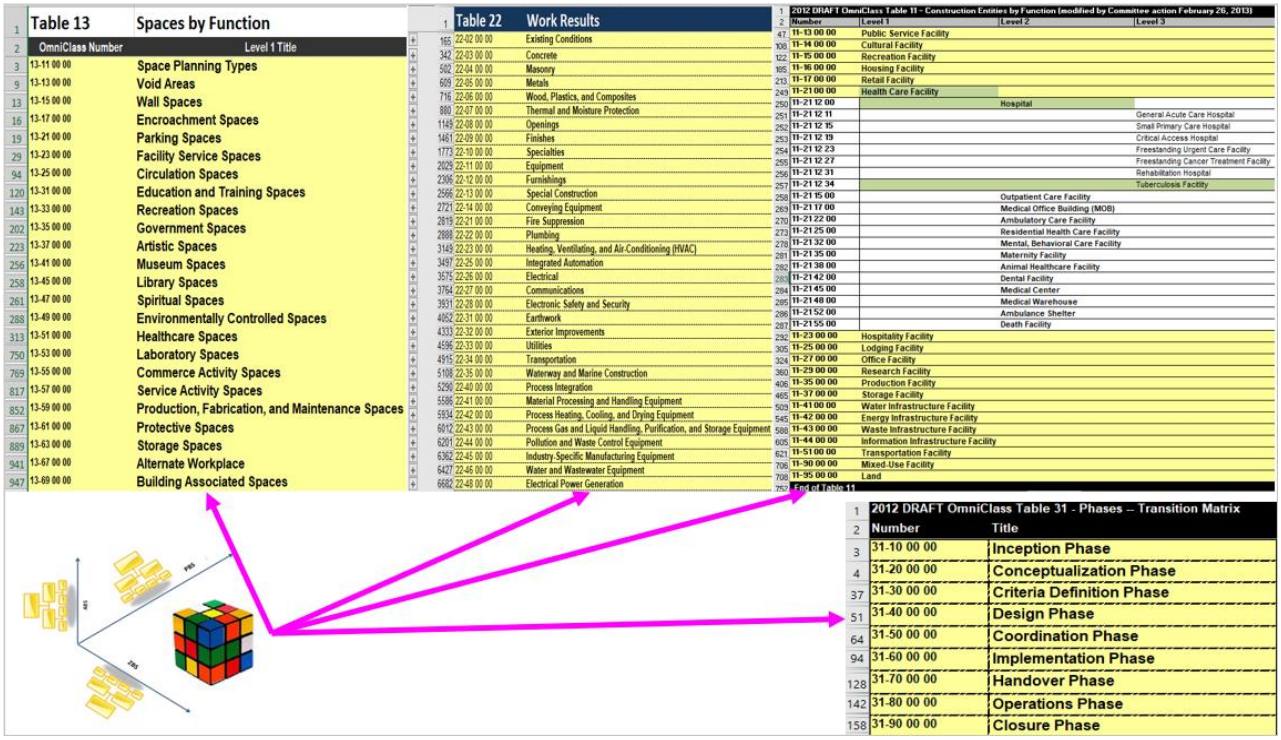

Table 13	Spaces by Function
OmniClass Number	Level 1 Title
13-11 00 00	Space Planning Types
13-13 00 00	Void Areas
13-15 00 00	Wall Spaces
13-17 00 00	Encroachment Spaces
13-21 00 00	Parking Spaces
13-23 00 00	Facility Service Spaces
13-25 00 00	Circulation Spaces
13-31 00 00	Education and Training Spaces
13-33 00 00	Recreation Spaces
13-35 00 00	Government Spaces
13-37 00 00	Artistic Spaces
13-41 00 00	Museum Spaces
13-45 00 00	Library Spaces
13-47 00 00	Spiritual Spaces
13-49 00 00	Environmentally Controlled Spaces
13-51 00 00	Healthcare Spaces
13-53 00 00	Laboratory Spaces
13-55 00 00	Commerce Activity Spaces
13-57 00 00	Service Activity Spaces
13-59 00 00	Production, Fabrication, and Maintenance Spaces
13-61 00 00	Protective Spaces
13-63 00 00	Storage Spaces
13-67 00 00	Alternate Workplace
13-69 00 00	Building Associated Spaces

Table 22	Work Results
22-02 00 00	Existing Conditions
22-03 00 00	Concrete
22-04 00 00	Masonry
22-05 00 00	Metals
22-06 00 00	Wood, Plastics, and Composites
22-07 00 00	Thermal and Moisture Protection
22-08 00 00	Openings
22-09 00 00	Finishes
22-10 00 00	Specialties
22-11 00 00	Equipment
22-12 00 00	Furnishings
22-13 00 00	Special Construction
22-14 00 00	Conveying Equipment
22-21 00 00	Fire Suppression
22-22 00 00	Plumbing
22-23 00 00	Heating, Ventilating, and Air-Conditioning (HVAC)
22-25 00 00	Integrated Automation
22-26 00 00	Electrical
22-27 00 00	Communications
22-28 00 00	Electronic Safety and Security
22-31 00 00	Earthwork
22-32 00 00	Exterior Improvements
22-33 00 00	Utilities
22-34 00 00	Transportation
22-35 00 00	Waterway and Marine Construction
22-40 00 00	Process Integration
22-41 00 00	Material Processing and Handling Equipment
22-42 00 00	Process Heating, Cooling, and Drying Equipment
22-43 00 00	Process Gas and Liquid Handling, Purification, and Storage Equipment
22-44 00 00	Pollution and Waste Control Equipment
22-45 00 00	Industry-Specific Manufacturing Equipment
22-46 00 00	Water and Wastewater Equipment
22-48 00 00	Electrical Power Generation

2012 DRAFT OmniClass Table 11 - Construction Entities by Function (modified by Committee action February 26, 2013)			
Number	Level 1	Level 2	Level 3
11-13 00 00	Public Service Facility		
11-14 00 00	Cultural Facility		
11-15 00 00	Recreation Facility		
11-16 00 00	Housing Facility		
11-17 00 00	Retail Facility		
11-21 00 00	Health Care Facility		
11-21 12 00		Hospital	
11-21 12 11			General Acute Care Hospital
11-21 12 15			Small Primary Care Hospital
11-21 12 19			Critical Access Hospital
11-21 12 23			Freestanding Urgent Care Facility
11-21 12 27			Freestanding Cancer Treatment Facility
11-21 12 31			Rehabilitation Hospital
11-21 12 34			Tuberculosis Facility
11-21 15 00		Outpatient Care Facility	
11-21 17 00		Medical Office Building (MOB)	
11-21 22 00		Ambulatory Care Facility	
11-21 25 00		Residential Health Care Facility	
11-21 32 00		Mental, Behavioral Care Facility	
11-21 35 00		Maternity Facility	
11-21 38 00		Animal Healthcare Facility	
11-21 42 00		Dental Facility	
11-21 45 00		Medical Center	
11-21 48 00		Medical Warehouse	
11-21 52 00		Ambulance Shelter	
11-21 55 00		Death Facility	
11-23 00 00	Hospitality Facility		
11-25 00 00	Lodging Facility		
11-27 00 00	Office Facility		
11-29 00 00	Research Facility		
11-35 00 00	Production Facility		
11-37 00 00	Storage Facility		
11-41 00 00	Water Infrastructure Facility		
11-42 00 00	Energy Infrastructure Facility		
11-43 00 00	Waste Infrastructure Facility		
11-44 00 00	Information Infrastructure Facility		
11-51 00 00	Transportation Facility		
11-90 00 00	Mixed-Use Facility		
11-95 00 00	Land		
End of Table 11			

2012 DRAFT OmniClass Table 31 - Phases -- Transition Matrix	
Number	Title
31-10 00 00	Inception Phase
31-20 00 00	Conceptualization Phase
31-30 00 00	Criteria Definition Phase
31-40 00 00	Design Phase
31-50 00 00	Coordination Phase
31-60 00 00	Implementation Phase
31-70 00 00	Handover Phase
31-80 00 00	Operations Phase
31-90 00 00	Closure Phase

Figure 17: Time and cost information in a multidimension using the different Tables of Omniclass, by author[31]

Step 6

As we have seen from the previous steps, and our previous paper, "Multi-dimensional Project Breakdown Structures to Ensure Efficient Delivery of Hospital Construction"[32], the proposed multidimensional WBS/CBS structure will allow the PMO team to monitor the performance of the contractor, which will be the same for the two projects, with the necessary flexibility and responding to the needs of the clients both in terms of the quality of the product and the construction monitoring during construction while leaving to the executing office of the Health Minister the tools for future hospital construction ensuring the best process and procedure to achieve providing the best service possible to the populations while ensuring efficiency in spending of public finances.

Step 7

So, what about our initial question? And how are we going to truck it?

[31] Time and cost information in a multidimension using the different Tables of Omniclass, by author
[32] MULTIDIMENSIONAL PROJECT BREAKDOWN STRUCTURES TO ENSURE EFFICIENT DELIVERY OF HOSPITAL CONSTRUCTION. (n.d.). PM World Library | A Global Resource for Continuous Learning in PPM. https://pmworldlibrary.net/authors/danilo-arba/

1. Develop the actual integrated system of our integrated WBS/CBS based on the results of our previous analysis[33]. The Author developed the actual multidimensional WBS/CBS structure that will be used during the international tender process as a reference for the contractors and for the subsequent implementation during construction. The contractor will develop the finale structure to be submitted to the PMO 28 days after the contract signature.

CONCLUSIONS

The paper showed different types of breakdown structures and the multidimensional structure suitable model for hospital projects. Health projects suffer from many issues starting from inaccurate cost estimation to insufficient master project schedule, and the breakdown structure is one of the powerful tools to come over such issues. The advantages of multidimensional structured showed how useful it is in the health field and health project managers need to start adopting this trend in order to practically evaluate it and cope up with other fields which already start using it.

Flat WBS (or flat-file database) are used currently by many health managers; however, they have deficiencies, and people are still debating on what is best to be used in the health sector. Multidimensional in this case can be a more suitable option to invest on. How multidimensional can link information together and facilitate reporting, will bring different stages of a health project together. As discussed earlier in this paper, an ERP system – for example - will be more manageable if we link the phases of the project together. The importance of standardisation in health project becomes obvious day by day.

If we want to achieve full integration with BIM and multidimensional structures are the best fit to respond to stakeholder's necessity and achieve the social objectives that come with this type of investment by the state.

FOLLOW ON RESEARCH

As we are moving towards the use of Augmented Reality (AR) or Virtual Reality (VR) we will have to develop a wider structure that will respond to our eight fundamentals questions, What, Where, How, When, Who, Why, How much and For What with a Tesseracts as below image. This is what the unfolded 4D tesseract WBS/CBS coding structure would look like:

[33] MULTIDIMENSIONAL PROJECT BREAKDOWN STRUCTURES TO ENSURE EFFICIENT DELIVERY OF HOSPITAL CONSTRUCTION. (n.d.). PM World Library | A Global Resource for Continuous Learning in PPM. https://pmworldlibrary.net/authors/danilo-arba/

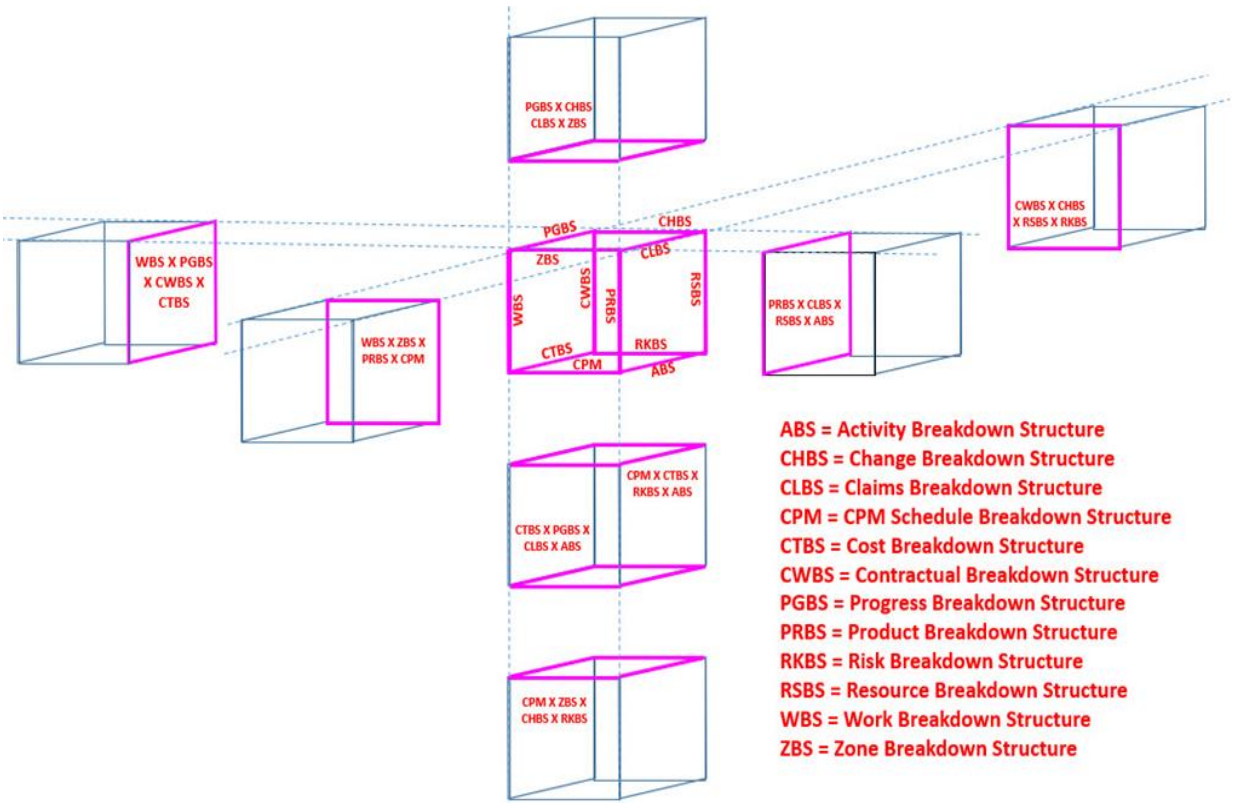

Figure 18: Mapping the typical project documentation to the breakdown structures

As we have previously said, the actual structure and the analysis of before and after will be done 6 months after project start in a different technical paper to review the result and lesson learned.

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Danilo Arba is a project controls & management enthusiast, with 20 years of experience. Certified Cost Engineer and Executive MBA from Politecnico di Milano. Thorough understanding of EPC (Engineering, Procurement, and Construction) industry, with verifiable track record of planning multimillion/billion-dollar worldwide construction projects. He lived & worked all his life around the world from South America, Africa, South East Asia to Europe. Adept at building and leading cross-functional teams from project conception to completion, optimising performance, contractual, and financial deliverables. Currently furthering his education by way of a distance learning mentoring course, under the tutorage of Dr Paul D. Giammalvo, CDT, CCE, MScPM, MRICS, GPM-m Senior Technical Advisor, PT Mitrata Citragraha, to attain Guild of Project Controls certification.

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