Cloud platform for smart product-service systems

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Abstract. The paper deals with the problem of decision-making support for digital production planning. The analysis of the stages of organization and production planning currently is poorly represented in existing software solutions. Main stages of digital production planning are identified such as optimization of manufacturing placement; optimization of suppliers selection of resources and its delivery to the place of manufacturing. Taking into account the conditions of the modern stage of development of technologies for the digital production, we can identify the key requirements for the functionality and use of the software platform. The formalization (ontology) based on the approach of production and operational management and the architecture of a digital cloud platform and its functional modules has been developed for the digital production planning process. It is a decentralized platform as a public network consisting of independent software modules (cloud services), connected into a tool with expandable number of modules. The software tool consists of production-planning unit and production-management support unit. Currently, a number of modules of the system have been developed and experimentally tested; now we are developing the full-featured tool.

1. Introduction

Modern business is largely based on digital technologies that affect market competition by giving such advantages like reducing costs, expanding the geography of supply, increasing the market share. The relevance of using digitalization technologies is discussed, for example, in [1], wherein the areas of application information technologies in modern business are systematized. As a result of the study, 157 managers of 50 large companies in 15 countries of the world were interviewed. Comparative analysis showed that those who successfully use digital technologies in their activities are more competitive than those who lag behind in digitalization.

Digital technologies provide broad opportunities to automate production processes. Digital platforms as complex digital solutions aimed at digitalizing processes within groups of business processes, such as logistics, production, supply management and others help to manage and implement digital technologies in business.

This paper provides an overview of existing digital services, describes the architecture of a software platform aimed at automating the production planning process.

2. Digital software solutions

In paper [2] the authors reviewed the problems of organizing digital production. Currently, especially in Russia a few number of digital services and platforms are developed that partially or fully implements the above-mentioned groups of business processes of the firm's activities.
The authors of paper [3] have identified the following types of software tools, systems and platforms:

1. Social networks: Facebook, Twitter, ‘VKontakte’, Instagram, etc.,
2. Search engines: Google, Yandex, Yahoo, etc.,
3. Messengers: Telegram, WhatsApp, Viber, Uber, etc.,
4. Specialized software systems and tools: ‘1C’, SAP, ‘Parus’, ‘Galaktika’,
5. E-commerce platforms: EBay, Amazon, Alibaba, Taobao, Aliexpress, etc.

Widely used aggregator platforms act as collectors of information on the prices of various products from individual manufacturers and also allow large businesses and brands to trade directly on the Internet. Aggregators combine sellers into a single system and verify each seller on their platform. Aggregator platforms act as an intermediary between the seller and the buyer, ensuring the security of the exchange operation. They have a unified logistics system which consists of order acceptance points and logistics companies located in all major cities to which suppliers deliver products for shipment to the buyer. This type of platforms is primarily focused on trade but not the production. And therefore functionality is severely limited. This makes it possible to use them only as a private solution for the production phase aimed at finding a supplier and logistics.

The Ministry of Economic Development and Trade in Russia has developed a number of communication platforms that allow business, science, consumers and the state to interact on modernization and scientific and technological development in certain technological areas. An example of a popular state information service that integrates various systems and provides for a management subsystem is gosuslugi.ru service.

We analyzed each type of systems and platforms [2], their advantages and disadvantages, focusing on comparing software solutions in terms of the tasks to be solved. The results of the analysis showed that despite a wide range of Russian and foreign platforms, not all tasks required for the processes of the organization and production planning stage, including choosing the optimal location, analyzing demand for products, selecting reliable suppliers, and a number of others, are covered by modern software solutions. That is why the development of new solutions that use modern information technologies to support various stages of digital production is an urgent task aimed at improving the functioning of production in the country.

3. Software platform architecture

The architecture of the platforms is shown at Figure 1. The platform is implemented as a set of independent units, each of which performs its own functions and communicates with others through internal interfaces. The number of units, as well as the composition of each unit, are extensible.

The platform architecture consists of the production-planning unit and the production-management support unit of modules.

The production-planning unit contains modules for:

- Production location optimization,
- Optimal supplier selection,
- Delivery and transport optimization.

The platform has its own information resources and modules. Some of them are used by all platform units. Shared resources and platform modules are:

- Client environment interface. It provides user interface for interacting with the platform,
- Internal aggregator of products. This module contains a list of products and services provided by suppliers of resources. The module is a data aggregator with API (Application Programming Interface) that is available both for external services and for internal modules within the platform. This software solution implements such an aggregator that helps for entrepreneurs to find available resources for production from suppliers and order its delivery,
- Information resources. This module contains information about the geography of places where production resources are provided. Access to information is available both within the platform and through the API.
Figure 1. Architecture of the software platform.

The platform has its own set of modules:
- Digital geemap is used to determine the production and suppliers location to simulate the
  possible placement of manufacturing,
- Contractors validation module. This module interacts with the external API to access on the
  legal entity information,
- External information resources aggregator. The application receives information about
  products available on external aggregators of production resources. The application is
  expandable with new aggregators.

The platform is scalable and provides the possibility for new modules implementation.

4. Mathematics of manufacturing placement problem
Let’s describe the mathematical model of manufacturing placement problem which is solved in
production placement unit.

The company produces its products usually called ‘final products’ from other products or ‘raw
materials’ which are delivered from different suppliers of products. The suppliers are located at the
nodes of transportation network. The company can deliver raw materials from different suppliers. A
single supplier might not always provide a shipment to the node. The criteria of potential
manufacturing placement for a company at the node can be formalized as the minimization of total cost of delivery of raw materials to this node from the others.

Notice that the cost minimization problem can be decomposed into independent problems for each delivered product. Thus, we describe the simple model for one delivered product and let its amount is given as $D$. Also for this simple model, we consider that only one supplier is located at each node. The price of delivered product and the amount of this product at node $i$ that can be provided from supplier $i$ are given. We consider transportation unit costs among nodes as $r_{ij}$. We introduce the set of unknown variables $x_{ij}$ as volumes of delivered product from node $j$ to $i$.

For each node $i$ as a potential place for manufacturing placement the total cost of delivery from all the nodes is $L(i) = \sum_j (p_{ij} + r_{ij})x_{ij}$. First constraint of a problem setup is such that the total amount of delivered product from different suppliers is given as

$$\sum_j x_{ij} = D. \quad (1)$$

As the amount of which can be provided from supplier $i$ are For each supplier $j$ we need to consider the constraints

$$0 \leq x_{ij} \leq q_j. \quad (2)$$

Obviously, we should also require the condition $\sum_j q_j \geq D > 0$ to have feasible non-trivial solution of a problem.

So we need to solve linear programs $\min_{x_{ij}} L(i)$ for each $i$ under above-mentioned constraints (1), (2). Then we can find the optimal node for manufacturing placement as $i^* = \arg \min_i L(i)$.

We solve these linear programming problems using PuLP and Scipy applied math package based on the 'numpy' python programming language extension. The client application implemented using other tools and technologies can use this service by accessing the HTTP protocol using the popular data exchange format JSON.

5. Conclusion

The paper provides an overview of existing solutions for organizing digital production. We propose software platform architecture and software solution for planning placement of production.

At present a number of modules of the system have already been developed and experimentally investigated [4, 5]. The work is now underway to implement a fully functional instrumental complex [6].

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