

Application of Database Technology to Improve the Efficiency of Inventory Management for Small Businesses

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Abstract: Full, accurate and evident information about stocks is a key factor of successful inventory management process. Effective inventory management should include a comprehensive solution, based on mathematical methods and control of current balances and software. Such solution for small businesses should be effective and should not be too expensive. The paper shows an approach to using database technology for solution of inventory management problems of small businesses with both single-product and multi-product inventory models.

Key-Words: inventory management tools, support decision-making, OLAP tools, economic order quantity model, single-product inventory model, multi-product inventory model, SQL-instructions.

1. Introduction

In business environment, users typically use data stored in databases to produce information that can help them make business decisions [1]. Today database is an important part of enterprise architecture model [2]. Database technology allows to use the functionality of economic-mathematical methods in the enterprise, such as the calculation of goods stocks [3, 4], estimation of the investment attractiveness enterprises [5]. It emphasizes importance of database technology in today's information systems of enterprises. Database technology has tools used to support management decisions by producing information for assessment, analysis, planning and control.

Efficient management at all levels with greatly improve efficiency of any company. The area of great importance is inventory management. Effective inventory management increases "frozen" in stocks asset's turnover. Due to effective inventory management (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. Today the problem of reducing the cost of small business is very relevant and considered in various fields by other researchers [6]. In this article we discuss about the tools of decision support systems based on mathematical methods and databases.

Inventory management tools (IMT) are important part of the company's management. IMT could be divided into 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, 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 sizes Online analytical processing (OLAP) are key technologies for enterprise decision support systems. They provide sophisticated technologies from 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 [7]. Most OLAP tools we 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 management system.

This article provides the tools of decision support systems based on mathematical methods and databases.

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

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 [8]. 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, i.e. 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 [9].

The concept of OLAP (On-Line Analytical Processing) was formulated by E. F. Codd in 1993 [10]. 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. However, OLAP application are quite expensive even for large enterprises, and require staff training. Therefore, use 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 [11]:

- 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 [12]. 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.

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 and 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 [13, 14].

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

Main points:

- Demand is known;
- Instant receipting of product;
- Discounts aren't considered;
- Deficit isn't admitted;
- Resources may be analyzed separately

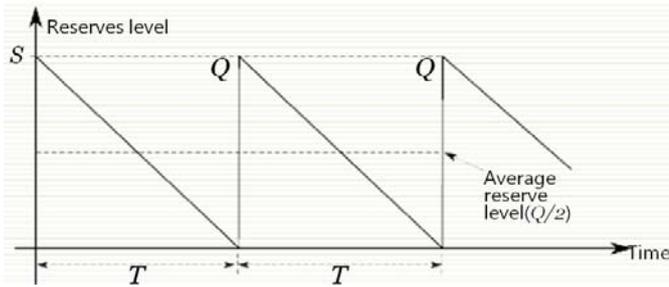


Fig. 1. Model of optimal order quantity

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

Total annual cost, rub/year:

D – average consumption of resource, unit/year;

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

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;

μ – intensity of resources consumption, unit/t;

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

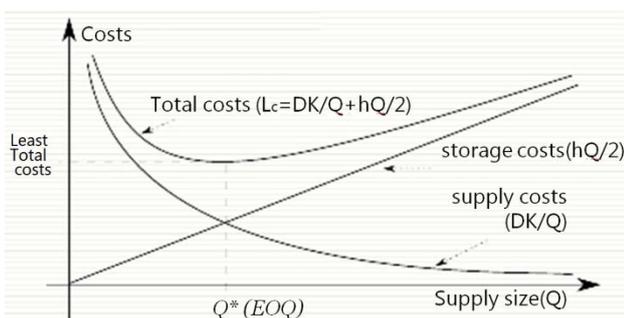


Fig.2. Economic order quantity model

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. [8].

3.2. 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 [15].

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 [16].

Inventory management software allow you to calculate the parameters: the size of supply, supply period, reorder point [7].

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 [17].

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.

3.3. 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 (Fig. 3):

$$Q^* = \sqrt{\frac{2K\mu \cdot \left(1 + \frac{h}{d}\right)}{h}}; \tag{5}$$

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

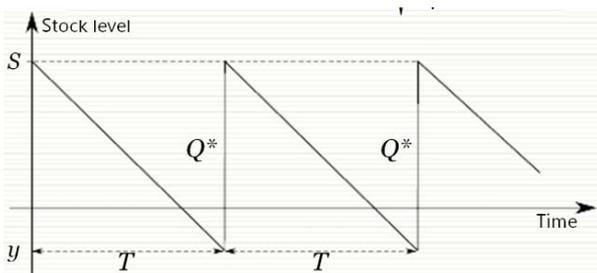


Fig.3. Static model with deterministic demand.

The optimum batch size

$$Q^* = \sqrt{\frac{2K\mu}{h}} = \sqrt{\frac{2 \cdot 10 \cdot 500}{0,4}} = 158,11 \approx 158 \text{ (unit)} \tag{7}$$

Annual costs are

$$L_c = K \frac{\mu}{Q^*} + h \frac{Q^*}{2} = 1000 \frac{500}{158} + 0,4 \frac{158}{2} = 6325 \text{ (rub/year)} \tag{8}$$

Delivery of each new order should be made through

$$T^* = \frac{Q^*}{\mu} = \frac{158}{500} = 0,316 \text{ (year)} \tag{9}$$

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

$$S_0 = \mu T_0 = \frac{500}{300} \cdot 12 = 20 \text{ (unit)} \tag{10}$$

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

3.4. Decision-making support system tools based on databases

3.4.1. Single-product inventory model

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 [18].

It is known solution, based on SQL-instruction using the WHERE clause [19].

The problem of representing data on current stocks propose to solve consistently using two SQL-instructions [21].

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:

$$S = \sum_{i=1}^n s_i = \sum_{i=1}^n (I_i - E_i) \quad (11)$$

s_i – current stocks;

I_i – current income;

E_i – current expenses.

In the Appendix 1, Fig. 1 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 the Appendix 1, Fig. 2.

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 the Appendix 1, Fig. 3 and Fig.4.

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

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

3.4.2. Multi-product inventory model

The proposed approach can be used for multi-product inventory model.

For example, we have three types of goods: monitors, notebooks and printers. We are selling these goods during the year. We want to have information about sales, current stocks, displaying the results in the form of graphics, which facilitate a decision on procurement. We use modified SQL-instructions to solve this problem. SQL-instructions will have the following form:

- 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 each goods:

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

Notice, SQL-instructions includes the data grouping by attribute "Goods".

- 2) The query RunningTotal calculates current stocks of each goods as progressive total:

```
SELECT GroupingOperations_1.Goods,
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) AND
(GroupingOperations.Goods=GroupingOperations_1.Goods)
GROUP BY GroupingOperations_1.Goods,
GroupingOperations.Date
ORDER BY GroupingOperations_1.Goods,
GroupingOperations.Date;
```

In the Appendix 1, Fig. 5 it presents the dataset reflecting the chronological flow accounting (income and expenditure) of many types of goods during the year.

The results of calculations of current stocks (balances) and the graph for the year shown in the Appendix 1, Fig. 6, Fig. 7.

In the Appendix 1, Fig.7 you can see an example of possibly interrelated sales and purchases of three goods: Printer, Notebook and Monitor. First of all goods are interrelated by the period of sales and purchases. We have for about the same volume of sales and purchases of three goods.

The following graphic (Appendix 1, Fig. 8) illustrates the qualitative ratio of the size of the current inventory for unrelated goods. The graph shows a possible association procurement and sales of printers and notebooks. Notice, sales of monitors differs from other goods both on the period of change of purchases, and on volumes of purchases.

We constructed the following query to create the chart in MS Access:

```
TRANSFORM Sum([Stocks]) AS
[Cymma_Stocks]
SELECT [Goods]
FROM [RunningTotals]
WHERE ([Date] BETWEEN #01/01/14
20:24:39# AND #12/31/14 20:24:39#) GROUP
BY [Goods] PIVOT[Date];
```

The query result is generated three-dimensional diagram of a theoretically unlimited number of products. As this example shows, the results of the running total inventory for multi-product model get just enough.

In addition, such approach improves the query processing. The speed of processing is raised, because the query RunningTotal contains INNER JOIN operation to join object GroupingOperations and its replica GroupingOperations_1. Stock calculation is carried out without using the WHERE clause. The proposed solution is the most effective due to the implementation of relationship with using the SQL JOIN operation. The SQL JOIN operation does not require processing conditions for each data rows.

4. Conclusion

The paper proposes a solution to the problem of accounting balances and the use of the decision support with simple tools. 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 both single-product and multi-product inventory models.

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Appendix 1

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. 1. Data set accounting in the first period (six months)

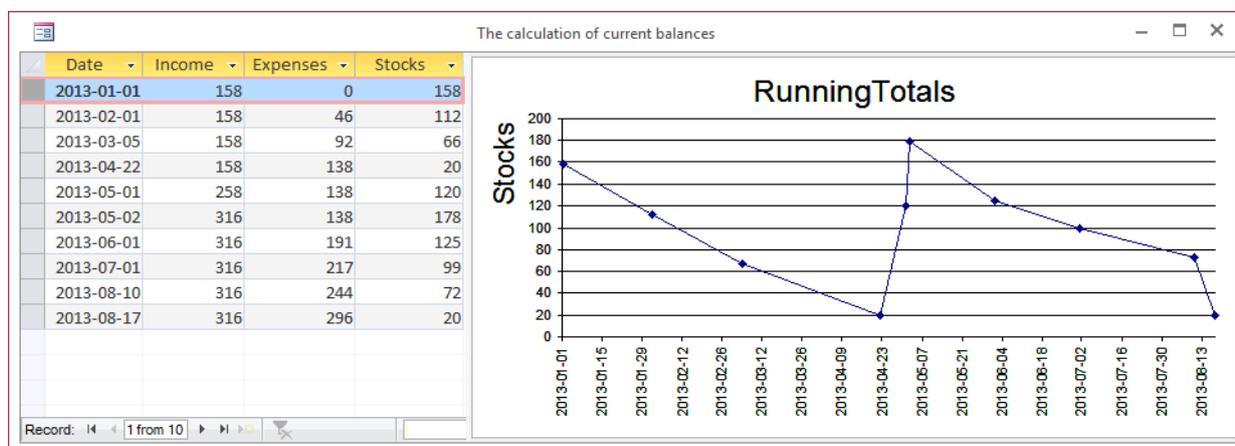


Fig. 2. Current balances and the graph for the first period.

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.3. Data set accounting for the year.

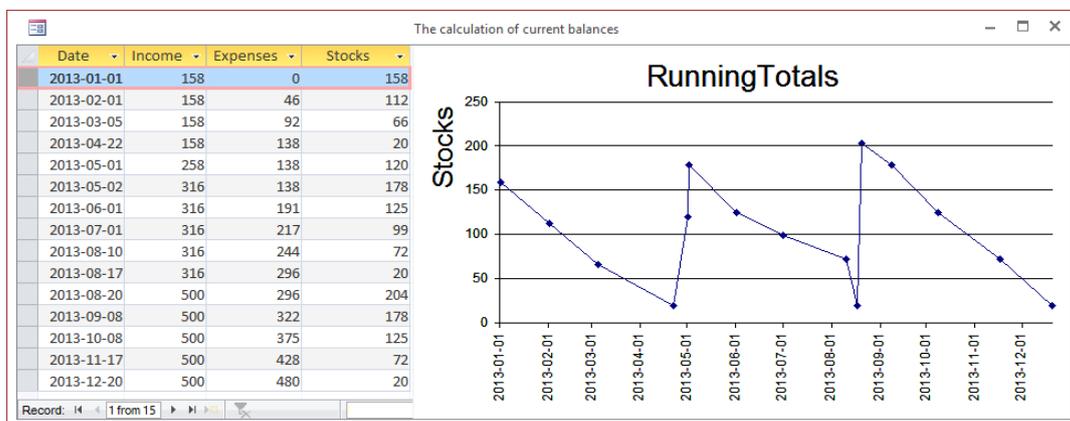


Fig.4. Current balances and the graph for the year.

SupplierBuyer	Goods	Date	IncomeQuantity	ExpensesQuantity
XXX	Notebook	2014-01-01	128	0
XXX	Monitor	2014-01-01	158	0
XXX	Printer	2014-01-01	188	0
xx1	Notebook	2014-02-01	0	36
xx1	Monitor	2014-02-01	0	46
xx1	Printer	2014-02-01	0	56
xx2	Notebook	2014-03-01	0	36
xx2	Monitor	2014-03-01	0	46
xx2	Printer	2014-03-01	0	56
xx3	Notebook	2014-03-30	0	36
xx3	Monitor	2014-03-30	0	46
xx3	Printer	2014-03-30	0	56
YYY	Notebook	2014-04-01	110	0
YYY	Printer	2014-04-01	145	0
YYY	Monitor	2014-04-01	100	0
YYY	Monitor	2014-04-02	58	0

Fig. 5. Chronological flow accounting (income and expenditure) of many types of goods for the year.

Goods	Month	In	Ex	Date
Monitor	1	158	0	2014-01-01
Monitor	2	0	46	2014-02-01
Monitor	3	0	46	2014-03-01
Monitor	3	0	46	2014-03-30
Monitor	4	100	0	2014-04-01
Monitor	4	58	0	2014-04-02
Monitor	5	0	53	2014-05-01
Monitor	6	0	53	2014-06-01
Monitor	7	0	26	2014-07-17
Monitor	7	0	26	2014-07-31
Monitor	8	158	0	2014-08-01
Monitor	9	0	53	2014-09-08
Monitor	10	0	53	2014-10-11
Monitor	11	0	52	2014-11-30
Notebook	1	128	0	2014-01-01
Notebook	2	0	36	2014-02-01
Notebook	3	0	36	2014-03-01

Fig. 6. Data set accounting for the year (multi-product model).

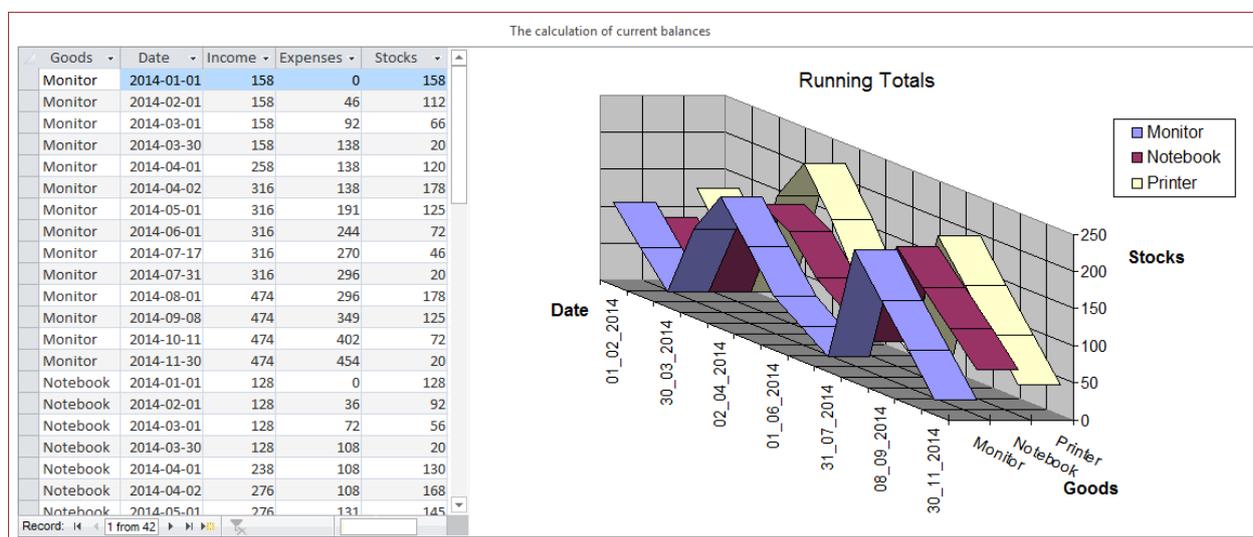


Fig. 7. Current balances and the graph for the year (multi-product model).

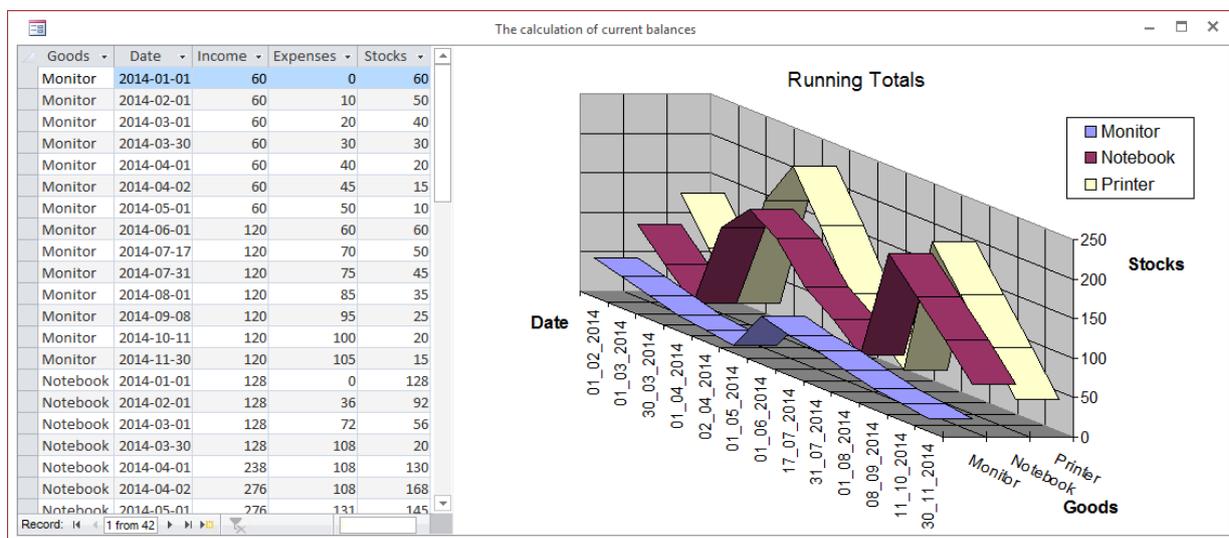


Fig.8. Current balances and the graph for the year (non-interrelated purchases and sales of goods).