Information System Articulated Techno-economic Decision Tree Template – Managing Digital Drilling Campaigns and Prospect Analytics

Nimmagadda Shastri
Curtin Business School
Curtin University
shastri.nimmagadda@curtin.edu.au

Andrew Ochan
Petroleum Authority, Entebbe Uganda

Mahtab Rashidifard
University of WA Perth, Australia

Ausama Giwelli
CSIRO, Perth Australia

SUMMARY

In the entire life cycle of the exploratory drilling campaigns, the technical and financial documents, Geotechnical Order (GTO), and Authorization for Expenditure (AFE) have a role in stakeholder and portfolio management, including investment opportunities. Executing GTO and AFE documents has challenges in committing huge capital outlays contributing to operational costs. Lack of operational awareness, manual documents, and disparate databases, including discrete accounting and reporting systems, make the upstream businesses challenging with shattered budgets. Other issues are intricate supply chains, disengaged standards, rigid government regulations, political uncertainties, and inconsistent fiscal systems. The authors investigate the existing inconsistent guidelines of exploratory drilling campaigns, information barriers, uncertainties, and bottlenecks of implementing Joint Ventures (JV) under the Production Sharing Contract (PSC) with stakeholders.

We design Information System (IS) articulated techno-economic decision tree template and its associated multidimensional attribute journey modelling to integrate the technical and financial documents with exploration business knowledge. High Performance Computing (HPC), Business Information Systems (BIS) and Cloud- and fog-computing services can be added tools for investments in the oil and natural gas industry. Customer Relations Management and Enterprise Resources Planning extranets can collaborate with the techno-economic framework and template. In addition, a multidimensional repository system with fine-grained data structures can attract the Exploration and Production (E & P) portfolios. The techno-economic facts-guided decision-tree template can digitally customize the exploratory drilling campaigns and make realistic technical and financial decisions. The methodology can deliver timely, valuable, and accurate information to explorers, investors and managers involved in the E & P projects, including two-way communication and business-to-business interactions. The decision-tree template can be reusable and interoperable in multiple domains of the E & P industry. The techno-economic decision tree template is usable in various oil and gas finds, easing stakeholder and portfolio management, including flexible GTO and AFE document structures.

Key words: Exploratory drilling campaigns, GTO, AFE, Investor Opportunities, Multidimensional Repository, Techno-economic Decision Tree Template.

INTRODUCTION

We realize the significance of technical and financial documents in the upstream exploration businesses and associated drilling campaigns. The Geotechnical Order (GTO) and Authority for Expenditure (AFE) are crucial documents in the entire life cycle of the upstream petroleum business information system (Sinha, 2022 and Nimmagadda et al. 2019). In GTO, the sub-surface data attributes such as formation boundaries, pressures, drilling objectives, casing policies, mud systems, and prognosis are designed. In the AFE, a budgetary document is prepared, listing all the estimated expenses. Specified depths and casing points with geological objectives, including completion or abandoning of the well, are pieces of data and information shared between stakeholders. Drill site preparation, drilling-rig rentals, costs of fuels, drill pipes, bits, casing costs, cementing, and logging, including coring and testing of wells, are all detailed. These documents are typically shared among stakeholders before the commencement of the prospect area drilling activities and are mutually agreed upon by all parties.

ISSUES AND CHALLENGES

Implementation of GTOs and AFEs has challenges in larger companies. Massive capital investments, high costs of operations, complex supply chains, lack of standardization, rigid government regulations, and political instabilities can affect technical and financial systems. These constraints may have made exploration businesses ineffective. The lack of operational insights from disparate data systems, automated operating documents, and logical accounting and reporting systems has motivated us to undertake the current study. The authors examine the existing roadblocks, loopholes, and bottlenecks in the transmission of data and information among various shareholders and Joint Ventures (JV) under the Production Sharing Contract (PSC). We plan to design a techno-economic decision tree template as a multidimensional attribute model to integrate the GTO and AFE documents, share business knowledge and make timely and effective technical and financial decisions.

METHODOLOGY

In oil & gas drilling operations, the Geo-Technical Order (GTO) supports various exploration and drilling campaign activities as exploration managers and drilling engineers necessitate. As discussed in Table 1, several attribute dimensions associated with GTO, Geology, Mud, Drilling and Well entities are construed for modelling. Formation boundaries, pressures and well or exploratory drilling objectives have relevance in formulating GTO, based on which drilling plans are prepared. Casing policy and mud systems are designed, including schemas relevant to GTO parameters, geological data, mud parameters, drilling, and well details are incorporated.

GTO Attributes	Geological Attributes	Mud Attributes	Drilling Attributes	Well Attributes
Well Name	Depth	Type of Mud	Casing Policy, cementing	Location
Well Number	Age	Specific Gravity	Type of Drilling	Field
Area of Investigation	Formation	Viscosity	Type and Bit Size	Structure
Location	Lithology	pH Value or Instance	Number of Bit Expected	Name
Water Depth	Interval of coring	Percentage of Sand	Meterage per bit	Type
Elevation	Electro Logging	Filtration Loss	Weight on bit	Depth
Well Type	Collection of Cuttings		RPM of Rotary	Operator
Category	Angle of Dip		Stand – pipe pressure	Rig
Objectives of Well	Oil/Gas Shows		Pump discharge	Rig Type
	Formation Pressure		Big nozzle details	Cost
	Formation Temperature		Drilling time	Evaluation
	Mud Loss/caving			Hydraulics

Table 1: Multidimensional attributes of GTO

Logical design and development of artefacts within the data warehouse rely on knowledge-based attributes of drilling operations. Fact constellation schemas are frequently used to design and document petroleum data instances in a large-size data warehouse. Fact constellation schema interprets multiple fact tables with connectable dimension tables, perceived as a collection of stars. It can be seen as an extension of the star schema. A fact constellation schema can have multiple fact tables, representing a multidimensional model of tables (Figure 1). In other words, the schema delivers the connectivity among several star tables that may have different fact and dimensional tables. However, based on data warehouse objectives and user demands, the repository combines star and snowflake schemas with fact constellation schemas (Nimmagadda, 2015). In the current research, fact constellation schema can serve the purpose of interfacing with multiple schemas relevant to GTO, Geology, Mud, Drilling and Well entities. The GTOs can be effective and capable in the current business applications because the schema is logically designed to make and assess the online analytical processing (OLAP).

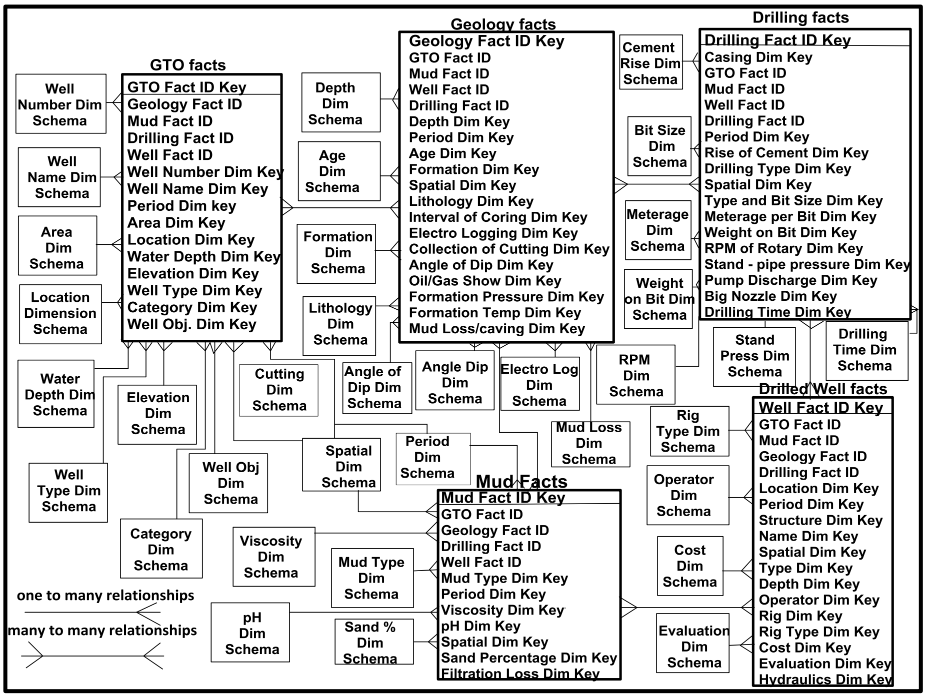


Figure 1: Fact constellation schema model connecting GTO, Geology, Mud, Drilling and Well facts that share common dimension tables (spatial dimensions) and (periodic dimensions)

The design science research (DSR) approach develops template constructs and models (Peffers et al. 2018). Entities, dimensions, and attributes are the building blocks of a data model. Several constructs and models are built to connect various entities and dimensions of multifaceted petroleum businesses. Figure1 is a demonstration of one of the models designed to connect technical phases of the drilling operations. In addition, we have designed multidimensional data structures to unite multiple attribute dimensions of the exploratory drilling campaigns and their associated GTO and AFE-related constructs and models. Figure 2a shows schemas designed for GTO and AFE constructs and interconnect them through common attribute dimensions (Avin and Lin, 2007). Several primary and secondary keys are described for building the schemas, along with attribute keys for each dimension. A characterization of attribute dimensions and conceptual model, including hierarchies and fact instances, is described in Figure 2b.

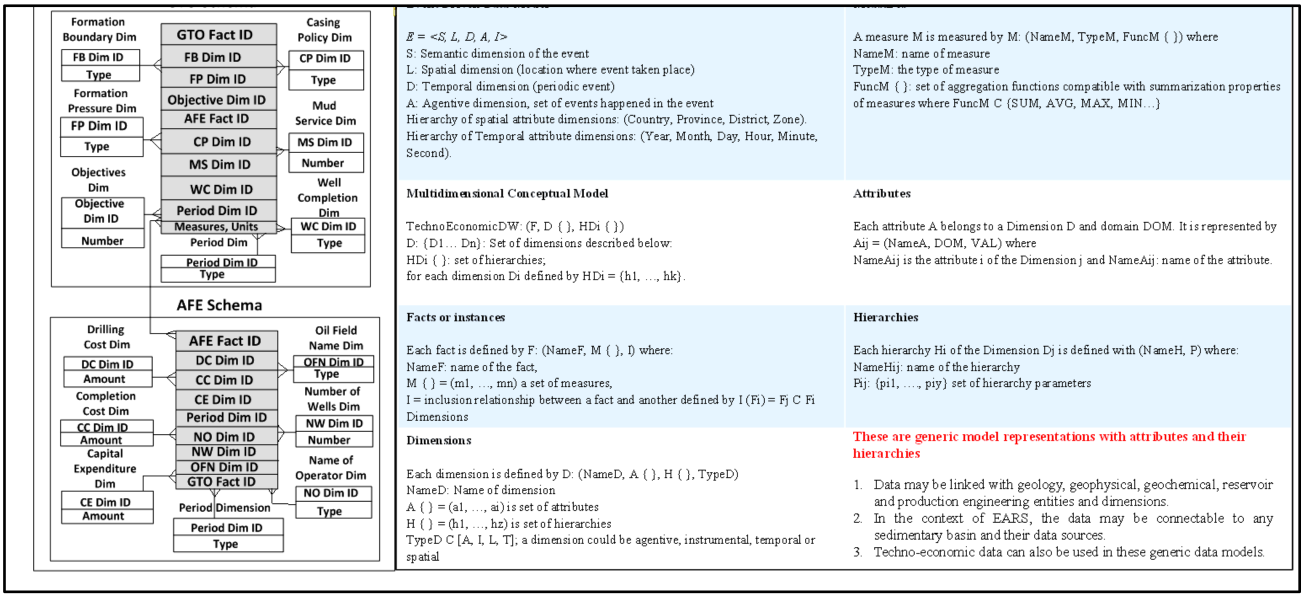
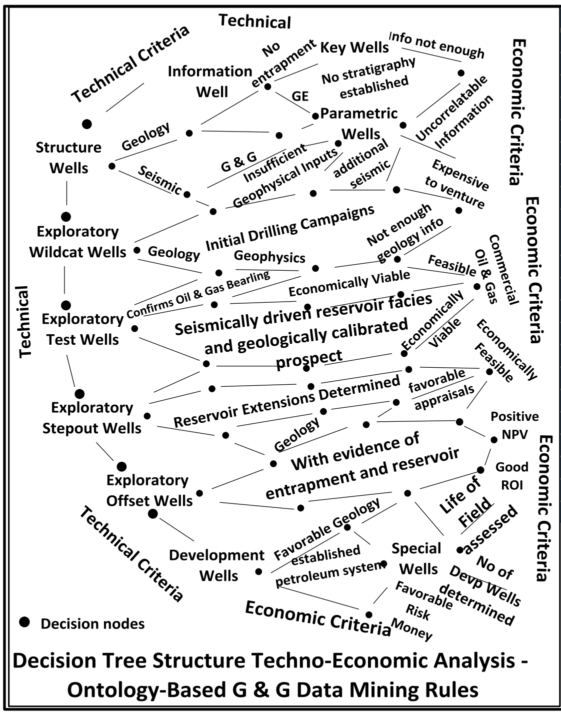


Figure 2: Data structures (a) Multidimensional star schemas connecting GTO and AFE entities (b) Conceptual template model

The template is a sample document that contains technical and economic details that can be added, removed, or changed through an automated iterative process (Eby, 2019). Currently, the template contains pre-made designs and documents that can be customized to meet specific standards, so they are consistent between users and processes. The template is a pattern to make it work or classify well with its multiple attributes and instances. It can be a content builder or navigational element that characterizes technical and/or economic makeup. We can simplify the creation of documents through template designs. Other advantages are easing the workload, besides increasing efficiency, including increased attention of multiple users.



S No	Techno-economic Attributes	Attribute Instances
1	Name of Basin	Midwest Basin1
2	Name of Structure/Prospect	Prospect1
3	Name of Location	RELM-A
4	Number of Wells (Exploratory + Delineation)	1 + 0
5	Average Depth in Metres	1000
6	Number of Reservoir Sands	One
7	Most Likely Geological Reserves	4 MMT
8	Most Likely Recoverable Reserves (R.F: 0.17%)	2 MMT
9	Cost of Exploratory Drilling (Exploratory + Delineation)	6 Million USD
10	Number of Development Wells	1
11	Average Depth in metres	1000
12	Cost of Drilling Development Wells	4 M USD
13	Cost of Production Facility	8 million USD
14	Total Investment (including operating cost)	15 million USD
15	Life of Field (Build up + Plateau + Decline)	1+5+5 Years
16	Sale Price of Oil (per Tonne)	545 USD
17	Net Present Value (Profit)	50 million USD
18	Pay-out Period, Years	2
19	Discounted Profit Investment Ratio	4
20	Profit to Investment Ratio (ROI)	6.5
21	Risk Money	70%

Techno-economic Summary – A Sample Data View (a demonstrative sample view only for explorers, investors and share holders)

Techno-Economic Decision-Tree Template Model

Figure 3: Technoeconomic (a) decision tree template (b) a sample view

Attributes related to technical and economic measures are identified for creating data relationships and designing logical data models and mining rules between Geology and Geophysics entities. As shown in Figure 3, several nodes are defined with which programming code is designed in different classes that may allow a programmer to manage generic data types in drilling projects. Based on decision rules made in G & G contexts, technoeconomic content is put together in the exploratory drilling campaigns. A template is thus designed, as shown in Figure 3. Several primary and secondary keys, as shown in Figures 4 a and 4b, are typical attributes considered in the modelling.

Sl No	Technical Attributes	Primary Keys	Secondary Keys
6	Appraisal Well	AW ID	Depreciation ID
7	Condensates	Condns ID	Depletion ID
8	Development	Devp ID	
9	Development Well	Devp_Well_ID	
10	Enhanced Recovery	ER ID	
11	Exploration	Expl ID	
12	Exploration Well	Expl_Well_ID	GTO ID
13	Heavy Cut	HC ID	
14	Integrated Petroleum Company	IPC ID	OGA ID
15	Liquified Natural Gas	NLG ID	OC ID
16	Liquified Petroleum Gas	LPG ID	AP ID
17	Mining Lease	ML ID	DC ID
18	Natural Gas Liquids	NGL ID	Expend ID
19	Oil Equivalent Gas	OEG ID	CC ID
20	Petroleum Exploration Licence	PEL ID	EC ID
21	Reserves	Reser ID	PC ID
22	Service Well	SW ID	PC ID
23	Unit of Production Method	UP ID	
24	Work-Over	WO ID	Invent ID
25	Oil/Gas/Formation Pressure	OGP ID	
26	Formation Boundaries	FB ID	

Typical GTO and AFE data considered in the modelling

Sl No	Economic	Primary Keys	Secondary Keys
1	Account Policy	AP ID	RC ID
2	Accrual Basis of Accounting	ABA ID	AW ID
3	Acquisition Cost	ACC ID	Condns ID
4	Absorption Cost	ABC ID	Devp ID
5	Balance Sheet	BS ID	Devp_Well_ID
6	Book Value	BV ID	ER ID
7	Business Combination	BC ID	Expl ID
8	Capital Commitment	CC ID	Expl_Well_ID
9	Capital Employed	CE ID	HC ID
10	Capital Reserve	CR ID	IPC ID
11	Contingent Asset	CA ID	NLG ID
12	Contingent Liability	CL ID	LPG ID
13	Current Asset	CA ID	ML ID
14	Current Liability	CL ID	NGL ID
15	CESS	CESS ID	OEG ID
16	Decomm, Restore Costs	DRC ID	PEL ID
17	Development Costs	DC ID	Reser ID
18	Depreciation Method	DM ID	SW ID
19	Dividend	Dividend ID	
20	Effective Interest Rate	EIR ID	
21	Expenditure	Expend ID	
22	Expenses	Expenses ID	OGP ID
23	Exploration Cost	EC ID	
24	Financial Asset	FA ID	Expl ID
25	Financial Instruments	FI ID	
26	Financial Liability	FL ID	
27	Fixed Cost	FC ID	
28	Inventory	Invent ID	UP ID
29	Investment	Investment ID	WO ID
30	Liability	Liability ID	
31	Materiality	Materiality ID	
32	Net Assets	NA ID	
33	Net Profit	NP ID	
34	Net Realisable Value	NRV ID	
35	Non-Current Asset	NCA ID	
36	Non-Current Liability	NCL ID	FB ID
37	Non-Controlling Interests	NCI ID	
38	Net Present Value	NPV ID	
39	Oil & Gas Assets	OGA ID	
40	Geo Technical Order	GTO ID	
41	Net Present Value	NPV ID	AP ID
42	Production Cost	ProdC ID	DC ID
43	Net Profit	NP ID	Expend ID
44	Net Realisable Value	NRV ID	CC ID
45	Recoupled Cost	RC ID	EC ID

Figure 4. Typical GTO and AFE data considered in the modelling

Frequently, the repositories document exploration datasets with several data attributes in columns and rows to build and make a model. In a relational data model, entities and attributes exist together. Attributes are of different types: simple, composite, singlevalued, multi-valued and derived attribute. In the current application, several attributes are derived relevant to GTO and AFE composited entities, as shown in Figure 4. These attributes are building blocks of the data schemas.

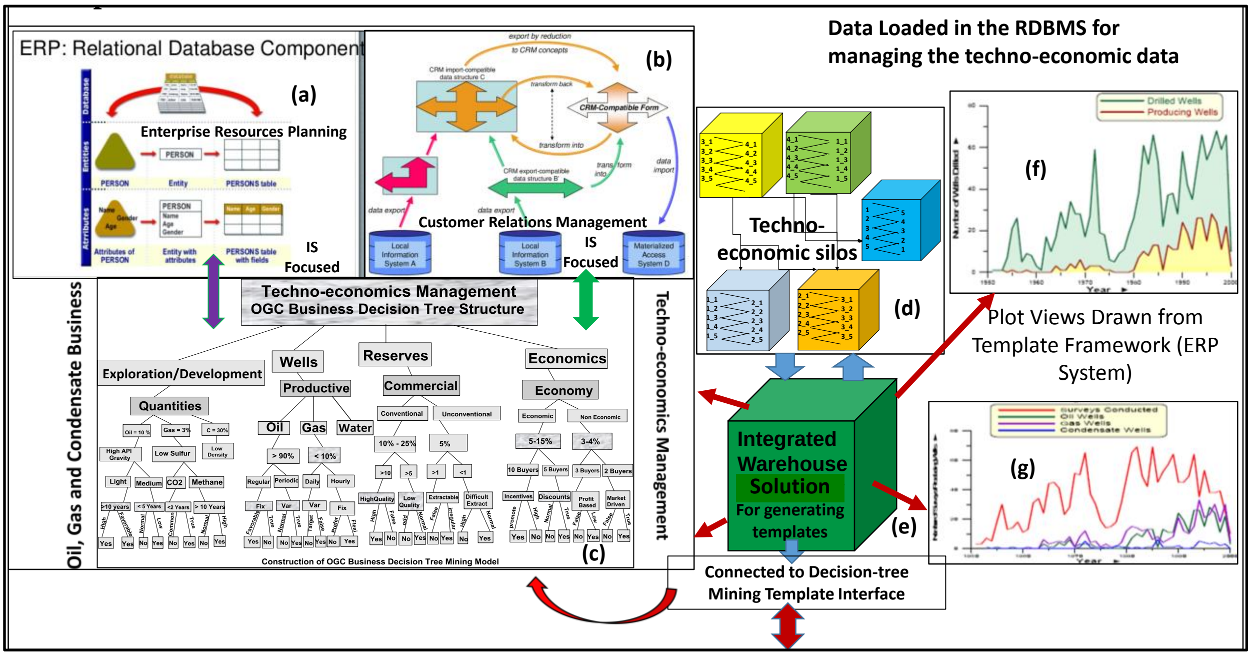


Figure 5. Template framework with GTO and AFE attributes connectable to (a) ERP (b) CRM systems (c) decision tree mining model (d) technoeconomic silos (e) integrated warehouse solution (f) mining – slice 1 (g) mining – slice 2

Template framework can generate several data objects needed in the data modelling process and facilitate the exploration of data visualization and interpretation. Interfacing with templates has significance in the current research. Presentation of multiple objects in a single campaign and integrated framework is practical for exploration and drilling managers. Figure 5 demonstrates the advantage of the warehouse repository that can deliver multidimensional data, plot, and map views for interpretation. Enterprise Resources Planning (ERP) and Customer Relationships Management (CRM) tools are connectable to the multidimensional repository system, as discussed in Figures 5 a and 5 b. A decision tree structure is generated, as shown in Figure 5c, emphasizing techno-economic attributes and their mining rules. Silos can be added to the integrated warehouse, as demonstrated in Figures 5d and 5e. Figures 5f and 5g are slices of the warehoused cube. Though database silos are operative, for collaborative purposes, isolated data stores hundreds of excel sheets can be connectable to the real-time repository systems for making effective drilling plans and exploration and production (E & P) management. The repository can generate multiple templates, as required by drilling managers in the petroleum company. In addition, several data mining and visualization artefacts are implementable through integrated repository systems.

RESULTS AND DISCUSSIONS

The resources associated with the GTO and AFE have collaborated on a techno-economic framework in which the decision tree template or an artefact triggers the Customer Relations Management (CRM) and Enterprise Resources Planning (ERP) extranets. The techno-economic-based decision tree is templated to customize the drilling campaigns digitally and make the right decisions more analytically through E & P activities and functions. The methodology can deliver timely, valuable, and accurate information to explorers, investors, promoters, and resource planners, including data and business analysts (Nimmagadda et al. 2019). The process can improve two-way communication and collaboration, including business-to-business interactions and transactions. The operators can achieve usability and interoperability and even reuses templates in multiple domain applications. New drillable locales can make several GTOs and AFEs, triggering the same techno-economic decision tree template by documenting various business rules, including numerous attributes and instances needed to build up GTO and AFE documents. These instances impact foreseeable exploratory leads, business predictability, optimization, share prices, and ownership stakes. The study can create new business scopes and opportunities for managing non-renewable and renewable resources, including generating updated business models and templates of standardized documents in petroleum industries.

CONCLUSIONS AND RECOMMENDATIONS

Associations between GTO and AFE attribute dimensions have motivated us to digitally integrate exploration and drilling campaigns in the Oil & Gas industries. The process can help understand the specific details of the oil & gas businesses during collaboration with the exploration activities and functions of the industry. CRM and ERP are added tools if linked with data modelling and data-warehousing tools. Such implementations can attract several customers and investors worldwide. The collaborations can add value to new exploration and drilling knowledge management. Techno-economic decision tree mining models can be cost-effective for assessing drillable exploration targets and optimizing the resources involved in the upstream petroleum businesses.

REFERENCES

Avin, M., and Lin, M., 2007, Multidimensional Schemas for Engineering Asset Management. In Gelman, L (Ed.) Proceedings of the 2nd World Congress on Engineering Asset Management and the 4th International Conference on Condition Monitoring. Coxmoor Publishing Company, CD Rom, pp. 1387-1397.

Eby, K., 2019, The Power of Iterative Design and Process, https://www.smartsheet.com/iterative-process-guide

Nimmagadda, S.L. and Dreher, H., 2012, On new emerging concepts of petroleum digital ecosystem. WIREs Data Mining Knowledge Discovery, 2: 457-475. https://doi.org/10.1002/widm.1070

Nimmagadda, S.L., 2015, Data Warehousing for Mining of Heterogeneous and Multidimensional Data Sources, Verlag Publisher, Scholar Press, OmniScriptum GMBH & CO. KG, p. 1-657, Germany.

Nimmagadda, S.L. and Ochan, A., and Reiners, T., 2019, On a Techno-Economic Decision Tree Template for Managing Digital Drilling Campaigns in the Exploration & Field Development Projects, East African Petroleum Conference (EAPCE, 2019), Mombasa, Kenya.

Sinha, S. N., 2022, GTO-Well Attribute Dimension Descriptions: https://kb.oges.info/library/137361/GTO-_-MANY-E_-P-COMPANY-SAY-AS-WELL-PROGRAMME-OR-D.

Sudhir, K., 2016, Good International Industry Practices, DGH, ONGC, India, http://petroleum.nic.in/sites/default/files/GIPIP_Final_approved.pdf.

Peffers, K., Tuunanen, T., and Niehaves, B., 2018, Design science research genres: introduction to the special issue on exemplars and criteria for applicable design science research, European Journal of Information Systems, 27:2, 129-139, DOI: 10.1080/0960085X.2018.1458066.