The Technology of Information Modeling in the Arrangement of Cluster Sites of Oil and Gas Fields

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Abstract. The article highlights the peculiarities of the information modeling during the design of the construction of facilities of different types comprising the overall system of the development of cluster sites at oil and gas fields. Project management software (MS Project, Oracle Primavera and similar ones) do not fully solve the problems of design solution optimization for different types of construction facilities. The method proposed is based on the staged generation of the integrated project model. Block diagram of the information modeling algorithm is provided. At the first stage local models are selected and calculated based on the specific features of the three organization forms of the facilities: linear, site, industrial building and units. As applicable to the linear facilities (motorways, pipelines) structure-modular approach enabling implementation of the design and technological solutions based on the environmental situation along the structure length. For the site facilities and industrial buildings matrix models are recommended (critical path analysis, continuity of the resource utilization and work scope). The integrated schedule at the second stage is provided in MS Project. At the third stage probabilistic prediction of the construction timelines by means of simulation modeling in MS Project is performed. An example of the method practical implementation is provided. Information modeling technology development aimed at the construction information model visualization is provided.

1. Introduction

The facilities of oil and gas field development include facilities of the process complex of the facilities for the production, collection, transport and treatment of the oil and gas for the sale to the user [1]. From the construction management prospective these facilities may be conditionally classified into three groups: linear facilities (motorways, various pipelines); site-type earth structures (cluster pad foundations), industrial sites and units ensuring oil and gas production process. This diversity of industrial construction types requires special organization forms for the concerted actions of the stakeholders of the construction projects comprising the general oil-production programme.

The processes of the oil and gas fields’ development in the Russian North, especially at the initial stages, are related to a large scope of pre-construction activities in the hard-to-reach areas with complicated natural and climatic conditions. Besides, oil and gas production facilities are often built simultaneously with the drill-out of the field areas, i.e., the construction and assembly companies have to operate in the active company conditions [2]. These factors have to be accounted for during the construction management design and development of the design information models.
Before the construction and assembly work commencement it is necessary to review the cluster site development strategy based on the adopted fundamental solutions on the development thereof. These solutions include: selection of the well cluster formation diagrams; calculation of the drilling sequence and process parameters; determination of the sequence of the wells’ commissioning; development of the plan for the feedstock production and product routing to the user. [3].

During the design of the cluster site development arrangement in parallel with the design of the construction management design numerous innovative engineering problems need to be solved. In a number of papers [4-6] proposed the application of new materials, processes non-trivial design solutions. The examples considered enable making a conclusion that during the field development ongoing review of the design solutions efficiency, update of organization and process design, alignment of the timelines of the completion of individual construction and assembly works and action parties is necessary. Despite a number of promising scientific developments related to the modeling of various patterns of the oil and gas field development and construction, the issues of comprehensive design of concerted design and process solutions require improvement and further development based on variant-based study if computer technologies are used.

2. Problem Statement
The present-day information modeling technologies (BIM, TIM) enable automatic controlling the facility parameters in case of the impact factors change. The facility elements are parameterized not only at the level of the project information model but also at the design implementation stage (construction information model) [7-10]. Automatic project management systems, such as Oracle Primavera, MS Project, may be successfully used for the design and routine adjustment of the field development schedules, including for the arrow diagram calculation using critical path analysis [11, 12]. However, these programs do not completely solve the design solution optimization problems based on the specific peculiarities of the industrial construction facilities.

Considering the diversity of the construction types during the field development, harmonized work management requires using models most customized for the description and optimization of the organization and process diagrams in each special construction type. Then the information technologies should be combined in the uniform system.

3. Modeling Methods.
In case of the transport facilities design solutions of individual structural elements and work scopes substantially depend on the natural situation varying along the facility length. The task of the separation of the long linear facility into sections with different natural environment characteristics need to be addressed at the pre-design stage using linear zoning method [13, 14]. Special models for the linear construction scheduling account for the peculiarities of creating special departments, their operation modes and rates, interface principles during the work completion [15, 16]. These circumstances enable segregation of this group of facilities as a single information modeling unit.

As applicable to the site facilities the work scope zoning is related to the machine set working methods and sequence of the commissioning of the areas for drilling or construction. For the civil engineering facilities the decomposition into modules shall be performed based on the design peculiarities of the facility and structure stability conditions provision. In this case the basic information for the scheduling is provided as matrices: rows – work structure, columns – work scope areas, crossing – durations of the operation completion in the measurement units adopted (hours, shifts, days etc.). Matrix calculation algorithms provide for the irregular stream parameter optimization based on the criteria of density factor and juxtaposition increase, reduction of the construction timelines with the set resource utilization conditions [17, 18].

Work completion duration is the key calculation parameter in these scheduling models. At a small number of operations in the simple technological process parametric method is used – the work duration is determined based on the work scope and the action parties’ capacity. In more complicated situations operational sequence flowsheets or organization and technological diagrams will be
required. In the absence of the reliable data of the machine capacity, information of the previous projects implemented in similar conditions is used to assess the work duration. At the same time, the present-day information modeling technologies enable calculation of the rated man-hours for the technological operations using production process visualization software [19]. The same software is applied to remove the collisions at the confined construction site related to the work safety conditions and design error correction [20].

Local schedules for individual structures in case of the cluster site development are integrated in MS Project environment in the set work duration conditions. Overall operation mode, seasonal calendar introduction are performed based on the real-life construction conditions. To join the individual projects into a single complex process and organization links are assigned. The software automatically calculates the integrated network diagram. Oil and gas field development projects are typically characterized by the probabilistic nature and high degree of the statistical uncertainty of the time parameters of all the production processes, including construction and assembly works. To manage risks during the cluster site development it is necessary to predict potential unfavourable situations and promptly respond in case of their occurrence.

The method proposed is based on the comprehensive approach to the information modeling of the interrelated design and organization and technological solutions. The modeling process provides 3 main stages. The modeling algorithm is provided as block diagram in Figure 1.

4. Experimental Work Findings

The findings of the pilot application of the method proposed are exemplified by the design of the organization of the comprehensive cluster site construction during the development Severo-Labatyugaskoye oil field at Nizhnesortymskneft Oil and Gas Production Directorate. Table 1 provides a fragment of calculation of two project cycles (indices A and B) at the 3rd stage of the modeling. At the program entry organization and technological links are set. The resource utilization is analyzed. Rated durations of the facilities’ construction duration (tasks A1 – A4, B1 – B4) were initially calculated and optimized using matrix modeling and linear facilities’ calculation program. The project option with the probabilistic timelines of the facility construction durations were calculated in MS Project. Optimistic and pessimistic deviations from the rated timelines were determined based on the statistical analysis of the similar facilities. The expected duration of the facilities’ construction duration is calculated on the following equation [21]

\[ T\mu = \frac{(2\beta + 3\alpha)}{5}, \]

where \( \alpha \) and \( \beta \) are, respectively, optimistic (minimum) and pessimistic (maximum) duration of the on-site works.

The reliability of the project implementation in the contractual timelines (rated duration plus 10% safety margin) was evaluated using modified PERT methodology [22, 23]. The probability of the project completion not later than the contractual target date was 82%. Based on the predictions made risk management action plan for the work programme implementation was worked out.

5. Conclusions

The comprehensive approach to the work organization design during the oil and gas field cluster sites as described in the article reveals additional possibilities for the improvement of the processes for the development of the project information model. The use of the adequate model for different structure types enables accounting for the peculiarities of these facilities’ construction, provision of innovative engineering and process solutions during the design. During the consecutive implementation of the modeling stages a reliable prediction of the construction timelines in the conditions of the time parameters’ statistical uncertainty. Development of the modeling methods in the area of visualization of the solutions adopted during the design and real-life construction management.
Figure 1. Algorithm of Structural Information Modeling during the Cluster Site Development.

Basic data preparation for the project information model based on the conceptual solutions in the cluster site construction system.

**Stage 1.** Facility structuring by the functional groups. Modeling using models by the facility groups.

**1.A. Linear Transport Facilities:**
1.A.1. Structure route zoning based on the change in the natural environment conditions (taxonomic analysis);
1.A.2. Design and organization and technological solutions on the facility structure modules;
1.A.3. Model calculation for the comprehensive linear flow based on the criterion of minimization of the construction terms with the limited resources (special departments’ components).

**1.B. Site Facilities:**
1.B.1. The Site zoning based on the technological work methods of the machine sets and commissioning sequence of the drilling or construction areas. Zone-based work type structuring;
1.B.2. Calculation of the work sequence based on the matrix model using the criterion of the resource utilization continuity without juxtaposing the mechanized sets within the work scope.

**1.C. Industrial Buildings and Units:**
1.C.1. Structuring based on the facility elements;
1.C.2. Calculation of the schedules using matrix models by means of critical path analysis or continuous use of the work scope.

**Stage 2.** Integrated Schedule Calculation:
2.1 Integration of the local schedules into the comprehensive program for the cluster site construction in MS Project. Assignment of the precedence links based on the extension or juxtaposition;
2.2. Network schedule calculation.

**Stage 3.** Probabilistic Prediction of the Construction Timelines:
3.1. Assignment of the probabilistic parameters of the work duration.
3.2. Simulation modeling of the comprehensive project in MS Project environment;
3.3. Evaluation of the probability of the execution of the cluster site development program in the timelines set. Risk management method development.
Table 1. Probabilistic Assessments of the Project Works Durations.

| Index | Task name | Work Duration, days | Rated | Optimistic | Pessimistic | Expected |
|-------|-----------|---------------------|-------|------------|-------------|-----------|
| 0     | Project of the Cluster Site Development | 165 | 140 | 228 | 176 |
| A     | Area Preparation | 77 | 66 | 104 | 82 |
| A.1   | Infield road to the well cluster | 20 | 17 | 27 | 21 |
| A.2   | Engineering preparation | 10 | 9 | 14 | 11 |
| A.3   | Earth works | 43 | 37 | 58 | 46 |
| A.4   | Making pits and vessels | 4 | 3 | 5 | 4 |
| B     | Construction works | 88 | 74 | 95 | |
| B.1   | Metering station | 33 | 29 | 45 | 35 |
| B.2   | Valve manifold | 29 | 25 | 39 | 31 |
| B.3   | Mud lubricator site | 24 | 21 | 32 | 25 |
| B.4   | Pumping unit foundation | 21 | 18 | 28 | 22 |

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