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Conceptualization of smart solutions in oil and gas industry

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Abstract

Technological solutions called "smart wells" and "smart fields" have been applied in petroleum industry for nearly two decades. They aim to improve the knowledge of petroleum production processes, and thereby improve the efficiency of operations. Researchers and companies in pursuit of their goals tend to use one-sided implications and numerous synonyms when describing the substance of the term, which leads to an occasional confusion. In order to study the concept of smart field from a general perspective, a literature review has been conducted, and main characteristic attributes of such solutions have been revealed. Selected marketed products offered by engineering companies have been analyzed as examples of the technology implementation. A definition has been proposed along with its practical implications. Additionally, an attempt has been made to place these solutions in a broad scientific context of intelligence and sustainability in contemporary business processes.

Keywords: definitional approach; information technology; intelligence; intelligent field; literature review; production logistics; smart field.

1. Introduction

Information technology (IT) is one of the major driving forces in modern businesses practices. It expands the industry boundaries and even reshapes the industries [19]. Application of IT is essential for oil and gas industry. The efficiency of expensive and dangerous operations largely depends on employment of IT in the form of process automation and control tools. Over the last several decades, the complexity of petroleum production operations increased. By the end of the 20th century, many large conventional hydrocarbon reserves have depleted, and production has shifted to offshore locations and nonconventional petroleum reserves [4,17]. Costly operations, inconvenience of frequent interventions for remote locations and subsea wells, harsh weather conditions and many other technological, economic and safety issues require significant scientific intensity to adapt the known technologies to the non-conventional environments of hydrocarbons recovery. In 1990s, a demand for innovative process control tools ensuring economic efficiency of producing oil and gas in these challenging circumstances [17] emerged in the industry.

The accumulated research in the oil and gas domain provided abundant capabilities to improve production management through applying the mathematical modeling in order to achieve necessary economic goals. New

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machinery and instrumentation was also engineered for long uninterrupted operations in complicated conditions[9]. The pilot project of a solution named “smart well” was implemented in 1997 on the Snorre Field in the North Sea by a Norwegian company Saga Petroleum (presently a subdivision of Statoil). Since then, hundreds of smart well systems have been put into operation around the world[8,24]. The scope of the term later evolved to “smart field”, which implies a larger scale of integration. Oil bearing formations, wells, gathering and processing facilities become addressed as consolidated hydrodynamic systems. In terms of decision making, the lifecycle viewpoint is now applied: every decision made should be optimal with regards to the goals set for the entire system lifecycle.

Several terms are presently used in business and research for addressing this approach to development and operations in petroleum industry. In the literature, the terms “smart” and “intelligent” fields are widely used. Among other popular synonyms “i-Fields”, “digital oilfields”, “fields of the future” can be named. In addition, several broader terms, e.g., “integrated operations”, “intelligent operations” and “intelligent energy”, are often used to describe similar solutions.

The smart solutions have by now gained fair recognition in both industry and academia. However, there is still occasional confusion around this concept. On the one hand, engineering companies in pursuit of marketing success for the solutions they are offering, tend to use an ample variety of terms to name similar products and attributes. On the other hand, academic articles tend to focus on certain particular aspects of the complex concept, e.g., some authors address advances in automation and measurements, others emphasize advanced control techniques, still others focus on process simulations and predictive modeling. Thus, the accumulated theoretical and practical research results require analysis and synthesis to maintain the entirety of the perspective. The purpose of this research is to study the concept of smart field from the most general perspective. The main research points are to identify what these smart solutions actually are, what basic attributes they have and what technologies constitute to this notion. The obvious value of a smart field definition is contribution to the glossary of petroleum engineers and managers. More importantly, however, a proper definition would help identify the achievable benefits of such solutions. The definition would facilitate the system thinking of energy industry managers, becoming the first step in helping the managers to regard the decision of deploying or not deploying a smart field as a strategy of organizing the upstream sector of petroleum industry supply chain, rather than a decision on purchasing certain advanced instrumentation.

The methodology of this research involves literature review on the topic, carried out up to the present moment. This allows to generalize the knowledge about smart solutions in the upstream petroleum sector and to distinguish their characteristic features. In addition, selected solutions which became trademarks of a number of well established engineering companies are reviewed. Their main attributes are summarized in a concept matrix. Finally, plausible views on the philosophy of contemporary management science and the role of systems intelligence in it, are presented. This aims to account for smart technological solutions beyond petroleum industry, and therefore, the perspective of organizing the production activities in the context of logistics and supply chain management is contemplated.

2. Overview of smart solutions in the upstream petroleum sector

2.1. Smart solutions in the literature

The literature review presented below is largely based on the ideas of Webster and Watson[26]. The search of relevant literature has been conducted over the scope of papers published in academic journals and conference proceedings distributed in electronic journals and available in the following databases: OnePetro, ScienceDirect, Springer Link, Emerald Insight and ProQuest.

Textbooks, dissertations and unpublished research have been disregarded in the considered pool of literature. With this the author aims to reflect the research tendencies in the field that is relatively young and rapidly developing. The overview scope is limited to English language only. There is, of course, a considerable amount of research in courtiers like Brazil, Norway, Russia, Saudi Arabia and others in the respective native languages, however the author assumes that the adequate amount of academic and practical results is presented in English language on numerous conferences, symposiums and seminars, especially those organized by the Society of Petroleum Engineers.

The temporal scope for the search includes the last two decades, given that the history of the smart solutions dates back to 1997[13,17]. The search was run for the relevant words and phrases in the titles, abstracts, and keyword lists of the papers in the aforementioned databases. The search operands included: “smart well”, “intelligent well”, “smart field”, "intelligent field", "i-Well", "i-Field", "digital oilfield", "digital field", "intelligent energy", "integrated operations" and "field of the future". This search does by default not cover the papers where authors do not explicitly mention the search words however present certain technological advances that are incorporated into the smart solutions. However, the reference lists (if available) of the papers were studied to cover the possibly missed research.

A thematic scope outside the upstream petroleum sector is not considered in this literature review, i.e. potential smart solutions in broader pool of industries are disregarded. This is mostly due to divergent demands for IT tools by different business sectors, specifics of each industry's glossary, and of course, the author's research area. The general direction of IT spread and rationale for its industrial applications is however discussed in the following section of this paper in the context of management science evolution.

The results of the conducted overview are summarized in Table 1 and Fig. 1. Nearly 2800 papers have been included in the reviewed scope of literature. An overwhelming majority of the papers come from the Society of Petroleum Engineers. The statistics in Fig. 1.a. demonstrate general increase in number of papers published per year, suggesting that this knowledge domain is expanding. Table 1 summarizes the characteristic attributes of smart oil and gas fields in comparison to standard industry solutions. The frequencies of referencing the particular attributes in the analyzed research are revealed in Fig. 1.b. The given attributes have been deduced from the literature as well as detailed investigation of selected papers.

The benefits of smart fields originate in detailed knowledge and control of operations. Detailed representation of the operations begins with measurements of pressure, temperature, flow rate and flow composition inside the wells at different points along the well tubing. Additionally, special sensors for geophysical imaging of the reservoir (also known as "4 dimensional seismic") can be employed to observe the fluid movements inside the petroleum-bearing medium as well as relevant property changes. The thorough control of well operations is achieved by shifting from the standard 0/1 control elements to the continuously operated inflow control valves (ICVs) and variable frequency pumps. Thus, the operations at any given well segment can be adjusted smoothly, or independently shut off if necessary. The field network of microprocessor-based instrumentation is programmed to ensure the safety of operations even in case

Table 1. Smart field solution characteristics presented in comparison to standard solutions.

Attribute	Standard solutions	Smart solutions
Instrumentation: measurements and control		
Sensors	located at the wellheads	located at the wellheads and distributed inside the wells
Control strategy and organization of control loops	reactive (passive) control; low sampling rate (monitoring parameters and adjusting operations once a day); control loops ensure control and safety of each single well	reactive (passive) and proactive (predictive) control; higher sampling rate (e.g., once an hour or in real time); control loops ensure control and safety of each particular well segment
Actuators	0/1 controlled devices (open/closed valves and on/off artificial lift pumps)	continuous control with inflow control valves (ICVs) located inside the wells; variable frequency artificial lift pumps
Attitude to the project lifecycle		
Development and production planning	development and production are regarded as separate projects	development and production are consolidated and regarded as a field or reservoir lifecycle
Reservoir draining	reservoir is drained through wells, unchaperoned by any special modeling or seismic software	movement of oil, water and gas is monitored; reservoir modeling software is used to choose production rates
Software and workflows	telemetry system, supervisory control and data acquisition (SCADA) system, implementing operative control	SCADA in the loop of lifecycle optimization software covering decisions on strategic, tactical and operative control levels; special information system for collaborative work environment

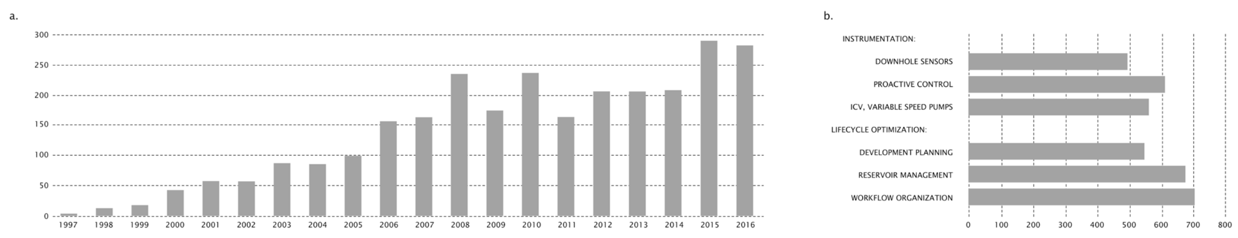

Fig. 1. a. Number of papers published per year during time period 1997-2016. b. Number of papers mentioning particular characteristic attributes.

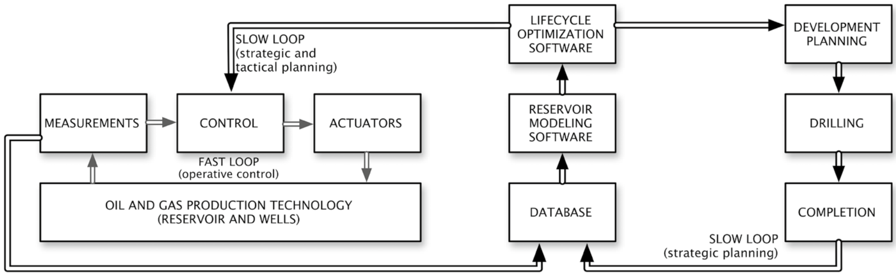

Fig. 2. Fast loop and slow loop of a smart solution, based on the ideas of Rossi et al.[20]

the connection to the operators is lost. The operative control is implemented with the aforementioned equipment and described as the "fast loop" in the diagram in Fig. 2 illustrating the smart field control.

Aside from the operative control, smart solutions grasp the idea of lifecycle modeling and optimization. This strategic and tactical decision support software is demonstrated as a part of the "slow loops" in Fig. 2. The point of lifecycle optimization is to complement the traditional reactive approach of process control (i.e. adjusting the instrumentation settings to compensate for emerging difficulties) with a proactive strategy (i.e. anticipating the future and making decisions accounting for the uncertainty about the future). Simply put, modeling of the technology is carried out on every phase of the field lifecycle, and all relevant decisions (e.g., whether to expand the gathering system or not, decision on location for the next well drilling, choice of well operating rates, etc.) need to be optimal for the entire field lifecycle. Naturally, the views on what is considered optimal need to be suggested. These ideas are formulated as a reservoir management philosophy, a set of indicators, priorities, requirements and plans for the field lifecycle.

Above, the technological and software developments for smart oil and gas production solutions have been reported. In addition to those, several researchers[5,13] highlight the issue of workflow organization in petroleum producing companies. Knowledge of the relevant information, availability of the data for the appropriate personnel in a timely manner, data accessibility and convenient storage contribute to the propriety of information flows. Communication and collaboration between specialists in different engineering areas as well as managers results in fast and adequate decisions, which ultimately leads to effective performance of the entire smart system[5].

The advantages of smart solutions applied in challenging non-conventional environments have been demonstrated in numerous studies[1,6,7,10]. Several authors[27,28] argue that application of such solutions is also beneficial for regular conditions (i.e., single onshore reservoir with vertical mono-bore wells), if only due to being efficient for preventing water coning and cusping. Many studies[17,21,22] prove that the smart field approach leads to accelerated production, increase in total petroleum recovery, reduction of capital and operation expenditures, and risks.

2.2. Engineering and IT solution examples

Actual engineering and IT solutions for the petroleum sector have played an important role in forming the smart well and smart field technology up to its current state. Engineering companies like WellDynamics (now a division of Halliburton), Weatherford and Honeywell, and IT companies like IBM and ABB contributed to the development projects of oil and gas field operators like BP, Shell, Statoil and others. Several solutions of the selected contractors[1] are named in Table 2. The presentation of the solutions on the companies' websites generally follows a logic that

[1] The presented solutions were studied by the documentation on the companies' websites. The websites were accessed on December 2, 2016.
http://www.halliburton.com/en-US/ps/consulting/digital-oilfield-design.page?node-id=hkv12s6f
http://www.weatherford.com/products-services/production/software
https://www.honeywellprocess.com/en-US/explore/solutions/industry-solutions/oil-and-gas/off-shore-production/Pages/digital-suites-oil-gas.aspx
http://www.slb.com/services/additional/ipm.aspx?t=2
http://www2.emersonprocess.com/en-us/industries/oil-gas/offshoreexplorationproduction/solutions/pages/intelligentfields.aspx
http://new.abb.com/oil-and-gas/systems-and-solutions/collaborative-operations
http://www-935.ibm.com/industries/chemicalspetroleum/solutions/integrated-operations.html

does not entirely concur with the one used earlier in the literature review. The companies tend to manifest the following features of the smart technologies that they are offering:

- Decision support for drilling operations and reservoir management: field development planning, supervision of drilling operations with diagnostics and visualization of target locations, production scheduling models based on simulation and reservoir monitoring (4d seismic).
- Production optimization: monitoring reservoirs and wells in real time, independent control of well segments, controller tuning, optimization of equipment operating modes based on reservoir modeling.
- Asset management system: monitoring the operability of the equipment, maintenance planning and accounting for replenishment of spare parts and maintenance tools.
- Communication systems for remote operations: telemetry and SCADA systems for remote operations, wired and wireless networks for data collection, storage and transfer.
- Information (knowledge) management: companywide information storage, sharing and reporting system, establishment of collaborative environment.

Such a way of describing smart solutions is plausible. The description of these exact characteristics represents the engineering perspective on solving certain practical issues in oil and gas industry, which is favourable for marketing these solutions. However, for the purposes of this research, the author considers important to highlight the life-cycle approach to the smart field solutions, i.e. all three decision-making levels (strategic, tactical and operative) are important for the field development project to become smart or intelligent. In the descriptions above the focus on the operations is apparent, however, strategic and tactical planning is not quite obvious. Further, the attributes revealed in the literature review will be used. Table 2 contains a concept matrix, demonstrating the investigated companies' solutions embodiment of the specific attributes of smart technology. The matrix reveals that not all solutions cover the full scale of smart field attributes. Some only provide certain instrumentation developments along with process monitoring software, others pertain closer to oil and gas field development optimization, and yet others focus primarily on information management and workflows. This however doesn't diminish the value of these lesser-scale developments. System integrators like ABB and IBM provide the information systems compatible with engineering and software developments that work by the standardized protocols. Thus, the responsibility of deploying an appropriate technology lays on the companies operating oil and gas fields. Therefore, it is important for the managers and project engineers of the operating companies to clearly understand the smart field concept.

Table 2. Selected marketed solutions, offered by the leading engineering contractors and system integrators. Concept matrix of smart solution attributes in the companies' developments.

Solution	Advanced measurements and control			Lifecycle optimization		
	downhole sensors	proactive control	ICV	development planning	reservoir management	workflow organization
Halliburton's Digital Oil Field	✓	✓	✓	✓	✓	✓
Weatherford's Field Office and i-DO	✓	✓	✓	✓	✓	✓
Honeywell's Digital Suites for Oil and Gas	✓	✓	✓	✓	✓	✓
Schlumberger's Integrated Project Management	✓	✓	✓	✓	✓	✓
Emerson's Intelligent Fields	✓	✓				✓
ABB's Collaborative Operations		✓			✓	✓
IBM's Integrated Operations						✓

2.3. Overview results discussion

In the conducted literature analysis and overview of the technologies, numerous attempts to generalize the ideas behind the smart solution concept have been found. These observations are made by the authors for the purposes of the research they are presenting. Below, a few selected quotes are provided. A group of authors focusing their work on the instrumentation components, state that an intelligent completion known as a smart well "enables operators to actively monitor, remotely choke or shut selected zones with poor performance without intervention"[8].

The authors from WellDynamics focus on reservoir management and workflow organization for the field lifecycle, saying, “Successful exploitation of the new technologies requires an understanding of information flow, control and automation capabilities, knowledge management, interpersonal communications, and decision processes to develop performance indicators, workflows, philosophies and protocols suitable for the fields of the future” [13].

Several valuable attempts to define the smart concept have been made by other researchers outside the reviewed literature pool. A Norwegian government proposition states, “The use of information technology to change work processes, to achieve improved decisions, to remotely control of processes and equipment, to relocate functions and personnel to a remote installation or an on-shore facility” [25]. A Norwegian researcher Larsen [14] writes, “Integrated operation (IO): the integration of people, work processes and technology to make smarter decisions and better execution. It is enabled by the use of ubiquitous real time data, collaborative techniques and multiple expertise across disciplines, organizations and geographical locations.”

To summarize the attributes of smart solutions in oil and gas industry after reviewing the accumulated research in the area and investigating the selected compnanies’ products, the following definition is concluded.

Definition

A smart solution (in the narrow sense, for upstream petroleum industry) is an approach to field development management involving two closely related aspects:

- lifecycle optimization based on development and production operations research and defined strategic, tactical and operative goals
- advanced instrumentation as an enabling technology for precise monitoring and control of operations.

3. Intelligence and rationality in the contemporary scientific context

Now that the smart technological solutions in petroleum industry have been studied, it appears reasonable to place these solutions in a broad scientific and industrial perspective. Businesses striving for improvement of their operations pay much attention to organizational efficiency. Applications of IT to various production processes in many industries is associated with operations research and computer-aided management. The rationale behind the detailed research of the processes lies in pursuit of such control strategies that would ensure sustainable production in rather uneven economic, social and political conditions [18]. This is why the insight in functioning of facilities, technologies, units, networks and instrumentation becomes essential for the efficiency of any production activity.

The evolution of management science since the middle of the last century and up to the present time has led to thinking of business processes as networks with flows of various nature (e.g., materials, human resources, information and money), and thereby, saturating business areas with applications of logistics and supply chain management [12]. Logistics “aims to supply recommendations for action on the design, implementation, and mobilization of such networks and flows through accepted scientific methods. Scientific questions of the discipline are related primarily to the configuration and organization of these networks, and to the mobilization and control of flows. The ultimate goal of logistics science is progress in the balanced achievement of economic, ecological and social objectives” [3].

The branch of the discipline dealing with organization of production processes and operations is often called “production logistics” [18]. Network configuration and flow organization in the value-adding systems is naturally associated with computer-aided decision making. The term “cyber-physical systems” is often used in the context of production processes, especially manufacturing. The term accounts for computation and communication solutions integrated into physical processes, contributing to the range of the process capabilities [2,15]. Additionally, terms “Industry 4.0” and “Industrial Internet” are used to describe smart solutions and integrated IT products [16,19], incorporated into production processes. The measure of how smart / intelligent these products and systems can be, is defined by several researchers [11,19] according to the products and systems functionality and their capabilities for self-improvement. Two descriptions of the intelligence levels are summarized in Table 3. Each higher level is build on the capabilities of the previous levels with an added faculty. One may observe here that the understanding of the primitive levels (1 and 2) does not entirely concur in the two descriptions. However, the perception of the eventual

Table 3. Levels of intelligence, as defined by the two sources [11,19].

Level	Capabilities of smart, connected products [19]		Levels of intelligent control [11]	
	Function	Description	Function	Description
1	Monitoring	sensors monitoring the product and environment	Robust control	keeping the system stable
2	Control	control of product's function, potential for personalization	Adaptive control	adjusting parameters to changes within the system
3	Optimization	optimization of products operations: performance enhancement, predictive diagnostics & maintenance	Optimal control	optimization of the system variables according to the set objective
4	Autonomy	autonomous operation, self-coordination with other systems, self-diagnostics	Planning control	adaptive planning, considering uncertain situations, reacting to the environment

capabilities of the contemporary smart systems (level 4) unanimously encompasses the idea of the system's autonomy and sustainability.

Smart solutions are becoming ubiquitous in process industries, energy sector, manufacturing, etc. Contemporary philosophy of science explains this leading role of intelligence with the evolution of the rationality concept. A renowned Russian philosopher, Vyacheslav Stepin, proposed the rationality evolution model with three steps: classical, nonclassical and post-nonclassical rationality [23]. The classical paradigm refers to 16^{th}–19^{th} century science, when research mainly engaged observations and experiments. The later emerging nonclassical paradigm (late 19^{th} century – mid-20^{th} century) encompasses the idea of control and addresses the self-regulating objects and processes. The modern post-nonclassical rationality (mid-20^{th} century – present) concerns establishment of self-organizing systems capable of choosing the necessary self-regulating modes, and with this achieve the set goals. These self-organizing systems possess certain organizational hierarchies, i.e. the components are arranged into subsystems which coordinate their activities to act according to the current system priorities and its life-long philosophy. The "human dimension" is also inherent in the systems organization, and complex information systems, including Internet, are employed for interaction of people and machines to achieve sustainability.

The idea of self-organization has thereby been observed in a broad spectrum of human activities including business and research. From these observations modern philosophy has concluded that self-organization constitutes to the contemporary rationality. Since rationality is the basis for what is generally accepted to be reasonable actions, it is to be expected that academia and industry sectors will continue to work together on establishing intelligent business solutions for sustainable development.

Considering the functional aspects of the state-of-the-art solutions applied in various industries, as well as modern tendencies in management and philosophy, a generally applicable definition may now be composed.

Definition

A smart industrial solution (in a broad sense) is an approach to project management when facilities, infrastructures and workflows are established and operations are planned, scheduled and conducted with clearly set objectives, meanwhile a control functionality for self-coordination of the system components (i.e. facilities, units, devices and people) is employed to follow these objectives over the entire solution lifecycle, thereby ensuring the system sustainability and autonomy.

4. Conclusions

A broad scope of theoretical and practical research reviewed in the conducted analysis allows to reveal the characteristic attributes of smart field solution applied in upstream petroleum sector. A general consensus among the researchers is observed with regards to the meaning of the term. A conceptual model in the form of a definition has been proposed.

The suggested definition aims to assist and guide the future research in the area of petroleum engineering. A significant body of research and mathematical models covering various issues of planning oil and gas field development and operations has been accumulated over a timespan of more than a century. For nearly seven decades, researchers have been applying optimization models and techniques to gain insight in planning and control. The proposed definition for smart field solutions underlines the importance of lifecycle thinking, thereby suggesting that it is reasonable to coordinate the decision-making for the entire lifespan of a given field. When strategic planning is conducted, the problems such as well structure design and drilling, gathering infrastructure design and development planning, production scheduling and abandonment planning are often segregated. The lifecycle thinking implicit in smart solutions aims to prompt the researchers to develop such models that would integrate the decision-making for the phases of development and production, therefore balancing all the project expenditures and revenues. This allows to use the net present value (NPV) indicator for the project evaluation in order to identify the achievable benefits of the implemented technology. Such integrated strategic planning models and evaluation of the projects by their NPVs may be useful for the field appraisal and the early stages of field development planning. Regarding tactical and operative decision-making, the smart solution approach suggests predictive control and coordination of all the actions corresponding to the production phase, i.e. regulating equipment operating modes, water flooding, resource distribution (gas for gas-lift, fluid for jet pumps, etc.), and formation stimulation (injection of chemicals). A mathematical model for the reservoir must be employed, and an algorithm for production optimization working in conjunction with this reservoir simulator must be run periodically, thus, gradually resolving the geophysical uncertainty inherent in the process.

The proposed definition along with the analysis of currently marketed solutions allows to draw a practical implication for the companies operating oil and gas fields: it is entirely up to the management of these companies to ensure the employment of the appropriate instrumentation, software and workflows establishment for reaping the benefits of smart solutions.

One of the limitations of the presented review is its very general perspective. Details of the technological instrumentation, modelling software and IT products for engineering solutions have not been thoroughly examined in this research. A proper account of these details and analysis of advantages and disadvantages of certain instrumentation alternatives and modelling approaches, as well as challenges associated with smart field deployment, may be a good prospect for future research. Given the large amount of information to be studied and presented in such a work, it should perhaps be done in a form of a monograph. The challenge of smart technological solutions addressed in this review is understanding the substance of the term. Therefore, this research is only the first step to help to the managers to think of smart fields as a strategy of establishing, organizing and mobilizing the upstream sector of oil and gas industry. In some countries with large land-based hydrocarbon reserves (for instance, Russia) and decades of experience in application of standard technological solutions, companies are sometimes hesitant to deploy smart solutions. The management of these companies often demonstrates a conservative attitude towards new and expensive instrumentation, complex software and information systems, all of which require a certain expertise and training for the engineers, operators and managers. Skepticism to the achievable benefits of smart fields and suspicion that they may turn out over-invested often incline the managers towards the time-tested conventional solutions. In order to help the managers overcome these conservative views, the definition proposed in this research emphasizes the detailed knowledge of processes and operations in smart solutions. The main disadvantage of standard solutions is the lack of awareness as to how any given control decision really affects the reservoir draining, both at the time the decision is made and afterwards. The advanced instrumentation and software employed for smart fields aim to compensate to a large extent for significant geophysical uncertainty inherent in hydrocarbon production, thereby ensuring an efficient way to manage the field lifecycle. Thus, the practical value of the proposed definition for the companies with conservative views on the technological innovations lies in facilitating the managers' efforts to understand that smart solution approach, in fact, aims to mintage uncertainty, which makes it more appealing for decision-makers.

Another limitation of the presented research is its strong focus on petroleum industry. Nevertheless, the two proposed definitions contribute to theorizing of intelligence concept for production processes in general by addressing the issues of production system lifecycle optimization and sustainability. The conducted review has summarized the research and engineering practice in petroleum industry over the past two decades. With time, the technology of producing oil and gas shifts to nonconventional reserves and becomes increasingly complex. The scientific paradigm is also expected to continue evolving, which will bring new technology for process control and new management strategies. As to managing the energy sector, it may be expected that energy companies and national governments will coordinate the energy markets (i.e. activities of producing and consuming hydrocarbon reserves, nuclear energy, hydropower, as well as renewable sources of energy and others) with a goal of achieving sustainability in the energy sector.

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