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Financial Resource Allocation in Higher Education

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Abstract. The paper considers a problem of financial resource allocation in a higher education institution. The basic financial management instruments and the multi-stage cost minimization model created are described involving financial instruments to constraints. Both societal and institutional factors that determine the costs of educating students are examined and involved into the model, too. A financial flow planning model of an education institution (e.g., university) has been created, using two-stage or four-stage stochastic programming algorithms, with easily selected education institution's accounting data. The created model has been adapted to solve the two-stage and multi-stage financial flow optimization problem of the branch of university, and the obtained results of two-stage and multi-stage tasks have been compared. A mixed integer programming algorithm, realized in the model using CPLEX Studio 126 for optimization, can be flexibly adapted for practical needs of financial planning of education institutions.

Keywords: financial planning, financial management, two-stage stochastic programming, multi-stage stochastic programming, mixed integer optimization.

1. Introduction

All education institutions face financial flow planning problems, when they need to decide how to use the available options for planning revenues and expenses of a certain period. This problem is of special interest in countries, where legal environment makes possible to use some financial instruments for rational financial resource allocation (Hills and Mahoney, 1978; CHEPS. (2010); Lepori B. *et al.*, 2013; Raudla *et al.*, 2015). Note, many similar planning and decision-making tasks, especially in resource allocation, are associated with different types of data uncertainty. Therefore, stochastic programming methods are applied in solving these problems because efficient treatment of uncertainty problems. In deterministic linear programming the data are fixed, while in the stochastic linear programming these data are not known, but their probabilistic distribution or distribution function may be known (Birge and Louveaux, 2011; King and Wallace, 2012).

According to the new Education and Studies Law (*Lietuvos respublikos mokslo ir studijų įstatymas*, 2009) Lithuanian universities became public institutions and now they have more options in managing their finances, i.e. can plan their expenses by using various financial instruments. The Education and Studies Law, adopted in 2009, provided for changing the management of the higher public schools, i.e. adoption of new statutes, formation of councils and election of leaders. It also changed their legal status: budget universities and colleges became public institutions. This change allowed them to have an independent disposition of the purchased and state entrusted assets.

According to article 81 of this Education and Studies Law „Public higher education asset management, use and disposal of ownership", assets that higher education institutions can manage, use, and dispose on the right of ownership are:

- State invested assets.
- Income received as tuition fees, as well as income from economic, scientific activities and services.
- Funds and other assets, which are received as an aid under the Charity and Support Act.
- Other monetary resources, except for the state budget.
- From the state budget and from this part of the funds provided for in paragraphs 2–4 acquired assets other than real property, acquired by the European Union's support for the state budget and state funds.
- Gifts.
- Inherited property.
- Property rights arising from the results of intellectual activity (science or art works and industrial property right objects such as discovery patents, designs, trademarks and topographies of semiconductor products, and other intellectual property objects).
- Incomes, assets or other benefits obtained by managing the funds mentioned above or other assets, and having them at disposal.

The purpose of this paper is to examine the optimization problem of university financial flows by applying a multistage cost stochastic linear optimization method, taking into account the possibilities offered by the universities after becoming public entities.

All public education institutions have short period cash management problems (Pogue and Bussard, 1972; Covaleski *et al.*, 2003; Cambou and Filipović, 2014). Cash need usually arises because of lack of the synchronization between the cash income and costs (outflows) and because of difficulty to foresee their amounts. The main point of the cash management is to adapt a compound of institution assets and liabilities by minimizing the cash surplus/shortage in case of a beforehand set planning horizon. The cash balance problem is to determine liquid asset allocation to cash and short-term investment portfolio, which corresponds to a permanent stochastic income, costs, and other financial commitments. A two-stage stochastic linear programming model with simple recourse for the short-term financial planning, described in (Hansotia, 2006; Thiele *et al.*, 2010) is presented below.

2. Two-Stage Stochastic Linear Programming Model with Simple Recourse

Forecasted cash requirements, liquidation and termination costs of this model are all random variables the distribution of which is completely described by the absolutely continuous principle. The objective is to minimize funding costs of the use of different sources. The costs also include charges for violation of restrictions. The basic (SLPR) model is

$$\begin{aligned} &\min_{x\geq 0} Z(x) \equiv c'x + E_{\mathrm{x}}[\min_{y^+,y^-\geq 0}(q^{+}{}'y^{+} + q^{-}{}'y^{-})],\ s.t.\\ &Ax = b,\\ &Tx + Iy^{+} - Iy^{-} = \xi \end{aligned} \tag{1}$$

where
I – is the identity matrix,
ξ – is a random variable (distributed independently of x) in the probabilistic space (Ξ,F,F),
$A\ is\ m_1 \times n,\ T\ is\ m_2 \times n,\ I\ is\ m_2 \times 1,\ \xi\ is\ m_2 \times 1,\ c,x \in R^n;$
$y^+, y^-, q^+, q^- \in R^{m_2}.$

SLPR model can be interpreted as a two-stage model: firstly, we choose a decision vector x, secondly, we review the random vector ξ and then we make the corrective action (y^+, y^-). It is said that the model has a simple recourse, because the second stage minimization is fictitious, as far as (y^+, y^-) are effectively unique function of (x, ξ) (Hansotia, 2006; Thiele *et al.*, 2010).

The model described above has been applied in the development of the financial flow planning model of education institutions. Next, we describe the financial instruments that are used in the model.

3. Financial Instruments

We use the following financial instruments for satisfying financial needs of education: a line of credit, factoring, stretching of accounts payable, term loan, and securities.

The following formulation refers to a "typical" short-term financial planning model based on Pogue and Bussard (Pogue and Bussard, 1972). The funds are received or paid at the beginning of the period. Let x_i denote the amount obtained from financing option i. AP_j / AR_j are accounts payable/receivable at the planning moment j = 0, 1, 2.

a. Line of Credit

The firm has the ability to obtain credit from a commercial bank, which makes it possible to borrow up to β_1 with a 9% annual interest rate (for the amount used). In addition, the firm must pay the fixed 0.7% interest of the unused line of credit sum for providing the service. Thus, the upper bound for the Line of credit is β_1:

$$x_1 \le \beta_1. \tag{2}$$

b. Factoring (Pledging of Accounts Receivable)

The company can borrow by pledge its accounts receivable (the amount that customers owe the company) as collateral for bank loans. The maximum possible amount outstanding, using this option, is β_2. The bank will lend up to 90% of the nominal price of the pledged receivable arrears. Loan costs through this alternative are 8% per annum on the average amount of outstanding loans during the period.

$$x_2 \le 0.9AR_0. \tag{3}$$

c. Stretching of Accounts Payable

The funds may also be obtained by stretching (i.e. delaying) the payments of the firm account payables AP_0 (up to 80%) during a period. The operational costs are 27% per annum.

$$x_3 \le 0.8AP_0. \tag{4}$$

d. Term Loan

Firms may get a fixed-term loan to a maximum of β_{4v} at the beginning of the initial period. The minimum loan amount is β_{4a}. For a fixed-term loan the payment is with a 10% interest rate per annum.

$$\text{Thus, } \beta_{4a} \le x_4 \le \beta_{4v}. \tag{5}$$

e. Constraints on Financing Combinations

The fixed-term loan acquisition limits the amount of the credit line:

$$x_1 + x_4 \le \beta_{41},\ x_2 + x_4 \le \beta_{42} \tag{6}$$

f. Long Term Assets

It is possible to purchase securities *x5* with a random interest rate under the normal law.

g. Sources and Uses

The income from all resources must be equal to the amount of expenditures. Cash surplus is used to purchase securities x5 with a random interest rate, distributed according to the normal law:

$$x_1 + x_2 + x_3 + x_4 - x_5 - x_6 = AP_i - AR_i \tag{7}$$

h. Stochastic Cash Requirements

Receivables and payables at the end of the period are also stochastic variables in a certain interval.

i. Objective function

The objective is to minimize costs of the various sources of funds employed plus the expected penalty costs due to balance violations: $min_x F(x) = c * x + E_\xi (q^+ y^+ + q^- y^-)$, on constraints (2–7).

When solving this problem, we need neither surplus (cash freezing) nor shortage (high borrowing costs).

4. Financial Data of the University

We consider the revenue-expenditure balance and the planning model of the Siauliai University financial activity in 2007–2010 as an example.

Siauliai University is the largest institution of higher education in Northern Lithuania, established in 1997. At the moment of research this university consisted of 6 faculties and 2 institutes, where you can choose a permanent or long-form study programs. The programs are proposed from 6 fields of studies: biomedical, physical, humanitarian, social, technological, sciences and arts. Siauliai University performs not only bachelor's, master, and doctoral studies, but also continuous education, non-formal public education programs, additional studies, programs for college graduates who intend to became postgraduate student. Also, applicants have the opportunity to choose a joint-degree programs with the Lithuanian and foreign institutions of higher education, programs with the adjacent studies, leading to a double degree. The university successfully participates in the city, national and international projects, carries out the academic staff and student exchanges. It has close relations with regional and national companies, and business partners. The number of Siauliai University graduates (since 1998) exceeds 33 000.

Fig. 1 shows a chart of the Siauliai University income distribution. Siauliai University income consists of: the state budget appropriations, the targeted state budget, special incomes, and EU structural funds. From the chart we can see that most of the incomes consists of state budget appropriations, that is about 50.2% of total revenue. Special incomes, which mainly consists of the tuition fee, makes up 35.6% of total revenue.

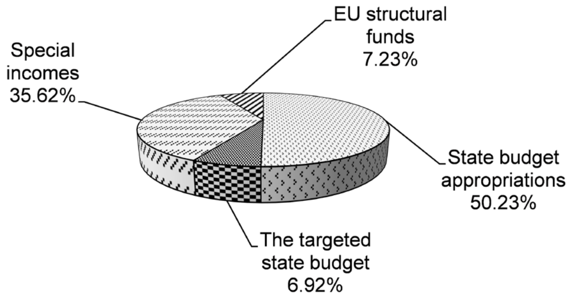

Fig. 1. Chart of Siauliai University income distribution in 2007–2009.

Table 1

Revenue structure of Siauliai University in 2007–2009 (thousands of LTL)

Revenue structure	2007 year	2008 year	2009 year
1. State budget appropriations	**27687.0**	**32978.2**	**31011.0**
1.1. Ordinary funds	21636.0	27978.2	26573
1.2. Contingency funds	927.0		
1.3. Scholarships	5124.0	5000	**4438.0**
2. Targeted state budget	**5452.3**	**5148.8**	**2026.1**
2.1. State Science and Study Fund	12.0	14	39
2.2 State education program	2307.7	2296.3	456
2.3. Revenue for building renovation		754	503
2.4. Compensation of student contributions			5.7
2.5. International programs	1649.2	1559	760
2.6. Sponsored material support	35.5	62.6	80.3
2.7. Other target budgetary funds	1447.9	462.9	182.1
3. Special incomes	**20850.4**	**20849.5**	**23309.1**
3.1. Customers' funds for scientific research	520.9	496.2	153.7
3.2. Tuition fee	17337.5	17784.5	20225.8
3.3. Refresher Courses	494.2	406.8	284.3
3.4. Economic and other activities	2497.8	2162	2645.4
4. EU structural funds	**7741.9**	5333.7	115.0
Total:	**61731.6**	**64310.2**	**56461.2**

The Siauliai University revenue structure is presented in Table 1.

Calculations were performed using income and expenditure data of the Siauliai University Mathematics and Informatics (MII) faculty, presented in Tables 2 and 3. SU MII debt at the beginning of the period: –378028, common university deductions: –303119.1204.

Appropriations for scholarships: 232494.5.

Balance 2010: –288524.99.

Calculation criteria of Siauliai University budget appropriations were described in Order No. V-524 approved by rector on December 16, 2015. The order describes the

Table 2

Revenue and expenditure data of Siauliai University Faculty of TIF in 2009 (by quarters)

Incomes	I quarter	II quarter	III quarter	IV quarter	Total
Tuition Fee	249422.2	83043.5	112246	192355	637066.7
The fee for the exam retake	12481	6864	3432		22777
Appropriations by program 1.1	317245.3	354568.3	597167.6	597167.6	1866148.8
Total incomes	**579148.5**	**444475.8**	**712845.6**	**789522.6**	**2525992.5**
Wages	383098.7	447020.5	280698	292754.4	1403571.5
Social insurance	119546.3	138470.2	86979.53	91459.86	436455.85
Heating	23851.03	666.68	0	10851.16	35368.87
Electricity	13650.73	11960.34	9726.8	12764.39	48102.26
Communication services	1082	976.12	770.44	942	3770.56
Water supply	1567.21	1346.35	1699.92	1719.57	6333.05
Transport	1537.47	938.19	270.2	278.96	3024.82
Duty journey	457.3	4617.73	2120.63	437.73	7633.39
Rental of fixed assets, repairs, acquisition.	8370.34	14770.1	69076.35	8511.02	100727.81
Prints	428	907.75	266.28	1882.06	3484.09
Other services	21561.64	3196.6	9490.02	20362.48	54610.74
Other products	14642.57	3030.23	1953.07	10661.6	30287.47
Total costs	**589793.3**	**627900.7**	**463051.2**	**452625.2**	**2133370.37**
The difference between incomes and expenses	**–10644.8**	**–183425**	**249794.4**	**336897.4**	**392622.13**

Table 3

Scholarships by quarters

	I quarter	II quarter	III quarter	IV quarter	Total
Scholarships	55927	72637.5	37245	66685	**232494.5**

allocation criteria applied: wages, social security contributions and contributions to the guaranty fund, heating, electricity, communications, transport maintenance, print, goods, missions, water and sewerage, the long-term tangible property lease, plant and equipment assets for current repair, in-service training, acquisition of fixed assets, grants and other services.

According to the financial data of Siauliai University two models have been developed: multi-stage (four) and two-stage. Semi-annual data of the two-stage model have been obtained by summing up the data of the respective quarters. The details of the four-stage financial flow management model are given below.

5. Details of the Model

The four-stage financial flow management model has been created. The financial instruments a line of credit, factoring, stretching of accounts payable, term loan, and securities has been used in the model.

Details of a four-step model:

$ks1$, $ks2$, $ks3$, $ks4$ – the number of variables in the first, second, third, and fourth stages,

$ns1$, $ns2$, $ns3$, $ns4$ – the number of constraints in the first, second, third, and fourth stages,

AP_j / AR_j – amount of payables/receivables at the j planning moment, j = 0, 1, 2, 3, 4,

x_{2j} – line of credit at the j planning moment, j = 0, 1, 2, 3, 4,

x_{2j} – factoring at the j planning moment, j = 0, 1, 2, 3, 4,

x_{3j} – stretching of accounts payable at the j planning moment, j = 0, 1, 2, 3, 4,

x_{4j} – term loan at the j planning moment, j = 0, 1, 2, 3, 4,

x_{5j} – securities at the j planning moment, j = 0, 1, 2, 3, 4,

LR – liquidity reserve, L_l – liquidity reserves from the line of credit,

x_{6j}^{+} / x_{6j}^{-} – surpluses/shortages at the j planning moment, j = 0, 1, 2, 3, 4,

y_i – indicates whether to use of factoring or not, y_i = 1, 2, 3, 4,

$r11$, $r12$, $r3$, $r4$, $r5$, $r6$, $r7$ – costs rates of financial instruments used;

rv – percentage of potential investment funds,

β_1 , β_{4v} , β_{41} , β_{42} – upper bounds on combinations of financing instruments.

For model details see section 3. Four-stage model constraints are shown in Table 4.

Initial balance:

$$x_{11} + x_{21} + x_{31} + x_4 - x_{51} + x_{60}^{-} - x_{60}^{+} - [\, r_6 \cdot x_{60}^{-} \,] = AP_0$$

First stage balance:

$$x_{12} + x_{22} + x_{32} - x_{52} - x_{60}^{-} + x_{60}^{+} + x_{61}^{-} - x_{61}^{+} - [\, r_{12} \cdot x_{11} + r_{11} \cdot L_1 + r_2 \cdot x_{21} + r_3 \cdot x_{31} + + r_4 \cdot x_4 - r_5 \cdot x_{51} + r_6 \cdot x_{61}^{-} \,] = AP_1$$

Second stage balance:

$$x_{13} + x_{23} + x_{33} - x_{53} - x_{61}^{-} + x_{61}^{+} + x_{62}^{-} - x_{62}^{+} - [\, r_{12} \cdot (x_{11} + x_{12}) + r_{11} \cdot (L_1 - x_{12}) + + r_2\,(x_{21} + x_{22}) + r_3 \cdot (x_{31} + x_{32}) + r_4 \cdot x_4 - r_5 \cdot (x_{51} + x_{52}) + r_6 \cdot x_{62}^{-} \,] = AP_2$$

Table 4

A four-stage model constraints

I stage constraints	II stage constraints	III stage Constraints	IV stage constraints
$x_{11} + L_1 \le \beta_1$	$x_{12} - L_1 \le 0$	$x_{12} + x_{13} - L_1 \le 0$	$x_{12} + x_{13} + x_{14} - L_1 \le 0$
$x_{21} \le 0.9 \cdot AR_0 \cdot y_1$	$x_{22} \le 0.9 \cdot AR_1 \cdot y_2$	$x_{23} \le 0.9 \cdot AR_2 \cdot y_3$	$x_{24} \le 0.9 \cdot AR_3 \cdot y_4$
$x_{31} \le 0.8 \cdot AP_0$	$x_{32} \le 0.8 \cdot AP_1$	$x_{33} \le 0.8 \cdot AP_2$	$x_{34} \le 0.8 \cdot AP_3$
$x_4 \le \beta_{4v}$	$x_{52} \le x_{61}^{+} \cdot rv$	$x_{53} \le x_{62}^{+} \cdot rv$	$x_{54} \le x_{63}^{+} \cdot rv$
$x_{51} \le x_{60}^{+} \cdot rv$	$x_{51} + x_{52} + L_1 \ge LR$	$x_{51} + x_{52} + x_{53} + L_1 \ge LR$	$x_{51} + x_{52} + x_{53} + x_{54} + L_1 \ge LR$
$x_{51} + L_1 \ge LR$	$x_{11} + x_{12} + x_4 \le \beta_{41}$	$x_{11} + x_{12} + x_{13} + x_4 \le \beta_{41}$	$x_{11} + x_{12} + x_{13} + x_{14} + x_4 \le \beta_{41}$
$x_{11} + x_4 \le \beta_{41}$	$x_{21} + x_{22} + x_4 \le \beta_{42}$	$x_{21} + x_{22} + x_{23} + x_4 \le \beta_{42}$	$x_{21} + x_{22} + x_{23} + x_{24} + x_4 \le \beta_{42}$
$x_{21} + x_4 \le \beta_{42}$			

Third stage balance:

$$x_{14} + x_{24} + x_{34} - x_{54} - x_{62}^{-} + x_{62}^{+} + x_{63}^{-} - x_{63}^{+} - [\, r_{12} \cdot (x_{11} + x_{12} + x_{13}) + r_{11} \cdot (L_1 - x_{12} - x_{13}) + r_2\,(x_{21} + x_{22} + x_{23}) + r_3 \cdot (x_{31} + x_{32} + x_{33}) + r_4 \cdot x_4 - r_5 \cdot (x_{51} + x_{52} + x_{53}) + r_6 \cdot x_{63}^{-}\,] = AP_3$$

Fourth stage balance:

$$-x_{11} - x_{12} - x_{13} - x_{14} - x_{21} - x_{22} - x_{23} - x_{24} - x_{31} - x_{32} - x_{33} - x_{34} - x_4 + x_{51} + x_{52} + x_{53} + x_{54} + x_{63}^{+} - x_{63}^{-} + x_{64}^{-} - x_{64}^{+} - [\, r_{12} \cdot (x_{11} + x_{12} + x_{13} + x_{14}) + r_{11} \cdot (L_1 - x_{12} - x_{13} - x_{14}) + r_2\,(x_{21} + x_{22} + x_{23} + x_{24}) + r_3 \cdot (x_{31} + x_{32} + x_{33} + x_{34}) + r_4 \cdot x_4 - r_5 \cdot (x_{51} + x_{52} + x_{53} + x_{54}) + r_6 \cdot x_{64}^{-} + r_6 \cdot x_{64}^{+}] = AP_4 - AR_4$$

The objective function includes all option costs:

$$F(x) = r_6 \cdot x_{60}^{-} + r_{12} \cdot x_{11} + r_{11} \cdot L_1 + r_2 \cdot x_{21} + r_3 \cdot x_{31} + r_4 \cdot x_4 - r_5 \cdot x_{51} + r_6 \cdot x_{61}^{-} + r_{12} \cdot (x_{11} + x_{12}) + + r_{11} \cdot (L_1 - x_{12}) + r_2\,(x_{21} + x_{22}) + r_3 \cdot (x_{31} + x_{32}) + r_4 \cdot x_4 - r_5 \cdot (x_{51} + x_{52}) + r_6 \cdot x_{62}^{-} + r_{12} \cdot (x_{11} + x_{12} + x_{13}) + r_{11} \cdot (L_1 - x_{12} - x_{13}) + r_2\,(x_{21} + x_{22} + x_{23}) + r_3 \cdot (x_{31} + x_{32} + x_{33}) + r_4 \cdot x_4 - r_5 \cdot (x_{51} + x_{52} + x_{53}) + r_6 \cdot x_{63}^{-} + [r_{12} \cdot (x_{11} + x_{12} + x_{13} + x_{14}) + r_{11} \cdot (L_1 - x_{12} - x_{13} - x_{14}) + r_2\,(x_{21} + x_{22} + x_{23} + x_{24}) + r_3 \cdot (x_{31} + x_{32} + x_{33} + x_{34}) + r_4 \cdot x_4 - r_5 \cdot (x_{51} + x_{52} + x_{53} + x_{54}) + r_6 \cdot x_{64}^{-} + r_6 \cdot x_{64}^{+}$$

At every stage, the variable y_i determines whether the financial instrument of factoring will be used or not. The above model is intended for solving the four-stage task if MII-quarter financial data are used. Two-stage model constraints and balances are similar, and can be easily obtained from the four-stage model.

6. Calculation Results

The calculations were carried out by computer, the parameters of which are: the Intel (R) Core (TM) i7-4500U CPU @ 1.80 GHz and 2.4 GHz, 8.00GB, x64-based processor. The program is implemented in the Microsoft Visual Studio 2010 C ++ language, using the IBM ILOG CPLEX optimization package. The two-stage model has 31 variables and 18 restrictions. The four-stage model has 57 variables and 34 restrictions. Up to 10 scenarios in each stage can be generated. Table 5 provides the cost rates used in the model. Changes in cost rates can easily simulate different financial situations.

The objective function values of two-stage and four-stage optimal solutions of the models, and the numbers of variables and constraints of models are shown in Table 6.

Two-stage and four-stage optimal solutions are shown in Table 7. The four-step model renders more possibilities in choosing the financial instruments and allows a greater flexibility in the management of financial flows.

Table 5

Interest rates

r11	r12	r2	r3	r4	r5	r6	r7
0.007	0.09	0.08	0.12	0.1	0.06	0.22	0.02

Table 6

Calculation results

Model	Variables	Constraints	Objective
Two-stage	31	18	283.161,62
Four-stage	57	34	275.079,10

Table 7

Comparison of four-stage and two-stage optimal solutions

Four-stage		Two-stage	
1. Line of Credit			
I stage	140000	I stage	140000
II stage	10000	II stage	0
III stage	0		
IV stage	0		
2. Factoring			
I stage	0	I stage	0
II stage	443048.603	II stage	783072.59
III stage	340023.987		
IV stage	171927.411		
3. Stretching of Accounts Payable			
I stage	271147.12	I stage	261147.12
II stage	66327.62	II stage	303010.87
III stage	221694.20		
IV stage	262269.95		
4. Term Loan			
I stage	270000	I stage	280000
5. Securities			
I stage	0	I stage	0
II stage	0	II stage	0
III stage	0		
IV stage	0		
6. Shortages			
I stage	0	I stage	0
II stage	0	II stage	0
III stage	0		630537.46
IV stage	0		
	622454.93		
7. Surpluses			
I stage	0	I stage	0
II stage	0	II stage	0
III stage	0		
IV stage	0		

As we can see from the results of the four-stage model, the objective function value is 8082.53 lower than that in the two-stage model, i.e. using a four-stage model after one year lower shortages are obtained than using a two-stage model.

7. Conclusions

With easily selected education institution's accounting data, it is possible to create a financial flow planning model of an education institution (e.g., university), using two-stage or four-stage stochastic programming algorithms. Although the universities have become public institutions, the financial management is a topical problem, since this topic has not been examined in the scientific literature. Comparison of the different financial instruments options allows us to reduce the costs of financial instruments, to ensure the liquidity and optimal planning of cash flows. A line of credit, factoring, stretching of account payables, securities, and term loan financial instruments can be applied to the financial management of education institutions. The created model makes it easy to examine various financial environment scenarios, changing interest rates of financial instruments. Depending on the financial situation different financial instruments can be used. A four-stage model renders more flexibility in the management of financial tools.

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