Information efficiency, information design and information system of an organization

Yuri A. Zelenkov
Adviser to the Chief Designer
NPO Saturn
Address: 163, Lenin Ave., Rybinsk, Yaroslavl Region, 152903, Russian Federation
E-mail: yuri.zelenkov@gmail.com

Abstract

This article proposes a methodology for analyzing an organization management system and selecting the most relevant strategy to enhance its information efficiency. Information efficiency is determined through the amount of information that is required to ensure the coordination and motivation processes. We discuss four organizational design strategies aimed at improving information efficiency. Two of them are associated with a reduction of the amount of information required for management: creation of buffers (stocks of raw materials, work in progress and surplus resources) and system decomposition into independent operating units. Two other strategies are aimed at increasing the organization capabilities to process information, i.e. develop information systems and create a context facilitating information exchange.

It is shown that the strategy of creating buffers leads to inefficiency, but it spontaneously occurs under conditions of the lack of information. The implementation of other strategies requires the organization's efforts. The policy of measuring the information efficiency of the organization is discussed, and since at present it is hardly possible to develop a single method, it is recommended that one use benchmarking.

Estimates of the information volumes which are being handled by high-technology machine-building enterprises in Russia and abroad are provided. It is demonstrated that due to underdevelopment of the technological infrastructure domestic enterprises are forced to process overly great amounts of data, which leads to information overload and, as a consequence, creation of buffers at all production stages. The result is an overall inefficiency of the enterprise as compared to similar foreign enterprises, and this gap cannot be overcome only by creation of enterprise information systems. In this regard, we present an example of production system decomposition which enables one to reduce the amounts of management information.

Key words: management efficiency, organizational design, manufacturing management system, manufacturing planning, ERP system.

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Introduction

Modern information technologies (IT) allow us not only to improve existing practices, but also to create new business models that increase the organization's efficiency. A large number of studies has been devoted to the study of the IT effect on efficiency [1–4]. At the same time, many researchers note that the introduction of IT into organizations is always connected not only with a change of information systems (IS) themselves, but also operational principles, user skills and other complementary resources [5], all of which increase the complexity of such projects. Investigation of the factors affecting the project success of implementing new IT systems is a very trendy topic [6], inasmuch as vast literature is devoted to the analysis of barriers and constraining factors [7, 8].

An assessment of the potential impact of new IT and identification of risks to achieve it are an essential component of strategic IT management, but the common methodology of making such decisions is not available. Most of the afore-mentioned papers have a descriptive character and empirical data, although generalized, is not converted into action norms and regulations.

This paper uses a methodological approach based on a combination of concepts of the organization's information efficiency [9] and information design [10]. In the first section, the theoretical aspects of both concepts are discussed, and in the subsequent sections the practical application of the proposed methodology is illustrated using the example of selecting a strategy of improving the information efficiency of the NPO Saturn manufacturing system (http://www.npo-saturn.ru).

1. Information efficiency and the information design of an organization

According to paper [9], the main organizational functions are coordinating the efforts of all its participants in agreeing upon common goals and motivating compliance with the agreements reached. On this basis, an organization's information efficiency criterion (IEC) was proposed: an organization that requires less information to support coordination and motivation processes is more efficient [9]. This criterion can be used specifically while making decisions on the implementation of new IT initiatives; however, this causes a problem of its quantitative assessment. Most likely, it is not possible to develop a universal approach for measuring IEC, therefore, the most obvious and simple approach is benchmarking, namely comparing the amounts of information operated by different organizations performing closely related activities. An example of evaluation of the information efficiency of the manufacturing system of a high-technology machine building enterprise will be presented in the next section.

In addition, it is worth noting that the information efficiency of an organization can be enhanced not only through reduction of the amount of information needed for coordination and motivation, but also by increasing the organization's capability to process this information. This point of view is verified by results of empirical studies of the impact of IT investments on the company's productivity [11, 12], namely, introduction of new IT primarily reduces the labor costs of the employees involved in information processing, that eventually leads to reduction of transaction costs.

Paper [10] addresses general principles of organizational design through the lens of information efficiency, and two main types of strategy are distinguished: reduction of information required for management, and increase of the organization's capability to process it. The first type of strategies includes:

✦ compensation of uncertainty (i.e. lack of information) through creation of buffers (slack resources in term of [10]). This strategy is realized through increase of raw material stocks, increase of work in progress, emergence of excess capacity. It results in a decrease of economic efficiency. It is in contradiction with such modern concepts as "lean manufacturing" and "just in time", but is spontaneously formed at the enterprises suffering from information inefficiency;

✦ decomposition of the system into loosely coupled modules grouped around the same-type products or services. Such a module must have all necessary resources to provide the entire value chain, and after that it can be considered as a "black box" hiding internal information flows. This is today's mainstream in the organization of manufacturing systems [13], while outsourcing is a natural development of this area.

The strategy of increasing the information processing capabilities implies:

✧ development of enterprise information systems. It is worth noting that the term "information system" is used here not in the narrow sense (IT based system), but in the wider sense, like any system enabling us to collect, transmit, store and process information. In this regard, the accounting system, for example, is the information system;

✧ development of communications between the employees (direct contacts, introduction of special functions – integrators, working groups, matrix organization, etc.).

The organization can combine simultaneously all these strategies, but in each specific case it is necessary to analyze which strategy can make the greatest contribution to increasing information efficiency. The most obvious conclusion is that, generally speaking, the reduction of the amount of information in the coordination and motivation processes achieved by system decomposition is the more attractive way, since it is directly aimed at reducing transaction costs. However, such restructuring in most cases comes into conflict with accepted practices; it requires radical changes and always encounters a significant resistance [14, 15].

The strategies related to improving information processing capabilities should be applied when capabilities of reducing this information are either unavailable, or for some reason are unrealizable. At the same time, preference is given to a strategy aimed at developing communications between employees, creating the context enabling us to propagate information [16] and, in a more comprehensive sense, enterprise knowledge [17].

The development of enterprise information systems, especially through the introduction of IT, is always associated with difficulties that have several sources. First, it requires changes not only in the information processing methods, but also in complementary resources, namely, user skills, IT infrastructure, and so on [5]. In this case, the complexity of IS implementation is connected with the area of its implementation [18]: it is minimal for systems aimed at reducing the transformational costs of an individual employee, and increases with the transition to coordination of activities of the organizational unit, the entire organization and, further, to management of interaction with external agents. In addition, the authors of paper [19] point out that the appearance of new technologies is a source of techno-stress for users. On the other hand, the users often try to use IS to solve problems which were not foreseen by its developers [20]. Finally, the IS implemented can become an obstacle to subsequent changes in the organization, since it provides for a limited set of business process execution options [21].

Creation of buffers, i.e. stocks of raw materials, work in process and excess capacity is an extreme case. This strategy should be resorted to when other capabilities cannot be implemented. However, there are situations, when the presence of a buffer is a prerequisite for successful operation. For example, the theory of constraints by E.M. Goldratt [22] provides for creation of buffers to the system bottlenecks, which determine its performance.

Thus, the introduction of new IT should be considered as a special case of a more general problem – organizational design strategy selection. The information efficiency criterion, assessing the amount of information in the coordination and motivation processes, is an effective tool for evaluating various options for organizational design solutions. This raises the problem of quantitative evaluation of this criterion. Since a unified methodology of such an assessment can hardly be developed, we propose to use the benchmarking technique to compare the amounts of information required for management in companies using close business models. The next sections will address the implementation of these proposals in practice.

2. Information efficiency of NPO Saturn manufacturing system

This section addresses practical experience of PJSC NPO Saturn, a Russian company engaged in the design, manufacture and aftersales service of aircraft gas turbine engines.[1] One of the key projects of NPO Saturn in the early 2000s was to develop the SaM146 engine for the regional Super Sukhoi Jet 100 aircraft in partnership with the French company Snecma[2] (these products were primarily oriented to the international market).

Partnership with the leading foreign manufacturers and claims to market entry with extremely high business competition revealed many problems of the Russian project participants. For example, by labor efficiency (revenue per employee), Snecma outperformed NPO Saturn by more than seven times. It became obvious that for the collective success of the project all its participants must ensure the same efficiency in terms of costs, labor efficiency and duration of the production cycles. As a consequence, NPO Saturn launched changes covering almost all areas of activity, i.e. retooling and modernization, implementation of new methods of organization of work and management, staff development, establishment of long-term stable relations with partners having necessary competencies, reduction of stocks, etc.

At the same time, an ERP system was proposed to be used as the main information processing tool. A rather advanced set of in-house designed IS supporting various tasks of manufacturing management existed at the enterprise. Nevertheless, it was expected that the ERP system would provide a significant head start due to switching to new "optimal" business processes purchased with the system. However, a number of pilot projects showed that the required efficiency cannot be achieved only by replacing the existing IS with ERP. Detailed analysis revealed that the main differences between the Russian and foreign enterprises of high-tech machine-building are in the field of information efficiency, rather than anywhere else, and it is these differences that prevent the implementation of the processes that are implemented in the ERP system. Let us consider these differences by the example of the manufacturing system.

From the information point of view, the main task of the manufacturing system is to form a feasible manufacturing plan, record the actions taken in accordance with

[1] In 2003–2008 the author of the article was responsible for IT-support of the SaM146 program on the Russian side, and in 2009–2014 he held the position of the IT director of PJSC NPO Saturn.
[2] At present Safran Aircraft Engines division of Safran group.

this plan, detect deviations and respond to them. All these activities are based on the data of the production facilities (product and its components) and resources (equipment, personnel, finance, etc.). The atomic unit of planning and accounting is the manufacturing operation, to which the equipment, tooling, time and material consumption rates, etc. are related. The more precise this data is, the more accurate the calculation of the manufacturing plan, which is a time schedule of a sequence of operations for manufacturing specific products at a given time.

It should be pointed out herewith that the manufacturing facilities of Russian companies are derived from the Soviet period and have not been radically updated yet at any of the large enterprises (the average age of the equipment is 20–25 years at the most). This means that on average a part is manufactured in a greater number of operations than in a similar foreign manufacturer. According to the author's estimates, for similar process stages Russian machine builders need to perform 4–10 times more operations compared to their foreign counterparts. In addition, foreign enterprises which manufacture small-scale high-technology products, all alone manufacture only about 10–20% of the variety of all parts coming to the assembly line, with all the rest being obtained from second-tier suppliers, which, due to their specialization, provide much greater efficiency. Domestic enterprises produce almost 100% of the assembly parts themselves. A trade-off analysis of the amount of data needed to ensure the manufacturing planning and accounting operated by PJSC NPO Saturn and Snecma is shown in *Table 1.*

Table 1.

Volumes of information required for manufacturing planning

	Snecma	NPO Saturn
Variety of parts for assembly (pcs.)	36,000	36,000
Number of parts of in-house production	6,000	30,000
Average number of operations to manufacture a part	20	80
Number of information objects (operations), the correctness of which must be maintained	120,000	2,400,000
Number of employees responsible for entry of information	100	400
Number of information objects per one employee	1,200	6,000

It follows from what has been said that with the same throughput capacity, the amount of data required for manufacturing management at a Russian enterprise is 20 times greater than at a foreign enterprise having a more efficient production infrastructure. This leads to low-quality plans, a huge amount of dispatching, unreliable and conflicting data on the actual situation with manufacturing of products. Therefore, most domestic enterprises use their in-house developed IS, which somehow enable them to handle unreliable information.

An additional problem is obtaining accurate data on the configuration of the manufactured product. The configuration in this case is taken to mean a description of all units, parts and purchased components forming bill of materials (BOM) of the final product. Low-batch production is characterized by a continuous change of BOM, since the product design is constantly refined either by the operation results, or the requirements of a particular customer. The problem for domestic enterprises is that this process is not completely automated anywhere and, moreover, the existing regulatory structure allows for several types of documents changing the product configuration (engineering change orders, assembling specifications, etc.), each of which has its own peculiarities. Therefore, the configuration is defined manually on the basis of paper documents, which leads to errors. At the same time, the study of the best practices of foreign enterprises shows that with the information systems available it is possible to provide a configuration management process based on only one document – an engineering change order.

The impacts of unreliability of information on the product configuration and manufacturing operations on the quality of the manufacturing plan were investigated in paper [23]. The results obtained in this paper are provided in *Figure 1*, where curve 1 represents the impact of errors in determination of the operation execution time; curve 2 represents errors in assignment of work centers, and curve 3 represents errors in definition of the product configuration.

Analysis of this data shows that even if there is an error in determining the execution time for each tenth manufacturing operation, 65% of manufacturing orders are assigned incorrectly. The share of errors in the manufacturing plan reaches its maximum value of 92% in incorrect determination of the execution time for 45% of operations. However, it is worth noting that in this case the share of errors in the plan never reaches 100%, since the assignment of the first operation in the manufacturing routing is always performed correctly.

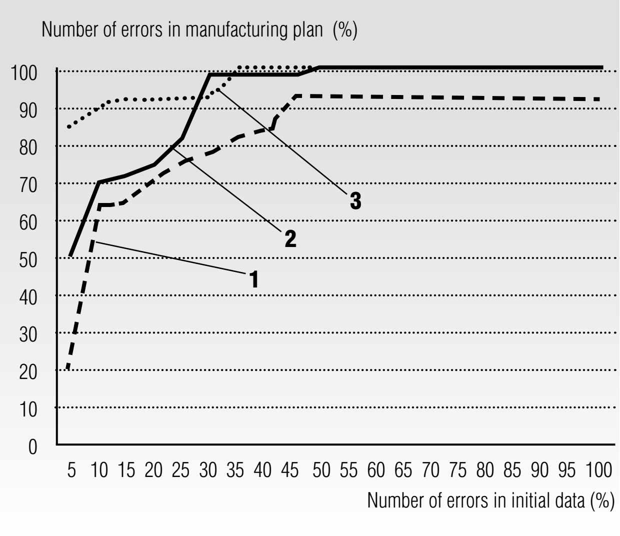

Fig. 1. The impact of initial data errors on the accuracy of manufacturing planning

With errors in determining the work centers (curve 2), the number of misdirected work assignments increases more intensively and reaches 100% already at a 30% level of unreliability of the initial data. The influence curve 3 shows that even a negligible level of errors in the configuration data of the product leads to almost complete unreliability of the manufacturing plan. Therefore, the manufacturing system is non-linear, and minor errors in the initial data lead to significant errors in decision making (planning).

From the data presented, it follows that there is an unambiguous cause and effect relationship: imperfect technical and management infrastructure – the amount of information for management – the management system quality. Imperfection of the technological infrastructure leads to a sharp increase in the volume of manufacturing operations. Insufficient maturity of business processes, such as configuration management, leads to unreliable data on the product BOM, that affects on the planning quality are even more unfortunate (it should be noted that, contrary to technological processes, the amount of configuration data for similar products is approximately the same for Russian and foreign enterprises). The infrastructure problems cause an information overload of the management system. The enterprise responds to this overload by creating buffers from raw materials and purchased parts, work in progress and excess capacity, and all of that eventually leads to a sharp drop of its efficiency. It is obvious that this problem is extremely difficult to fix through introduction of an information system based on IT or any other data collection and processing principles. It is necessary to involve other organizational design strategies.

3. Decomposition of manufacturing system

Analysis of the information processed by NPO Saturn (*Table 1*) shows that the volume is a critical constraining factor in terms of efficiency. Alternatively, according to the logic outlined in Section 1, the idea of decomposing the manufacturing system into loosely coupled modules organized around the same parts was put forward. This proposal encountered a sharp negative reaction, especially on the side of representatives of the manufacturing system, which confirmed that the existing structure of workshops and groups was bound by complex connections which impeded the transformation. Historically, the equipment necessary for processing parts of the same type is located on the territory of different workshops.

The possibility of the proposed decomposition was verified by cluster analysis using the *k*-means method. The results were presented in a table, where rows list key parts of the aircraft engine, and columns list manufacturing groups, while the filled cells at the intersection of the row and the column indicate that the parts of this type are processed in this group. It was revealed that the NPO Saturn manufacturing system is divided into several clusters, each of which provides a full cycle of operations for manufacture of a certain type of parts; in this case, a significant intersection between the clusters is practically absent. We have to note that such clustering, as expected, does not comply with the established structure of workshops.

Based on these studies, NPO Saturn top management decided to divide the manufacturing into independent divisions which are to manufacture a narrow range of similar products (rotating parts, hull elements, rotating blades, etc.). Each of these divisions receives orders from product directorates (civil engines, military engines, industrial plants), the structure of which includes assembly lines and divisions interacting with the consumers. The activities of each division are assessed by economic indicators. This decision made it possible to reduce a total amount of information needed to coordinate the manufacturing system of the whole enterprise. The first tangible result of such transformation was an increase of the share of production orders executed when required. In the course of time, other effects of reducing the information flows have become apparent, in particular, such functions as bottleneck analysis, assessment of investment needs for development, unification of technical processes for similar parts, "make or buy" analysis. Outsourcing development began to demand much less effort.

It is worth noting that it was possible to achieve these results without modernizing the enterprise IS, just by reducing information flows and, consequently, increasing the information efficiency. Implementation of the ERP system supporting optimized single-type processes is the next step after stabilization of the new manufacturing structure. This should give greater freedom to information processing in the newly established divisions.

Conclusion

Enterprises trying to improve economic performances must first investigate the potential of various strategies to increase the information efficiency. In this case, it is preferable to avoid strategies of creating resource buffers. NPO Saturn experience shows that the greatest effect in such conditions reduces information flows through system decomposition, which can be accompanied by an increase of the company's ability to process information through development of enterprise IS and communications between the employees. ■

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Информационная эффективность, информационный дизайн и информационная система организации

Ю.А. Зеленков

доктор технических наук, советник генерального конструктора
НПО «Сатурн»
Адрес: 152903, Ярославская обл., г. Рыбинск, пр-т Ленина, д. 163
E-mail: yuri.zelenkov@gmail.com

Аннотация

В статье предлагается методология анализа системы управления организацией и выбора наиболее актуальной стратегии повышения ее информационной эффективности. Информационная эффективность определяется через объем информации, который необходим для обеспечения процессов координации и мотивации. Обсуждаются четыре стратегии организационного дизайна, направленные на повышение информационной эффективности. Две из них связаны с сокращением объема информации, необходимого для управления: создание буферов (запасов сырья, незавершенного производства и избыточных ресурсов) и декомпозиция системы на независимые рабочие подразделения. Две другие стратегии направлены на увеличение способностей организации обрабатывать информацию: создание информационных систем и создание контекста, способствующего обмену информации.

Показано, что стратегия создания буферов ведет к неэффективности, но стихийно возникает в условиях недостатка информации. Реализация остальных стратегий требует усилий со стороны организации. Обсуждаются подходы к измерению информационной эффективности организации и, поскольку выработка единого способа в настоящее время вряд ли возможна, рекомендуется использовать бенчмаркинг.

Даны оценки объемов информации, которыми оперируют предприятия высокотехнологичного машиностроения в России и за рубежом. Показано, что отечественные предприятия из-за отсталости технологической инфраструктуры вынуждены обрабатывать чрезмерно большие объемы данных, что ведет к информационной перегрузке и, как следствие, созданию буферов на всех этапах производства. Результатом является общая неэффективность предприятия по сравнению с аналогичными зарубежными, причем данное отставание невозможно преодолеть только за счет создания корпоративных информационных систем. В связи с этим представлен пример декомпозиции производственной системы, позволяющей снизить объемы информации для управления.

Ключевые слова: эффективность управления, организационный дизайн, система управления производством, производственное планирование, ERP-система.

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