# METHOD OF ASSESSMENT OF INFORMATION AND CONTROL DECISION SUPPORT SYSTEMS OF THE PRODUCTS FOR VIRTUAL INSTRUMENT-MAKING ENTERPRISE BASED ON THE SPIRAL MODEL OF THE PRODUCT LIFE CYCLE

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**Abstract**

In the article it is reviewed and modified a method of product life cycle assessment (LCA) with the help of a new stage "market monitoring", which allows at the stage of strategic planning to identify priorities for product release and production technology design. It is also found that the use of OLAP technology enables to visualize not only the stages of "start-release", but also to assess the necessity of termination of further production, using a developed spiral model of product life cycle assessment for virtual instrument-making enterprises. The developed model have shown that when reaching break-even point it should be the right way to conduct strategic planning, modernize the product in accordance with the consumer needs and give the product a new round or complete the project. Development of such models helps to ensure that the product life cycle for virtual instrument-making enterprises can stretch to infinity.

**Keywords:** product life cycle (LC), virtual enterprise, life cycle assessment (LCA), OLAP (online analytical processing), spiral model.



## 1. Introduction

In Ukraine, one of the main industries of the economy in the market conditions are mechanical engineering (includes instrument-making), which defines the scientific and technical policy of the country, ensuring the competitiveness of products and economic security. Development of other industries in Ukraine is depended from the effective activity of the enterprises of this industry, and not only the satisfaction of consumer demand. For every businessman is very important to understand when to stop investing in some product, device and others. Often the business is closed just from the production of the wrong product, production of already unnecessary product. It should be clearly understood when the product "has outlived its". These factors mean searching the methods for solving the above-mentioned typical situations.

The most fully disclose the concept of "product life cycle" is [1] a set of processes performed by the detection of the needs of society in certain products, investigate the possibility of its production until the satisfaction of these needs, and the termination of its use.

Formation of the "virtual enterprise" definition based on the research [2] enterprise consisting of community of geographically dispersed subcontractors, which interact in the production process, functioning through telecommunication means.

In the context of the concept of sustainable development of the economy, the majority of authors believe that the existing approaches to information and control systems require new principles to make decisions and directions for development of domestic enterprises [3, 4]. In their works the best tool is the situation analysis, because in the volatility the role of the situation is increase, because the situation – this event, limited in time and localized in space [5].

One of the few practitioners with the practical side applied techniques related to the assessment of complex technical systems and decision-making in their design, production and further improvement, and this is already establishing, suggested the methodology for formation of decision support systems [6].

So, research of new aspects of management information and control decision-support systems for virtual enterprises is urgent.

In conducting research for the aim was to determine the necessity of life cycle assessment for management decisions, and how to determine the moment of i-type product termination with data visualization.

There is the following list of tasks to achieve this aim:

– consider the features of life cycle assessment, as well as the rationality of its implementation;

– determine at what stage of the LCA occurs decision-making on the release of a certain type of product;

– consider the use of OLAP systems in the context of model visualization of the product life cycle;

– determine the time of i-type product termination with data visualization.

## 2. Materials and methods used for research of assessment of information and control decision support systems of the products for virtual instrument-making enterprise

### 2. 1. Materials and equipment used in the work

The studies were conducted on the data of "KIATON" enterprise, which is a research and production enterprise in the development, modernization and production of marking equipment. Visualization models were examined using OLTP-systems, which are designed to automate business processes. In addition, the store is replenished by statistics. Thus, we used data about production of «EKST DATA 3M» marking printer for the period of 1997–2015. Also, the data of Statistics of Ukraine were used.

### 2. 2. Features of the product life cycle assessment

Today, one of the leading tools of information and control decision support systems in the European Union is designed to assess the economic fluctuations in production systems method of product life cycle assessment (LCA).

LCA method is a systematic approach to the assessment of all types of resources used for manufacturing of the products throughout its life cycle from procurement and processing of raw materials to the recycling of the individual components [7].

Full LCA analysis consists of four distinct but interrelated components:

1. Goal Definition and Scoping – description of the product and the production process (service). Creating conditions for assessment, definition of the sides of analysis and impacts on the economic situation. In other words, to life cycle assessment it first of all determine its goal (define the ultimate goal of the analysis), and therefore determine what we analyze (scope of analysis), i. e. we define the object of study.

2. Life Cycle Inventory. This analysis involves determining the quantitative characteristics of the input parameters (components, raw materials, energy, materials) and output parameters (component, design, unit, device) for each LC stages of the selected object of research.

3. Life Cycle Impact Assessment – assessment of the potential labor forces and economic impacts, used energy, components, raw materials and materials identified in the preceding analysis

(inventory analysis). At this stage of the study life cycle components are revealed. The change of these components will influence on the economic component of the output product. Also, an impact of these components is assessed, i. e. determining their degree of influence and what it is expressed.

4. Interpretation – processing analysis results of input, output parameters and assess their impact on the economic component is made to correctly choose the most preferred products (services) for production [8].

Thus, at the example of SPE "KIATON" (enterprise producing marking equipment) before start the production of a certain type of product is carried out all the above stages of life cycle assessment.

Research of life cycle assessment consists of four stages. Their interrelation is shown in **Fig. 1.**

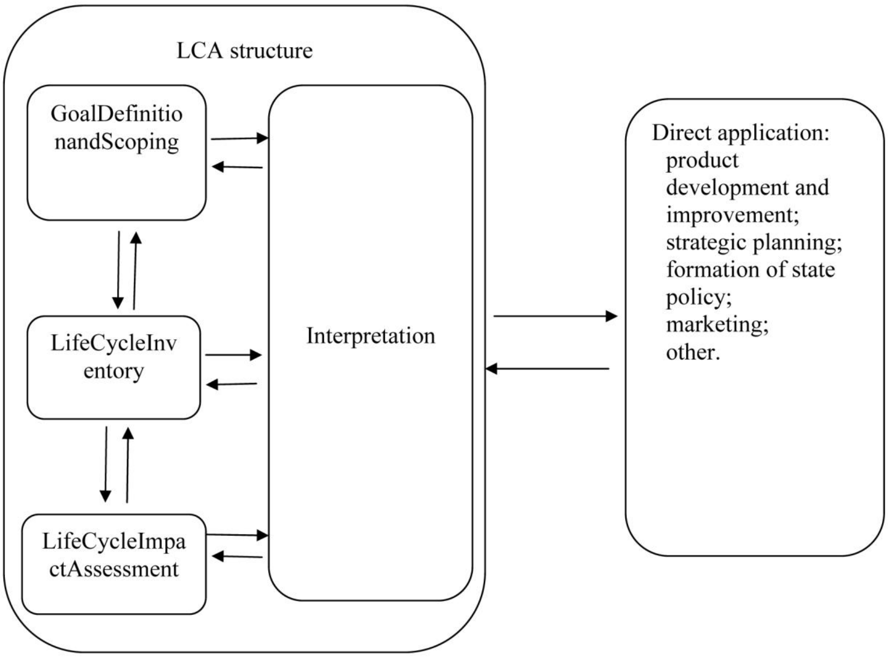


**Fig. 1.** Stages of product life cycle assessment and their interrelation

In **Fig. 1** we show the main LCA application:

1) product development and improvement;
2) strategic planning;
3) marketing;
4) other application.

The analysis is conducted in order to manufactured products, firstly, will be marketable according to the criteria of service, durability, suitability for maintenance, cost of components and consumable materials, and, secondly, will be relevant in the market upon end of production, while equipment will be available to the users in the finance component.

It is also important that manufactured products will be marketable after production and relevant in the market, because the production process can be both in the short term and in the long term.

Thus, marketing component should be considered at LCA. Therefore, it will be rational to add the fifth component ("Market Monitoring") to this LCA method. At this stage we should conduct research of the selected segment of the market, aimed at studying the consumer demand in time. In other words, what the buyer is overdue now (criteria that guided at purchase), as well as prediction of the selection criteria within six months, a year (cycle of the production process). And only after this assessment and analysis we can proceed to the next stage goal definition and scoping.

Based on the LCA general principle «from cradle to grave", production chain is analyzed and evaluated from the instrument-making production planning to consumption of manufactured products and the location of production and consumption waste (recycling). The whole complex of

interrelations between the production and the environment can be represented by using product life cycle (LC) in the form of production chain. LC is a set of consecutive and interconnected stages of production chain from a perspective of managing the impact on economic component (economic management).

Scope of LCA, including the boundaries of the system and the level of detail depends on the object and goals of research purposes. The depth and breadth of LCA can vary depending on the goals of specific LCA.

Life cycle analysis allows assessing the resource flows for each unit of production chains, thereby allowing controlling and changing the input and output flows, and as a result improves the integrated resource efficiency and minimizes economic risks.

This analysis will enable the virtual enterprise:

1. Choose the criteria for determining the resource requirements necessary for the profitable operation of the system.

2. Highlight the system components, which are aimed at efficient use of resources.

3. Compare alternative materials, components of the products for the production process.

4. As a result, choose the most preferred products (services) for the production.

Thus, assessment of information control systems is important for the developing country – Ukraine, the correct assessment is important primarily for small mechanical engineering enterprises (for fast and flexible decisions about the production of a particular type of product). The development of small mechanical engineering enterprises in recent years are shown in **Fig. 2** [9].

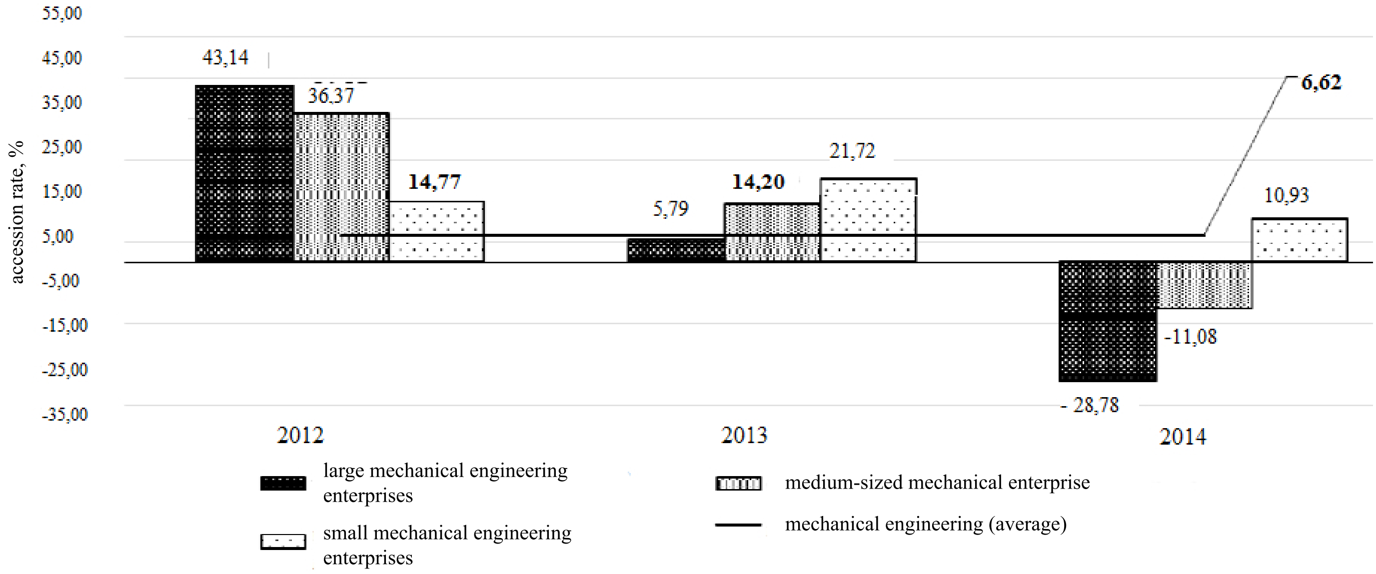


**Fig. 2.** Dynamics of volumes of sales of mechanical engineering enterprises of Ukraine (% to last year)

**2. 3. Application of OLAP systems for visualization of the product life cycle model**

The theoretical description of OLAP systems is carried out fragmentary. Three main methods can be used in OLAP systems for storage [10]:

– MOLAP (Multidimensional OLAP) – output and aggregate data are stored in the multidimensional database.

– ROLAP (Relational OLAP) – output data remains in the same relational database in which they are located. Aggregate data is stored in a specially created supporting table for their storage in the same database.

– HOLAP (Hybrid OLAP) – output data remains in the same relational database, where they were in the first stage, and aggregate data are stored in a multidimensional database. We used a widespread MOLAP system (OLAP system) as the analyzed system.

The general scheme of such OLAP system comprises the following individual steps:

1. Data acquisition as table or SQL query execution result (in a case where the construction of the multidimensional data cube of OLAP system takes place "on the fly" as it is implemented in ROLAP system) [11]. Here it is advisable to pay attention to OLAP system, as an object of an algebraic system. From this perspective, the set of OLAP system data is a two-dimensional matrix:

$$\mathbf{A}^{(k)} = \sum_{i=1}^{M}\sum_{j=1}^{N} a_{ij} I_{ij} = \left\{a_{ij}^{(k)}\right\},\ i \in 1, M;\ j \in 1, N, \tag{1}$$

where a data (elements) of matrix A, N dimension of the matrix A in the general form (facts and dimensions for OLAP system).

In step 1: k=1.

IJ=matrix of size N×M, all of whose elements are zero except for IJ elements, which are equal to one (the position of non-zero elements of the matrix A correspond to the positions of non-zero elements of the matrix IJ).

2. The procedure of transformation into a multidimensional cube conveniently presented in the form of block matrices [11], to form a matrix A from the series of matrices Aαβ it is necessary that the subset of matrices in the set with the same value of the index α have the same number of rows and a subset of matrices with the same value of the index β − the same number of columns. These subsets form the "block" columns and "block" rows which respectively correspond to certain rows or columns of normal matrix:

$$A = \begin{pmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{pmatrix} = \left(\begin{array}{cc|ccc} a_{11} & a_{12} & b_{11} & b_{12} & b_{13} \\ a_{21} & a_{22} & b_{21} & b_{22} & b_{23} \\ \hline c_{11} & c_{12} & d_{11} & d_{12} & d_{13} \\ c_{21} & c_{22} & d_{21} & d_{22} & d_{23} \\ c_{31} & c_{32} & d_{31} & d_{32} & d_{33} \end{array}\right), \tag{2}$$

where

$$A_{11} = \left\{a_{ij}\right\}, A_{12} = \left\{b_{ij}\right\}, A_{21} = \left\{c_{ij}\right\}, A_{22} = \left\{d_{ij}\right\},$$
$$i \in 1, M;\ j \in 1, N.$$

that in the general case takes the following form:

$$A = \begin{pmatrix} \overbrace{A_{11}}^{n_1} & \overbrace{A_{12}}^{n_2} & \dots & \overbrace{A_{1t}}^{n_t} \\ A_{21} & A_{22} & & A_{2t} \\ .. & .. & .. & .. \\ A_{s1} & A_{s2} & \dots & A_{st} \end{pmatrix} \begin{matrix} \}m_1 \\ \}m_2, \\ \\ \}m_s \end{matrix} \tag{3}$$

where m, n the corresponding dimension of the elements of block matrix A. For cases of the basis of three-dimensional space, which is a mathematical analogy of building OLAP systems, the matrix A is a three-dimensional (cubic) data table, whose elements are block matrices. This matrix takes the form:

$$A = \left\| A_{ijk} \right\|, \left(i, j, k = 1, 2, \dots, n\right). \tag{4}$$

The secant orientation of the index (e. g., i-th) – an assembly of elements of the matrix (4) with fixed values of the index (e. g., i), it takes the form (3), which will be called a two-dimensional secant (data cube slice). Using two-dimensional secant we can write a cubic matrix (database) in the form of a square or rectangular array (two-dimensional secant are separated by vertical or horizontal line (in the case of the order of base p>=3): the arrows indicate the direction in which the

growing respective indices (facts, measurement). For a clearer image the spatial distribution of the elements in a typical cubic data matrix is shown in the **Fig. 3**.

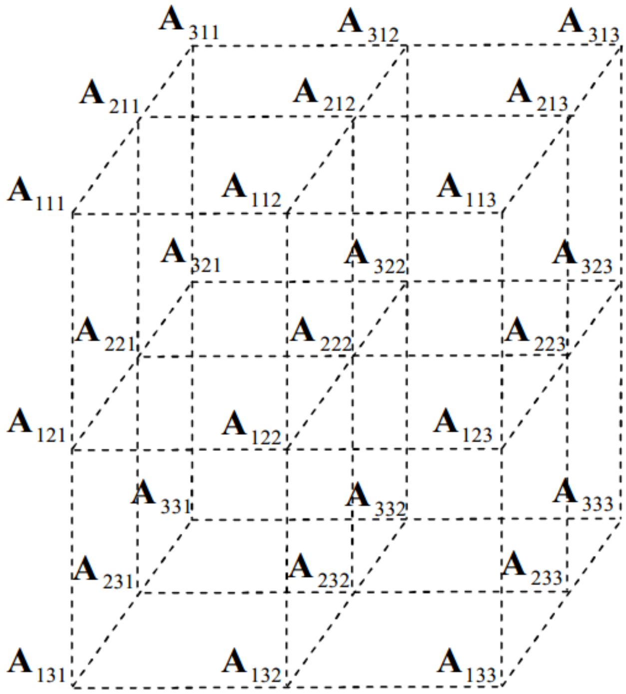


**Fig. 3.** Structured image of the data matrix

3. Reflection of cube using cross-tables or diagrams, etc. In general, any number of reflections can be connected to one cube. Reflections used in OLAP systems often are of two types: cross-tables and diagrams.

It should be noted that the original data matrix, that necessary for the phase of building data cube and data cube slices (used during the specified reflection of the cube) will be very sparse. Therefore, to work with such matrix is necessary to use special mechanisms to work with sparse matrices. Mathematical interpretation of one of the following ways (in general), which provides for the "exception" of the empty blocks of specified array, means the "exception" of the required block by multiplying the left original data matrix $\widetilde{A}$ by the matrix of $E_m^*(z)$ "ledge" [11]. For simplicity, let us explain the operation as an example the case of one-dimensional data table. Suppose that the matrix is sparse and has the form:

$$\widetilde{A}=\begin{vmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ A_{41} & A_{42} & A_{43} & A_{44} & 0 & 0 & 0 & 0 \\ 0 & A_{52} & A_{53} & A_{54} & A_{55} & 0 & 0 & 0 \\ 0 & 0 & A_{63} & A_{64} & A_{65} & A_{66} & 0 & 0 \\ 0 & 0 & 0 & A_{74} & A_{75} & A_{76} & A_{77} & 0 \\ 0 & 0 & 0 & 0 & A_{85} & A_{86} & A_{87} & A_{88} \end{vmatrix}. \tag{6}$$

Simple operation

$$A=E_m^*(z)\widetilde{A}, \tag{7}$$

release ("exceptions") fully sparse block.

Thus, the resulting table will look like:

$$A = \begin{vmatrix} A_{41} & A_{42} & A_{43} & A_{44} & 0 & 0 & 0 & 0 \\ 0 & A_{52} & A_{53} & A_{54} & A_{55} & 0 & 0 & 0 \\ 0 & 0 & A_{63} & A_{64} & A_{65} & A_{66} & 0 & 0 \\ 0 & 0 & 0 & A_{74} & A_{75} & A_{76} & A_{77} & 0 \\ 0 & 0 & 0 & 0 & A_{85} & A_{86} & A_{87} & A_{88} \end{vmatrix}. \quad (8)$$

In the formula (7): $E_m(z)$ – is $mxM$ matrix composed of m adjacent rows of the identity matrix IM, starting with z-th (in this case – from 4th)

$$E^*(4) = \begin{vmatrix} 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{vmatrix}. \quad (9)$$

The procedure of component processing when creating a data cube. Here is a practical example of building a data cube structure and procedure of linking its components from a practical point of view. For this purpose we use the database (DB) fragment of the function module «Marking printer» «EKST DATA 3M». Output data for building OLAP cubes typically stored in relational databases, they are also called data warehouses [12]. Such data storages are intended only for processing and analysis of information and designed so that the time to queries execution was minimized.

Typically, data is copied to the repository from operative database in accordance with a certain interval, for example, once a quarter, or a year. If we compare the structure of a standard relational database, the typical data warehouse structure differs significantly from the usual relational database. This structure is non-normalized (allows to increase the query execution speed), and therefore can avoid data redundancy.

The main element of the data storage structure is the fact table and dimension table. The fact table is the main table containing information about objects or events, the totality of which will be further analyzed [13]. The most common are four types of facts, which are: the facts related to the transaction (based on specific events, such as receipt of the message); facts related to the "snapshots" (based on the state of the object, for example, the state of the rental payment for the real estate at the end of the month or the end of the year); facts related to the document elements (based on a particular document, such as reporting forms of real estate, accounts for services, etc.); facts related to the events or state of the object (in fact of the occurrence without further details).

Let's consider a data structure of a table (OLAP cube slice) from the viewpoint of OLAP machine. Grid columns for OLAP system can be either the facts or measurements. In this case, the logic of these columns will be different. The hypercube Measurements in the hypercube are the axis, and the measured values – the coordinates on these axes. This cube will be filled with highly uneven. For data loading it is necessary to do the data reaggregation, that is, to combine records with identical measurement values calculated with the previous aggregate value of facts. As a result of this procedure, in the future we will be able to work with a fewer record, increase the speed and reduce the requirements for the RAM capacity.

### 3. Application of building OLAP systems using visualization models for virtual instrument-making enterprises

Multidimensional nature of the building product life cycle for virtual enterprise using OLAP technology enables to visualize not only the stages of "start-release", but also to assess the necessity of ending further production, in other words, the close-out phase of the project.

Thus, in the example of activity of LLC SPE “KIATON” it can be detected necessity of termination of the further production of the marking printer «EKST DATA 3M», summarized basic data are presented in **Table 1.**

**Table 1**

NPP “KIATON” data for the period of 1997–2015 years for production «EKST DATA 3M» marking printer

| № | Value | | |
|---|---|---|---|
| | Profit, c.u. | Demand, items | Time, year |
| 1 | −56000 | 0 | 1997 |
| 2 | −25000 | 73 | 1998 |
| 3 | 21000 | 23 | 1999 |
| 4 | 0 | 0 | 2000 |
| 5 | −31000 | 78 | 2001 |
| 6 | 0 | 49 | 2002 |
| 7 | 22500 | 19 | 2003 |
| 8 | 0 | 0 | 2004 |
| 9 | −19000 | 68 | 2005 |
| 10 | 15700 | 40 | 2006 |
| 11 | 0 | 0 | 2007 |
| 12 | −5000 | 19 | 2008 |
| 13 | −10000 | 21 | 2009 |
| 14 | 15500 | 24 | 2010 |
| 15 | 10100 | 19 | 2011 |
| 16 | 5300 | 8 | 2012 |
| 17 | 0 | 0 | 2013 |
| 18 | −2650 | 4 | 2014 |
| 19 | 2650 | 4 | 2015 |

Based on the data presented in **Table 1**, spiral life cycle model of electrical bubble-jet marking printer «EKST DATA 3M»is built using the method of assessment of information-control decision support systems (**Fig. 4**)

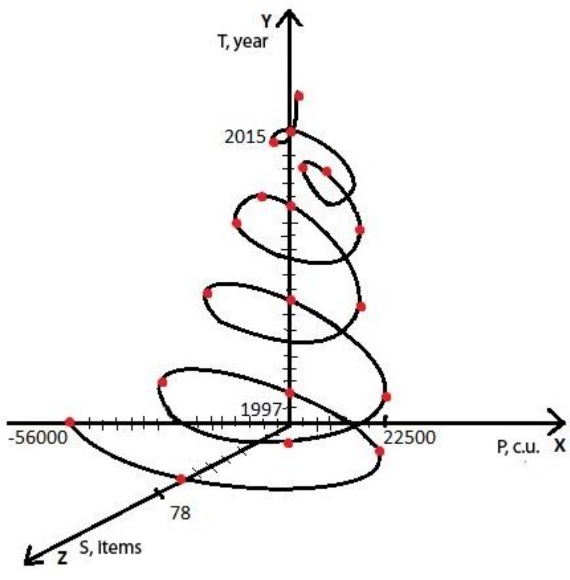


**Fig. 4.** Spiral life cycle assessment model of marking printer «EKST DATA 3M»

Visualizing life cycle data of matrix printer «EKST DATA 3M», we can clearly detect the moment when the production of this type has become irrelevant in the market, and, therefore, unprofitable for the enterprise. The model has shown that the invested funds are equal to proceeds from the sale. This indicates future losses, as realizable value includes not only the cost and margin, and a number of accrued costs.

From the spiral we can also keep track of the cycle "a new turn" of life cycle. Start of the turn is a time of modernization of this type of equipment to prolong its operation, i. e. soft recycling. The model allows visualizing the moment when demand fell sharply, this suggests the necessity of modernize. By investing in the modernization, it isn't observed any increase in demand or profit. This indicates that further release doesn't make sense – this type of equipment is outdated both morally and physically.

Using this model, the spiral can stretch to infinity with each turn extending the product life cycle and, thus, is relevant for the unstable economic situation in the world.

## 4. Discussion of the results of life cycle assessment model

Principles of OLAP systems provide a high level of efficiency and effectiveness of the access to large volumes of information in real time and presenting data in the context of different analytical trends transforms data into valuable information that can be used for analytical processing of the information and make grounded decisions in the production process of the virtual instrument-making enterprises.

Spiral life cycle assessment model for virtual instrument-making enterprise is built. That allows to quickly and flexibly taking management decisions to discontinue further investment in the modernization and further production of products.

## 5. Conclusions

As a result of the research:

1. It was found that the life cycle assessment is an integral part of decision-making. Life cycle analysis can be used to improve the economic performance of products at various stages of its life cycle. It can be applied at the organization level for strategic planning supply and service life up to a soft recycling by using the method of product support including maintenance and recycling.

2. The study distinguished two stages of the life cycle are revealed for decision-making about release of a product:

– at the life cycle impact assessment, i. e. after analysis and assessment of qualitative and quantitative characteristics, determined by the rationality of the release of a product, identification of priorities, designing the product;

– at the offered new stage – market monitoring. Decision-making at this stage is very important, because this stage defines the strategic plan of the enterprise, design of a product or process, i. e., direction of activity. Wrong decision (without assessment), could lead to the ending enterprise life cycle.

3. Researches have shown that the multidimensional nature of the building product life cycle for virtual enterprise with application of OLAP technology enables to visualize not only the stages of "start-release", but also to assess the necessity of ending project.

4. Spiral model is built for product life cycle assessment for virtual instrument-making enterprises, which make it easy to determine when further investments in the i-type model are meaningless. Reaching this point, it should be the right way to conduct strategic planning, modernize the product in accordance with the consumer needs and give the product a new round or ending project.

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# ADVANTAGES OF OPTICAL ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING IN COMMUNICATIONS SYSTEMS

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**Abstract**

The role of the optical transmitter is to generate the optical signal, impose the information bearing signal, and launch the modulated signal into the optical fiber. The semiconductor light sources are commonly used in state-of-the-art optical communication systems. Optical communication systems has become one of the important systems after the advent of telephone, internet, radio networks in the second half of the 20-th century. The development of optical communication was caused primarily by the rapidly rising demand for Internet connectivity. Orthogonal frequency-division multiplexing (OFDM) belongs to a wide class of multicarrier modulation. Orthogonal frequency-division multiplexing has succeeded in a wide range of applications in the wireless communication domain from video/audio digital broadcasting to wireless local area networks (LANs). Although their very low loss compared to that of the wireless counterpart, optical systems still need renovation for spans commonly less than 150 km. In this paper advantages of optical orthogonal frequency division multiplexing in communications systems will explained.

**Keywords:** OFDM, WDM, optical signal, communication systems, radio networks.



## 1. Introduction

Communication systems transmit information from a transmitter to a receiver through the construction of a time-varying physical quantity or a *signal*. Optical communication systems use light rays with a wavelength of 380 nm to 3000 nm region of the electromagnetic spectrum. The spectral efficiency and reliability of wireless optical channels can also be improved by using multiple transmitter and receiver elements after the invention of the optical amplifier in the 1990-s. The advent of the optical amplifier heralded a new era of optical communications in which a massive number of wavelength-division multiplexing (WDM) signals can be conveyed over thousands of kilometers [1]. Fiber optic communications are light wave systems that employ optical fibers for data transmission. The natural trend was to study the light wave communication systems, in which