

# Decision-making support tools in data bases to improve the efficiency of inventory management for small businesses

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*Abstract:* The article highlights the questions of the use of mathematical methods and control of current balances by databases for solution the problems of inventory management. Also considered the game-theoretic approach to multiobjective optimization for resource allocation. Proposed means of information systems are invariant under the mathematical methods that are used in the planning of inventory management.

*Key-Words:* inventory management tools, support decision-making, the game-theoretic approach to multiobjective optimization, OLAP tools, economic order quantity model, SQL-instructions.

## 1. Introduction

Efficient management at all levels will greatly improve efficiency of any company. The area of great importance is an inventory management. Effective inventory management increases "frozen" in stocks asset's turnover. Due to effective inventory management product (necessary resource) will always be available and easy to access. That will prevent losing possible clients/customers. Information Systems Supply Chain Management (SCM), as well as warehouse management modules (Inventory Management System) contain serious mathematical apparatus designated for inventory management optimization. Small businesses, however, prefer to employ less expensive but less efficient software such as Microsoft Office, compare to specialized information systems. In this article we discuss about the tools of decision support systems based on mathematical methods, game theory and databases.

Inventory management tools (IMT) are important part of the company's management. IMT could be divided in two parts. One of them consists of mathematical models and methods of planning of the optimal size of the stocks, calculation of optimal reserve supply chain, and methods of optimal service in reserve. Another includes an information system, which provides a continuous registration data of the goods accounting, stocks calculation and visualize results for decision-making support.

Decision-making support is an important part of IMT for enterprises of any size. Online analytical processing (OLAP) are key technologies for enterprise decision support systems. They provide sophisticated technologies for data collection, integration, retrieval, and analysis; query optimization, and advanced user interfaces. There are many OLAP tools, which are widely used in this field.

The history of the development of OLAP technologies rather significant [18]. Most OLAP tools were developed for decision support at large enterprises, and require significant funding. Small businesses, most probably, will be interested in the tools based on standard software such as spreadsheet or desktop database manage system.

This article provides tools for the decision support systems based on mathematical methods, game theory and databases.

The article highlights the issues of implementation of decision-making support tools involving methods of database manage systems.

## 2. Problem Formulation

Effective inventory management should include a comprehensive solution. This solution must include proper software. When it comes to small business, software should be affordable and ease of use. As mentioned above, small businesses prefer to use

Microsoft Office, rather than expensive specialized information systems.

Due to the limited financial capacity, small business often faces necessity for the allocation of resources or reserves, for example, by projects within the company. In general, any mathematical programming concludes selection from a given feasible set of variables that achieves maximum or minimum of the objective function [11]. Here we are talking about single-criterion optimization. However, in practice, often there are cases when there is a diversity of purposes, the extent to which expressed a number of criteria, ie vector. So, when deciding on the allocation of the resource (reserve) between projects or departments, company needs to consider multiple criteria facing the problem of multicriteria (or vector) optimization [2].

The concept of OLAP (On-Line Analytical Processing) was formulated by E. F. Codd in 1993 [5]. The main idea of this system is based on Multidimensional conceptual view, and consists of the construction of multidimensional cubes (multidimensional tables) available by user's request. These multidimensional cubes are based on the source and aggregated data (are you sure about source data, in biology we say "row" data), all of them could be stored in relational as well as multidimensional databases. Software on the base of the OLAP system allows flexible and fast information search, variety of analytical operations including multiple data reports, and data comparison analysis over time. All work with OLAP-system is in terms of the subject area.

Currently a market offers a huge variety of OLAP-systems. There are several classifications of this type of products: for example, classification by type of data storage, by the degree of accessibility. Let's review the first of the above classifications. There are three ways of data storage in OLAP-systems [18]:

- MOLAP (Multidimensional OLAP). This type of storage provides high performance OLAP operations. However multidimensional cube most often be redundant and depend on the number of measurements.
- ROLAP (Relational OLAP). The source data are stored in a relational database on the file server. Aggregate data may be placed in special tables in the same database. Converting data from a relational database in multidimensional cubes happens by request of OLAP tools. Based on that the cube building speed will strongly depend on the type of data source, decreasing response

time of the system and, sometimes, making the process unacceptably slow.

- HOLAP (Hybrid OLAP). In this type of OLAP original data remains in a relational database and aggregates are placed in a multidimensional. Construction of OLAP cube happens in response of OLAP tools request on the base of relational and multidimensional data. This approach allows you to avoid the explosive growth of data, and achieve optimal runtime of client's request.

There are main advantages of OLAP [19]:

- Subject orientation. That means that information in cubes is collected and stored based on various aspects of business: purchasing, sales, etc. That's distinguishes the OLAP database from the operational database, where data is organized according to different processes such as registration or issue of documents, registration of orders, etc.
- Multi user mode. Client-server architecture of OLAP products provides simultaneous access for a large number of users. Despite the large number of users the analysis is equally fast in all aspects of information regardless of the size and complexity of the database structure.
- Direct access to data allows a user to see all the information at once, not filtered out by the report.
- Concentration of the necessary data in one place. For example, all sale information including calculations, contractor, manager, date, type of transaction, etc. is stored in the same cube, and does not require referral to extra sources (manuals and etc).
- Convenient means of access, view and analyze business information (friendly interface). The user receives an intuitive model of data, organized in the form of multidimensional cubes. This allows comparative analysis of indicators, analysis of different scenarios on the principle of "what-if", based on forecasting and statistics of the company.
- Convenient data navigation with a mouse allows to move through the hierarchy within the dimension (the transition from analysis by year to the analysis by quarter, sales analysis by managers to the analysis of sales by region and so on); as well as to move between dimensions (transition from

analysis by the dimension of "Time" to the analysis of "Goods", etc.).

However, OLAP applications are quite expensive even for large enterprises, and also require staff training. Therefore use of such tools for the small enterprises is problematic. Small enterprises widely use universal software like MS Excel. MS Excel tools use OLAP functions and provides the implement for support decision making. There are main advantages of OLAP tools in universal software like MS Excel [6]:

- easy of using;
- no requires special staff training;
- low cost;
- versatility

As a rule, the technology of using OLAP functions of MS Excel provides data export from one DBMS, for example, from SQL server or MS Access. Data table is exported from the database to Excel, following an employment of the OLAP functions in Excel [8]. But the disadvantages can include some complexity data export technologies (two-level technology): preparation of the data in the database and export to Excel. Alternative MS Excel can be a simple solution using general-purpose DBMS.

The database is a system for storing information in a structured form. Database management system (DBMS) is the software that controls access to the database and interact with the user, other applications, and the database itself to capture and analyze data. Database programs enable manipulation of data that is stored to be presented in various ways. Mathematical operations can also be performed on the data stored in these devices. Database management systems allow extremely complex operations to be done on massive amounts of stored data.

A general-purpose DBMS is a software system designed to allow the definition, creation, querying, update, and administration of databases. Well-known DBMSs include MySQL, Microsoft SQL Server, Oracle, LibreOffice Base, Microsoft Access etc.

A typical DBMS has the following features [10]:

- Provides a way to structure data as records, tables, or objects.
- Accepts data input from operators and stores that data for later retrieval.
- Provides query languages for searching, sorting, reporting, and other decision-making support activities that help users correlate and make sense of collected data

- Provides multiuser access to data, along with security features that prevent some users from viewing and/or changing certain types of information.
- Provides data integrity features that prevent more than one user from accessing and changing the same information simultaneously.
- Provides a data dictionary (metadata) that describes the structure of the database, related files, and record information

A general-purpose DBMS use SQL queries as queries for complex data views and decision-making support activities. So, in general-purpose databases, OLAP tools implemented with SQL queries.

The article describes one of the ways of the structural organization of tools for database. That includes requests for specific data grouping, specific SQL-calculation, and graphical interpretation of the results for facilitating decision-making by managers of enterprises. As an example, we use one of the calculations of inventory management from economic order quantity model (EOQ).

### 3. Problem Solution

#### 3.1. Wilson`s model. Economic order quantity model (EOQ)

There are two types of inventory management models - deterministic and stochastic inventory management models. Among stochastic models produce stable and non-stable models.

Wilson`s model (EOQ - Economic order quantity model) is one of stable models with determined demand [1, 13].

Model with high intensity of completion reserves and big penalties for deficiency.

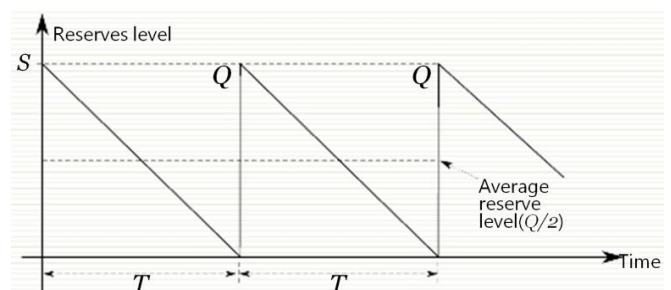


Fig. 1. Model of optimal order quantity

Main points:

- Demand is known;
- Instant receipting of product;
- Discounts aren`t considered;

- Deficit isn't admitted;
- Resources may be analyzed separately

Total cost (LT), rub = supply costs + storage costs

Total annual cost, rub/year:

D – average consumption of resource, unit/year;

$$L_c = \frac{LT}{T} = \frac{K + \frac{hTQ}{2}}{T} = \frac{DK}{Q} + \frac{hQ}{2} \rightarrow \min \quad (1)$$

K – supply cost, rub/order;

Q – size of supply (order), unit;

T – supply period, year;

h –marginal cost on storage of stocks during the year, rub./(unit \* year).

Optimal supply size:

$$Q^* = \sqrt{\frac{2DK}{h}} ; \quad (2)$$

Optimal order period

$$T^* = \frac{Q^*}{D} = \sqrt{\frac{2K}{Dh}} ; \quad (3)$$

Supply quantity:

$$n^* = \sqrt{\frac{2K\mu}{h}} ; \quad (4)$$

K – fixed outgoings, independent of order rub/order;

$\mu$  – intensity of resources consumption, unit/t;

h – marginal costs of maintenance, rub/ (unit \* t);

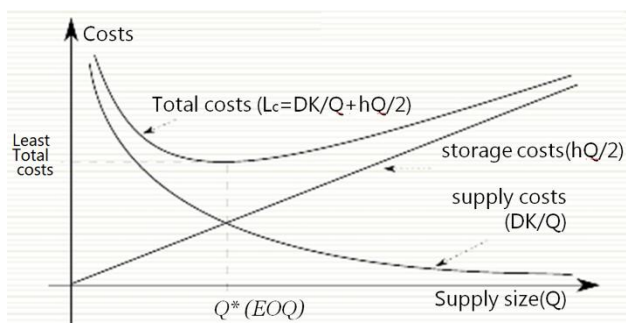


Fig.2. Economic order quantity model

There are many type of Wilson`s models: model of optimal order quantity EOQ, model inventory management with the assumption deficit, the inventory model without an admission of a deficit, etc [11].

### 3.2. Problem multicriteria (or vector) optimization.

Multiojective optimization problem is formulated as follows:

Let there be a controlled event (operation), the outcome of which depends on the chosen side A strategy  $X \in \mathbf{X} \subset \mathbf{R}^m$ . Effectiveness of side A vector valued criterion  $e = (e_1, e_2, \dots, e_n)$ , a local criterion  $e_i$  ( $1 \leq i \leq n$ ) is associated with a certain relation strategy X

$$e_i = e_i(X), \quad i = 1, \dots, n. \quad (5)$$

Assume that the goal is to maximize all local criteria by selecting a strategy  $X \in \mathbf{X}$  (the problem of minimizing some local criteria is easily converted into their maximization problem by changing the sign of these criteria). However, in vector optimization problems has non-antagonistic contradiction between local criteria: improving the quality of decisions on some criteria may degrade the quality of decisions on others. If this should not be given to local criteria corresponding weights, ie harmonize local criteria, to solve the problem, you can use an arbitration scheme [17].

Going to arbitration scheme reduces vector problem of decision-making to the equivalent (in the sense of the principle of optimality for both Nash arbitration schemes) scalar problem, which has a unique solution. It is convenient to move from the space  $\mathbf{R}^m$  strategy sets X to the space  $\mathbf{R}^n$  criteria vectors  $e = (e_1, e_2, \dots, e_n)$  on the coordinate axes which are deposited values of local criteria.

Let U denote the image of the set of all admissible strategies X under the mapping defined by formula (5).

Now, to reduce the problem of multicriteria optimization to arbitration scheme  $G = \langle I, U, u^* \rangle$ , where  $I = \{1, 2, \dots, n\}$  - a set of local criteria, it is necessary to determine the point  $u^*$ . This point can be determined from the content of the problem of multicriteria optimization or common sense, as well as enlisting the skills and intuition. Also as a point of status quo often take  $u^* \in U, u_i^*$  components are equal to the guaranteed value of the local criterion  $e_i$  ( $1 < i < n$ ) for all values of all other criteria. Then the solution of any multiobjective problem can be obtained using computational optimization scheme. Of course, in this case the solution is optimal [12].

### 3.3. Inventory management software

The mathematical methods allow to plan the size of supply, the minimum allowable residues and the supply period. Considering the distribution in real time, some specifications can change. For example, the supply period can change depending on demand. It's necessary to consider such factors as, for example, changing the dynamics of demand for

making purchasing decisions. The information systems requirements should decide tasks of accumulation of data on merchandise and contain the tools for decision support [4].

Companies use information systems to reduce their carrying costs. Inventory management software is an important component of computer system to monitor levels of enterprise sales, deliveries and stocks [3].

Inventory management software allow you to calculate the parameters: the size of supply, supply period, reorder point [14].

Also, computerized systems allow to track the real state of the company to ensure the stocks.

As a tool for the data used spreadsheets. The database are a tool for the accumulation of data on current inventories. It's necessary to have tools for intelligent decision support. All these qualities correspond to the requirements for Big Data [16].

The main disadvantages of the inventory management software based on Big Data are its cost and complexity. The high cost of inventory management software allow to use these tools only by large companies. Small businesses can't to afford to use expensive software. In addition, the management of companies, which use Big Data technology, should provide training of stuff to use of Big Data in the future.

As said before, we describe problem's solution of account balances and the use of tools for decision-making support using simple tools. The classic example is the task based on model of optimal order quantity EOQ.

**3.4. Practical solution of inventory management for small business**

The sale of the certain store is 500 units of production in the year. The level of demand is distributed evenly throughout the year. For the delivery of the order the store owner has to pay 1000 rubles. Order delivery time from the supplier is 12 working days (6-day work week). According to experts, the cost of storage is 40 rubles per year for a package. It is necessary to determine: how many bars must store owner order for one delivery; frequency of orders; reorder point and the annual cost of managing inventory. It is known that the shop is open 300 days a year.

This mathematical tools allows to calculate the re-ordering time and optimum batch size.

Stable models with determined demand:

$$Q^* = \sqrt{\frac{2K\mu \cdot (1 + \frac{h}{d})}{h}}; \tag{6}$$

$$T^* = \sqrt{\frac{2K}{h\mu}} \cdot \sqrt{1 + \frac{h}{d}}; \tag{7}$$

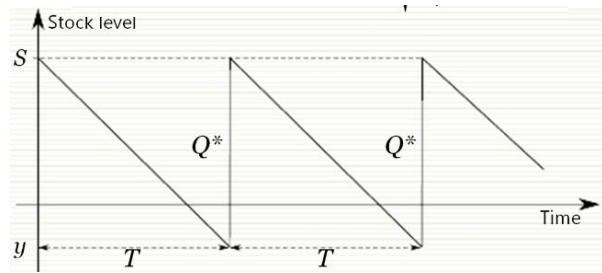


Fig.3. Static model with deterministic demand.

The optimum batch size

$$Q^* = \sqrt{\frac{2K\mu}{h}} = \sqrt{\frac{2 \cdot 10 \cdot 500}{0,4}} = 158,11 \approx 158 \text{ (unit)} \tag{8}$$

Annual costs are

$$L_c = K \frac{\mu}{Q^*} + h \frac{Q^*}{2} = 1000 \frac{500}{158} + 0,4 \frac{158}{2} = 6325 \text{ (rub/year)} \tag{9}$$

Delivery of each new order should be made through

$$T^* = \frac{Q^*}{\mu} = \frac{158}{500} = 0,316 \text{ (year)} \tag{10}$$

Since in this case the year is 300 working days, the order should be served at the level of reserve:

$$S_0 = \mu T_{\partial} = \frac{500}{300} \cdot 12 = 20 \text{ (unit)} \tag{11}$$

i.e., these 20 units will be sold for 12 days until the first order will be delivered.

**3.5. Solution of practical task with the use of multiobjective optimization (game-theoretic approach)**

Consider a concrete example for a small enterprise. Suppose that you want to allocate 100 unit of some resource between the two projects in the company's vector criterion

$$u = (u_1, u_2) = \left(1 - \frac{x}{100}, \sqrt{\frac{x}{100}}\right), \tag{12}$$

where  $x \in [0, 100]$  - amount of resource, allocated to the second draft.

Using an arbitration scheme  $\langle I, U, u^* \rangle$ , where  $I = \{1, 2\}$ , and  $u = (0, 0)$ .

Seen that if  $x = 100$ , than  $u_1 = 0$  and  $u_2 = 1/10$ , and if  $x = 0$ , than  $u_1 = 1$  and  $u_2 = 0$ . After we may express through local criterion  $u_1, u_2$ , i.e. we find

$$u_1 = 1 - 100u_2^2 \quad (13)$$

and define the set  $U = \{u | u_1, u_2 \in [0, 1]\}$ .

Then we find the arbitration solution  $\tilde{u} = (\tilde{u}_1, \tilde{u}_2)$ , this solution maximizes:

$$g(u', U', u^*) = u_1 u_2 = (1 - 100u_2^2)u_2 \quad (14)$$

Differentiating this equation and equating to zero the derivative, we obtain  $\tilde{u}_2 = (10\sqrt{3})^{-1}$ , and then find  $\tilde{u}_1 = 2/3$ . Consequently,

$$\tilde{u} = \left(\frac{2}{3}, \frac{1}{10\sqrt{3}}\right) = \left(1 - \frac{x}{100}, \frac{\sqrt{x}}{100}\right), \quad (15)$$

where  $x = 100/3$ .

Thus, according to the principle of optimality for general Nash [15] arbitration schemes first project in the company should allocate  $200/3$  unit, and the second  $100/3$  unit of resource.

There are many software to solution such task.

This task can be solved by OLAP tools in DBMS. Such tools allow you to use cheaper technologies of decision-making support for small business.

### 3.6. Decision-making support system tools based on databases

Information systems of enterprises solve the problem of continuous registration data of the goods accounting. In addition, it requires the development of tools to carry out of estimating size of stocks in real-time and to support decision-making [9].

It is known solution, based on SQL-instruction using the WHERE predicate [7].

The problem of representing data on current stocks propose to solve consistently using two SQL-instructions:

1) The query GroupingOperation carries out the group all data according to the chronology and

calculates the current amount of the issue and receipt of goods:

```
SELECT Month([Date]) AS [Month],
ItemsRegistration.Date,
Sum(ItemsRegistration.IncomeQuantity) AS
[In],
Sum(ItemsRegistration.ExpensesQuantity) AS
[Ex]
FROM ItemsRegistration
GROUP BY Month([Date]),
ItemsRegistration.Date
ORDER BY ItemsRegistration.Date;
```

2) The query RunningTotal calculates current stocks as progressive total:

```
SELECT GroupingOperations.Date,
Sum(GroupingOperations_1.[In]) AS Income,
Sum(GroupingOperations_1.[Ex]) AS Expenses,
[Income]-[Expenses] AS Stocks
FROM GroupingOperations AS
GroupingOperations_1 INNER JOIN
GroupingOperations ON
GroupingOperations_1.Date<=
GroupingOperations.Date
GROUP BY GroupingOperations.Date
ORDER BY GroupingOperations.Date;
```

We use this formula for the calculation of current stocks:

$$S = \sum_{i=1}^n s_i = \sum_{i=1}^n (I_i - E_i), \quad (16)$$

$s_i$  – current stocks;

$I_i$  – current income;

$E_i$  – current expenses.

In Fig. 4 it presents the dataset reflecting the chronological flow accounting (income and expenditure) of goods in the first period residues according to the calculated data above.

Implementation of the proposed queries for calculation of current balances shown in Fig.5.

SupplierBuyer	Date	IncomeQuantity	ExpensesQuantity
XXX	2013-01-01	158	0
xx1	2013-02-01	0	46
xx2	2013-03-05	0	46
xx3	2013-04-22	0	46
YYY	2013-05-01	100	0
YYY	2013-05-02	58	0
yy1	2013-06-01	0	53
yy2	2013-07-01	0	26
yy4	2013-08-10	0	27
yy5	2013-08-17	0	52
*		0	0

Fig.4. A set of data tables accounting in the first period (six months)

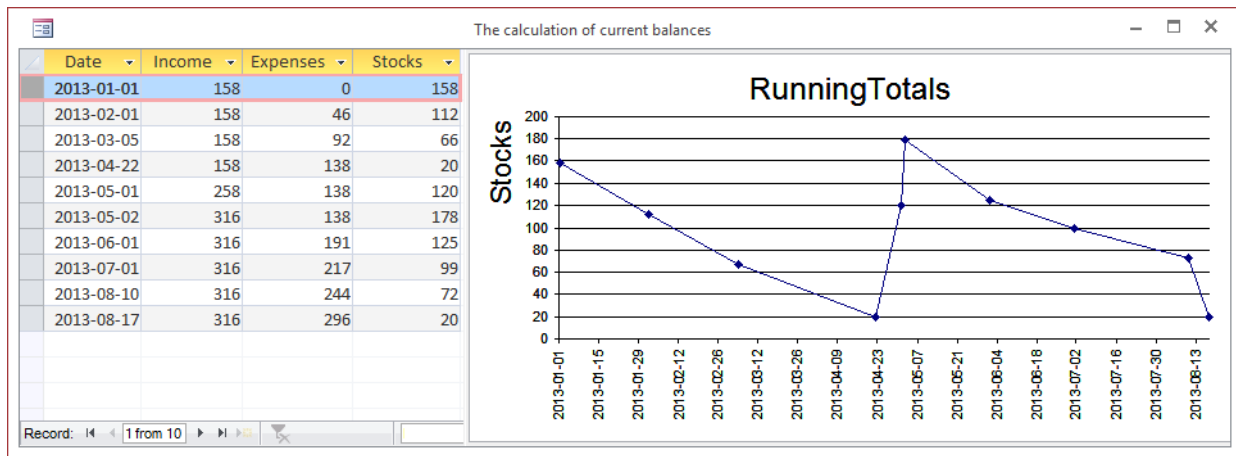


Fig.5. Current balances and the graph for the first period.

The graph shows, the current stocks correspond to the calculated: the supply - 158 units, uniform sales - for the period of 4 months, the stocks is 20 units on the eve of the second supply. Then the model reflects the supply 158 units (in 2 periods: 100+58). Last points of the graph show the situation of increasing of goods sales to a marginal stocks size of 20 units. This fact supports the decision about the new order. Taking into account the

dynamics of demand, a possible solution is to rise the size of the order (158+26).

The model of implementation of this order and further change in stocks up to the end of the year you can see in Fig. 6 and Fig.7.

The graph of inventory changes and dynamics of reserves is a good way to make decisions on adjusting the time and size of supply.

SupplierBuyer	Date	IncomeQuantity	ExpensesQuantity
XXX	2013-01-01	158	0
xx1	2013-02-01	0	46
xx2	2013-03-05	0	46
xx3	2013-04-22	0	46
YYY	2013-05-01	100	0
YYY	2013-05-02	58	0
yy1	2013-06-01	0	53
yy2	2013-07-01	0	26
yy4	2013-08-10	0	27
yy5	2013-08-17	0	52
ZZZ	2013-08-20	184	0
yy3	2013-09-08	0	26
zz1	2013-10-08	0	53
zz2	2013-11-17	0	53
zz3	2013-12-20	0	52
*		0	0

Fig.6. A set of data tables accounting for the year.

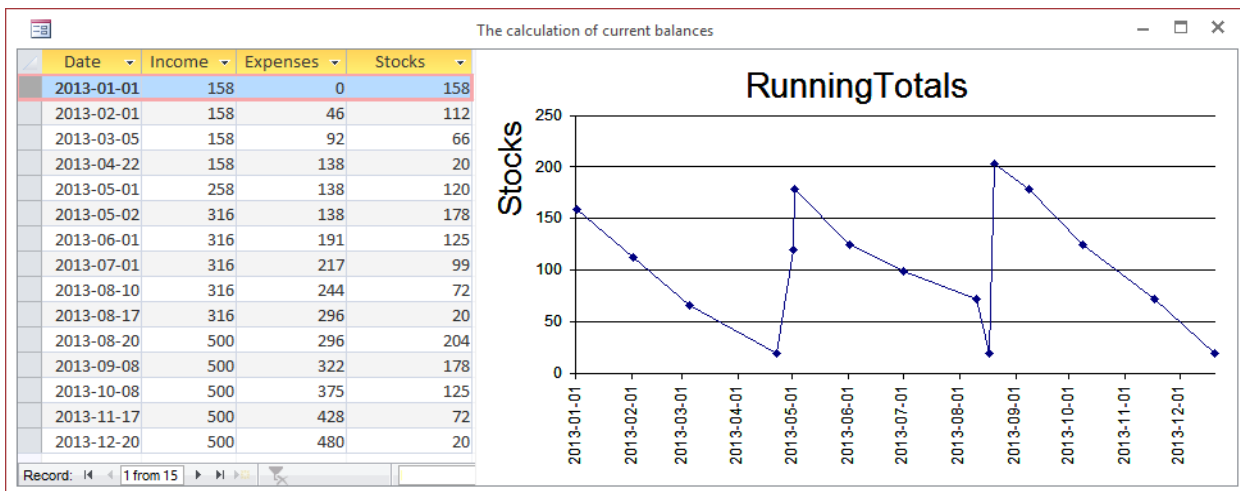


Fig.7. Current balances and the graph for the year.

As this example demonstrates, running totals are simply to create.

In addition, such approach improves the query processing. The speed of processing is raised, because the query RunningTotal contains operator INNER JOIN to join object GroupingOperations and its replica GroupingOperations\_1.

#### 4. Conclusion

The paper proposes a solution to the problem of accounting balances and the use of the decision support with simple tools. Also invited to the game-theoretic approach to multiobjective optimization when deciding how to allocate resources (reserve) between projects or departments within the company. The suggested queries, providing

registration of balances in real time, displaying the results in the form of graphics, which facilitate a decision on procurement. The considered example demonstrates full compliance of basic parameters between the characteristics of inventory management processes, described using mathematical models, and practical implementation of a process by means of databases. This proves the correctness of using this mathematical model in the inventory management tasks, within the limits of the subject area. The offered means of information systems invariant with respect to the mathematical methods, which is using in the planning of stocks management.



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