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“Car Wash For Data”: Best Practice for Information & Configuration Management of a industrial facility (id 5; P_005)

“CAR WASH FOR DATA” BEST PRACTICE FOR INFORMATION AND CONFIGURATION MANAGEMENT OF AN INDUSTRIAL FACILITY

Keywords: Information Management, Configuration Management, Common Data Environment, Digital Twin, Semantic modeling.

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ABSTRACT

With respect to an industrial facility, information and configuration management is important throughout its life cycle, but in practice both information and configuration management appears to have insufficient maturity within organisations. Many organizations within the industry in general and specifically within the nuclear industry struggle with implementing a sound, maintainable and integral Information and Configuration Management process. The design of a complex facility is fragmented and based on tools from different vendors and different versions, even by discipline. The lack of adequate methods, technologies, and tooling wastes money, reduces efficiency of the facility, hindering reuse of design knowledge and can even cause safety issues. This paper presents a pragmatic and proven implementation of information and configuration management in the Pallas nuclear facility in the Netherlands that elegantly meets the needs of information and configuration management as required by the equilibrium triangle as specified by the International Atomic Energy Agency (IAEA) and coping with the legacy systems as in use within current engineering departments. The result forms a solid starting point for developing a digital twin as well as unlocking and reusing design knowledge.

INTRODUCTION

The Pallas organisation is preparing the replacement of the ageing High Flux Reactor (HFR), as shown in Figure 1, which produces medical isotopes in the Netherlands. Pallas aims to maintain and ensure the integrity and validity of design basis knowledge and engineering and construction information over time to support asset management including a safe and efficient operation. Pallas has opted for a linked data and graph database technology to realize a Common Data Environment (CDE).

Figure 1. The ageing High Flux Reactor (HFR) to be replaced.

The objective of the CDE is to classify, harmonize and integrate all relevant data from the fragmented (software)tool set used during the life cycle of the facility. The CDE is based on ISO 15926-11 combined with a Reference Data Library (RDL). In this paper the CDE solution will be presented which was developed to by means of a coherent set of breakdown structures (i.e. System-, Work- and Geographical Breakdown Structure) seamless to merge all relevant data produced by the engineering environment. For this the CDE is supported by an Integrated Information Model (IIM) based on ISO 15926-11 and a Reference Data Library (RDL) mainly based on ISO 15926-4, the Capital Facilities Information Handover Specification (CFIHOS) as developed within the Oil and Gas industry community, Industrial Foundation Classes (IFC) and 'private' classes in the context of the nuclear domain. A novel workflow was developed to clean and classify all relevant data derived from the various kinds of engineering tools including 2D and 3D modelling software. This data-cleaning process, like a "car wash for data", is an essential part of the integral concept to arrive at a sound Common Data Environment (CDE) as defined in ISO 19650. The result is an effective hybrid solution with respect to a traditional document and data a centric approach of information and configuration management process including regular baselined handovers of design and engineering results from the CDE to the Client, using neutral, structured data (complying with the IIM and RDL) and linked to additional content described in traditional documents. The result is the secure and free flow of reliable and updated information to all stakeholders of the facility. The described approach also offers a gradual path from a document-driven organization to a data-driven organization and is a way to move forward in the attempt to achieve interoperability in projects, realizing complex systems (Ruijven 2018).

THE CHALLENGE OF CONFIGURATION MANAGEMENT

From the perspective of an owner-operator of a nuclear installation, it is essential to always have reliable and consistent data representing the as-required, as-designed and as-maintained configuration over the entire life cycle of the nuclear facility. To be more specific with respect to data in this context one can one can distinguish the next three categories of data that unambiguously represent:

The approved 'Why' information of the nuclear facility. Especially the capabilities 'as required and specified' of the nuclear facility should have a central emphasis. Capturing and assuring the design base of the facility (including stakeholder requirements, functions, system breakdown structure and mutual relationships) representing the 'Why'.

The 'How' information from the engineering phase, connected explicitly and traceably to the 'Why' information of the nuclear facility. The composing systems and external and internal interfaces between the systems that compose the facility need to be explicit and fully documented. The same for the FMECA and fault-tree analysis of all systems and their integrated analysis (including e.g., functions and related

SSC’s, failure modes and measures). The capabilities of the reactor should be unambiguously qualified and quantified both ‘as designed’ and ‘as commissioned’.

The ‘What’ of the system, connected in a traceable manner to both the ‘Why’ and the ‘How’ resulting in integrated operator manuals and maintenance manuals, based on the PFD’s, P&ID’s and FMECA analysis concerning the ‘How’ of the Pallas Reactor to be able to monitor the performance of the Pallas Reactor and be able to monitor the capabilities ‘as in use’. This should support decision making concerning maintenance and replacement programmes executing the maintenance program derived from and traceable to the FMECA and asset management and maintenance plans. Furthermore, capturing all maintenance activities, including their results and findings, representing the What, and enabling the analysis of measurements obtained from operations and maintenance to adjust and improve the configuration and safety of the nuclear facility.

This view on data can be seen as both to support the safety demonstration of the facility (which require consistent and integrated data describing the Why, How and What) in order to ensure the possession of the license to operate and to be able to perform effective asset management.

Sound asset management requires an integrated long-term view of several topics across the full plant lifecycle that have historically been largely managed separately such as (but not limited to):

Stakeholder requirements including required capabilities.

Engineering data.

Maintenance and inspections, including surveillance and periodic testing.

Management of ageing and obsolescence.

Performance monitoring and feedback of operating experience.

Management of modifications.

In this light it is essential to maintain and ensure the integrity and validity of design basis knowledge and derived information generated over time to support the safe and efficient operation of nuclear facilities, support effective decision-making, and mitigate the risk of knowledge and information loss. Decision making in this context concerns decisions at technical facility level as well as business processes. Therefore, the scope of life cycle information management covers not only design basis knowledge but also the engineering and physical construction of the various assets composing the facility, including their redesign and replacement. What has been described previously can be fully understood as configuration management of the nuclear facility, whereas information management can be seen on one hand as the process to retrieve information from the various sources and the delivery of required information to end-users and stakeholders on the other hand. IAEA expresses the essence of configuration management by means of the so-called equilibrium triangle as shown in Figure 2. However, over the life cycle of a facility, in general practice, multiple information systems and database systems from different vendors are used for different purposes. Most of these systems are not integrated with one another and cannot easily share plant data during different phases of the plant life cycle, such as design, operation, and decommissioning. This results in redundancies in capturing, handling, transferring, maintaining, and preserving facility data. This combined with the inability to use a common language between the systems leads to a lack of interoperability, which is exacerbated by the fragmented nature of the construction and construction industry, paper-based document control systems, a lack of standardization and inconsistent technology adoption by stakeholders. (represented by the barriers in Figure 2).The end result is the inability to guarantee the integrity as presented in Figure 2 and wastes money, reduces overall facility efficiency significant and may even lead to safety issues (Ruijven 2018).

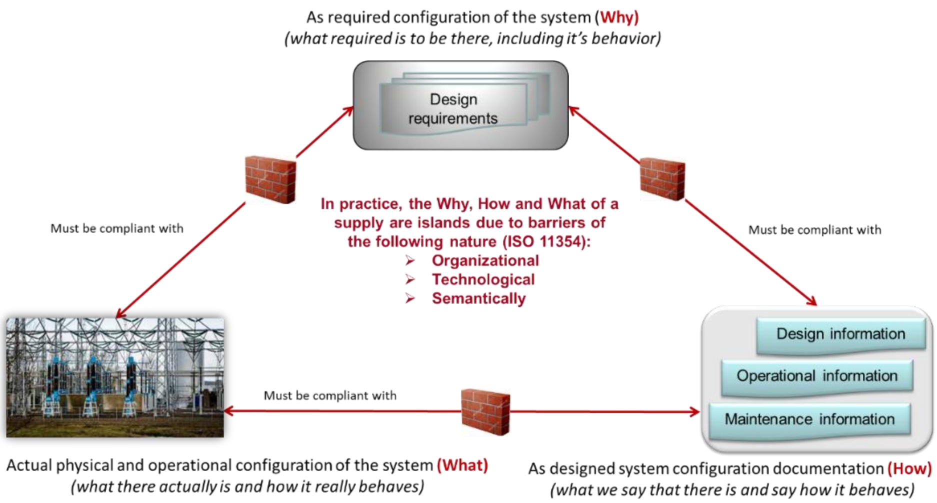


Figure 2. Equilibrium Triangle representing the challenge of configuration management.

An important principle within configuration management is to structure all data using various breakdown structures as described in e.g. ISO 18346 (Structuring principles and reference designations). This is shown in Figure 3 where the composing elements of the various breakdown structures are all in fact Configuration Items (CI's) which are defined by their classifications, characteristics and relationships with other CI's. CI's can have relationships with one or more documents stored in a document management system (DMS) and one or more 3D objects in the integrated 3D model, representing the facility with respect to its composing elements.

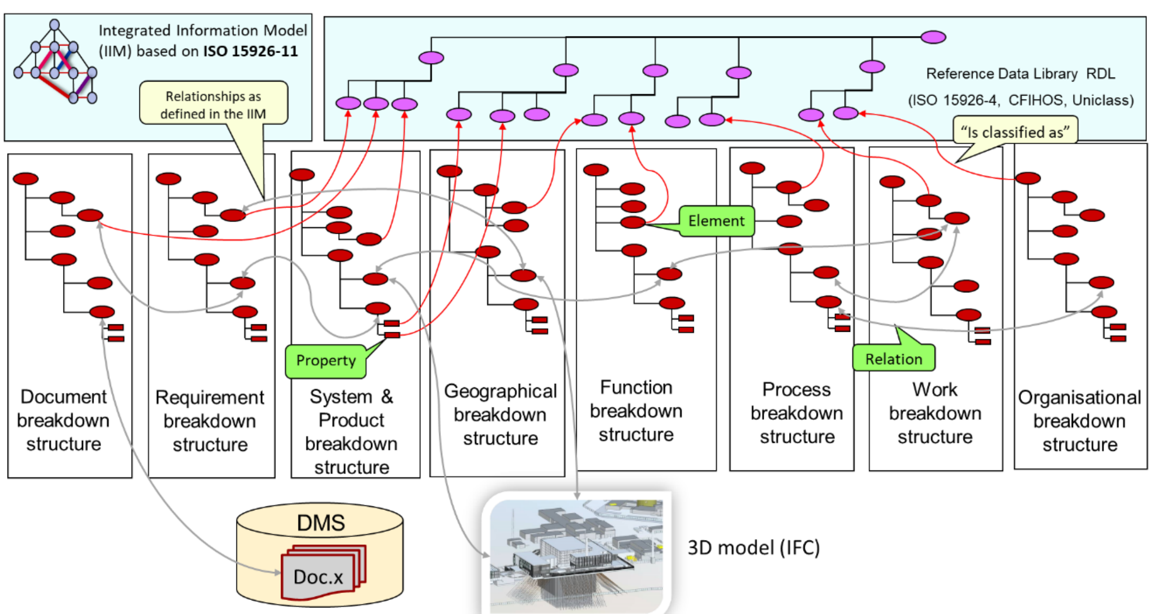


Figure 3. Breakdown structures, used to organize the data in the CDE and built with relationships defined in the IIM

In this light, the breakdown structures also are a bases for a sound Bill of Quantities (BoQ). The commercial management of complex facilities like nuclear reactors heavily depends on the availability of a reliable BoQ which is up to date and can be used in every phase of the project including backwards traceability of changes. It is one of the communication tool which connects the parties (Client, consultant and contractor) of a construction project. BoQ is a schedule which categories, details and quantifies the materials and other cost items to be used in construction project. It is important to know that, direct costs and indirect costs are to be considered for complete cost of the project which are covered in different parts of the BoQ, represented by a cross section of the various breakdown structures. Ultimate the BoQ is a model, fully captured and integrated in the CDE.

Specifying the composing elements of the System Breakdown Structure of a facility (including the seamless transition to and integration with the Product Breakdown Structure of that facility), complies with the life cycle model as shown by Figure 4. Respecting the life cycle model shown in Figure 4 is extremely important for supporting asset management and enabling Digital Twin functionality by other applications that connect to the CDE. This life cycle model is fully supported by the IIM and supports for example the traceability of which assets have been ever the realization of a planned technical object and how these different assets have performed from a functional point of view as a realization of the planned functional object. This is important for asset management and to be able to operate full Digital Twins (for prediction of the effect of changes in either the Why, How or What of the facility, but also to predict cost changes based on the BoQ).

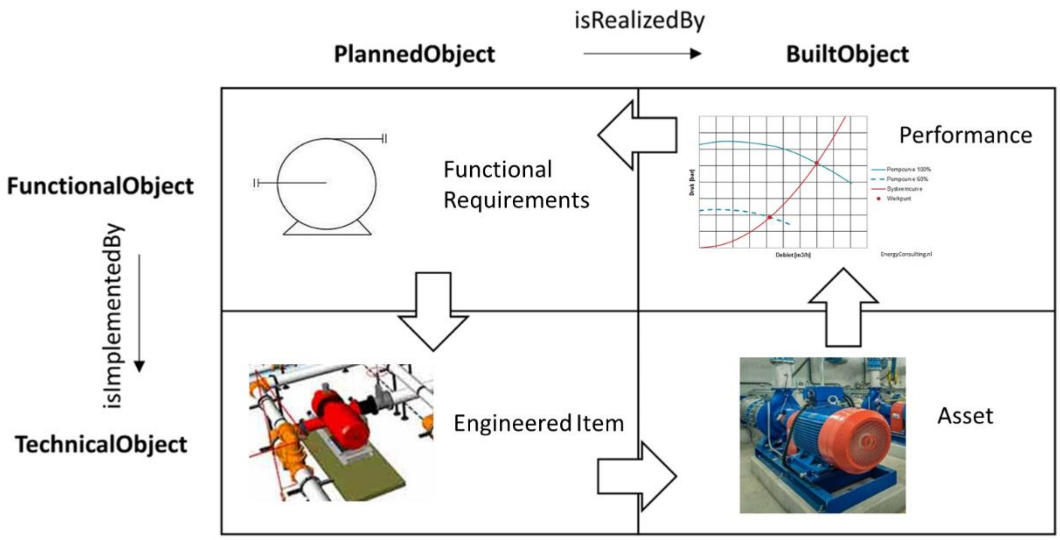


Figure 4. Life cycle model of facility elements, split into functional and technical and planned and as-built

The life cycle shown in Figure 4 recognizes the planned functional object, its implementation by a design, the realization of the design by a built asset (in general an instance of a manufacturer model) and finally the planned functional object as built. The latter represents the real performance of the functional object with respect how it was planned to perform.

THE COMMON DATA ENVIRONMENT CONCEPT

Despite that the landscape of software tools during the project in practice is fragmented and there appears to be lack of interoperability between those tools, Pallas aims to maintain and ensure the integrity and validity of design basis knowledge and all related information over time to support safety demonstration and asset management including a safe and efficient operation. Therefore, Pallas has opted for a linked data and graph database technology approach using the Resource Description Framework Schema (RDFS) from the World Wide Web Consortium (W3C) to realize a CDE, based on ISO 15926-11. This concept enables flexible and robust Model Based Systems Engineering approach using semantic modelling technology (Ruijven 2015).

Intentionally, only use of RDFS was chosen despite in many cases also is made use of OWL which is an extension on top of RDFS. OWL appeared to complicate the whole matter significantly and does not outweigh the alleged benefits at this moment in time, and secondly there is no off-the-shelf software available that supports the use of OWL for the use in an engineering enviroment. The concept of the CDE itself was taken from ISO 19650 which makes intentionally a split into three parts: a Document Management System (DMS), a geographical environment by means of a 3D model collecting platform (e.g. BIM 360) and the non-graphical data environment (e.g. a Graph Database). For the Pallas project the non-graphical part of the CDE will contain all relevant data from the fragmented engineering software tool set used over the life cycle. The data will be classified, harmonized, and integrated based on a common integrated information model (IIM) and a Reference Data Library (RDL). For creating the IIM a set of semantic relations was derived from ISO 15926-11 (also based on RDFS) and a RDL was created based upon a combination of ISO 15926-4, the Capital Facilities Information Handover Specification (CFIHOS) and Industrial Foundation Classes version 4 (IFC4). Furthermore the RDL classes references when applicable to classes in e.g. Uniclass and other external sources. Recognising and respecting that each involved (sub)contractors has their own information management maturity and ideas about a roadmap to evolve from a document centric working company to a company that is capable to work in a data centric manner, the next principles and rules have been used to validate the CDE concept:

Make it as simple as possible but not simpler (Free to Einstein).

Use international standards and dare to make simplifications to them.

Offer a Single Source of Truth (SSOT) to ensure all parties involved base business decisions on the same, valid and consistent data.

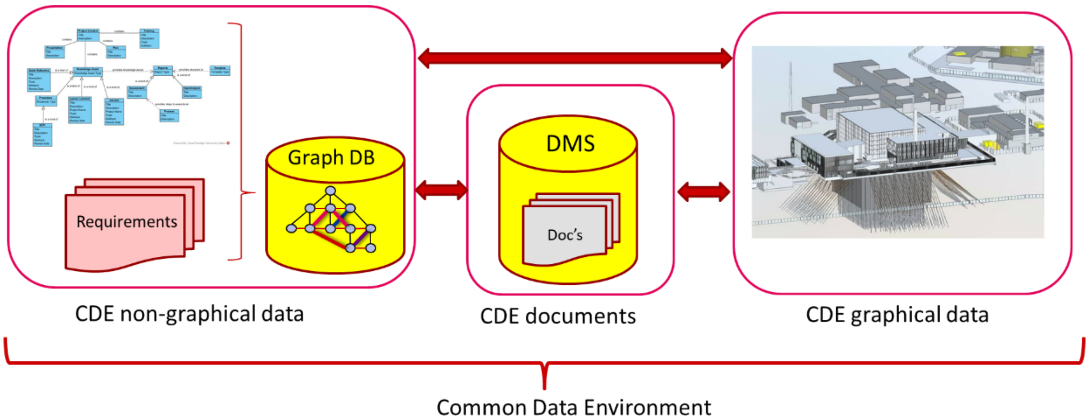
Distinguish and separate geographical related data, non-geographical data and documents.

Don’t force involved companies to change their work process in order to deliver their results.

Accept the data created by the tools as is and focus on cleaning and classifying of that data.

The idea behind this is that involved companies will gradually see the benefits of harmonized and integrated data of the whole facility, which during the project will probably lead to a higher maturity with regards to information management in general.

Figure 5. The three parts of the CDE, integrated by means of common identifiers.



Breakdown Structures themselves as shown in Figure 3 are as much possible derived from the engineering tools (so based on input from the engineers) and made consistent and harmonised and finally integrated in the CDE. Any breakdown structure is supported by the IIM and can be applied in the CDE when useful, enabling specific aspect views (as long the aspects are modelled as such).

A novel workflow was developed to clean and classify all relevant data derived from the engineering tools including the output of 2D and 3D modelling software. This data-cleaning process is an essential part of the integral concept to arrive at a sound Common Data Environment (CDE) as defined in ISO 19650. The result is an effective hybrid solution (respecting data, documents, and 3D models), with regular, baselined handovers of design and engineering results captured in the CDE to the stakeholders including the Client, using neutral, structured data (complying with the IIM and RDL) and linked to additional content described in traditional documents and objects in the 3D models. The result is the secure and free flow of reliable and updated information (digital signed) to all stakeholders of the facility such as:

All technical information that describes the requirements, the design and as-built of the facility.

Supporting Configuration Management by offering a Single Source of Truth (SSOT) to ensure that all parties involved base business decisions on the same and consistent data.

Technical information that enables the confirmation what is required to be there, that it conforms to what is stated in the documentation and conforms to what really is there.

The CDE including the DMS, 2D and 3D Models can be seen as a Facility or Plant Information Model which forms the basis for Asset Management Business Intelligence Solutions using the compendium of documents, data and 3D models and their mutual relationships (captured by the CDE). This should describe in an unambiguous way the requirements, design and construction of assets and must be keep updated and in sync during the operational lifetime and eventual decommissioning which is one of the main tasks of configuration management. This is especially important in the light that increasingly, the management of nuclear facilities in general and PALLAS specifically has the following vision regarding asset management and digitalization, derived from their business model:

Management of facilities has a responsibility to its community to effectively and efficiently manage the safety and services provided by all its assets.

Asset management should support sustainable and flexible services delivery, community satisfaction, sustainable financial position and acceptable risk exposure.

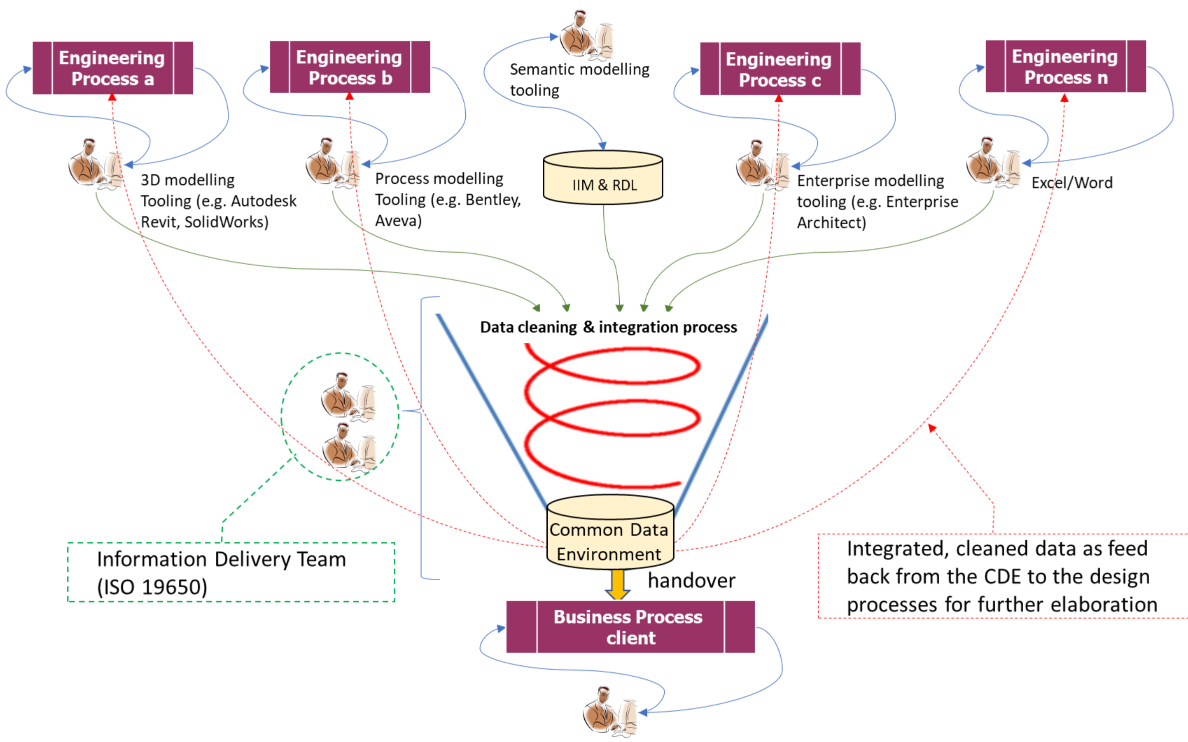
The vision of Pallas is that this only can be achieved by a sound digitalization strategy and implementation of it.

THE ROLE OF INFORMATION MANAGEMENT

As stated before, information management is in the context of this paper seen on one hand as the process to retrieve information from the various (master) sources of information from the engineering environment and on the other hand the delivery of required information to end-users. With respect to the first part a method is developed to capture and integrate the output data of the various engineering tools in use. In general, engineering tools all have their own core model and data export functionality and use a tool-specific set of terms and definitions of these terms. This leads to multiple data streams each having their own structure, syntax and semantics to be interpreted by the CDE. Therefore, all data streams are treated by a cleaning process in which a seamless integration of all data streams is performed by applying a common language defined by the IIM and RDL. When processing these data streams to integrate the data in the CDE, data quality principles are applied as defined in ISO 8000 (Data Quality). The main data quality characteristics are defined by ISO 8000 as semantic quality, syntax quality and pragmatic quality (usability of the data). Figure 6 shows the principle of receiving raw, baselined and signed datasets from the engineering environment passing through the cleaning process. In this cleaning process, syntax of used coding identifiers is checked and eventually corrected, the meaning of the data (semantics) is interpreted and agreed with the origin of the data and all data is classified according the RDL. All successfully imported data files are archived in the CDE for traceability. Each data element in the CDE has a signature (set of meta data) that refers to its original import file and containing knowledge such as when that data element was imported, which software tool was the origin and if it was a first creation, change or soft deletion. This all leads to a full “book keeping” functionality with respect to all imported data, necessary for supporting provenance, integrity, consistency checks and audit trails, similar to systems used in professional accounting software. In fact, it also supports basic functionality of block chain technology for greater security and integrity.

This data cleaning process requires specific roles in the project organisation with adequate skills which are not the same as engineers need to have for doing their job. Therefore a specific Information delivery Team is defined in ISO 19650 to do this work and require knowledge of the technical domain, Systems Engineering practices, semantic modelling and IT (see Figure 6). The tasks of such a team goes quiet far beyond the tasks of a traditional BIM coordinator since it covers the non-graphical data, documents and graphical data as well.

Figure 6. The principle of cleaning, harmonizing and integrating data streams based on a common language formed by the IIM and RDL.

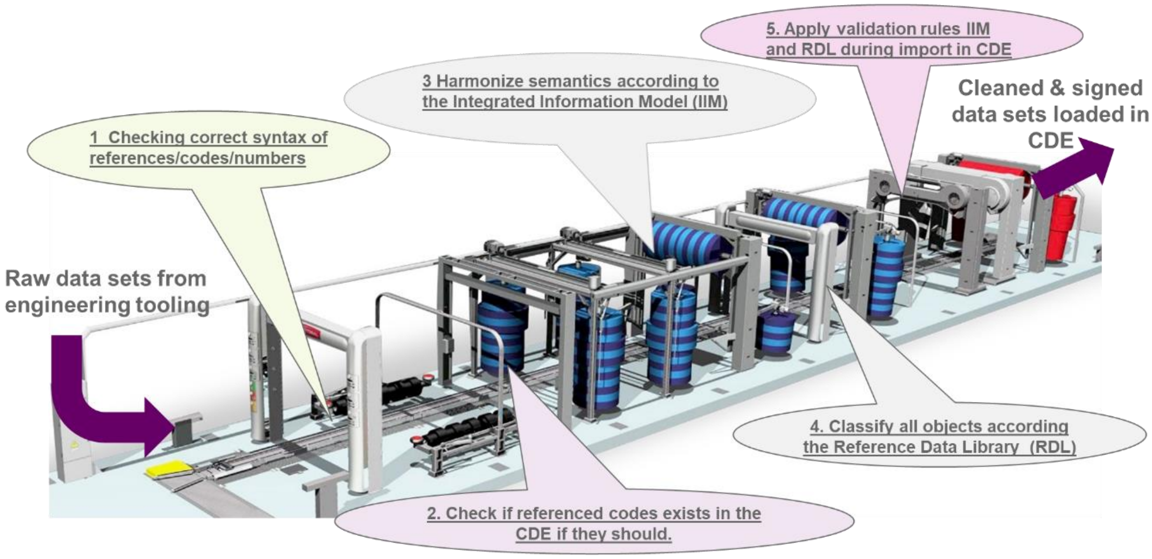


The tools on top of figure 6 in fact holds the "work in progress" engineering environment while the CDE functions as a "shared", integrated environment which should be used as input for further development of the design for all disciplines. For this a baseline strategy is defined and implemented in the CDE. Because of the use of RDF statements (atomic information facts) as basis for the CDE, the CDE offers semantically time travel capabilities with respect to the history of the content of the CDE.

During the data cleaning process, represented by Figure 6, syntax is checked and eventually corrected as far as possible, the meaning of the data (semantics) is interpreted and modelled according to the IIM and all data is classified according the RDL. If things cannot be done or completed due to ambiguousness, the data file is rejected and discussed with the originator. When this step has completed, the file will be imported in the CDE and references to documents and codifications like Tag code, location codes are checked whether they exist in the CDE when the data implies that they should be in the CDE, otherwise the import will be rejected and again checked with the originator of the data. Also, the modelled data according to the IIM will be validated if the data modelling was done compliant to the domain and rang of the applicable relationships forming the IIM. This all is represented in Figure 7 by means of a "car wash for data".

This "car wash for data" and the resulting content of the CDE in fact leads to a clean and efficient workplace for engineering being the CDE and can be compared with the aims of the so called 5S workplace organization method, describing the steps of a workplace organization process (Salanti 2020).

Figure 7. Data Car Wash which applies the data quality principles of ISO 8000



The 5S method, presented in Figure 8, with respect to the goal of the car wash for data can be summarised as follows:

1. Sort – Distinguishing between necessary and unnecessary (meta)data from the “work in progress” engineering environment and define clearly the master or origin of data sets. Also define frequency of retrieving an update of the data from the tooling.

2. Straighten – The practice of orderly storage so the right item can be picked efficiently (without waste) at the right time, easy to access for everyone. A place for everything and everything in its place. For this the breakdown structures plays a crucial role.

3. Shine – Create a clean Common Data Environment (“digital workspace”) without garbage, dirt and dust, so problems can be more easily identified (leaks, spills, redundancy, lack of integrity etc) and here has no time to be waste for searching of relevant data and checking of consistency and completeness of that data.

4. Standardize – Setting up standards for a neat, clean, digital workplace and formulate data quality objectives and data exchange requirements. Make it easy for everyone to identify the state of normal or abnormal conditions: provide a visual dashboard with key parameters of the CDE.

5. Sustain – Implementing behaviours and habits to maintain the established standards over the long term, and making the workplace organization the key to managing the process for success:

Toughest phase is to Sustain – many fall short of this goal.

Establish and maintain responsibilities – requires leader commitment to follow through.

Every one sticks to the rules and makes it a habit.

Participation of everyone in developing good habits and buy-in.

Regular audits and reviews.

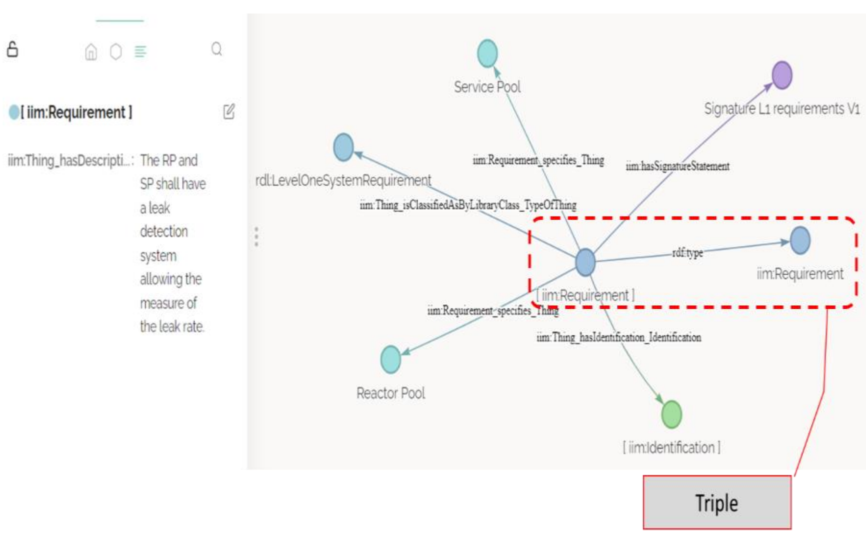
Get to root cause of issues.

Figure 8. 5S approach of optimizing working places which can compared with the car wash for data approach.

TECHNICAL IMPLEMENTATION

The CDE supports additions, changes (by means of explicit replace relations) and soft deletions of data to manage baselines and reporting of differences between any baseline and another baseline. This is made possible by adoption of the W3C Resource Description Framework (RDF) standard that formalize the use of “triples”. A triple is a linking structure that forms a directed, labelled graph, where the edges represent the named link between two resources represented by the graph nodes. In Figure 9 an example of a graph view containing six triples is shown.

Figure 9. Graph view on a node in the CDE being an instance of an iim:Requirement.



Each element of the triple (subject, predicate and object) is capture by a rdf:statement which is uniquely identified through a Unique Reference Identifier (URI) which enables to make statement about statements (including replacements of statements), necessary for configuration management. in Figure 9, is an instance of an IIM Requirement and is the subject of in this case six triples. The triples are defined as RDF statements as shown in Figure 10 were specifically the rdf:type and label triples of the central node of Figure 9 are expressed. Intentionally not is being made use of OWL and or SHACLE in order to keep it simple and also understandable for engineering people and finally in this way to be able to introduce and integrate new IT technologies in the engineering world.

```
:9e844849-515d-4464-a02c-6bc2d6c5edd7 a rdf:Statement ;
    rdf:subject :0b757cc8-45d2-4b65-a70b-754c9e82585a ;
    rdf:predicate rdf:type ;
    rdf:object iim:Requirement ;
    iim:hasSignatureStatement :57cdfc1a-4678-4def-9bc0-5c4a5759ed30 .

:0e1e75f9-f6f9-446e-90c9-50b7dc7b8378 a rdf:Statement ;
    rdf:subject :0b757cc8-45d2-4b65-a70b-754c9e82585a ;
    rdf:predicate iim:Thing_hasDescriptionByLiteral_Xsd ;
    rdf:object "The RP and  SP shall have a leak detection system to able to identify the area in which the
    leak is produced. " ;
    iim:hasSignatureStatement :57cdfc1a-4678-4def-9bc0-5c4a5759ed30 .
```

Figure 10. Technical view on the content of the CDE by means of two RDF statements, each stating a fact concerning a system requirement.

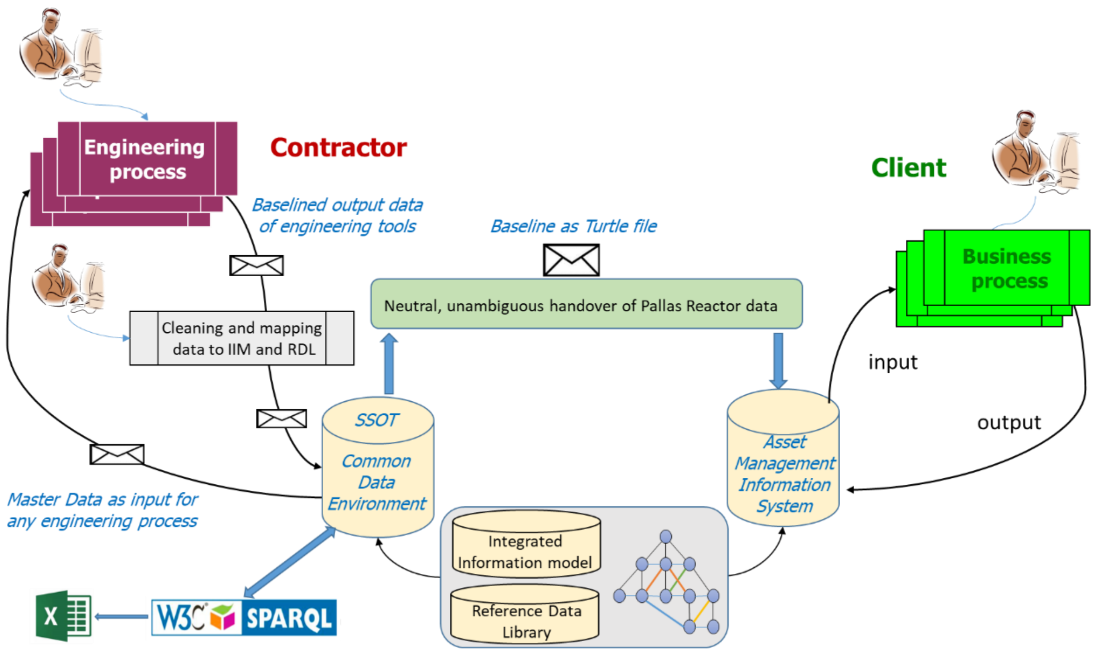
Each rdf:statement is also provided with a signature for traceability of its origin and nature. In fact, the signature mechanism covers some block chain characteristics in a practical way. With aim of the signature mechanism, a baseline mechanism is realized where a baseline aggregates a coherent set of signatures (with date-time stamp and provenance data) and a following up baseline refers to the previous one and the signatures that defines the changes introduced between both baselines. In this way one is always able to retrieve a previous baseline or the delta between two baselines in a unambiguous way.

Figure 11. Technical view on the definition of a signature attached to every RDF statement.

```
:bfa1492b-59b2-4b98-8bba-9f5e931f12ed a rdf:Statement ;
    rdf:subject :57cdfc1a-4678-4def-9bc0-5c4a5759ed30 ;
    rdf:predicate rdf:type ;
    rdf:object iim:Statement ;
    iim:hasSignatureStatement :57cdfc1a-4678-4def-9bc0-5c4a5759ed30 .

:fc190061-4947-4ecf-a570-93fdfa7c1858 a rdf:Statement ;
    rdf:subject :57cdfc1a-4678-4def-9bc0-5c4a5759ed30 ;
    rdf:predicate iim:Thing_isClassifiedAsByLibraryClass_ClassOfIndividual ;
    rdf:object rdl:SignatureStatement ;
    iim:hasSignatureStatement :57cdfc1a-4678-4def-9bc0-5c4a5759ed30 .

:e01e18a3-da8c-4ec1-aabf-05b6fb8d1864 a rdf:Statement ;
    rdf:subject :57cdfc1a-4678-4def-9bc0-5c4a5759ed30 ;
    rdf:predicate iim:Thing_hasNameByLiteral_Xsd ;
    rdf:object "Signature L1 requirements V1" ;
    iim:hasSignatureStatement :57cdfc1a-4678-4def-9bc0-5c4a5759ed30 .

:5d4873b8-25eb-43d2-9141-c9039e452b79 a rdf:Statement ;
    rdf:subject :57cdfc1a-4678-4def-9bc0-5c4a5759ed30 ;
    rdf:predicate iim:Statement_isOwnedBy_Party ;
    rdf:object :8d900575-2232-4f84-96bc-cfafb1a7b3d5 ;
    iim:hasSignatureStatement :57cdfc1a-4678-4def-9bc0-5c4a5759ed30 .

:84921a3f-7f20-4fa2-b396-b4453e32fed7 a rdf:Statement ;
    rdf:subject :57cdfc1a-4678-4def-9bc0-5c4a5759ed30 ;
    rdf:predicate iim:Statement_hasStatusByLibraryClass_ClassOfStatementStatus ;
    rdf:object rdl:Valid ;
    iim:hasSignatureStatement :57cdfc1a-4678-4def-9bc0-5c4a5759ed30 .

:f41b5111-73be-4585-a2ff-4676f18ca7a3 a rdf:Statement ;
    rdf:subject :57cdfc1a-4678-4def-9bc0-5c4a5759ed30 ;
    rdf:predicate iim:Statement_hasAccessRightByLibraryClass_ClassOfRdfStatementAccessRights ;
    rdf:object rdl:Restricted ;
```

An alternative which is still in considering is to implement the signature mechanism by creating a Named Graph for each signature. In that case the Named Graph represents the signature of every triple contained by the Named Graph. The combination of integration of all relevant facility life cycle data (multi-disciplinary, multi life cycle stages), strict use of a common language (IIM and RDL) and configuration management capabilities guarantees a neutral handover of any selection from the CDE content. The handover architecture is shown in Figure 12 (Ruijven 2016).

Figure 12. Data handover architecture connecting the Engineering process, cleaning and mapping ("Car wash") process, CDE and creation of neutral handover files.



The result of using a common language based on an integrated information model and RDL based on RDF triples is shown in Figure 13. In this a figure, the central node is an instance of a document type, is the output of a work package, has as subject the Core structure, has two versions, is referenced in four other documents, has a unique identification, and has a signature. By deriving more and more explicit meta data and relations (according to the IIM) from traditional documents one can gradually move from a document-based way of working to a data-centric way of working.

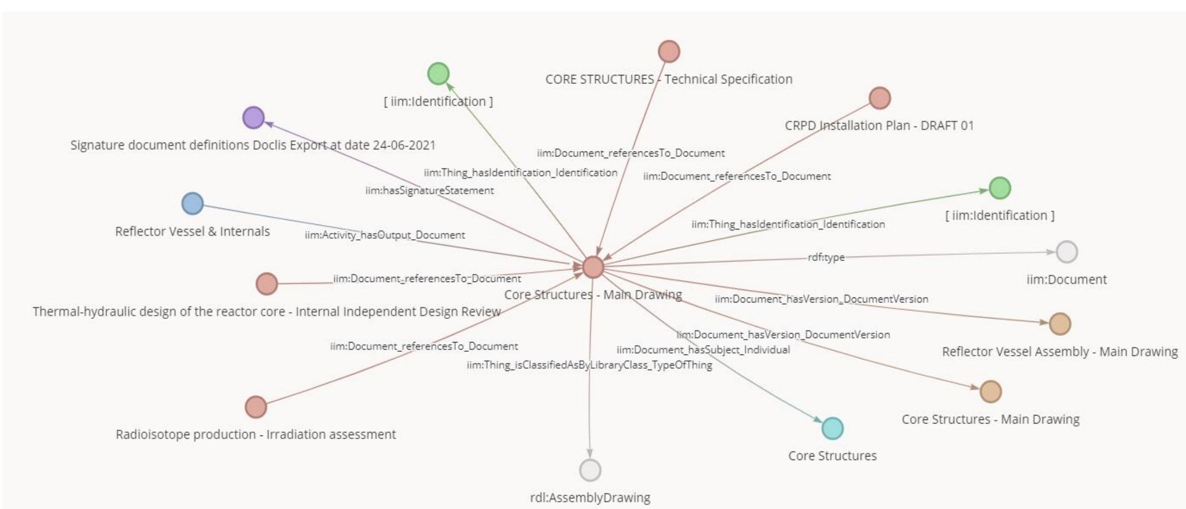


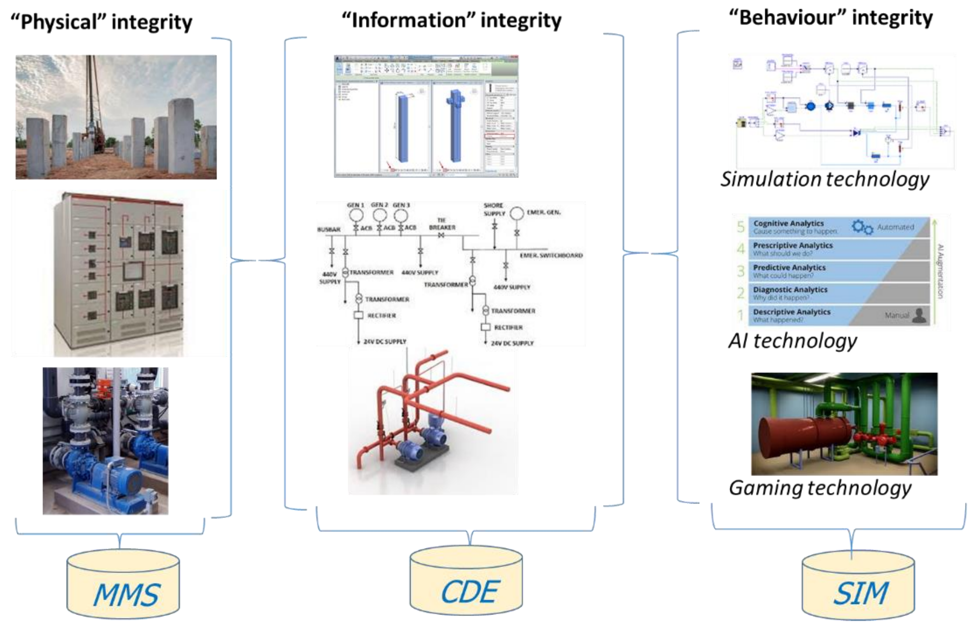
Figure 13. Example of a graph view on the content of the CDE showing the integration capability of various kinds of information.

EXTENDING THE CDE WITH DIGITAL TWIN CAPABILITIES

Since the CDE represents the complete configuration over the life cycle of the facility over time, it makes the CDE a solid base for realizing a Digital Twin to support better operations and safety. In Figure 14 the Digital Twin concept realised by connecting a Computerized Maintenance Management System (CMMS), Common Data Environment (CDE) and Artificial Intelligence (AI), modelling and videogaming technology to really give substance to the principle of the equilibrium triangle as presented at the start of this paper. By collecting and linking dynamic data (eventually based on IoT) to the breakdown structure elements in the CDE, a Digital Twin can be realised which is consistent with the configuration as defined in the CDE and reflecting the real configuration and performance of the facility in real time. The potential of an approach as described in this paper does not only enable unambiguous communication in a new construction project but is extremely valuable when digitizing existing facilities to unlock the knowledge as contained in the design and to be able to realize more efficient asset management and operations. The CDE feeds the digital twin environment with a comprehensive configuration of the facility as well as harmonised calculation codes as a feed for simulators. These calculation code models can cover various aspects from neutronic aspects of the reactor core to thermal-hydraulics or chemistry. Some codes focus specifically on a particular component and its operation, while others deal with system-wide phenomena. The IIM and RDL both play a key role in ensuring the interoperability of all the various calculation codes. The application of open standards as applied in the CDE concept and enabling the integration of additional data sources and inviting third party extensions to the platform allows the creation of a fully explorable Digital Twin Simulator, even linked to Project Lifecycle Management (PLM) and other platforms. Companies in the nuclear industry in France like CEA's nuclear energy department EDF and Framatome believe that digital twins will help in the process to continuous improvement of safety and quality of operations and will allow operators of nuclear facilities to better validate their action strategies in case of an event. The "digital" reactor is an important tool for the simulation to demonstrate the safety of equipment in a range of operating scenarios. With the collaboration of various originators of calculation codes, progress has been made in France realizing Digital Twins. As a concrete example, EDF has already trialled virtual reality devices to simulate opening or closing

valves in the reactor building.

Figure 14. Digital Twin approach with the CDE as central source of information.



Pulling from a harmonized and verified data base stored in international standards, integrating IoT sensor data and merging this with the advanced visualization software of current videogames, it is very likely that future operators will manage complex industrial and nuclear facilities using immersive, real-time simulators, such as those being developed and implemented by Dynatec's Talent Swarm division in Spain as shown below in Figure 15 (Novack and Ruijven 2021).

Figure 15. Rendering of Immersive Digital Twin Simulator (

Total cost management and energy transition (id 10; P_010)

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ABSTRACT

The purpose of the paper is to show how the energy transition, besides being a cost, can be also an opportunity for investments either public or private. Several form of renewable or other energy production plants shall be taken into consideration with a summary analysis of costs and revenues during their lifetime. In addition, some organization and authorization problems shall be taken into consideration, together with other issues that seems to be ancillary but are not: land finding, network problems, future scenarios.

FOREWORD

It is neither for engineers nor for economist to discourse about the climate change and its causes, whether they are anthropic, astronomic or a combination of them. This is matter to be analyzed by earth scientist while the relevant decisions, if any, are to be made by politicians.

However, some decisions have already been made through international agreements reached in several conferences, the last in Glasgow in November, 2021.

The agreed commitment is to have a carbon neutral economy within 2050 (for some countries postponed to 2060 or 2070). The European Union has been implementing its part of tasks, that have been written into law: -55% by 2030, climate neutral by 2050.

This will not be easy: some people says that it will be quite impossible. Might be, however since it is a legal obligation, we must do all we can to reach the goal.

The role of engineers and economists shall be to advise the politicians about the way they are undertaking, providing them with the specialist know how as well as relevant competencies. This is even more applicable to the expert in total cost management or in project management and controls, since the way to a carbon neutral economy as a whole can be considered as a gigantic program, to be managed and controlled with the same techniques that are used for major engineering projects with highly stochastic components.

This activity shall be done at all levels:

- global (politics of energy production and network interconnection),
- national (electric networks, power generation)
- local (distribution, energy communities)

While the decision about when the carbon neutral economy have to be implemented have been made by international agreement, is up to the national governments to decide how to implement them and to define the general criteria about the environmental impact of those measures, while the local authorities shall be involved in the support to energy communities, if any, as well as in the mitigation of the environmental impact.

The major part of the projects shall be then at the national level. Those projects shall be funded with private equity[1] as far as the renewable energy power plants are concerned, while the improvement of the electric distribution network shall be financed with government or European funds. The problem of energy storage is still open:

- privates are willing to install a storage capacity in their plant to cope with the daily variation of electricity price, this will allow a photovoltaic plant to keep the energy generated during the day and sell int after sundown at a higher price, while
- the electric network authority needs really huge storage capacity to stabilize the networks as the percentage of energy supplied through renewable sources increases.

ENERGY AND ECONOMIC DEVELOPMENT

Availability of energy has been, since the beginning of the human civilization, the key factor of any economic development, as a condition that is necessary but not sufficient. As a matter of fact,

- the limit to the economic development in the antiquity where due to the use of human or animal energy in agriculture, namely to the balance among the energy need for cultivating versus the energy produced, that in this case means foods for mankind as well as for work animals;
- the Roman Empire from year 100 before Christ to year 200 after Christ had all the precondition for a substantial economic development, however this development was severely limited by the lack of a proper source of energy as well as by the trap of slavery;
- the Middle Age development from year 1000 to 1300 was due in part to an improvement in the efficiency of processes together with the use of hydraulic energy;
- the first industrial revolution was due to capital accumulation as well as to the introduction of a new source of energy (coal) while,
- the second industrial revolution to the improvement of financial mechanism as well as to the introduction of electric power.

As a general rule, a revolutionary economic development can become reality when three conditions are simultaneously met, namely:

- new information properly distributed,
- new or better machineries and
- improvement in materials.

However, we should be aware that some preconditions (political, cultural, social) have to be met.

Over the centuries, we can see the transition from a subsistence economy to an economy of accumulation and eventually to an economy based on the consumption; we must now create an economic system that balances the needs of consumption and investment.

In addition, in some historical periods, we had a local view of the economy while in other times there has been a wide interdependence of the various economies throughout the world: the world since the second half of the nineteenth century until the early twentieth century was not less globalized than today's world, and probably the same can be said for the Roman Empire from fist century before Christ to the second century after Christ. It is now essential to achieve integration between the local dimension and global dimension.

At the bottom line, we must understand that the economic development has been always triggered by technical innovation, either process or product innovation: without that development will be only a dream.

Technical innovation means, in our case, to use the energy transition as an opportunity not only as a cost, by keeping the availability of energy of developed countries at the same level, that means without reducing the production" and, in the meantime, to increase the availability of energy in developing or emerging countries in order to give them the same chances that developed countries have already had.

SOURCES AND VECTORS OF ENERGY

When speaking about energy, we should have clear in our mind the difference among primary energy and energy vectors or secondary energy, that can be substantially identified with electricity. In the whole world, only 30% about of primary energy is used to produce electricity, while majority of it is used directly for heating, cooking, fuel for transport, etc.

If we refer to the Italian case, it is enough to look at the energy balance sheet (source ARERA 2020) to understand that, out of 106996 ktep of energy available, electricity stays for 23618 ktep.

A further confusion is caused by an erratic use of units: according to international measurement standard, energy should be measured in J (joules) and its multiples, however since this unit is quite difficult to manage, other units are normally used

- electrical energy is measured in Wh or its multiples (1 kWh = 3600 kJ)
- global energy balance is drawn in tep (equivalent oil tons - 1 tep = 41 868 kJ)
- heat is measured in kcal (1 kcal = 4,184 kJ)

Useless to say, the use of incongruent units creates additional difficulties in understanding a matter that it's already difficult by itself.

The earth of the matter is that energy transition will be relevant to the whole energy system, not only to electricity. In plain words, while today the electricity covers only a minor part of energy consumption, while transportation, heating and industrial processes use direc

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The other source of confusion is that, as far as electricity is concerned, it is important to understand the difference between the peak power of a power plant, that is measured in kW or MW and the relevant production that is normally measured in kWh or MWh.

A power plant that produced energy from heat, including power, has a production factor of about 9000 MWh/MW year, in other words 9000 equivalent hours, it is to say that from a power of 1 MW we can obtain 9000 MWh about. On the other side a photovoltaic plant in central Italy has a production factor of 1500 equivalent hours, that means that out of a power of 1 MW we can produce 1500 MWh only.

This information are to be clearly understood when we try to understand data relevant to the importance of different sources of energy.

THE TRANSITION

The energy transition aims at creating a carbon neutral energy system, that means a system whose balance, in terms of difference between production and consumption of carbon dioxide be zero.

Since out target date is 2050, namely less than 30 years from now, we have to rely only on existing technologies and their improvements, if any, while completely new technologies, albeit could be introduced, will not be significant to obtain those results. In other words, albeit energy coming from nuclear fusion can have an important impact on the second half of the century, is not likely that its impact be significant within 2050.

Let's have a rapid look on the possible sources that can be used for energy transition:

SOURCE	PROS	CONS	NOTES
Oil	high energy density flexibility easy transport high production factor low cost	pollution emissions'" erratic price	difficult to get rid of it
Coal	availability high production factor low cost (at least apparently)	pollution (is the most dirty source of energy) emissions	the countries that have mines will try to use it as much as they can
Natural gas	availability high production factor	emissions (less than oil or coal) high cost of transport	good source for transition, even in the long term if we can succeed in compensation the emissions
Hydroelectric'"	local resource high production factor	environmental and social impact high investment costs not fully reliable in case of drought	to be used whenever possible with limited impact
Nuclear"	emission free high production factor	radiation nuclear waste high investment costs	ideology is hindering the technical and economic evaluation
Wind mills	emission free local resource	low and erratic production factor	
Solar	emission free local resource	low production factor disposal of panels consumption of land	
Raw vegetable sources (wood, organic waste, manure)	low cost local resource	highly pollutant (production of lampblack)	
Biomass (ethanol. bio-diesel)	suitable as fuel for transport	emissions consumption of land (higher than solar)	limited production, will be only a niche energy
Geothermic	available without limits high production factor	high investment and research costs	big potential but limited possibility to have a significant impact within 2050

The following have to be considered:

- in order to avoid emissions, majority of energy has to be supplied through sources carbon free, that means converting the heating systems as well as majority of industrial production to the use of electricity only
- the renewable energy creates instability in the network due to the lower production reliability as well as to the lack of moment of inertia, the only way to compensate it will be to introduce a proper capacity of energy storage for the whole network; as things are now, the only real possibility is based on chemical batteries (mainly lithium batteries) that, on the other side, shall be subject to the availability of lithium and can create disposal problems due to the use of heavy metals

We did not include in the above table hydrogen, since this is not an energy source but only a vector that has to be produced through several processes that need primary energy.

Those processes are divided into "brown" and "green" processes.

- ❖ BROWN HYDROGEN
  - from coal
  - natural gas reforming
  - coal gasification
  - partial oxidation of methane
- ❖ GREEN HYDROGEN
  - bio-hydrogen from photolysis of water (through algae or bacteria)
  - electrolysis of water
  - high temperature electrolysis of water
  - thermochemical production from water
  - catalytic process

Hydrogen could be used in the transition period as fuel for transport, since it has no carbon emission and it's no polluting, furthermore it could allow the use of existing motors with modest modifications". On the other side, there are still problems to be solved for a safe storage.

As far as cars and airplanes are concerned, hydrogen shall be a competitor of electricity stored in batteries while for ships the main competitors shall be the small size, sealed, nuclear devices.

We should be careful about counterproductive effects. As an example, some researches believe that it could be possible to transform Sahara in a gigantic photovoltaic plant that could supply four times the energy that the World need, however this is science fiction: besides political problems, there are some technical problems to be considered:

- distribution problems for connecting this plant to the users throughout the world
- energy storage (is there enough lithium available)

However, the main issue is that solar panels are dark colored, they transform in electricity about 15% of the solar irradiation while the remaining 85% is given back as heat, affecting the climate. A project of this size, concentrated in a limited area would reduce the albedo of the concerned area, should the area be 20% of the Sahara as a whole, it would create a steep difference in the temperature of land and oceans, Sahara would become a gigantic oasis while the global temperature of the world increase and the global warming accelerate. A remedy worse than evil.™

the last point to be considered ids the complexity of the life cycle of an energy plant. Without going into too much details, let's summarize the main steps:

- ❖ **PLANNING**
  - new idea and design
  - feasibility
  - analysis of the alternative
  - decision
- ❖ **AUTHORIZATION**
  - engineering
  - environmental impact
  - authorization
  - decision to proceed
- ❖ **IMPLEMENTING**
  - Engineering & Construction
    - engineering
    - authorization
    - logistics
    - construction
    - commissioning
  - Operation & Maintenance
  - Dismantling or revamping

THE PRICE OF ENERGY AND ITS STABILIZATION

The price of energy is variable in an unpredictable and quite erratic way both in short and medium term. this price is related to the cost of the energy source (both CAPEX and OPEX) as well as to the mix of energy sources.

While the preferences and expectations of the majority of people are for a low cost of energy, some additional consideration should be made:

- ✓ low cost of energy kills the energy transition since gives priority to the use of known low-cost sources (coal, oil, in the best hypothesis natural gas) and furthermore does not give margin for any kind of research, either scientifical or technological as well as to research of new sources, the main risk is that, in case those sources be not found in time, after 2050 the alternative shall be or not to cope with the commitment for a neutral carbon energy or to face a severe energy shortage that can lead to energy rationing and relevant consequences;
- ✓ on the other side, a cost of energy too high can kill any possibility of economic development and lead to a severe recession, that is to be avoided at any cost since the "happy degrowth" does not exist and the real degrowth shall be unhappy, violent and bloody.

According to Maugeri (2011) the best price of energy should correspond to a crude oil standard price within a range among 50 to 70 US$ in the medium term.

The price of energy, then, has to be kept within a restricted range and stabilized as much as possible. this will be a task for Governments, that must avoid

> either to use the taxation on energy to collect cash, taking the opportunity from the low elasticity of energy consumption to price or
> to allow that energy price becomes too low, in order to create consent or for other demagogic purposes.

It means that the fiscal leverage, through the excise duties, has to be used as an instrument to stabilizing the prices, increasing the duties when the price becomes low and decreasing the duties progressively as the price becomes higher, applying a negative excise if needed. If the desired value of the energy price has been chosen with a suitable and balanced criterion and not in an unrealistic way, it should be possible that the balance among negative and positive excises in the medium term be equal to zero, in a kind of a zero-sum game.

The further requirement to be able to stabilize the price of energy without hindering the economic system as a whole shall be to have redundant capacity or, at least, the real possibility to adjust the production capacity in short time. It means to give up in part the efficiency in order to acquire resilience.

By this way, energy will become a really stabilized value and in theory it will similar to a currency.

ENERGY AS CURRENCY

It is universally known that, in the past, money was not representative of a value but had an intrinsic value, corresponding to its actual weight in gold, silver or any other metal less some coinage rights. On the other side, the **sovereign prerogative of the coinage** was the only way to guarantee the real value, weight and purity of the stuff.

In more than one historical period the authorities tried to modify the coinage, starting from the Isia&x0£ia *(seisakhtheia)* of the Athenian Solon (about 594 a.Ch.) to the coinage in impoverished silver *(vellon)* in the Spain of XVI century and so on: all those measures led in some cases to huge speculative bubbles, but never succeeded due to the so called Gresham's law™.

The system was internationally standardized in the XIX and first half of the XX century through the **silver standard** and the **gold standard** and then, from 1944 to 1971, through the **gold exchange standard** as defined in the United Nations Monetary and Financial Conference held in Bretton Woods in July, 1944.

After 1971, money has been issued by sovereign authorities in a full arbitrary way, it's then named ***fiat money**,* that in a limited period of time has been a positive factor of economic development but, according to several economists, is not sustainable anymore. The creation of the Euro allowed some improvements inside the European Union, being quite a partial substitute of the gold standard, however it had a negative impact (at least in some countries) as far as the economic development in concerned, due to the lack on an overall economic vision.

The weak point of the gold and silver standard was that they were based on a commodity whose availability had nothing to do with the need of the economic system, this limitation would continue to exist, at least in part, should the standard be shifted to a basket of commodities internationally agreed, with the further problem that such basket should be amended every, let's say, ten years, due to the different economic importance of each commodity in evolving times.

The second alternative that has been proposed was a **multi-currency standard**, namely to define the value of each currency with reference to a defined basket of other currencies. This in reality is not solving the problem, is only shifting it from the national to the international environment, it would work more or less like the Euro, with some positive aspects for a limited period of time, but not sustainable in the long term.

Then we need some innovative thinking, let's start with some ideas found looking through history as well as through the works of modern thinkers.

- The first is the development of **virtual currencies** by privates"*, governments or international organizations**;**
- The second is a **labour standard**, that is to define the value of the currency in terms of SMh (standard man-hours or normal man-hours): it's has quite a Marxian appeal but, to be objective, has some substantial limitations, due to the fact the SMh, albeit well defined, it's statistically defined and its definition is not stable in the long term. As a matter of fact, the companies that are using the SMh in their project controls, such as major engineering & construction companies, are updating their definition every fifth year. In reality, this standard has already been uses:
    - 1863 President Lincoln, pursuant to art. 1 of the Constitution of the United States of America, had printed "loan notes (Greenbacks)" granted without interest or coverage by the people to their government and guaranteed only by the work of the people themselves, albeit in a generic and not quantitative manner;
    - in Germany, the "Mefo-Wechsel" introduced by the Central Bank in 1933 were, albeit with a complex mechanism, only guaranteed by the production capacity of the system.
- The third is an **energy standard**, that is to define the value of the currency in terms of energy, namely in kWh or equivalent unit. In this case the unit is defined by a stable physical law and it seems more stable and promising in the medium term[x]. Besides any personal idea on that matter, I believe that it's a matter that is worthy to discuss about.

CONCLUSION

The goal for a carbon neutral economy in 2050 is quite an ambitious and difficult goal, but cannot be missed.

Furthermore, it has to be obtained in a way that allows the carbon neutrality not to be penalizing for economic development, in our world still there are a lot of countries that are on the way of the development, and we cannot clip their wings.

To succeed it is necessary a strong willingness, that starts from a political decision but should be accepted and shared by majority of the world population.

But willingness is pointless and cannot be implemented without theoretical scientific and technical knowledge and applied competence, program management and control skills, etc.; this is the field when total cost managers have something to say.

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[1] A photovoltaic plant on an area of 1 kmq (100 ha) can have a peak power of 600 to 700 MW and a yearly production of 700 000 to 1 100 000 MWh, the investment cost shall be about 60 000 000 € (plus the cost of the land) and the internal rate of return out of 30 to 35 years can be 6% to 8%.

[ii] some reduction could be made through improvement of efficiency and reduction of energy wastage, but wiiill be matter of some unit percent only

With the word "emission" we refer to the production of carbon dioxide (CO_2) that is not a pollutant agent, with the word "pollution" we refer to the pollutant agents properly so said.

[iv] Water is not an energy source, the hydroelectric source is kinetic energy from rivers

[v] Since fusion will not be available on time, we refer to second and third generation plants since forth generation plants., either thermal or fast, will probably not be available in time to be significant. The same can be said about hybrid reactor (fission and fusion) or thorium power generation. However, there is a chance that CANDU reactors can be converted to thorium. \

[vi] However, to be competitive on the energy efficiency point of view, hydrogen cars and planes should use fuel cells instead of endothermic motors.

[v]" The relevant research, made by Zhengyao Lu and Benjamin Smith, has been published in 2021 (Solar panels in Sahara could boost renewable energy but damage the global climate - here's why (theconversation.com)

[vi]" Gresham was a merchant living in XVI century. However, his law was previously formulated (Nicole d'Oresme, XIV century - St. Thomas of Aquino, XIII century - Aristophanes, V century before Christ)

[ix] On the 25.th of July, 2019, Mike Orcutt wrote an article on Technology Review about private currencies. The earth of the matter is: "We've had private currencies like Libra before. It was chaos. If private digital currencies start competing with national currencies, it could cause some of them to be more volatile. Almost 200 years ago, we saw something similar."

The article was referring to the '30s of XIX century, when 90% of money supply in the US had the form of private banknotes, difficult to trade outside the town where were issued and subject with fluctuating exchange rates

The key factor that keeps a currency stable is the credibility of its issuer. If the issuer is a private company, even extremely big, in case the business model declines or people start to have doubts about the future viability of the company, the currency could lose value or even collapse. The same can happen in case of financial crisis: then it's unlikely that any cryptocurrency can challenge stable national currencies.

On the other hand, a cryptocurrency like Libra might be a genuine competitor to government money in places that have unstable currencies.

To be considered the possibility of disruptive effects, whose result might be a modern version of the type of price volatility that private currencies caused in the US back in the 1830s.

[x] In theory (I know that for the time being is only science fiction) we could think about coins with an intrinsic value in energy, namely a kind of power bank.

ASSESSMENT OF KEY PERFORMANCE INDICATORS IN SUSTAINABLE HOUSING PROJECTS IN LAGOS STATE, NIGERIA

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ABSTRACT

To tackle the adverse effects of housing activities on the environment, sustainable housing has emerged as the guiding and encouraged paradigm of development in the building sector. Thus, this paper focused on assessing the key performance indicators on the sustainable housing projects. Structured questionnaire survey was used to collect data from 259 stakeholders involved in sustainable housing projects in Lagos State, Nigeria. A total of 203 responses were retrieved, representing 78% response rate. Primary data regarding the level of importance attached to performance indicators in sustainable housing were collected. The data collected were analysed using mean ranking analysis and analysis of variance (ANOVA). The data collected were used to determine the significant key performance indicators of sustainable housing projects in Lagos State, Nigeria. Study showed that the top 5 key performance indicators used in measuring the performance of sustainable housing projects comprise of delivery within the scheduled time, delivery to specified quality, delivery within budget, overall sustainability rating achieved by the project and energy efficiency rating of the building. Further analysis using Analysis of Variance showed that the different categories of stakeholders surveyed were unanimous in the level of importance they placed on differing kep performance indicators. The knowledge of the identified significant key performance indicators provides invaluable information to stakeholders regarding the most important performance indicator to focus attention on in achieving sustainable housing projects. The study provides a veritable basis for assessment of sustainable housing project in Lagos State, Nigeria.

Keywords: housing, indicators, performance, stakeholders, sustainability.

Paper type Research paper

INTRODUCTION

Building activities, ranging from extraction, processing and transportation of raw materials to design, construction, operation and demolition of built product adversely affect the environment in form of excessive resources use, wastages, and greenhouse gas (GHG) emission (Ozorhon, 2013; Zou & Couani, 2012). The energy consumption from the housing sector alone accounts for approximately 25% of carbon emissions (United Nations Report, 2016). United States General Services Administration (2011) agreed that sustainable buildings save 19 per cent of the cooperative cost-in-use, and 36 per cent of CO_2 releases while traditional buildings consume about 40 per cent of universal energy, 40 per cent of other resources, 25 per cent of universal water and releases one-third of sustainable house gas emissions. As at 2012, energy consumption in residential structures was 135 petajoule (PJ), 3.5% of the year's total, and it was projected to rise by 24% during the duration of 2009 to 2020, attaining just under 170 PJ by 2020 (U.S. Green Building Council, 2017). These figures obviously point to the adverse consequence of construction activities on the environment and which make the obtaining of housing projects in the traditional way unsustainable. This evidence underlines the need for a market uptake of sustainable housing in order to protect ecological processes and safeguard the welfare of future generations. The above evidence among others also highlights the need to focus on research into sustainability in housing provision. United States Environmental Protection Agency (2017) defined sustainable buildings as: "The practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle and consists of design, construction, operation, maintenance, renovation and deconstruction". This activity expands and stabilizes the traditional building design in relation to economy, utility, durability and comfort.

To tackle the adverse effects of housing activities on the environment, sustainable housing has emerged as the guiding and encouraged paradigm of development in the building sector (Dobson *et al*, 2013). Sustainable housing projects are expected to alleviate the poor performance in energy consumption, carbon emission of built environments and also reduction in the cost-in-use of a building. Basically, sustainable housing is the practice of creating constructed facilities by using best-practice, clean and resource - efficient measures from the extraction of raw materials to demolition and disposal of its components (Hwang & Tan, 2012; Ojo, Mbowa, & Akinlabi, 2014). Research indicates that in Europe, the implementation of sustainable housing projects can reduce energy use by 42%, the total GHG by 35%, materials extraction by 50% and water consumption by 30% (Dobson *et al*, 2013). There are some performance indicators normally used to examine the extent to which project targets have been achieved. Osuizugbo (2018) recommended project completion to time, cost, quality, freedom from defects, meeting stakeholders expectation and the volume of dispute as project performance measurement criteria. Korkmaz *et al*. (2011) categorised performance indicators as energy rate, indoor air quality, and energy efficiency rating. Their study attempted to establish performance indicators though the focus was on mass housing project different from sustainable housing projects in this study. Furthermore, Sibiya *et al*., (2015) assessed the construction projects' key performance indicators. Findings from their questionnaire survey revealed that the most significant construction projects KPIs are: construction time, profitability, project management, material ordering, handling and management, risk management, quality assurance, client satisfaction (product), safety, time predictability (project, design, construction), productivity, client satisfaction (service).

LITERATURE REVIEW

Sustainable Construction

Sustainable construction is a certainty for disabling the negative effect of construction and attaining sustainable development in the process (Anigbogu, 2015). With construction being fundamental to all nature of growth, it is unavoidably connected to sustainable (or unsustainable) development (Anigbogu, 2015). Construction involves infrastructural facilities like roads and railways, harbours and ports, airfields, dams and power stations, fresh water supply, drainage and buildings by this means actualising the built environment (Mogbo, 2014, Jiang & Wong, 2016). Globally, the built infrastructural facilities constructed in 2016 are valued at US$9.1 trillion. These provisions have great effect on human lives different sectors and lifestyles (Xiong *et al*, 2016). Sustainable construction is execution of sustainable development goals to a building evolution from planning of the project, development, mining raw material to production and becoming construction material, operation, demolition, maintenance and waste disposal. It is a complete process which purpose is to guarantee harmonization between the nature and built environment by generating permissions which suit human and support economic fairness. In the exhibited concept by Kibert (Figure 1), sustainable construction is existing at the joining of mechanisms of principles, phases, and resources (Kibert, 2005). In this model, sustainable construction concepts are valuable to any desirable resources at all the different stages throughout the construction process which are the planning, development, design,

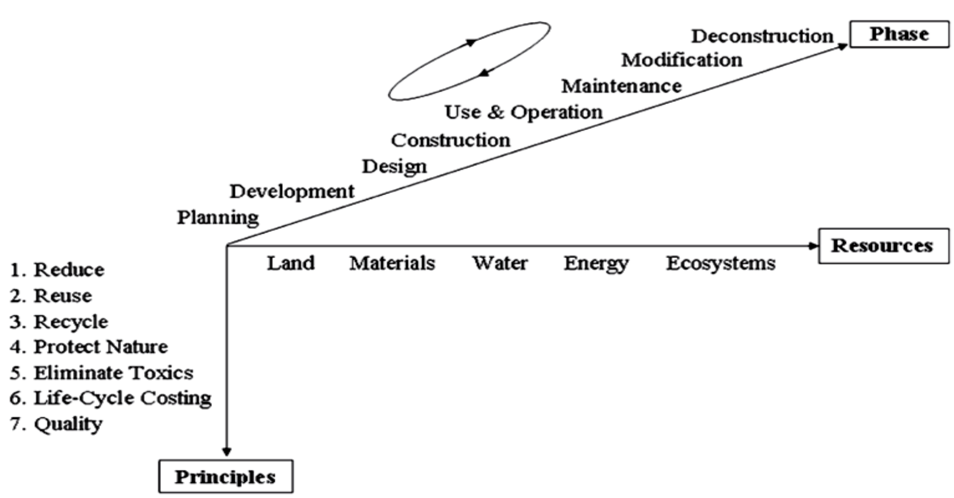

Figure 1: Sustainable construction model

Extraction, processing and transportation of raw materials, construction, use and demolition of built products which are construction activities use a lot of resources and energy (Zhao *et al*., 2012), which is destructive on the physical environment network in the form of greenhouse gas emission, wastes, and carbon emission (Zou & Couani, 2012; Ozorhon, 2013), and social existences in the plan of poor health and safety (Close & Loosemore, 2014; Jiang & Wong, 2016).

The First International Conference on Sustainable Construction in Tampa, Florida, in 1994 discussed growth in the new innovation of `sustainable construction' or, as it has definitely been named, `green construction'. In addition, sustainable construction accepted the concept of sustainability and relates it to construction activities. At first, the term `sustainable construction' was anticipated to describe the apprehension of the construction industry in achieving `sustainability'. Sustainable construction was initially defined as promoting a wealthy construction environment using well-structured resources, environmentally based principles' (Kibert, 2013). Mostly, it is used to describe a development which starts well initially in the planning and design stages and remains after the project team has moved away from the site. It is also the organization of the serviceability of a building during its lifecycle and up till its final demolition and the re-use of properties to reduce the rate of waste commonly related with demolition (Saunders et al., 2016).

The complete level of the construction activities suggests that it is probably one of the major significant industrial sectors in which positive results of sustainability is achieved. The outcome of the division makes up about ten percent (10%) of universal Gross Domestic Product (GDP) even though also making use of about 7 percent of the worldwide labor force (Pearce *et al*., 2012). The term '*sustainable construction*' (SC) was fashioned to create the concept of SD amongst the construction industry. Nevertheless, sustainable construction has of various challenges like definitions, in depth knowledge and transition to practice (Murray and Cotgrave, 2007; Bourdeau, 1999; Hill & Bowen, 1997).

The construction sector has a 'portioning' and it is a complex construction with the responsibilities of design far separate from the construction responsibilities. This peculiarity is also extended by the collaboration between different types of stakeholders in this construction industry. This structural portioning and complexity of projects has impacts on how sustainability is implemented in each sector, for better consideration and the social networks amongst different business concerns and how it can be handled.

Key Performance Indicators for Sustainable Housing Projects

Traditionally, the success of projects has been largely assessed with the traditional measures of delivery to budget, delivery within scheduled time, and to specified quality. However, beyond the traditional measures, sustainability metrics have been utilised in more recent studies. This sustainability metrics include energy rate, sustainability rating, indoor air quality, and energy efficiency rating (Olanipekun, 2017). Key Performance Indicators (KPIs) are metrics for assessing construction project success. This is the reason why performance measurement of construction projects is usually carried out by establishing KPIs which offer objective criteria to measure project success (Sibiya *et al*., 2015). Korkmaz *et al*., (2011) and Mogbo (2014) highlighted the interest in improving the performance of buildings and the need to make projects perform sustainably. Generally, performance indicators are measures that describe --the efficiency with which project resources have been managed to achieve objectives (Mao *et al.,* 2015). Over time, a number of studies have been conducted on project performance. Osuizugbo (2018) pointed out that the success of a project can be differently conceived by the stakeholders on the project.

However, there are variety of criterion for evaluating whether a project has been successful or otherwise. Mulligan *et al*., (2017) divided project success into four dimensions which are: meeting design goals, benefit to end users, benefit to organisation, and benefit to national infrastructure. Osuizugbo (2018) recommended project completion to time, cost, quality, freedom from defects, meeting stakeholders expectation and the volume of dispute as project performance measurement criteria. The study's submission is very similar to the position of Ametepey *et al*., (2015) that classified performance indicators into four, which are: environmental, customer satisfaction, overall cost and time, and quality. As a result of the complexities associated with sustainable building projects, Korkmaz *et al*., (2011) highlighted the need for a clear focus on the performance of such projects. Basically, the eventual performance of a project describes available resources that have been utilised to achieve the desired outcome (Gultekin *et al*., 2013).

Furthermore, Banihashemi, *et al*. (2017) highlighted Compliance with anti-corruption rules and regulation in the decision-making process, awareness of sustainable project delivery in the project management team (PMT), safety records, human resource management and public acceptance towards the project as the key performance indicators for integrating sustainability into construction project management practices and public acceptance of the projects. Arising from the above review, a comprehensive list of sustainability KPIs is provided in table below.

Table 1: Key Performance Indicators for Sustainable Housing Projects

SN	Indicators	Literature sources
1.	Delivery within scheduled time	Sibiya *et al*., (2015); Korkmaz *et al*., (2011)
2.	Delivery within budget	Sibiya *et al*., (2015); Osuizugbo (2018)
3.	Delivery to specified quality	Korkmaz *et al*., (2011); Osuizugbo (2018)
4.	Energy efficiency rating achieved by the project	Sibiya *et al*., (2015); Korkmaz *et al.,* (2013)
5.	Overall sustainability rating achieved by the	Sibiya *et al*., (2015); Mulligan *et al*., (2017)
6.	Indoor air quality	Mulligan *et al*., (2017); Osuizugbo (2018)
7.	The amount of rework for defective Work or call backs	Mulligan *et al*., (2017); Osuizugbo (2018)
8.	The amount of dispute	Sibiya *et al*., (2015); Ametepey *et al*., (2015)
9.	Overall stakeholder satisfaction rating	Ametepey *et al*., (2015); Olanipekun, (2017).
10.	Safety record	Chen *et al* (2012); Olanipekun, (2017).
11.	Transparent and competitive procurement Process	Chen *et al* (2012); (Olanipekun, 2017).
12.	Human Resource Management	Gudiene *et al* (2013); Banihashemi, *et al*. (2017)
13.	Productivity/periodic Productivity	Banihashemi, *et al*. (2017)

14.	Risk assurance	Chen *et al* (2012); Olanipekun, (2017).
15.	Compliance with anti-corruption Rules and regulation in the decision-making process	Olanipekun, (2017); Chan, Scotto & Chan (2004)
16.	Knowledge and awareness of sustainable Project delivery in the project management Team (PMT)	Sibiya *et al*., (2015); Banihashemi, *et al*. (2017)
17.	Satisfaction of user needs	Sibiya *et al*., (2015); Banihashemi, *et al*. (2017)
18.	Public acceptance of the project	Banihashemi, *et al.* (2017); Olanipekun, (2017)

METHODOLOGY

Structured questionnaire survey were distributed to identified 259 stakeholders involved in sustainable housing projects in Lagos State, Nigeria. A total of 203 responses were returned, representing 78% response rate. Primary data regarding the level of importance of key performance indicators on the delivery of sustainable housing projects were collected. The data collected were analysed using mean score analysis alongside analysis of varainace (ANOVA). The data collected were used to determine the key performance indicators of sustainable housing projects in Lagos State, Nigeria. The target population of respondents comprised of all the stakeholders that participated essentially on sustainable housing projects in the study area. This consists of Architects, Structural Engineers, Quantity Surveyors, Project Managers, Electrical Engineers, Mechanical Engineers and Builders and Government Regulatory Agencies. The mean score and analysis of variance was adopted for this study. A 6-point Likert-type scale was employed for data collection and a mean analysis was done using the mean score analysis formula given as:

$$MS = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1 + 0n_0}{n_5 + n_4 + n_3 + n_2 + n_1 + n_0}$$ (Equation 1)

where MS = Mean Score

Where n_o= no of respondent who answered “Not applicable”
n_1 = no of respondent who answered “very low”
n_2 = no of respondent who answered “low”
n_3 = no of respondent who answered “Moderate”
n_4 = no of respondent who answered “high”
n_5 = no of respondent who answered “very high”

ANOVA was used to examine the difference in perceptions of the respondents based on the identified stakeholders.

DATA ANALYSIS AND DISCUSSION OF FINDINGS

The objective of this research assessed the level of importance of key performance indicators for sustainable housing projects in Lagos State, Nigeria. In order to achieve this, the level of importance of 18 identified key performance indicators for sustainable housing projects were rated by the respondents on a scale of 0-5. The data obtained were subjected to Mean Response Analysis (MRA) and Analysis of Variance (ANOVA). The result obtained is as presented in Table 2.0. The result of MRA presented in Table 2.0 shows that seventeen (17) of the identified key performance indicators had mean value of more than 3.50 which signifies that these key performance indicators have a high level of importance in sustainable housing projects. This implies that the respondents attach high importance to these key performance indicators. The five (5) top important key performance indicators include: delivery within the scheduled time; delivery to specified quality and delivery within budget; overall sustainability rating achieved by the project; and energy efficiency rating of the building.

It is worth noting that the topmost five key performance indicators which represent 5 most important ones were remarked and selected for discussion; The traditional measures are delivery to time, quality and budget while the ones that focused more on sustainability are overall sustainability rating and energy efficiency rating of the project (Li, *et al.,* 2014; Robichaud & Anantatmula, 2010; Olanipekun., 2017) . Assessing the various stakeholders and how they analised result ranked the importance of listed performance indicators on the delivery of sustainable housing projects, it is observed that the results are not too far from each other. There was no much variation in how stakeholders perceived the most important performance indicators. This shows that level of importance attached to the listed performance indicators by the individual surveyed categories were high; hence these performance indicators should be given due consideration by the stakeholders in the delivery of sustainable housing projects.

Table 2: Importance of key performance indicators

S/N	Performance Indicators	All		Project Manager		Quantity Surveyor		Architect		Engineer		Builder		Government		ANOVA	
		MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	F- value	P- valu
1	Delivery within scheduled time	4.07	1	4.19	3	3.81	8	4.15	1	4.36	1	4.23	1	4.08	1	1.456	0.206
2	Delivery to specified quality	4.04	2	4.44	1	4.00	3	3.9	3	3.96	3	3.90	4	4.08	2	1.271	0.278
3	Delivery within budget	4.04	3	4.33	2	3.90	5	4.05	2	4.16	2	4.03	2	3.97	3	0.747	0.589
4	Overall sustainability rating achieved by the project	3.91	4	4.11	6	3.97	4	3.65	7	3.68	13	3.97	3	3.92	4	1.178	0.321
5	Energy efficiency rating of the building	3.83	5	3.96	10	3.90	6	3.70	6	3.72	10	3.70	5	3.87	5	0.531	0.753
6	Needs assessment of people	3.82	6	4.04	8	4.02	2	3.85	4	3.92	4	3.43	9	3.59	9	2.16	0.06
7	Indoor air quality	3.74	7	4.11	6	3.69	12	3.60	8	3.76	8	3.67	6	3.67	7	1.009	0.413
8	Knowledge and awareness of sustainable project delivery in the project management team (PMT)	3.71	8	4.15	5	4.03	1	3.45	14	3.68	14	3.27	14	3.41	16	4.303	.001*
9	Overall stakeholder satisfaction rating	3.7	9	4.19	3	3.73	11	3.75	5	3.76	9	3.23	15	3.64	8	2.811	.018*
10	Safety	3.68	10	3.85	13	3.69	13	3.60	9	3.72	11	3.40	10	3.79	6	0.741	0.593
11	Risk assurance	3.66	11	3.96	10	3.82	7	3.60	10	3.72	12	3.13	18	3.56	10	2.397	.039*
12	Productivity	3.63	12	3.81	14	3.81	9	3.60	11	3.64	16	3.17	17	3.56	11	1.848	0.105

Table 4.3 Importance of key performance indicators (Cont'd)

	Performance Indicators	All		Project Manager		Quantity Surveyor		Architect		Engineer		Builder		Government		ANOVA	
	S/N	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	MS	R	F- value	P- value
13	Human Resource Management	3.61	13	3.81	14	3.63	14	3.50	12	3.84	7	3.37	11	3.51	13	0.905	0.479
14	Transparent and competitive Procurement process	3.6	14	3.81	14	3.58	15	3.50	13	3.88	5	3.33	12	3.54	12	1.065	0.381
15	Public acceptance towards the project	3.59	15	4.04	8	3.76	10	3.35	15	3.64	17	3.3	13	3.31	17	2.447	.035*
16	Compliance with anti-corruption rules and regulation in the decision-making process.	3.53	16	3.93	12	3.53	16	3.15	17	3.88	6	3.23	16	3.44	15	2.015	0.078
17	The amount of rework for defective work or call backs	3.51	17	3.81	14	3.4	17	3.2	16	3.68	15	3.53	7	3.51	14	0.961	0.443
18	The amount of dispute	3.22	18	3.44	18	3	18	2.55	18	3.56	18	3.53	8	3.28	18	3.294	.007*

MS = Mean Score; R = Rank; * Sig at p < 0.05

The paper also categorized the surveyed stakeholders into Government, Project Managers, Quantity Surveyors, Architects, Builders and Engineers etc. On Project Managers level of awareness of key performance indicators, table 2 shows that the Project Managers view the most important key performance indicator is delivery to specified quality with a mean score. This is followed by delivery within budget, delivery within scheduled time, overall stakeholders satisfactory rating, sustainable project delivery in the project management team.

Similarly, Quantity Surveyors view the most important key performance indicator to be sustainable project delivery in the project management team (PMT) with a mean score. This is also closely followed by need assessment of people, delivery to specified quality, overall sustainability rating achieved by the project, delivery within budget. The Architects view the most important key performance indicator to be delivery within scheduled time with a mean score. this is followed by delivery within budget, delivery to specified quality, needs assessment of people, and overall stakeholders satisfaction rating. Engineers most important key performance indicator to be delivery within scheduled time. This is followed by delivery within budget, delivery to specified quality, needs assessment of the people and transparent and competitive procurement process. In the same vein, Builders view the most important key performance indicators to be delivery within scheduled time. This is followed by delivery within budget, overall sustainability rating achieved by the project, delivery to specified quality, energy efficiency rating of the building. Government category view the most important key performance indicator to be delivery within scheduled time with a mean score, delivery to specified quality, delivery within budget, overall sustainability rating achieved by the project, energy efficiency rating of the building.

Differences in the perceptions of the respondents on the importance of the identified key performance indicators in sustainable housing projects based on these categories were further assessed through Analysis of Variance (ANOVA). The result revealed that significance difference existed in the perception of the respondents on importance level of 5 of the identified key performance indicators in sustainable housing projects based on the category of stakeholders. This is revealed by their *f*-values at $p<0.05$. These Key Performance Indicators include knowledge and awareness of sustainable project delivery in the project management team (PMT); overall stakeholder satisfaction rating; risk assurance; public acceptance towards the project; and amount of dispute. This implies that the respondents, based on their categorisation, perceived the level of importance of those identified 5 key performance indicators on sustainable housing projects in different ways. It can be inferred that category of stakeholders had significant effect on the views of the respondents on the level of importance of only 5 (28%) of 18 key performance indicators in the delivery sustainable housing projects while their views on the level of importance of other 13 (72%) key performance indicators had no significant effect. This depicts that the category of stakeholders doesn't affect the importance of most of the key performance indicators in the delivery of sustainable projects.

The high ranked performance indicators as observed by the study has been inferred to be very important in the delivery of sustainable projects which is in agreement with Sibiya *et al*, (2015). According to the study, delivery within the agreed and scheduled time as shown by the surveyed respondents should be highly prioritized by all stakeholders. Considering the importance of these project objectives (cost and time) and the possible consequences of mismanaging them in the course of construction, especially, in achieving sustainable building; identifying them in his study is very apt and should be attached such essentiality. As to maintain the goal of a sustainable society, delivery to specified quality and delivery within budget by the Project Managers, Quantity Surveyors, Architects, Engineers and Builders should be taken seriously and not with levity. All stakeholders should be well involved in the overall sustainability rating achieved by the project so as to ensure prompt delivery of the proposed sustainable project. The Energy efficiency rating of the building should be well measured as energy efficiency is one of the focus for consideration in sustainable or green building; its rating should be of concern to achieve the purpose of sustainability in building projects especially in the study area. Thus, it should be accorded the respect of an important indicator in the delivery of sustainable project.

Zahirah *et al*., (2013) established an influence of stakeholder on energy efficiency of housing: development which confirmed the reality of this study and energy efficiency as one of the performance indicators of sustainable construction in the study area. Pulaski et al., (2016) alluded that sustainable construction aimed at saving energy, reducing costs, and adhering to policy; hence sustainable projects should be recognized when it saves energy, reduces cost and responses appropriately to any laid down rules guiding performance. These performance indicators are expected to be present as appropriate for a project to be rated as sustainable; they are important measurement of project sustainability as established by this study. This study corroborated Zhao *et al.,* (2017) which defined key indicators to be considered in assessing sustainable construction and Windapo (2014) which suggested that the identified key indicators should be selected with consideration of certain standards including building types, location, the building life cycle among others.

CONCLUSION

This paper concluded that the five (5) top important key performance indicators include: delivery within scheduled time; delivery to specified quality, delivery within budget; overall sustainability rating achieved by the project and energy efficiency rating of the building. The study further concluded that significance difference of opinions existed in the perception of the different categories of stakeholders regarding the level of importance they attached to the identified key performance indicators in sustainable housing projects. The study examined the level of key performance indicators on sustainable housing project in Lagos State, Nigeria. Further study to examine the level of importance of key performance indicators of other types of sustainable building project could be embarked upon for comparable results. Furthermore, other studies to compare key performance indicators on sustainable housing projects between Lagos and other States as well as regional comparison could be instituted.

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Costing Tools Adoption Survey (id 27; P_027)

COSTING TOOL ADOPTION SURVEY

ABSTRACT

Cost are a key factor in the performance and competitive position of companies. In the 1990s the adoption of innovative software tools like Computer Aided Design (CAD) and Enterprise Resource Planning (ERP) was one of the key methods for many industries to modernize their way of working. Today these tools are de facto standard in manufacturing companies and considered crucial to their operation. Cost estimating tools have been around for more than two decades but their use is not as widespread and as standard as CAD and ERP. Cost engineers commonly use spreadsheets and struggle to further advance their approach. There is no overview that shows what costing solutions are used in different industries, conditions of use and IT landscapes. To provide desired insights an online survey has been initiated and was shared with cost engineers via four communication channels. The questionnaire was organized in three sections according to type of questions. The response from different channels has been aggregated in one database which is used to analyze the data set. Pivot tables have been used to produce different cross sections of the data. Associated graphs are used to guide the visual interpretation of the data. The survey has been designed to facilitate replication every few years in order to create a picture of the development of the use of the costing tools and their IT landscape embedding. The survey has produced original insights on the use of costing tools across industries and is anticipated to be a catalyst for further advancement of the cost engineering profession.

KEYWORDS

Innovation adoption, community survey, cost engineering, computer aided cost estimation, software tools.

INTRODUCTION

Cost play a central role in many industries and are key to the competitive position of companies. Cost engineers or cost estimators play a central role in estimating, controlling and optimizing cost for products manufactured and projects executed. The cost engineering profession resolves around handling large amounts of data. More sophisticated handling and analysis of cost data holds a promise of advancing the cost engineering profession.

Digitalization took command of many processes in diverse industries. Computer Aided Design (CAD) has its roots in the early 1960s and the first commercial use dates back to 1970 [1]. Five decades later the pen, ruler and compass appear to have been phased out. Advancing CAD applications became instrumental to innovation in disciplines ranging from chemical plant design [2, 3] to dental engineering [4]. Enterprise Resource Planning (ERP) brought major change to the way businesses organize processes and information. The term Enterprise Resource Planning was coined by Gartner in 1990 to describe a next generation software for managing

Material Resource Planning (MRP) and Manufacturing Resource Planning (MRP II) [5, 6]. ERP systems became the de facto standard in large and particularly multinational companies during the 1990s. Current ERP systems extended their scope now including modules for sales, finance and human resources [6].

Digitalization also reached cost engineering and more advanced ways of working have been devised over the decades. In 1980 Boothroyd and Dewhurst created software to analyze and optimize Design For Assembly (DFA). In 1985 they added a module on Design For Manufacturing (DFM) to analyze cost of machining and injection molding [7, 8]. Over the years different authors published on using computers to estimate cost [9, 10]. One of the authors of this work anticipated further advancement of Computer Aided Cost Estimating (CACE) taking a place in the IT landscape between CAD and ERP [Figure 1 in 11]. However, it is now evident that costing tools did not yet develop with the same speed and industry changing impact as observed for CAD and ERP.

With the advent of the personal computer in the 1980s and early 1990s spreadsheet software slowly but surely became part of the standard office applications. Spreadsheet software is very flexible, versatile, cheap in use and has a relatively low entry barrier. They are great general purpose calculation tools for diverse applications. Many companies therefore transferred paper costing practices to spreadsheets, which often involved the development of proprietary templates.

Over the course of recent decades, also many dedicated cost estimating tools have been developed and were made available to the market. These tools have functionality not part of the standard spreadsheets software. For example there are tools that use functionality derived from Computer Aided Manufacturing (CAM) software that allows to calculate cost of manufacturing a metal or plastic part based on a 3D CAD file. The insights produced can support the design process towards cost targets. A complete different type of challenge is addressed by Building Information Model (BIM) based software that supports construction companies estimating cost of built assets like buildings and physical infrastructures like roads, railways or electricity networks [12]. These challenges are so diverse that entirely different software is used for them.

Dedicated costing tools are sold by software vendors and consulting firms, all of which recommend their own wares. Gartner, an information technological research and consulting firm, is a leading source of market intelligence on software. However on costing software it does not provide comprehensive insights. Hiller Associates, a consulting firm focusing at discrete manufacturing companies, supports clients with product cost management. They provide some blog reports on related software [13], its evolution [14, 15] and a world map of product cost management [16]. Hiller Associates & CIMdata, Inc. conducted an on-line survey to better understand the emerging discipline of Product Cost Management (PCM) within discrete manufacturing industries [17]. PolarixPartner published a survey on cost management in the manufacturing industries and concludes, as befits consultants, that considerable potential remains untapped [18]. It is evident that a survey into cost management in itself is not new. We did not find an independent and cross-industry discourse on costing tool adoption, its relation to specific types of use and the embedding in the IT landscape.

Professional associations like the Dutch Association of Cost Engineers (DACE) in general seek to further advance a particular profession and in particular the skills of their members. In DACE the use of costing tools is a recurring theme. Some members use CACE tools, but many more use spreadsheet solutions with home grown templates. Both CACE and spreadsheet solutions appear to have particular usage challenges. In general, it is not clear which variants are used to what extent in various industries. To resolve the lack of insight, a workgroup in DACE set out to develop a costing tool adoption survey in the cost engineering community. This paper aims to share the insights produced with peers in order to advance our profession.

APPROACH

To acquire a better understanding of the use of costing tools as desired in DACE, a survey has been developed that can be used amongst cost engineers and the like. A number of practical considerations has set the outlines for the design of the survey.

First, it is desired to collect responses from an as large as possible international audience to do justice to the international field of cost engineering, which may have reached more mature level in international companies. For this reason the survey uses the English language.

Second, both filling and processing the questionnaire should be as simple as possible. Respondents are not willing to participate in surveys if it takes too much effort or time, assumed is the maximum time spend should stay below 15 minutes. Automatic processing of response is desired to reduce workload and to make it easy to repeat the survey at an appropriate interval potentially gaining valuable insights on trends in the use and adoption of costing tools.

Third, anonymous participation to the survey was set as prerequisite for the following reasons. Sharing operational information that can be traced back to specific individuals or companies is highly undesired and is likely to discourage participation. A second reason is that the survey has to comply to European privacy legislation known as General Data Protection Regulation (GDPR).

A last design criterion is that the questions will lead to meaningful data and conclusions. Since this is a subjective criterion, this was achieved through an iterative process involving stakeholder cost engineers, as discussed below.

Online survey tools appear ideal for our purpose and many different variants are available. Microsoft Forms is freely accessible in commonly used Microsoft Office business software and was therefore identified as a potential tool to execute the survey. It is possible to respond anonymously in Forms which takes away concerns about confidentiality GDPR compliance.

Research questions

A first version of the questionnaire was developed in the Special Interest Group (SIG) Cost Engineering Machine and Manufacturing (CEMM) of DACE. Questions into reasons why certain solutions are being used and what difficulties are being experienced lead to open questions that are undesired both for filling in and processing the questionnaire. To circumvent this issue, it was decided to frame closed questions that assess costing tools and settings of use. Three high level questions have been framed.

What is the state of use of costing tools in DACE (the Netherlands), and outside DACE (different geographies)?

What is the relationship between the conditions of use (industry, reporting line, # cost engineers, geographic region) and the cost estimating tool being used?

What is the relationship between the IT landscape & embedding and the cost estimating tool being used?

It was verified with the SIG CEMM that this baseline is likely to lead to potentially interesting outcomes for their decision making with respect to adoption of tooling.

Designing the questionnaire

With the design considerations listed in the section above, a questionnaire was designed primarily based on multiple choice questions. Assuming that the multiple choice options offered were not exhaustive, an option ‘Other’ with a free text field was included for 9 of the 13 questions. One question required numerical input (year of start using a solution). For two questions the multiple choice options sufficed.

To avoid responses being influenced by the sequence in which multiple choice answers were offered, the options where shuffled. Some questions allowed multiple answers, others only a single answer.

The research questions have been organized in three thematic groups:

Main setting of use.

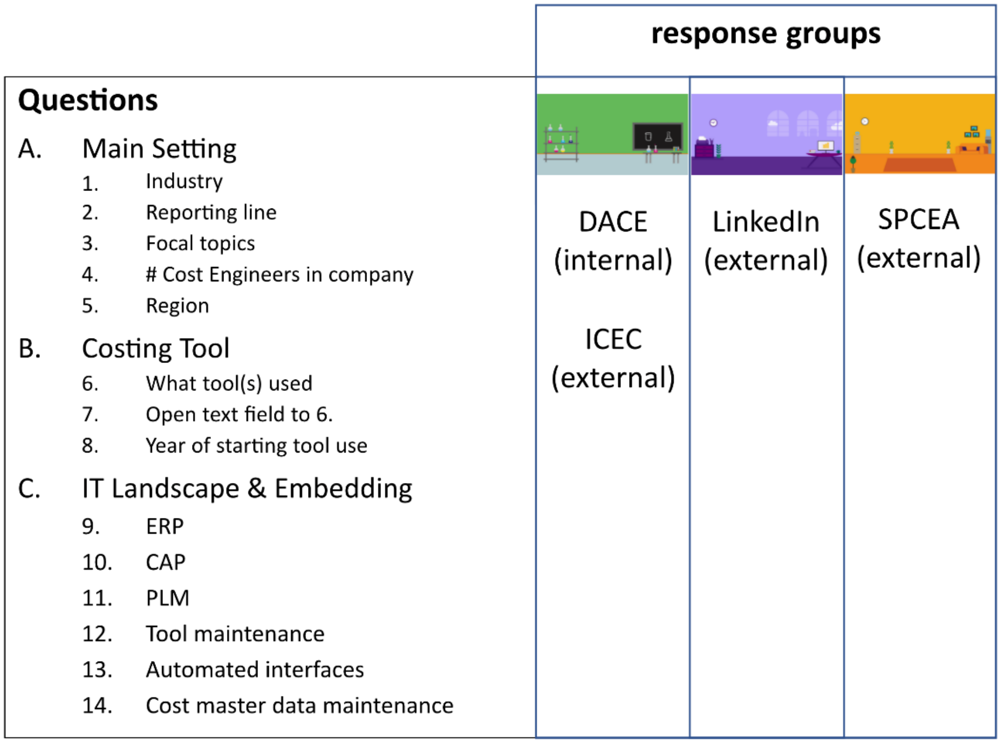
Costing tool use.

IT landscape and embedding.

As discussed, anonymous participation to the survey was the starting point in the survey. As consequence, extra measures were needed to be able to investigate the difference between different response groups. To that end the same questionnaire has been made accessible to different response groups, each with a different Uniform Resource Locator (URL), to create a low threshold separation mechanism.

Figure 1 provides a graphic overview of the three thematic groups including keywords of questions and the partitioning used to distinguish different response groups. The response column includes two different groups separated in time by moment of introduction to the URL. The survey was introduced to the second group of respondents via the International Cost Engineering Council (ICEC) three weeks after introduction to the first group.

Figure 1 Structure of survey questions and response groups addressed via different URLs.



ANALYSING RESPONSE DATA

Each response group provided graphical output for all responses per multiple choice question. The survey tools used (Forms) does not allow to combine response from different lines. For that reason the response of each line was downloaded in the form of an Excel file. This allowed to aggregate results from different groups in a single file and analyze all responses together. Pivot tables were used to correlate different questions. The database with aggregated response required some data cleaning and interpretation in order to produce easy to read graphs. Two entries contained no response data and have been removed. The resulting data set contains 102 responses. When in this paper the data set is discussed, it refers to the aggregated set of responses.

Two levels of analysis

The data set produced by the survey has been analyzed on two levels. The first level concerns analysis of the response provided to the 13 questions in the survey in relation to response groups and/or geographies. For example the pie chart in Figure 2 provides an aggregated overview of geographic regions from which response was received.

The second level of analysis concerns correlations between different answers. For example the relation between particular industrial sectors (question 1) and costing tool used (question 6) is analyzed and graphically displayed in Figure 7.

Assumption

In analyzing the data, the following assumptions were made:

Response was correct in terms of interpretation of questions. The data is not contaminated by bogus response or similar.

Colleagues from the same company respond in the same or very similar way.

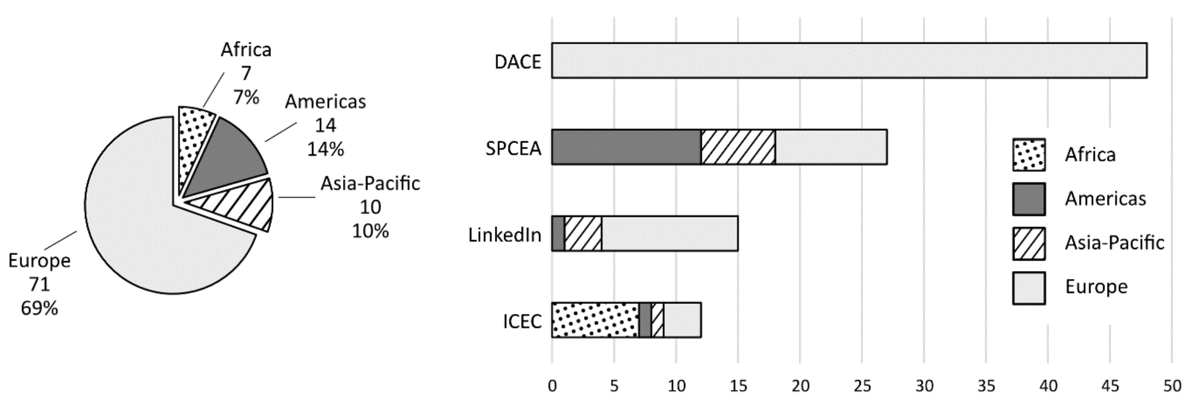
INSIGHTS LEVEL 1 ANALYSIS – RESPONSE GROUPS

From what regions do we have response

The cost estimating tool adoption survey received response from 102 individual contributors. The Figure 2 left side provides an overview of response distribution across geographies in absolute numbers and relative shares. By far the largest share of response is coming from Europe. The following response shares in descending order are Americas, Asia-Pacific and Africa.

Figure 2 right side provides an overview of the geographic response distribution per response group. DACE only being active in the Netherlands implies its response comes exclusively from Europe. SPCEA, the second largest response group in this data set, shows response shares in descending order from the Americas, Europe and Asia-Pacific. The third response group in this data set being LinkedIn shows response shares in descending order from Europe, Asia-Pacific and the Americas. The ICEC response group shows response shares in descending order from Africa, Europe, Asia-Pacific and the Americas.

Figure 2: Left, survey response per geography. Right, response per response group and geography.



In what sectors do cost engineers work

Figure 3 shows a plot of Industry Sectors from which response has been collected. The response groups DACE and General (all others) have been separated in order to assess differences. The diagram reveals the following information.

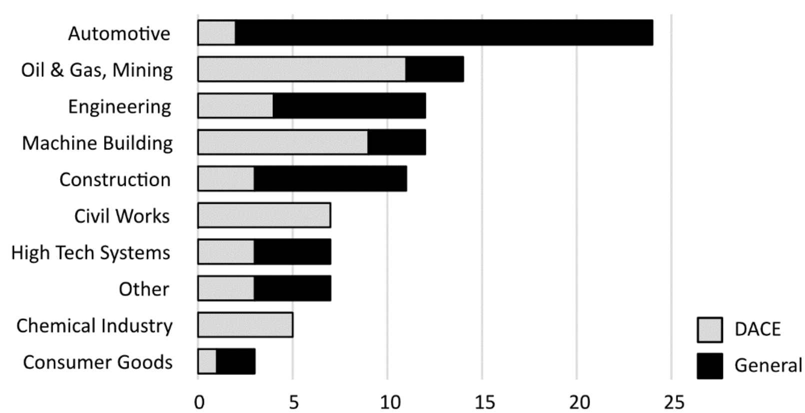
The Automotive industry provided the single largest response in this survey. The DACE response group has only a small amount of response from the Automotive industry (2 from 24 in total).

Oil & Gas, Mining provided the second largest response. The DACE response group is responsible for the highest amount of response in this industry (11 from 14 in total).

Some sectors have response from only DACE (Chemical Industry, Civil Works) or General (Manufacturing).

It is commonly known that the industry sectors Chemical Industry and Civil Works also provide significant employment in the world at large and the advanced economies specifically. It is therefore doubtful whether this data set is a correct reflection of the total population of cost engineers. It may be due to a bias in the involved associations.

Figure 3: Industry Sectors of employment.



What tools do we use

Figure 4 shows a plot of tool use responses. The response groups DACE and General (all others) have been separated in order to assess differences. All tools for which response was 2 or lower have been summed in ‘Other Tools’. The diagram reveals the following information.

By far the most used costing tools is Excel (80 from 102 responses). A significant share (29 from 80 responses) uses 'Excel Only’ while other report also using another tool.

There is little difference in the amount of use of Excel between DACE and the General response group.

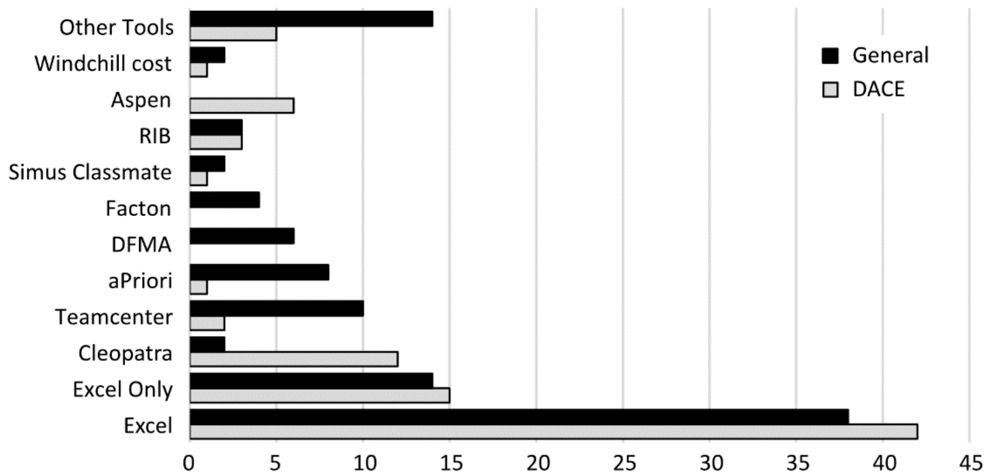
For all other tools there is little correlation between DACE and General response. The only exception is RIB. This is an indication that context of use has influence on tools embraced.

In DACE the tools with highest response contribution (Excel taken aside) are Cleopatra and Aspen. In General the tool Aspen has no use reported and Cleopatra very little use reported.

In General the tool Teamcenter (Product Cost Management), aPriori, DFMA and Facton all have reported use (Excel taken aside). In the DACE response group Facton and DFMA show no reported use and Teamcenter and aPriori a low reported use.

It appears that the use of costing tools beyond Excel is fragmented in the sample.

Figure 4: Tool use in response groups DACE and General.



INSIGHTS LEVEL 2 ANALYSIS - CORRELATIONS

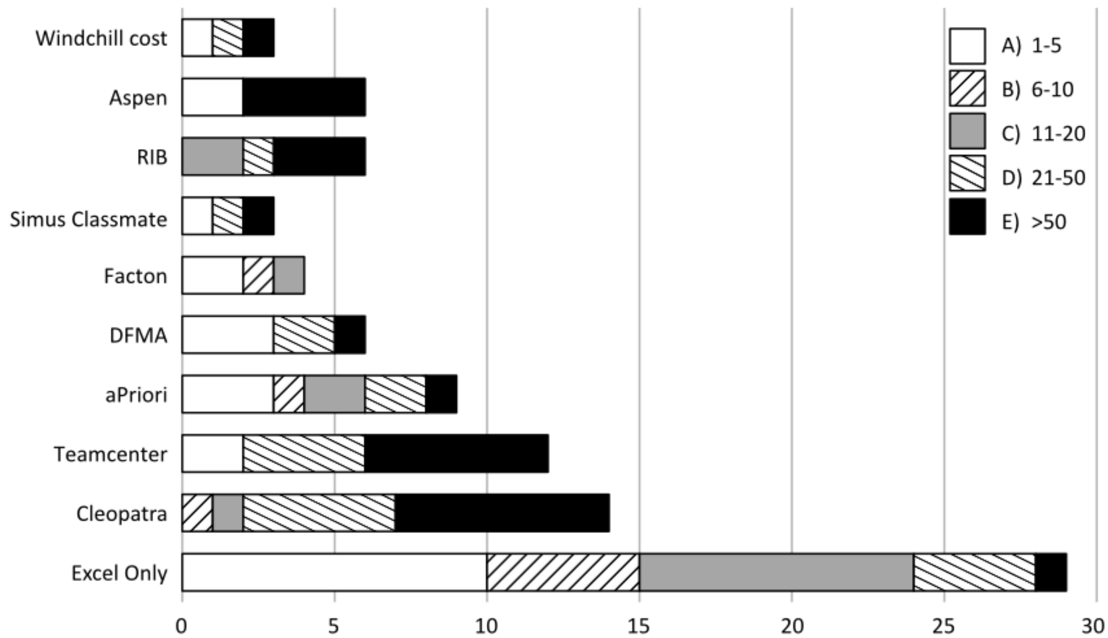
Tool use and amount of cost engineers

Figure 5 provides an overview of tool use in relation to the total amount of cost engineers in the company. The segments A, B, C, D and E have an increasing number of cost engineers as displayed in the legend. As known from figure 4 Excel is by far the most used costing tool in this data set. In order to provide more detail in the use of 'Excel adjacent to other costing tools' has been omitted from Figure 5.

Response in this data set suggests RIB and Cleopatra are not so much used in the smaller cost engineering teams.

The low amounts of response in this data set for Windchill cost (3), Simus Classmate (3) and Facton (4) make it not useful to connect a lot of meaning to these responses.

Figure 5: Tool use and amount of cost engineers per company



Reporting lines per industry sector

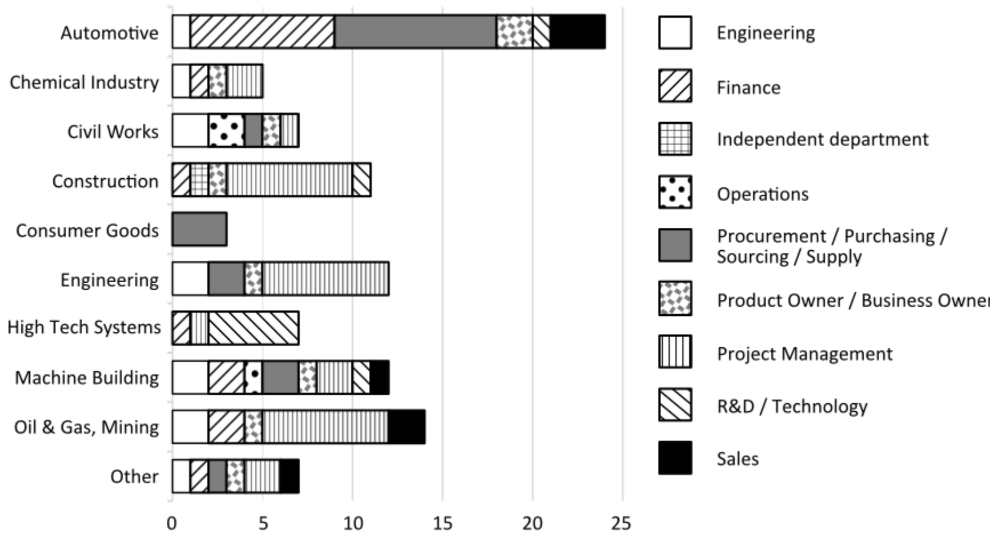
Figure 6 provides an overview of Reporting Lines per Industry Sector. The totals per Industry Sector are the same as displayed in Figure 3, where response was split between DACE and General . Figure 6 reveals the following information about the response group.

Project Management is the largest reporting line in this data set (29 from 102 responses), followed by Procurement (18 from 102 responses), Finance (16 from 102 responses) and Engineering (11 from 102 responses).

The Procurement / Purchasing / Sourcing / Supply reporting line is large in Automotive (9 from 24 responses) but much smaller in other industry sectors. For Consumer Goods (3 from 3 responses) which has low response it is the only reporting line in the data set.

The Finance reporting line is large in Automotive (8 from 24 responses). From this data set, finance appears not a common reporting line in other Industry Sectors.

Figure 6: Reporting Lines per Industry Sector.



Tool use per industry sector

We are interested in understanding if some costing tools have a particular high use in specific industries. We applied a threshold of 10 responses per industry sector. This resulted in four industry sectors being visible and seven not included as they are below the threshold. From Figure 7 we derive the following observations on tool usage per industry sector based on the used data set.

‘Excel Only’ shows a high reported use rate in Automotive (9 from 22 responses), Machine Building (4 from 10 responses) and Oil & Gas, Mining (4 from 13 responses).

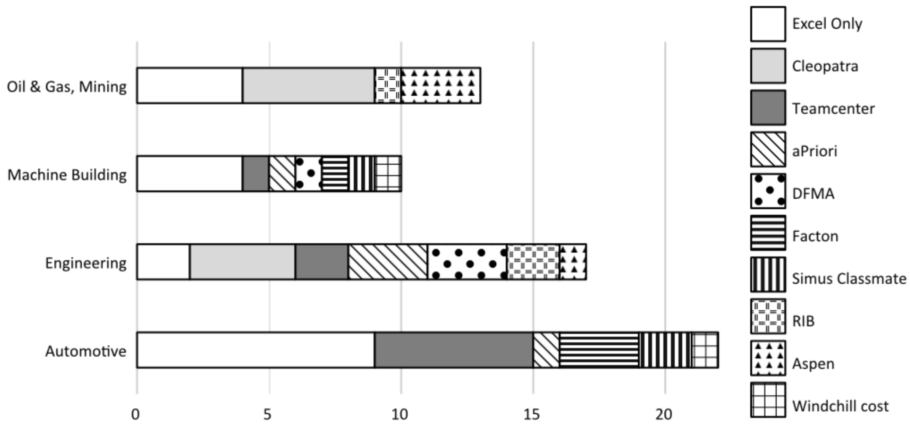
Cleopatra show a high use rate in Oil & Gas, Mining (5 from 13 responses) and Engineering (4 from 17 responses), and does not appear in Automotive and Machine Building. In total this tool appeared 14 times in the data set.

Teamcenter (Product Cost Management) shows a high use rate in Automotive (6 from 22 responses) and does not appear in Oil & Gas, Mining. In total this tool appeared 12 times in the data set.

aPriori appears in the industry sectors Engineering (3), Automotive (1) and Machine Building (1). Not visible in Figure 7 is reported aPriori use in Construction (1), Consumer Goods (2), and Other (1). In total this tool appeared 9 times in the data set.

Cleopatra and Teamcenter (Product Cost Management) are the most prominent costing tools besides Excel in this data set. The fact that Cleopatra does not appear in Automotive could indicate it does not well meet the needs in this industry sector. The same line of reasoning applied to Teamcenter (Product Cost Management), which is absent from Oil & Gas, Mining, could indicate it does not provide specific functionality desired in this industry sector.

Figure 7: Industry sectors and tool use.



Tool use and automated data connections

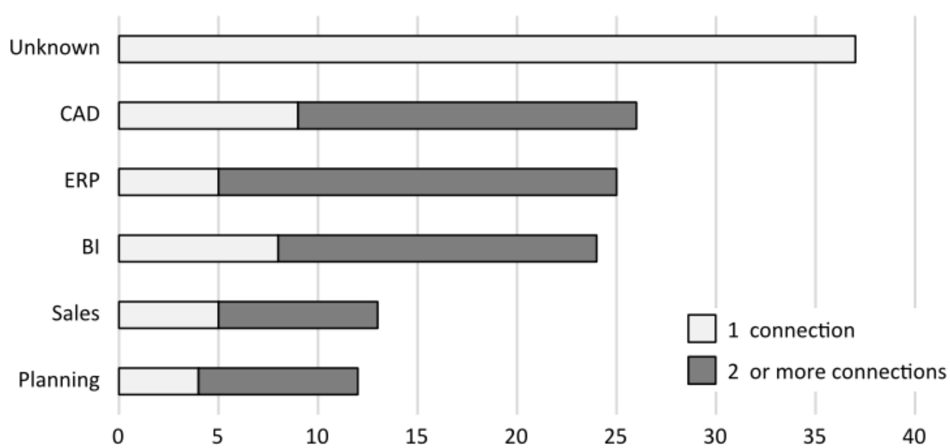
An accurate calculation starts with high-quality data, both of product and production processes. An automated connection can be used to prevent data latency and human error in importing data. Hence the interest in the use and possible couplings to other software packages, such as ERP, CAD and PLM. The data set reveals the following about automated connections to other applications.

In the data set of 102 responses there are 37 that report no or unknown connections. This 36% implies 64% uses one or more connections. Figure 8 indicates that multiple connections are reported more often than just a single one.

The most common connections reported are to CAD, ERP and BI, each representing around 25 responses or about 25% of response. Connections to sales or planning applications are less common.

From the data set used it is not clear how connections are used.

Figure 8: Automated connections between costing tool and other applications.



However, no clear correlations were found between these packages and the costing tool used, the industrial sector or reporting line in the used data set. Figure 9 shows the automated connections between costing tools and other applications. In the survey one could not indicate the connection per tool. Hence if a response contained more than one tool, the assumption is all tools have the same automated connection:

Excel Only represents the lowest amount automated connections to other applications with 50% of response indication no or unknown connections.

ERP is often used (>2) for Excel, Simus, Teamcenter, Cleopatra.

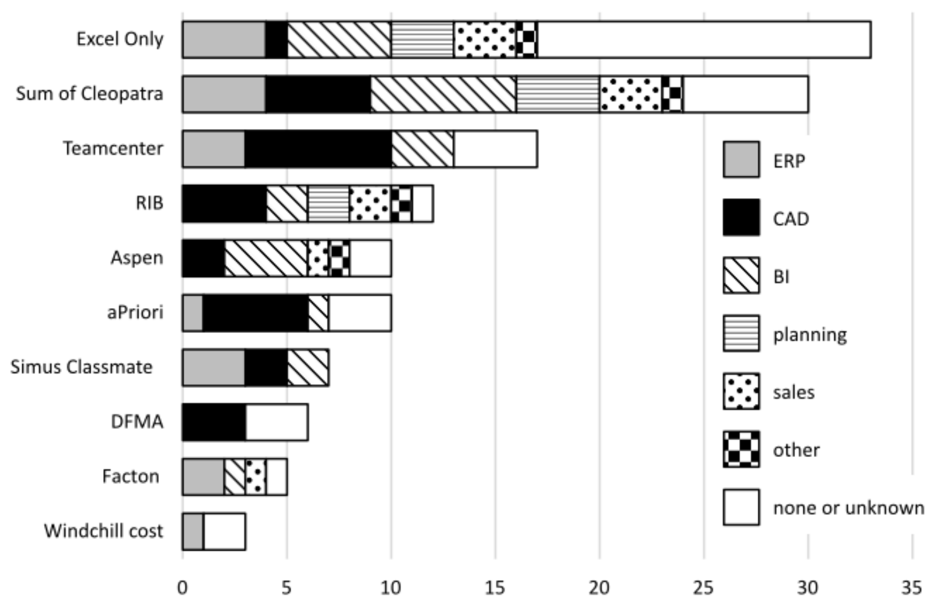
CAD is often coupled (>1) but not for Excel, Simus, Windchill.

BI is often used (>2) in Excel, Teamcenter, Cleopatra, Aspen.

No clear correlation was found between costing tool and coupled applications. It remains unclear what property was dominant in selection of the automated coupling software.

From the survey it is not clear how much accuracy, latency and lead time is improved due to the automated coupling.

Figure 9: Automated connections and tool use.



DISCUSSION

Industry sector designations

Preparing this paper the authors discussed various ways to produce a next version of the questionnaire that is less ambiguous and more complete. Doing so would both make the questionnaire easier to fill in as well as to process the data. It can also be expected to increase the quality of the research and the insights gained from it. From below reflections it appears that e.g. the industry sector designations listed can be improved.

First, the eight industry sector designations used in the questionnaire in retrospect appear not to be mutually exclusive. For example a respondent working at a company manufacturing equipment for crushing minerals in mining can select Oil & Gas, Mining but also Machine Building. A respondent working at a company manufacturing lithography machines for integrated circuit production, is the Netherlands often associated with High Tech Systems, and may also be connected to Machine Building. Instead of having many designations that overlap it could be argued that a wider definition that unambiguously covers all cost engineers with a clearly identifiable common denominator will make the survey more clear. For example ‘Discrete Manufacturing’ could be used to cover the industry sectors Automotive, Consumer Goods, High Tech Systems and Machine Building.

Second, the eight sector designations used in the questionnaire are also not commonly exhaustive. The questionnaire offered a text box at the option Other for respondents that did not want to select a predefined industry sector. The survey response produced several entries that in this paper have been covered under Chemical Industry. The following entries are Agriculture Machinery, Aircraft Manufacturing, Consultancy, Defense, Manufacturing, Network Manager, Investments (renewable energy) have been grouped together in Other.

Third, characteristics of the work of cost engineers may lead to a simple dichotomy. The difference between product and project based industries is expected to have significant impact on the cost engineering challenges faced. We assume these are reflected in different software solutions. Civil Works like road construction, subways or bridges use a design that is commonly only used once and involve huge planning efforts before construction can commence. The design and construction of a chemical plant or an oil rig are similar complex one-off projects. These complex one-off projects require cost estimates in the bid phase followed by cost control in project execution phase.

Mass manufacturing of consumer goods or cars is again a complete different world. The design used for example for a particular electric tooth brush handset is typically produced in many millions per year. Cars of one particular model are typically produced in tens of thousands up to over a million per year using different combinations of color, engine and interior trim. The design of mass manufactured items is optimized for an optimal ratio of performance and per piece cost.

IT landscape and embedding

The survey discussed in this work is organized in three thematic areas, one of them being IT landscape and embedding. The reason for including this topic is the observation that typical IT landscapes in modern industries comprise of many different software applications which provide value in relation to a costing tool. Enterprise Resource Planning (ERP) applications can provide access to costs of purchased parts. Product Data Management (PDM) and or Product Lifecycle Management (PLM) solutions are used to store references to products manufactured like 3D CAD drawings and Bill Of Material (BOM) information. Configure Price Quote (CPR) software is used by sales organizations in various industries. Costing tools operate in this landscape. What connection is the most obvious and provides most value, is depending on the operating mode of the cost engineer at stake. Building these connections requires effort additionally next to acquiring the software. Commonly, consultants are hired to configure the standard interfaces. It might well be that further customization is required, which commonly implies a larger effort and thus higher cost. Once a company has chosen to use specific software, in general it becomes difficult to change. This is particularly true if, in search of even higher added value, complex interfacing to other applications in the IT landscape is built.

To get a better understanding of the IT landscape context in which the costing software is used, questions on the main applications (ERP, CAD, PLM) and automated connections to them, have been included. The questionnaire did not include questions on how cost engineers actually use automated connections. Consequently, insights regarding details of these automated connections are limited. It is obvious that this is an interesting subject to explore further. If this research is repeated in the future, it is advisable to explore how this topic of IT landscape embedding can best be approached in the questionnaire.

Sample size

The purpose of the survey discussed in this paper is to get valid answers on the research questions posed. In general, the optimal sample size for a survey depends on the population investigated and the type of questions explored. The question what sample size is relevant for the survey discussed in this work remains unanswered here. Statistical analysis or statistical interpretation is not yet part of this work. In case the survey is repeated the quality of insights produced can benefit from a better understanding of the sample size needed to get statistical relevant insights. The International Cost Engineering Council claims to have access to more than 300,000 cost engineers and project managers over 120 different nations [19]. It is not clear how this figure relates to the total cost engineering world population, but we assume it will be more than enough to involve a statistically relevant sample.

The previous section on industry sector designations discussed the large differences between the work of cost engineers in different industry sectors with respect to costing approaches and costing tools used. It is recommended to think how different groups of cost engineers can best be addressed in order to have a good representation of the whole population, but also to distinguish between meaningful subgroups.

It is obvious that an online survey is a very suitable method to survey a large and international population. The use of online surveys has become prevalent. Literature discussing the use of online surveys [20] can support further improving the quality and fit for purpose of the questionnaire design.

Observation

From this work it appears that there is no dominant approach to costing software yet, not in tools nor in IT embedding. Also it is clear that costing software is used across a range of very different industries. Conjectures about the costing software are that costing tools will slowly but surely acquire a place in the IT landscape at the cost of Excel. Research into this phenomenon may well be an emerging field of scientific research. As befits researchers, we therefore call for further investigation into the adoption of costing tools and their use in advancing IT landscapes.

Next

The recommendations section discusses ideas for a next version of the questionnaire to further advance surveys into costing tool adoption. We suggest that professional associations like ICEC are ideally suited to carrying out this type of research for several reasons. ICEC is a worldwide operating non-profit organization with the object of promoting cooperation between cost engineering organizations. The large coverage may therefore result in a significantly larger number of responses than those contained in this paper, increasing the quality and value of a next survey. To address all types of features and functionality in costing tools equally and unbiased, it is recommended to separate research from direct commercial interests. We are confident that this will catalyze further advancement of the cost engineering profession and in particular, stimulate the use of ever more advanced tools.

In addition to the above, we have only reported on the most immediate findings and correlations from the data set. It may well be that further analysis will provide additional insights. This will be explored further.

CONCLUSION

This paper described the inception and preliminary results of a survey that was conducted to get a better understanding of the adoption and use of costing tools. The survey produced 102 useful responses from four geographic regions, 9 industry sectors and 9 reporting lines. The data set produced reveals 10 different types of costing tools being used amongst which Excel is still the most prevalent approach. The survey does not investigate how respondents use Excel but it becomes clear that Excel is used both as only tools as well as next to other tools. The data set reveals that there is no significant difference in use of Excel between DACE respondents and the other respondents combined in General.

From the survey and the data set produced, first evidence appears that certain use conditions particular to an industry imply that some costing tools are deemed useful while other are not. Cleopatra appears to have a high fit in the Oil & Gas, Mining industry and no fit at all with Automotive. Similar Teamcenter (Product Cost Management) appears to have a high fit in the Automotive industry and no fit at all with Oil & Gas, Mining. Therefore conjectures about the costing software are that there will be a separation into types of costing tools that serve distinctly different user purposes in different industries.

The use of multiple connections between a costing tool and its surrounding IT landscape appears already quite common amongst respondents. In particular, connections to CAD, ERP and BI systems are reported. Excel Only users report the lowest amount of connections to other applications. From the data set it is not well possible to draw conclusions on connections between particular combinations of listed costing tools and other applications.

From above stated conclusions it becomes clear that this type of online surveys can be used to get a better understanding of the state of use of cost engineering tools. However it also became evident that there is still much to improve in questionnaire design, and the survey does not provide answers to all questions that emerged during analysis. In retrospect we can list a number of imperfections that may have limited the degree of insight produced by the survey. These insights can now be used to make future research even more valuable.

The survey discussed in this work is the first of a kind in the way it relates costing tools, usage conditions, IT landscape and embedding. The authors anticipate that further continuation of investigations into the relation between costing tools, usage conditions and IT landscape may lead to a new emerging field of scientific research. Ultimately, it is our firm believe that this will lead to broad embedding in companies, but also in medium and higher education, similar to other (engineering) methodologies and tools.

RECOMMENDATIONS

The trade-off for using dedicated costing software is obvious to many a cost engineer. The benefits expected are robustness, accuracy, low lead time, low effort calculations. Disadvantages lies in effort for setup, integration and adaptation, and the risk on lock-in or failure, as there is no guarantee a certain software tool will perform in all markets and niches. This uncertainty with respect to tool performance and investments is the main driver for the research in this paper. Further research on costing tools should provide better insights into what type to choose and reduce disadvantages.

The benefits can also enable secondary ones, e.g. more design iterations and faster time to market. It can contribute to fact-based negotiations that can influence commercial relationships as well. As appears from the following statement. 'It has done wonders for our relationship with our Chinese producers. They no longer receive three to four requests for quotes per project, which reduces their own costs and minimizes the risk of mistakes ' [21]. Although this might very well be a commercial statement, it suggests costing tools can hold a promise of changing the relationship between commissioning parties and suppliers. Anecdotical discussions within the DACE community certainly support this claim, but further research should provide proper validation.

To what extend a costing tool is used, also drives the trade-off. From these properties, a suggestion for a future questionnaire is drafted:

What is the current type of cost estimation software and the extend of use? What characteristics are desired?

Accuracy, lead time, effort, usage (for how many quotes), more design iterations, faster time to market, fact-based negotiation.

To what extend is the costing tool used per product category, e.g. novel designs, redesigns, configure to order, repeats, or one-offs, consumer mass products.

To what extend are own (person specific) templates developed and used.

To what extend and in what way is data from other sources used, what is the main added value of this connection.

What disadvantages do you experience regarding following topics; Software setup and maintenance, training personnel, risk on underperformance, risk on commercial lock-in.

What is the main objection to (further) expand costing software within your organization?

How likely would you recommend the costing tool to cost engineers outside your company, assuming there is no commercial interest or competition?

Repetition and temporal aspects.

It is foreseen that repetition of this survey will lead to significant additional insights. Not only will updated results demonstrate a more accurate representation of the actual situation of tool adoption, but changes in time can be translated in rates of changes for particular outcomes, which are new outcomes by themselves.

Update and improve industrial sector designation as described in the section Discussion.

Add short descriptions of industrial sectors to reduce ambiguities.

Further advance the survey by adding more diverse easy to answer and process question formats.

Ratings can be used to assign values to questions.

Repeat questions if multiple costing tools were selected and treat this as different entries

Preference rankings can be used to evaluate relative preferences for types of solutions or features. It can for example be used to gauge preference of a series of costing solutions or specific features over another.

Likert scales can be used to gauge attitudes and opinions about topics (like how user-friendly is your costing solution).

Evaluate the relevance of using branching in a questionnaire. This can help to reduce the length of the questionnaire by offering questions and options that have a higher relevance to a share of the respondents. Questions exploiting a dichotomy as described in the section Discussion are an example. A question that directs to either ‘product’ or ‘project’ oriented industries could be used to steer towards most relevant questions.

ACKNOWLEDGEMENTS

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The board of DACE (Robin de Vries, Jan-Willem Sanders, Paul van Brussel, representing different industrial sectors) provided valuable suggestions for making the survey useful for more diverse types of industries.

The second version of the questionnaire was detailed in Microsoft Forms by Huub Ehlhardt (Vanderlande) and Patrick Strating (NTS). Data analysis used to produce this paper has been done by Ivan van der Kroon (NTS).

ABBREVIATIONS

BIBusiness Information.

BOMBill Of Materials.

CACEComputer Aided Cost Estimating.

CADComputer Aided Design.

CAMComputer Aided Manufacturing.

CPRConfigure Price Quote.

DACEDutch Association of Cost Engineers.

DFADesign For Assembly.

DFMDesign For Manufacturing.

ERPEnterprise Resource Planning.

ICECInternational Cost Engineering Council

ITInformation Technology.

MRPMaterial Resource Planning.

MRP IIManufacturing Resource Planning.

PLMProduct Lifecycle Management.

PCMProduct Cost Management.

PDMProduct Data Management.

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The Value Factory. A series of interactive workshops about the engineering of value. (id 43; P_043)

VALUE FACTORY - VALUE ENGINEERING TOP 10

Abstract

Value Engineering (VE) is a philosophy to create and optimize designs that perform well and don't cost too much. Optimization requires a multi-disciplinary team including a Cost Engineer. This article gives a summary of four Top 10 checklists and a description of two core techniques to improve the value of a project.

Introduction

Value Engineering (VE) approaches decision making and aligning scope with budget in a systematic way. Value Engineering is undertaken in a workshop setting with a multi-disciplinary team including Cost Engineers, following a series of steps to create and evaluate alternative ways to meet objectives.

Everyone wants to achieve a reasonable balance between costs and project requirements, but it can be difficult to achieve. Sometimes the scope is not well defined, the cost estimation shows the scope is over budget, or decision makers do not agree on the proposed solution. How can a Cost Engineer help a client resolve these challenges? Value Engineering includes processes that will increase confidence that the most reasonable solution has been found. The Value Engineering or Value Management process is a systematic and function-based approach to improving value in projects.

What is important for a Cost Engineer when thinking about Value? This article is a compilation of the Top 10 lists from the authors, an international group of practitioners in Value Engineering. It does not describe in depth all ins and outs of value engineering (that would require a training), nor what happened in its 70 years' history or where it saved billions of dollars around the globe. Instead, it gives some practical checklists ready to use by Cost Engineers and delivers some useful sources of information. The top 10 lists will be presented and discussed during the ICEC 2022 conference in Rotterdam and online, using the format of the Value Factory. It is a mix of interactive presentations and workshops which was developed for and used by the international value engineering societies around the globe in times of Covid-19.

This article delivers checklists answering the following questions:

What are top 10 characteristics of projects that may benefit from a VE-study?

What are top 10 questions to ask to designers to create more value?

What are top 10 cost driving functions in a design?

What are top 10 examples of projects that benefitted from VE?

Furthermore, two core techniques from value engineering are mentioned in this article, which will be explored interactively during the ICEC conference:

Function diagramming and

Specifying the performances of functions (FPS).

Top 10 characteristics of projects that most likely benefit from a VE-study. By Mushtaq Rabbi.

Projects that comply to one or more of the following characteristics, may benefit from a value engineering study for a range of reasons. Usually someone's "gut feeling about poor value" has to do with those characteristics:

Politically sensitive programs/ projects

Unclear or confusing scope in a project

Projects that cross large geographical areas

Projects with complex processes or process technology

Projects with high level of complicacy and complexity

Large investments in a project that will be audited

Projects that are potential risks to an organization's reputation

Demonstrating due diligence when requesting significant funding for a project

When too many options are available in a project's solution

Project investments requiring cost efficiencies

Top 10 questions to ask to designers to create more value. By Hein de Jong

Value Engineering studies usually are done in a pressure cooker setting with a duration of 16 hours or more. Some questions and discussions are repeated often. Here are the top 10 questions to ask designers to ensure value creation. There are similarities with Socratic questioning. Everybody, including VE-facilitators or Cost Engineers, can start and lead interesting and highly informative discussions for at least an hour, by asking the following top 10 questions:

Do we really need it?

How much do we need it?

Is it logical?

Is this the best that can be done to solve the problem?

What are equally performing alternatives?

What if we spend less money?

What if we spend a bit more?

Which assumptions remain?

What are the main risks and how are they mitigated?

Did the major stakeholders participate? Whom did we miss?

If needed, focus can be put to the most expensive parts of the project (a Pareto analysis will help), the top risks, or based on your experience you may show similar alternatives that were realized elsewhere. The discussion will be even more effective when held in a multi-disciplinary group that includes stakeholders and end users.

Top 10 cost driving functions in a design. By Alvin Tehmono

Which functions are often cost drivers in a project? Next follows a list of often expensive (and disputed) functions. They are categorized into: (a) higher order functions, (b) main functions, and (c) lower order functions. The context of the functions are *roads and bridges* projects. The top 10 functions below often cost more than 50% of the total costs of the project. These functions are derived from a database of about 30 VE-projects value engineered since 2018 in Indonesia.

Develop economy of isolated area (the higher order function that always shows up in a VE study)

Access isolated area [main function]

Transport commodity – from production area to distribution area [main function]

Cross River [main function]

Separate traffic flow [main function]

Facilitate high traffic volume [main function]

Level road [meaning: to give a desirable road elevation] (lower order function)

Improve soil bearing capacity (lower order function)

Acquire land (lower order function)

Transfer load [this is where the structure component cost gather] (lower order function)

These functions are one of the many functions in a project, often represented in a function diagram (see Core Technique 1: Function Diagramming).

What are top 10 projects that benefitted from Value Engineering?

The authors of this article have asked some well-known value engineers around the globe to give an elevator pitch in 2 minutes of one of their projects. See the list of useful links. During the Value Factory the pitches are shown and discussed by participants afterwards.

Core technique 1: Function diagramming (by Steve Holmes and Hein de Jong)

A function diagram is a graphical representation of the needs of a project abstracted into a verb-noun function. It shows the logical relationships between functions based on the questions “How” and “Why”. The Function Diagram aids in thinking about the problem objectively and in identifying the scope of the project. The organization of the functions enables participants to identify of all the required functions and quantify functions by resources required to achieve the function. Resources can be for example costs (calculated and allocated with help of the Cost Engineer), required labor to realize the system, and by performance (see core technique 2: Function Performance Specification). Analyzing a project in a workshop session with help of a function diagram, creates space for a design to be optimized by the Value Engineering team.

A function diagram shows the functions of a system like a building, infrastructure or machine on different abstraction levels. It shows <u>why</u> a function exists, and <u>how</u> it is realized. It takes many hours of practicing before a value engineer can make a fairly good function diagram, but the discussions are nearly always rewarding. Questions can be asked like “Which functions are the most expensive, and does it make sense they are so expensive”, or “Is the reasoning of the design the best we can make to create best value for money”? The average value engineering study has an internal rate of return of greater than 1:100 and a much lower failure rate.

Core technique 2: Specifying the performance of functions (by Hein de Jong).

When a function diagram is made, the value engineering team specifies how well the functions should perform, including the current designed performance, the allowable range, and how flexible the range really is. The discussion in the value engineering team often lead to more flexibility, identification of overcapacity and identification of too narrow thus expensive margins. This often stimulates creativity to come up with better solutions that perform better or cost less.

It is found that any design that has not been optimized before with VE techniques, can be reduced in costs and rise in performance by 10%, without compromising quality and often speeding up the planning.

Top 10 tricks and tips for cost engineers when thinking about optimizing value

One of the lists that is still being researched while writing this article, is about the top 10 tips and tricks for cost engineers when thinking about optimizing value. The available results will be presented during the ICEC congress in June 2022 by Cost Engineer and Value Practitioner Cosmo Smeets.

Useful links

Dutch Association of Cost and Value Engineers: www.Dace.nl

Society of Canadian Value Engineers: https://www.valueanalysis.ca/

Previous Value Factories Value Factory October 2021: https://youtube.com/playlist?list=PL0n61UwBhMWPTznsQNgBu2aVuVsIsBYzj

Value Factory February 2021: https://youtube.com/playlist?list=PL0n61UwBhMWMdnxiAR5Y1J6sfkKG7vXhm

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Cosmo Smeets (Cost and Value Manager, Netherlands). https://www.

Current Development of Prefabricated Prefinished Volumetric Construction (PPVC) In Singapore (id 46; P_046)

CURRENT DEVELOPMENT OF

PREFABRICATED PREFINISHED VOLUMETRIC CONSTRUCTION (PPVC)

IN SINGAPORE

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Keywords: COVID-19, DfMA, ITM, Modular Construction, PPVC.

INTRODUCTION

With the aim of transforming Singapore’s built environment to be more advanced and integrated through adoption of new game-changing technologies, the Singapore Government launched the Construction Industry Transformation Map (ITM) in October 2017. The Construction ITM is one of the 23 ITMs identified under a $4.5 billion Industry Transformation Programme proposed by the Government’s Future Economy Council (FEC). One of the 3 key approaches of the Construction ITM is Design for Manufacturing and Assembly (DfMA).

The concept of DfMA has been introduced since 2015 through the launching of the 2nd Construction Productivity Roadmap which set aside a funding of S$450 million aimed to improve Singapore's construction productivity. It is a design approach that focuses on ease of manufacturing and efficient assembly, in the minimum time and lower cost. Some of the examples of DfMA concepts are Prefabricated Bathroom Units (PBUs), Mass Engineered Timber (MET) and

Sustainable Excellence for Generations (id 47; P_047)

Paper of presentation for ICEC World Congress 2022. Authors Thera de Kramer, Cosmo Smeets and Maurice van Rooijen.

Keywords: Generations, Value, Decision making, Impact, Sustainable Excellence

SUSTAINABLE EXCELLENCE FOR GENERATIONS

ABSTRACT

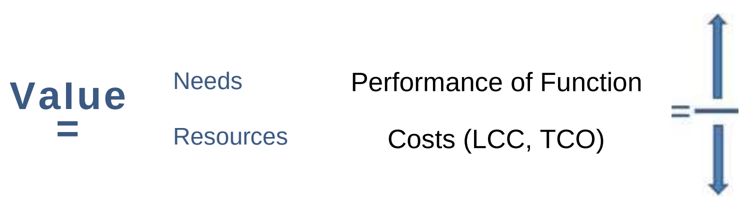
Operational Excellence emphasizes organisations to excel in operations. Customers and shareholders today want immediate gratification. (Roman, 2020) Comparing commercial companies with the same strategy, selling the same product to the same clients, the most operational excellent company will create better operational results.

Operational Excellence supports the organisation to focus on short-term implemented improvements. Operational Excellence doesn't support with creating long-term sustainable solutions. The United Nations with the Agenda 2030, Sustainable Development Goals, article 53 stimulates to pass the torch to the future generations. (United Nations, 2015) We need to change. Organisations should emphasize to excel in sustainability for generations.

Sustainable Excellence for Generations (SEG) is a method to measure *value for multiple generations* and improve accountability to unborn generations. This method improves decision making by measuring sustainable excellence in a more integrated, multi generations, way.

We, the current generations, shape the value available for the future generations.

Sustainable Excellence for Generations (SEG) combines Future Design (Saijo, 2020) and Value Management (EN 12973, 2020). Both methods use participation in processes, to stimulate dialog and creativity in multidisciplinary teams. Value is an expression of the relationship between the performance of functions relative to the resources required to realize them (VM



Guide, 2020):
Performance is defined as the capacity of a project, product, process, service of organization to fulfil its functional requirements. Functions describe what is required by users, client, stakeholder, etc. (FAST, 2007 and VM Guide, 2020)

Resources include monetary costs, time required, labour, materials, etc. to produce the desired performance. (VM Guide, 2020)

Sustainable Excellence for Generations describes what the needs of present and future generations are in ratio to resources used by present and future generations.

OPERATIONAL EXCELLENCE VS SUSTAINABLE EXCELLENCE

Operational Excellence emphasizes organisations to excel in operations by focusing on the management system in the organisation and the organisational culture of operational discipline. A management system identifies risks, manages change, improves constantly, reduces overlap, increases redundancy and reduces conflict.

The organisational culture, values, norms and behaviours, of operational discipline supports doing the right thing, the right way, every time. Integrity, questioning attitude, level of knowledge, backup and formality are values that go with a culture of operational discipline.

As society changes, organisations are challenged to change to. The values, norms and behaviours are supported by tooling in the organisations that contribute to implemented improvements. Organisations are challenged to excel in operations in a fast changing society, fast results seem logical, which supports short-term thinking.

Roman Krznaric: "We live in an age of pathological short-termism. Politicians can barely see beyond the next election of the latest opinion poll or tweet. Businesses are slaves to the next quarterly report and the constant demand to ratchet up shareholder value. Markets spike then crash in speculative bubbles driven by millisecond-speed algorithms. Nations bicker around international conference tables, focused on their near-term interests." (Roman, 2020)

The concept of Operational Excellence supports short-term implemented improvements and doesn't encourage developing long-term sustainable solutions. By changing one word - i.e. Sustainable Excellence instead of Operational Excellence - the management system will include a sustainable way of looking at the elements of the management system such as risks, manage change, etc. Consequently, the management system still identifies risks, including sustainable risks, manage change on a sustainable way, improve continuously, reduce overlap, redundancy and conflict, in a sustainable way.

The organisational culture will change into the culture of sustainable discipline supporting doing the right thing right on a sustainable way, every time. Integrity, questioning attitude, level of knowledge, backup and formality are values that remain with a culture of sustainable discipline.

DECISION-MAKING AND SUSTAINABLE EXCELLENCE

Decisionmakers are accountable for the decisions that are made. To help them methods are developed to make decisions by:

- Authority;
- Majority;
- Ranking;
- Unanimity;
- Consensus.

Responding quicker, delivering higher quality, producing more are measurable results of the improved operation using short-term decision making. These results are welcomed by decisionmakers and used in accountability to shareholders.

Accountability of sustainable efforts focusses on activities contributing to sustainability. Like investing in sustainable energy production (solar or wind), use of electric vehicles, sustainability demands in purchasing. Decision-making processes within organisations and projects may contain a criterium on sustainability when clients ask for it.

Sustainability concerns a lot more and is hard to capture in a single criterium within decision making processes. Article 53 of the Declaration United Nations Transforming our World: The 2030 Agenda for Sustainable Development: "The future of humanity and of our planet lies in our hands. It lies also in the hands of today's younger generation who will pass the torch to future generations. We have mapped the road to sustainable development; it will be for all of us to ensure that the journey is successful and its gains irreversible." (United Nations, 2015)

Mary Catherine Bateson: "The great irony of our time is that even as we are living longer, we are thinking shorter." (Mary, 2011)

Can we improve today's decision-methods to deliver in sustainable excellence for generations to come?

SUSTAINABLE EXCELLENCE FOR GENERATIONS (SEG)

Ways to measure sustainability are available today. We measure emissions and reduce them. We implement recycling systems. We gather life cycle information about materials. We choose and use materials in a more sustainable way. We are contributing with these efforts on shaping the value available for the unborn generations. Measurement systems are been developed and implemented. The system is changing. How can we know we are doing the right things today? Can we look into the future and know the unborn generations are been provided by the things we do today?

The Conference on the future of Europe: "Long-term decision-making requires both appreciating and understanding the need to include younger generations, and the generations of tomorrow, in these decisions." (Young Minds)

Extent the concept Sustainable Excellence into Sustainable Excellence for Generations and the future thinking asked by the younger generations of today will be possible. **Sustainable Excellence for Generations (SEG)** is a method to prioritise and measure this **sustainable value for multiple generations** and improve explaining the efforts we take for those unborn generations. This method improves decision making by measuring sustainable excellence in a more integrated, multi generations, way. And at the same time find continuous improvement of the sustainable organisational excellence using future thinking. We can measure and manage value-creation today knowing the value we are creating for the future generations.

Customers and shareholders, now and in the future, want immediate gratification without loss of sustainability for unborn generations. Comparing commercial companies with the same strategy, selling the same product to the same clients, the most Sustainable Excellent for Generations (SEG) company will create better sustainable operational results, creating more sustainable value for customers and shareholders of today and decades to come.

Sustainable Excellence for Generations (SEG) uses the combination of Future Design (Saijo, 2020) and Value Management to stimulate sustainable excellence for generations in decision making processes where unborn generations have a voice.

NEEDS FOR MULTIPLE GENERATIONS

Future Design (Saijo, 2020) transforms policymaking by adding the perspective of future genarations. Professor Tatsuyoshi Saijo of the Kochi University of Technology promotes this simple idea:

"Ask people to become an imaginary future generation, think, act in the interests of that generation." (Saijo, 2020)

This supports policymaking into the far future. Policymakers tend to think about issues, solutions that last generations on a scale of a few years instead of generations. Problems aren't solved when they are small because the present generations cannot benefit from the solutions and can deal well with the implications, restrictions of the problems now. We start solving them when they get big and the impact are felt by the present generations. The problem got out of hand. Climate change is an good example of a problem noticed in time. Or problems are solved with solutions that have negative impact for future generations. Like improving food packaging by using disposable plastic. Solving problems having present generations pay the highest costs and future generations decades to a hundred years later benefit most are rare. Programs like the Delta Werken, Ruimte voor de Rivier are a few Dutch examples.

Biggest problem in decision-making is involving those infected by the decision. Participating with inhabitants is becoming more and more standard these days. But future generations are still not involved. It is the present generations that are at the decision tables and engaging. (Saijo, 2020)

Future Design designate people to concern with the interest of the future generations. Using roleplaying scenarios the concerns and interests of future persons, future generations are defined. Once these concerns and interests are defined they can be translated into needs, performances of functions, of future generations. Using Functional Analysis System Technique (FAST, 2007) these concerns can become logically prioritised, tangible and related to Sustainable Development Goals (United Nations, 2015).

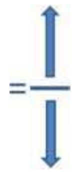
THE DEFINITION OF VALUE

According to NEN-EN 12973 Value Management (EN 12973, 2020) maximum value is defined as:

> • an assessment (sometimes measure) of how well an organization, project or product satisfies both the need of the users and the objectives of stakeholders considering the impacts, uncertainties and resources required to satisfy the need. (EN 12973, 2020)

The need is defined as:

$$\text{Value} = \frac{\text{Needs}}{\text{Resources}}$$



- what is necessary for or desired by the user. (EN 1325, 2014)

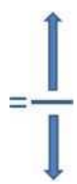
The resources are defined as:

- everything that is required to satisfy the needs. (EN 1325, 2014)

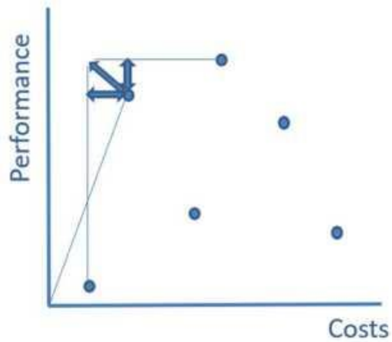
There are a lot of ways to make value measurable. For now we like to focus our attention to measure value by measuring performance of functions and resources:

- Performance of function is defined as the capacity of a project, product, process, service of organization to fulfil its functional requirements. Functions describe what is required by a user, client, stakeholder, etc. (FAST, 2007 and VM Guide, 2020) A drink glass may contain water for us to drink. We require this to prevent dehydration. The function is 'preventing dehydration', the 'amount of water' a drinking glass can contain is the performance.
- Resources include monetary costs, time required, labour, materials, etc. to produce the desired performance. (VM Guide, 2020) Taking the example of the glass, the resources would include materials (glass, recycled or newly created), labour, machines needed to create the glass, transportation, etc.

$$\textbf{Value} = \frac{\text{Performance of Function}}{\text{Costs (LCC, TCO)}}$$

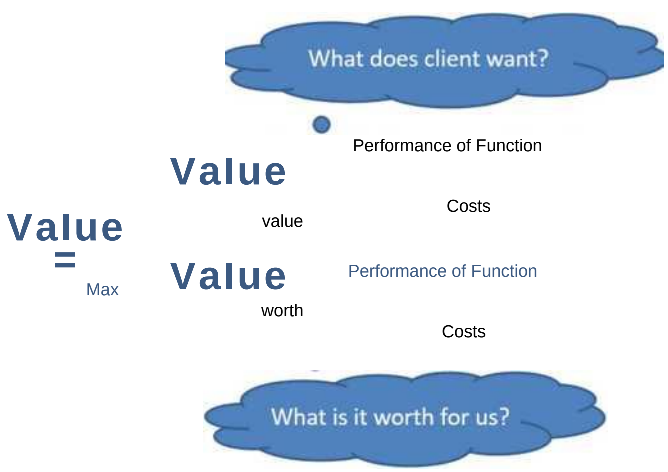


Operational Excellence organisations seek high performances of functions using low expenditure of resources. The most optimal value delivers high performances to customers by investing low costs in production, transportation, etc.



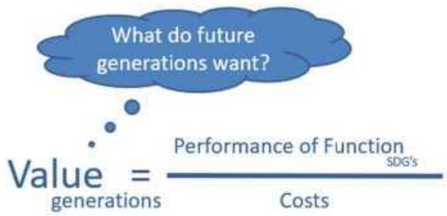
Using the drink glass example high performance would be the optimum of the amount of water and the experience handling the glass while drinking. The cost is usually described in monetary value but can also be described in CO2 emissions, natural material use and use of energy by production.

Value Management is style of management, particularly dedicated to motivating people, developing skills and promoting synergies and innovation, with the aim of maximising the overall performance of an organization. (EN 12973, 2020) Value Management is used to stimulate innovations to optimise the relationship between performance of functions and resources for clients and producers. The people, skills, synergies, innovations in the organisation are valuable to take into account when improving the organisational excellence. This can be done by looking at the concept of worth. The concept of worth is benchmark or target determined by the lowest theoretical cost to perform a function on, or attributable to, a given product. (EN 12973, 2020) The factory producing the drink glasses employs workers, educates them and implements improvements. Organisations don't only make profit, they are social places for people to meet and stimulate innovations. These needs, functions, maintain factory operations.



THE DEFINITION OF VALUE FOR FUTURE GENERATIONS

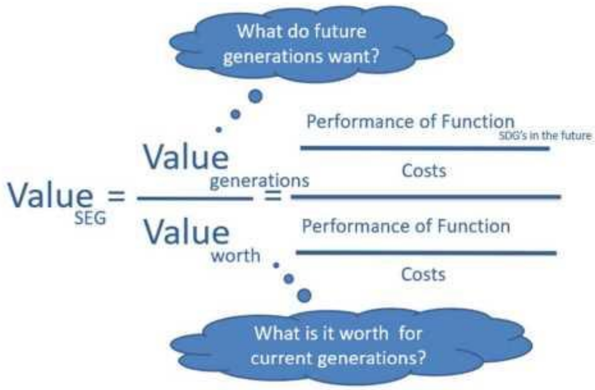
Factories producing the drink glasses have been employing workers, educating them and implementing improvements already for centuries, 4 thousand years (Wikipedia) and will be doing this into the future. These social places for people to meet and stimulate innovations are needs, functions, that maintain operations of the factory and are related to the Sustainable Development Goals mentioned in the United Nations Agenda 2030. (United Nations, 2015).



The clients of the current generation are the future, unborn, generations. They are the ones that will have to live with our wanted and unwanted creations. The *current generations shape the value available for the future generations.*

The history of drink glass making teaches us that the working places of the employees have changed over the decades and centuries in relation to the needs and resources of the generations of that time. So have the shape of the glasses changed to the needs and resources of the clients, users, of that time. This process of always changing with demands and possibilities of generations is not stopping.

Future Design (Saijo, 2020) provides the functions and performances of the future generations. Value Management provides the functions and performances of the current generations, clients and producers. Sustainable Excellence for Generations brings both together, combining them, making them tangible. Providing to have future generations needs and resources into the discussions and decision making processes of value creation for the current generation.



COSTS (RESOURCES) FOR MULTIPLE GENERATIONS?

Looking into the future with the knowledge of today! That seems impossible especially over multiple generations. However with the cost estimating methods of today, like Life Cycle Costing and mitigating costs for effects that take place, measured on sustainability development goals, we can calculate costs and effects. Doesn't say it is immediately right, but just being aware and trying to make costs insightful, helps making choices and adjusting choices over time. Without disadvantaging the future generations.

Context:

- Take it into steps. We don't have a Cristal Ball to look that far in to the future. Take one-step and on completion or after one generation we look back and evaluate on the bases of the SDG's. The goals within the SDG's change over time, within one or more generations. So you can adapt and evolve. Working Agile in periods of generations instead of weeks, months or years.
- Nowadays were used to fix a certain horizon in the period we try to overlook. For example, when designing a road we use a live span of 30 years for the construction or a bridge for 100 years. When you place this in perspective of multiple generations and looking 7 generations ahead you debate about the horizon, because needs increasingly change over time. Is the span of time correct in relation to societies development on that specific location.
- Do not make choices that harm future generations, with the knowledge of today and past generations.
- Use all or a set of generally acknowledged methods to evaluate/rate.
- When using new technology, monitor the effects (health, environment etc) and adjust.
- With the knowledge of today, calculate hidden cost effects so you get an more even equation when comparing different scenario's.
- Use a (fictive) currency/unit when comparing.
- Translate this in LCC and measure the effect on the relevant SDG's. Then you get insight on the value's of a design for multiple generations and you can make objective decisions on the best price/effort combination.

CONCLUSIONS

Using Sustainable Excellence for Generations in projects and organisations will contribute to Cathedral Thinking (Roman, 2020). What the project will deliver once created, the performances of functions relative to the resources invested for the coming generations. Projects can be planned beyond a human lifetime (Saijo, 2020). The value needed by future generations relative to the value of current generations can be part of decision-making methods, contributing to the short-term decisions with long-term considerations. Creating sustainable organisations making products as sustainable and valuable as drink glasses

The tug of war for time

^®@©| From The Good Ancestor: How to Think Long Term in a Short-Term World *by Roman Krznaric. Graphic design by Nigel Hawtin.*

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BIM Education: The Review of Land Survey (Geomatics) Programs in South Africa (id 52; P_052)

BIM EDUCATION: THE REVIEW OF LAND SURVEY (GEOMATICS) PROGRAMS IN SOUTH AFRICA

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The current uptake of BIM by the Geomatics profession is slow, despite the profession being significantly affected by the changes in technology. The use of the technology is prevalent on the project's design stage, intending to extend use to the construction stage. Land Surveyors data collectors for the pre-design stage require setting out during construction and will be required later in the project cycle for as-built surveys. The involvement of a Land Surveyor in building design has always been from a civil engineering perspective. The involvement of Geomaticians in the BIM process would have a meaningful impact on the technology uptake and, therefore, necessary for Geomatics education to incorporate BIM teaching. This study aimed to determine the status of BIM education in Land Surveying/Geomatics. The study used a purposeful sampling method to interview participants. Primary data was collected in the form of semi-structured interviews. The study found that the Universities that participated in the study didn't have BIM-designated programs, but all offered Geomatics branches related to BIM, such as remote sensing, GIS, 3D scanning, and Engineering Surveying. All respondents conceded that the universities' offering includes the creation of 3D models of buildings and infrastructure on a conceptual basis to prepare students for lifelong learning as technology is forever changing. The study concludes that South African Geomatics programs are not far behind BIM adoption. However, together with the regulatory body, universities must package modules to talk to BIM application and mention BIM on the Academic framework.

Keywords: BIM, Curriculum, Geomatics/Land Surveyors, Higher Education, South Africa.

introduction

Geomatics is the science of "what is where?"; Whittal (2014:1) describes Geomatics as a variety of spatial science disciplines that enable one to register with the South African Geomatics Council as either as Land Surveyor, Professional Land Surveyor, Engineering Surveyor, Photogrammetrist or GIS specialist. It is worth mentioning that there is an overlap in the work done by personnel on different registration categories. However, cadastral surveys are the preserve of the Professional Land Surveyor. Hendrich du Plessis (2006:6) defines Geomatics as "a modern scientific term referring to the integrated approach of measurement, analysis, and management of the descriptions and location of earth-based data often termed spatial data." In the definition, it is clear that there are various sources of spatial data, and the application of geomatics skills can be in various disciplines such as forestry, environmental studies, town planning, and engineering.

Geomatics, in its form, incorporates various disciplines such as land surveying, remote sensing, photogrammetry, cartography, and Geoinformation systems into a new body of knowledge. Geomatics is highly technical with mathematical elements and poses the social aspects and legislation necessary to help understand people's relationships with land (Whittal, 2014:1). Land surveyors in South Africa must have various technical skills and knowledge in property development, Land Law, Engineering surveying, Construction surveys, and other skill sets

To improve cost, planning and productivity advanced digital technologies such as Building Information Model have become popular within the construction industry. The model has been increasingly used throughout the world and has the following benefits: improved communication between stakeholders, visualisation of design, detection of design flaws, design efficiency, costs reduction, and increased design quality (Nasila & Cloete, 2018:1). This increase in interest has led to collaboration across various disciplines to improve the management of projects. However, the BIM cycle tends to leave out Land Survey. The consequence of leaving out the Land Survey in the BIM cycle can prove to be catastrophic for construction planning. Geomatics is a measurement science that has been at the center of resolving topographical and positional challenges in the construction industry in times immemorial. As construction projects are all based on land, the measurement of land, positioning, and mapping of topography are the forte of Land Surveyors due to their ability to provide ongoing, reliable, and accurate spatial data

Building Information Modelling is a widely used term and has many definitions. Motamedi (2013) refers to it as a technological information management process, while Gardezi et.al. (2014) refers to it as a 3D virtual model. One of the most cited definitions of BIM is by Sabongi (2009:2), who defines BIM as "the representation of migration of the architectural design field from two dimensions to three dimensions by creating intelligent, multi-dimensional building models". Another is by Macdonald (2012:224) citing a definition by Eastman et al (2013:13) describes BIM as a modeling technology associated with the production, analysis, and communication of building models.

Halal et. Al. (2019) state that BIM is centered on design and the construction phase. Despite the wide usage of the term Radie, Comiskey & McKane (2020), citing Snook (2009), state the official definition of the term is "a digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition." The view by Radie, Comiskey & Mckane (2020) that there is an official definition of BIM is countered by Macdonald (2012:224), who argues that the is no widely accepted definition of BIM.

The impact of emerging spatial technologies in Land Survey has had dire effects on the profession despite their outstanding capabilities. The change in technological trends has meant that Land Surveyors shift from being specialist data collectors and manipulators to data managers due to the advent of technology such as Global Navigation Satellite System (GNSS), Geographic Information System (GIS), and Remote Sensing (Markus, 2004).

Background to study

According to Motala (2018), the first recorded surveyor in South Africa was an artist with no actual Surveying education. Landman, Akombelwa, and Forbes (2017) put forward that land surveying education in South Africa dates to the early 20th Century with the first technical programme offered by the Pretoria Technical College. After that, universities like The Cape Peninsula University of Technology, the Mangosuthu University of Technology, Durban University of Technology, and the Tshwane University of Technology followed suit. These universities are known for producing Land Survey/Geomatics Technologists in South Africa.

Over the years, various legislation has been passed, which led to the current situation. Wherein Cape Peninsula University of Technology, the Mangosuthu University of Technology, the Durban University of Technology, and the Tshwane University of Technology offering Geomatics programmes have a technical focus, thus producing Land Survey/ Geomatics Technologists.

The country's first Bachelor of Science programme was in the University of Cape Town in 1929 (Landman, Akombelwa and Forbes (2017); this marked the beginning of the Honours degree programs by traditional universities. At UCT, Land Surveying/Geomatics forms part of the school of Architecture planning and Geomatics. The current programme at the University of KwaZulu-Natal was established in 1948 by Professor Harry Biesheuvel (Akombelwa et al., 2013). The programme is part of the School of Engineering and offers an Honours degree in Land Surveying (Geomatics). Students who graduate from UCT and UKZN can register as Professional Land Surveyors. Similar programs have opened and closed over the years. The Wits university program started in 1929 and closed down in 1989 due to fewer students. Other universities that have closed their programs over the years are the University of Fort Hare and the University of Pretoria, which closed their program in 1995.

Marcus (2004) paints a dire picture of the Geomatics programmes in higher education. The author describes how most programmes have closed due to low student interest and low graduate numbers. The trend has remained unchanged, even though the general public and professionals alike, and the general public which rely on the surveying services and the general public are aware and recognise the integral role played by Geomatics professionals in land development.

The teaching of Geomatics is across different sectors due to the nature of Surveying and its application. Behan (2013) puts forward that the conduct to teach land surveyors across different sectors offers an incredible opportunity to adopt and efficiently use BIM across different sectors allows surveyors to embrace the collaborative nature of BIM. Furthermore, he alludes that land Surveyors are the first professionals to be on-site for the initial construction phase. Their role is to reproduce the site and its contents which becomes the base map for design and planning. This role has contributed significantly to the Geomatician/Land Surveyors on the BIM process. However, over time the land surveyor has primarily been underrated and underutilised in the construction industry. Furthermore, the author advises that including a Land Surveyor in the BIM process would reduce construction costs, reducing the need for post-construction 3D modeling that is often costly and redundant.

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Due to the change in technology over the years, there has been increased availability of 3D information due to laser scanning and point cloud-based data technologies. Laser scanning and point cloud data technology have enabled full utilisation of Scan-to-BIM, ensuring 3D surveying throughout the project life cycle. According to Behan (2013), Land Surveyors are often the first professionals working on construction and redevelopment projects. For this reason, they have an essential role in any BIM project team. In addition, land Surveyors collect Topographical information, forming a base for planning purposes. Geomatics has been underutilised in the construction sector and has more potential to contribute to the BIM process.

BIM and Geomatics/Land Survey

In the context of Land Surveying/Geomatics, BIM is the transition from two-dimensional representation to three-dimensional representation using new technological advances in the market.

Importance of BIM and BIM education within the Geomatics space, Geomatics programmes deliver education relevant to BIM (Behan 2013), namely: Topographical, Engineering and Construction Surveying, CAD/3D data visualisation, GIS, and remote sensing. These are similar offerings in the South African context, as all Geomatics graduates are expected to have a working knowledge of all Engineering Surveys, GIS, and remote sensing. These skill sets require graduates to be competent when dealing with multi-dimensional data.

Speaking to the appropriateness of Geomatics graduates and the need for Geomatician to be part of BIM, Behan (2013) points out that Geomatics graduates are, from when they enter the university, taught to manipulate Spatial information using a variety of software to meet client needs. The author alludes that this is readily needed in the BIM process. The author's assertions further provide a theoretical basis for Land Surveyors to be part of the BIM project team. Lastly, Several Geomatics/Land Survey courses can easily incorporate BIM. Behan (2013) affirms that Geomatics programs are relevant to BIM theoretically and practically and, most importantly, focus on spatial data management and manipulation. From literature and practice, Geomatics courses that are likely to incorporate BIM technology are Topographical Surveying, Engineering Surveying, CAD, GIS, Remote sensing, and Photogrammetry.

According to Moodley, Mathyr, & Radebe (2016:13), South Africa is no exception to the global problems requiring BIM as a solution. Thus, teaching BIM to tertiary students would help address the many problems encountered by the construction industry. Furthermore, Moodley et al. (2016) concede that few studies have critically analysed the incorporation of BIM into the curriculum. However, this study presents it as an opportunity for long-term research on this concept (BIM) to be explored and also add to the existing complexity that has left many Land Surveyors struggling to keep up with technological changes and no longer exist within the "specialist data collectors and manipulators" role.

Approaches and methods used in teaching BIM

Barison and Santos (2014:1) allude that BIM can first be introduced as a module and then introduced as the discipline (Citing Hietanen and Drogemuller 2008). On a BIM curriculum, the first two years are dedicated to learning modeling and model analysis. The later years of the study will be collaboration and working on a team (Barison and Santos, 2014:1). Boston, Forgues & Halin (2018:2) argue that the graduate's skills need help to determine the strategy to implement BIM education.

Furthermore, the authors believe that implementation of an effective BIM education should be gradual. The strategy should seek to create awareness, implementers must be open to learning, and the strategy based on the BIM needs of the local industry. They were indeed proving that BIM curriculum development is not a straightforward process. It is cumbersome and requires input from different stakeholders.

Barrison & Santos (2014), in a content analysis study to review strategies of implementing a BIM programme, highlight the following issues and steps to planning a BIM program. See table 1

Table 1: Adoption of BIM in various countries. Source: Ndhlela (2018) (citing John Rodgers et al. (2015))

RESEARCH METHOD

The research aimed to determine the status of BIM Education in Land Surveying/ Geomatic. in South Africa. A qualitative approach to the research process was chosen. Semi-structured interviews were conducted with education stakeholders from universities that offer Land Surveyor Geomatics. five (5) Universities out of six (6) responded and were permitted to participate in the study. Wherein heads of programs were interviewed to inform the composition of their programs to BIM teaching and learning. Of the five respondents, two respondents were from traditional universities and the other from the university of technology.

Data analysis

The study used qualitative methods to analyse results wherein after raw data was gathered as audio records that were later transcribed. Responses were then grouped into themes as per questions. The data was then coded to clearly defined themes that related to the research questions. Patterns as per the themes were determined to understand the responses relative to every theme as informed by the research questions. Due to the limited number of respondents for the study, there was no need to use coding software.

Sampling

The target sample for the research is the head of departments, Land Surveyors, and those involved in Land Survey syllabus formulation. For this reason, purposeful sampling was chosen as an appropriate sampling method in the study. Patton (2002) alludes that purposeful sampling is utilised in qualitative research to select informants that are well abreast with the researched subject.

Presentation of data

Interview Data

Five heads of departments and /or program coordinators were identified for the interview. Two are from the traditional university and three are from the university of technology. Three are Ph.D. holders and two are Masters holders.

Table 2: Higher education institutions and Qualifications

Geomatics in University Structure

Geomatics is part of the Civil Engineering and Quantity Surveying department as per respondent A, for respondent B it is part of Architecture and Planning. For the respondent, C Geomatics is a standalone department and lastly, Geomatics is part of the Civil Engineering depart for respondents D and E

BIM understanding and 'its relation to Geomatics

All the respondents expressed that BIM is a 3-dimensional platform that makes it easier to manage multiple-dimensional data.

Respondent C D, E pointed out that a BIM system as a platform requires input from all the different disciplines in the built environment in a BIM system

Respondents C and E noted BIM to be a discrete system, multi-layered and with significant entry and exit points for all professionals involved. The multi-layered nature of BIM is similar to Geospatial Information systems (GIS), wherein information about data (metadata) is as important as data.

All respondents conceded that all Land Surveyors are required to conduct a Topographical survey to reproduce a 3-dimensional profile for design purposes. The topographical survey becomes the framework for the design

Influence of BIM on Geomatics programme

All respondents did admit that the uptake of the fully-fledged BIM process by industry has been slow but gradually gaining traction. In some instances, it has contributed to BIM’s lack of influence on the Geomatics programs to a significant degree. However, all the respondents spoke about the influence of the industry on the constitution of the academic programs. Moreover, all the respondents considered it a "nice to have" with no impact on the composition of Land Surveying/Geomatics programs

All the respondents expressed the similarities of BIM to geospatial data collection and analysis, and geospatial data analysis is a component of Geomatics/Land Surveying. All the respondents cited that Land Survey is broad and incorporating BIM within the framework would be a challenge.

All respondents cited that BIM teaching is incorporated within the existing courses and not offered as a stand-alone module. The lecturers are motivated to refer to newer technologies when offering modules. The respondents reiterate that BIM technology and software knowledge offered to Geomatics/Land Survey students are the most relevant for BIM education

All respondents concede BIM cannot be a stand-alone model

BIM-related software and instruments used and the difficulties associated with their acquisition

All respondents concede to students being introduced to various software to grasp a variety of geospatial information analysis techniques. Among these are traditional survey software with 2 Dimensional capabilities, e.g. survey maker, model maker, surpac, and software with 3D capabilities.

All respondents concede to the other approach has been over the years to incorporate software that is prevalent in the built environment. These are software such as Civil Design, Auto Cad, and Revit

Approach to introducing BIM

All of the respondents said the is no stand-alone programme for BIM. The approaches to learning varied from offering students a conceptual basis enabling them for lifelong learning.

All the respondents admitted that there is no standalone BIM program, however, the respondents did acknowledge that lecturers are always encouraged to introduce students to the different applications of geospatial data such as BIM

All respondents did express that Geomatics as a Profession has the building blocks for BIM and is best placed to be part of BIM development

FINDINGS AND DISCUSSIONS

The respondents understood that BIM is a spatial data application tool that allows manipulation of Three Dimensional data. The respondents all understand BIM from the manipulation of point cloud to create a 3D model. The respondent’s understanding of BIM is similar to Sabongi’s (2009:1), wherein BIM is defined as a transition of design capability from two-dimensional to an intelligent and multi-dimensional 3D model. It is also noteworthy that respondents also relate to BIM in acquiring and processing point cloud data. Similar to Mathye et al. (2016:51), the respondents in the study describe BIM according to software, not as a process to acquire building models. these findings indicate how different professionals describe BIM is related to the tools, skillsets, and software required to participate in the BIM process.

In all the universities interviewed, there is no BIM designated program, however, the universities offer all the data collection applications such as remote sensing, photogrammetry, 3D scanning, engineering surveys, and CAD. The respondents all pointed to the broadness of Geomatics/Land Surveying as the impediment to teaching new technologies. The approach seems to be teaching the core values of Geomatics/Land Surveying such as calculations of angles and directions, programming, geospatial data management and collection, photogrammetry, remote sensing, and other modules. The reason given for the approach is that graduates will still apply fundamentals to learn newer technologies. The universities appreciate the influence of technology, henceforth prepare students for lifelong learning. Mcdonald (2012:225) cautions this viewpoint on teaching as it is more beneficial to exposing students to BIM as it enhances the students' ability to understand the construction of infrastructure. The use of BIM goes beyond visualisation but helps facilitate technological and cultural change and also helps simplify the construction process.

Another approach that universities use to expose students to new technological applications is by inviting practitioners already in practice to present projects undertaken and all the state-of-the-art equipment used to get desirable results.

Lastly, universities were adamant that they believe what they offer is enough given the country's slow uptake of BIM technology. Furthermore, the universities did show an interest in possibly having Stand-alone programs in the future, with other institutions suggesting possible post-graduate programs or short courses in BIM.

Contribution to the Geomatics industry and BIM education.

The research aimed to investigate the status of BIM education. The focus was land Survey programs across the country. Five universities that offer Land Surveying participated out of the six that offer Land Surveying in South Africa.

The main research question was whether Land Surveying/Geomatics programmes capacitate graduates with enough skills to meet industry expectations. The study concludes that Geomatics programmes have the foundation to incorporate BIM into the curriculum and a significant advantage due to the module offering of their programs. The other aspect considered is the positionality of these programs, with most paired with other disciplines while associated with other soft sciences disciplines like Town Planning, Land Management. The current status quo, as outlined, is fertile ground to create a collaborative setting required for BIM education (Macdonald, 2012).

The study recommends that the regulatory body (SAGC) incorporate BIM into the geomatics education framework to encourage universities to incorporate BIM into the Geomatics curriculum. Furthermore, creating a separate registration category for experts in the industry that are actively involved in BIM projects would help universities teach when specialists are required and help universities with information about the BIM industry needs of the country. The information about the industry would also help determine the BIM incorporation strategy.

Conclusion

Though the uptake of BIM is slow in the South African Geomatics space, the is a greater need for the industry to embrace changes in technology as the change affects land Surveying the most. Research has shown the importance of Geomatics graduates entering the industry abreast with technological developments to increase their employability and penetrate practice areas taken over by other professions.

Geomaticians should embrace technology and structure their programs accordingly. It is safe to conclude that South African Geomatics programs are not far behind in BIM adoption. However, these institutions, together with the regulatory body, must package modules to talk to BIM application and mention BIM on the Academic framework.

Lastly, the nature of the work of Geomaticians/Land Surveyors is collaborative. Moreover, the variety of module offerings in Geomatics/Land Survey programs makes the profession a front runner in embracing the BIM process's collaborative nature, making the professionals the front runners in being BIM project managers.

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IMPACT OF CLIMATE CHANGE ON PROPERTY PERFORMANCE: A CASE STUDY

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ABSTRACT

The purpose of this research was to investigate the impact of climate change on the performance of retail properties with specific reference to a shopping mall in Gauteng, South Africa, and to recommend strategies that minimise the negative effects of climate change.

METHODOLOGY

The research was a mixed method of both quantitative and qualitative methods. The process of study was three-pronged and included a review of literature on climate change and the impact on retail properties, as well as a questionnaire to gather information from respondents in a shopping mall, the case study.

FINDINGS

Results of the research indicated causes of climate change and negative impact on the retail sector. There are various measures to combat the effect of climate change on retail properties.

IMPLICATIONS

The study found that the implications and negative impact of climate change on retail properties were multi-pronged. These impacts range from high energy use, loss of fresh products, logistics disruption, logistics to inaccessibility of resources. The ultimate result is a decrease in the return on investment.

VALUE

The value of the paper is that the study found the negative impact of climate change on retail properties to be multi-pronged.

CONCLUSION

Several causes of climate change were cited, and the prominent ones were air pollution, irresponsible human pollution; uncontrolled use of fossil fuels; and artificial induced factors such as excessive carbon emission. It can be deduced that the human factor is at the centre of climate change.

Key words: climate change, human factor, property performance.

INTRODUCTION

Retail properties in South Africa have, in the past, been profitable. Although still profitable and thriving, the impact of various environmental attributes on the retail properties and the real estate industry at large is threatening the sustainability of this vivacious economic sector (Nikolaos, Dimitra and Agapi, 2011).

South Africa has been faced with unprecedented natural disasters ranging from seismic activities and other natural occurrences such as cyclones, wildfire, snow, floods, hailstorms and heatwaves. Globally, natural disasters have been on the rise, putting the whole world under siege as the sea levels continue to rise due to melting ice. In contrast, flooding has become commonplace in most parts of the world, and South Africa is no exception (IPCC, 2009).

It has further been predicted that extreme events that occurred less frequently in the past will take place often in future (Kropp, 2012). Given these environmental threats, economic losses due to disruption of the value chain and property damages may not be ignored or underrated. Pitt (2008) states that due to decades of extreme weather events worldwide, assessing interventions has become a policy concern. These concerns will further rise given a growing scientific consensus that climate change is expected to amplify the prevalence and severity of flood risk, due to changes in winter precipitation, sea levels, storm surges and extreme weather events (Foresight, 2004; Houghton, 2009; IPCC, 2007; Stern, 2006, 2008).

Given that climate change has become a debated topic, with out of control natural phenomena like wildfires that are raging and consuming vast areas of Australia's forests, it would be beneficial to explore the impact of climate change on retail properties.

Retail Property Market

The retail environment in South Africa comprises a significant presence of informal and formal retail trade. The diverse population in the country has several cultures and ethnicities that present opportunities for different retail brands to flourish (Broll, 2019a).

The competition in South Africa's retail market is intense, with more than 25 million square metres of formal retail space. The retail space has over 2,000 existing shopping centres and nearly 3 million square metres of formal retail space in the pipeline (Broll, 2019b). With increasing competition, retail property practitioners need to be alert to, and agile in responding to the latest trends, consumer behaviour and technology in a fast-paced, ever-evolving industry (Broll, 2019b).

According to to the MSCI data from FNB, the average capital value per square metre by property segments, retail property's cumulative rise has far exceeded that of the office and industrial segments over the past twenty-two years (Loos, 2019). For a few years following the end of the pre-2008 property boom, there was a perception amongst some that it was the residential property market that had 'overshot' the mark the most during those prior boom years, while commercial property remained relatively 'cheap' (Loos, 2019). It seems to be so in the case of office property and even, to a lesser extent, industrial property. However, retail properties began to outpace residential property significantly after the 2008/9 recession and appear to have become South Africa's 'expensive' property category (Loos, 2019).

Considering the data available, the retail properties appear to have been the better 'cumulative' performer of the three major commercial property sectors over the past twenty-two years from 1996 to 2017, according to MSCI historical data, and possibly even over the past thirty years judging by Rode's Cap Rate data (Loos, 2019). Retail properties have achieved superior capital growth even excluding all the capital expenditure on properties over the years (Loos, 2019). PropertyWheel (2018) states that retail sector's operating cost per square metre outpaced the others categories, as well as far outpacing general economy-wide price inflation. The sector has been able to recoup much of its capex and rise in operating costs through its recoveries and having the strongest rental inflation rate over the two-decade period.

However, having entered a more stagnant economic period in recent years, the big question is whether this general affordability deterioration in the retail property sector hastens the search for cheaper alternatives for retailers, notably online retail and greater use of Warehouse Property (Loos, 2019).

CLIMATE CHANGE AND THE IMPACT OF CLIMATE CHANGE ON RETAIL PROPERTIES

The United States Environmental Protection Agency (EPA, 2010)defines climate change as a term that refers to major changes in temperature, rainfall, snow, or wind patterns lasting for decades or longer. Both human-made and natural factors contributed to climate change in global or regional climate patterns, in particular, a change apparent from the mid to late 20th century onwards and attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels. The main characteristics of climate change are increases in average global temperature (global warming); changes in cloud cover and precipitation, particularly over land; melting of ice caps and glaciers and reduced snow cover; and increases in ocean temperatures and ocean acidity due to seawater absorbing heat and carbon dioxide from the atmosphere (Archer and Tadross, 2008).

The question of what causes climate change has been debated over a long period of time, because climate change may be due to natural variability or as a result of human activity and because the climate system is complex (IPCC, 2007). There is, however, evidence that most of the warming over the last 50 years is due to human activities. IPCC (2007) report states that ice cores taken from deep in ancient ice of Antarctica show that carbon dioxide levels are higher than at any time in the past 650,000 years.

Developing countries bear the brunt of adverse consequences primarily due to high poverty rates, high vulnerability levels and low adaptation capacities. Ringler (et al., 2010) adds that the population in developing countries for whom agricultural production is the primary source of direct and indirect employment income will be most affected because of agriculture's direct exposure to climate change. Agriculture, which is a primary source of retail products, once affected by climate change, triggers a ripple effect on the performance of retail properties (Nhemachena and Hassan, 2011).

The climate in South Africa seems to be affected by the changes in the global climate. South Africa is itself a contributor to the global climate change problem. South Africa contributes about 1.8% of total GHGs, making it one of the top contributing countries in the world (Bond, 2006). The implication of increased temperature and extreme weather patterns will largely be felt through impacts on water resources, such as changes in water resource availability and a higher frequency of natural disasters, such as flooding and drought, with cross-sectoral effects on human settlements, disaster risk management and food security (UNICEF, 2017). Furthermore, the impact of water resources, high temperature, flooding and natural disasters will be felt on real estate development specifically.

The retail properties in South Africa are exposed to extreme weather conditions such as hailstorms, intense rainfall and flooding, bushfires, cyclones and extreme temperatures (Cox, 2012; Smith, 2013; DEA, 2013).

The impact of climate change is multifaceted depending on the severity of the occurrence of the natural disaster question. The impact may be minor or extreme. The impact of climate change includes an increase in electricity prices, increase in the vacancy rate, rising material costs, water unavailability and rising compliance requirements (Sweeney, 2013).

METHODS OF MITIGATING THE IMPACT OF CLIMATE CHANGE ON RETAIL PROPERTIES

The ways or measures in which the impact of climate change may be mitigated are the following, but are not limited to these ways.

Investing in renewables; Businesses that make a conscious effort to switch from coal to more sustainable energy sources, such as wind or solar power, may help to reduce CO2 emissions greatly (Cox, 2012).

Policy matters related to climate change; The property and construction sector is regulated principally by planning policies set by state and local governments and the National Building Codes of South Africa (Kennedy, 2010). Many of these regulations were developed decades ago with, at best, outdated consideration of climate change risks. Buildings built to earlier standards are likely vulnerable to climate impacts (IPCC, 2013). To prevent costly damage and reduce long term operational and insurance costs, major real estate companies should examine their exposure to climate risk and develop strategies to minimise vulnerability. Property developers should examine the climate risk profile of each asset within its property portfolio, assessing each one on its location and design, structure, operation and maintenance, utilities and services and stakeholders (Levine et al., 2007). *Regarding coastal areas,* flood defence measures are required. Hard engineering and armouring, which involve the construction of shore protection measures, including conventional and unconventional structures or measures are required as a matter of urgency (UNFCCC, 2007). Structures such as groynes, seawalls, revetments, rock armour, gabions, offshore breakwater, cliff stabilisation, entrance training walls, and floodgates are some of the hard engineering solutions to be considered (Niang, 2007).

Retrofitting existing buildings; Climate change adaptation seems to be a wise investment because it is generally less expensive to increase resilience prior to an event than to recover after, whether repair or replacement; and mechanisms to increase resilience tend to be more cost-effectively implemented early through planning, design, or policy than through subsequent retrofit (Smith, 2013).

Green building compliances; It is encouraged that during construction, the property owner invests in energy efficiency opportunities (CIDB, 2011). Properties have to be designed to be energy efficient by improving the thermal building envelope with improved building insulation, high-performance window glazing, external window shading, proper window coverings and natural ventilation, painting roofs reflective white may reduce airconditioning loads by as much as 20%, reducing internal heat generation by retrofitting with the latest energy- efficient lighting and equipment (Smith, 2013). Under the Green Building Certification Document, sellers or lessors of office space are encouraged to specify that new buildings, or buildings that are to undergo major renovations, are to be designed, constructed, and certified to meet, at a minimum, a Four Star Green Star SA standard where such Green Star SA rating tools exist for the class of building (CIDB, 2011).

Maintenance and stormwater management; Managing and maintaining properties to retain the value and prevent damage by floods or intense storms is important to proactively maintain properties (Niang, 2007). Strategies for managing stormwater effectively are key in managing runoff that may cause flooding. Stormwater drainage flumes, inlets, and other conveyances should be free from sediment and vegetative clippings or debris. They should be inspected and maintained regularly to ensure stormwater appurtenances are not obstructed (Naidu et al., 2006).

Water resources; Water shortages are expected in the future due to climate change. To mitigate against this challenge, investors should design, build and retrofit property assets to be water efficient and ensure landscaping is done with drought-tolerant plants (Smith, 2013). Numerous profitable ways to reduce water consumption in new and existing buildings include reducing water leakage, water-efficient amenities and dry/wet hybrid cooling systems. Commercial properties tend to have large roof spaces to harvest significant amounts of water in rainwater tanks to then use, at no cost, to reduce further dependence on mains water (Foresight, 2004). Similarly, it is projected that underground aquifers may be recharged better due to heavy rainfall that is expected in future (UNICEF, 2017). The groundwater source of water should be considered during design as an alternative to diminishing surface water sources. These methods might help to secure green building ratings.

Reduce, reuse and recycle building materials; Reducing, reusing and recycling help reduce humanity's environmental footprint, carbon dioxide emissions and energy use and limits the amount of landfill space people create (Houghton, 2009). It is imperative for construction companies to minimise pollution by reusing and recycling construction materials, especially facade and structure materials, thereby reducing embodied energy and thus might reducing capital costs for new buildings (Smith, 2013).

Innovative building technologies; The South African market has a plethora of alternative building technologies approved by Agrement South Africa (CSIR, 2019), most of which are energy efficient.

RESEARCH METHODOLOGY

Research methodology refers to ways of collecting, organising and analysing data (Polit and Hungler 2004). Mahlangu (1987) defines research methodology as the study of the logic or rationale underlying the implementation of the scientific approach to the study of reality.

Leedy and Ormrod (2005) developed a criteria for selecting quantitative or qualitative as an appropriate research approach for a study, summarised in Table 1.

Table 1: Criteria for selecting quantitative or qualitative approach

Use this approach If	Quantitative	Qualitative	Choice for this study
You believe that	There is an objective reality that may be measured	There are multiple objective realities constructed by different individuals	Qualitative
Your audience is	Familiar or supportive of quantitative studies	Familiar or supportive of qualitative studies	Both
Your research question is	Confirmatory or predictive	Exploratory or interpretive	Qualitative
The available literature is	Relatively large	Limited	Both
Your research focus	Covers a lot of depth	Involve in-depth study	Qualitative
The time available is	Relatively short	Relatively long	Both
Your ability or desire to work with people is	Medium to low	High	Both
Your desire for structure is	High	Low	Both
You have skills in the area of	Deductive reasoning and statistics	Inductive reasoning and attention to details	Both
Your writing skills are strong in the area of	Technical, scientific writing	Literary, narrative writing	Both

Source: Adapted from Leedy and Ormrod (2005)

From the above table, it can be deducted that the research methodology for this paper is the mixed-method approach, which combines qualitative and quantitative research. The mixed-method can balance the requirements of both the quantitative and the qualitative approaches and produce meaningful results (Choy, 2014).

Reliability may be ensured by minimising sources of measurement error such as data-collector bias (Holloway and Wheeler, 2002). In this study, data-collector bias was minimised by the researcher being the only one to administer the questionnaires and standardising conditions such as exhibiting similar personal attributes to all respondents. Macnee and McCabe (2008) define credibility as the confidence that may be placed in the truth of the research findings. To ensure a credible study, respondents were used to evaluate the interpretation made by the inquirer and to suggest changes where the responses have been misreported. Validity refers to the extent to which adequate controls are put in place to ensure that the conclusions drawn are supported by the data that has been assimilated (Leedy and Ormrod, 2005). This study complied with a number of validity issues, such as data sampling and analysis. Confidentiality, informed consent, anonymity, and scientific honesty were important and complied with during this study.

The study was based on primary data collected from 18 representatives of retail shops, the population operating at a shopping mall in Gauteng, South Africa. The data was collected from the population using a questionnaire. Saunders et al., (1997) state that a response rate of about 50% for postal surveys and 75% for face-to-face interviews are acceptable. A response rate of 70% and above will be considered acceptable for this study.

DISCUSSION OF RESULTS AND FINDINGS

The discussion of the results focuses on proving the objectives of examining the causes of climate change, investigating the impact of climate change on retail properties and recommending mitigation measures.

The questionnaires were distributed by email to 18 respondents, and 14 of them responded, a response rate of 78%.

The questionnaire was divided into three sections. Section A collecting data on the level of experience, Section B focused on collecting information on respondents' understanding of climate change, meaning, causes and effects of climate change on retail properties, and Section C collected information on the respondents' opinion on the measures to mitigate the impact of climate change on retail properties.

Section A; The majority of respondents, 50%, had experienced between 5 to 10 years in the retail property industry, although most respondents have not worked at a specific shopping mall. Regarding the section or roles where respondents work, 50% of the respondents worked in the facilities and property management section of the retail property industry, and 29% worked in the general management area.

Below is table 2 which shows the distribution of respondents' role in the retail industry.

Table 2: Distribution of respondents' roles in the retail space

In which section is your role in the retail space?	Accounts and Finances	Logistics and Distribution	General Management	Facilities and Property Management	Shop Floor
	1	1	4	7	1
	7%	7%	29%	50%	7%

Table 2 summarises the employment status of the participant respondents.

Section B; The results indicated that the respondents have a fair understanding of climate change, as it is clear that climate change has to do with change in "weather or climate" patterns and that such a change harms the environment at large. Data on the causes of climate change included:

Air pollution.

- Irresponsible human pollution.
- Uncontrolled use of fossil fuels.
- Man-made factors such as excessive carbon emissions.

The data indicates that there is a human factor in the cause of climate change. The majority of respondents indicated that operational costs increase due to high energy consumption induced by high demand for cooling and heating. However, one respondent stated that climate change does not affect retail properties.

Data on the opinions of respondents on the impact of climate change was analysed and ranked in the table 3.

Table 3: Distribution of respondents' opinion on the impact of climate change

Question: The impact of climate change		Agree strongly (1)	Agree (2)	Neither agree nor disagree (3)	Disagree (4)	Disagree strongly (5)	% agreeing = (1+2)/14	Rank
b)	There is an increase in demand in electricity and water due to extreme temperature.	9	5				100%	1
c)	Extreme weather events damage property and infrastructure.	7	6	1			93%	2
f)	Changes in prices for goods and services is likely to happen due to increase in production costs.	7	6		1		93%	2
e)	Climate related disasters leads to mass migration and scarcity threats.	6	6	2			86%	3
h)	Insurance companies may bear a great loss due to pay-outs for losses	4	8	1		1	86%	3
d)	Disruptions in daily life related to climate change means loss in production.	6	5	3			79%	4
g)	Climate change brings a great risk for safety and security.	3	8	3			79%	4
a)	Adverse effects of climate change impact supply chain negatively.	2	8	4			71%	5
i)	Climate change impacts employee performance.	2	6	5	1		57%	6
TOTAL		46	58	19	2	1		

The table shows the respondents' responses regarding the impact of climate change according to a 5-point Likert scale. Regarding the question on the impact of climate change on retail properties, 93% of respondents agreed and strongly agreed that all the statements are possible impacts of climate change.

All 14 respondents (100%) concurred that there is an increase in demand for electricity and water due to extreme temperature, and 93% of respondents believe that climate change will damage property and that prices of goods and services are likely to increase. 86% of respondents believe that climate change may lead to mass migration and that insurance companies are likely to bear huge losses on insurance pay-outs. In the fourth place, 79% of respondents believe that climate change disrupts daily life and that climate change brings great risk for safety and security.

Section C; The respondents opinion on mitigation measures of climate change on retail properties is summarised in table 4.

Table 4: Distribution of respondents' opinion on the mitigation measures for climate change

Question 8: Mitigation measures		Agree strongly (1)	Agree (2)	Neither agree nor disagree	Disagree (4)	Disagree strongly (5)	% agreeing = (1+2)/14	Rank
a)	Creating a culture of carbon consciousness.	8	6				100%	1
b)	Increasing the use of renewable energy sources.	9	5				100%	1
e)	Employees should be empowered on environmental issues.	8	6				100%	1
f)	Higher stretch goals should be set toward innovation.	6	7	1			93%	2
g)	Businesses need to be proactive in developing the capabilities needed to succeed in an era of climate change.	6	7	1			93%	2
d)	Develop environmentally conscious, or "green," products and services.	10	3	1			93%	2
c)	Combination of market-driven and regulatory measures that vary from sector to sector.	5	7	2			86%	3
h)	Assign value on companies that capitalize on business opportunities posed by climate change.	7	5	2			86%	3
TOTAL		59	46	7	0			

The above table shows the data collected on the mitigation measures for climate change. Regarding the question on mitigation measures against climate change, 94% of respondents concurred that all the statements are a possible mitigation measure for climate change. None of the respondents disagreed or strongly disagreed with any of the statements.

Notably, all respondents concurred with statements (a), (b) and (e). These three statements ranked first as the most possible mitigation measures to climate change. Ten of the 14 respondents strongly agreed with statement (d) which states that developing environmentally conscious, or "green," products and services is a mitigation measure for climate change. This indicates that 72% of respondents strongly believe that environmental consciousness and green products are good way of mitigating climate change. Ranked second are the responses to statements (d), (f) and (g) which all scored affirmatively at 93% while statements (c) and (h) received the least

affirmation of 83% as a possible mitigation measure of climate change and these two statements came jointly third on the ranking.

CONCLUSION

The purpose of the study was to examine the impact of climate change on the performance of retail properties, with specific reference to a case study of a retail property in Gauteng, South Africa. The study recommends mitigation measures that minimise the negative impact of climate change. In pursuit of the broad objective, the following three specific objectives were outlined:

1. To examine the causes of climate change.
2. To investigate the impact of climate change on retail properties.
3. To recommend mitigation measures.

A mixed-methods approach was used for this study to achieve the study objectives. This method is a hybrid mix of both quantitative and qualitative methodologies. The data was collected with a questionnaire, and 18 respondents, on the management level were identified, of which 14 responded.

Climate change is a phenomenon that the respondents understood. Several causes of climate change were cited. The prominent ones were:

- Air pollution.
- Irresponsible human pollution.
- Uncontrolled use of fossil fuels.
- Man-made induced factors such as excessive carbon emission.

It can be deduced from the data that the human factor is at the centre of climate change.

Although one respondent indicated that climate change did not affect retail properties, most of the respondents shared a contrary view. In the main, climate change was found to harm the retail sector through increased operational costs due to high energy consumption induced by high demand for cooling and heating; damage to property that results in increased insurance premiums; increased prices of goods and services; and higher loss of fresh products than previously experienced.

There are various mitigation measures to combat the impact of climate change on retail properties. Creating a culture of carbon consciousness; increasing the use of renewable energy sources, and empowering employees on environmental issues; a combination of market-driven and regulatory measures that vary from sector to sector; and investment in relevant innovation were cited as the most important and common mitigation measures against climate change and its impact on the retail sector.

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Computer assisted model of multiple analytical structures in economic evaluation of construction projects (id 55; P_055)

COMPUTER ASSISTED MODEL OF MULTIPLE ANALYTICAL STRUCTURES IN ECONOMIC EVALUATION OF CONSTRUCTION PROJECTS

Tendering is one of the most delicate phases of the construction project lifecycle. Precision in economic evaluation will render the basis for decision-making and discovery of potential risks later. Unit price estimate with proper resource allocation is fundamental for the selling price as well as the schedule. In the next step, the project is analyzed to establish the financial structure needed for decision-making. A standard cost structure is commonly used, which recognizes direct and indirect costs. Direct costs categories are analyzed by labor, materials, and machinery operational costs, often with a variable number of subcategories, while indirect costs fork into site and company indirect costs also with further subcategories.

Using alternative wording, we may say that we applied standard cost structure to analyze the project and obtain the financial weight of the project's operational perspective. This, however, is not the only perspective needed. Accounting, for example, will use a somewhat different structure to cost analysis, as they have to take into account different business units and multiple projects. So, if we can categorize each cost item by accounting code, we would have a basis for budgeting. If we applied Machinery Operational Cost Structure to the project, we would get the financial weight of fuel/lubricant/electricity/auxiliary materials for the entire project and could estimate how susceptible this project is to oil price changes.

We should be able to analyze projects by multiple analytical structures so that multiple financial perspectives may be used in estimating project risks.

This paper proposes a computer-assisted model of user-definable multiple analytical structures used to calculate financial weight in each structure node, based on standard unit price estimates. Financial weights in multiple projects can be compared by the same structure.

Keywords: digitalization, cost analysis, estimating

INTRODUCTION

Estimating construction costs is the most important process in all phases of the project. Any project will fail or succeed depending on how accurate the cost estimate is. Recent research in cost-benefit analysis suggests that, at least in capital infrastructure investments, the benefits are grossly overestimated while the costs are grossly underestimated. On average, overestimates in ex-ante benefit-cost ratios are in order of 50% to 200% depending on investment type (Flyvbjerg and Bester, 2022).

Although in non-infrastructure projects the values are more conservative, they still pose a significant problem leading to change orders, delays, and cost overruns. Lately, artificial neural network procedures are introduced in pre-tender estimating procedures. Although showing acceptable accuracy in estimating the cost, the challenges during the learning phase make them too selective for a large variety of construction projects.

In the bidding phase, the contractor is facing challenges in tender analysis from different perspectives before bid/no-bid decisions as it is difficult to introduce a new analysis tailored to emerging market development. After the bid decision is made, the construction phase has to control the costs so that they stay under budget. Although practically every contractor has cost tracking in place, this is often inefficient due to temporal anomalies in the budgetary type of cost control (Bacun, 2019).

Emerging challenges do not stop with a positive bid decision. They continue during the construction phase and during the whole project life cycle. The contractor often has a need to analyze the project from a different perspective to understand how susceptible is the project to the challenge from a particular angle.

Cost tracking systems seldom integrate Bill of Quantity (BoQ) data, schedule, and site reporting, which makes new analysis difficult. This paper addresses this problem and proposes a model that allows quick analysis of project data from different views.

Various authors researched estimating procedures:

The lack of clarity and adequacy of tender documentation is another source of poor estimate accuracy, claims and disputes, shows a study conducted by Laryea (2011). Despite various standards that exist in UK that should help provide better tender documentation, the study registered numerous number of tender queries, amendments and addenda from the participants.

Elfaki & al. (2014) performed an analysis of proposals for construction cost estimation for the period 2004-2014 based on sources from special journals for construction. The analysis showed a research gap in the estimation area and proposes future directions for forthcoming proposals.

Kim & al. (2004) compared three different methods of cost estimation during early phases of the project: multiple regression analysis, neural networks and case-based reasoning. Although the neural network estimating model rendered more accurate results, the case-based reasoning model performed better in long term use and gave more information from the result.

In recent times research on usability of artificial neural networks in estimating the total cost of construction is more and more popular. Juszczyk & al. (2018) obtained satisfactory results in terms of correlation between real costs and cost predictions. The training of the model indicates the neural network suitability for a narrow specific type of construction projects.

An extensive review of past works dealing with application of artificial neural networks for cost, productivity, safety and risk analysis was performed by Kulkarni & al. (2017). They concluded that the authenticity of data and the experience of the modeler are important factors to achieve acceptable results.

Artificial neural networks are primarily used for solving problems related to learning. Their application is mainly in decision making, pattern recognition, optimization, forecasting and data analysis. Doroshenko (2020) presents an overview of their application in construction industry, energy efficiency, structural analysis, construction materials and BIM technologies.

Feng and Li (2013) present a model to estimate the construction cost based on seven parameters: foundation types, structure form, flor number, windows and doors, outside wall adornment, wall body and plane combination. They use a GA-BP type of artificial neural network and conclude that this model, as opposed to BP model can get lower forecast error which makes it suitable for construction cost estimation.

Waziri & al. (2017) conducted a study of neural network application in construction engineering and management. They concluded that neural networks demonstrated potential in construction cost prediction, schedule estimating and productivity forecast, but observed that despite high advantage for parametric modelling and other decision making usage, they lacked general procedure in selection of its initial weights and other initial parameters for effective application.

Unbalanced bidding is not always in the owner’s best interest. Hyari (2016) presents a model that detects such bids by balancing all the bids submitted for a particular project while still maintaining competitive bidding.

Contractors build multiple projects at the same time. Some of them are implemented successfully, some have less success. Their performance is difficult to analyze across the enterprise due to lack of up to date data and indicators measuring the problem (Zavadskas & al., 2014).

Bill of Quantity (BoQ) is largely used by contractor companies. The lack of literature regarding its’ significance in the project, motivated Bin Bandi (2014) to conduct a review of existing literature with industrial experts. The review identified thirty fundamental usages of BoQ in construction organizations during tender period, pre-contract, construction and post-construction period.

The bid/no bid decision is one of the extremely important process during post-tender phase. It is a complex and unstructured process that is influenced by many interrelated factors. Polat and Bingol (2017) propose a Data Envelopment Analysis (DEA) approach to help managers decide whether to engage or not the bid. DEA is a non-parametric linear programming technique used for benchmarking, performance measurement and decision making process.

Accurate estimate of indirect costs is important for any contractor in the bid/no bid phase of the project. That element of the bid lacks accuracy and needs significant improvement. In a survey of 40 large Hong Kong contractors, Chan and Pasquire (2004) found that 40% of surveyed companies consider that indirect cost were both under and over-estimated.

Analysis of estimate data and BoQ takes a significant amount of time in the post-tender estimate procedures (Urquhart & al., 2017). Internal tender review processes by commercial, legal, financial and risk departments consume between 10% and 15% of estimating period, significantly shortening the time for actual estimates. Extensive internal reporting requirements dilute estimator focus on efforts to commercially win the tender.

Literature suggests that indirect project cost account for 8%-15% of total project costs. The study by Saini & al. (2021) also revealed a direct relation between contractor's operational revenue and project's total indirect costs.

Domingues & al. (2017) researched indirect cost deviations in construction projects. They found that 88.4% of the 67 studied projects showed an increase of indirect cost. The impact of indirect costs increase was, on average, the loss of 80% of the predicted gross margin. The study shows that indirect costs and project duration have great importance on the economic performance of the projects.

Unbalanced bidding is a group of techniques that address different allocations of mark-up between contract project items to attempt and increase the win chance. These techniques were neglected in the last decades. Aziz and Aboelmagd (2019) established scientific fundamentals for seven different techniques of unbalanced biding for better pricing of bid items by contractors in civil engineering.

A min-max regret approach to unbalanced bidding was the focus of research done by Afshar and Amiri (2010). They studied the influence of uncertainties, like quantities of works, on possible extra losses using regret criterion.

Unbalanced bidding model was also researched by Cattell & al. (2008) and presented a simplified model that incorporates all three standard types of item price loading: front-end loading, individual-rate loading and back-end loading.

Liu & al. (2009) integrated stochastic simulation, neural network and genetic algorithm to solve the unbalanced bidding problem with stochastic engineering quantities to maximize the present value of contractor's bidding price.

Elattar (2009) proposes a hierarchical model framework for construction project success as an uncompleted hierarchical list of success criteria from different participant's viewpoints. The list is based on individual perception and lacks numerical verification.

METHODOLOGY

The proposed model is based on post-tender bidding procedures and analysis, done between 1992 and 2008 for the estimating department of the largest construction company in Croatia. The goal was to obtain the precise financial weight of different perspectives of bid data, so that project exposure to possible challenges could be assessed. In this paper, the model is significantly expanded to include the evaluation of tender data using arbitrary analytical structures.

The contractor in question was a civil engineering company located in Split, Croatia, and involved in road, bridge, tunnel, and dam construction, including complex facilities. They had about 3000 employees and bidding calculations were conducted by a team of ten estimators using a software package called Tendrix (in Windows renamed as Carpio). They developed their own set of corporate standards for units of work, which consists of specific quantities of resources (materials, labor, equipment, subcontractors, and/or work subassemblies). They also defined technology templates that specified the resources needed per unit of time (day/week/month). The latter was used to estimate total resource quantities, where work progress was limited by the technology used, for example in tunnels. Such totals were later used to load resources into each BoQ item.

The total quantity and amount of each resource were calculated at the tender level. For each BoQ item, the unit price was calculated as the sum of the amounts of resources used. The quantity of BoQ item was used to calculate the total resources used in the item and provide the basis for cost tracking.

For a successful bid/no-bid decision, further analysis is needed. Direct and indirect costs, equipment costs, labor structure, etc. need to be evaluated to assess the project challenges fully. This means that the same data has to be analyzed from a different perspective to give the information-rich enough for decision making.

RESULTS

For this paper, a project of tunnel construction on the highway between the cities of Zagreb and Rijeka was singled out, construction estimated in the year 1994 because this project revealed the need for multiple analyses. All the analyses were performed at the project level.

Fourteen classes of analysis were created, each one with different categories. Eleven were planar with categories defined in a single level, while three had a structure of subcategories up to five levels in depth. Actual analysis was performed on seven classes. Two of the classes were used to analyze the materials database, while the rest of the five classes were used to analyze the BoQ data and resources.

In the Operating costs class, costs were analyzed per machine, per group of machines of the same type, and the total for the project. Five categories were evaluated: fuel, lubricants, electricity, consumables, and others.

In the Chart of accounts class, nineteen cost codes were selected to evaluate the estimated and expected costs of the project and render a basis for cost tracking.

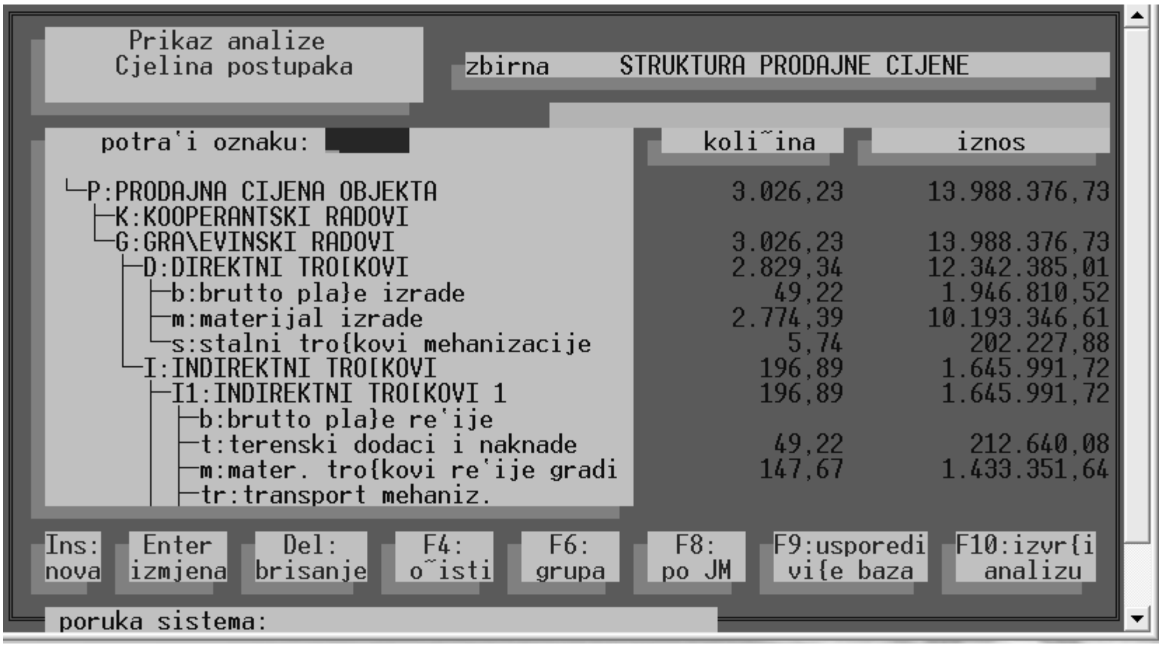
Two classes were created for the slide scale: one for the tunnel and another one for the lower deck. Both classes had the same set of categories: costs of living, transport and communication costs, tools, elements and materials in construction, construction materials manufacturing, fuel and lubricants, and transport equipment. The Tunnel slide scale had three additional categories: stone and gravel manufacturing, converted timber, and ferrous metallurgy.

The class of preliminary work contained sixteen categories including access roads, electrical substation, transport of tunnel equipment, lab, reservoir, compressor, warehouse, etc.

The selling price structure class had two subcategories: Subcontractor works and Construction. The latter was divided into direct costs and two categories of indirect costs. Direct costs contained gross wages of construction, construction materials, and fixed costs of equipment. The first Indirect costs category contained overhead gross wages, site labor allowance, overhead material costs, equipment transport, operating overhead costs, fixed overhead equipment costs, and preparatory works. The second Indirect costs category contained costs outside the site, like insurance costs, interest and bank provisions, reserved funding costs for the guarantee period, costs of the head office, legal obligations, and profit.

Figure 1 presents an actual display at the time of the Selling price structure analysis at a random point of the estimating process.

Figure 1



DISCUSSION

In the above project, the bidding price was calculated with a markup percentage on the actual estimated cost. Estimating actual costs was indispensable to establishing the correct criteria for cost tracking during the build phase.

The actual build cost was calculated as the sum of elementary resources consumed for each unit of BoQ element. The elementary resources were defined as materials, labor, equipment, subcontractor, or unit of standard work. Machines, trucks, and other equipment were standardized per mileage or hour and contained any or all of the elementary resources introducing another level of depth to the calculation. A standard unit of work, for example, a cubic meter of concrete, consisted of any or all elementary resources also introducing another level of depth.

A standard unit of work could contain another standard unit of work which results in multiple levels of depth. Although the depth of the levels is not constrained, in practice no depth resulted in more than five levels, and in the end, all resolved into materials, labor, and equipment. Circular references were checked during the standard definition.

Any non-elementary resource was considered “other”, described with a text description and a price tag.

Subcontractors could have been engaged for the whole quantity of the BoQ item, or multiple subcontractors could be engaged each one serving a particular quantity of BoQ item units, or a particular subcontractor could provide a single or multiple elementary resources. A different margin could be defined for each subcontractor and a particular subcontractor could participate with a different margin for different BoQ items.

Build unit price was multiplied by markup percentage to obtain BoQ item unit price which multiplied by item quantity rendered the bidding price of the item. The sum of the item price across the whole tender structure gave the selling price of the project.

There were five different markups available: a markup percentage for each material, labor, equipment, or subcontractor. This enabled the estimator to apply different markups for labor and machinery and no, or agreed on percentage for materials. The manager markup percentage was applied to the whole build cost unit price.

Any of the markup percentages could be applied at the tender level or any node of the tender structure, which enabled the estimator to lower the bid on the competitive items or group or works and compensate the value on less competitive ones. Any of the markup percentages could be forced upon a single BoQ item, in which case it would override the percentages on the upper nodes.

Multiple analytical structures

Calculating build cost unit price across multiple depth levels has a useful side effect. All the quantities of elementary resources for a single unit of BoQ item are known. This is essential for site cost monitoring and tracking. Further, it facilitates linking BoQ items with schedule activities and their resource loading. Each activity consumes resources of a single or multiple BoQ items and such a link enables activity cost tracking and control. These links also enable schedule analysis by the same classes used to analyze BoQ data which controls the correctness of schedule data and renders a time dimension to the class analysis.

Simple calculation of each resource quantity is mandatory primarily for procurement but does not give useful information for equipment engagement which is needed to estimate the actual cost of equipment usage and the number of operators needed. The number of operators needed influences the schedule and selected number of shifts. This further influences activity duration which changes the fixed cost of equipment.

Machinery direct costs are commonly analyzed with the Equipment ABC class which consists of Operating costs (A), labor (B), and fixed costs (C) categories. Operating costs are further analyzed as fuel, lubricants, electricity, auxiliary materials, and other. In the above project, there were a total of 25 different lubricants and five types of fuel needed by different machines.

However, the situation gets more complicated if we consider another project perspective, the Cost Accounts Class. When fuels are used to operate the machines the cost is recorded under the account code for fuels. The site workshop uses both diesel and gasoline for cleaning and testing and in that case, the same fuel has to be recorded under the auxiliary materials account code. On the other hand, there are other materials besides fuels that will get recorded under the auxiliary materials account.

This proves the need for project analysis via multiple analytical structures or classes to understand different perspectives of the project. More to the point, a single resource, like the fuel above, must allow categorization into multiple categories, one per class. This means that the system must allow the assignment of a particular category to a resource for each class defined. This implies that there will be a register of classes where categories or a structure, as in Figure 1, are defined.

As unit price analysis implies resource specification and both units of work and elementary resources resolve in the end into elementary materials, labor, and equipment, categorization of elementary resources will enable the automatic analysis of the project from different perspectives. Further, a BoQ element could be assigned a category in a specific class, in which case the whole financial weight of the element would fall into the selected category in the class, overriding the categorization of its resources for that class. By the same principle, the categorization could be forced on any node of the BoQ structure overriding the eventual categorization of any sub-structure nodes and their resources.

Linking schedule activities to BoQ items will enable the calculation of activity cost at bid time and compare it to actual cost during construction. The schedule can be analyzed by the same classes used to analyze BoQ. A particular activity or group of activities can be assigned a category in the same way as a node in BoQ structure, overriding sub-structure analysis while still maintaining financial bid weight.

This approach can be further expanded. The class structure is just that, a structure within the class registry with a category name and some other attributes. The class structure can be arbitrary, of any depth, and its leaves are category candidates to be assigned to a resource or a node in BoQ or schedule activity. By traversing the BoQ nodes and items or schedule activity links, the financial weight of the class category can be calculated and totaled across the project. Upper nodes in the class structure will be calculated as a sum of sub-structure values.

It is easy to imagine an Environmental class structure with categories describing green elements construction, noise levels, or hazardous materials and calculate the amount tied influenced by each category.

An obvious project perspective that comes to mind is a Risk class where schedule activities could be assigned a category of arbitrary structure and amounts in each category calculated.

The ability to analyze a project BoQ or schedule by multiple arbitrary class structures opens unlimited possibilities to the estimator.

The ability to design the shape of the class structure, allows the contractor to quickly confront emerging market challenges by creating a new class, assigning class categories to elementary resources, and analyzing the project. This could be valuable both in the decision-making phase and during the project build phase. During the build phase, such an analysis will reveal projects' vulnerability to new market conditions.

The downside of this approach emerges from the very nature of class structures. If we allow the class structures of arbitrary shape, then the categorization of the resources must be manual. This is addressed in the Model proposal section. The elemental resources can be also structured, for example, all fuel types in the Materials data set could be grouped in a Fuels node. This would allow the assignment of all fuel types to the Fuels category in a single action. Each fuel type could still be accessed using its inventory code, as usual, some overhead effort would be needed to maintain nodes/groups in the Materials data set, but it would greatly simplify class analysis.

Model proposal

There model consists of three components: the class registry, the category assignment procedure, and the class analysis procedure.

It requires QoB and Schedule data organization as described in the Discussion section.

Class registry

A class registry item is identified by a name and an abbreviation which are presented to the user when selecting the current class for category assignment. A class record has a target identifier which tells the system target is current when the calculation procedure is invoked. There are five possible options: materials data set, labor, equipment, QoB, and schedule. There can be any number of classes defined in the registry. The registry is searchable by name and abbreviation.

Each class has a tree-like structure of categories. Each category is defined by the name and an abbreviation. The abbreviation is unique inside a class. Categories with identical abbreviations in different classes allow cross-class comparison of data. A category record inherits the target identifier from the class. It also contains a parent identifier so that the tree-like structure of any shape can be maintained and an ordinal by which a particular level is sorted. Ordinals need not be unique in which case the records from the same level and same ordinal are processed randomly.

The class structure is shaped with four functions: add a new category, add a new subgroup, edit the selected record and delete the selected record. Add a new subgroup adds a new record as the first record at the level below the selected record. The selected record becomes a parent record. Any target record that was assigned a category that became parent will be considered invalid and the new category selection will be forced during the calculation procedure.

Add a new category adds a record at the same level as the selected record. It inherits the parent of the selected record. Edit a category function allows for editing of category attributes and deleting a category deletes the selected category. If the delete function is invoked on a parent, the whole substructure, regardless of the number of levels, will also be deleted.

Any category of a parent can contain additional attributes, like direct/indirect/other cost indicators and accounting codes. The accounting code, if applicable, would render the total amount per account for the selected class or project perspective.

The structure has additional three functions: printing the class structure and calculated values, invoking a new calculation that deletes previously calculated values, and cross class comparison. Cross class comparison will show the values calculated for a category in any other class that the same category abbreviation.

Category assignment

Category assignment procedure maintains a many-to-many dataset between the class categories and target records. The user enters any of the data set targets (materials, labor, equipment, BoQ or Schedule), selects a record that needs categorization and invokes category assignment function. He/she is presented with all the assignments the selected target record has across all the classes. He/she can add a new assignment and correct or delete an existing one. The system will permit only one category assignment per class.

If a new assignment is selected and no class is current, the user is presented with the class registry to select the current class. The selected class remains current until the user invokes the class registry again. After the current class is set, the user is presented with a class structure from which he/she select the category to assign to the selected target record (material, labor item, machine, BoQ item, or schedule activity).

The user will not be permitted to select a parent record in the class structure, only its leaves, only a single category. He/she can, however, select a node in the target data set and the system will create/change assignments to every item in the selected substructure.

Resource data sets can also have a structure defined. Category assignment to an upper node greatly simplifies the job. In the above project, Fuels and Lubricants was a node with a structure of 35 items. There was a group of fuels, a group of oils, and a group of lubricants. Selecting the ABC Equipment class, the category of Operational costs was assigned to the Fuels and Lubricants node, and all 35 items were categorized in a single action. When using the Machinery Operational Costs class, the category Fuels was assigned to the Fuels group and all five fuel types were categorized in a single action.

Class analysis

The analysis of a particular class is invoked from the class structure display. If the analysis of selected data has already been performed, the values of the class structure points are displayed. If not, the target menu selection is displayed and a target is selected. In most cases, targets are BoQ or schedule for a particular project.

In the first step of the analysis, the system checks that all the target records have a category assigned. If an uncategorized record is found, the category assignment function is invoked and the user is prompted to assign a category. In the next step, all the calculated values are initiated.

In the third step, the system traverses the target structure to the full depth of the structure and resource analysis. If it finds a BoQ element that has an assignment to a class category, it will take the total value of the element (unit price * quantity) to the class category and continue. If the BoQ element has no class assignment, it will drill down into the element's resources and the value of the resource for the full BoQ element's quantity. As each resource can be assigned a different class category, the total value of the element will be distributed among assigned class categories.

After all the elemental categories are evaluated, all upper nodes of the class structure are calculated as the sum of the nods in the lower level.

The result is the financial view of the project where financial weights are distributed according to the selected class structure. The same project may be analyzed by multiple class structures, as many as needed, which renders all the necessary financial perspectives for bid/no-bid decisions.

CONCLUSIONS

A thorough post-tender analysis is essential for the bid/no-bid decision for the contractor. Different financial project perspectives need to be carefully evaluated. This paper proposes a computer-assisted model of financial analysis of a project, using an analytical structure tailored to user needs.

Each project can be analyzed using any number of class structures. The same class structure can be used to analyze different projects evaluating project performance against others by each category.

As the class structures are just structures that describe a particular view of the project, the model can be expanded to analyze the project from other standpoints, like environmental or risk exposure or any other perspective that is needed.

The model allows the contractor to design new analytical classes and shape their structure. This allows quick reaction to emerging economic challenges and analyzes project susceptibility to new market conditions.

Future work will be done towards the comparison of different classes and combining class values into multidimensional otherwise unrelated data to obtain compound perspectives of a project.

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Developing and Delivering Competency-Based Training and Assessment in Support of the UN's Sustainable Development Goals (id 66; P_066)

ABSTRACT

This paper is based on 30+ years of experience developing and delivering training to mid-career path working professionals, nearly all of whom come from developing countries and most who speak English as a second language. In those 30+ years, we have adopted 6 "standards" or "specifications" that we found consistently produce COMPETENT practitioners while at the same time developing or enhancing the CAPACITY of those organizations who are paying for their training.

These are the 6 Standards or specifications we have adopted and will explain in this paper and presentation:

DESIGN our course content using the ILO's "

Considering legislation changes to include Value Management planning using suicide prevention designs in homes for Risk Management in Design Planning (id 71; P_071)

CONSIDERING LEGISLATION CHANGES TO INCLUDE VALUE MANAGEMENT PLANNING USING SUICIDE PREVENTION DESIGNS IN HOMES FOR RISK MANAGEMENT IN DESIGN PLANNING

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Abstract

Built Environment has design purpose to construct environments for society to enjoy, with modern times providing combined work and occupation situation. Users can benefit from further human wellness research impacts. Numerous studies on improving work-space, productivity and improving health and healing environments provides a substantial evidence base for improving the 'home construct' using a cost/benefit analysis. This scoping review analyses existing peer reviewed literature into health and healing environments, learning and workspaces by including environmental psychology, economics, and architectural design aspects. Economic considerations for comfort, safety, security for improving mental health by design are considerable to improve emotional wellbeing in homes. This research identifies design methods as a qualitative analysis to be compared and quantified against pareto analysis of design impacts using economic modelling. The pareto optimality (cost-benefit analysis) considers societal wellbeing of the greater impact of individual loss of life, or intentional injury event. These can be considered as impacts to greater society, and future generations. Work, leisure, exercise, child raising, home schooling, and manufacturing now exist alongside modern day-to-day residential activities, through lock-down periods. Residential design methods can be compared against environmental psychology methods used for mixed use spaces to provide design impact information. By quantifying values to remedy negative impacts of confinement, such as COVID-19 we can provide impact values for better design. Legislation provides rectification and justice after an injury event in a built environment; however, this research will consider economic planning analysis to support prevention. Impact values can be used for considering intensive home use impacts of lock-down events, against existing legislation research into building standards for mixed use environments. This design research aims to improve mental health and wellbeing in homes by design, to combat rising suicide rates in at-risk groups with focus on youth, middle age, and unemployed groups in Australia.

Keywords: Building design, Suicide Prevention, COVID-19, Value management, Economics.

Introduction

Built Environment has the design purpose to construct environments for society to live and enjoy. Over the last decade approximately 9500 to 24000 building approvals occur each year as shown in ABS statistics from June 2006 to June 2021 (statistics, 2021). Recent lockdown periods highlighted the frustration of people where the home construct is not set up for work, safety, and home schooling, where building approvals do not account for mixed class uses. Recent lockdown events have resulted in injury and suicide events in more homes (Manzar et al., 2021). The rise of suicides and suicide attempts has increased in recent times, that can be directly or indirectly influenced by lock-down events and emotions related to these events (Manzar et al., 2021).

This literature review will examine housing uses in modern times, that is providing home uses expanding into mixed use occupation. This review is scoping benefits to be gained from further human wellness research impacts. Current legislation provides construction standards with aspects for health and safety, neglecting environmental design psychology impacts such as wellbeing issues, as presented in recent times. The 'gap of knowledge' regarding suicide prevention in environmental design is broad, with previous research covering health and healing environments, workspaces with this research connecting research benefits into home designs. This research will provide increased public safety in homes during lock down (safety) events. The knowledge available in previous building design studies can incorporate biophilia, social and spatial design as part of wellness research, including ART and SRT as part of this review for housing designs.

The scope of the current study has been designed correlating information that home designs can benefit from knowledge expansion in the following areas:

Numerous studies on improving work-space, productivity and improving health and healing environments provides: a substantial evidence base for improving the 'home construct' relative to a cost-benefit analysis.

This scoping review compares recent research (10 years) and key findings in environmental psychology, construction economics and building design. Design methods for wellness include Stress Reduction Theory (SRT) and Attention Restoration Theory (ART). Design methods of SRT and ART are examined to address comfort, safety, and wellbeing in homes, by design. Key theory foundational research has been included by Ulrich and Kaplan into biophilia, SRT and ART (Ulrich, 1984, Kaplan and Kaplan, 2008).

Building legislation for mixed-use adoption is considered for homes because: work, leisure, exercise, child raising, home schooling, office work and manufacturing exist alongside residential activities, in lock-down periods. Residential design methods can be used (compared) with environmental psychology methods adopted in commercial mixed-use spaces for improving home designs, to remedy impacts of confinement.

Preventative (suicide/design) measures: Legislation provides rectification and justice after an injury event in a built environment; however, this research will combine preventative measures for injury events, and consider existing virus impacts of intensive occupation.

National Construction Code (NCC) Legislation research into building standards for homes, and mixed use environments, provides overview (find gaps) in design and safety legislation provided for safety and wellbeing in homes.

A cost benefit Value management (VM) design will consider home design aspects of, safety, security, health, comfort, and family for design, whilst including VM suicide prevention impacts, for homes.

By comparing health and wellbeing benefits of biophilic, social and spatial design for VM we can model future economic quantification toward pareto optimality analysis for suicide prevention awareness. Future Pareto optimality modelling can provide society wellbeing quantification for greater impact of individual loss of life or injury events. A value cost/benefit VM impact to greater society can be used for home design planning. Economic modelling is useful for health awareness and suicide prevention in designs, by creating information for VM planning in future designs.

The research included search terms surrounding environmental psychology, suicide prevention and environmental design. Secondary searches and expansive research were conducted with many others too numerous to list, as the research is examining theory related to architecture, economics, psychology, legislation, social policy, suicide prevention, COVID-19, and others. The search terms list is very expansive due to the topic uniqueness as unresearched emerging home design theory.

The research combines research into suicide prevention as mentioned previously that spans across academic disciplines of building design, economics, engineering, property, Australian law, building codes and regulations. This review is a small section of research in this area conducted by the primary author. Considering all the expected findings above, the current study aims to improve mental health and wellbeing in future home constructs', by investigating and scoping design impacts qualitatively and quantitatively to provide a holistic evidence based design methodology for increased suicide prevention in Australian and International homes.

Methodology for carrying out this Literature Review

The methodology for the research into theoretical design methodology identified gaps in knowledge for suicide prevention design in homes. The "gap in knowledge" for research shows there is no research or limited knowledge existing for 'suicide prevention in homes using building design'. This scoping review identifies wellness benefits provided from previous research into suicide prevention in healing and health environments. Existing wellness research has also been conducted into healing environments and workplaces that can be used in home designs.

The literature review shows environmental design psychology benefits with clear connections between Stress Reduction Theory (SRT), Attention Restoration Theory (ART) and the use of Biophilia design. These design methods provide wellness benefits through environmental psychology design for healing and improved wellbeing and productivity in workspace environments. The literature review has identified knowledge that can be used for suicide prevention in homes for wellness benefits and for injury prevention.

Suicide prevention can be bolstered using design methods of SRT, ART both including Biophilia and social and spatial design methods. These design methods can be used for designs in homes with a demonstrated connection for wellbeing design impacts. Literature reviewed shows the link to wellbeing with restoration and stress reduction that can be used for injury and suicide prevention by design in homes. Existing design methods for commercial and mixed use spaces provide compliance areas for building information, as researched related to homes. The review of the NCC building legislation incorporates mixed-use legislation to highlight safety issues with design for homes and the uses as mixed use spaces through lockdown events, in an attempt to prevent injury events and/or suicides.

This scoping review findings can be utilised for combatting rising suicide rates in high-risk groups of youth, middle-aged males, unemployed and all mental illness affected persons in general. The suicide prevention uses and methods for homes combines access and means restriction with positive wellness impacts as a holistic prevention research theory and scoping (provisional) methodology.

1. Environmental psychology: Stress Reduction Theory (SRT)

Studies on SRT for improving work-space, productivity (Peters and D'Penna, 2020) and improving health and healing environments (Connellan et al., 2013) provides evidence for the improvements of home-construct considering the aspects of safety, security, health, comfort and family. Stress reduction theory can be used for improving health and safety in homes, that was first proposed by Ulrich (1983) and the Biophilia hypothesis expanded by Kaplan and Kaplan (1989) including Attention restoration theory (ART).

1.1 Biophilia and SRT

The effects of the built environment on human perception, emotions and behaviour has been valued and improved by architectural and psychological researchers for decades (Zuniga-Teran et al., 2020). Buildings are historically built for comfort and function with aesthetics before modern century design shift to arts and crafts for aesthetic preferences.

Recent design methods focus on building function and services improving reliability, efficiency and cost reduction while putting paramount importance in achieving legislative compliance. The interaction of humans and nature is defined in environmental psychology studies, with a clear link between natural environments defined across research investigating restoration (Nilsson, 2006). Restoration is related to wellbeing that translates into psychological and physiological advantages of nature environment exposures (Berg and Joye, 2012).

Research into restoration and wellbeing has included benefits of walking in nature (Nghiem et al., 2021) and having a window view of (Ulrich, 1984) showing proven restoration benefits. The restoration experienced in healing environments is the most extensively researched part of wellbeing in the built environments field (Abdelaal and Soebarto, 2019, Golembiewski, 2010, Connellan et al., 2013). Design theory research is dominated by the two Biophilic theories of nature's positive effects for human wellbeing that are; Attention restoration theory (ART) and Stress-reduction theory (SRT), provided that the first part of this scoping review focuses on SRT.

SRT provides benefits for users from a biophilia perspective that aligns with Wilson's biophilia hypothesis (Wilson, 1984), where humans, as a product of evolution, have an innate affinity with living things and the natural world in general (Wilson, 1984). In SRT, this implies that built environments that are devoid of nature and or natural shapes and patterns are perceived by humans as a source of potential threats (Oana et al., 2020). Environments that are unnatural for occupation, over time, are leading to a stress response. Whereas, elements of nature such as water, greenspaces and treescapes elicit positive affective responses, as an evolutionary response to increased chances of survival (water security) (Nicolosi et al., 2021).

The combination of these processes results in a more rapid reduction of psycho-physiological stress when people are exposed to scenes of nature, as compared with no exposure to nature (Nielsen et al., 2021). Ulrich demonstrated patient recovery rates showing an average of 9.3% quicker recovery from surgery if they were placed in rooms with a window showing a view on nature vs. windows showing a featureless brick wall (Ulrich, 1984). Individuals also show quicker recovery from stressful situation with natural landscapes where psychophysiological response can decline from perception of spaces and emotions attached to spiritual or cultural connections to spaces (Escolà-Gascón and Houran, 2021).

Stress reduction, relaxation and wellbeing activated by experiences in nature has beneficial emotions and positive psychological experiences (Berman et al., 2019) for stress reduction (Peters and D'Penna, 2020) that provides benefit for users. SRT and ART can be used for inclusive benefits for cost/benefit pre-construction planning as a value management tool and suicide prevention consideration.

Although SRT is similar to ART supporting psychological evolutionary foundation, studies based on SRT focus to restorative effects of nature exposures through physiological stress quantification.

1.2 Spatial design and SRT

Spatial design considerably increases wellbeing in homes by wayfinding (Mackett, 2021), with spatial designs including safety and refuge (Peters and D'Penna, 2020). Spatial design for safety and security provides wellbeing with further wellbeing benefits from including nature in home designs. Biophilia and SRT designs can include benefits for home designs with lowered risk of injury events (Thodelius, 2018) and boost wellbeing (Julie, 2019). By using spatial design aspects with biophilia methods, it can provide improved wellbeing and serve to decrease impacts of isolation (Connellan et al., 2013) and social deprivation, to provide a sanctuary for safety, restoration (Mackett, 2021) and improve wellbeing.

1.3. Social design and SRT

SRT includes design method as a focus for human wellness in the field of environmental restorativeness that focuses on psycho-physiological stress as wellbeing (Escolà-Gascón and Houran, 2021). Human connections with nature are evolutionary and people have constructed designs apart from nature in modern times. Stress reduction theory provides evidence that the human subconscious has not adapted to modernized urban settings, or that more urban and unnatural settings provide stress and abject human reactions. Stress reduction theory can incorporate sustainable designs for wellness and promoting activity such as social design that covers a variety of scales (Zuniga-Teran et al., 2020, Weber and Schneider, 2021). Social designs provide comfort with green access, social views to public spaces and natural lighting and ventilation with comfort that is conducive to creative working (Peters and D'Penna, 2020).

In larger social applications considering urban scale, new design routes in cities, (Weber and Schneider, 2021) using blue or green spaces within infrastructure works (Newton and Rogers, 2020) and related design strategies provides for increased mixed-uses of green infrastructure approaches. Social design combined with design aspects of stress reduction theory demonstrates the importance of developing local responses to social and environmental contexts (McGregor et al., 2017) with ART providing restoration to improve brain functioning to facilitate improved social experiences (Berman et al., 2019).

2. Environmental psychology: Attention Restoration Theory (ART)

The Environmental psychology included in design of health and healing environments provides a relationship of nature with stress reduction as discussed (Chrysikou, 2019, Gaminiesfahani et al., 2020, Connellan et al., 2013, Wang et al., 2020) with restoration and healing experienced by users (Abdelaal and Soebarto, 2019, Blaschke et al., 2020).

Environmental psychology is often considered for aged care designs (Marston et al., 2021) that can be incorporated into home designs for aged space designs and or for children (Gaminiesfahani et al., 2020) to improve function. Environmental psychology for design considering Attention restoration theory can provide benefit of rejuvenation, healing, stress reduction (Connellan et al., 2013) and increase cognitive function (Oana et al., 2020).

The benefits of mental health cannot be understated during lock-down periods (Manzar et al., 2021) where poor mental health effects can trigger injury events (Connellan et al., 2013, Chrysikou, 2019, Wirz-Justice, 2018). ART provides cost benefits as impacts for economic cost/benefit quantification toward pareto optimality modelling to include ART modelling in BIM design and VM pre-construction planning.

2.1 Biophilia and ART

ART assumes natural environments do not require attention to elicit stress recovery, more so that soft fascination (Kaplan and Kaplan, 2008) provides recovery for brain function (Berman et al., 2019).

Restoration best occurs in presence of natural environments (Nghiem et al., 2021) that trigger mild-to-moderate interest (Serenari and Aiyadurai, 2021), even when these are in the background (Ulrich, 1984). ART covers brain reception to environments by attention, focus, processing and cognitive fatigue (Berman et al., 2019). ART focuses on mental fatigue, depletion (Chrysikou, 2019) and restoration of directed attention, a form of attention restoration that is rejuvenated by nature exposures (Peters and D'Penna, 2020).

Cognitive function and brain reception to environmental experiences can provide for restoration relative to cultural belief system (Zingraff-Hamed et al., 2021) and emotional precognitive perceptions (Escolà-Gascón and Houran, 2021). Directed attention as a cognitive resource relative to stress and mental fatigue where depletion typically leads to cognitive fatigue (Egner et al., 2020). Restoration of directed attention occurs by nature exposures for effortless brain processing of complex fractal and natural symmetry (Berman et al., 2019).

2.2 Spatial design and ART

Natural environments can be used as part of spatial designs to trigger spontaneous attention restoration by avoiding excessive emotional arousal, or soft-fascination (Egner et al., 2020). ART proposes three environmental qualities to elicit attention restoration processes: being away, compatibility and coherence (Egner et al., 2020). Attention restoration processes are shown from environmental design research to include fractal patterns (Kumar et al., 2020), natural design methods (Mata et al., 2020) and shapes or colours (Rossi, 2021).

ART and spatial design is useful for positive environmental psychology by wayfinding (Mackett, 2021) and wellbeing improvements to users (McLachlan and Leng, 2021) for emotions, place attachment (Chrysikou, 2019, Connellan et al., 2013), developmental psychology (Gaminiesfahani et al., 2020) and safety (Thodelius, 2018).

2.3 Social design and ART

Environmental psychology considering ART and social design combines positive social psychology design for preventing social exclusion (Wang et al., 2020) and self-isolation associated with suicide triggers (Jiang et al., 2021). Social design for homes including ART methods can provide improvement for dense urban spaces to provide safety through casual observation, social connectedness and reduce isolation. Nature spaces can provide for refuge spaces (Peters and D'Penna, 2020) and sanctuary spaces in homes (Zingraff-Hamed et al., 2021) with natural shading, privacy, weather protection and improved wellbeing.

Social design for public spaces can include prevention information (Pollock, 2019), casual observation spaces for prevention (Raby, 2018, Connellan et al., 2013, Peters and D'Penna, 2020) as a means for suicide prevention. Social design with ART by including public residential nature spaces will increase public wellbeing (Weber and Schneider, 2021), by preventing negative health effects of confinement in homes (Wang et al., 2020).

3. Building legislation for mixed-use adoption in homes (NCC)

This section focusses on the Australian building codes board (ABCB) National Construction Code (NCC) as the principle guiding document for construction of homes. The expansion of home uses during lock-down events is a consideration for improved safety in homes. The NCC can incorporate mixed use legislation to improve safety in homes regarding suicide prevention. Legislation for safety can be reviewed for elements to improve safety and psychological wellbeing in homes or mixed use spaces for lockdown events.

Home designs are provided for domestic dwelling uses and during safety events are used as, learning environments (9b), offices (5) and healing environments (9a) with volumes of approvals for dwellings not considering mixed uses within legislation for homes.

Environmental design to improve wellbeing by considering mixed use research (healing environments and workspaces) can provide benefits listed in sections one and two of this review with nature, not included in the NCC. The NCC includes safety improvements for housing design relative to schooling with wellbeing design to improve anthropomorphism in homes.

This scoping research provides a holistic approach for suicide prevention to evaluate any improvement by existing research into mixed use environment legislation. The scoping shows existing injury prevention and means restriction design codes in the NCC for mixed use designs, that can be considered for improving safety in homes.

The NCC review shows limitations for the code regarding suicide prevention in homes that is a clear gap of information highlighted in this review.

3.1 Learning environments: Class 9b

Legislation stemming from the ABCB's National Construction Code applies to all new homes (dwellings) and or renovations to existing homes. The NCC is the governing document for construction. Local authorities include acts or regulations for building safety and approval standards to inspect a finished building for occupancy approval.

Approvals for dwellings differ by class of building as defined in the NCC and are somewhat different relating to class 9b (school) construction, that provides for comfort, lighting, ventilation, spatial design (safety), that is applicable to height class and higher density buildings.

Class 1a (residential home) legislation lacks safety for school spaces when compared to class 2-9 buildings for mixed uses as a legislative safety limitation. Consideration for wellbeing is included by lighting, ventilation and spatial design for mixed use building legislation that is applicable to home designs for more intensive higher occupancy uses, as a further legislative limitation.

Spatial design for access and safety by barriers at D2.17 (b) and further at D2.24 'Protection of openable windows' that can provide consideration for safety improvements in homes used for schooling by fall prevention legislation for 9b buildings to be adopted for Class 1a.

Systems and services provide safety required for homes by Table E1.6 'Requirements for extinguishers - General provisions—Class 2 to 9 buildings' that provides requirement for class AE extinguisher for class 5 & 9 buildings.

Smoke alarm system are to comply with AS 3786 as class 2-9 buildings require, and in Volume 2 also for residential buildings, with relevance to combine class 2-9 extinguishers in homes for mixed uses, to increase fire safety and reduce injury and manage risk of self-harm events.

3.2 Office spaces: Class 5

Class 5 buildings are required for fire safety considerations listed with smoke alarm systems to consist of alarms complying with AS 3786 and fire extinguisher provisions listed in 3.1.

3.3 Health and healing environments: Class 9a

Fire extinguishers, access and egress, lighting standards AS1680, Ventilation AS1668, Smoke alarms and automatic fire safety suppression devices are increased in class 9a built environments. Minor consideration for comparable legislation is considered applicable for applying to high density residential spaces for elderly, or reduced function persons.

4. Legislation: Suicide Prevention in Built Environments (NCC)

Various researchers suggest that suicide prevention can be considered when designing health and healing spaces (Abdelaal and Soebarto, 2019, Berg and Joye, 2012, Blaschke et al., 2020, Chrysikou, 2019, Connellan et al., 2013, Gaminiesfahani et al., 2020, Golembiewski, 2010) where the NCC review highlights "no provision for suicide prevention through building design" in the NCC. Therefore, the review of the NCC highlights a knowledge gap by this scoping review for theoretical design algorithms, and further that these can be applied to home design solutions.

Design for safety is legislated in the NCC supported by the Australian standards as preventative and passive measures for fire safety, spatial requirements, barrier widths, heights, methods of assembly, material strength, and access restriction for preventing accidents or injuries in homes. The legislative body of knowledge provides historical measures for safety in design, increasing relative to emerging safety issues, methods, and extensive material applications, that can be used for mixed use legislation in homes where the identified gaps for home safety exist.

Legislation provides frameworks addressing changing safety issues, where designers use building Information modelling (BIM) software to achieve compliance in design drawings. Pre-construction planning and BIM is used to suit client design objectives ultimately fast sales, high profit returns and/or operational improvement to suit company bottom-lines.

This review considered legislation by reviewing Volume one of the NCC where Part; C, D, E, and F are considered for safety issues with mixed use applications. Volume two of the NCC provides legislations for class 1a dwellings with residential home design safety reviewed for use in mixed use home applications. NCC legislation review shows the provision in design for physical safety characteristics for injury prevention, with limitations for home designs, for user wellbeing and suicide prevention. A "gap in knowledge" exists in methods used in building design for health spaces to be considered for suicide prevention in homes (Thodelius, 2018, Pollock, 2019, Connellan et al., 2013). Existing suicide prevention design method research for commercial applications (Abdelaal and Soebarto, 2019, Golembiewski, 2010, Connellan et al., 2013) can be considered for homes with NCC legislation mixed use adoption to improve safety.

Access restrictions and safety provisions for high-risk spaces provide supporting theory to the current topic for 'preventing suicide in homes' by access and means prevention (Pollock, 2019), along with improving wellbeing (Kaplan and Kaplan, 2008, Weber and Schneider, 2021, McGregor et al., 2017) and restoration measures (Kaplan and Kaplan, 2008, Egner et al., 2020) for homes. The scoping review of literature into suicide prevention and existing legislation examines a combination of existing design research methods for suicide prevention. These environmental psychology applications of SRT and ART can be applied in environment design for home designs.

The topic for NCC legislation and design costing is a considerable suicide prevention quantification for economics value quantification. The future information gap for research can consider use in Value management (VM) of Construction projects, for economics consideration. Suicide prevention design as VM considerations in the planning process can be used for suicide prevention quantification or impact and prevention measures. VM measures for cost/benefit evidence can be useful by designs to address research information for designers and/or building governance. VM benefits future research can investigate 'limitations' for education surrounding suicide prevention in building designs.

5. Construction Economics as Value Management (Design) planning

Value management (VM) of building projects provide opportunity to improve benefits as presented in project life cycle and life cycle cost planning measurements. VM considers planning decisions for specified performance outcomes, such as legislative compliance.

Value for clients relates to design outcomes and is improved through planning and data analysis. Value can be considered by more detailed designs, changes of plant or change to construction methods to improve value outcomes such as; efficiency, material durability, or aesthetics (Kelly et al., 2014). VM provides opportunity for issues analysis, risk management, function analysis, legal issues, and community consideration to suit design goals. Suicide prevention analysis can include VM cost/benefit measures for residential projects (Wang et al., 2020).

The value workshop phase part of VM planning can include preventative (suicide) access measures, wellbeing considerations for community impact, and suicide prevention design as risk management. Risks can be reduced by social, spatial and biophilic designs as presented in sections 2 and 3 of this research and then evaluated by cost/benefit measures.

Therefore, design consideration for 'suicide prevention' provide VM analysis with a simple 5 point Likert scale benefit/cost table demonstrated below. The table shows base impact measure considerations for VM planning cost/benefits for design planning and includes NCC design planning cost/benefit changes. Construction costs relating to suicide prevention measures and benefits are yet to be quantified in future studies for this theoretical research. For this reason VM planning and cost/benefit knowledge can only be referred to in this scoping review with some further example provided in the cost-benefit analysis in table 1.

Table 1. Cost-benefit analysis - Home design aspects (Booth, 2022)

Conclusion

This review compares existing research into design psychology, construction economics, building legislation and design aspects for comfort, safety and improving mental health. This scoping review finds links between design psychology in healthcare spaces for suicide prevention using designs to promote wellbeing in homes, using SRT and ART aspects of social, spatial and biophilic design.

The review shows some existing design evidence supporting suicide prevention from health spaces that can be used in home designs. The literature review of the NCC shows injury prevention standards that can be adopted for mixed use design methods to be applied to home uses and improve safety in homes during lockdown events. The review shows limitations to legislation considering suicide prevention design measures or methods. The value management section provides examples in table 1 from findings attributed to review findings. The review finds that evidence based design for prevention methods are available and design planning methods can support suicide prevention in design stages. Designers can therefore consider home design aspects identified to prevent injuries and increase suicide prevention in homes.

VM modelling of suicide prevention design methods for cost/benefit consideration and risk management can be considered for future research. VM modelling values can be developed in future studies to calculate pareto optimality values, as a further analysis for suicide prevention planning. Pareto optimality modelling (cost-benefit analysis) considers wider society wellbeing and quantifies greater impacts of individual loss of life or injury event (Thodelius, 2018) for solutions. Economic modelling development can consider greater society impact for future generations (Spence et al., 2010). VM planning would consider means and access restrictions in design planning for risk management, with this research showing wellbeing design benefits for economic cost/benefit value of preventative design. This information can be used to combat rising suicide rates and highlights information gaps in design for suicide prevention in homes. This review provides future considerations for legislative impact consideration, with future research required for more detailed VM as pareto modelling quantification considerations.

This scoping review of literature demonstrates evidence and theory supporting the topic of improving mental health and wellbeing in homes with methods for suicide and injury prevention. Homes improve wellbeing, with VM planning benefits shown for considering design psychology (SRT, ART) methods. Building design using social, spatial and biophilic design aspects can be used for risk management by providing improved safety and suicide prevention.

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How COVID-19 will impact the future of Project Management and the work of healthcare technicians (id 77; P_077)

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How COVID-19 will impact the future of Project Management and the work of healthcare technicians

Abstract

For project managers the impact of COVID-19 has been hugely challenging. A reliance on working remotely has obstructed the collaborative approach often shared among a traditional team environment. Lockdowns have caused major disruption to supply chains, exponentially increasing the risks related to managing projects. In a world beyond COVID-19, project management remains the key to success for many healthcare projects and building work.

Managing the complexity - as throughout the pandemic - requires a new set of technical skills and goals can be reached with extensive communication, collaboration and innovation.

The Covid-19 pandemic has presented an array of novel and acute challenges and serves as a reminder that we live in a complex and unpredictable world. The article demonstrates the complexity from a scientific perspective, offering a framework for creating resilience and agility in an uncertain future.

One key area of focus is the creation of customized flexible spaces in healthcare and adaptive reuse. Another aspect of the article examines futureproofing and design flexibility management. In addition, the use of Value Management approach and BIM will be explored in the context of emergency accommodation providing the opportunity to transform the pandemic experience into more agile and resilient learning systems.

THE GLOBAL EXPERIENZE RESULTS ORIENTED

The impact of COVID-19 was profound for all aspects related to project management, but the development of project management techniques can become extremely important and useful for the future, especially in the post-emergency reconstruction phase.

The global experience in dealing with the COVID-19 emergency has been strongly "results-oriented" overcoming the barriers of professional belonging and organizational ones that limited the ability to work together. Throughout the emergency, everyone had to and knew how to go immediately to the "heart" of the problems and find the best solutions together to give people an adequate response (both in the different phases of evolution of the pandemic and in the management of the largest vaccination campaign ever faced).

The joint work of all professionals (doctors, directors, nurses, pharmacists, healthcare engineers, IT engineers, clinical engineers, engineers management, architects, etc.) has highlighted a great "added value" determined by multi-professionalism and interdisciplinarity, demonstrating that the managerial skills are not something extraneous and additional to the technical and professional skills of those who work in the hospital and healthcare world, but an integral part of the professional identity.

For example, the competence on communication and listening is central, because it has to do with the need to understand the point of view of the other, be it an external or internal stakeholder, to build relationships of exchange and trust.

All professional roles and positions of responsibility move in highly dynamic contexts, in which not only knowledge and know-how count, but knowing how to deal with others, in conditions of great uncertainty.

In particular, the function of middle management is precisely that of being authoritative and recognized in terms of technical and professional skills and that of knowing how to move and relate within the company by leading their group or operating unit. A more complete figure is thus outlined, who knows how to make use of managerial tools through which to influence corporate decision-making processes more effectively.

The development of managerial skills comprises of in particular:

• being authoritative in providing / implementing provisions and enforcing the rules;

• being influential in the work of others, sharing increasingly complex objectives;

• being able to delegate and empower their collaborators with a view to professional growth.

The issue of manageriality is closely connected to that of responsibility. By placing itself in an intermediate position between the strategic top and the more operational divisions, middle management plays a fundamental role in the chain of responsibilities and in the pursuit of corporate objectives.

Having outlined the managerial skills, it will be possible to better orientate the training planning and the development and enhancement policies of the various professional figures and at the same time rethink many of the themes of innovation and challenges contained in the National Recovery and Resilience Plan (PNRR) as common construction sites, for which the ability to work together, in a more cohesive and faster way, will allow us to make a leap in the design and implementation dimension of plans and activity programs.

If we make an international comparison, it is clear that reflection and investment on managerial skills in the public sector and in the health sector are a common priority in many countries (US, GB, FR, CH). The novelty of the approach is to enhance them not as mere professionals, but as real managers, increasingly responsible and protagonists in the management of change alongside company management.

Covid-19 as a stress test

The problems related to the impact of the coronavirus (COVID-19) have been (and in some respects continue to be) a real "stress test" for the ability of companies, bodies, public administrations and organizations in general to be able to carry on and finish projects and programs successfully.

The COVID-19 pandemic has exposed the fragility of *work organizations* and the answers to the problem have been very varied, but it is still possible to draw a *common scenario* from a first moment of disorientation to a general reorganization of work that factors in a new balance.

It is the responsibility of the managers (portfolio, program and project managers) to create and determine all the ways and means necessary to allow a successful conclusion of their activities, using the disadvantages and advantages of the new reality that has arisen. Surely the perception of IT tools by those who, up to that point, considered them unreliable has also changed and it will be possible to resort to a greater percentage of working remotely, having acquired practices and methodologies (as well as a certain confidence) to the management of the mix of activities in presence and remotely.

The approach within companies will presumably change in terms of selection and delivery of projects as will the role of the project manager.

For many, even during the period of the health emergency, it was productive to start planning and planning reconstruction actions, taking into account the changes induced by the emergency both in the way of working and in people's attitudes. There is and will therefore be a great need for project management and also for innovation to make the best use of the new operating methods that we have been forced to experiment and / or use on a large scale due to a global health emergency that has influenced our lifestyles and our values.

No turning back

Nothing will be the same again and the recovery must be supported by a large investment program that needs qualified project managers who are indispensable to manage the investment projects of companies and to support the economic initiatives that will be implemented by public institutions to encourage recovery.

Italy is usually observed and taken as an example for its ability to respond to emergency management, but we are instead lacking in the ability to prevent and prepare in advance.

To guide this reconstruction it is essential to have widespread project management skills as well as a considerable number of highly qualified project managers.

This is all the more true for the Public Administration, which must plan and guide, at the same time, both how to deal with the emergency and how to direct the reconstruction phase.

Surely the discipline of Project Management can help to tackle these initiatives with greater probability of success, most of which are real “projects” or better still “programs” (correlated set of projects).

As is well known, even if the decisions are initially political, they reverberate on the whole Public Administration (PA) and consequently on all of us.

The program and project management can help in the operational phases to deal with the emergency, and perhaps even more so in the previous planning phases, i.e. those of prevention of the emergency itself: therefore, competent people must be involved at all levels, and related measures and actions must be planned and implemented consistently.

NEW OPPORTUNITIES

New rules must be agreed, also in terms of cooperation and solidarity.

This is precisely the time to put people back at the center: in fact, stakeholder-centered values have always been valid, and can constitute a fundamental reference for living both in health and in well-being.

For example, with the arrival of extraordinary funds, in addition to "ordinary" planning, there will be many opportunities for project management in which innovation and digitization can lead to progress and benefits in the most diverse and heterogeneous areas.

Indeed, we all share two key challenges that face our world: the pandemic and climate change. The topic of Artificial Intelligence is not only important as a technology for the future, but also as a tool that can bring benefits to healthcare and make healthcare accessible to more people. We have to make sure that the technology is used to benefit the people who need it most, especially those in low-income countries or in countries where healthcare simply isn't affordable for many.

Participating in calls for proposals, drawing up projects that are innovative requires two things**.** Firstly, profound *competence* in project management issues, as a structural element through whose disciplines we can create a framework capable of supporting the project initiative. The other component needed alongside project management, is the ability to coagulate, in a project proposal, multiple skills, with a *multidisciplinary* character.

In a world beyond COVID-19, project management remains the key to success for many healthcare projects and construction works.

The pandemic demonstrated that the future of project management lies in working remotely, but implementing this mode of work for project management is not easy.

Building a digital team

Building a digital team requires addressing the issues of collaboration, responsibility and culture.

To best manage a virtual team, project managers need to focus on clear lines of communication, clear expectations and objectives, and direct feedback.

When managed properly, working remotely offers many benefits to an organization, project managers and teams including:

- Increased productivity
- Access to the best talent globally
- Reduced turnover rates
- Reduced stress levels
- Better work-life balance

It is essential to pay more attention to the control of suppliers and operators necessary to complete the project, to carefully analyze contracts and perform risk analyses to prevent the risk of interruption arising from a lack of reliability.

Border lockdowns and closures have created serious problems for supply chains, resulting in higher costs and longer lead times.

Project managers need to be proactive to limit the potential threat of a supply chain disruption. This can include the storage of critical materials or the procurement of local alternatives.

For better or for worse, the way project managers work has changed. With this change comes the growing need for retraining staff to improve operational practices and achieve successful project results.

To manage people, given that cultivating the best talent and inspiring innovation does not come easily through a computer monitor, it is essential to improve skills in order to learn new collaborative approaches and lead in a virtual environment.

Project managers thus help guide companies in terms of futureproofing, which is why improving everyone's knowledge to keep pace with emerging technology is critical for long-term success.

Finally, small budgets leave little or no margin for error in managing a project.

Agile management

Agile management has also become a common way to manage the organization and the unexpected. Decisions in conditions of uncertainty, short planning horizons, adjustment of activities which are based on pandemic indicators.

Among the impacts that COVID-19 has produced on the skills of the Project Manager, one of the most relevant is the change in communication inside and outside projects (internal and external communication) which occurred very quickly.

Among the negative aspects, the loss of some pieces of informal communication on the context of the project and the nuances that are acquired in normal conversations over coffee should be emphasized: there is no face-to-face contact and online communication requires more effort and concentration.

The main key competences of project managers at the time of COVID-19 and POST-COVID-19 are:

• Communication skills in a virtual environment and mastery of technologies

• Personal agility: adaptability and rapid reaction to changes in the environment

• Resilience and stress management

• Coping with complexity and the ability to select the most valuable information

• Knowing how to motivate people using empathy and emotional intelligence

• Leadership based on human values, values of sustainability and trust.

Complexity science

Complexity science views healthcare organizations as complex adaptive systems operating in highly complex and unpredictable environments. The view assumes that much of organizational life is unknowable, uncertain or unpredictable and therefore cannot be standardized and controlled.

In this context, already highly complex for the ordinary, all the effective responses to the Covid-19 pandemic proposed by the top and middle management of hospitals and health systems, consistently with the principles of the science of complexity, have emphasized communication, collaboration and innovation.

Insights from complexity science can help healthcare organizations increase their agility, resilience and learning to more effectively cope with future surprise events. The Covid-19 pandemic is a powerful reminder that we live in a highly complex and unpredictable world and that, from the perspective of the science of complexity, when the future is unknown it is necessary to create resilience and agility. Furthermore, an “open” (humble) leadership is necessary, favoring interaction, interdependence and creative tension and identifying the right person at the right time (beyond roles and hierarchies).

All of these processes have occurred in health organizations that have responded effectively to the Covid-19 pandemic. In the construction field, hospital and healthcare construction was one of the few types of non-residential buildings that increased over the course of 2020.

IMPACT ON HEALTHCARE ESTATE

Contagion control and security protocols put in place at the start of the pandemic are becoming standard for new projects and renovations.

The pandemic has created opportunities for design and construction, as it is understood that health systems must continue to bring their services closer to where patients live and the system is looking for ways to design and build "*futureproofing*" by organizing structures to accommodate whatever happens next, which are flexible and able to cope with present and future crises.

It is essential to rethink current and future space needs, deconstructing buildings in order to understand what is and what is not essential.

These re-evaluations have opened the door to more flexible design options that include adaptive reuse, so as to leave patients in their own environments as much as possible.

Alternative forms of patient care are being embraced, particularly telemedicine.

With the help of technology, telemedicine will bring about changes in the physical building and plant environments; waiting rooms in the outpatient and diagnostic areas will give way to waiting for patients in the individual examination rooms.

Regardless of space decisions, structures must be made as controllable as possible with respect to the spread of infections. While it was recognized during the pandemic that healthcare facilities lacked the infrastructure design to be converted quickly and efficiently to meet infection control needs, new designs must have those requirements. As a result, the pandemic has triggered a "dramatic need" for building controls, improved air quality, increased HVAC capacity and overall facility resilience.

Futureproofing is now part of the planning lexicons of most health systems. "Every aspect of each facility, from arrival to discharge, is reviewed and reconsidered during the design of new or renovated spaces".

During the pandemic, emergency facilities were built very quickly. That "design and build speed" mentality now permeates all hospitals and healthcare projects internationally, even if there is no real consensus on which delivery method is the most efficient. In this regard, in countries where it is possible, more new delivery models are being developed that can accelerate projects. These include Integrated Project Delivery (IPD), Progressive Design Build (PDB) and Modular Design and Construction (MDC).

Fixed point is that the project will fall within the budget and on schedule.

NEW TOOLS FOR A NEW TIME

The pandemic has made it more difficult to keep up with the demands of healthcare companies and hospitals. To this end, prefabrication and modularity have become important tools.

Even if we return to a new normal, some principles will be fixed points in imagining the places of territorial and hospital health care.

Telemedicine will continue to expand and the evolution of telemedicine could establish new patient-health system relationships especially in rural areas where services are often scarce.

It will be possible to create real "*command centers*" that are powering telemedicine solutions, allowing doctors from all over the world to consult and maintain visibility on the condition of a remote patient and to act as a "central call center" for the facility or the system.

The energy consumption of hospitals is typically three times that of other commercial buildings and attention must certainly be paid to controlling and ideally limiting/reducing energy consumption.

CONCLUSIONS

Today we have to work with new technologies, new project management tools and we have to be agile in the way we work and in how we communicate, with new working model as well as new engineering processes. We need to develop flexible working systems, whether it is remote work or up-skilling to improve operation practices.

Above all, we have to keep our people safe, inside and outside our healthcare systems and hospitals, from COVID-19 and future pandemics and we have to do that without harming our planet and ecosystems. We also have to guarantee that we don't compromise our fight against climate change in our preparation against pandemics. This is our great challenge.

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Life Cycle Cost Estimating (id 85; P_085)

Life cycle cost Analysis can promote a Sustainable future

By Larry Dysert

Abstract

For the capital project industries, project teams generally focus on minimizing the capital cost of facility planning and construction. This asset acquisition cost may, however, be a small fraction of the total cost of ownership of the asset that includes costs to operate, maintain, and eventually dispose of the physical asset. For example, a manufacturing plant or a liquified natural gas plant may operate for 30 to 40 years (or more); and the costs to operate and maintain the facilities over that life cycle may exceed to original capital construction cost by a multiple ranging from 20 to 100 or more.

Life cycle cost analysis (LCCA) provides an economic evaluation and estimating methodology for assessing the total cost of ownership over the *total lifetime* of an asset. In order to provide an effective evaluation of costs over the extended lifetime of an asset, LCCA relies on the concept of discounting to provide a methodology to convert various measures of future value (lump-sum, uniform, or incremental) to a present value. The comparison of present value cost estimates between potential alternatives provides a consistent methodology to evaluate the life cycle costs for asset alternatives that may have different time periods for asset construction and operation. Life cycle cost analysis supports effective comparison between competing alternatives where both costs and benefits may be spread over an extended life cycle, improving decision-making for a sustainable future.

This paper will provide a brief overview of Life Cycle Cost Analysis and introduce its applicability to the justification for sustainable construction.

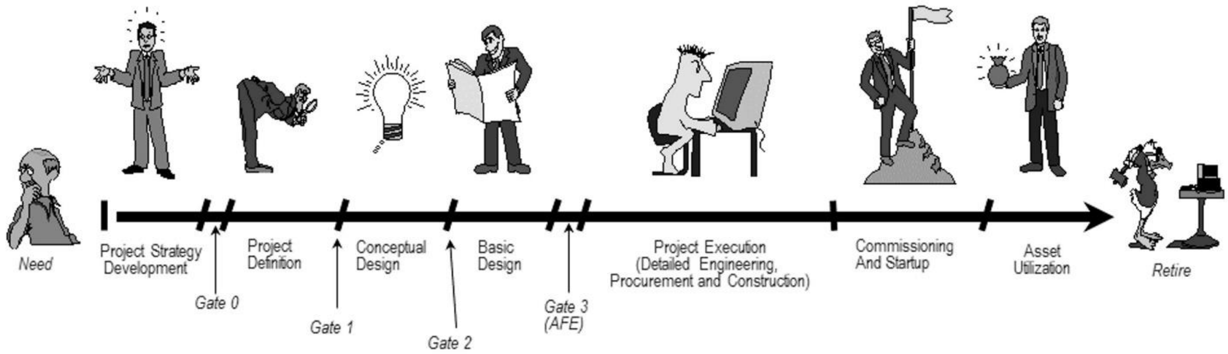
Introduction

An asset is a unique physical or intellectual property that is of long-term or lasting value to an organization or enterprise. Although usually referencing capital assets, the term is inclusive of assets developed under expense costs as well. An asset may be a building, a process plant, a software product, a stage play, or an airplane.

The term Asset Lifecycle is commonly referred to as the sequence of stages that an organization’s assets will go through from the initial identification of the need for an asset through creation of the asset, operation and maintenance, and eventual retirement of the asset. For capital projects (e.g., the development of some type of facility), a stage-gate system of project development is commonly used to support decision-making leading up to the eventual construction of a physical asset. Figure 1 shows a typical stage-gate project development process.

The early project development stages are separated by decision gates, leading up to the final gate (Gate 3 in this generic example) that leads to the Approval for Expenditure (AFE). If approved, the project proceeds to an execution stage for final design and construction of the planned facility. During the progression of the stages, various technical and project deliverables are incrementally developed leading to full project definition upon which to base the funding decision.

Figure 1 – Stage-Gate Project Development Process

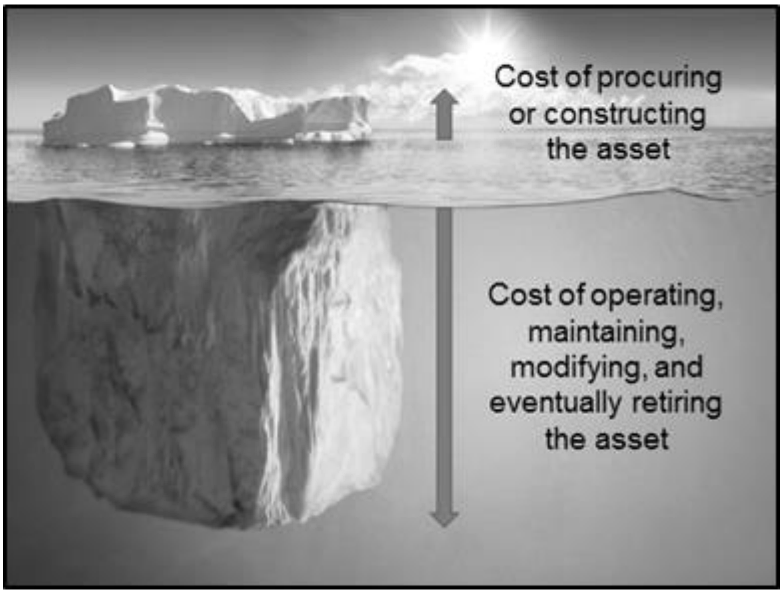


Business Management	Project Team			Operations	Project
Asset Planning	Front-End Loading (Project Planning)	Project Execution (Detailed Design and Construction)	Commissioning and Start-Up	Operation, Modification, and Maintenance	Asset Disposal

During the planning stages, many project teams are focused on minimizing the capital cost of project development (through the construction and start-up of the facility). Although the capital development cost is important to decision making; however, that may not be where most of the money is spent by the asset owner over the life of the asset.

For many (if not most) capital assets, the stage of asset utilization that includes operation, modification, and maintenance costs may easily exceed the initial cost of capital investment, sometimes by multiples of the original investment cost. Figure 2 illustrates this concept.

Figure 2 – Life Cycle Asset Costs



Too often, decisions on capital projects are based on examining only the tip of the iceberg. The cost of operating the asset is not considered as thoroughly as it should be. As an example, for an operating process facility, the operation and sustaining capital costs over the asset's lifetime may be 20 to 100 times the initial capital investment cost. Operating costs typically include such items as operating plant personnel, fuel or other energy costs, and on-going maintenance costs. Other sustaining capital costs typically include refurbishments, modifications, and replacements of components during the facility's lifetime.

Life cycle cost analysis provides an economic evaluation methodology for assessing the total cost of lifetime ownership of an asset, taking into account all the costs of acquiring, operating, maintaining, and eventual disposal of an asset. Life cycle cost analysis is focused on providing an assessment of long term cost effectiveness. A quote attributed to John Ruskin states "It's unwise to pay too much, but it's foolish to spend too little" (Shapiro, 2006). The goal for capital project decisions should be to focus effective cost decisions beyond the initial acquisition cost of the asset, and to include the long-term costs of operating and maintaining facilities into the decision process.

As cost engineers and estimators, our goal is to support decision making so that the best option among competing alternatives is selected, and then effectively managing project execution to realize all goals and objectives. Part of our support for early decision making should be a focus on determining the optimal life cycle cost option. Sometimes, other constraints such as limited capital, may not support the lowest life cycle cost option; however, due diligence should often include identifying life cycle costs as a part of the decision process.

The efforts in influencing and providing accurate data to support decisions during the early stages of project planning will have a direct impact on the long term cost of operation, modifications, and maintenance of our assets. Thus, the sooner that it is possible to influence the decisions made during the early stages of project development, the greater the potential impact we can have to the long term return on investment. Life Cycle Cost Analysis should be under consideration as a Value Improving Practice during early project planning and design activities. The intent should be to design a project or facility to provide the minimum life cycle costs for every asset.

It's always important to remember that investments in an asset, including operating and maintenance costs, are spread over a long extended time period; and that time has a monetary value (Humphreys, 1991). Life Cycle Cost Analysis helps us to quantify the monetary value of time.

Life Cycle Cost Analysis

As cost engineers, and I use that term broadly to describe the skill areas of estimating, scheduling, project controls, risk management, etc., our goal is to support decision making so that the best option among competing alternatives is selected, and subsequently managing project execution effectively to realize all goals and objectives. Alternatives under consideration may involve differing scope (and capital costs) to achieve the project objective; but may also involve variances in utility use, maintenance requirements, and staffing for operations.

Each alternative may involve different durations for the operational life of the asset; and well as different expenditures for maintenance and modifications to maintain the asset during its lifetime. Thus, a form of economic analysis that supports the long-term cost effective selection between competing alternative project scope and designs is required. The goal is to provide accurate comparisons based on the total cost of ownership for developing a new or modifying an existing asset rather than relying solely on least initial capital cost.

It should be noted that Life Cycle Cost Analysis is focused on the cost differences between competing alternatives, identifying the option that provides the lowest long term or life cycle cost. Life Cycle Cost Analysis may need to be combined with other forms of value analysis to support the best overall decision; as life cycle analysis cannot evaluate non-monetary considerations, such as overall comfort of a building or the aesthetics of a process facility that may be located near an urban area.

One of the key objectives of Life Cycle Cost Analysis is to manage the potential conflicts and perceptions of the various stakeholders involved in our asset development projects. Our Project Engineering team often wants to focus on minimizing capital cost. Maintenance Engineering wants to minimize repair costs during operation. The Plant Operations and Production Departments are interested in maximizing the uptime for the facility. Reliability Engineering is interested in avoiding failures. The Finance/Account Group is interested in maximizing net present value. And finally, Corporate Managers and Shareholders want to maximize stockholder wealth and value. Life Cycle Cost Analysis helps to manage all of these conflicting viewpoints by providing an objective, consistent decision analysis tool that focuses on the long term cost of ownership. As an analysis tool it focuses on data, time and money.

Life Cycle Cost Analysis takes a data-driven analytical approach to assess future capital, operating and management costs; and typically converts all costs to a present value to provide a consistent comparison across the alternatives or projects being considered. One of the objectives is to provide an effective comparison across alternatives that may have differing cost patterns at differing times across varying project life cycles. Note that in this paper, value is identified as Dollars, but the particular currency does not affect the analysis.

Discounting

Present value is a concept that recognizes that the value of a benefit received in the future is worth less than the same value received today. This occurs because an amount of money today can be invested to grow to the greater value received in the future. If I can earn an interest rate of 10%, then the value of $100 received a year from now is worth $100/1.1 or approximately $91. Similarly, if I need to pay $100 for an item one year from now, I could invest a present value of $91 at a 10% interest rate to pay the future cost. So $91 is the discounted present value of the $100 cost I need to pay in one year.

Discounting is the process of converting a value paid or received in a future time period (e.g., 1, 10, or even 100 years from now) to an equivalent value paid or received today. The basic concept can also work in reverse.

Future value is the value at a point of time in the future of a benefit received or a cost paid today. If I invest $1000 today at an interest rate of 6%, then in 10 years the future value of my $1000 investment is approximately $1,791. Similarly, If I paid $1000 today for an item today, the future value of the cost I paid today is $1,791 since I could have invested the $1000 cost and earned 6% interest over the 10 year period.

There are also other ways to measure value over time. A uniform series of value is typically the annualized series of value over time that equates to a present lump sum value, future lump sum value, or a gradient (incremental) series of value; and a gradient series of value is an incremental series of value over time (such as when accounting for inflation) that equates to a present lump sum value, future lump sum value, or a uniform (consistent annual) series of value.

Although the term Discounting formally refers to the conversion of a future value to a discounted present value, the term is generically applied to all conversions between present values, future values, equivalent annual values or other conversions of life cycle benefits or costs to a common basis, often for comparison between competing alternatives. We will be looking at and using various discount formulas in life cycle analysis, and they tend to follow a standardized notation whereby we determine a value X based on a given value Y obtained or expended at a different point of time, for a given interest or discount rate and a given number of compounding periods (usually expressed in years).

Discounting calculations are a fundamental element of Life Cycle Cost Analysis; and there are many mathematical calculations (formulas) that can be used to convert from one form of value (present, future, annualized, or gradient) to any other form.

Each conversion formula is typically identified by a standardized notation, commonly expressed as:

(X/Y, i, n)

which implies to find the equivalent amount “X”; given the amount “Y”, interest (discount) rate “i”, and number of compounding periods “n.”

Thus, the formula for the standardized notation (P/F, I, n) can be used to find the equivalent Present Value from a known Future Value, given an interest rate of "i" and the number of compounding periods "n."

Table 1 provides the various mathematical formulas for an array of various conversions between the types of value (Present, Future, Annualized, and Gradient).

Table 1 – Common Discount Formulas

Factor	Notation	Formula
Single Present Value Factor P from F	(P/F, i, n)	$(1+i)^{-n}$
Single Future Value Factor F from P	(F/P, i, n)	$(1+i)^{n}$
Uniform Present Value Factor P from A	(P/A, i, n)	$[(1+i)^{n} - 1] / [i (1+i)^{n}]$
Uniform Annual Series Factor (from P) A from P	(A/P, i, n)	$[i(1+i)^{n}] / [(1+i)^{n} - 1]$
Uniform Future Value Factor F from A	(F/A, i, n)	$[(1+i)^{n} - 1] / i$
Uniform Annual Series Factor (from F) A from F	(A/F, i, n)	$i / [(1+i)^{n} - 1]$
Gradient Present Value Factor P from G	(P/G, i, n)	$[[(1+i)^{n} - 1] / [i^{2} (1+i)^{n}]] - [n / (i(1+i)^{n}]$
Gradient from Annualized Factor A from G	(A/G, i, n)	$[1/i] - [n / ((1+i)^{n} - 1)]$
Modified Single Present Value Factor P from F(escalated)	(P/F^{escl}, e, i, n)	$((1+e)/(1+i))^{n}$
Uniform Present Value Factor with Escalation P from A(escalated)	(P/A^{escl}, e, i, n)	$[(1+e)/(i-e)][1-(((1+e)/1+i))^{n})]$

Note that in Table 1:

P represents Present Value

F represents Future Value

A represents Annualized Value

G represents Gradient Value

i represents the interest rate (discount rate) as a constant rate over the compounding periods

e represents the escalation rate as a constant rate over the compounding periods

n represents the number of compounding periods (typically in years)

Rather than applying the formulas to every conversion required in a Life Cycle Cost Analysis, it is easy to prepare (or acquire) a simplified table of discount factors (multipliers) to facilitate the required calculations.

Table 2 illustrates a sample Discount Factor Table showing the multiplying discount factors to convert a future lump sum benefit or cost to a present value. If the discount or interest rate is 7%, then the present value of $1000 received six years from now is approximately $666 (the individual factors are multipliers to be applied to the future value). In other words, one could invest $666 today at an interest rate of 7% to receive a future value of $1000 six years from now.

Similarly, If the discount rate is 5%, then the present value of $1000 received six years from now is approximately $746. Note that this illustrates the fact that the lower the interest or discount rate, the higher the present value will be. The use of Discount Factor tables simplifies the calculations required in performing discount operations.

Table 2 – Discount Factor to determine Present Value from a Future Value (given “i” and “n”

	Single Present Value Factor: P from F (P/F, i, n)						
	Discount Rate						
Time Periods (n)	4%	5%	6%	7%	8%	9%	10%
1	0.9615	0.9524	0.9434	0.9346	0.9259	0.9174	0.9091
2	0.9246	0.9070	0.8900	0.8734	0.8573	0.8417	0.8264
3	0.8890	0.8638	0.8396	0.8163	0.7938	0.7722	0.7513
4	0.8548	0.8227	0.7921	0.7629	0.7350	0.7084	0.6830
5	0.8219	0.7835	0.7473	0.7130	0.6806	0.6499	0.6209
6	0.7903	0.7462	0.7050	0.6663	0.6302	0.5963	0.5645
7	0.7599	0.7107	0.6651	0.6227	0.5835	0.5470	0.5132
8	0.7307	0.6768	0.6274	0.5820	0.5403	0.5019	0.4665
9	0.7026	0.6446	0.5919	0.5439	0.5002	0.4604	0.4241
10	0.6756	0.6139	0.5584	0.5083	0.4632	0.4224	0.3855
11	0.6496	0.5847	0.5268	0.4751	0.4289	0.3875	0.3505
12	0.6246	0.5568	0.4970	0.4440	0.3971	0.3555	0.3186
13	0.6006	0.5303	0.4688	0.4150	0.3677	0.3262	0.2897
14	0.5775	0.5051	0.4423	0.3878	0.3405	0.2992	0.2633
15	0.5553	0.4810	0.4173	0.3624	0.3152	0.2745	0.2394
16	0.5339	0.4581	0.3936	0.3387	0.2919	0.2519	0.2176
17	0.5134	0.4363	0.3714	0.3166	0.2703	0.2311	0.1978
18	0.4936	0.4155	0.3503	0.2959	0.2502	0.2120	0.1799
19	0.4746	0.3957	0.3305	0.2765	0.2317	0.1945	0.1635
20	0.4564	0.3769	0.3118	0.2584	0.2145	0.1784	0.1486

Discount tables exist (or can be easily created using Excel or other spreadsheet programs) to convert from any one Value Factor method to another (e.g., to calculate Present Value from a Gradient Value, or to determine an Annualized Value from a Gradient Value).

Simple Examples of Discounting

Example 1

One simple example of the concept of discounting is the comparison of two potential investment options.

Investment A requires an expenditure of $10,000 and will provide a return of $11,500 at the end of two years (a potential return of $1,500 after two years). Investment B requires only an expenditure of $8,000 and provides a return of $4,500 at the end of both year 1 and year 2 (a potential return of $1,000 after two years). Which investment provides the highest present value?

Investment A costs $10,000 now and pays back $11,500 in two years. The assumed Discount Rate is 5%.

P = -$10,000 + ($11,500 X (P/F, 5, 2))

P = -$10,000 + ($11,500 X 0.907)

P = $430.50

Investment B costs $8,000 now and pays back $4,500 each year for two years. The Discount Rate is 5%.

P = -$8,000 + ($4,500 X (P/A, 5, 2))

P = -$8,000 + ($4,500 X 1.8954)

P = $529.30

Option B returns the highest Present Value ($529.30 versus $430.50 for Option A) and therefore should be the selected option. This is just a simple example to illustrate the concept of discounting as it only takes into account the initial investment costs and payback or return. A more involved life cycle cost analysis for an operating facility of asset would incorporate operating, maintenance, and other on-going costs as well as disposal and potential salvage costs if applicable.

Example 2

A second example considers a contractor that is evaluating whether to purchase a piece of equipment that will provide estimated rental income, but also involves some predicted maintenance costs. The contractor wants a minimum acceptable rate of return of 6% on the investment over the first four years of the investment.

Table 3 shows the acquisition cost for the equipment, as well as the predicted maintenance costs and rental income. Before considering the effects of discounting, Table 3 shows a potential net profit of $4,000.

Table 3 – Sample Equipment Purchase Data

Financial Impact of Equipment Purchase			
Year	**Cost/Expense**	**Income**	**Net**
0	$38,000	$0	-$38,000
1		$12,000	$12,000
2	$1,000	$12,000	$11,000
3	$2,000	$12,000	$10,000
4	$3,000	$12,000	$9,000
Total	**$44,000**	**$48,000**	**$4,000**

Since the contractor wants to ensure an investment return of 6%, the desired interest rate will be used as the discount rate in converting the Future Values (for years 1 to 4 in the example) to Present Values.

Because the number of discrete periods is so small, it is pretty easy to determine the P/F Present Value factor for each year at the discount rate of 6%; and calculate the Present Value for each of the five years of the analysis. The Present Values can then be summed to determine the overall Present Value of the potential investment. Table 4 shows the Present Value calculations for the equipment purchase example.

Table 4 – Sample Equipment Purchase Present Value Calculations

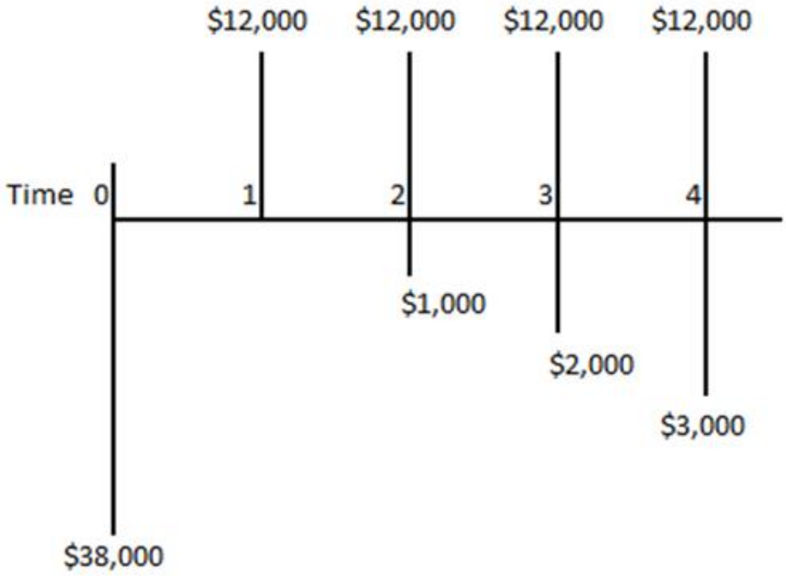
PV Calculation for Discrete Periods at Discount Rate of 6%					
Year	**Cost/Expense**	**Income**	**Net**	**P/F Factor**	**PV**
0	$38,000	$0	-$38,000	1.0000	-$38,000
1		$12,000	$12,000	0.9434	$11,321
2	$1,000	$12,000	$11,000	0.8900	$9,790
3	$2,000	$12,000	$10,000	0.8396	$8,396
4	$3,000	$12,000	$9,000	0.7921	$7,129
Total	**$44,000**	**$48,000**	**$4,000**		**-$1,364**

Since the Present Value of the investment at the contractor's desired discount rate of 6% is negative, the equipment purchase should not be made. Simply investing the equivalent of the purchase price ($38,000) at an interest rate of 6% will result in a higher return on investment.

Note some of the conventions typically used in Life Cycle Cost Analysis. The initial investment cost is assumed to be at time = 0. Sunk costs are excluded from the analysis – the only benefits or costs considered are those after time = 0 (i.e., sunk costs do not require discounting, and therefore do not affect the forward looking analysis). Benefits are assumed to be accrued, and costs paid at the end each year.

It is often helpful to diagram the cash flow impacts of the benefits and costs involved in the life cycle cost evaluation (see Figure 3). In this example, there is an initial lump sum cost for purchase of the equipment at time 0; an arithmetic gradient expense for maintenance of $1,000 and a uniform series of rental income of $12,000. Note that the acquisition costs (at time = 0) would include all costs to that point of time to acquire the asset and may include project planning, design, fabrication, procurement and or construction costs depending on the asset.

Figure 3 – Graph of Cash Flow Impacts of Sample Equipment Purchase



We can then calculate the Present Value for the equipment purchase opportunity using alternative Discount formulas (Gradient and Annualized) instead of the discrete year by year calculations. The total Present Value will equal the initial purchase costs plus the gradient series costs for maintenance plus the uniform (or annualized) benefits of the equipment rental income. We still utilize 6% as the discount rate and 4 years as the life cycle term.

$PV = P_0 + P_1 + P_2$, where

P_0 = Initial Purchase = -$38,000

P_1 = Maintenance Costs = -$1000 (P/G, 6%, 4)

P_2 = Rental Income = $12,000 (P/A, 6%, 4)

P_0 = Initial Purchase = -$38,000

P_1 = Maintenance Costs = -$1000 (4.9455) = -$4,945

P_2 = Rental Income = $12,000 (3.4651) = $41,581

$PV = P_0 + P_1 + P_2$

PV = -$38,000 + (-$4,945) + $41,581= -$1,364

Note that the appropriate discount factors (Present Value from Gradient Value and Present Value from Annualized Value) have been used in the calculations; and that the result is the same regardless of the discounting conversions used.

In this particular example, costs are treated as negative values and benefits as positive values; however, depending on the particular analysis involved this convention may be reversed. Always verify whether costs are treated as negative values or positive values (and similarly for benefits).

Constant Dollars (Value) versus Current Dollars (Value)

When the Life Cycle Cost Analysis values for future years include escalation (or potentially deflation), the analysis it stated to be in Current Dollars (i.e., the future dollars are current for the indicated year of the analysis). This implies that escalation must be considered both in the discount rate to be used in the analysis, as well as included in the values of future costs.

When the Life Cycle Cost Analysis excludes escalation (or deflation), the analysis is stated to be in Constant Dollars. This implies that the discount rate should be adjusted for escalation (the decrease in purchasing power over time), and that the costs identified for future years have not been escalated (i.e., they represent the un-escalated costs for the period of time of the analysis).

Constant dollars are at times referred to as “Real Dollars” (i.e., they represent value units of stable purchasing power). Thus, the cost of a particular good or service would be the same in Year 0, Year 1, Year 2, etc.

Note that the effects of an escalation rate and the discount rate used in Life Cycle Cost Analysis counteract each other. For example, if we are to assume an interest rate (or discount rate) of 10%; however, we also expect an escalation rate of 3% for the inflation of prices over time, then the future value of the 10% gain in interest value is countered by the reduction in purchasing power of the 3% escalation rate. Thus, the “net” discount rate is 7% (10% - 3%) in real terms. Thus, when performing a Life Cycle Cost Analysis in Constant (Real) Dollars, the net (or Real) Discount rate is used that has been adjusted to exclude the potential purchasing power loss of escalation (i.e., the Discount Rate used in Constant Dollar analyses is lower than the Discount Rate used in Current Dollar Analyses).

It is often safe to assume that the potential impacts of escalation (future loss of purchasing power) may affect both costs and benefits relatively equally. Since the impacts of escalation must be either included or excluded for both the discount rate and any future costs, the life cycle calculations will generally result in the same Present Value using either current or constant dollars (if assumed that the escalation rate is relatively equal for the elements of the analysis). Different organizations will have diverse opinions on whether to use current or constant dollars; however, most organizations will simply use Constant Dollars for most Life Cycle Cost Analyses. For rare occasions, where escalation rates may differ significantly for varying elements included in the analysis, then a Current Dollars analysis may be applicable.

Process Steps of Life Cycle Analysis

The following are the generic steps involved in preparation of a Life Cycle Cost Analysis:

Identify and Define the Problem Requiring LCCA

To be effective, each Life Cycle Cost Analysis should have clear objectives. This requires clear identification of the opportunity to be addressed by the analysis, which may involve creation of a new asset, modification of an asset, retirement of an asset or a combination of those activities. The study period or time period should be established. Note that the study period for the analysis may differ from the potential total life cycle of the asset. The type of results or life cycle cost metrics that are important to the eventual decision should be identified. Present Value is the most common criteria used in life cycle analysis, but determination of the payback period can also be important. The discount rate to be used in the analysis should be determined and may be specified by corporate or other financial guidelines.

Develop Potential Alternatives/Solutions to Consider in the Analysis

Life Cycle Cost Analysis is primarily used as a comparative analysis between asset design alternatives. Often, a base case is established that meets the minimum functional requirements of the potential opportunity or project. Generally, the base case may have proceeded through enough project planning and design to have a reasonable cost estimate for evaluation. The design team may then develop a number of alternatives to be used in comparison to the base case. The alternatives may not be developed to the same level of detail as the base case; but must incorporate sufficient detail to support preparation of the cost estimates required for the analysis and life cycle cost calculations. An important goal is to adequately identify the cost differences or incremental costs required by the alternatives.

Depending on the potential projects, both capital and non-capital solutions may be considered as options; and the alternative of making no change should often be considered an option.

Develop the Cost Breakdown to Support the Analysis

Identify the required cost breakdown structure that will support the required analysis. The cost breakdown structure will typically vary based upon the particular problem and alternatives under consideration, but at the highest level will typically include acquisition costs and various sustaining costs required during operation of the asset (operating costs, maintenance costs, replacement costs, and potentially asset retirement costs). It is best to focus on cost elements that will have substantial impact to the analysis and that may differ between the alternatives under consideration.

Collect Data and Information and Prepare Cost Estimates for each Alternative

Effective analyses will generally require a large amount of information to determine reasonable estimates for all the elements of the cost breakdown structure. The goal is to provide sufficiently reliable and unbiased cost elements for each alternative.

Prepare the Cost Profiles and LCCA Model for each Alternative

Develop the cost profile (cash flow) over time for each alternative. Depending on the specific analysis, this may involve costs, benefits, or both. Use the cost profiles to develop the LCCA cost models with the appropriate discount formulas to support the financial analysis. The models should address all significant impacts (sufficiently complex but not overly complex).

Analyze Results

Analyze the results for reasonableness and address any potential areas of concern with the analysis. Prepare supporting analyses such as pareto charts of key cost drivers or breakeven analyses. Test significant cost drivers with different assumptions or incorporate uncertainty (risk) analysis into the model to evaluate sensitivity. Recycle to previous steps to adjust the model if warranted.

Communicate Results and Determine Course of Action

Prepare a comprehensive report to communicate the results of the analysis. This may involve preliminary identification of a preferred alternative; however, realize that management may have other value considerations that may impact upon the results of the LCCA alone.

Components of the Analysis

There are various components of the analysis that need to be addressed in Life Cycle Cost Analysis.

Cost Elements

The cost elements typically involved in project-related Life Cycle Cost Analysis may include:

- The capital and expenses costs of facility acquisition
- Operating costs for the facility (e.g., utility costs, operating personnel costs, etc.)
- Maintenance costs (including routine maintenance, as well as assumed repairs and refurbishment costs)
- Disposal costs (end of facility life)

Salvage or residual value costs (if applicable)

Offsetting income and benefit costs may also need to be considered depending on the specific analysis (e.g., whole life costs)

Note that Acquisition costs are typically identified as Time (Year) = 0 Costs, and the other cost elements are cost occurring after acquisition and therefore requiring discounting applicable to the LCCA model to be employed.

An example of cost elements (cost breakdown structure) for a sample facility asset are shown in Table 5.

Table 5 – Sample Cost Elements for a Facility Asset in LCCA

Acquisition Cost Breakdown	Sustaining Costs
Asset Planning	Operations Personnel Costs
Project Planning (FEL 1, 2, 3)	Feedstock Costs
Detailed Engineering	Fuel/Energy/Utility Costs
Procurement/Fabrication	Planned Maintenance Costs
Construction	Unscheduled Maintenance Costs
Commissioning/StartUp	Planned Replacement/Refurbishment Costs
	Unscheduled Replacement/Refurbishment Costs
	Disposal Costs (including remediation)
	Salvage (Asset Recovery Costs)

Each type of asset involved in a Life Cycle Cost Analysis may have different elements in its cost breakdown.

When initially developing a cost breakdown structure for the analysis, include all potential elements that may be required to support the particular analysis. During LCCA model development, some elements of the cost breakdown structure may not be required and can be eliminated.

Not every alternative being considered in the Life Cycle Cost Analysis may require the same cost elements. Typically, cost elements that have the same discounted cost impact for all alternatives will not need to be considered in the analysis. Life Cycle Cost Analysis focuses on the differences in order to make a selection between alternatives. A cost element that has the same cost impact for all alternatives under consideration does not need to be included in the LCCA cost model, as it will not affect the decision.

Discount Rate

For capital project Life Cycle Cost Analysis, typically the discount rate will be established by the corporate finance group, which will also make the decision as to whether the discount rate is to include adjustments for escalation (i.e., the decision whether the LCCA will be prepared in Constant or Current Dollars).

Each business has a expected minimum attractive rate of return (MARR) for its investments. If the MARR is set too high, then many projects with potentially good rates of returns may not be approved (i.e., they do not meet the threshold MARR). If the MARR is set too low, then it is possible that too many projects will be approved reducing the funds available for other projects (perhaps identified later) that may have resulted in a greater return on investment.

In general, the discount rate should reflect a reasonable rate of return that could be obtained by using the funds in a completely different way than the alternatives under consideration in the LCCA.

The LCCA Study Period

The study period for a Life Cycle Analysis is the number of years (or timeline) to be considered. It may be the same as the overall asset lifecycle (through eventual retirement of the asset) but may differ depending on the objective of the particular analysis. LCCA is less complex when the study period is the same for all alternatives; however, there are various methods to perform LCCA when the study periods vary among the alternatives, but that is beyond the scope of this paper.

Sustainable Construction

The primary focus of sustainable construction is to reduce the construction industry's impact on the environment. This can be accomplished by the use of renewable and recyclable materials in facility construction; as well as reducing energy usage, water usage, waste, and maintenance requirements. Often, goals of improved comfort for the occupants of the facility are included as a facet of sustainable construction, which may potentially lead to improved workforce productivity as well as potential health benefits.

"By virtue of its size, construction is one of the largest users of energy, material resources, and water, and it is a formidable polluter" (Horvath, 2004). The construction industry basically supports all other industries in the creation of the facilities required to support the other industries (residential buildings, office buildings, manufacturing plants, power plants, oil/gas/chemical facilities, roads, highways, etc.). It is easy to recognize the importance of migrating to sustainable construction across all of construction's many forms.

Although it is possible to engage some of the concepts of sustainable construction at various stages during the project development process (refer to Figure 1), it will obviously be most impactful when sustainable construction is established as a primary objective and goal during Project Strategy Development. Subsequently, design decisions can be incorporated throughout the various stages of project planning, detailed design, and eventually construction to effectively maximize sustainability in a cost-effective manner. Thus, Life Cycle Cost Analysis decision making may be incorporated as value enhancing considerations throughout the various planning and design stages of a project.

Concepts of Sustainable Construction

There are many ways to incorporate sustainable construction goals in the development of physical assets and facilities. The list below identifies just a few of many potential sustainable construction opportunities:

- Use of durable construction materials to extend facility life and reduce maintenance
- Use of sustainable materials (such as those that do not use non-renewable materials) to lessen impacts on the environment
- Increasing energy efficiency to reduce energy consumption (this includes both the energy generation aspects of the facility itself, as well as the energy using appliances used in the facility)
- Use of renewable and clean energy supplies to reduce environmental impacts
- Use of energy efficient technologies and materials (such as LED lighting, windows that darken in sunlight to reduce HVAC costs, more efficient insulation, etc.)
- Incorporating energy-efficient designs (enhanced lighting and HVAC controls that can sense occupancy for efficient usage)
- Recycling of water and improving water use efficiency to lessen water usage
- Reducing waste in facility construction and in completed facilities

Cost/Benefits of Sustainable Construction

Sustainable construction is more expensive than typical construction in capital project costs (Hartungi and Pye, 2009); however, the cost variance between sustainable and non-sustainable construction is narrowing as the sustainable design technologies become routine, and sustainable materials become less expensive with growth in demand.

The benefits of sustainable construction, however, are impressive. LEED-certified buildings are reported to reduce maintenance costs by approximately 20% and decrease operational costs by 10% (U.S. Department of Energy, 2011). An earlier study identified an average reduction in energy use of 30% for LEED-certified buildings (Kats, 2003).

To overcome the upfront capital project costs, Davis Langdon (2007) stated that “One of the ways of improving cost competitiveness [of sustainable construction] was considered to be the implementation of life cycle cost tools and criteria in all key phases of the construction process. By taking into account not only initial costs but all subsequent costs, clients could undertake a proper assessment of alternative ways of achieving their requirements whilst integrating environment considerations.”

Simple Life Cycle Cost Analysis Example

For a simple example of LCCA applied to a Sustainable Construction project, consider the construction of an office building. The initial project estimate for the example office building and related infrastructure (parking lots, etc.) is $200,000,000. The owner of the office building is interested in optimizing the life cycle costs for the construction and operation of the office building over a 30-year period; and commissioned the designer to investigate potential design alternatives.

The final design alternative, which will provide LEED certification, involves providing solar panels on top of covered parking spaces that will provide significant electrical generation capacity, in additional to providing covered parking for improved comfort of the building occupants. The solar farm significantly reduces outside electrical supply costs and is integrated into the building management system that provides fully automated lighting control with sensors to detect occupancy to optimize usage. In addition, the HVAC systems are optimized to save wasted energy by also detecting occupancy to optimally control when and for how long the systems would be required to run. Carbon dioxide sensors will detect CO2 levels to engage louvers to allow more fresh air into the building when required for occupant comfort. All building equipment is specified to minimize maintenance and replacement costs over the 30-year period of building ownership.

The costs for the sustainable design option increases the initial project capital costs by 20% to $240,000,000, a substantial increase in up-front building acquisition costs. However, annual energy costs and maintenance costs were estimated to be reduced measurably as shown in Table 6.

Table 6 – Sample Building Economics

	Option 1	**Option 2**
Building Type	Standard Office Bldg	LEED Certified Bldg
Capital Cost	$200,000,000	$240,000,000
Energy Costs	$6,000,000/Year	$2,400,000/Year
Maintenance Costs	$3,500,000/Year	$2,500,000/Year

A Life Cycle Cost Analysis is performed to understand the potential impact of the life time ownership costs between the two alternatives. This analysis is performed in Constant Dollars (i.e., the energy and maintenance costs are assumed to remain fixed over the 3-year study period and the discount rate used for the analysis does not include an annualized escalation rate). The discount rate used for the anal

Table 7 shows the result of the analysis.

Table 7 – Life Cycle Cost Analysis for the Example

	Option 1	Option 2
Building Type	Standard Office Bldg	LEED Certified Bldg
Capital Cost	$200,000,000	$240,000,000
Energy Costs	(P/A, 5, 30) $6,000,000 * 15.3725 $92,235,000	(P/A, 5, 30) $2,400,000 * 15.3725 $36,894,000
Maintenance Costs	(P/A, 5, 30) $3,500,000 * 15.3725 $53,804,000	(P/A, 5, 30) $2,500,000 * 15.3725 $38,431,000
LCC Present Value	**$346,039,000**	**$315,325,000**

In this simplified example, the LEED-certified option provides a savings of approximately $30,000,000 over the standard office building construction.

Although the savings are significant, the final decision may rest on additional considerations. For example, if the owner cannot obtain the additional $40,000,000 in financing for the construction of the building, then the building owner may not be in a position to choose the construction of the most optimal case in terms of life cycle costs. Life Cycle Costs are but one of many factors that might be considered in decision making for choosing between alternatives. Life Cycle Costing is, however, an important tool in identifying long-term costs benefits to sustainable construction.

In practicality, many design options might be considered during project planning; and each option may have an individual life cycle cost analysis prepared to support the selection of final alternatives for all design options considered. Eventually, one or more total building cost life cycle cost analyses may be performed to understand to total impact of the design decisions.

Also, many supporting analyses and reports may be generated to provide additional information to support an informed decision. Evaluation of uncertainty and risk in the model values may be considered. Sensitivity analyses may be run to determine the effect of varying discount rates and length of the study periods. Analysis of other concepts of value (besides life cycle cost) may be important to the asset owner and affect the final decision.

Some common life cycle cost tradeoffs that may affect decisions include:

Constrained initial capital which may value the least capital cost over lowest life cycle cost

Perceived value to remain with an established equipment (or other vendor) rather than choose a lower life cycle cost from a new vendor

Perceived value to choose a less risky alternative over the lowest life cycle cost option

Perceived value to choose a *green* or environmentally friendly alternative

Perceived value of a short payback period

Conclusion

Life cycle cost analysis is intended to measure the *cradle to grave* costs for an asset or alternative under consideration. The basics of life cycle cost analysis were described, and importantly the concept of discounting. Discounting is the term used to convert present, future, annualized and gradient (or incremental) costs from one form to another. Typically, most life cycle costs for the alternatives under consideration are converted to a present value as the basis for comparison. However, the preferred option from the analysis will remain the preferred option regardless of whether present, future, or annualized value is selected as the final form of value for the analysis.

Sustainable construction is intended to reduce construction's impact on the environment and is important to society's future. Sustainable construction may take many forms, and many individual options may be combined in any specific project. More often than not, sustainable construction may be more costly in terms of initial construction costs; however, many costs incurred in the life cycle of the asset (such as operating or maintenance costs) may be significantly reduced. Thus, life cycle cost analysis is an important tool to identify the benefits of sustainable construction.

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AN ASSESSMENT OF THE IMPACT OF SUSTAINABLE CONSTRUCTION PROJECT DELIVERY ON THE ENVIRONMENT IN A CHANGING WORLD (id 86; P_086)

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AN ASSESSMENT OF THE IMPACT OF SUSTAINABLE CONSTRUCTION PROJECT DELIVERY ON THE ENVIRONMENT IN A CHANGING WORLD

ABSTRACT

Sustainability seeks to live in the now while saving for the future. Sustainable construction advocates using recyclable, reusable, and renewable materials during construction and reducing energy and water consumption as well as waste to reduce or possibly eliminate the impact of the industry's activities on the environment. This paper aims to study the assessment of sustainable project delivery on the environment in a changing world. Projects' stakeholders in the construction industry were contacted through structured questionnaires to sieve information. These industry's stakeholders represent the actual professionals of construction industries and can be generalized. Ten (10) sustainable project delivery factors from literature formed the basis for analysis. These include the lower supply of green material types, increased cost of the project, lack of environmental awareness, lack of environmental education and training (technical and managerial), need for change management, ignorance, corruption, pollution, waste generation, and lack of corporate social responsibility (CSR). Data were obtained through 130 structured questionnaires administered to construction projects' stakeholders and analyzed using the Relative Importance Index and Spearman's Rank Correlation Coefficient. The study reveals that there is a strong correlation between sustainable construction project delivery impact and the environment where construction projects activities impacts are greater than 0.5 in all cases and the p-value for the two-tailed test of significance is greater than 0.0005. The impacts of sustainable construction project delivery on the environment in a changing world must be given adequate attention to curb the menace on the environment. The study concludes that construction projects' successes and sustainability can only be achieved through environmental education and training and the use of green material in the projects' life cycle. The study recommends that construction projects participants must plan for sustainability from projects' feasibility studies to ultimate use of such projects to give positive value to such a project in tandem to a dynamic world.

(Keywords: Assessment, Change, Construction projects, Environment, and Impact).

INTRODUCTION

The thought of embarking on projects in the construction industry is not a fairy tale, especially in our changing world. The world is evolving in every sector especially the health section with the current global pandemic of COVID-19. Construction activities also deliver to this sector therefore using environmentally friendly materials will greatly benefit both the health and wellness of stakeholders and every other project participant in the face of global uncertainty. Construction projects are versatile, capital intensive, and impact the environment in many ways. The impact is both negative and positive. Environmental consideration is of utmost importance when delivering construction projects, especially in the area of construction materials procurement. The effects these materials will have on the environment are key to sustainable development. Economic inputs of the industry to a country's Gross Domestic Product (GDP) cannot be substituted to the adverse effects these construction activities will have on the environment. If sustainability is in view, then environmental determinants of healthy construction activities must be adhered to.

Construction projects are unique with distinct set out objectives with the integration of scarce resources and technologies to achieve desired goals. The construction industries unprecedentedly contribute greatly to the Gross Domestic Product (GDP) thus, its sustainability. Sustainability subscribes to living in the now and keeping for tomorrow. Sustainability in the project context has been a growing concern due to resource constraints, the increased number of stakeholders involved, and the balanced requirement of environmental, economic, and social activities (Martens and Carvalho, 2017, Schropfer et al. 2017, Banihashemi et al.2017, Siew 2016). It is crucial to integrate the tenets of sustainability which include environmental, social, and economic factors into the project process. These will challenge the project deliverables and process if the projects' goals must be achieved (Gareis et al.2013, Marcelino et al.2015).

The construction industry is one sector of the economy characterized by construction activities cutting across in magnitude and size from public or private organizations. Construction projects are complex and full of uncertainties involving many stakeholders and have profound impacts on society(Van et al. 2008 and Chang et al. 2016), therefore stakeholders collaboration will enhance projects' deliverables to be met and at the same time ensure high-level sustainability,(Kivila, and Vuorinen 2017, Silvius et al, 2012). Construction activities impact hugely on our environment hence, using sustainable designs and materials helps to maintain a clean and green environment for human existence especially in an evolving world with innumerable uncertainties Project delivery is poised at getting the definitions of the project within its tenets and functionality. Sustainable project delivery is key in a changing world to meet today's needs and also for future use within the life span of such projects.

CONCEPTUAL FRAMEWORK

The definition of Sustainability is widely disputed, and definitions vary depending on the context of its application, but here, sustainable development can be defined as “meeting the needs of current and future generations through the integration of environmental protection, social advancement, and economic property. It is a process of embarking on development without neglecting the privileges of future generations. People must have the right to a safe and generally satisfactory environment favorable to their development – conservation. Sustainability aims to ensure that renewable resources are not depleted and use of non-renewable resources are minimized

Sustainability could also be defined as the management of natural resources to support continued social and economic development in such a way that renewable resources are not depleted, and the impact of extraction and use of non-renewable is minimized. This allows for development but not at an acceptable cost to the natural environment.

Sustainability is relatively a new concept but one that has been widely accepted as a powerful way to envision the future and to move forward. The concept is a challenge to do things differently and to look for opportunities to improve in construction activities beneficial to the environment, society and economy at the same time rather than accepting trade-offs between them. Sustainability is seen as the only way forward for development. It provides the basis of hope for the future and a vision for quality of life. The transition to a sustainable future is a long-term agenda that requires rethinking the way we live, use resources, govern, and do business. Existing resources must be optimized and the involvement of interest groups. In planning for construction projects, there must be deliberate consideration of how to maintain the quality of the environment, human well-being, and economic security in terms of cash flow projections

EVOLUTION OF SUSTAINABLE DEVELOPMENT

The sustainability concept was introduced in 1987, by Brundtland (1987) in his book entitled "Our Common Future:" he defined Sustainable development as "meeting the needs of the present without compromising the needs of the future generation to be met." Three (3) fundamental components to sustainable development were pinpointed; these include environmental protection, economic growth, and social equity. Construction activities promote economic and social advancement and should adequately consider environmental degradation. The commission spotted the imminent conflict between development and the environment and concluded while development is necessary for human existence, It must be 'sustainable' that is, development to protect resources and ecological integrity over the long term, while greatly improving human well-being, especially infrastructure development in a changing world.

The MDGs provide a set of global targets in economic, environmental, and social development adopted by the UN in 2000 and are also crucial steps in the progress towards sustainability. Managing these resources for sustainable development means using, conserving, and enhancing the natural resources in such a manner that the ecological processes that underpin the quality of life are not compromised but managed to at least maintain and possibly enhance the total quality of life for every citizen. National resources are conserved, managed, and used sustainably for the common good and are world-renowned for being *clean, green, and sustainable*. An environmentally informed and educated community is involved in transparent management and planning processes.

TEN (10) PRINCIPLES OF SUSTAINABILITY

ASHE Green Building Committee (2015) highlighted the sustainable principles in the project delivery process. Projects are controlled to achieve the goals of sustainability, (Silvius and Schipper 2014). A construction project becomes sustainable when it has integrated design, site design, water, energy, indoor environmental quality, materials and products, construction practices, commissioning, operation/maintenance, and innovation. A construction project adheres to these principles with there is an adequate and positive understanding of the use of construction resources and their impact on the environment through the incorporation of environmental impact assessment (E.I.A.), especially in a dynamic world.

CONFLICTS BETWEEN THE ENVIRONMENT AND CONSTRUCTION ACTIVITY

Construction clients and government recognize the significant impact the design, construction, and occupation of buildings have on the environment and society. The construction industry and government have a central role in driving sustainable development agenda. Good sustainable design can deliver buildings with low running costs, an attribute that is highly attractive to both society and business (Ochieng et al., 2018)

The impacts of the construction industry should be brought into harmony with the environment and its contribution to overall economic growth should be exploited, all to the advantage of society at large. Similarly, the UN Conference on Environmental Development (UNCED) held in Rio de Janeiro in June 1992, while understanding the importance of construction sector activities for overall socio-economic development, has included in its Agenda 21 a separate section titled: “promoting sustainable construction industry activities”. The agenda recommends a set of actions to be taken to reduce the impact of construction activities on the environment.

The agenda has placed such an importance on sustaining construction activities and practices within the environment since the construction industry is a major contributor to the overall socio-economic development in every country and a major consumer of natural non-renewable resources, on the other hand, a significant polluter of the environment.

Recent studies showed that one-tenth (1/10) of the global economy is devoted to the construction and operation of residential and office buildings and one-sixth (1/6) to one-half (½) of the world’s major resources are consumed by construction and related industries (Rainer Nordberg (2001). The building industry alone consumes 40% of the world’s energy, 25% of forest timber, 16% of the world’s freshwater. 7% of Sulphur oxides produced by fossil fuel combustion are produced through the generation of electricity used to power homes and offices. 50% of Co_2 emissions (mainly in industrialized countries) are a result of operations in building-in-use (heating and cooling). Indoor air quality is inadequate in 30% of buildings around the world. Current practices in construction industries are tilting towards better living conditions sustainably.

CONSTRUCTION METHODS AND MATERIALS FOR SUSTAINABLE CONSTRUCTION PROJECT PERFORMANCE

The construction industry is the biggest user of our natural resources especially fossil fuel and greatly impacts our environment negatively. Sustainable construction means using renewable and recyclable materials for new and old structures, reducing energy consumption and waste minimization. The primary aim of sustainable construction is to reduce the industry’s impact on the environment (Gatley, 2019). There are several construction methods materials for sustainable construction project performance. Sustainable construction goes well past even after the completion of such a structure to incorporate the building life span. This means that building elements must have a positive influence on our environment.

Construction stakeholders should be concerned with construction methods and materials that will be environmentally friendly. This brings us to where we must look at our design and materials to effect green construction. These include but are not limited to proper lighting, heat control, insulation, and alternative sources of energy like using solar panels, timber, and other eco-friendly building materials for sustainability. Alternative brick materials like mud, wool even cigarette butts can be used to create bricks that are just as strong without a need for the kiln fires that result in harmful emissions(Gatley,2019).

Using sustainable design methods is imperative for eco-friendly construction but the only barrier is cost.

FACTORS AFFECTING CONSTRUCTION ACTIVITIES FOR SUSTAINABLE CONSTRUCTION PROJECTS DELIVERY

Ten (10) sustainable project delivery factors from literature formed the basis for analysis. These include the lower supply of green material types, increased cost of the project, lack of environmental awareness, lack of environmental education and training(technical and managerial), need for change management, ignorance, corruption, pollution, waste generation, and lack of corporate social responsibility (CSR).Gatley(2019) states that with the growing awareness and interest in CSR, the idea that businesses should support good ideas is paramount.

STRATEGIES TO IMPROVE ENVIRONMENTAL FRIENDLY- CONSTRUCTION PROJECTS

The global pandemic in 2020 slowed our usual hustle and bustle incredibly, (Abiola, 2021). There is a significant reduction in carbon dioxide emissions and other greenhouse effects due to forced reduction on air, sea, and land transportation, unoccupied commercial buildings, lowered amount of fossil fuels we burnt, and the associated gas emission into the atmosphere (Abiola, 2021). The intergovernmental Panel on Climate Change(IPCC) released its Assessment Report #6 OR AR6, which showed unequivocally that human activities resulting in greenhouse gas emissions are causing the plant to warm on at an accelerated rate(Abiola,2021). The UN secretary-general called the report, “a code red for humanity”, and with only 8 years to halve global emissions and curtail temperature rise, we need changes on a massive scale, (Abiola, 2021).

Huge solar panels can be used on-site to eliminate the use of fossil fuel that emits tonnes of carbon (Gatley, 2019). Even though plastic is the worst offender of the ecosystem, if used responsibly can play a vital part in sustainable construction.

IMPACT OF CONSTRUCTION PROJECTS ON THE ENVIRONMENT

The environment has seen a tremendous impact on unending human activities through industries that pollute, destroy, and waste natural resources daily. Global warming has been greatly impacted by fossil fuel, carbon dioxide, and other greenhouse effects to an extent that climate change has reached a crisis state and poses one of the highest threats in our world globally. United Nations General Assembly states that we have only 11 years left to prevent the irreversible damage to our planet caused by climate change.

One of the greatest offenders of our world is the construction industry dangerously impacting our environment. Bimhow states that the construction sector contributes to 23% of air pollution, 50% of climate change, 40% of water pollution, and 50% of landfill waste. 36% of global warming comes from the activities of the construction industry, 47% of carbon dioxide emissions in the UK alone. Construction industries stakeholders are encouraged to analyze their carbon footprint, how it can be reduced due to its impact on the environment. The goal for decarbonization is to reduce the current carbon dioxide equivalent greenhouse gas levels to net-zero by mid-2050.

Sustainable construction methods will not only reduce the impact on the environment but will also add immeasurable value to the construction concern. Green building has an increase of 7% value compared to traditional buildings as opined by (Gatley, 2019). This is not too much compared to the benefits that will accrue from green building in the projects’ life cycle in the environment it operates in.

METHODOLOGY

To justify the set objectives, literature reviews of related research and quantitative approaches were employed. 180 structured questionnaires were administered to construction projects' stakeholders operating in core construction projects. The population were construction projects carried out between 2015 to 2020 and respondents were construction professionals and contractors that were involved in the selected projects.

The questionnaires were sent to Quantity Surveyors Architects, Engineers, Builders, contractors, and other allies of the construction industry. To eliminate bias according to Leed, (1980), a systematic approach was employed in the companies' selections. 130 questionnaires were appropriately filled and returned representing a 72.22% response rate which agrees with the 30% minimum response generally held for any area of interest in quantitative approach (Sheldon, 2016).

The questionnaire was developed using the factors affecting the environment by construction activities 50 projects from previous literature. These projects represent the main categories of the construction industry in terms of environmental impacts. The preliminary section of the questionnaire dealt with the background information of the respondents while the other section focused on the factors affecting sustainable construction performance and its impact on the environment.

The findings from the pilot survey showed the number of professionals and contractors, that is; Quantity Surveyors, Architects, Engineers, Builders, and contractors that were involved in the projects to be one hundred and thirty (130) and analyzed using the Relative Importance Index and Spearman's Rank Correlation Coefficient. Chan and Kumaraswamy ((1997) and Kometa et al (1994) used the Relative Importance Index (RII) method to analyze the data collected from the questionnaire survey. Analysis was carried out for each group of respondents. . Relative Importance Index was used to rank the factors affecting sustainable construction project performance and the impact on the environment. The indices were then used to determine the rank of each item. These rankings enable factors to be compared to the relative importance as indicated by the operatives. The weighted average for each item for the five groups of operatives was determined and the Ranks (R) were assigned to each as indicated by the five groups of respondents. The RII was calculated for each item according to (Lim and Alum, 1995).

Relative Importance Index (RII) =   (1)

n5 = Respondents for Strongly Agree

n4 = Respondents for Agree

n3 =Respondents for Neutral

n2 = Respondents for Disagree

n1 =Respondents for Strongly Disagree

The projects' operators were requested to score on a Likert scale of 1-5 the severity of the impact of cash flow on their construction project performance with a scale of 5 representing strongly agree (SA), 4 represents Agree, 3 represents Neutral, 2 represents, and 1 represents strongly disagree. The stratified random sampling techniques were used. The questionnaires were structured in a closed question and open response manner. According to Wheather and Cook (2003), closed questions and open response manner allow respondents to express a variety of opinions. Some closed-ended questions were easy to ask and quick to answer. They had a set number of responses. They required no writing by either respondent or interviewer, and their analysis was straightforward, (Nachimias and Nachimias, 1996). Frequency distribution and percentiles were used for the analysis of the preliminary data on the various groups that are, type of company or organization, years of experience of the respondent in construction, and the respondent's professional background.

The statistical technique of Spearman's rank correlation coefficient was used for the evaluation of the impact of cash flow on sustainable construction project performances. The spearman's rank correlation coefficient is expressed as follows: Where d, is the difference between the ranks within each pair of data points and is the number of data paired.

(2)

DATA PRESENTATION AND DISCUSSION OF FINDINGS

Before data collection, views were obtained from experts who were involved in the construction industry and the results of a pilot survey carried out in selected projects. This was done to validate the contents of a questionnaire for its relevance in the construction industry. The breakdown of the 130 questionnaires in terms of the nature of the organization, profession, professional body of affiliation, type of professional membership, highest academic qualification, nature of project executed, years of working experience, the value of projects, and the coverage of the study area are shown in Table I. Engineers recorded the highest number of respondents because of the largest proportion of construction activities which they are involved.

The questionnaire listed 10 general factors that affect sustainable construction project performance. Each respondent was asked to rate and rank each issue based on his or her professional judgment. The impact of construction activities was analyzed and ranked according to their responses. As shown in Table V above, 10 factors that affected sustainable construction project performance were tabulated and ranked accordingly to their relative importance indices from the various professionals This was later weighted all every professional ranked the factors from their professional expertise. The first 5 of the weighted average form the basis for analysis.

Lower use of green materials ranked first (1^{st}) with a relative importance index of 0.93, which shows that stakeholders still rely on primitive construction materials that impact greatly on the environment. This was followed by a lack of environmental education and training ranking (2^{nd}) with an RII of 0.91, which indicates that stakeholders do not have the requisite training and education to make construction eco-friendly and sustainable within the project life cycle. Pollution and increased project cost ranked (4^{th}) respectively with an RII of 0.85. Stakeholders must do more in this regard from feasibility and viability studies.

The lower use of green materials on the table ranked 1st with an RII of 0.97. This is closely followed by project abandonment ranking 2nd with an RII of 0.94. Project cost ranked 3rd with an RII of 0.92. These are the negative impacts of construction activities that must be viewed adequately to achieve sustainable construction project performance.

Table VII Occurrence of negative environmental impact in the projects' life cycle

Negative environmental impact occurs majorly at the projects' implementation stage as depicted in Table VII. Workable feasibility and viability studies are very important to actualize eco-friendly construction.

Using Spearman's rank correlation coefficient for the evaluation of the impact of construction activities on the environment whilst the student's test formed the basis for the hypotheses testing, which was to ascertain if significant differences exist between the rankings of the factors impacting the environment through various construction activities. The spearman's rank correlation coefficient is expressed as follows: where d is the difference between the ranks within each pair of data points and is the number of data paired.

Spearman's Rank Correlation Formula

:

INTERPRETATION OF RESULT

Correlation varies between -1 and 1

Close to -1 = Negative

Close to 0 = No linear correlation

Close to1 = Positive Correlation

The result shows that there is a strong positive correlation as the value of ρ moves toward 1 recording $\rho = 0.77$. This means that construction activities impact positively on the environment

CONCLUSION

Construction infrastructure uses more energy thereby increasing the demand for the production of energy and directly contributing to global warming. This is attribution through poor design. Any non-functional design gives rise to more energy resources. The construction industry is a major contributor to the greenhouse gas mission through the use of building materials that are most times, not environmentally friendly. The burning of fossil fuels such as gas and diesel and even methane greatly pollutes the air thereby contributing to global warming. There is a clarion call on ways to reduce the drastic climate change for a sustainable environment. The construction industry is responsible for the indecent 50% of all-natural resource extraction worldwide.

Industrialized countries have taken steps to arrest the implications of resource depletion and environmental degradation caused by construction activities; developing countries have made little progress in this regard.

It is however patently clear that some very relevant developments may influence the present future. Professions should understand this and be prepared to participate in a pro-active manner. Society must be assisted in developing the skills and desire to serve its own need aimed at sustainability through environmentally friendly construction materials used.

Countries are desperate considering that many of them do not have resources and capacities to improve their technologies and many are faced with a fragile environment, involving natural disasters such as desertification, earthquakes, storms, aridity, flood occurrences, etc. not to mention the rapid population growth and the associated social, economic, and environmental problems.

RECOMMENDATION

Sustainable construction project delivery is the lifeblood of our world and to effectively manages cash flows on projects. Below are some recommendations to successfully manage cash flows on a project to ensure it remains profitable from start to finish to achieve a sustainable construction project performance.

To reduce construction's overall environmental impact, reduction of energy use is paramount

Environmental education on decarbonization for professionals in the construction industry

Use of renewable energy by industries collaborators.

Green building materials used are highly recommended.

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Investment predictability of conventional and innovative projects (id 93; P_093)

Topic / themaSustainability and Projects

Keywords: estimate cost first timers, innovative projects

Op staat het volgende onder dit thema:

Sustainability

Environmental impact TCO; Reduction of Carbon footprint; optimizing products and production chains; climate change, Renewable energy; how sustainable goal influence traditional costs/quality driven projects.

Guidelines:

Word; max 8000 woorden; marges 2,54 cm rondom; A4; heading (1) 12pt. not numbered, bold, calibra, capital; left

heading (2) 12pt. not numbered, bold, calibra; left

heading (3) 12pt. not numbered, bold, italic and calibra.

ABSTRACT

In the 20th century cost estimating has matured into a professional skill with ever increasing predictability of cost. Estimators use proven methods and have broad access to key figures, derived from estimates based on historic investment results and project metadata, and normalized cost information based on various comparable projects.

Nowadays estimators are increasingly faced with new challenges. Processes need to be flexible in order to adapt to rapid changing availability of energy and varying product demand. Stricter requirements with respect to emission levels drive the introduction of new technologies in otherwise ‘conservative’ industries. Increasingly interconnecting process feeds demand innovative solutions. Adaptation to these requirements call for iterative estimating processes. One aspect deserves explicit attention: ensuring that projects remain within time and budget. Since design changes hugely affect total cost, aspects like managing the redesign process have to be taken into account during the estimating process. These developments widen the portfolio of technologies to be considered, thus affecting the cost estimating profession.

The aim of this article is to describe the evolution of the cost estimating profession driven by these new challenges. How will the cost engineer be able to keep the predictability – and thereby the reliability – of cost estimates at a high level while giving sufficient path for innovative design options?

Our solution is firstly to focus attention on a process function level like mixing, heating, power supply, reacting, cooling, product storing, etc. On this level cost data can be made available. We re-evaluated existing project data to establish scaling relationships that can generate cost data at desired output.

Secondly, with respect to novel/innovative projects we strengthen the cooperation between cost estimators and in-house professionals like chemical/process and mechanical engineers. They specify novel process designs using proven engineering practices that yield main equipment dimensions and process functions. Cost engineers then need to reliably convert this type of output into estimates with sufficiently high accuracy.

We present two case studies to support our message. We envisage an ever accelerating application of novel technologies in a relatively 'conservative' industry. This will require additional skills from the cost engineer, as well as a closer cooperation with process engineering professionals.

The authors contributed to this paper as members of the Special Interest Group 'Cost Engineering in the Process Industry' (SIG CEPI), of DACE, NL. Please visit

Total Cost Management competences model: how assessment can help project predictability (id 94; P_094)

Total Cost Management competences model:

how assessment can help project predictability

Keywords: competence assessment, project risk assessment, project team, Total Cost Management certification.

Abstract

Each project is unique and contains different blends of elements that make it risky in different ways and measures. There is no absolute risk rating: the same project can be executed by distinct companies with different degree of risks simply because of organization, tools, assets, and competences involved.

In this view, main project/portfolio risks are those that cannot be properly managed because of a lack of competences, i.e., knowledges, experiences, and skills necessary to manage them. Therefore, project/portfolio risks rating depends on a measure of how available competences fit with project needs.

This work aims to describe a complete, structured, and integrated framework to evaluate the relationship between "value" of ongoing projects and "value" of the skills of involved resources. Only a proper combination and balance between project characteristics and resources competences allow to minimize project/portfolio risks and maximize opportunities.

The proposed framework is based on qualitative/quantitative assessment of different project elements (dimensions, contractual structure, technical and organizational complexities) allowing to rate economic-financial characteristics (profitability), risks, opportunities, technological innovation, and other intangibles (experience capitalization, image return, etc.).

On the other side, competences can be assessed using a qualitative and quantitative method based on AICE's Total Cost Management certification model. The assessment method is based on a Body of Competences structured in four groups (theoretical knowledge, business contexts, value chain impact, applied practices) and aims to rate personnel knowledge, experience, and skills in five different areas necessary to manage project/portfolio risks and opportunities.

Both assessments are compared to measure if and how competence needs of project/portfolio are satisfied by their availability (how much they overlap and how wide is the gap to cover or to consider as a primary component of project risk) driving commercial strategies, operational decisions, and/or HR policies (recruitment and training needs).

Human factor in risk assessment

The concept of risks is closely related to complexity. Identification, evaluation, prioritization, and mitigation of risks start from investigating the “dark side” of the projects, which is unpredictable and hard to keep under control.

In general, all depends on what we can control: a risk remains the same risk for everybody, but its value (the risk “score”) is related to our capability to mitigate and keep its complexities under control.

For this reason, we can affirm that the definition of “risk” is related to our capability to manage facts and phenomena which are intrinsically complex and interact each other in complex ways generating unpredictable situations that are hard to control and have some impact on the project (making it unpredictable in turn).

What today we consider relatively risky, some time ago was considered more difficult to control, so that today’s technological challenges and growing project dimensions are giving to the term “risk” new meanings.

Complexity can be reduced through a structured approach to projects. Best in class companies know that to address different degrees of complexities and, consequently, different degree of risks it is necessary to implement suitable organizational solutions, adopt efficient and effective processes, and implement modern information tools to manage project. But this represents only a single face of the medal. There is a “glue” that keeps organization, processes, and tools together and makes them work: competence of people. Even assuming that a company is well structured and organized, without competence this would be useless (and vice versa).

In this view, competences are not subsidiaries component of the risk management system but are fundamental and integral part. Especially, competences are needed to reduce complexity by working on “total” strategies to reach a balance between stakeholder’s needs (decision making) and technical sustainability.

To address project risks, companies put in place specific processes and tools aiming to identify and manage unpredictable events that could interfere with objectives. Therefore, specific responsibility may be assigned (among project team members), specific tasks should be accomplished (risk identification and analysis) and tools properly used (risk register).

But this constitutes only the framework where competences (knowledges and experiences) can express all their potential.

How can we identify risks? How can we evaluate? How can we design solutions to mitigate risks? It’s only a matter of knowledge and experiences. Organization, processes, and tools can only improve communication, efficiency and organizational learning but cannot substitute individual competences (that together make a kind of “collective competence tank”).

Prevention (identify and prevent dangerous situation), preparation (set-up fallback plans to face risks), and reaction (capturing trigger signals and act as appropriate when risks activate) need to be addressed primarily with competence rather than with procedures. In fact, since projects are unique and temporary by nature (especially those more innovative) no procedure can be enough sophisticated as to exceed or even substitute the power of competences.

The more complex the situation, the more you need to involve competent people since tools are helpful, but not enough.

context and objectives

This presentation is based on a real experience made in a company related to risk management services. The company had to execute projects with high-risk ratings and intended to have an overall risk assessment for their portfolio.

After a preliminary assessment of project management processes and architecture, the work focused on the competences of teams and people in relation with project complexities.

Regarding competences, the company shared with the consultant team the followings three questions:

Are our risks appropriately covered by competences of people and professionals that we involve in project teams?

Are there specific gaps between project complexities and people competence to control them?

If yes, which areas have the main gaps and how can we rate possible gaps?

The main goal of the consulting services was to support the top management in strategic business assessments through a comparative diagnosis of the relationship between project portfolio complexities and the competences of the resources engaged in project teams. This assessment was addressed more on the portfolio “as a whole” rather than to single projects diagnosis, although it started from a diagnosis of a sample of specific projects as described below.

Similarly, even if individual competences were properly analyzed, the survey could identify the global shapes of knowledges and experiences of people involved in project management processes of the company.

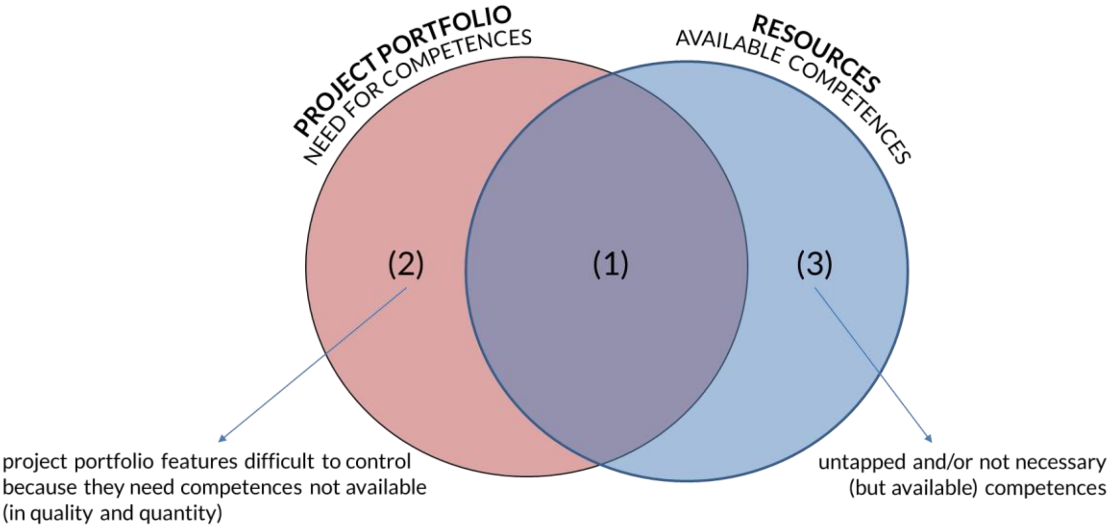
Finally, overlapping project requirements and available competences patterns has allowed to identify:

characteristics of project portfolio that correspond and can be properly controlled by available competences

characteristics of project portfolio that are difficult to control because they require competences that are not available (in quality and quantity)

available competences that are untapped and/or not necessary

Figure 1



Project and Project Team

The project started with the agreement with the company on the competence framework needed to manage a project. The framework was represented by the area of a triangle where the corners identify three main “poles” to be considered to manage a project:

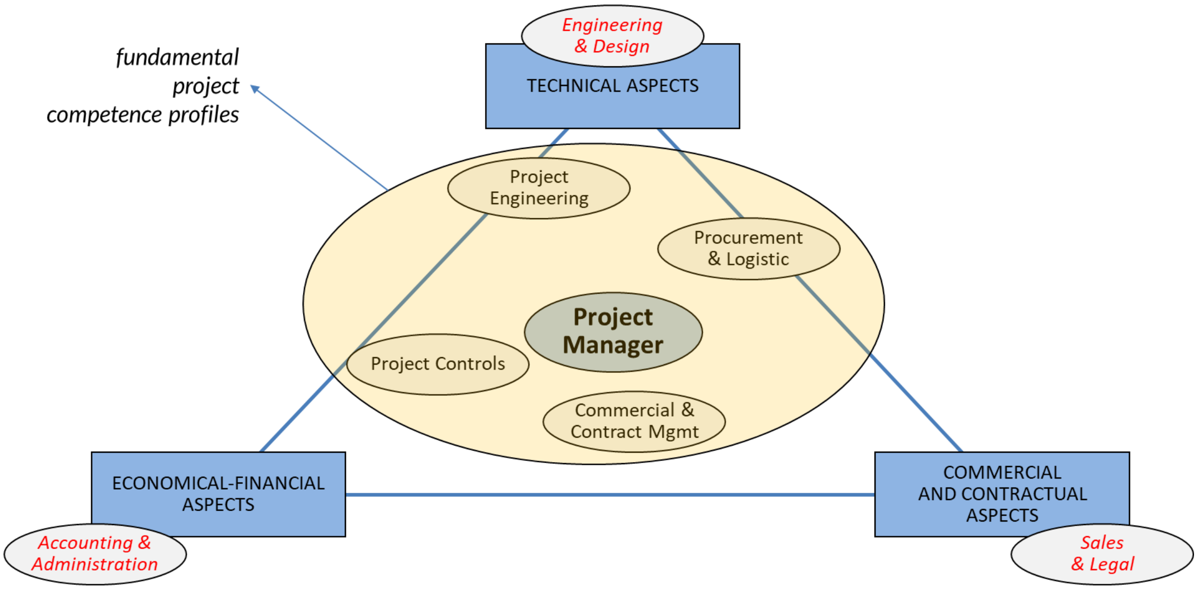
Economical and Financial aspects: resources are necessary to execute a project. No technically viable solution can be implemented without a certain amount of funds and resources that must be available in the right quantity and in the right moment.

Technical aspects: each project relates to technicalities on which is based the solution to be implemented. In this corner we have the “engineering and design” world covering the definition of the best possible solution under the technical point of view.

Commercial and contractual aspects: the overall context in which a project is being executed is substantially based on agreements and pacts made by companies (owners, contractors, suppliers) playing specific roles in the supply chain.

A perfect balance of these three elements makes project sustainability and a correct control of these dimensions makes the project predictable (technically, economically, and in practice). It is typical in project organization to find organizational solutions where these three aspects can be kept under control, building project teams around these three main guidelines.

Figure 2



Looking at figure 2 we can identify five typical “competence profiles” that are usually involved in a project:

Project Management (PM)

This profile is usually assigned to Project Manager role. A project manager usually works to “integrate” all the three dimensions. His competences usually grow from technical background toward economical-financial and commercial-contractual dimensions in second stages of professional career.

Commercial & Contract Management (CPM)

This profile covers mainly contractual-commercial aspects. This role works between the economical-financial and commercial-contractual dimensions of the project (e.g., managing the invoicing/payment certificates, change orders, claim management, etc.). For minor projects, these tasks can be executed by the project manager; however, when project dimensions and complexities grow, a specific figure is usually in charge in project team for these activities.

Project Engineering (PE)

This profile is dedicated to the technical solution. The engineering department usually can assign a professional to grant a proper design of project technical solution, but for greater project a dedicated Project Engineer (and relevant staff) can be assigned to the project team to work on technical dimensions while considering the other two dimensions as constraints. Despite this role profile is essentially technical in nature, a project engineer cannot forget economical affordability and commercial-contractual limitations (both agreed with client and subcontractors/suppliers), still working inside the project triangle.

Project Controls (PRC)

This profile guards the economical-financial aspects of the project. For this reason, under project controls (plural) it is usual to include many elements that can have significant impacts on the project profitability:

Planning and scheduling

Budgeting and cost control

Risk management

The set of elements that must be controlled by this profile asks for specific competences on cost engineering, but also asks enough knowledges and experiences to understand constraints coming from technical aspects and to create harmony with commercial-contractual ones.

In simpler cases, companies can provide some support to project team to control time and costs sharing part time employees dedicated to monitor project portfolio and/or assigning some “coordination control” (planning, scheduling, costing) to Project Management Office (PMO) but leaving project result responsibility to Project Manager.

In more structured companies, project controls tasks are usually assigned to professionals dedicated to project team and belonging to a specific department (Project Controls Department).

Procurement Management (PRM)

The fifth profile is dedicated to project procurement strategy. As project dimensions is growing, a complex network of relationships with subcontractors and suppliers must be set up. Professionals belonging to Purchasing Department are usually in charge for this but for bigger projects a dedicated procurement manager may have his slot in the project team organization chart. These competences have to do with all the triangle dimensions because this profile shall manage

subcontracts/supplies technical scope of work/supply

for a certain price

and constrained by a specific set of contractual provisions

The description given above is not enough to detail the complexities of these competence profiles (we will provide a better analysis below using the competence model of AICE). However, we can consider that:

The five profiles presented define a kind of “greatest common factor” to describe the shapes of competences needed to have a guard for project risks; a different subdivision of competence (in more or less) profiles is possible and depends on industry sector

It is not necessary to associate each profile to a specific role in the project team organization chart; although this may be common, it is fundamental to grant that competences needed by project complexities exist, are enough, and are properly engaged in the team

In the same way, it is necessary to grant that competences needed to keep complexities under control exist, are enough, and are properly engaged inside the company at project portfolio level

Each project may require a different mix of such competence profiles (more enhanced some of them, less others according to project peculiarities)

All the roles must work inside the triangle area or at least along the sides between the dimensions they must guard!

The value of projects and their need for competences

The examination has been carried out according to four groups of elements giving different degrees of complexity to project:

Size and financials: time, costs, contract price, expected margins and profitability, commercial aspects (guarantees and securities, payments) etc.

Contractual framework: number/size/characteristics of involved parties, contractual position of the company/structure, complexity of relations with counterparties (partner, customer), etc.

Technical complexity: technicalities of the work, clarity of project scope, technologies used (new / consolidated), tools, etc.

Organizational aspects: logistics, referenced standards, laws and regulations to be respected, strategic value and importance for the company/for the client/for the parties involved, etc.

There is no single/absolute reference to evaluate the listed elements for any project: the model adopted has used specific metrics that have been calibrated according to the dimensions and characteristics of the company's industry sector (infrastructures, buildings, environmental remediation etc.) and typical project dimensions.

First, a list of questions for each family were prepared with five answer options, for a total of 15 questions:

Size and financials: 4 questions

Contractual framework: 4 questions

Technical complexity: 3 questions

Organizational aspects: 4 questions

A score was assigned to each answer, grading such score in five steps to identify simple, intermediate, and complex situations (from 61 to 1.000).

The resulting numerical score (project rating) capture the dimensional relationship (proportions) between the phenomena examined, defining a broad concept of "value" which incorporates various elements such as:

economic value (e.g., order value and profitability)

value at risk (possible losses)

value of opportunities (possible earnings)

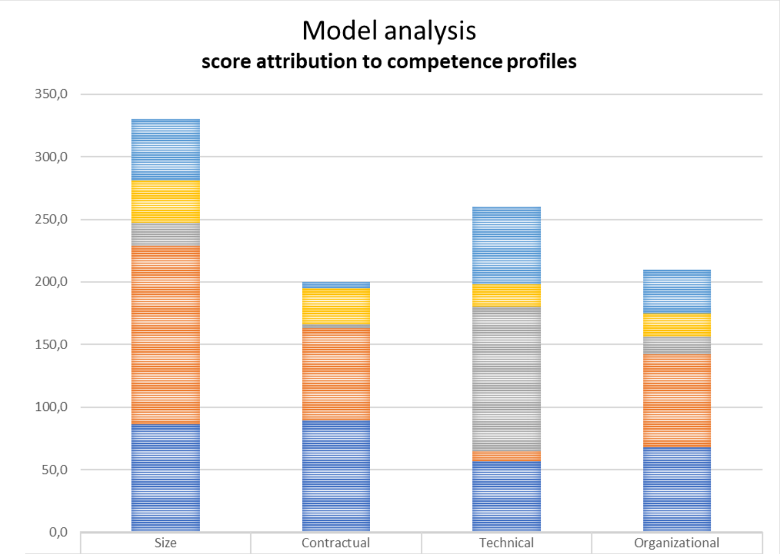
technical / technological value (innovation)

asset value (e.g., experience, image)

In a second step, all the scores of the questions were broken-down among competence profiles, grading the contribution of the specific profile to keep the complexity deriving from each question under control. Such analysis considered in depth the architecture of project management processes and the specific tasks that each role was supposed to accomplish during project management cycle.

The result of this second exercise is represented in figure 3 and define how much a specific profile of competence can contribute to control different project complexities.

Figure 3



	Size	Contractual	Technical	Organizational
PRM	49,0	5,0	62,0	35,0
PRC	34,0	29,0	18,0	19,0
PE	18,0	3,0	115,0	14,0
CPM	142,5	74,0	8,0	74,5
PM	86,5	89,0	57,0	67,5

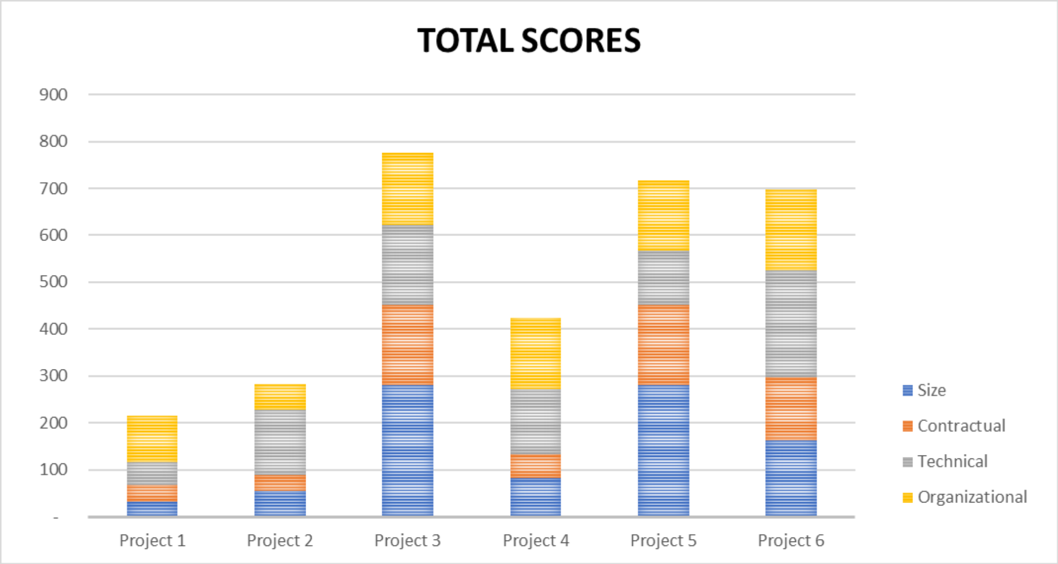
This information will make it possible to examine with more objectivity various strategic options that can be pursued and to identify with greater awareness the value of the company's offer for its customers and for the market.

PROJECT PORTFOLIO ANALYSIS: THE RESULT

The survey has been done for six projects considered "representative" of company's business and interviews were done with the members of the project teams.

The result (total score for each project) is shown in figure 4.

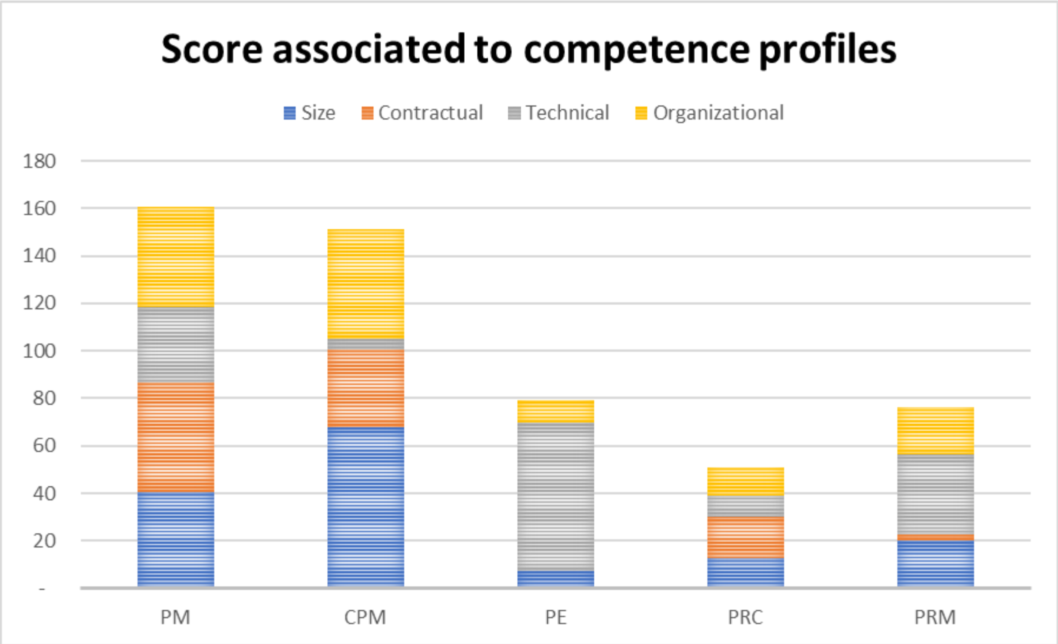
Figure 4



The average score for the sample is 519 points: considering the maximum score of 1.000 points, the complexity rate for the portfolio is about in the middle.

The Figures 5 shows the mean score associated to the five competence profiles.

Figure 5



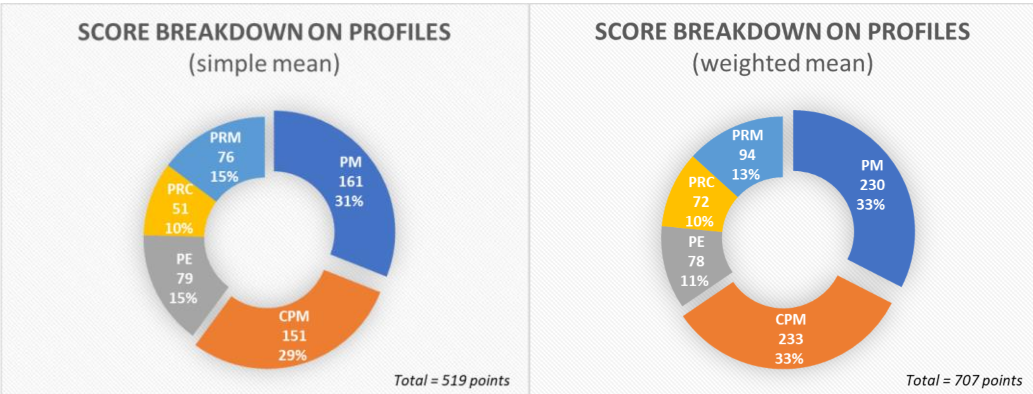
As it is clear from the chart, the sample is characterized by an extreme variability of situations.

A deeper analysis based on project details and some statistical descriptors has been shared with the company to understand the "sensibility" of the model and define how the sample can represent the current and future business strategies and current and future need of competences.

For instance, applying a weighting factor to each project in the sample (based for instance on monthly/annual turnover, giving more importance to projects that lead the company profitability and total business revenues) the mean of the score is 707. In this case, a slightly different mix of competence profiles is requested because, with the driver of the size, the managerial profiles (PM and CPM) have been enhanced to the detriment of more technical/applicative profiles (PE and PRM) while preserving the need of getting control of the situations (PRC profile).

This comparison is shown in figure 6.

Figure 6



THE VALUE OF PEOPLE AND THEIR COMPETENCES: THE AICE COMPETENCE MODEL

The assessment of competences is based on Total Cost Management certification model of the Italian Association for Total Cost Management (AICE). This model can define a map of what the candidates (i.e., the company's personnel participating to the survey in our case) know, and in which field they have specific experience.

This model is founded on the definition of "Competence" defined as the result of three main components / dimensions:

knowledge: topics and argument known and understood in the disciplinary field of interest

experiences: job opportunities that have allowed and allow the effective use of personal knowledge and skills

soft skills: personal aptitudes useful for the purpose of effective working and organizational behavior

The evaluation has been focused on the first two dimensions (knowledge and experiences) and aims to obtain numerical ratings representing the degree of alignment (capturing variety and quantity of known facts and capabilities) with some reference profiles (for the certification), as well as with the needs of the projects (for this examination).

Knowledge and experience will be assessed based on the Body of Competences (BoC) model that takes into consideration four main families of topics:

Basic theoretical fundamentals (identified with “EB”)

Concepts and theoretical notions of the disciplines / subjects of reference.

Context factors (identified with “FC”)

Elements that characterize the dynamics of the life cycle of various assets (especially those considered as reference for Company’s business) and related standards and regulations.

Value generation (identified with “GV)

Dynamics of business cycles, processes, systems essentially derived by Porter’s Value Chain model.

Applications (identified with “AP”)

Specific methods and techniques of work as applied in different contexts and industry sectors.

Each of these BoC’s families is developed in a series of topics (49 in total) whose content is described in detail covering all the arguments related to Total Cost Management.

Table 1 represents the global architecture of these families and relevant 49 topics (detailed arguments for each topic can be found on AICE’s web site).

Table 1

All the candidates have been invited to a training session receiving transparent information on the scope of the assessment and specific instruction to fill a self-assessment model to map and rate personal competences (in quality and quantity).

This tool is based on the model represented in Table 2 and is organized in four Sections:

Personal Background

Knowledges

Experiences

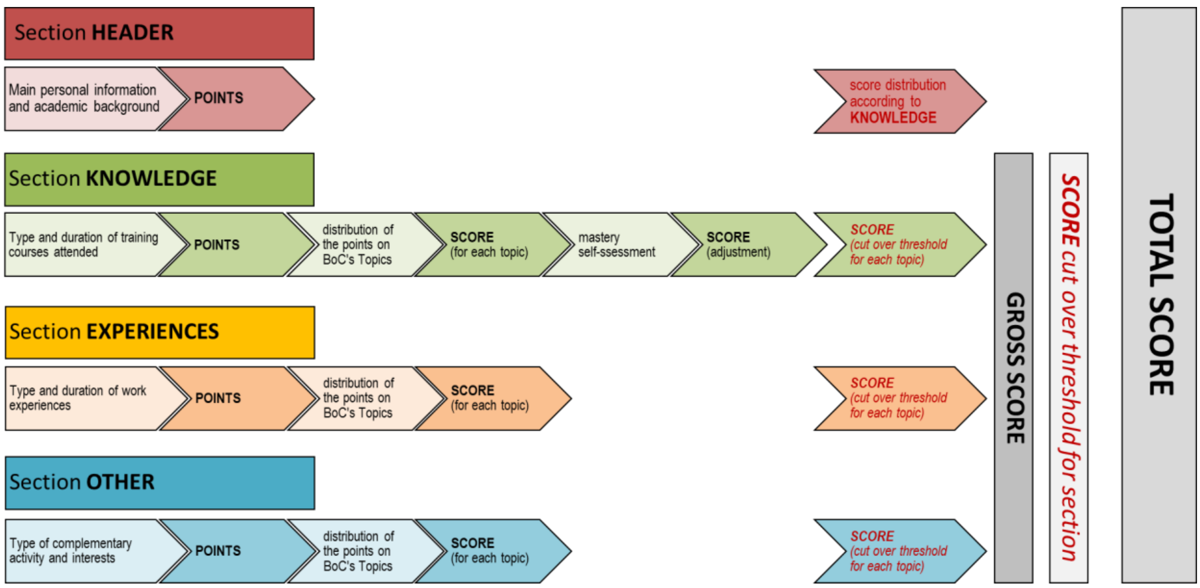
Other activities (such as articles, books, participation to congresses, volunteering, etc.).

Table 2

BoC Family *Sections*	*Background*	*Knowledge*	*Experiences*	*Other*
Basic theoretical foundations (EB)	*Schools and Academic career*	Know-how	Abstraction capacity	*Personal interests and initiative* *Autonomous elaboration and development of concepts*
Context factors (FC)		Life Cycle Dynamics	Professional context	
Value generation (GV)		Role perspective understanding	Role perspectives experienced	
Applications (AP)		Application knowledge	Practice in doing	
TOTAL SCORE	**1.000**			

For each section, the candidate indicates the activities (training courses, experience in companies, articles, books, participation to congresses, volunteering etc.) and gains a certain number of points that can be distributed on the relevant topics of the BoC. Earned points depends on the type of activity, while distribution on topics is decided autonomously by the candidate according what is pertinent.

Figure 7



During the scoring process, the AICE model applies some cuts to predefined thresholds (for each topic and for each section) to avoid an excessive concentration of the points on few elements: this is a peculiarity of the AICE model and is in line with the principle that a "good" competence is "balanced" (especially when dealing with Total Cost Management). If a professional has great knowledge (attended a lot of courses) and great experience (worked for many years in the same position) on few topics, probably he is a good "specialist". Total Cost Management competence is characterized by a wider balanced knowledge and experiences, especially if we consider the five profiles of reference (PM, CPM, PRC, PE, and PRM), that need ability to cross-functional work and attitude to address problems in an interdisciplinary way.

Maximum total score of the AICE model is 1.000 (in line with the total score of the project assessment model described above) and includes a quota for an oral exam. For the application of this model, no exam was considered, preferring a faster return from a wider sample (25 professionals and managers). To ensure the necessary quality of the results, autonomous self-assessment by candidates was then followed by individual interviews to check, adapt, correct, and align the results of self-assessment.

Consequently, the maximum score for each section was adjusted to reach the necessary 1.000 points.

An overview and a comparison between the scoring models (AICE vs adjusted) is represented in Table 3.

Table 3

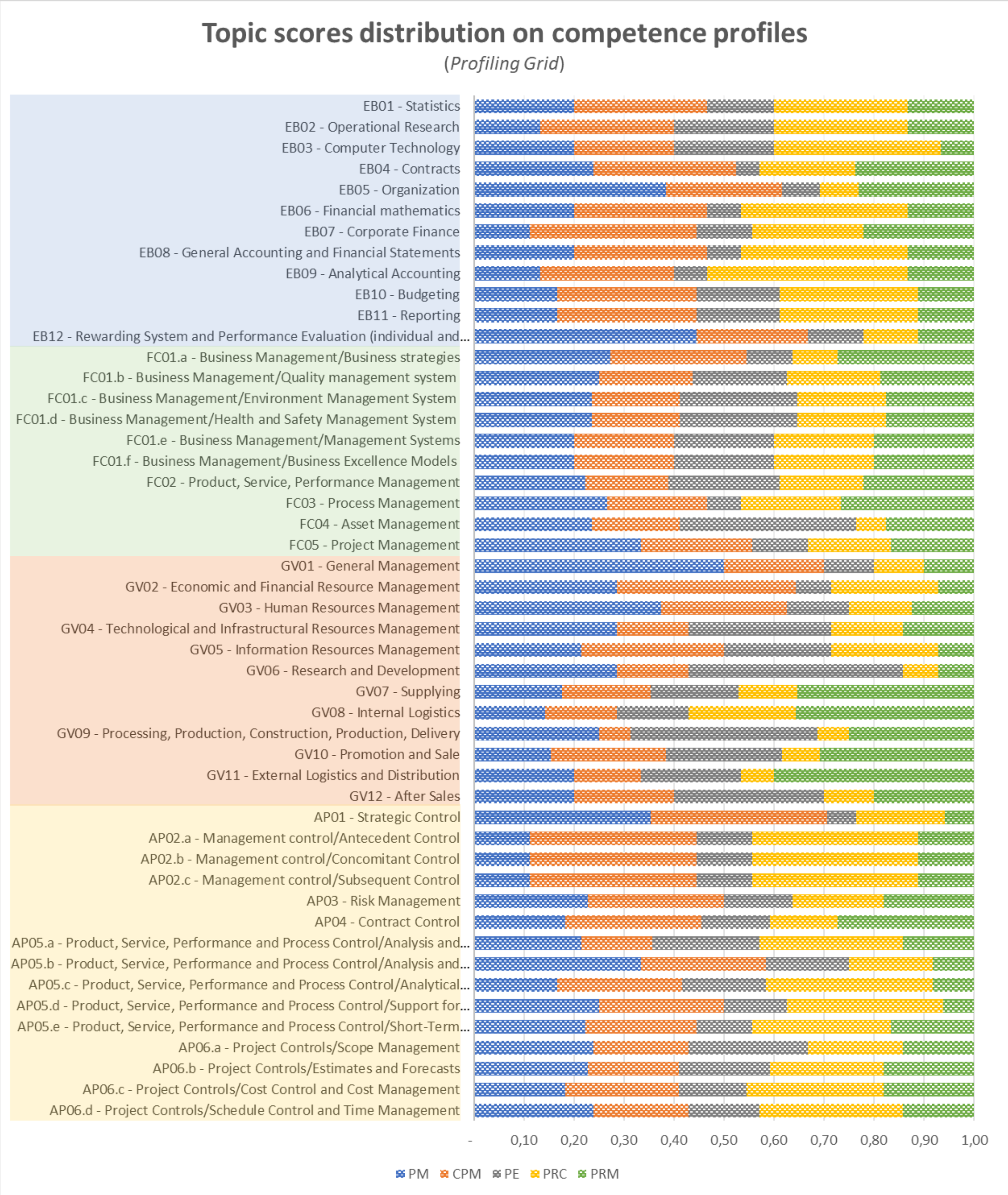
Sections	***Max Score***
Background	100
Knowledge	400
Experiences	400
Other	100
MAXIMUM SCORE	**1000**

A further step necessary was to define competence profiles, defining for each profile the needed competence for each topic of the BoC.

The calibration of the model was based on the same assumptions made for project portfolio survey and was carried out with company top management. During the calibration sessions, a driving criterion was the definition of the boundaries between the roles that the company intended more management oriented (Project Management and Commercial/Contract Management) and operational oriented (Project Controls, Project Engineering and Procurement Management).

Figure 8 show the profiling grid resulting from this exercise.

Figure 8



The resulting grid defines how the profiles are built with competences in various topics. Looking at the chart, all the topics in the BoC can shape the competences framework for all the five profiles, even if with different contributions.

For instance, the PM profile (the dark blue portion of the bars at left) requires more competences in topics having strong managerial content (such as General Management, Strategic Control, etc.), while other profiles require competences on topics associated to their specific fields (for PRM for instance Supply, Logistic, etc.).

Using this profiling grid, the score of each participant to the survey can be projected on the five profiles defining how better he can cover a role. In the same manner, applying the profiling grid to the total score of the sample it is possible to obtain a general shape of competence distribution for the company. This shape represents competence availability.

COMPETENCE ASSESSMENT RESULT

It was a critical step to grant the quality of self-assessment. For this reason, a preliminary training was organized with all the professionals participating to the survey. Such training was focused to clarify the followings:

Understanding the general objectives of the assessment, the method of analysis and the method of calculating the scores

Understanding the different sections and topics of the BoC on which the analysis is based for a correct attribution of scores

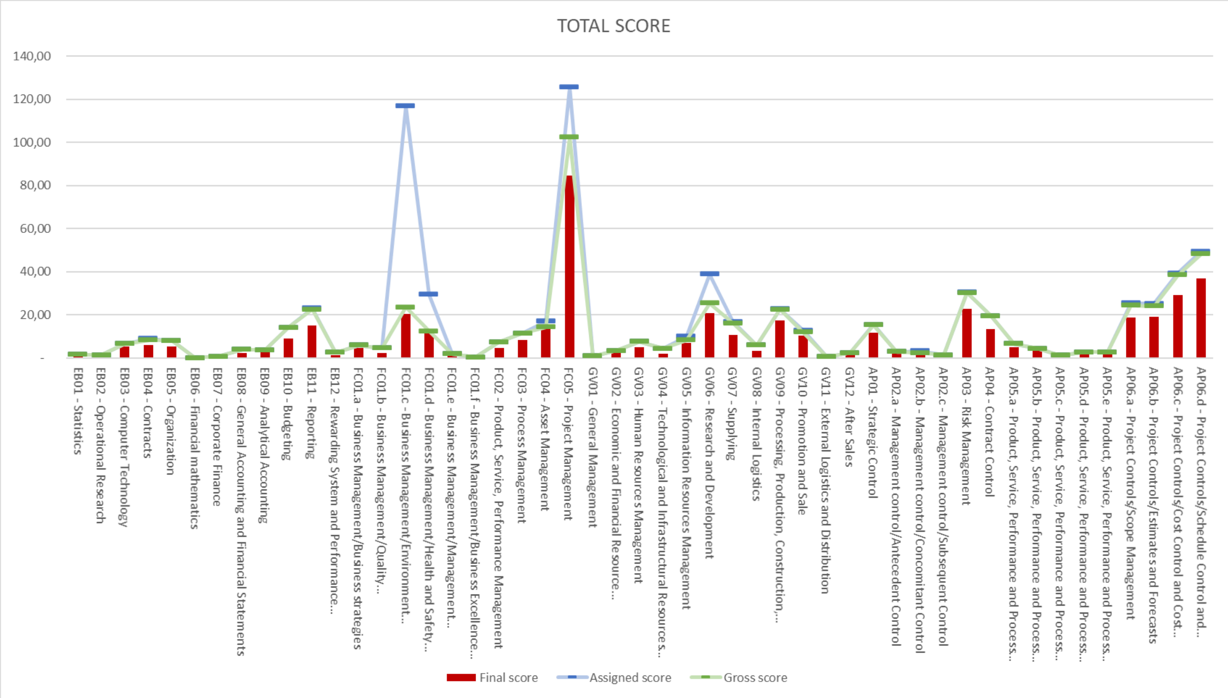
How the use of the model requires a serious introspection on personal and professional history to obtain an honest and objective self-assessment based on real and verifiable facts: attendance of training courses, past experiences, other complementary activities carried out in relation to subjects of interest

How the model rewards the distribution of the score rather than the total.

The candidates (24 employees participated to the survey) had an average age of 40 years and a seniority in employment ranging from less than 5 years to more than 25 years with an average of about 15 years, most of which in the company. All the members of the sample had a master’s degree (and four of them a doctorate) in various disciplines (engineering, architecture, geology, environment) and specific professional interest in the field of the business where the company operates.

Self-assessments models were returned after 3 weeks. The results of the survey are shown in figure 9. The mean score was 504.

Figure 9

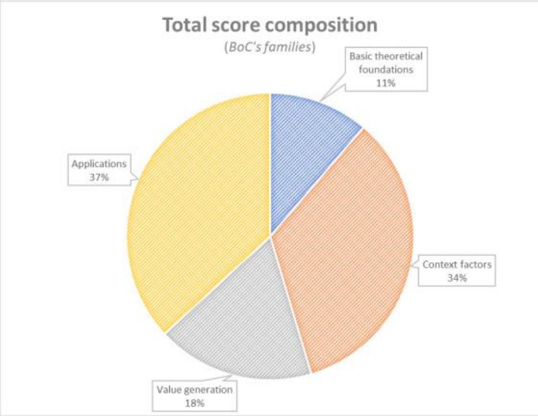


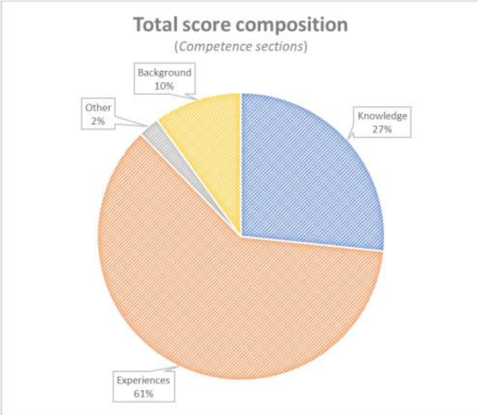
The chart shows the total score assigned and the reductions applied by the model to promote a balanced distributions of competences on more topics.

Just less than 20% of the mean score (94 points out of 504) was due to knowledge and experience in Project Management. Many participants were in charge as “Project Manager” and rated the corresponding topic of the BoC (Project Management) but did not distribute enough points on other supporting competences (such as strategic control and general management) causing an overflow of about 40 points captured by the model.

A great part of the score is due to experience (61%) while knowledge contributes for about one fourth (27%). More balanced is the distribution of the score among the BoC’s families: Applications and Context factors received about three fourth of the total score (71%). These data are represented in the two pie-charts in figure 10.

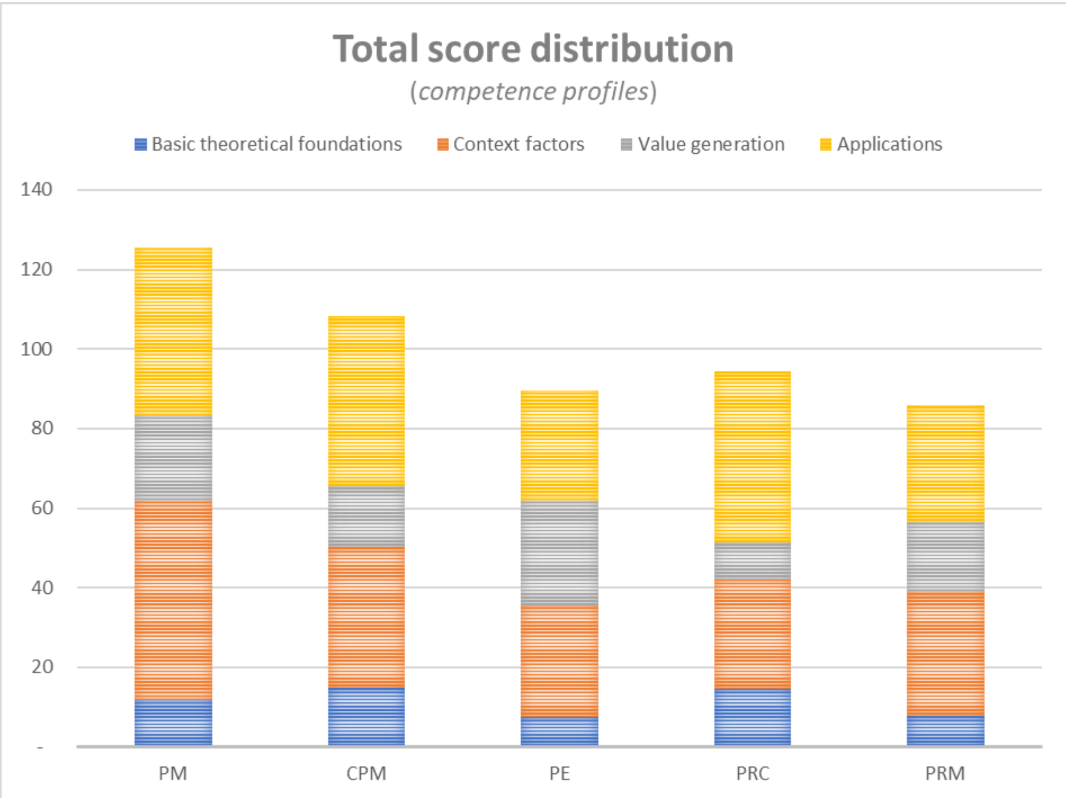
Figure 10





By applying the profiling grid to the total score, it is highlighted how the final distribution of the score in figure 11 shows a substantial balanced distribution among competence profiles, with a prevalence for the PM profile.

Figure 11



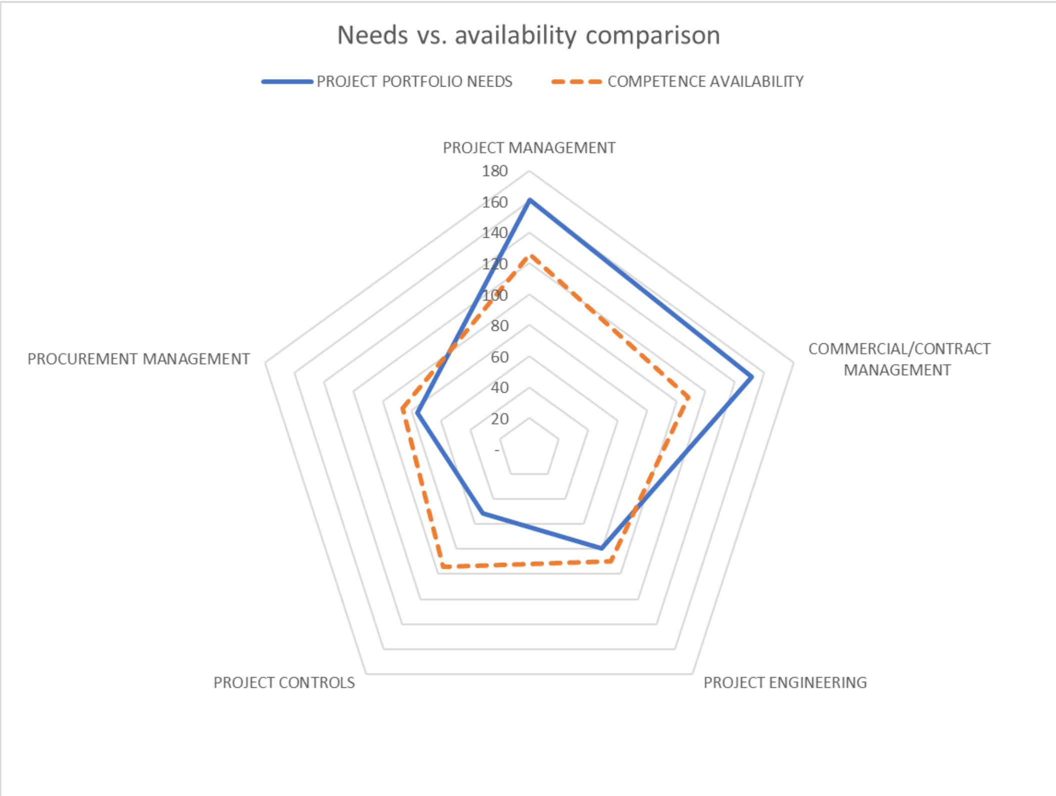
OVERLAPPING THE PATTERNS: THE GAP ANALYSIS

The model considered projects of different nature and size, obtaining a result that can be interpreted both at "system" level and for the specific project.

The comparison between the result of the survey for project portfolio (mean of project competence needs) and of the overall self-assessment (available competence needs) is shown in figure 12.

The two patterns show some distance between project management and contract management need of the project and relevant available competence profiles.

Figure 12



The same gap analysis at a project level can give some highlights to specific situations (figure 13):

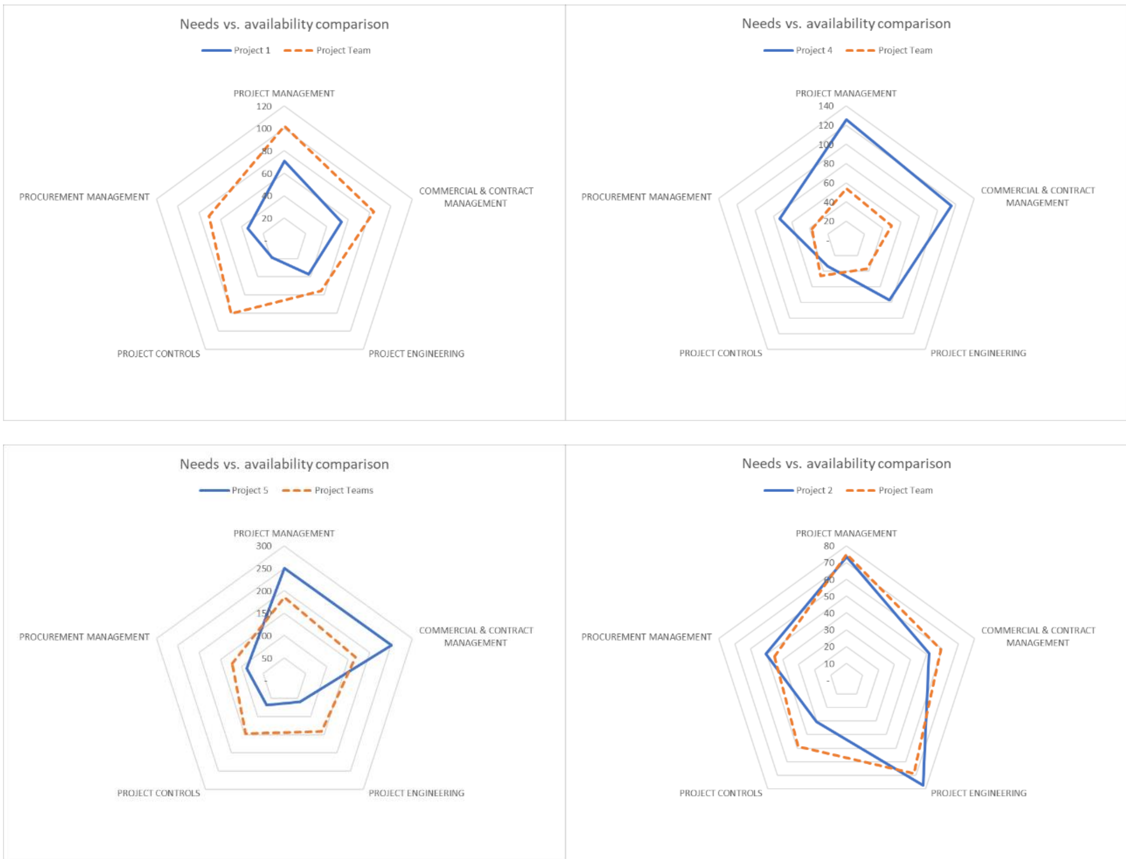
the team can easily cover all project needs

the project needs exceed team capabilities

the needs and availability are unbalanced

the needs and availability are substantially in line

Figure 13



Conclusions

The result of the survey returned to the top management of the company the picture represented in the previous charts and allowed to answer to the questions made by the company (to be further explored):

Question 1: are our risks appropriately covered by competences of people and professionals that we involve in project teams?

Answer: in general, the model highlighted a need for more managerial competences (Project Management and Commercial Contract Management), while technical profiles were in general enough available. However, the analysis could identify some specific criticality at project level.

Question 2: are there specific gaps between project complexities and people competence to control them?

Answer: main gaps are associated to managerial profiles where competence is more distributed, while the personnel of the company are generally specialists in their discipline.

Question 3: If yes, which areas have the main gaps and how can we rate possible gaps?

Answer: the model identified all the topics of the BoC that were not enough rated by the candidates, showing specific gaps. The main topics that could have further increased the score for managerial profiles were General management, Business management, Contract management, Strategic control.

The model adopted considers the need for skills for the resources involved but leaves the need for organizational processes partly unexplored. Good application skills can be sacrificed and weakened if the work processes are not optimized. A good organizational set-up (roles, processes, and systems) allows for the implementation of good practices as a basis, especially for the development of technical/applicative competence. Young new hires can start to acquire competence in performing tasks guided by corporate tools and methodologies, simply relying on procedures, and transforming what they do into competence (if correctly supported). The training can cover complementary domains of knowledge to enable the abstraction of concepts useful in the execution of tasks and improve the ability to manage the output.

The need for managerial competences (Project Management and Commercial/Contract Management) has a different rate of growth with some characteristics of the projects (size, commercial, contractual, and organizational aspects). Furthermore, it is not certain that smaller projects create less complexities as compared with bigger ones: a portfolio made of many small projects has different problems and different risks of a portfolio made of few big projects. Simply, these two businesses need a different combination of competences.

Finally, it is also interesting to observe how this approach to project portfolio risk management can go far beyond the pure assessment of “as-is” situation, helping for instance the Chief Operating Officer (COO) to properly drive project handover.

The same approach can be useful in driving commercial strategies (analyzing the gap between competences requested by new markets, new projects, new business models) or HR policies (improving internal competence assessment and mapping, designing new recruitment and training strategies to cover current and/or new needs).

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Investing time in children's education is imperative now to assure business continuation in the future (id 95; P_095)

INVESTING TIME IN CHILDREN'S EDUCATION IS IMPERATIVE NOW TO ASSURE BUSINESS CONTINUATION IN THE FUTURE

Keywords: education, project, volunteering

Motto: "Education is the most powerful weapon which you can use to change the world." – Nelson Mandela

ABSTRACT

Successful projects require highly educated team members and contractors with experienced workers. Unfortunately, COVID19 pandemic corroborated with the financial crisis have exposed humanity to new means of communication and new ways of learning and teaching.

This new learning style revealed the weaknesses in the education systems, and a higher negative impact was observed on the pupils who were already in an unfavorable position before the pandemic crisis started.

A recent EU statistic presents a depreciation of quality of children's education and the EU reported an increasing number of early leavers from education and trainings in 2020 throughout Europe along with higher underachievement in science, math and reading. A similar trend was also observed in adult participation in learning.

To ensure availability of highly skilled professionals for future projects, we need to increase today participation in the early education of today's children starting with early childhood education, exposing them to basic project concepts: project scope, resources, project controls, quality, project closing, end-product and project abandonment.

Resources are available – professionals, education systems, ideas of projects targeting any education level and children's age, education materials and curricula, non-governmental organization, etc.

It is paramount to start involving the young generations in early education by spending time with them, sharing our knowledge, educating by example, playing games (e.g. role-play), innovating and teaching them about sustainable projects. Thus, we improve the school retention, increase the awareness about project working environment, improve school achievements and thereby influencing the youngest to choose a career in the project management domain.

We can make the difference! It's up to us to give back something to society!

PROBLEM STATEMENT

Education is shaping us as individuals, it helps us become better versions of ourselves.

It empowers us to become emphatic individuals, to become aware about our strengths and address our weaknesses, build our confidence, and boost our personal growth.

We are living in an unprecedented time in history. The COVID-19 pandemic changed our World, affecting nearly every aspect of our lives and impacted all individuals worldwide. The pandemic is a scary and confusing occurrence for children. Schools went online, many parents started working from home overnight and only a minority number of homes allowed simultaneous activities to run under the same roof, being properly equipped with Wi-Fi and educational technology (EdTech).

Unfortunately, 124 million children across the world are out of school and 250 million are not learning basic skills as a result of poor-quality education.

In the last 2 years it was observed an increase in education abandonment and in early leavers from education and training (statistics presented in the STATISTICS chapter). This will have an impact in 10-15 years from now on when it will be observed a shortage in the availability of fresh graduates trained to become a valuable resource for project teams, indifferent of the specialized domain (e.g. project manager, project engineer, operation engineer, cost engineer, cost estimator, planner, scheduler, document management.

DIGITALIZATION IN PROJECT MANAGEMENT

In the twenty-first century we cannot pretend that we will be able in 20 years from now on to fully-digitalize the Project Management processes by replacing the human resources with machines using artificial intelligence.

We still struggle to become more agile in classic project management environment and final-product oriented by switching our mind from “what’s in it for me” to “what can I do the best to contribute to deliver a happy project”.

We succeeded to automate the reporting, to optimize certain processes, to minimize the level of bureaucracy, to ensure autonomy of processes, to train ourselves to become more flexible and agile, to implement innovative business models.

All of these digitalization initiatives require highly skilled professionals with experience in project implementation who have boarder view on processes and interfaces between different work packages (WP) and responsible departments for delivering the WPs.

CHILDREN LEARNING

“A child without education is like a bird without wings” – Tibetan Proverb

International Academy of Education issued Educational Practices Series (Ref.1) focused on learnings improvement and provides timely syntheses of research on educational topics of international importance. In the 7th booklet highlights that the children learn best when education is performed:

with active involvement and engagement of the learner, in a room for discovery experiential learning through inquiry and reflection

with social participation with peer collaboration and adult support

with meaningful activities

through connections between new information and prior knowledge

engaging in self-regulation and being reflective

iterative with chances to form, test, and revise hypotheses about how the world works

in such a manner to create motivated joyful learners

allowing sufficient time to practice

being strategic to understand and solve the problems in ways that are appropriate for the situation in hand.

These guiding principles are recognized by child psychology and are essential for quality learning in the twenty-first century. A quality education can transform a kid into a future valuable professional resource that will contribute to successful project implementation. Educating the next generation helps ensure future resource availability in all the domains. The children of today are the cost engineers/project managers of tomorrow.

The pandemic period severely impacted the quality of education and the immediate consequences consists in school abandonment and leaving education early.

STATISTICS"99 percent of all statistics only tell 49 percent of the story" – Ron DeLegge II, Gents with No Cents

EUROSTAT published a statistic related to education attainment level and early leavers from education and trainings in 2020 in Europe (Ref.2).

In EU Member States, school attendance is compulsory at least for primary and lower secondary education. The pupils who completed the lower secondary education, they may enter upper secondary education that typically ends when students are aged 18 years. Afterwards, the student may continue with the next education level (tertiary level provided by universities or tertiary educational institutes) or to start a specific occupation or trade (vocational programmes).

In 2020, 16.3% of EU population ageing from 20 to 24 years have less than primary, primary and lower secondary education (Fig.1), 64% of the 20-24 year-olds in the EU had completed at least an upper secondary level of education (Fig.2) and more than 40% of the 25-34 years-olds completed tertiary education (Fig.3).

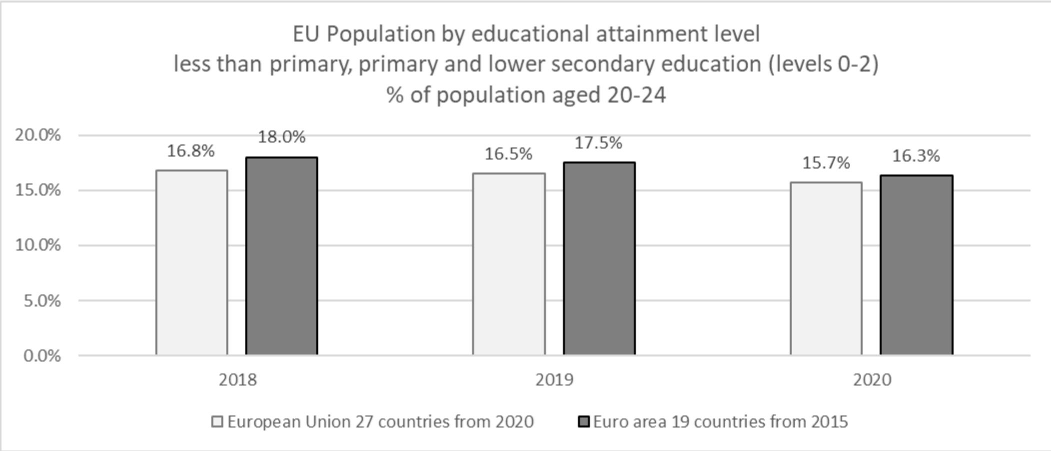

Fig.1 EU Population by educational attainment level – less than primary, primary and lower secondary educational attainment (levels 0-2), from 20 to 24 years-old, Annual, Total, Percentage

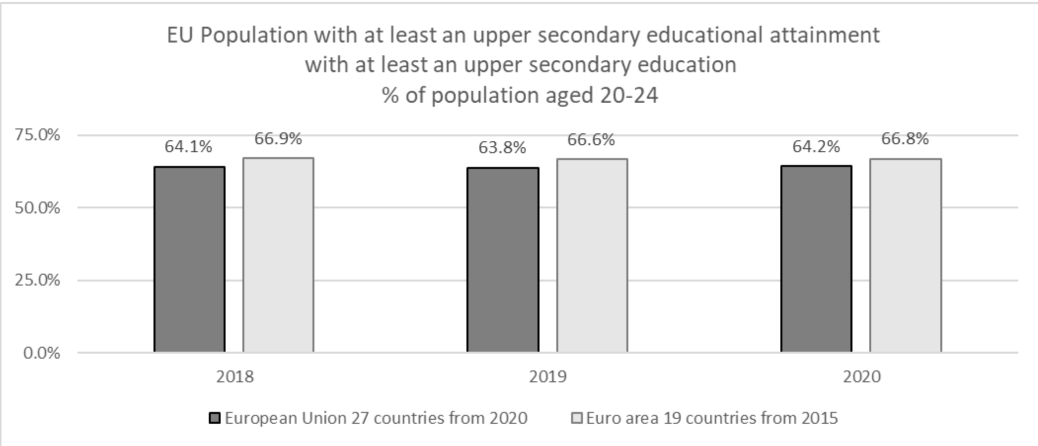

Fig.2 EU Population by educational attainment level – with at least an upper secondary educational attainment (levels 0-2), from 20 to 24 years-old, Annual, Total, Percentage

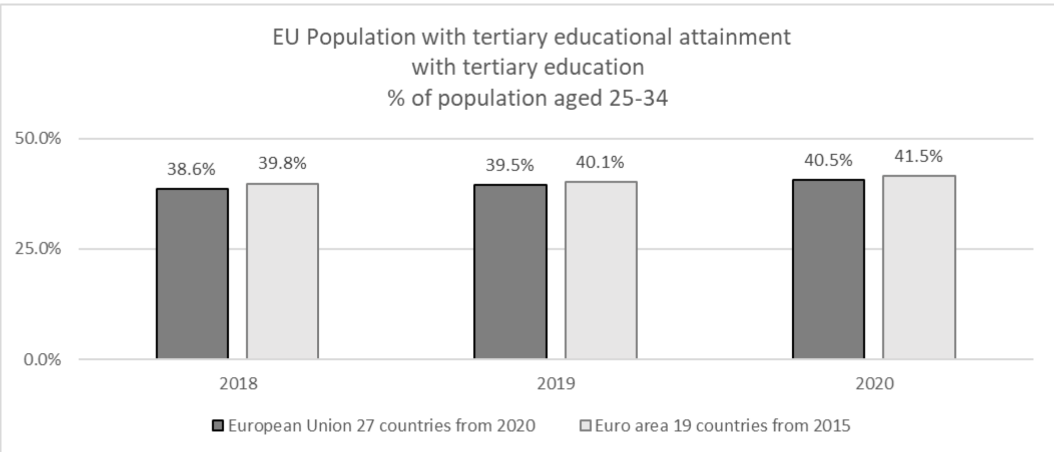

Fig.3 EU Population by educational attainment level – with tertiary educational attainment, from 25 to 34 years-old, Annual, Total, Percentage

In addition, there is observed almost 10% early leaving from education and training of the population aged 18-24 years-old.

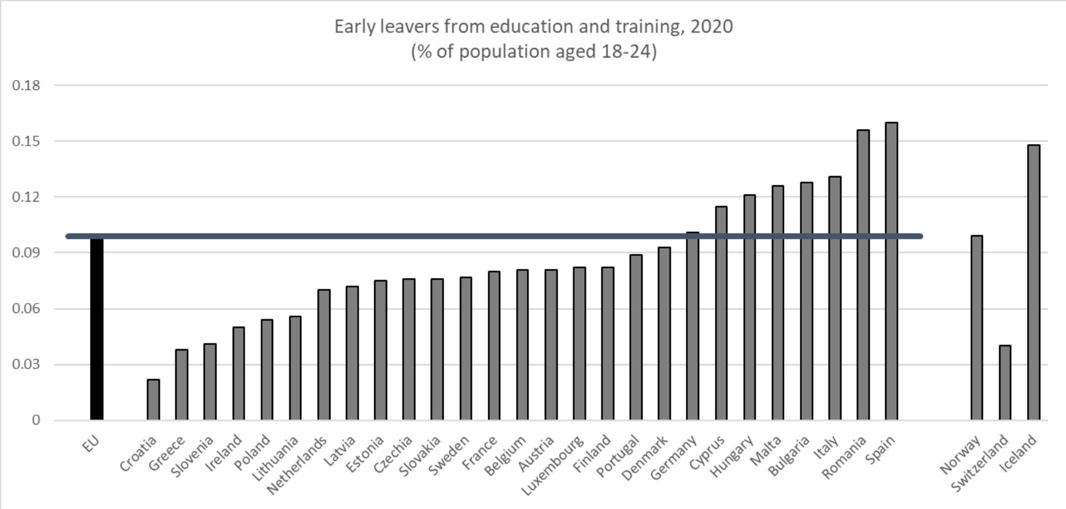

Fig.2 Early leavers from education and training, 2020 – percentage of population aged 18-24)

MAKING A DIFFERENCE

“As for the future, your task is not to foresee it, but to enable it.” – Antoine de Saint Exupery

People involved in Project Management domains are highly skilled professionals who can MAKE THE DIFFERENCE in the education of the young generation!

TODAY is the proper time to INCREASE our PARTICIPATION in the early education of today’s children starting with early childhood education, exposing them to basic project concepts: project scope, resources, project controls, quality, project closing, end-product and project abandonment.

There are resources available and professionals who can act as teachers, mentors, models for the young generation (Ref.3), guiding them through the project management disciplines, making them aware about different future career options, helping them to find their way and the suitable field of expertise where their contribution will make the difference.

By constant support and presence in their education, we can improve the school retention, and rouse the ambition to continue education beyond tertiary education attainment, influencing the youngest to choose a career in the project management domain.

Our continuous and constant involvement in the education of the younger generation will make the difference and at the end we will be proud also by our trainees’ achievements (Ref.4).

HOW TO INVOLVE“Knowledge is power” – Sir Francis Bacon

Our involvement will imply spending qualitative time with the young generation, to be perseverant and to be committed to ensure continuation in delivering education – no fortune to be spent is required.

One option would be to choose to do it by your own in case you identified in your circle of acquaintances a young person whose education quality is jeopardized.

The second option would be to become volunteer in one of the Non-Governmental-Organization (NGO) established in your country. There are a multitude of NGO involved in children education:

International

Childhood Education International –

Transforming the civil engineering surveyor (id 102; P_102)

Transforming the civil engineering surveyor

A white paper

From the Chartered Institution of Civil Engineering Surveyors

Contact

Chief Executive Officer

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Introduction: Embracing digital engineering and information management

Digital transformation is key to delivering a construction industry fit for 2050 and beyond. In this paper, the Chartered Institution of Civil Engineering Surveyors (CICES) considers the changing nature of the surveying professions amid the development of digital engineering, encompassing information management, data sharing and building information modelling (BIM) during the full infrastructure asset lifecycle.

The pace of technology development, particularly artificial intelligence, machine learning and data management, means surveying roles will change, requiring different skills on top of those honed in their rich history of being the key suppliers and curators of geospatial information throughout the civil engineering plan of work.

All the engineering professions are facing change, some more than others. The UK government mandate for the use of BIM on all centrally procured projects by 2016 instigated change in many contractors and consultancy firms. The 'BIM4' groups sprang up under the BIM Task Group and the BS1192 series of standards developed as the precursor to the international BS EN ISO 19650 series we have today. Throughout these early days, the challenge lay in demonstrating the relevancy of information management to surveyors.

Geospatial surveyors have witnessed lost opportunities because of a lack of awareness of their expertise and understanding of location data and data capture methods. Commercial managers have faced new ways of working using software platforms that they could not interact with to reflect the true progress on a project, which has exacerbated the 'silo mentality' information management has tried to counter.

Two factors since 2016 have accelerated the pace of digital transformation. The first is the growing awareness of climate change and the commitments that governments globally are making to mitigate its effects in a timeframe of just a few decades. The second is the COVID-19 pandemic which led to an increase in digital communications, reduced site visits and brought remote technologies such as automated monitoring and drone (also known as unmanned aerial vehicles/UAV, or small unmanned aircraft/SUA) progress reporting to the fore. 'Agility' and 'pivot' have become terms that businesses take pride in achieving. The information management trailblazers of the 2010s are now sharing their successes and lessons with their supply chains.

The remit of the BIM Task Group was taken forward by the Centre for Digital Built Britain and now by the UK BIM Alliance and British Standards Institution within the UK BIM Framework. The National

Digital Twin Programme being delivered by the Department for Business, Energy and Industrial Strategy (BEIS) is continuing to evolve, with the focus for the next three years moving to exploring and demonstrating how existing and near-to-market information gathering and management systems and information visualisation tools of increasing complexity can support decision making.

The Centre for the Protection of National Infrastructure is working with BEIS and the National Cyber Security Centre on the security of digital twins and underpinning information. It has been engaged to protect all that is digital in the digital twin, demonstrating that information about assets is as critical as the physical asset, system or process it relates to. It is supporting the development of a standard interoperable approach to asset information through the Government & Industry Interoperability Group (GIIG). The pace of change shows no sign of slowing. As emerging technology drives surveyors to acquire new capabilities and competencies, their expertise is essential in realising the efficiencies of digital engineering.

In 2021, CICES supported the global study Accelerating Digital Transformation Through BIM. It showed 70% of civil engineers have adopted BIM since 2016, demonstrating the rapidly growing use of information management for infrastructure work. Contractors deploying information management on at least 50% of projects reported significant benefits in areas such as bid efficiency, fewer defects, cost control, forecast accuracy, scheduling, reduced rework and fewer on-site challenges.

CICES was established in 1969 and has a Latin motto, omnia metimur quae videmus, we measure all that we see. The fashion for having a Latin motto may have gone, but the principle is relevant today and will be in 2050 and beyond. Measurement equals accuracy. Accuracy equals efficiency. Transforming the civil engineering surveyor simply reshapes that function for the future.

Key to this transformation is a better understanding of the expertise of geospatial engineers and commercial managers, and how they can inform decision making on infrastructure projects. This paper recommends a shift in the traditional timing of when civil engineering surveyors are engaged in projects, identifying that they will have more impact in the planning phase. Knowing what data will be needed when and to what accuracy and how this data will be used in scenario planning, costing, scheduling and monitoring will realise efficiencies and make full use of the surveyor's expertise.

While the majority of papers and initiatives referred to in this paper are from the UK, digital transformation of civil engineering surveying is global. Each country faces its own unique challenges and hope that lessons learned and shared here will benefit our colleagues overseas.

Perceptions and purpose throughout the phases of a project

Transforming the civil engineering surveyor also means transforming the perception of the civil engineering surveyor. Better understanding of the expertise of geospatial surveyors and commercial managers and how they can inform decision making at all phases of a project is a relatively simple step that can have a large impact.

For geospatial surveyors this was an issue tackled in 2016 by Survey4BIM, a specialist group under the UK government's BIM Task Group umbrella. Survey4BIM published Survey and the Digital Plan of Works2 to address a gap in the published UK BIM Level 2 standards for the role and responsibilities of the surveyor. The guidance followed a series of eight (0-7) work phases broadly aligned to those within PAS1192-2:2013 describing survey activities and recommendations for each phase.

The past few years has seen the move to the UK BIM Framework. The framework is intended to be applicable to all types of appointment and project, under any procurement route and for all participants. Consequently, it has framed guidance around a simplified set of phases focused on information management; design, build, operate, integrate.

Design, build, operate, integrate

The role of the surveyor within the UK BIM Framework remains critical to correctly specifying geospatial requirements at the outset of a capital delivery project to how survey data is used in asset operation and connected to other datasets. Obligations within the UK BIM Framework are described as:

- Design - Where digital techniques are deployed to design better performing infrastructure. Information management should be secure by default and managed in a way that gets data right from the start.

- Build - Where new and emerging digital construction and manufacturing technologies, processes and techniques should be exploited. Secure, shared information should enable clients, design teams, construction teams and the supply chain to work more closely together to improve safety, quality and productivity during construction.

- Operate - Where real-time information should be used to transform the performance of the built environment and its social and economic infrastructure. Smart asset management should predict and avoid disruption of services, while existing assets and infrastructure should be digitalised.

- Integrate - Where it is understood how spaces and services can improve quality of life. That information should be fed into the design and build of economic and social infrastructure and the operation and integration of services they deliver.

These phases are entirely applicable to the surveyor, whose role in the project and asset lifecycle needs to be better appreciated and integrated. The obligation of the surveyor is to align to standardised information management processes, identify and embrace appropriate technologies and commit to trusting the data they receive from other participants. The risk averse nature of the construction sector, reliance on inefficient legacy procedures and limited investment in technology and people needs to be retired in order for effective change to happen.

Geospatial considerations

By considering the standards and guidance for the phases within the UK BIM Framework, coupled with the still applicable recommendations in Survey and the Digital Plan of Works, geospatial surveyors can better demonstrate the criticality of their role in the asset lifecycle and ensure their data needs and outputs are integral to successful project outcomes.

Information management solutions and processes have become familiar to many professionals and organisations over the past few years. Moreover, the pace of technology innovation has introduced new solutions and opportunities to increase productivity, improve quality and challenge traditional thinking. For example, surveyors are able to undertake unmanned aerial surveying, set out directly from models, leverage sensor data for real-time information, drive machinery remotely and many other options to improve their work and collaboration with other project participants.

The Transforming Infrastructure Performance: Roadmap to 2030 (TIP)4 from the Infrastructure and Projects Authority notes that there are technical capabilities that are not yet being asked for or applied on government projects. It particularly highlights 5G networks, artificial intelligence, wireless sensors, monitoring, fixed and mobile sensors, photogrammetry, 3D laser scanning robotics and augmented reality, and calls for improvement and acceleration of their adoption. Such innovations need to be introduced with consideration for the value they bring to a project and wider downstream operational and service provision. Technology for technology's sake is not worth adopting without both a resulting material improvement and an assurance of no unintended negative consequences. The geospatial

4 https://www.gov.uk/government/publications/transforming-infrastructure- performance-roadmap-to-2030

surveyor is the expert on this technology, and as an appointed consultant will be able to advise on the most appropriate technology and data requirements for every stage of the project. The geospatial surveyor can assist in the specification of requirements, advise on where coordination is missing and what is required, and plan how information quality will be developed over the design, construction, handover, operation, maintenance and decommissioning of an asset.

The emergence of geospatial project execution plans shows that with the right data capture and management methods in place, other project team members can focus on their specialist contribution, using technology as an enabler, not a distraction.

Commercial management considerations

The commercial manager and quantity surveyor roles are transforming to ones of proactive data management to drive value and monitor project progress.

The TIP highlights the increasing use of information management as a planning tool to coordinate construction to a critical path and undertake clash detection in line with resource management, capacity planning and scheduling. Taking this further to cost modelling, some software already has the capability to incorporate costed components and materials in the information model, alongside linked availability and access. This can then drive bills of quantities and optimise resources whether work is on site or during offsite manufacturing.

The key message in TIP is that embracing information management and a multidimensional approach starts in the planning phase with highly detailed information and better integration that can then inform the work packages. By establishing the core contribution of the commercial team early, and with regular engagement throughout the project to ascertain how data can be used to drive efficiencies, the data measurement role of the commercial civil engineering surveyor can be fully exploited. As cost modelling becomes more mainstream, now is the time for commercial surveyors to reaffirm the key role they play in ensuring project efficiencies, with a focus on data and value, as well as cost.

Planning: All about timing

The timing of when to engage a surveyor needs to be rethought. Early engagement with both commercial managers and geospatial engineers is key to releasing efficiencies. The first step is to determine what data the project needs throughout its lifecycle.

Engage early, plan for life

Engineering surveyors are often called to provide professional services within a very narrow window of requirements by the project stakeholders to meet an immediate need. However, by working with clients, as an appointed consultant, they are best placed to specify, procure and manage geospatial information throughout the planning phase through to operation of an asset. This holistic approach enables clients and appointed parties access to geospatial information at an appropriate level of need in the lifecycle of the project.

The geospatial engineer is a custodian of location data. This kind of data has until now been managed in appointed party silos through the phases of an asset's lifetime. Geospatial information needs to be managed through a balanced and structured approach throughout each phase. Engaging a geospatial engineer as an appointed consultant is key to unlocking the transformation from individual stakeholders managing and setting their own requirements for geospatial information to a collective plan of project needs embracing specification, collection, added value and handover of geospatial data between stakeholders.

This adds value to design integrity and provides as-built information to aid and inform asset management and monitoring.

Survey4BIM's Survey and the Digital Plan of Works can help pinpoint what survey data is essential at what stage of a project and is a useful resource when commissioning and planning geospatial data requirements.

Ask and you shall receive

Our focus groups revealed some commercial managers still struggle to see the benefit of information management. One quantity surveyor commented: “The 3D models I'm told to use present a pretty picture but the data behind them is often unusable.” The perception persists that planners and BIM managers provide data they think the commercial team needs without talking to them first. This can lead to mistrust and the contractor's commercial team commissioning its own data and working on that independently in a silo. To get over this mismatch of presumed usage and actual take- up, a combined data/commercial cost plan is needed. Monitoring integrated cost models, data levels and reports needs to be a key activity on the programme, with all involved responsible for driving it forwards.

Commercial teams have to step up in adopting new work practices that leverage the opportunities from information management. Reliance on traditional trusted, but actually inaccurate, methods has to go or the efficiencies of digitalisation will never be realised. Within a project controls team, this shift is naturally facilitated, but on smaller projects where commercial, planning and design teams sit separately, it is imperative that these teams no longer see each other as stumbling blocks.

The commercial management team should be fully engaged and asked at the start what their information requirements are and how they need to see information presented. By integrating commercial, planning, design and BIM specialists - or at the very least, having weekly interdisciplinary meetings - information requirements can be clear from the outset and processes around sharing and management defined.

When data and information deliverables are agreed, they should be recorded in task information delivery plans. These are amalgamated into a master information delivery plan, together with the geospatial project execution plan encompassing the data requirements and the technologies it has been agreed will manage the process. This will provide a foundational framework to maximise data efficiencies.

Skills: Custodians of accuracy

Engineering knowledge is no longer a prerequisite to working in construction. Data analysts, information managers and gaming/visualisation specialists are increasingly regular appointments. These new roles work hand in hand with surveyors and the skills of each should complement each other in the digital engineering team.

The Construction Innovation Hub's Digital Capabilities:

A Framework for early career professionals across built environment disciplines1 set out six digital capabilities required in construction:

- Data collection and instrumentation
- Information management
- Data interpretation and analysis
- Data governance
- Data visualisation
- Software development

The current civil engineering surveyor could lay claim to involvement in the first five of those six, with many contributing to all six with their involvement in software development through bespoke systems and early adopter relationships with developers. While project teams do not centre their career on software development, they have to embrace new technology as a digital capability.

The skill-set of the commercial manager in particular is in danger of not developing in line with the systems being used and not fulfilling the potential it has to transform projects.

For the geospatial surveyor, the fast pace of technological development over the last half-century has resulted in an agile profession at remarkable ease with new tools.

1 https://constructioninnovationhub.org.uk/wp-content/uploads/2021/11/Digital-

Capabilities-a-framework-for-early-career-professionals-across-built-environment-

disciplines.pdf

However, its chief concern is the lack of entrants to the profession.

New skills: what might we need?

The commercial manager and quantity surveyor roles are transforming. Commercial and planning teams are increasingly coming together under the joint banner of project controls. They no longer stand in silo functions, this is about bringing together their expertise to give a full picture of a project's health and progress.

While measuring cost continues to be a key commercial role, especially in the post-pandemic and post-Brexit UK, this is just a part of one of the capitals that need to be measured under the UK government's focus on value.

The Value Toolkit from the Construction Innovation Hub aligns with HM Treasury's Green Book, against which public sector investment decisions are made. Value is measured over four capitals:

■ Natural capital - valuing the natural environment and addressing solutions to climate impacts.

■ Social capital - valuing engagement and consultation, equality and diversity, and the positive impact of the built asset on society.

■ Human capital - valuing employment opportunities and skills development.

■ Produced capital - valuing a combination of capital cost, operational cost and revenue, taking a whole- life approach to efficiency and quality of design, construction and operational processes.

The commercial manager is a specialist at measuring produced capital. Transformation will involve acquiring skills in measuring the other three capitals as well.

Clients have to think differently about their long term plans. Balancing affordability and the four capitals will naturally change tender specifications. This shift is a challenge and the Construction Innovation Hub recognises that it “demands considerable rigour in defining the outcomes to be delivered and understanding the client's approach to project delivery and risk.” Again, success will lie in early and regular engagement between the commercial, design and planning specialists.

Tackling a skills shortage: The role of CICES

When looking at skills in civil engineering surveying, one has to consider both the shortage of digital skills in the current surveyor and the shortage of skilled new surveyors. As a professional qualifying body, CICES has a role to play in addressing both issues.

For new entrants, CICES needs to ensure it continues its collaboration with organisations involved in schools engagement, including Construction STEM Ambassadors, Get Kids into Survey and Class of Your Own (the organisation behind the Design Engineer Construct! curriculum). CICES must maintain its involvement with steering groups for the Geospatial Survey Technician, Geospatial Mapping and Science Specialist, Construction Quantity Surveying Technician and Construction Quantity Surveyor apprenticeships; and build on its successful university accreditation programme. Involvement with the Construction Leadership Council Skills Plan is a necessity to avoid a fragmented approach to careers promotion.

The image of the surveyor as 'data custodian' needs to be better promoted. Protocols and standards focus on quality process, while surveyors focus on quality data - this and the technology and expertise required to capture and define quality is rarely recognised by the

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wider project team, and almost never in schools' careers departments.

Civil engineering surveying is rightly proud of its openness to all as a career. Many industry leaders talk about joining the construction industry straight from school, and progressing to attain company directorships with professional, rather than academic, qualifications. Historically, construction is seen as a male-oriented career, and with CICES female membership sitting at just over 10%, CICES has a duty to build on that socially mobile heritage and ensure that the profession is open to a diverse range of talent.

CICES plays a vital role in linking industry requirements with education and apprentice providers. For this to be effective course accreditation and re-accreditation needs to reflect the digital astuteness necessary for civil engineering surveying. As this area develops and the standards around it grow, regular engagement between professional and academic institutions is crucial.

To upskill its existing membership, CICES has already committed to embedding digitalisation within its membership competencies. However, the award of membership is a point in time. Professional bodies need to look at how they engage existing qualified members to upskill through their continuing professional development requirements. The Construction Innovation Hub calls on professional bodies to develop a common understanding of sector-wide core digital capabilities and to work with members to determine what digital capabilities they need in their work. Answering this call rests with both individual institutions and the UK BIM Alliance, whose Affiliates Programme can assist in providing a forum for professional bodies to share experiences and best practice.

digital transformation. Members need to be aware of their own professional accountability to upskill and should be encouraged to assess their own digital maturity to gauge where they need further development. CICES, and other professional bodies, need to play a non-judgmental role in signposting to further information and knowledge banks, providing time for discussion at events - rather than rushing Q&A at the end of webinars and seminars - and they must promote support from specialist technical committees and regions.

Professional bodies should be 'safe spaces' for the sharing of lessons learned and mistakes overcome in

Data: Navigating a new currency

The Construction Playbook1 stresses that: “A critical success factor for the effective completion and transition of a project or programme is the sharing of high quality, robust data and information between parties during the project lifecycle and into operation.” A few years earlier in 2018, the Gemini Principles around data sharing for the forthcoming National Digital Twin valued this assumption, stating that greater data sharing could release an additional £7bn per year of benefits across UK infrastructure, which is equivalent to 25% of total spend.

Establishing protocols and processes around data sharing is essential for the transformation of construction. While data sharing practices have yet to be fully established and normalised, they will happen - and civil engineering surveyors should be enacting best practice and ensuring their continuing professional development factors in skills in data management. While protocols and standards focus on quality processes, surveyors focus on quality data and therefore are natural leaders in managing and specifying data requirements.

The information delivery lifecycle

Information is developed and built up through the lifecycle of a project, commonly referred to as the digital plan of work (DPoW). The unified CIC/APM digital plan of work consists of eight generic stages:

- Strategy
- Brief
- Concept
- Definition
- Design
- Construct and commission
- Handover and close-out
- Operation and end-of-life

The level of information need (formally known as the 'level of definition') is defined for each stage gateway and is the aggregate of level of detail and level of information. The 'level of detail' is the description of graphical content required to address the decisions at each stage gateway. And the 'level of information' is the description of non- graphical content required for this.

As information progressively develops at each stage throughout the project delivery it collectively forms the Project Information Model. The graphical representation may not change at each stage but 'Information' will be added at each stage.

For example, at concept stage graphical detail may look very realistic but spatially inaccurate, plus information is likely to be low grade with a lot of unknowns. Whereas at handover and close-out, graphical detail will accurately reflect the as-built position of the works and information delivered will be sufficient to maintain and operate it.

The production and delivery of information on a project is assigned to specific Task Teams (Disciplines) - for example civil, mechanical and electrical. These 'own' the information they are responsible for producing and only they can create or edit that data.

All information, regardless of the work stage it is developed at, can be assigned one of three states:

- Work-in-progress (the only state in which files can be edited by the discipline that 'owns' that output)
- Shared (non-contractual, used for collaboration)
- Published (contractual - such as client deliverables or instruction to fabricate or build)

The work-in-progress state is used for information while it is being developed by its task team/discipline.

Information in this state is not visible or accessible to any other discipline.

When the discipline is ready to share its information, it must pass through a check, review and approval workflow and is given a status code (often referred to as a suitability code). This is necessary so the receiving party can have confidence in the information shared and has some understanding of the purpose for which it was shared. The status codes that can be assigned are:

- S1 - suitable for geometrical and/or non-geometrical co-ordination within a delivery team
- S2 - suitable for information or reference by other disciplines within a delivery team
- S3 - suitable for review and comment within a delivery team
- S4 - suitable for review and authorisation by a lead appointed party
- S5 - suitable for review and acceptance by an appointing party (client)

The purpose of the shared state is to enable constructive and collaborative development of the Information Model within a delivery team.

When a discipline promotes information to the published state it must pass through a further review and authorization workflow. The published status codes assigned - A0, A1, A2, A3, A4, A5, A6, A7 - all indicate the stage gateway of the digital plan of work they refer to.

The information at shared and published states is visible and accessible by other disciplines within a delivery team but is not editable by them. If the information requires editing it is returned to the work-in-progress state for amendment and resubmission by the discipline that owns it.

This process of information development and exchange is defined by BS EN ISO 19650-2:2018 and is undertaken within a common data environment (CDE). A CDE is the single source of information for a project, used to collect, manage, and disseminate all relevant project information through a managed process. A critical function of the CDE is to provide a clear and secure audit trail or journal of all changes and amendments to that information, including who created it, who read it, who edited it, who shared it (and for what purpose), who checked and reviewed it, who approved it, who authorised it to be 'published' and when all these activities took place.

At the end of Stage 6, the as-built information represents the as-built asset in content and dimensional accuracy and is submitted to the client for acceptance, along with the commissioning and handover documentation.

The complete PIM is handed over at the end of the project and culminates in the transfer of relevant information from the PIM to the asset information model (AIM), for use in asset management and potentially within a digital twin.

Leading up to this state of high quality and robust information requires a careful and structured approach, which includes adherence to strict processes and standards and an element of risk management.

Standards and standardisation

The UK government's National Data Strategy5 of December 2020 stated that while the standards were 'well recognised', SMEs generally do not use information management. The key hurdles to be overcome included software licensing and cost; lack of in-house training and skills; interoperability; a perception that BIM was only for larger construction projects; and a lack of demand from clients.

Since then, the Construction Playbook has clearly set out to ensure that client demand is there (at least in the public sector); the Government and Industry Interoperability Group (GIIG) has been established to support interoperability; software houses and market forces are addressing licensing costs; and training is filtering through the supply chain from the

5 https://www.gov.uk/government/publications/uk-national-data-strategy/ national-data-strategy major contractors. Perception will change in time and professional bodies have a role to play in providing learning opportunities around specification requirements and standards, and the importance of a balanced and structured approach to data management throughout the lifetime of an asset.

Standardisation of data is necessary for collaboration. The Construction Playbook is very clear about government expectations of contractors around data management, explicitly saying they should use the UK BIM Framework to standardise the approach to generating and classifying data, data security and data exchange, and to support the adoption of the Information Management Framework and the creation of the National Digital Twin.

Naming protocols for information containers for objects and layers should be established early in a project and align to the needs of the client. It is imperative that these requirements are communicated to the project delivery team via the BIM Execution Plan (BEP) and that everyone adheres to them. The Geospatial Commission uses FAIR terminology6 to assess the fitness for purpose of data, with data that is:

- Findable
- Accessible
- Interoperable
- Reusable

The term Q-FAIR is also used by the commission and adds 'quality' to the data ideal. Civil engineering surveyors - both commercial and geospatial - should keep the Q-FAIR principle in mind when commissioning, capturing and managing data. The role of the surveyor in determining quality is key to the success of projects and will cover the currency, accuracy level, verification and suitability of data - addressing concerns around how much the data can be trusted and how it will be used with

6 https://www.gov.uk/government/collections/best-practice-guidance-and-tools- for-geospatial-data-managers other data. This relates to the 'level of information need', which might require a higher level of detail and accuracy at DPoW Stage 4 (detail design), than at DPoW Stage 2 (concept design), for example.

Another initiative that will aid data standardisation is the International Cost Measurement Standard (ICMS). ICMS provides a high-level structure and format for classifying, defining, measuring, recording, analysing and presenting life cycle costs and carbon emissions associated with construction projects. CICES is one of 49 global bodies in the coalition steering the development of the standard.

Sharing securely

Geospatial surveyors should be mindful of the adage, capture once, use many times. The geospatial project execution plan should be developed as part of early engagement with the client and address what existing data is known about and available, and ensure that new data capture is carried out with the whole project life¬cycle in mind.

The potential for sharing data in future projects needs to be addressed in the contract. The surveyor is best placed to comment on how the data could be used in future projects for other clients.

Surveyors have access to a huge range of data, and need to be mindful of their responsibility to keep that data secure, especially on national infrastructure projects. Clients will increasingly specify data security requirements, such as Cyber Essentials accreditation, in tender documents. The Centre for the Protection of National Infrastructure (CPNI) has a wealth of guidance material on developing a security-mindedness approach and assessing the security of data management systems. The National Cyber Security Centre (NCSC) has developed guidance on cyber security for construction businesses.

For underground utility surveys, the cross-industry endorsed Secure Data Management for Utility Surveys11 published by CICES is also useful.

Facing the risks

Data sharing can appear highly risky to those whose careers have been shaped though the traditional adversarial culture of construction. This leads to a reluctance to share between stakeholders, particularly where added value has been embedded based on personal judgments and interpretation of information.

Further work needs to be carried out to determine the most effective processes for data validation. Currently, the recipient of data expects it to have been validated by the sender. However, there is a chain of thought that turns the table on this expectation and recommends that the recipient verifies the data it receives. Recipient verification transfers risk from the sender and has a commercial implication around who is paying for verification and the actions that may need to be managed stemming from the outcome of verification and any resulting change management. This model is outlined in the Construction Playbook where in a list of dos and don'ts, one is: “Don't... hold incoming suppliers responsible for errors in data (excluding forecasts) where they are unable to complete due diligence. Where data turns out to be incorrect, there should be a contractual mechanism for reflecting this adjusting for errors.”12

However data validation is carried out, the process should be collaborative with a structure in place to notify parties of any discrepancies and clashes. Who is in charge of the truth and when needs to be thought about right at the start of a project. In the Construction Playbook, the second step in the delivery model assessment for public works projects and programmes is to identify data inputs. This sits right after framing the challenge of what type of sponsor and governance approach is being taken, and

11 https://www.cices.org/content/uploads/2022/03/Secure-Data-Management- for-Utility-Surveys.pdf

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before considering the delivery model. That narrow view of protecting commercial returns has to

widen.

With data thought about early and often, and an accurate and reliable pipeline of information flowing through a project, the natural progression is to put it to further work. Good data should be used as a benchmark to aid decisions in forthcoming projects. Ensuring the quality of this data as it is used in future evaluation is a further role where the skills of the commercial manager will be beneficial. Machine learning programs are already being used by public sector clients to manage risks on mega¬projects by assessing historical data. As machine learning and AI become more developed and familiar tools, this kind of analysis will become more common.

We cannot not share

Open data initiatives, where non-sensitive data is made available without constraint for transparency, engagement and innovation purposes, are increasingly encouraged by the UK government. Surveyors need to take care that legal and security liabilities are considered when sharing data for the public good.

Commercial barriers to data sharing were addressed in Data for the Public Good from the National Infrastructure Commission in December 2017, where perceived commercial risk was studied under the glare of overall industry efficiencies. Putting it simply, the report stated that: “By refusing to share data, a private company or organisation keeps control of that data as it grows... as the volume of data increases and machine learning techniques are applied, the quality of the data improves and so becomes more valuable. Thus there are increasing returns to data, which if retained in the private sphere, will remain as narrow returns to the private company rather than wider returns to the economy as a whole.”

Professional civil engineering surveyors are bound by the royal charter that governs them to benefit society.

Contracts and protocols: Carefully enabling the digitalisation journey

Contracts should enable, and not constrain or conflict, with the digitalisation journey. Data sharing and collaboration need to be carefully supported. This can be addressed either through conditions of contract or dealt with in a protocol that overlays contracts.

Data takes the form of outputs and deliverables identified as part of the scope of works or service that the supplier is to provide, the format in which it is to be provided and when. Data will in many ways be the same as any other deliverable under the contract, however there are issues that need to be considered due to the fact digital information will be shared with others and combined and developed in an integrated or federated information model. The timing of information releases, the liability and responsibility for the information provided and the development and use of this in an integrated or federated model have to be thought about carefully. Ultimately, the end product will be a model that combines information provided by the parties that the client will use to manage the completed asset.

In order for the information model to meet the client's overall requirements there will be a need for each party to have a guiding hand on its development, following requirements which may need to change as the project develops. There may be clashes with the requirements in individual bi-party contracts and commercial managers should be prepared for this.

Traditional bi-party contracting creates a hierarchical structure with risk and responsibilities split across the different parties, including responsibility for the creation, sharing and development of data which can be ultimately used in an information model. This way of contracting creates multiple interfaces that need to be effectively managed. However, due to the individual allocation of risk to each party, the approach can drive a silo mentality in which each party seeks to protect its own position, instead of collaborating on the basis of what is best for the project. To overcome this silo approach, clients and their suppliers are moving to more collaborative engagement models such as alliancing.

Alliancing

In practice, there is a sliding scale of alliancing from simply having some form of partnering charter or non¬binding agreement overlaying another engagement model, all the way through to the creation of a formal contractual alliance. In all cases, the parties are encouraged to work together on a best-for-project basis and are incentivised to do so via shared performance measures. When a contractual alliance is created, the parties sign up to the same contract and share the majority of risk and reward.

There is support for alliancing from government in the Construction Playbook,1 which states that while alliancing arrangements are not always appropriate, “they should be considered on more complex programmes of work as the effective alignment of commercial objectives is likely to improve intended outcomes as well as drive greater value for money.”

Enterprise

Project 13 from the Institution of Civil Engineers is an illustration of what currently constitutes 'good'. Described as an enterprise model for infrastructure delivery, Project 13 brings together numerous partners and suppliers who integrate their capabilities, processes and information under incentives and long-term relationships. The asset owner, or client, is the central driver of change, and the parties are rewarded based on their value to the

overall project outcome - not on a transaction of time or volume of work. Risk is aligned with capability, and is not cascaded down the supply chain.

Coming from an adversarial and competitive approach to contracting, the shift to enterprise and alliancing is immense, but it is doable. Success lies in the hands of the client, or 'capable owner' as Project 13 calls them. However, many owners will take time to become capable. Contractors need ways to transform their methods of working that can be driven by themselves in the meantime, whilst forming those long term relationships with the supply chain that will be called upon in the future.

Change takes time

Whilst the use of alliancing and enterprise ways of contracting may be the way forward, we need to consider how to deal with the more traditional bi-party contracts that pervade the industry. Even in a move to alliancing, not all members of the supply chain will form part of the alliance and there will still be bi-party contracts at subcontract and subsubcontract level. We therefore need to consider the digital maturity of all parties and recognise that the expertise and ability to transform will vary, and yet each part of the chain has a part to play in the move to a more digitally enabled industry.

The wider supply chain needs to be engaged in information management, however the level of their involvement, the data they supply and the format of this needs to be proportionate to their role and their level of digital maturity. The approach adopted across contracts should be scalable to reflect the differing levels of maturity. Levels of IT literacy will vary and Tier 1 contractors have a duty to engage with their supply chains and train them on the systems they are employing on projects at an appropriate level of detail to ensure the project's security. While the wider supply chain may need an incentive to 'do BIM' - to contribute to the collaborative information management of a project and to work with that information themselves, whether accessing the model interface or inputting data, everyone must take responsibility for their part in the information delivery process.

Protocols

Protocols allow a consistent set of requirements to be used for all parties that contribute to the information model, however this can lead to clashes between the terms of the protocol and the contract it overlays. Careful consideration has to be given as to how protocols and contracts interact and the interfaces between them need to be actively managed.

Where alliancing approaches are adopted, the need for protocols to manage the interfaces between the parties contributing to the information model is reduced or removed as the parties share in the performance risk of the information model.

The Construction Industry Council (CIC) BIM Protocol was the first to guide information sharing and collaboration as responsibility for the design model changed on a project. A second edition was released in 2018. These have since been developed into two information protocols within the UK BIM Framework4 (for ISO 19650-2 and ISO 19650¬3). While there is a wealth of helpful processes and procedures, parties will still need to find a way to 'talk to each other' digitally and trustfully.

Protocols are 'points in time' and do not address the wider behavioural change that needs to occur. Ways of working with protocols and standards in general need to be addressed by contractors. While there has been a government information management mandate since 2016, neither clauses nor protocols can be forced onto parties arranging a contract outside of the mandate.

4 https://www.ukbimframework.org/resources/

The only persuasive argument will be demonstrative. Contractors and clients need to share case studies and experiences, facilitated by professional bodies and their knowledge sharing platforms, highlighting reduced re¬work and reduced disputes on projects.

Whatever contracting model is adopted, successful information management requires the parties to work collaboratively and this should be made a contractual obligation, such as the requirement in the NEC4 suite of contracts for the parties to act in a spirit of mutual trust and cooperation.

The question of responsibility

One of the largest questions that will need to be addressed contractually is around responsibility for the information model and the data within it. This issue needs to be considered both during the development of the model and upon its completion. This is unfortunately a common objection to collaboration in information management.

In alliancing, depending on the specific form of contract used, the parties share in the risk of the creation of the digital information, removing the need for each party to protect its own position and have this addressed in the contract or protocol. Such an approach is adopted in the NEC4 Alliance Contract in which the alliance as a whole is responsible for updating or creating the information model and correcting any errors within it.

With this kind of contract there is no requirement to allocate responsibility and risk for elements of the model that each party creates or inputs into, with all parties sharing the risk to the extent of their liability under the contract. This allows them to work collaboratively, without the need to protect their individual position, and the information within the model becomes the property of the client on completion.

However, this flow does not work with multi-party contracts. If the client holds a federated model, it needs to consider at the earliest planning stages how it will provide secure, relevant and proportionate access and how it will manage the information contributions of others. In some contracting models, such as Design,

Build and Operate, the responsibility for the creation or modification of the federated model may be passed to the first tier supplier, who will co-ordinate the inputs into the model from the supply chain and then pass the federated model back to the client at the end of the contract.

Planning for the transferrence of responsibility should take in soft landings guidance and the Line of Sight methodology from the Centre for Smart Infrastructure and Construction, which echoe the principle of keeping the end use of the asset constantly in mind. As the National Digital Twin Programme ramps up, the information model has to be put to use. Asset management objectives and any client-operated information management platforms have to be considered at the time of contract formation.

Contracts should enforce the principle that the client is ultimately paying for the information model and hence owns the delivered data. This does not preclude intellectual property or technical responsibility of those who have contributed to it. In general, while the output is project specific, the skills to create it reside within the professionals employed on the project. The 'golden thread' philosophy, set out in the Hackitt Report, supports this ideal of being able to go back in time to determine who made what decision, when and why, by having a robust history of decision making within an information model. A properly BS EN ISO 19650 compliant common data environment (CDE) archive should provide this. In BS EN ISO 19650:2018, the archive state is used to hold a journal of all files that

have been shared and published during the information management process as well as an audit trail of their development and any revisions.This should not be confused with an IT archive, which usually refers to a process where a file is removed from a live computer system to an offline environment where it is archived for subsequent retrieval.

Reducing disputes

Better information management should in theory lead to fewer disputes, as design and scheduling clashes are spotted before work begins on site, and an audit trail - or golden thread - of digital information should support change management, and also mediation and arbitration should a dispute fully develop.

In 2016, the Centre of Construction Law and Dispute Resolution at King's College London released its research report Enabling BIM through Procurement and Contracts. While almost six years old, it highlights many considerations for contract drafters and managers, notably that most contract forms in use are unsuitable alone for good information management. More recently in 2021, Constructing the Gold Standard - An Independent Review of Public Sector Construction Frameworks was published by the Cabinet Office to aid government clients in adoption of the Construction Playbook.

While not highlighting digitalisation specifically, the Conflict Avoidance Pledge,11 supported by CICES as a member of the Conflict Avoidance Coalition Steering Group, demonstrates that signatories have committed to deliver value for money and work collaboratively.

The behavioural changes that come with digital transformation will help signatories in fulfilling the pledge, which has been recognised by government in the Construction Playbook.

Another initiative supported by CICES and a good example of industry-wide collaboration is the Multidisciplinary Steering Group for Cost Assurance and Audits on Infrastructure Projects and Contracts. This brings together construction lawyers, contractors, clients and finance advisors to address issues around cost assurance.

The 2018 Winfield Rock Report: Overcoming the Legal and Contractual Barriers of BIM13 is also imperative reading. The report gives a good overview of legal professionals' understanding of the contractual issues around information management.

The future

Contractual arrangements that enable data sharing to truly transform civil engineering surveying and construction itself are yet to be fully realised. The commercial component of projects has to mature to allow industry to exploit the potential of information management to deliver benefits during the capital and operational phases of assets. In a nutshell, if contracting carries on as normal, then information management will always be pushing water uphill.

Progress is being made. The UK government is very clear on that, saying: “We will ensure that contracts are structured to support an exchange of data, drive collaboration, improve value and manage risk.”14

Change: Trusting and being trusted

It is understandable that any mention of change in the construction industry is met with scepticism. A few civil engineering surveyors will remember the Banwell Report1 of 1964, more will remember the Latham Report of 1994, the Egan Report of 1998, and even early career surveyors will be aware of the Farmer Review from 2016. All incredibly sensible, but the change these reports called for was never fully realised. In 2009, the Wolstenholme Report assessed the lack of progress since the earlier reports. The key reason for little change was the acceptance of the status quo by investors and suppliers.

There are signs that things are different now, and mechanisms are starting to drive change. The first real enabler of transformation was the 2011 UK government's mandate for centrally procured construction projects to be delivered using BIM by 2016. This was followed in 2020 by the Construction Playbook, which specifically calls on contracting authorities to use the UK BIM Framework of standards and guidance, and to support the adoption of the forthcoming Information Management Framework, which will sit behind the National Digital Twin.

These requirements need change to happen. The Infrastructure and Projects Authority's Transforming Infrastructure Performance: Roadmap to 2030 (TIP) calls for a "step change in productivity and efficiency in the ways we plan, design, manufacture, construct and operate infrastructure."

For this step change, "successful delivery will require clients and suppliers to develop and adopt new ways of working across the board; to share information and embrace new technologies that deliver better performance and more balanced outcomes across the asset lifecycle. Project leaders will need to steer innovative delivery in line with the government's complex policy objectives, and embrace responsibility for the delivery of outcomes as well as outputs."

Added to these industry and government movements are two societal impacts; the COVID-19 pandemic and climate change. The pandemic brought the benefits of autonomous and remote technology on site to the fore, with video communications and augmented reality replacing site visits, whilst further minimising the associated safety risks of being on site. The UK government's Build Back Better commitments are centred on sustainability and carbon economy. It is impossible to achieve change using traditional approaches. Increased digitalisation, offsite assembly and manufacture, and modern methods of construction are seen as key to reducing carbon emissions. Balfour Beatty, Costain, Laing O'Rourke, Skanska, Kier, Galliford Try, BAM, Amey and many other major contractors all have net zero pledges with dates ranging from 2030¬2050 requiring them to embrace digitalisation as a carbon cutting benefit. All these things are happening now. There is no room for scepticism as change is finally underway.

Fitting into a changing landscape

Where does the civil engineering surveyor fit in this changing landscape? As civil engineering is chiefly from public funds for public good, change is largely going to be driven by government mandates, policies and

9 Page 6, Transforming Infrastructure Performance: Roadmap to 2030 procedures. This doesn't mean it will be without its challenges - as the TIP states, the government's policy requirements are 'complex'. One common theme that came through workshops with geospatial surveyors was that clients don't always know what to ask for. For example, a client will ask for a 'drone survey', without any prior discussion with the surveyor over what the purpose for the survey is and what data and accuracy is actually needed. One surveyor used the term 'digital handholding' to describe the client/surveyor relationship throughout this transformational period. The geospatial surveyor is ideally placed to offer advice on the most efficient survey method to get the data that is needed and can 'hold the hand' of the client as they become more familiar with data-driven construction and asset management.

This kind of early communication is called for in the Construction Playbook, which stresses the need for early supply chain involvement when developing the business case for projects. Civil engineering surveyors, both commercial and geospatial, must be a part of this.

Within civil engineering surveying, as within construction as a whole, there is a huge variability in size and digital capability throughout the supply chain. There is a wealth of expertise and experience in some of the smaller links in the construction chain that should not be overlooked. The risks and responsibilities of information management need to be carefully managed by those higher up the supply chain to ensure the contributions of smaller, less digitally astute and equipped businesses, are transformed to fit the world of digital engineering.

In a joint report10 from the Centre for Digital Built Britain and KPMG in 2021, the importance of SMEs in realising the productivity gains and cost savings of information

10 The value of information management in the construction and infrastructure sector, 2021

management was highlighted. According to the analysis, world, contractors cannot lose sight of the fact that data direct labour productivity gains are potentially between efficiency is as, if not more, important than cost.

£5.10 and £6.00 for every £1 invested in information management, and direct cost savings are between £6.90 and £7.40 from reductions in delivery time, labour time and materials. However, the report states:

“The wider economic returns we have estimated rely on the productivity gains of IM [information management] being realised by organisations of all sizes, including the sector's 'long tail' of SMEs... there are particular barriers for smaller firms adopting IM which still need to be overcome.”11

Tier 1 contractors can play a part in overcoming this hurdle as role models and by providing training on data management software to their supply chains. The interfaces of software systems should be clear and tasks should mirror those in widely used systems such as Microsoft Excel, to reassure those who have worked on these systems all their working lives and encourage them as they move to more collaborative and interoperable platforms.

Expectations need to be realistic, and many will employ dual systems for a short time while they build up trust in new systems. Commercial surveyors are by their nature suspicious - that questioning and fact checking trait is one of the chief skills that they are employed for and will play a key quality assurance role in the construction team of the future. However, telling a commercial team to use a new system without any prior engagement and understanding of their concerns will delay change and could build resentment.

Leaders need to play a role in giving their teams time to explore new systems and become familiar with them. Contracting is incredibly fast paced, and while it may be quicker for a quantity surveyor to download data into a spreadsheet and work on it independently, it is not an efficient use of that data. In this changing

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