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A method of determining risk zones of investment in real estate

by

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Abstract: In the real estate sector, especially in construction or purchasing of commercial buildings, adequate evaluation of market development and property management is of paramount importance. In this paper, application of mathematical modelling to evaluating the efficiency and risk of investment projects is discussed. Most of the microeconomic models are discrete, implying that the initial data and the results obtained are discrete values. In the suggested model, the most likely variability intervals of the parameters are taken as the basis of modelling. The models suggested in the present paper deal with local investment problems, which should be promptly solved in the presence of a great number of alternative investment possibilities. The modelling is aimed at determining zones related to the quality of decisions in the area of investment. The principles of mathematical modelling and determination of various financial risk zones are described. An example of determination of risk zones of investments in Vilnius are presented.

Keywords: mathematical modelling, investment efficiency in construction, investment projects.

1. Introduction

In the real estate sector, especially in construction or purchasing of commercial buildings, adequate evaluation of market development and property management is of paramount importance. To ensure the reliability of the investment projects, which is closely associated with the appropriate research into the problems of market and property management and processing of the data obtained, it is necessary to define a set of criteria for the appropriate building selection. A comprehensive analysis of reliable market data is the most important factor for developing the construction investment projects (Tarasevich, 2000; Ustinovičius and Stasiulionis, 2001) as well as for selecting a property management project and the appropriate processing of attributes by various mathematical models.

The method of simulation is widely used in solving the problems of strategic planning (Mosmans et al., 2002) and financing of large industrial companies (Guerard and Stone, 1987; Dhrymes and Kurz, 1967; Ginevicius and Cirba, 2003; Damon and Schramm, 1972; McCabe, 1979; Peterson and Benesh, 1983; Rutkauskas, 2000, 2001; Hamilton and Moses, 1983; Burton et al., 1979; Larichev et al., 2003), as well as in organizing the work of small corporations (Kim et al., 2002; Sinha and Chandrashekaran, 1992; Sutcliffe, 1996), and developing strategies for construction management and planning (Larichev et al., 2003, Skitmore and Ng, 2001; Ng et al., 2001; Nowak, 2005; Ustinovichius and Stasiulionis, 2001). The method considered is also applied to simulation of building processes (Alkoc and Erbatur, 1997; Cheng and O'Connor, 1993; Huang and Halpin, 1993; Moselhi and Hanson, 1994; Senior, 1995; Shi and AbouRizk, 1997; Vanegas and Opdenbosch, 1994; Vaidogas, 1998) and developing financial solutions by construction firms (Lam and Runesos, 1998; Zavadskas et al., 2002, 2003, 2004a,b). In each case it is necessary to analyse the initial data (Olinsky et al., 2003; Jenkins and Anderson, 2003).

The state of macroeconomics in the country also has an indirect impact on real estate market, meaning that the individuals and firms engaged in real estate business experience its effects (Prorvich, 1998; Vaidogas, 1998). The economic situation and the legislative basis determine their activities in this area. The better the macroeconomic indices, the better the situation in real estate market.

In addition to global investment problems, there is always a need to solve local investment problems associated with urban and regional development. In this case, decisions about investment profitability should be made quickly in the presence of a large number of alternative investment projects.

The models suggested in the present paper are aimed at solving local investment problems and may complement classical methods extensively used in practice, i.e. NPV, IRR, time value of money, etc. (Cuthbertson and Nitzsche, 2001). An investor will make her/his decision to purchase a real estate in Vilnius, the capital city of Lithuania, by calculating NPV, IRR and comparing the results with alternative investment opportunities in, for example, Riga, Tallinn, Helsinki, or Warsaw. In this case, relatively small local investment projects of a particular country are considered. The method can be of interest to real estate owners (private or municipal). It can also diversify an offer to investor, or make a part of a selling strategy.

Actually, a new mathematical model should be constructed for any particular case. In very few cases, application of a model in a particular scientific field or area of practical activities may be extended to other areas without making essential changes. Most of the economic models are discrete, implying that the initial data and the results obtained are discrete values. In the suggested model, the most probable variability intervals of the parameters are taken as the basis of modelling. The application of this approach was demonstrated by Lee and Tanaka (1999). Modelling is aimed at determining zones relating to the quality of decisions in the area of real estate investment.

In this paper, application of mathematical modelling to evaluating profitability and risk of investment projects is discussed.

2. A method of determining risk zones of investments

Mathematical modelling can be used for determining profitability of investment projects (Ustinovichius and Podvezko, 2003; Ustinovichius, 2004). A quantitative method for evaluating profitability of investment in the commercial building purchase, repair and sale is specified below. In developing this method much attention is paid to the accuracy of the initial data and investment risk analysis. Notations: k – grade (category) of a building; $1 \leqslant k \leqslant q (k \in N)$, q – total number of various grades of premises (categories); $P(k)$ – building selling price; $P_{\min}(k)$, $P_{\max}(k)$ – minimum and maximum price; $R_{\min}(k)$, $R_{\max}(k)$ – minimum and maximum repair cost (the initial purchase cost included); $\overline{P}(k)$, $\overline{R}(k)$ – average prices, respectively.

Based on the statistical data $P_{\min}(k)$, $P_{\max}(k)$, $R_{\min}(k)$, $R_{\max}(k)$, where $k = k_{\min}, k_{\min}+1, \ldots, k_{\max}$, interpolation polynomials of $n = k_{\max} - k_{\min}$ degree are obtained, which are written as $a_n k^n + a_{n-1}k^{n-1} + \ldots + a_1 k + a_0$ for $P_{\min}(k)$, $P_{\max}(k)$, $\overline{P}(k)$, $\overline{R}(k)$, $R_{\min}(k)$, $R_{\max}(k)$, where variable k is changing continuously, rather than discretely: $k_{\min} \leqslant k \leqslant k_{\max}$. This set is denoted $\boldsymbol{K}$. All functions given above are usually increasing functions of the argument k.

Determining the zones of various investment risk exposure. Risk zones may be defined as riskless, standard risk, high risk zones and unprofitable zones. Their detailed analysis is given below.

2.1. Riskless zone of investment

This is an area where the minimum selling price of premises $P_{\min}(k)$ is higher than the maximum price of a repaired building $R_{\max}(k)$ (initial purchase price included), i.e. a set K_+ of values k satisfying the inequality: $P_{\min}(k) - R_{\max}(k) > 0$. This set may be either empty $\emptyset$ or represent a set of separate intervals of $k \in [k_{\min}, k_{\max}]$.

Algorithm for determining the riskless zone K_+. The algorithm considered is represented as a series of steps:

1. The real roots (if any) $k_1 < k_2 < \ldots < k_l$ $(l \leqslant n)$ belonging to the interval $[k_{\min}, k_{\max}] : k_i \in [k_{\min}, k_{\max}]$ $(i = 1, \ldots, l)$ are found for the polynomial equation $P_{\min}(k) - R_{\max}(k) = 0$.

2. For all the intervals $(k_{\min}, k_1)$, (k_1, k_2), …, $(k_l, k_{\max})$ the signs of the difference $P_{\min}(k) - R_{\max}(k)$ are determined. To assess the behaviour of the function $P_{\min}(k) - R_{\max}(k)$, it is sufficient to find the sign, i.e. to determine the value at the end points of each interval.
3. The intervals with a positive difference $P_{\min}(k) - R_{\max}(k)$ (if existing) are selected from the intervals obtained. They form the set K_+.

If a set K_+ matches the interval $[k_{\min}, k_{\max}]$, then the whole interval $k_{\min} \leqslant k \leqslant k_{\max}$ is a riskless investment zone. In this case, no other zones are sought.

In Fig. 1 cases in determining the particular riskless zones are graphically illustrated.

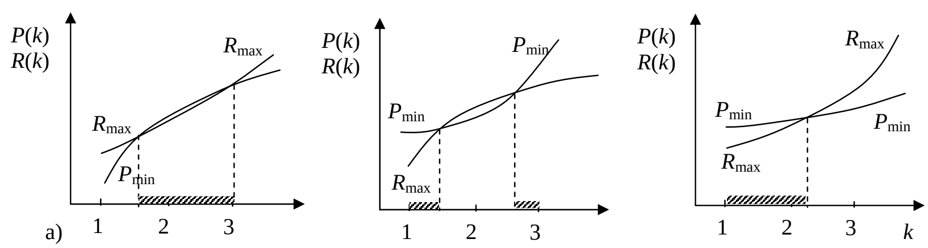


Figure 1. Determining the riskless zones

2.2. Standard risk zone of investment $K_=$

This is the zone, where an average selling price $\overline{P}(k)$ is higher than an average repair price $\overline{R}(k)$ (initial purchase cost included), except for riskless investment zone $K_+ : K_= = \overline{K} \backslash K_+$.

Determination of the standard risk zone is shown in Fig. 2.

Algorithm for determining zone $K_=$ consists of the following steps:

1. Real roots (if any) $\overline{k}_1 < \overline{k}_2 < \ldots < \overline{k}_m$ $(m \leqslant n)$ of the polynomial $\overline{P}(k) - \overline{R}(k) = 0$ in the interval $[k_{\min}, k_{\max}] : \overline{k}_j \in [k_{\min}, k_{\max}]$ $(j = 1, \ldots, m)$ are determined.
2. In all the intervals $(k_{\min}, \overline{k}_1)$, $(\overline{k}_1, \overline{k}_2)$, …, $(\overline{k}_m, k_{\max})$ the differential signs of $\overline{P}(k) - \overline{R}(k)$ are determined, i.e. the different signs in at least one point of every interval are found.
3. The intervals with a positive $\overline{P}(k) - \overline{R}(k)$ difference are chosen from the intervals obtained. This is zone $\overline{K}$.
4. The intersections of the intervals found with the zone K_+ are singled out from zone $\overline{K}$ intervals, i.e. $K_= = \overline{K} \backslash K_+$ is found (Fig. 2).

If zone $\overline{K}$ matches all the intervals $k_{\min} \leqslant k \leqslant k_{\max}$, then the search for investment zones is over.

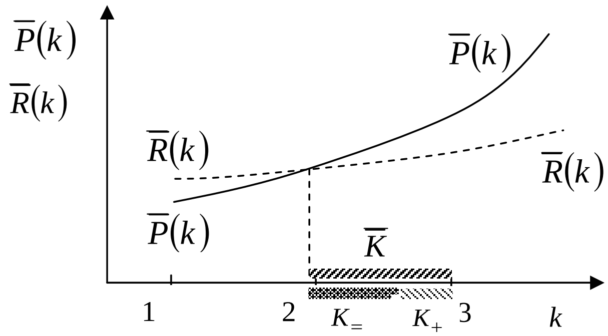


Figure 2. Standard risk investment zone

2.3. High risk investment zone K_0 and unprofitable zone K_-

These two zones may be defined simultaneously, or K_0 may be determined after K_-.

Zone of unprofitable investment K_- (if any) is a zone where the maximum selling price of premises $P_{\max}(k)$ is lower than the minimum repair cost (the initial purchase price included) $R_{\min}$ (see Fig. 3).

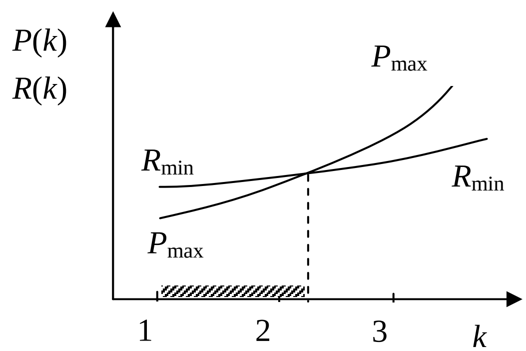


Figure 3. Determining the unprofitable zone

An algorithm for determining zone K_- is similar to that for defining K_+: it is based on the intervals, in which the difference $R_{\min}(k) - P_{\max}(k)$ is positive.

A zone of high risk K_0 is such an area, where the mean selling price of the spaces $\overline{P}(k)$ is lower than the average price of the repaired spaces $\overline{R}(k)$ including the initial price (except for the unprofitable zone K_-). K_0 may be found as the difference between the interval $K = \{k_{\min} \leqslant k \leqslant k_{\max}\}$ and the earlier obtained sets $K_0 = K \backslash (K_+ \cup K_= \cup K_-)$. It is assumed that there are no other investment zones, i.e. $K = K_+ \cup K_= \cup K_- \cup K_0$. A set K_0, like $K_=$, may be an empty set $\emptyset$.

The above zone K_0 may be defined, and the intervals may be determined in a similar way as for zone $K_=$, where the difference $\overline{P}(k) - \overline{R}(k)$ is negative. A set K_- (or, perhaps, also the earlier defined sets K_+ and $K_=$) may be singled out from the obtained intervals.

3. The analysis of real estate investment in Lithuania

Recently, the real estate market in Lithuania has become more brisk. The need for modern newly built offices is great. However, the quality of the premises (spaces) does not always meet the requirements. For rented offices adaptability for various needs of clients is essential. The rent and market price of the premises largely depend on the quality of a particular building (Stasiulionis et al., 2002). Buildings are divided into three groups (grades) according to construction quality: A, B and C (Joint-stock company "Ober – Haus", 2002).

The requirements for office buildings of the grade A include air conditioners, modern lifts, a large parking area, good communication lines, modern IT systems, 24 hour guard, accessibility for transport and good visibility. B grade office buildings are of sufficiently high quality, however, they may lack lifts, air conditioners or sufficient parking space. C grade offices are of satisfactory quality, located in old buildings. They often do not meet any of the requirements for A grade buildings.

In fact, market selling price of real estate was rising for the whole period from 1990 to 1999. Then, there was a period of recession. It can be accounted for high inflation rate, interest rate higher than the bank rates, profitability of investments, real estate shortage, etc. In the middle of 1999 prices have sharply fallen. Since the first quarter of 2000 they have been stable up to the present time. The dynamics of commercial buildings selling price in the period 1996-2001 is shown in Fig. 4. The first column presents the dynamics of prices in the centre of Vilnius, the second column – in the suburban districts, and the third column – in the outskirts of the city (these prices have been stable during the whole period considered).

Analysis of office repair, initial purchase and selling prices in Vilnius

On the basis of the calculations made, the cost graphs were drawn showing the dependence of the estimated cost of 1 m^2 of the total office space on the grade of a commercial building (Fig. 5). The graph is rather subjective, because cost estimation of building finishing is a complicated problem associated with individual, often unique, features of particular buildings. Therefore, the costs

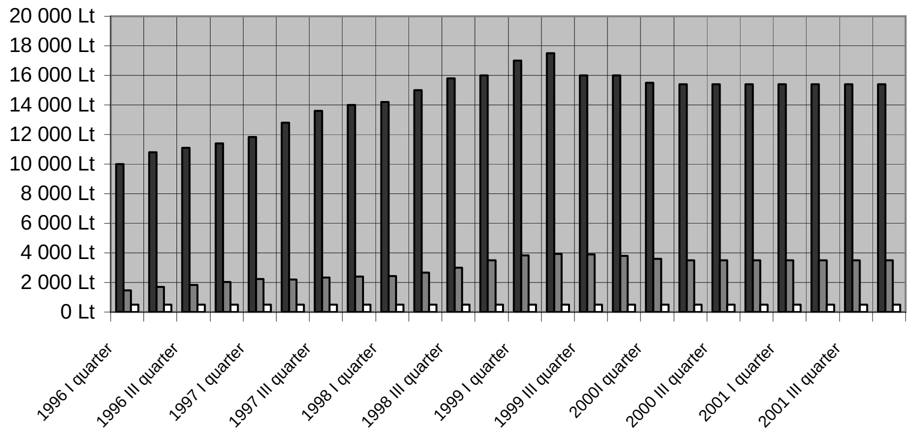


Figure 4. The dynamics of selling prices of commercial buildings in Vilnius in 1996 – 2001 (Lt/m^2)

are estimated in terms of the intervals separating the maximum and minimum costs.

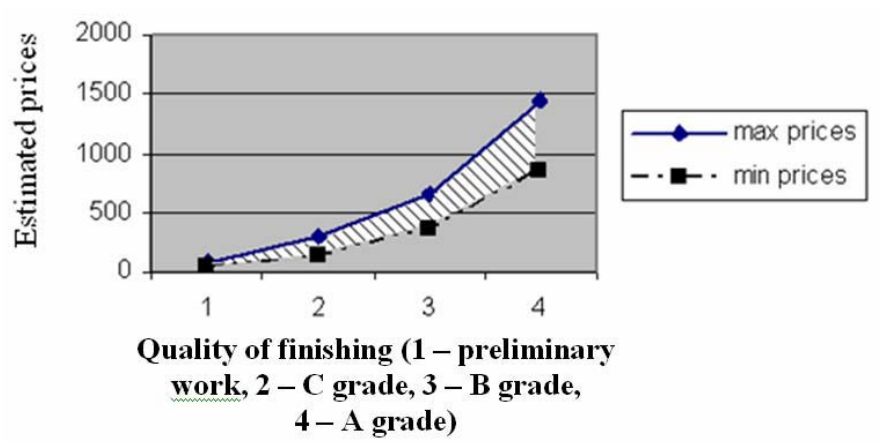


Figure 5. Cost of office repairs

Cost analysis of office buildings

The cost of 1 m^2 of office space in a repaired building depends on its grade (A, B, C) as well as location. The city area may be divided into zones of buildings practically of similar grades. However, there will be some differences between the buildings of the same grade, depending on the location of a particular building. This is why costs of office space are represented in terms of intervals (separating the maximum and minimum prices).

Initial purchase price of non-repaired offices

The price of such offices depends primarily on their location. A division of the city into respective areas is similar to that used in the selling price analysis.

4. A mathematical model for cost analysis of purchasing, repair and sale of office spaces in Vilnius

Let us demonstrate the application of the suggested method to determination of various types of investment zones by considering the available data on various districts of Vilnius. The office premises analysed belong to three various categories, therefore interpolation with 2nd degree polynomials has been used. The problem with more than three categories may be solved in a similar way. In addition to the main variable k (grade of premises), a model may include some other variables, r (e.g. a district for investment).

EXAMPLE 4.1 The minimum selling price of the spaces of the grades k=1;2;3 is, respectively, $P_1 = 545$, $P_2 = 1430$, $P_3 = 2500$, and the interpolation polynomial is as follows:

$$P_{\min}(k) = 92.5k^2 + 607.5k - 155.$$

The maximum selling price of the spaces is $R_1 = 1252$, $R_2 = 1698$, $R_3 = 2433$, and the polynomial is:

$$R_{\max} = 144.5k^2 + 12.5k + 1095.$$

Let us consider the expression:

$$P_{\min} - R_{\max} = -52k^2 + 595k - 1250.$$

The difference is positive in the interval (2.77;3) and this is zone K_+ of riskless investments.

For the mean values $\overline{P}_1 = 974.5$, $\overline{P}_2 = 1769$, $\overline{P}_3 = 2526.5$, we will consider

$$\overline{P}(k) = -18.5k^2 + 850k + 143,$$

while for the mean values $\overline{R}_1 = 1184$, $\overline{R}_2 = 1540.5$, $\overline{R}_3 = 2137.5$:

$$\overline{R}(k) = 120.25k^2 - 4.25k + 1068\,.$$

The difference $\overline{P}(k) - \overline{R}(k) = -138k^2 + 854.25k - 925$ is positive in the interval (1.4; 2.77) – a zone of normal risk $K_=$. There is no unprofitable zone K_-, because the maximum selling prices of spaces $P_1 = 1404$, $P_2 = 2108$ and $P_3 = 2553$ are considerably higher than the respective minimum repair costs $R_1 = 1116$, $R_2 = 1382$, $R_3 = 1842$.

The remaining zone, i.e. the interval (1; 1.4), is a high risk investment zone K_0, where the difference $\overline{P}(k) - \overline{R}(k)$ is negative.

Example 4.2 For the minimum values $P_1 = 1589$, $P_2 = 2474$, $P_3 = 3674$ and the maximum values $R_1 = 2600$, $R_2 = 2850$, $R_3 = 3650$, expression $P_{\min}(k) - R_{\max}(k) = -117.5k^2 + 987.5k - 1881$ is obtained. The difference $P_{\min}(k) - R_{\max}(k) > 0$ in the interval (2.92; 3], which is, therefore, a riskless zone K_+.

For the average values $\overline{P}_1 = 1994.5$, $\overline{P}_2 = 2837$, $\overline{P}_3 = 3837$, and the respective $\overline{R}_1 = 2470$, $\overline{R}_2 = 2705$, $\overline{R}_3 = 3350$, the expression $\overline{P}(k) - \overline{R}(k) = -126.25k^2 + 986.25k - 1155.5$ is obtained and a zone of normal risk $K_=$ is determined as the interval (1.435; 2.92), where the difference $\overline{P}(k) - \overline{R}(k) > 0$.

In the unprofitable zone K_-, $R_{\min}(k) - P_{\max}(k) > 0$. The expression is calculated using the values $P_1 = 2400$, $P_2 = 3200$, $P_3 = 4000$ and $R_1 = 2340$, $R_2 = 2560$, $R_3 = 3050$: $R_{\min}(k) - P_{\max}(k) = 135k^2 - 985k + 790$. The above difference is negative over the interval [1; 1.435) implying that an unprofitable zone does not actually exist: $K_- \sim \emptyset$.

The remaining zone, i.e. the interval [1; 1.435), is a zone of high investment risk K_0, where the expression $\overline{P}(k) - \overline{R}(k) < 0$, i.e. an average selling price $\overline{P}(k)$ is lower than an average repair cost $\overline{R}(k)$.

Example 4.3 For the values $P_1 = 2400$, $P_2 = 3600$, $P_3 = 4400$ and $R_1 = 2651$, $R_2 = 3098$, $R_3 = 3834$, the expression $P_{\min}(k) - R_{\max}(k) = -344.5k^2 + 1766.5k - 1693$ is obtained and a riskless investment zone K_+ is found as the interval (1.25; 3].

For the values $\overline{P}_1 = 3336.5$, $\overline{P}_2 = 4288.5$, $\overline{P}_3 = 4911.5$, and $\overline{R}_1 = 2583.5$, $\overline{R}_2 = 2940.5$, $\overline{R}_3 = 3538$, the expression $\overline{P}(k) - \overline{R}(k) = -284.75k^2 + 1449.25k - 411.5$ is obtained, and a zone of normal risk investment $K_=$ is obtained found to be the interval [1;1.25). It is evident that other investment zones do not exist.

By collecting the statistical data and grouping the districts with similar conditions of investment, it is possible to introduce a generalized district factor r into a model of identification of various investment zones, in addition to the factor K, determining the grade of spaces.

Based on correlation analysis of data, major relationships were derived. Regression models based on office prices in Vilnius are presented in Table 1. The power r of the polynomial in the model is determined by minimizing individual deviation between the data and the forecast.

Models for determining risk zones of investment in office buildings

A set of relationships obtained can be used for developing mathematical models for determining various types of investment risk zones.

Table 1. A set of relationship to determine the effectiveness of repairs

Relationship No	Coefficient of mixed correlation	Correlation coefficient	F-test	Total square error	Model application	Model (relationship) (in the given models k=2, 3, 4 values are used; r – district No; $1 \le r \le 14$)
1	1	1	104.24	72	Maximum repair cost	$R_{\max} = 225.5 - 275.9k + 144.5k^2$
2	1	1	156.09	35.55	Minimum repair cost	$R_{\min} = 152.25 - 208.55 + 95.25k^2$
3	1	1	130.17	53.78	Average repair cost	$\overline{R} = 188.88 - 242.23k + 548.5k^2$
4	0.97	0.98	168.58	2.78	Maximum selling price	$P_{\max} = -1520 + 1368k + 847.3r - 135.6k^2 - 129.7r^2 + {}$ $+ 0.74k^3 + 7r^3$
5	0.91	0.949	60.18	4.42	Minimum selling price	$P_{\min} = -1040 + 359.7k + 596.37r + 66.64k^2 - {}$ $-82.18r^2 + 10.096k^3 + 4.3658r^3$
6	0.94	0.96	114.38	3.6	Average selling price	$\overline{P} = -1280 + 863.85k + 721.84r - 34.48k^2 - {}$ $-105.94r^2 + 5.418k^3 + 5.6829r^3$

By determining a riskless investment zone based on inequality as $P_{\min}(k) - R_{\max}(k) > 0$ (Section 2), a model given below is described (r – district No):

$$P_{\min}(k) - R_{\max}(k) = \\ = -1265.5 + 635.6k + 596.37r - 77.86k^2 - 82.18r^2 + 10.096k^3 + 4.3658r^3.$$

In a similar way, models for determining normal risk, high risk and unprofitable zones were derived (Table 2).

By applying the defined mathematical models, the graphs of distribution of various investment risk zones in Vilnius districts were plotted (graphs for individual districts are shown in Table 3).

The analysis of the graphs obtained allows us to conclude that, taking into account the investment risks, the effect of investments may be determined. Several groups of districts may be identified with respect to the type of investment:

- For districts $r = 8;10;13;14$ (which are the most fashionable and prestigious districts in Vilnius) practically any kind of repair of the purchased spaces

Table 2. Models for determining risk zones

No	Model application	Model expression
1	Riskless investment zones	$P_{\min}(k) - R_{\max}(k) = -1265.5 + 635.6k + 596.37r - 77.86k^2 - 82.18r^2 + 10.096k^3 + 4.3658r^3$
2	Normal risk zones	$\overline{P}(k) - \overline{R}(k) = -734.44 + 553.04k + 721.84r - 291.49k^2 - 105.94r^2 + 5.418k^3 + 5.6829r^3$
3	High risk and unprofitable zones	$R_{\min}(k) - P_{\max}(k) = 836.13 - 788.28k - 847.3r + 544.05k^2 + 129.7r^2 - 0.74k^3 - 7r^3$

is effective because all investments are in a riskless zone. The high quality repair work is preferable, but a medium quality work will also pay;

- For districts $r = 2;3;4;5;9$, riskless zone embraces spaces of grade A. However, investment into a medium quality repair will also pay off;
- In districts $r = 7;11;12$ riskless and profitable investments are associated with average grade spaces. Investments into higher grade spaces are also profitable. However, in this case, the initial investments are considerably larger;
- For the investments into buildings in districts $r = 1,6$ to be profitable, a more detailed analysis of the particular cases is needed. Zones of normal risk are characteristic of these districts.

5. Conclusion

The suggested technique allows for computer-aided determination of risk zones in making profitable investments in real estate. The available database of various types of premises and typical districts of the city provides an opportunity for prompt and reliable determination of the most probable risk zones for investment in particular projects. The model used in the present investigation allows for extension by including other criteria determining investment risk. The calculations made for various districts of Vilnius proved the effectiveness of the described method. The developed methods were validated by solving actual problems of selecting the best variants of construction and reconstruction investment projects. The investment projects selected have been implemented.

The models offered in the present paper are aimed at solving local investment problems in particular cities and their districts, when prompt decisions about investment project profitability are required in the presence of a great number of alternative investment opportunities.

Table 3. Graphs of distribution of investment risks in different districts

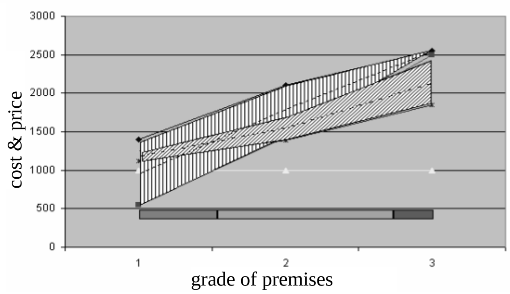
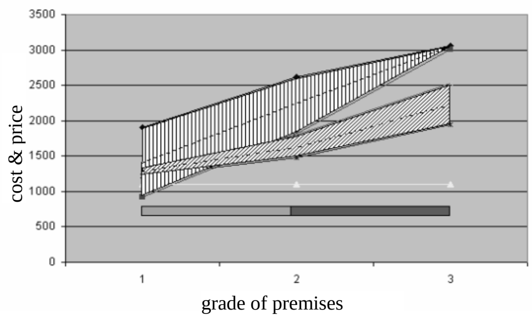
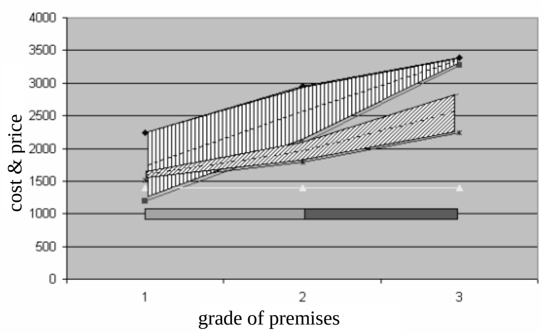
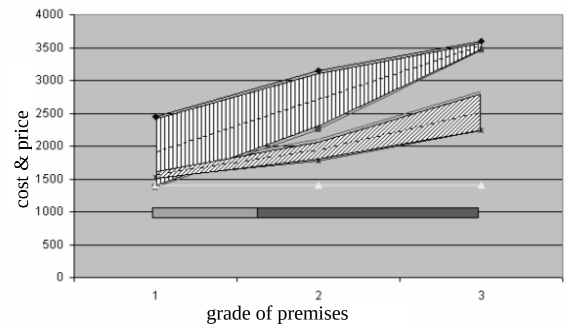
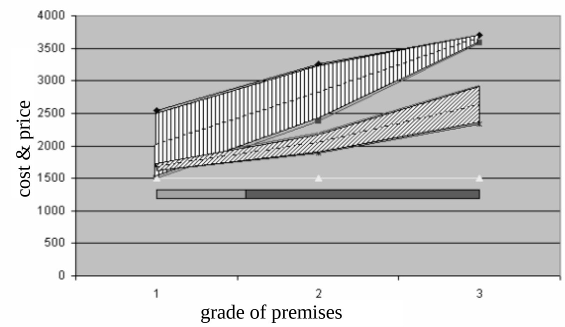
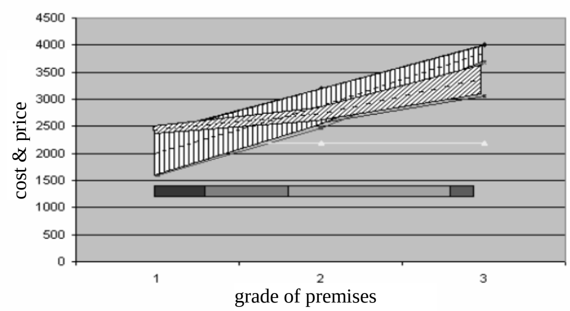
r	District	The graphs
1	Modern residential districts (Seskine, Baltupiai, Lazdynai, Karoliniskes)	
2	Snipiskes, Zirmunai	
3	Other streets of Naujamiestis district (Savanoriu ave., etc.)	
		selling price of office space cost of repair average cost of repair average cost of sold premises riskless investments normal risk investments high risk investments unprofitable investments (losses)

Table 3. Continued

4	Pasilaiciai („Pas Juozapa“, Ukmergės str.)	
5	Algirdo, Svitrigailos, Naugarduko, Mindaugo str.	
6	Antakalnis	
selling price of office space cost of repair average cost of repair average cost of sold premises		riskless investments normal risk investments high risk investments unprofitable investments (losses)

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