Requirements to IT support of oil refinery supply chain

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Abstract. One of the factors that ensure the efficiency of any enterprise is effective supply chain management, in which the enterprise is a participant. The purpose of this article is to describe and model the supply chain of the oil refining industry and formulate requirements for IT support for supply chain management. As a result, the place of refining processes and related logistics in the supply chain of the oil industry was determined, a model of the supply chain of a refinery was formed, a high-level architecture of IT support for this chain was proposed, and high-level requirements for IT services of IT architecture subsystems were developed.

1. Introduction
For companies operating in the extraction and processing of minerals, inventories are one of the most expensive assets. Their share in the company’s invested capital can reach up to 40%. Despite reserves’ high cost, oil refining companies build them taking into account a number of specific features typical for the industry. First of all, this is due to the fact that supply bases are far removed from the production units, which makes it difficult to accurately plan supply processes. For this reason, the company must have a reserve of stock greater than the minimum required under traditional conditions. It is worth noting that oil refineries are faced with difficulties in accurately determining the size of stocks of finished products, since situations often occur when the volume of production changes, and it is not possible to change the speed of the production process [1].

Since industry specifics do not allow oil refiners to minimize the amount of reserves, enterprises strive to save on the costs that arise when creating reserves and managing efficiency, the organization of logistics processes related to both providing manufacturing with raw materials and shipping finished products plays a big part.

The goal of this article is to describe the problems of supply chain management in the oil refining industry, to create a model of the supply chain itself and to define the requirements for IT services that support the implementation of supply chains.

2. Methodology and literature review
The methodological basis of the work is connected to the approaches to modeling and management of supply chains. The concept of supply chain management has been widely used since the late 90s of the 20th century. The definition of the supply chain, based on a generalization of the formulations of foreign authors, can sound like this: «A supply chain is three or more economic units directly involved
in external and internal flows of products, services and information from source to consumer» [1][2][3]. The supply chain primarily involves the movement of material flow from the purchase of raw materials to the sale of finished products to the final consumer. Thus, it covers almost all subjects that interact with the enterprise.

Thus, supply chain management is a complex of management approaches, information and tools that ensure the effective integration of suppliers, manufacturers, intermediaries and sellers. Taking into account the requirements of the market and consumers, we can conclude that it is precisely such a logistics organization that ensures the availability of the right product at the right time in the right place with minimal cost [4].

In a competitive environment, the most important criteria for success is the quality of logistics service and satisfactory costs in the material goods movement chain and the formation of values. To achieve a positive result according to both criteria, it is necessary to promptly coordinate the execution of work by each type of activity involved in the supply chain.

As defined by Chima, «Supply chain management in the oil industry is the configuration, coordination and continuous improvement of sequentially organized sets of operations related to production, refining and transportation». Thus, the oil supply chain has three functional segments: the upstream, midstream and downstream [5]. The first segment includes processes related to the exploration and production of oil, the second – with transportation, the third – with the refining and sale of petroleum products. The focus of this work is the logistics processes of oil refineries, i.e. mid- and downstream segments of the overall supply chain [6][7].

In most cases, oil reserves are not located in the same geographic location as their processing sites and main consumption regions. Transportation is an important part of midstream operations and involves the use of specialized infrastructure: pipelines, a cargo fleet, tankers and railroad cars. Most of the companies in the world do not have their own facilities for the transportation of oil and petroleum products and therefore use the services of third-party companies at some stage of transportation.

The cheapest and safest way to transport oil is through a pipeline. This method allows for continuous transportation. There are pipelines for the transportation of crude oil and for the transportation of final petroleum products: diesel fuel, gasoline, kerosene [8]. A relatively inexpensive and effective way of delivering oil to the place of refining is transportation by special water vessels (tankers). Automobile transportation is the most expensive mode of transportation. Its advantage is flexibility, that is, the ability to deliver oil (petroleum products) to any point where there are road routes. This method is usually used to deliver petroleum products to filling stations. Transportation of oil and petroleum products by railroad is less costly than automobile transportation, but also less flexible [9][10]. Typically, railway transportation is used to transport petroleum products that are difficult to transport through pipes (bitumen, lubricants, machine oil). In addition, various petrochemical products that are dangerous for road transport are usually transported by rail. Railway transportation is especially common in Russia.

An important area of the midstream sector of the supply chain is the collection system. Collection systems are storage facilities where oil is stored until it is transported to a refinery, where it is converted into marketable products [11][12].

The downstream (third) segment of the oil supply chain includes refining and sales of petroleum products. Each refinery is set up to process a certain type of oil (light or heavy, with various impurity contents) and to produce various final petroleum products.

In addition to refining crude oil, distribution and sale of petroleum products, the down-stream segment also includes the storage of crude oil and petroleum products [13]. The need to store oil (and petroleum products) is due to various reasons:

- to smooth out seasonal fluctuations in demand for certain oil products;
- as insurance against possible unforeseen interruptions in oil supplies;
- to provide seasonal stocks in hard-to-reach (northern) areas;
many countries have national strategic oil reserves.

Storage of oil and oil products can be carried out in different ways:

- in underground (natural) reservoirs;
- in above ground (steel) tanks.

In underground reservoirs, they often store gas, sometimes crude oil, and never store petroleum products (gasoline, diesel fuel). Only above ground tanks are used to store petroleum products. Oil is also stored most often in above ground storage tanks [14].

Oil storage is an expensive element in the value chain of refineries' end products. Storage costs include tank maintenance, safety, insurance, tank capital costs and opportunity costs. Therefore, enterprises strive to minimize the amount of stored oil.

Improving supply chain efficiency is an important source of cost savings, especially in logistics. Since the costs of transporting, storing and distributing oil and petroleum products to end consumers are quite high, it is important to develop and implement new logistics technologies and improve product delivery processes [15][16]. Taking into account the structure of the oil industry, the following important factors of this process can be distinguished:

1. Availability of the right information at the right time for various participants in the supply chain;
2. Integration of all participants in the supply chain;
3. Corporate business solutions for transportation management, resource tracking, logistics and cost tracking;
4. Availability of new specialized IT solutions;
5. Study of supply and demand in the market for goods that best meet the needs of buyers;
6. Planning of deliveries in such a way that the goods do not stand idle or, conversely, there is no unsatisfied demand for the goods.

3. Results
This section presents the supply chain modeling results within the oil refining industry and describes the task of managing this supply chain.

3.1. Oil industry supply chain
Oil refining is one of the links in the oil industry value chain. Figure 1 shows the location of refining and related logistics in the oil industry. After extraction crude oil is transported to storage facilities and from there to the oil refinery. These processes are referred to as primary logistics. Then the raw material is processed to obtain various petroleum products. Final petroleum products are transported to warehouses (secondary logistics), where they are stored and from where they are delivered to consumers [17].

![Figure 1. Place of logistics and refining processes in the oil industry value chain.](image-url)

The logistics chain in the process of oil refining begins with the transportation of raw materials extracted from the fields to an oil terminal, where they are then stored (Figure 2). As a rule, the terminal is equipped with special tanks located on or under the ground. In addition, an oil terminal requires a special platform for receiving and shipping out oil and oil products. The crude oil is then...
processed into petroleum products, which are transported to various warehouses and storage facilities for further storage until they are transferred to consumers [18].

![Figure 2. Oil refining supply chain.](image)

3.2. Formulation of the problem of an oil refinery supply chain management

Baseline: Oil is supplied through marine terminals that are linked to oil refineries. Most of the transformation processes in the oil supply chain are continuous in their nature. This creates additional difficulties in managing the flow of oil, especially for the far removed participants of the supply chain. Oil transportation is carried out using specialized pipelines. Those pipelines are made out of the equipment that consumes a lot of energy and therefore requires careful management.

Oil refinery usually operates two main types of reserves – crude oil reserves for refining and stocks of final petroleum products for shipment, serving as components of technological processes. The company is bound by contractual relations and the corresponding restrictions on the volume and timing of supplies with suppliers of crude oil, consumers of final products, as well as with carriers of raw materials and petroleum products. Failure to comply with the contractual conditions for the shipment of the required amount of petroleum products to the consumer on time entails penalties from the latter. It is required to organize the processes of inbound and outbound logistics of the oil refinery in such a way that the logistics costs are minimal.

Such a system sets requirements for coordinated actions throughout all of the links of the oil transit chain – a terminal, a pipeline, an oil refinery. Likewise for oil products – refineries, pipelines, consumers.

The key task of the supply chain of the described type is to ensure consistency of the actions of the participants in the supply chain in terms of time, volume, quality. Coordination of such decisions is a difficult task due to the contradictory nature of the goals of the terminal and the refinery: it is important for the refinery to receive raw materials in the volume, quality and timeframe determined by the planned production; terminals strive to unload ships as soon as possible to avoid downtime costs.

The flexibility to control the flow of oil between the offshore terminal and the refinery is provided by storage tanks at each of these locations. These tanks have a limited capacity and are responsible: at the terminal – for storing oil coming from the production sites, at the refinery – for ensuring a continuous production process. The scenario is similar between refinery and consumer.

Demand management, efficient distribution of petroleum products to customers, accurate transportation planning, stock management, and the quality and timeliness of information are key factors in reducing costs and increasing a company's profit in supply chain management. However, the real effectiveness of supply chain management lies in managing these factors not individually, but as a whole [19][20].

Effective supply chain management in today's business environment is impossible without proper IT support. It is important to correctly and fully set the requirements for the services of information (and digital) systems and technologies in order to get an appropriate response from them. Figure 3 shows the top-level model of IT support for the implementation of oil refinery processes.
Figure 3. IT support model for the implementation of oil refinery processes.

It is important to correctly and fully set the requirements for the services of information (and digital) systems and technologies in order to receive an appropriate support for automated processes from them. The general requirements for the services of the information systems listed in Figure 3 are described below – both from the side of the supported business processes and from the side of adjacent systems. The list of requirements is compiled from the standpoint of effective supply chain management and is not exhaustive in relation to the full functionality of the listed systems.

Requirements for IT services of the Marketing Analytics System:
From the "Demand forecasting" process:
- Statistical analysis of petroleum products demand, incl. taking into account the seasonality factor;
- Oil, petroleum products and other manufacturing components price analysis;

From the adjacent systems:
- Manufacturing Execution System:
- Oil, petroleum products and other manufacturing components demand and price forecasting;

Requirements for IT services of the Warehouse Management System:
- From the "Stock management" process:
  - Monitoring and control of the current state of oil reserves;
  - Monitoring the levels in oil and petroleum products storage tanks;
  - Calculating the reorder level (date and volume for every type of material);

From the adjacent systems:
- Manufacturing Execution System:
- Materials stock levels information;
- Oil and petroleum products storage tanks levels information;

Requirements for IT services of the Manufacturing Execution System:
- From the "Operations management" process:
  - Manufacturing planning for the planned period in accordance with the planned sales volume by type, quality, timing and volume of petroleum products and available production facilities;
  - Possibility of dynamic adjustment and recalculation of the production plan;
• Reports about actual volume, type, quality and timing of manufacturing;

From the adjacent systems:

• Sales Management System:
• Manufacturing reports with information about actual production by type, quality, timing and volume in the order-specific context;
• Proactive information about the predicted risks of non-fulfillment of the production plan in the order-by-order context;
• Warehouse Management System:
• Manufacturing plan for the planned period, indicating the need for raw materials by type, quality, timing and volume;

Requirements for IT services of the Sales Management System:
From the "Sales management" process:

• Tracking concluded contracts for the sale of petroleum products (dates, volume and quality);
• Tracking the shipments made according to concluded contracts;

From the adjacent systems:

• Manufacturing Execution System:
• Manufacturing plan for the planned period (dates, volume and quality);
• Warehouse Management System:
• Manufacturing plan for the planned period (dates, volume and quality).

Figure 4 shows the IT support model for the implementation of oil refinery processes expanded with the services meeting these requirements.

Figure 4. IT services of the IT support model for the implementation of oil refinery processes.

The proposed requirements for the services of information systems that support the components of the refinery's supply chain are the top-level requirements and indicate the main directions for the
integration of subsystems (modules) of the corporate information system of the oil refinery. The above requirements are subject to further detailing down to the structure of individual documents provided to the subsystems and to detailed requirements in accordance with the service level agreement (SLA).

4. Conclusion
The paper analyzes the supply chain of the oil industry in general and the segment associated with oil refining in particular. Comprehension and analysis of such a chain makes it possible to more effectively plan the movement of material assets (raw materials and finished products) between the participants in the chain and provide an adequate response to the requirements of the participants in the chain to each other. Analysis of the oil refinery processes, which are links in the supply chain, made it possible to formulate top-level requirements for the architecture of IT support for such a chain and for IT services of information systems.

One of the essential issues for continuing research in the field of effective supply chain management in oil refining will be the development of the software for such a control system. So, a number of the requirements for IT services listed in this article require the use of systems of mathematical models (production optimization, inventory optimization, demand forecasting). Certain issues of mathematical support have already been solved by the authors of this article [21], others require a solution.

References
[1] Poljanskihh A, Levina A, Dubgorn A 2018 Investment in renewable energy: Practical case in Estonia. MATEC Web of Conferences, 193,05065
[2] Mukhambetov A M, Bogdashkina I V 2013 Supply management in the oil and gas industry. In: Actual problems of economic sciences: materials of the II Intern. scientific conf pp 118-120
[3] Chima C M 2007 Supply-Chain Management Issues In The Oil And Gas Industry. Journal of Business & Economics Research 5(6), 90-91
[4] Analysis of the organization of the supply chain, https://avege.ru/russian/project/pldob20.shtml, last accessed 2020/08/30.
[5] Kramer L, Upstream vs. Downstream Oil & Gas Operations: What is the Difference?, https://www.investopedia.com/ask/answers/060215/what-difference-between-upstream-and-downstream-oil-and-gas-operations.asp, last accessed 2020/09/10.
[6] Shcherbanin Yu A 2016 Logistics in the oil and gas industry: some provisions and considerations. Transportation and storage of petroleum products and hydrocarbons 4, 22-24
[7] Zubrevskaya T E, Moiseev I D, Shendalev A N 2017 Oil refining logistics features. In: Logistics-Eurasian bridge, pp. 20-24. Krasnoyarsk State Agrarian University, Krasnoyarsk
[8] Boschetto S N, Magatão L, Brondani W M, Neves-Jr F, Arruda L V R, Barbosa-Póvoa A P F D, Relvas S 2010 An Operational Scheduling Model to Product Distribution through a Pipeline Network. Industrial & Engineering Chemistry Research Vol 49(12), 5661–5682
[9] Bolotina Yu A, Rassokha N S 2017 Advantages and disadvantages of using your own warehouse in the activities of modern enterprises. Samara State Economic University Bulletin of Young Scientists 1(35), 128-130
[10] Tretyakova V A, Zimina M E 2019 Advantages and disadvantages of outsourcing in storage activities. Scientific electronic journal Meridian 10(28), 171-173
[11] Tretyakova V A, Zimina M E 2020 Outsourcing in warehouse activities. Moscow Economic Journal 3, 524-531
[12] Iliinsky A, Afanasiev M, Metkin D 2019 Digital technologies of investment analysis of projects for the development of oil fields of unallocated subsoil reserve fund. In: IOP Conference Series: Materials Science and Engineering, vol 497
[13] Financial statements of companies in the oil and gas industry
[14] Oil terminal,
[15] Kornelyuk A M, Pavlovskaya A A, Vakulich N A 2018 Logistic outsourcing. Logistic outsourcing mechanism. In: Logistics-Eurasian bridge, pp. 108-112. Krasnoyarsk State Agrarian University, Krasnoyarsk

[16] On the way to a new reality, https://www.gazprom-neft.ru/press-center/sibneft-online/archive/2019-july-august/3406688, last accessed 2020/09/10.

[17] Vasina A B 2012 A systematic approach to stock management at oil and gas enterprises. Russian entrepreneurship 9, 85-91

[18] Chernysheva A V 2015 Customer value creation for the product. New technologies for the oil and gas region. Materials of the All-Russian scientific and practical conference with international participation, pp. 75-78. Tyumen State Oil and Gas University, Tyumen

[19] Diagram of the supply chain of oil and petroleum products,

[20] Ilin I V, Bolobonov D D, Frolov A K 2019 Innovative business model as a factor in the successful implementation of IIoT in logistics enterprises. In: Proceedings of the 33rd International Business Information Management Association Conference, IBIMA 2019: Education Excellence and Innovation Management through Vision 2020, pp 5092–5102