Session 8

Application of Mathematical Methods to Logistics and Business

RESEARCH OF THE OPPORTUNITY OF APPLICATION OF MATHEMATICAL METHODS OF MODELLING FOR THE ESTIMATION OF PROBABILITY OF BANKRUPTCY OF THE ENTERPRISE

Olga Stepanova

Actuality of research of the methods of bankruptcy prognostication of the enterprise is based on the following – in Latvia until now there is not the method of calculation of coefficients debugged and adapted to the Latvian terms for prognostication of bankruptcy. The estimation of probability of bankruptcy is made on the basis of the real standards, which exist in the world practice, but does not take into account the features of Latvian specific.

Therefore, in this work the basic models of diagnostics of bankruptcy of enterprises are probed and the row of failings that hampers the possibility of their application in the conditions of Latvian enterprises functioning is exposed.

Thus, actuality of the real research, directed on the estimation of applicability of methods of mathematical design for determination of probability of bankruptcy is obvious; and also on the estimation of reliability and authenticity of the got results of probability the author stresses upon.

Keywords: the complex analysis, the traditional approach, mathematical methods of modelling

ИССЛЕДОВАНИЕ ВОЗМОЖНОСТИ ПРИМЕНЕНИЯ МАТЕМАТИЧЕСКИХ МЕТОДОВ МОДЕЛИРОВАНИЯ ДЛЯ ОЦЕНКИ ВЕРОЯТНОСТИ БАНКРОТСТВА ПРЕДПРИЯТИЯ

Ольга Степанова

Институт транспорта и связи
ул. Ломоносова, 1, LV-1019, Латвия
Тел.: (+371)-25971474, факс: (+371)-7100660
E-mail: olgastepanova@inbox.lv

Актуальность исследования методов прогнозирования банкротства основывается на том, что в Латвии до сих пор нет своей отлаженной и адаптированной к латвийским условиям методики расчета коэффициентов для прогнозирования банкротства. Оценка вероятности банкротства составляется на основе общепризнанных стандартов, которые существуют в мировой практике, но не учитывают особенностей латвийской специфики.

Поэтому в данной работе исследуются основные модели диагностики банкротства предприятий и выявлен ряд недостатков, которые серьезно затрудняют возможность их применения в условиях функционирования латвийских предприятий. Таким образом, очевидна актуальность настоящего исследования, направленного на оценку применимости методов математического моделирования для определения вероятности банкротства, а также на оценку надежности и достоверности полученных результатов вероятности.

Ключевые слова: прогнозирование банкротства, общепризнанные стандарты, математические методы моделирования

Современная экономическая действительность заставляет руководителей предприятий постоянно принимать решения в условиях неопределенности. В условиях финансовой и политической нестабильности деятельность предприятий чревата различными кризисными ситуациями, результатом которых может стать несостоятельность, или банкротство, и как следствие – потеря рабочих мест и увеличение социальной напряженности в обществе.

Актуальность исследования методов прогнозирования банкротства основывается на том, что в Латвии до сих пор нет своей отлаженной и адаптированной к латвийским условиям методики расчета коэффициентов для прогнозирования банкротства. Оценка вероятности банкротства составляется на основе общепризнанных стандартов, которые существуют в мировой практике, но не учитывают особенностей латвийской специфики.

Поэтому цель данной статьи – исследовать существующие математические методы оценки вероятности банкротства для составления собственного метода, который наиболее точно охарактеризует степень банкротства, учитывая специфику Латвии.

В экономической литературе предлагается несколько отличающихся методик и математических моделей диагностики вероятности наступления банкротства предприятий. Первые исследования аналитических коэффициентов для предсказания возможных осложнений в финансовой деятельности компаний проводились в США еще в начале тридцатых годов. В современной практике финансово-хозяйственной деятельности зарубежных фирм для оценки вероятности банкротства наиболее широкое применение получили модели, разработанные Э. Альтманом, У. Бивером и Таффлером. В связи с этим необходимо рассмотреть сущность этих подходов.

Для этого предлагается метод расчета *индекса кредитоспособности,* предложенный в 1968 г. экономистом Э. Альтманом [1, 2]. Он позволяет в первом приближении разделить хозяйствующие объекты на потенциальных банкротов и небанкротов.

Индекс Альтмана представляет собой функцию некоторых показателей, характеризующих экономический потенциал предприятия и результаты его работы за истекший период. В общем виде показатель, называемый Z-счетом Альтмана, имеет следующий вид:

Z-счет = 1,2 * К1 + 1,4 * К2 + 3,3 * К3 + 0,6 * К4 + 1,0 * К5,

где показатели К1, К2, К3, К4, К5 рассчитываются по следующим алгоритмам:
К1 = оборотный капитал / всего активов;
К2 = резервы + нераспределенная прибыль / всего активов;
К3 = результат от реализации / всего активов;
К4 = уставный капитал / заемный капитал;
К5 = выручка от реализации / всего активов.

Предприятие	**1999 г.**	**2000 г.**	**2001 г.**	**2002 г.**	**2003 г.**	**2004 г.**
SIA X	5,51	5,31	5,29	5,91	5,51	4,97
SIA Y	5,08	6,90	7,29	5,40	3,94	4,37

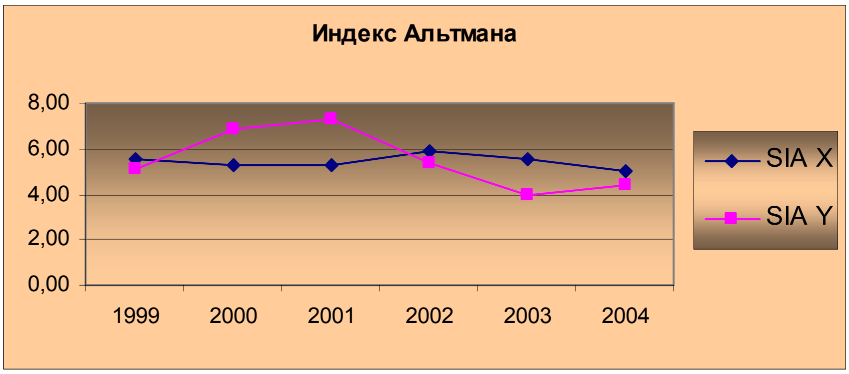


Рис. 1

Таблица 1. Степень вероятности банкротства

Значение Z-счета	**Вероятность банкротства**
1,8 и меньше	Очень высокая
От 1,81 до 2,7	Высокая
От 2,71 до 2,9	Существует возможность
3,0 и выше	Очень низкая

Интерпретируя полученные данные (рис. 1), можно предположить, что степень вероятности банкротства очень низкая (табл. 1), но возникает глубокое сомнение в правомерности показателя, рассчитанного 30 лет назад на крайне ограниченной выборке, в латвийских условиях «эмбрионального» развития рыночных отношений. В частности, один из факторов модели – отношение рыночной стоимости обычных и привилегированных акций к пассивам – может быть определен только для ограниченного числа латвийских предприятий, имеющих официальные рыночные котировки.

Российские аналоги Z-счета Альтмана также рассмотрены на эмпирически рассчитанных коэффициентах и не учитывают отраслевых особенностей и реалий латвийских предприятий. Рассмотренный метод Альтмана применим прежде всего для крупных акционерных предприятий, которых в Латвии не так и много [3] .

Рассмотрим четырехфакторную модель Таффлера, где показатели К1, К2, К3, К4, рассчитываются по следующим алгоритмам:

К1 = прибыль от реализации / краткосрочные обязательства;
К2 = оборотный капитал / сумма обязательств;
К3 = краткосрочные обязательства / сумма активов;
К4 = выручка от продаж / сумма активов;

Z-счет = 0,53 * К1 + 0,13 * К2 + 0,18 * К3 + 0,16 * К4.

Если величина Z-счета больше 0,3, это говорит о том, что у предприятия долгосрочные перспективы, если меньше 0,2, то банкротство более чем вероятно.

Предприятие	**1999 г.**	**2000 г.**	**2001 г.**	**2002 г.**	**2003 г.**	**2004 г.**
SIA X	1,05	1,01	0,95	1,10	1,05	0,94
SIA Y	0,92	1,4	1,59	1,12	0,94	1,02

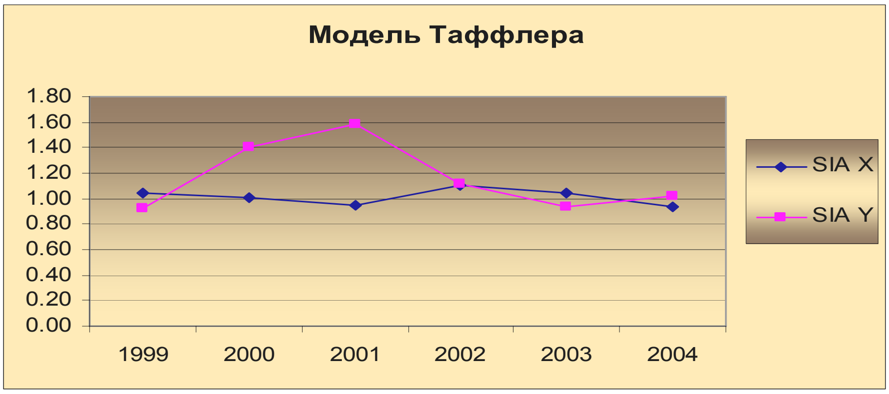


Рис. 2

Анализируя данные, рассчитанные по методу Таффлера (рис. 2), можно сказать, что норматив слишком низкий и конкретной оценки степени банкротства не получено.

У. Бивер предложил пятифакторную модель для оценки финансового состояния предприятия с целью диагностики банкротства, содержащую следующие показатели:

- коэффициент Бивера (чистая прибыль + амортизация) / заемные средства;
- рентабельность активов;
- удельный вес заемных средств в пассивах;
- коэффициент текущей ликвидности;
- доля чистого оборотного капитала в активах [3, 4].

Весовые коэффициенты для индикаторов в модели У. Бивера не предусмотрены, и итоговый показатель вероятности банкротства не рассчитывается. Полученные значения данных показателей сравниваются с их нормативными значениями, рассчитанными У. Бивером для трех видов фирм: для благополучных компаний; для компаний, обанкротившихся в течение года; для фирм, ставших банкротами в течение пяти лет.

Модель Бивера SIA X

Показатель	Формула						Значения показателей		
	1999г.	2000г.	2001г.	2002г.	2003г.	2004г.	благополучного предприятия	за 5 лет до банкротства	за 1 год до банкротства
Коэффициент Бивера	0,13	0,13	0,03	0,13	0,15	0,09	0,4–0,45	0,17	-15
Рентабельность актива	8,81	9,69	2,68	10,7	12,1	7,65	от 6 до 8	4	-22
Финансовый левередж	0,70	0,73	0,86	0,80	0,81	0,81	0,37	0,50	0,80
Коэффициент покрытия активов чистым оборотным капиталом	0,21	0,16	0,03	0,07	-0,1	-0,02	0,4	>0,3	0,06
Коэффициент покрытия	1,31	1,29	1,07	1,14	1,06	1,10	>3,2	>2	>1

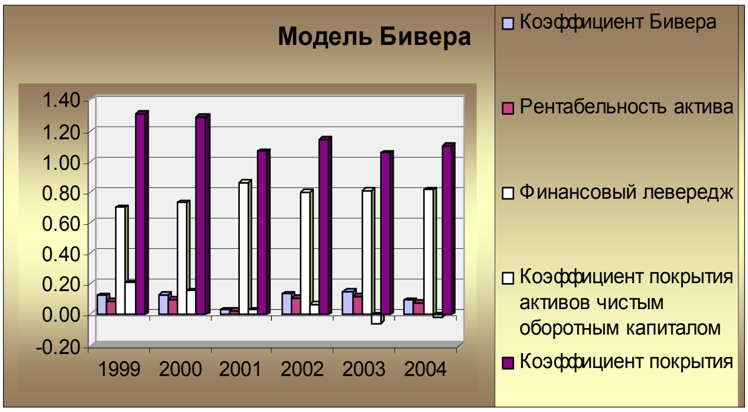


Рис. 3.1

Модель Бивера SIA Y

	Формула						Значения показателей		
	1999г.	2000г.	2001г.	2002г.	2003г.	2004г.	благополучного предприятия	за 5 лет до банкротства	за 1 год до банкротства
Коэффициент Бивера	0,20	0,39	0,77	0,03	0,04	0,01	0,4–0,45	0,17	-15
Рентабельность актива	14,4	21,5	35,2	1,79	2,57	0,80	от 6 до 8	4	-22
Финансовый левередж	0,73	0,56	0,46	0,55	0,68	0,70	0,37	0,50	0,80
Коэффициент покрытия активов чистым оборотным капиталом	-0,3	-0,1	-0,01	0,02	-0,3	-0,3	0,4	>0,3	0,06
Коэффициент покрытия	0,59	0,89	0,99	1,06	1,04	1,06	>3,2	>2	>1

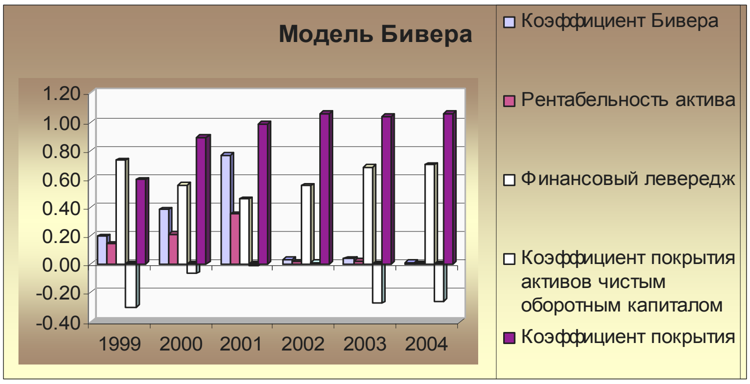


Рис. 3.2

Рассматривая и сравнивая полученные коэффициенты с нормативными значениями показателей, рассчитанных по методу У. Бивера, очень сложно получить однозначную оценку степени вероятности банкротства, так как каждый коэффициент противоречит друг другу.

Также можно отметить, что применение иностранных моделей прогнозирования банкротства в отечественных условиях не принесли достаточно точных результатов. Поэтому были предложены различные способы адаптации «импортных» моделей к условиям переходной экономики, в частности двухфакторной математической модели [3].

Эта модель основывается на двух ключевых показателях, от которых зависит вероятность банкротства предприятия. Эти показатели умножаются на весовые значения коэффициента, найденные эмпирическим путем, и результаты складываются. Если результат оказывается отрицательным, вероятность банкротства невелика. Положительное значение указывает на высокую вероятность банкротства.

С = -0,3977 + (–1,0736) * Кп + 0,0579 * Кз,

где С – показатель риска банкротства;
Кп – показатель текущей ликвидности;
Кз – показатель удельного веса заемных средств в пассивах предприятия.

Предприятие	1999 г.	2000 г.	2001 г.	2002 г.	2003 г.	2004 г.
SIA X	-1.76	-1.74	-1.49	-1.58	-1.48	-1.53
SIA Y	-0.99	-1.32	-1.43	-1.51	-1.47	-1.49

Рис. 4

Надо заметить, что данная методика не дает информации о базе расчета весовых значений коэффициентов. Тем не менее в любом случае следует иметь в виду, что в Латвии иные темпы инфляции, иные циклы макро- и микроэкономики, а также другие уровни фондо-, энерго- и трудоемкости производства, производительности труда, иное налоговое бремя. Однако саму модель с числовыми значениями, соответствующими реалиям латвийского рынка, можно было бы применить, если отечественные учет и отчетность обеспечивали бы достаточно достоверную информацию о финансовом состоянии предприятия.

Рассмотренная двухфакторная модель не обеспечивает всестороннюю оценку финансового состояния предприятия, а потому возможны слишком значительные отклонения прогноза от реальности.

Российскими учеными была осуществлена попытка модифицировать модель прогнозирования банкротства Альтмана и Таффлера с ее адаптацией к российским условиям [1, 6]. Модель показателя риска банкротства, полученная российскими учеными при исследовании предприятий торговли, получила следующий вид:

$R = 8{,}38k_1 + k_2 + 0{,}054k_3 + 0{,}63k_4$,

где k_1 – отношение оборотного капитала к активу;
k_2 – отношение чистой прибыли к собственному капиталу;
k_3 – отношение выручки от реализации к активам;
k_4 – отношение чистой прибыли (непокрытого убытка, взятого с отрицательным знаком) к затратам.

Предприятие	1999 г.	2000 г.	2001 г.	2002 г.	2003 г.	2004 г.
SIA X	8,06	7,97	7,82	7,98	7,09	7,25
SIA Y	4,39	4,90	4,73	4,96	3,68	3,91

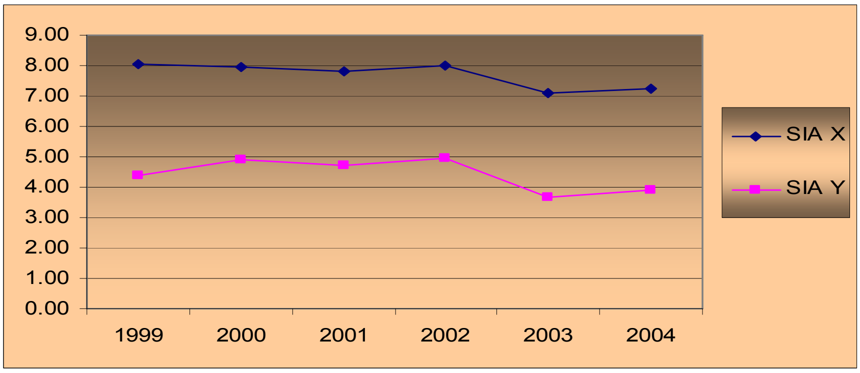


Рис. 5

Для оценки значений модели R была предложена шкала, состоящая из 5 интервалов, которая оценивала вероятность банкротства организации в зависимости от значения R (см. табл. 2).

Таблица 2. Значения вероятности банкротства

Значения R	**Вероятность банкротства, %**
Меньше 0	Максимальная (90–100)
0–0,18	Высокая (60–100)
0,18–0,32	Средняя (35–50)
0,32–0,42	Низкая (15–20)
Больше 0,42	Минимальная (до 10)

Рассмотренная четырехфакторная модель не обеспечивает всестороннюю оценку финансового состояния предприятия, а потому возможны слишком значительные отклонения прогноза от реальности.

Проанализировав все вышеописанные методики диагностики банкротства предприятий, выявлен ряд недостатков, которые серьезно затрудняют возможность их применения в условиях функционирования отечественных предприятий.

Во-первых, двух-, трехфакторные модели не являются достаточно точными. Точность прогнозирования увеличивается, если во внимание принять большее количество факторов.

Таблица 3. Сравнение полученных данных

Методы	Наименование предприятия	Оценка вероятности банкротства						Степень вероятности банкротства
		1999 г.	2000 г.	2001 г.	2002 г.	2003 г.	2004 г.	
Методика Альтмана	SIA X	5,51	5,31	5,29	5,91	5,51	4,97	Очень низкая
	SIA Y	5,08	6,90	7,29	5,40	3,94	4,37	Очень низкая
Методика Таффлера	SIA X	1,05	1,01	0,95	1,10	1,05	0,94	Низкая
	SIA Y	0,92	1,4	1,59	1,12	0,94	1,02	Низкая
Коэффициент Бивера	SIA X	0,13	0,13	0,03	0,13	0,15	0,09	За 5 лет до банкротства
Рентабельность актива		0,09	0,10	0,03	0,11	0,12	0,076	Благополучное предприятие
Финансовый левередж		0,70	0,73	0,86	0,80	0,81	0,814	За 1 год до банкротства
Коэффициент покрытия активов чистым оборотным капиталом		0,21	0,16	0,03	0,07	-0,1	-0,02	За 1 год до банкротства
Коэффициент покрытия		1,31	1,29	1,07	1,14	1,06	1,10	За 1 год до банкротства
Коэффициент Бивера	SIA Y	0.20	0.39	0.77	0,03	0,04	0,01	За 5 лет до банкротства
Рентабельность актива		0.14	0.21	0.35	0,02	0,03	0,01	За 5 лет до банкротства
Финансовый левередж		0.73	0.56	0.46	0,55	0,68	0,70	За 5 лет до банкротства
Коэффициент покрытия активов чистым оборотным капиталом		-0,3	-0,06	-0,01	0,02	-0,3	-0,26	За 1 год до банкротства
Коэффициент покрытия		0,59	0,89	0,99	1,06	1,04	1,06	За 1 год до банкротства
Двухфакторная модель	SIA X	-1,76	-1,74	-1,49	-1,58	-1,48	-1,53	Невелика
	SIA Y	-0,99	-1,32	-1,43	-1,51	-1,47	-1,49	Невелика
Модель адаптирована к российским условиям	SIA X	8,06	7,97	7,82	7,98	7,09	7,25	Минимальная
	SIA Y	4,39	4,90	4,73	4,96	3,68	3,91	Минимальная

Во-вторых, модели Э. Альтмана, У. Бивера и Таффлера содержат значения весовых коэффициентов и пороговых значений комплексных и частных показателей, которые рассчитаны на основе американских аналитических данных шестидесятых и семидесятых годов. Они не соответствуют современной экономической ситуации и организации бизнеса в Латвии, в том числе отличающейся системе бухгалтерского учета и налогового законодательства и т.д.

Данные коэффициенты могут быть рассчитаны на основе статистических материалов по предприятиям-банкротам в Латвии либо экспертным путем, с учетом специфики латвийской экономики.

В-третьих, различия между Латвией и развитыми рыночными экономиками в специфике экономической ситуации и в организации бизнеса оказывают влияние и на сам набор финансовых показателей, используемых в моделях зарубежных авторов. Так, использование формулы Альтмана предполагает наличие активно действующего вторичного рынка ценных бумаг, на котором может определяться их цена.

В-четвертых, латвийские предприятия, как правило, не отвечают многим нормативным значениям и могут быть отнесены в финансовом отношении к неблагополучным. Однако они успешно существуют в этом состоянии и продолжают ритмично работать.

Таким образом, очевидна актуальность настоящего исследования, направленного на оценку применимости методов математического моделирования для определения вероятности банкротства, а также на оценку надежности и достоверности полученных результатов вероятности.

Литература

[1] Савицкая Г.В. *Анализ хозяйственной деятельности предприятия*: Учеб. пособие. 7-е изд., Минск: Новое задание, 2002, 704 с.

[2] Ковалев А.И., Привалов В.П. *Анализ финансового состояния предприятия*: Изд. 4-е. М.: Центр экономики и маркетинга, 2000, 208 с.

[3] Глазов М.М. *Анализ и диагностика финансово-хозяйственной деятельности предприятия*: СПб.: Андреевой изд. дом, 2006, 448 с.

[4] Ковалев В.В. *Введение в финансовый менеджмент*. М.: Финансы и статистика, 2000.

[5] Шеремет А.Д. *Теория экономического анализа:* Учеб. пособие. М.: ИНФРА-М, 2002, 331 с.

[6] http://www.flcons.ru/main.php?page=57

VERBAL ANALYSIS – EFFECTIVE INSTRUMENT OF INVESTMENT RISK MANAGEMENT IN CONSTRUCTION

Edmundas Kazimieras Zavadskas [1], ***Leonas Ustinovichius*** [1], ***Dmitry Kochin*** [2], ***Galina Shevchenko*** [1]

[1]*Vilnius Gediminas Technical University*
LT-10223, Sauletekio al. 11, Vilnius, Lithuania
leonasu@st.vtu.lt, *Galina.Sevcenko@st.vgtu.lt*

[2]*Institute for System Analysis*
117312, prosp. 60-letija Octjabrja, 9, Moscow, Russia
dco@mail.ru

In practice it is impossible to avoid not exhaustive and inaccurate information, therefore, unfavourable risky situations occur, the consequences of which can be very damaging to the project. A superficial assessment of the risk related to capital investment is one of the reasons why investments are not necessarily successful in practice. A classification approach may be used for this purpose. Classification is a very important aspect of decision-making. This means the prescription of objects to particular classes. Classified objects are described by various criteria that can be qualitatively or quantitatively evaluated. In multi-criteria environment it is hardly possible to achieve this without resorting to special techniques. A new way to solve the problem is offered – the CLARA method (Classification of Real Alternatives). The paper presents a feasibility study of using verbal classification for determining a better project, depending on a risk level.

Keywords: investment project, risk, methods of verbal analysis; methods of solving multi-criteria classification problems, estimation of efficiency of investments, CLARA

1. INTRODUCTION

Risk is an integral element of any economical work. It is impossible to avoid, therefore, it is necessary being capable to estimate and minimize it. It is possible, that any of the investments into construction are risky. The basic purpose of the analysis of risk might be formulated as – to give to potential partners of the project the facts on the issue related to decision-making whether to participate in the project and which method to choose so that financial losses would be avoided [11].

Making a reliable qualitative analysis of the investments is a complicated task, since the criteria for assessing the probability of capital recovery has not been established yet. There are many factors which should be taken into account [7, 12, 13]. Each of these factors influences the probability of capital recovery.

Classification is a very important aspect of decision-making. It is the process of assigning projects to particular classes. Claims are often made that classes in decision-making are determined by particular parameters, i.e. the efficiency of technical and technological decisions, project credit value determination, etc. It is hardly possible to accomplish the classification (assigning projects to particular classes) without employing special techniques in multi-criteria environment [1, 5, 8, 9, 10, 11]. This article presents a verbal method of determining investment risk in construction. The problem under consideration is assessing investment projects depending on their level of risk. Formally, the problem is stated as multi-criteria classification. In fact, many different methods for solving multi-criteria classification problems are widely known. ORCLASS method, as an ordinary classification, was one of the first methods designed to solve these kinds of problems [3]. Then more recent methods appeared, such as DIFCLASS [4] and CYCLE methods [6].

A new way to solve the problem is offered – application of the CLARA method (Classification of Real Alternatives) [5]. The method is based on Verbal Decision Analysis approach. In this article methods of the verbal analysis are disclosed, their value is analyzed and it is indicated in what cases these methods could be used depending on their productivity. A hierarchical approach for consideration of efficiency indicators is proposed. The efficiency of the method is proved. The procedure of applying the method for the problem in question is described.

2. FORMAL PROBLEM STATEMENT

Given:

1. G – a feature, corresponding to the target criterion (e.g. treatment effectiveness).
2. $K = \{K_1, K_2, ..., K_N\}$ – a set of criteria, used to assess each alternative (course of treatment).
3. $S_q = \{k_1^q, ..., k_{w_q}^q\}$ – for $q = 1, ..., N$ – a set of verbal estimates on the scale of criterion K_q, w_q – a number of estimates for criterion K^q; estimates in S_q are ordered based on increasing intensity of the feature G;
4. $Y = S_1 \times ... \times S_N$ – a space of the alternative features to be classified. Each alternative is described by a set of estimates obtained by using criteria $K_1, ..., K_N$ and can be presented as a vector $y \in Y$, where $y = (y_1, y_2, ..., y_N)$, y_q is an index of estimate from set S_q.
5. $C = \{C_1, ..., C_M\}$ – a set of decision classes, ordered based on the increasing intensity of feature G. A binary relation of strict dominance is introduced:

$$P = \left\{ \begin{matrix} (x, y) \in Y \times Y | & \forall q = 1...N \\ x_q \geq y_q & \exists q_0 : x_{q_0} > y_{q_0} \end{matrix} \right\}. \tag{1}$$

One can see that this relation is anti-reflexive, anti-symmetric and transitive. It may be also useful to consider a reflexive, anti-symmetric, transitive binary relation of weak dominance Q:

$$Q = \{(x, y) \in Y \times Y | \forall q = 1... N, \; x_q \geq y_q \}. \tag{2}$$

Goal: on the basis of DM preferences to create imaginary F: $Y \to \{Y_i\}, i = 1, ..., M$, where Y_i – a set of vector estimations belonging to class C_i, satisfying the condition of consistency:

$$\forall x, y \in Y : x \in Y_i, y \in Y_j, (x, y) \in P \Rightarrow i \geq j. \tag{3}$$

In fact, many different methods for solving multi-criteria classification problems are widely known. Let us consider several most commonly used methods in more detail.

ORCLASS [4, 6]. This method (Ordinal CLASSification) allows us to build a consistent classification, to check the information and to obtain general decision rules. The method relies on the notion of the most informative alternative, allowing a great number of other alternatives to be implicitly assigned to various classes. ORCLASS takes into account possibilities and limitations of the human information processing system.

CLARA [5]. This method (CLAssification of Real Alternatives) is based on ORCLASS, but is designed to classify a given subset rather than a complete set of alternatives (Y space). Another common application of CLARA is classification of full set with large number of exclusions, i.e. alternatives with impossible combinations of estimations. In both cases CLARA demonstrates high effectiveness.

DIFCLASS [4]. This method was the first to use dynamic construction of chains covering Y space for selecting questions to DM. However, the area of DIFCLASS application is restricted to tasks with binary criteria scales and two decision classes.

CYCLE [6]. CYCLE (Chain Interactive Classification) algorithm overcomes DIFCLASS restrictions, generalizing the idea of dynamic chain construction to the area of ordinal classification task with arbitrary criteria scales and any number of decision classes. The chain here means an ordered sequence of vectors $\langle x_1, ..., x_d \rangle$, where $(x_{i+1}, x_i) \in P$ and vectors x_{i+1} and x_i differ in one of the components.

Method assessment: As comparisons demonstrate, the idea of dynamic chain construction allows us to get an algorithm close to optimal by a minimum number of questions to DM necessary to build a complete classification. The method can be successfully applied to classification of investment projects when the decision classes and the criteria used are thoroughly revised.

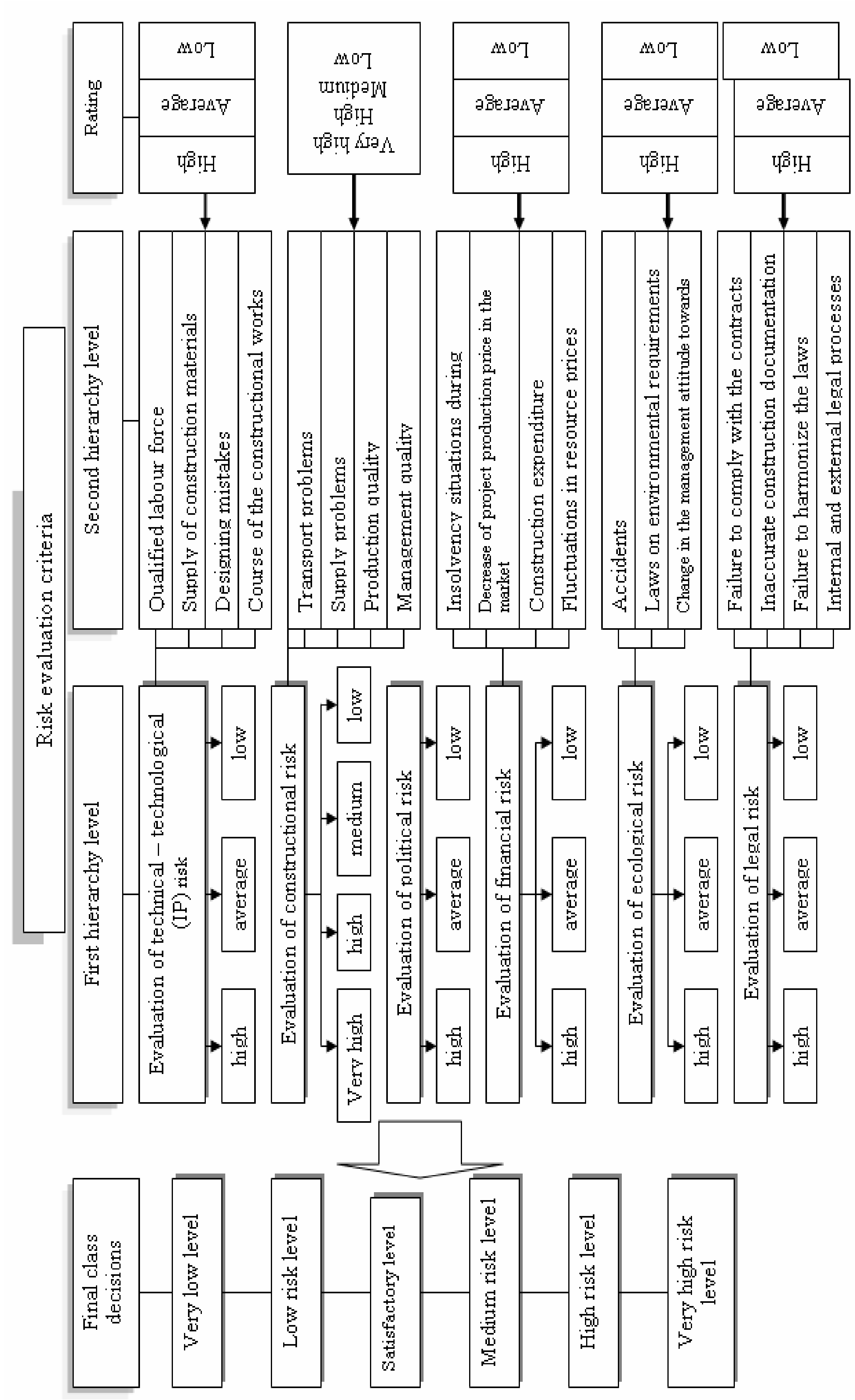


Fig. 1. *Classificator*

3. RISK DETERMINATION AND DESCRIPTION OF THE OPERATIONAL FACTORS OF INVESTMENT PROJECT

After a few iteration series such final decisions were chosen:

1. a) the lowest risk level b) low risk level
2. a) satisfactory risk level b) average risk level
3. a) high risk level b) the highest risk level

Detailed description of these groups is provided below:

Group "evaluation of technical- technological IP risk" is composed of: qualified labour force, supply of construction materials, designing mistakes, course of the constructional works.

Group "evaluation of constructional IP risk" is composed of: transport problems, supply problems, production quality, management quality.

Group "evaluation of political IP risk" – separate criterion.

Group "evaluation of financial IP risk" is composed of: insolvency situations during construction, decrease of project production price in the market, construction expenditure, fluctuations in resource prices.

Group "evaluation of ecological IP risk" is composed of: accidents, laws on environmental requirements, change in the management attitude towards the project.

Group "evaluation of legal IP risk" is composed of: failure to comply with the contracts, inaccurate construction documentation, and failure to harmonize the laws, internal and external legal processes.

Further the classification of the possible investment project risks must be established taking into consideration all levels of their multi-purpose quality descriptions. During that quality of the received results must be checked as well.

First of all, classification of the factors described in the second level is established; quality class – common evaluations of the first hierarchy level. After classification these common evaluations are filled with concrete contents. Afterwards classification of the first level factors is provided. Final result – rules for solving investment project risk evaluation problem.

It is suggested to establish the risk of the constructional investment project employing verbal analysis, using CLARA method, which is based on classification that allows evaluating constructional investment project by the decision made according to the accurately established classes taking into consideration the respectful offered criteria for risk size evaluation.

4. CLARA (Classification of Real Alternatives)

A classification problem, composed of risk evaluation criteria and final class decisions, is compiled for establishing investment project risks (Fig. 1) [2]. Constructional investment project risk evaluation criteria are provided in the first and second criteria levels.

First hierarchy level is the main one. Constructional investment project risk can be evaluated according to the criteria of this level. Each first hierarchy level criterion is allotted an evaluation: low, average, high or very high. When the evaluations are introduced, the result is received; i. e. risk levels are established. These criteria (I level) are not always enough for establishment of constructional investment project risk level. Therefore, each first hierarchy level criterion is split into lower level criteria. The second hierarchy level is composed this way. Criteria of the second hierarchy level are necessary for performing an accurate analysis (each of the risk types is analysed) [2].

Such risk evaluation work course is received following the drawn scheme (Fig. 2):

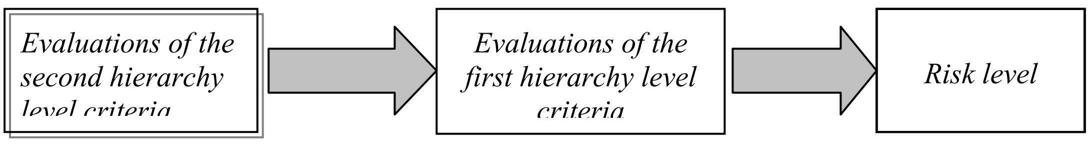


Fig. 2. *Risk evaluation*

Establishing risk level for any possible combination of criteria values is a very difficult task for any person, besides it takes a lot of time. Therefore, it is possible to use computer program CLARA (classification of real alternatives). This method allows classification of constructional investment project into accurately established classes with respect to offered criteria for risk size evaluation.

Classification course

1st STAGE. Evaluation of technical-technological investment project (IP) risk (Fig. 3).
For second hierarchy level evaluation criteria are introduced:

- Criterion 1 – qualified labour force;
- Criterion 2 – supply of construction materials;
- Criterion 3 – designing mistakes;
- Criterion 4 – course of the constructional works.

Criteria evaluation classes:

- Class A – high;
- Class B – average;
- Class C – low.

Criteria 1–4 are chosen for evaluation of technical – technological IP risk. While analysing the project the expert determines whether the chosen labour force is qualified enough, whether permanent continuous supply of materials will be ensured during the construction, what the estimated course of jobs is. After the project is analysed, it is determined if there are no mistakes in it.

2nd STAGE. Evaluation of constructional investment project risk. Data input into the program is analogous to the first stage.

- Criterion 1 – transport problems;
- Criterion 2 – supply problems;
- Criterion 3 – production quality;
- Criterion 4 – management quality.

Criteria for evaluating constructional IP risk are estimated in this stage: during the construction and after the construction.

3rd STAGE. Evaluation of financial investment project risk. Four criteria are used:

- Criterion 1 – insolvency situations during construction;
- Criterion 2 – decrease of project production price in the market;
- Criterion 3 – construction expenditure;
- Criterion 4 – fluctuations in resource prices.

Others evaluation of investment project risks (financial, ecological and any) data input into the program is analogous to the first stage.

Classification is performed after verbal risk evaluation scheme data are put into the program.

Classification implementation in the program. After introducing all the criteria that will be taken into consideration to classify all available investment projects, the process of classification can start.

The classification (Fig. 4) is made in the following way: the program composes combination of the criteria evaluations. The expert assigns the evaluations combination to the respectful class.

For example, if such a combination is put into the program:

1. (1) Qualified labour force – Average.
2. (1) Supply of construction materials – Average.
3. (0) Designing mistakes – High.
4. (0) Course of the constructional works – High.

The expert allots it to class A – high evaluation.

When the assigning is finished, a transfer is made to the next stage (by pushing the button “NEXT”). Another evaluation combination is provided. This is done until all the combinations are allotted to the respectful class.

During the work the expert might make a mistake or change his opinion, therefore, contradictions might appear in his answers. In such case, the program shows a warning that contradictions have occurred and it will ask to confirm the new answer or to change it. If program CLARA is used, all the contradictions are eliminated during the work. After the work is finished, the program saves all the data, performs analysis and shows the number of the given DM questions, the number of classified combinations and the number of eliminated combinations. It also shows how many of the evaluated combinations were assigned to classes A, B or C. Evaluations of all second hierarchy level criteria are established in an analogous way.

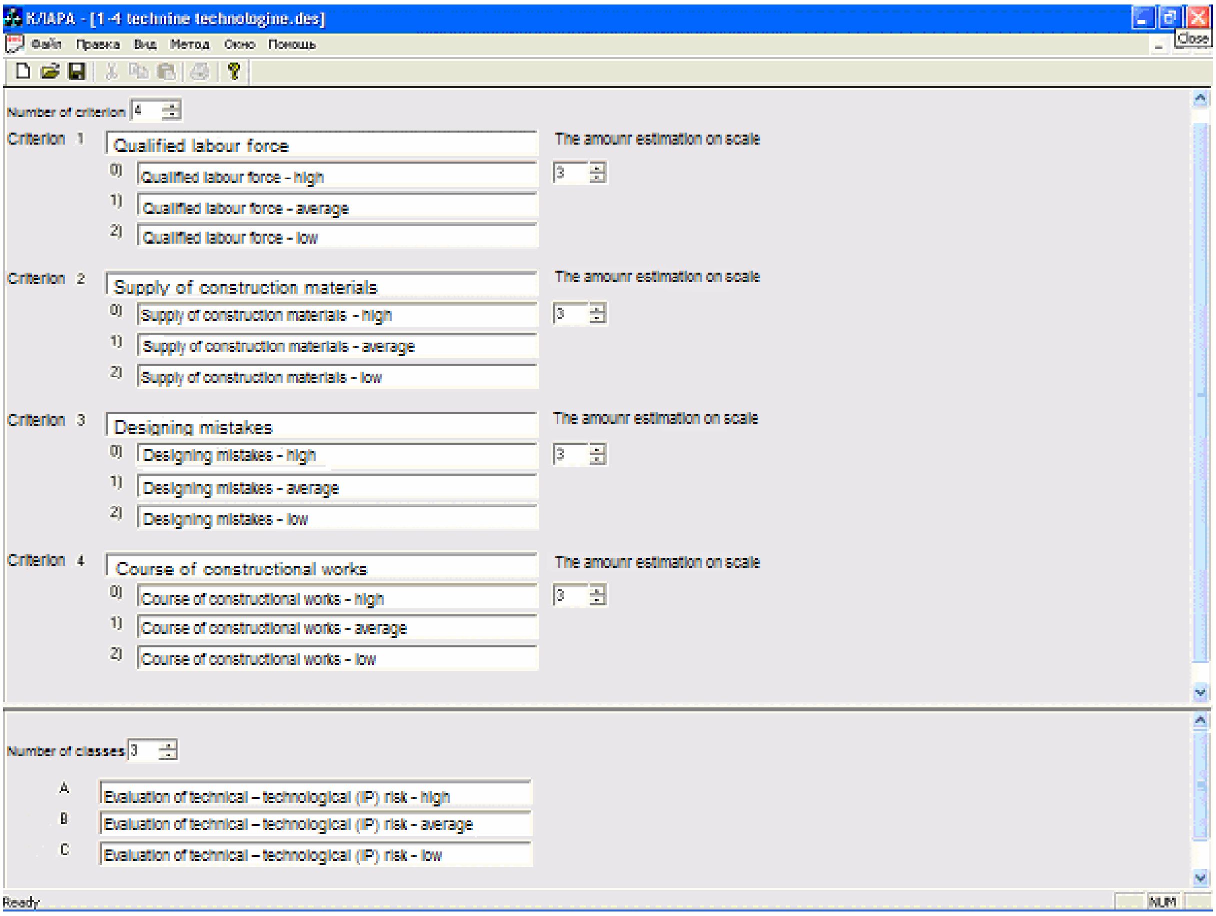


Fig. 3. Criteria for evaluation of technical-technological investment project risk

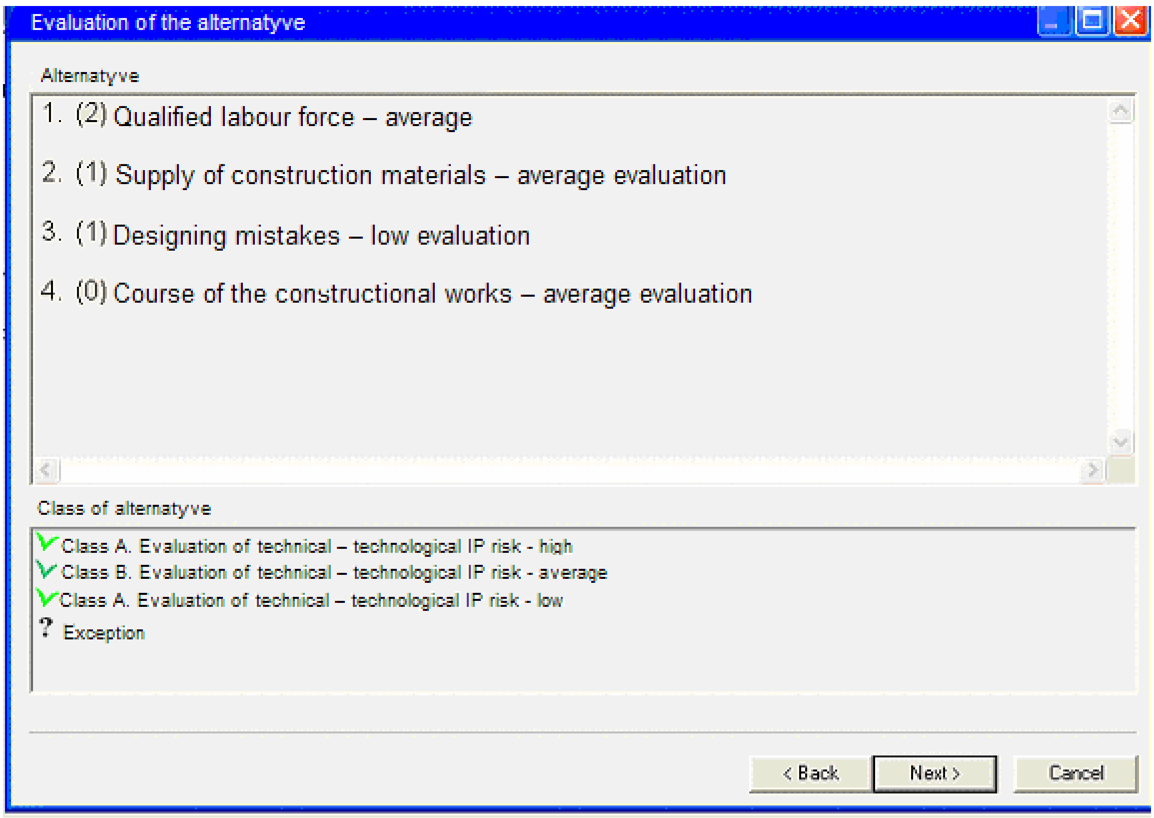


Fig. 4. Evaluation of the alternative

CONCLUSIONS

- In practice it is impossible to avoid not exhaustive and inaccurate information, therefore, unfavourable risky situations occur, the consequences of which can be very damaging to the project. Due to close cooperation of the participants of the project the risk occurring in one stage of the project can transfer to other stages and one type of risk can change into another one. This means that chain reaction is characteristic to the risk and it decreases efficiency and safety of any project.
- Various types of risk can be caused by different factors. Conceptually reasoned risk classification allows defining the role of each risk in the total system of all risks. For establishing the risk of common constructional investment project, i.e. for evaluation of all risk factors that make influence upon the efficiency of the project the available verbal solution analysis methods can be applied.
- After reviewing the scientific literature, it is possible to stress that there are many investment project risk evaluation methods, but most of them are joined by not all the types of evaluation. This creates difficulties when attempts are made to perform exhaustive and versatile investment project risk analysis, because often only certain risk evaluation criteria are taken into consideration.
- Investment risk in construction can be evaluated efficiently enough using CLARA method. This method allows classifying all possible constructional investment projects presented by evaluations on the predefined criteria into several accurately defined classes reflecting the project risk level. A method contains an algorithm to achieve the minimal amount of the DM questions.

References

[1] Slowinski R., Zopounidis C. Application of the rough set approach to evaluation of bankruptcy risk, *International Journal of Intelligent Systems in Accounting Finance and Management*, Vol. 4, No 1, 1995, pp. 27-41.

[2] Ustinovichius L., Kochin D. Verbal analysis of the investment risk in construction, *Journal of Business Economics and Management*, Vol. 4, No 4, 2003, pp. 228-234.

[3] Larichev O., Mechitov A., Moshovich E., Furems E. *Revealing of expert knowledge*. Moscow: Publishing house Nauka, 1989. (In Russian)

[4] Larichev O., Bolotov A. System DIFKLASS: construction of full and consistent bases of expert knowledge in problems of differential classification: The scientific and technical information, a series 2, *Informacionie Procesi i Sistemi (Information processes and systems)*, 9, 1996. (In Russian)

[5] Larichev O., Kochin D., Kortnev A. Decision support system for classification of a finite set of multicriteria alternatives, *Decision Support Systems*, Vol. 33, No 1, 2002, pp. 13-21.

[6] Asanov A., Borisenkov P., Larichev O., Nariznij E., Rozejnzon G. Method of multicriteria classification CYCLE and its application for the analysis of the credit risk, *Ekonomika i Matematicheskije metodi (Economy and Mathematical Methods)*, Vol. 37, No 2, 2001, pp. 14-21. (In Russian)

[7] Nowak M. Investment projects evaluation by simulation and multiple criteria decision aiding procedure, *Journal of Civil Engineering and Management*, Vol. 11, No 3, 2005, pp. 193-202.

[8] Zavadskas E. K., Ustinovičius L., Turskis Z., Peldschus F., Messing D. LEVI 3.0 – Multiple criteria evaluation program for construction solutions, *Journal of Civil Engineering and Management*, Vol. 8, No 3, 2002, pp. 184-191.

[9] Zavadskas E. K., Ustinovichius L., Stasiulionis A. Multicriteria valuation of commercial construction projects for investment purposes, *Journal of Civil Engineering and Management*, Vol. 10, No 2, 2004, pp. 151-166.

[10] Zavadskas, E. K., Kaklauskas, A., Raslanas, S. and Malienė, *V.* The application of multi-criterion methods for valuation recreation property, *STATYBA (Civil Engineering)*, Vol. 7, No 4, 2001, pp. 327-333.

[11] Ustinovichius L. Determination of Efficiency of Investments in Construction, *International Journal of Strategic Property Management*, Vol. 8, No 1, 2004, pp. 25-44.

[12] Baccarini D., Archer R. The risk ranking of projects: a methodology, *International Journal of Project Management*, Vol. 19, No 3, 2001, pp. 139-146.

[13] Nedzveckas J., Rasimavichius G. Investment currency risk and ways of its decrease**,** *Economy*, Vol. 51, No 2, 2000, pp. 63-74. (Publishing House of VU, Vilnius)

APPLICATION OF A MULTIPLE-ATTRIBUTE EVALUATION METHODOLOGY TO APARTMENTS RANKING

CASE STUDY OF VILNIUS CITY

Milda Viteikienė, Edmundas Kazimieras Zavadskas, Zenonas Turskis

Vilnius Gediminas Technical University
Department of Construction Technology and Management
Sauletekio al. 11, LT–10223 Vilnius-40, Lithuania
E-mail: zenonas.turskis@st.vtu.lt

The main objective of this survey is development of a complex analysis model of the most appropriate residential area from the point of view of urban population following the variable surroundings factors which are settling effective selection of housing, comprehensive description thereof taking into consideration the gained experience and knowledge, application of the methods of multiple attribute analysis to help in dealing with urban problems.

This survey uses a technique for determining a rank of housing construction alternatives and a technique for determining weights of attributes. The key to this innovative approach is adoption of an Entropy method to determine weights of attributes. A complex analysis was based on ELECTRE method. This paper deals with the application of the aforementioned methodology to the case study of ranking housing in Vilnius, Lithuania. The methods suggested in this study can also be applied to solve similar problems in other cities and countries.

Keywords: multiple attributes ranking, weights, residential areas, urban

1. INTRODUCTION

Recent changes of public, economic and social situation in Lithuania have highlighted the relevance of housing problems. Problems of residential areas assessment are manifold and no complex examinations thereof have been made yet. Selection and evaluation of real estate play a very important role. These are different residential areas in a city and all of them can be described according to many attributes such as: Housing price; Maintenance costs; Administrating company; Equivalent noise at the house; Age of construction works; Windows, doors (quality); Roof (roof structures, roofing quality); Exterior finishing (quality); Highness of the building; Air pollution. The complex analysis provides possibilities to select the most desirable apartment.

Various systems of residential areas indicators have been applied worldwide and the methods of making such systems are analyzed. On the grounds of analysis the complex comparative indicators systems describing housing are suggested. The attributes describing apartments have not equal importance to each customer.

The problem is solved according algorithm (Fig. 1.)

2. OVERVIEW OF REAL ESTATE SELECTION

Selection of a qualitative housing is an important point to a buyer. The buyer has to evaluate a lot of financial and qualitative criteria. This chapter covers analyses carried out into the housing price, quality, location and procurement issues that were performed in different countries.

D.C.Ho, H.F. Leung and et al. [1] presented the schemes that assess a hierarchy of building factors that have a bearing on environmental qualities, and thus occupants' health. They propose an index method to integrate the assessment outcomes into a simple and user-friendly performance indicator for public consumption. The index can inform the public of the health and hygiene risk of different buildings and facilitate building owners, developers, and government bodies to make more informed and socially responsible decisions on environmental health and hygiene improvement. Although the assessment scheme is tailored for the institutional and cultural settings of Hong Kong, the assessment framework for the development of the scheme is also applicable to other cities.

In the report of the University of Auckland Uniservices [2] about living apartment in inner city Auckland an advisory group of property professionals, planners and others was established to guide the development of the research instruments and criteria for the selection of apartment buildings. Interviews were undertaken with 40 apartment occupants and building managers and 15 property professionals. Surveys of the physical attributes of apartment units were also undertaken in conjunction with the interviews of apartment occupants.

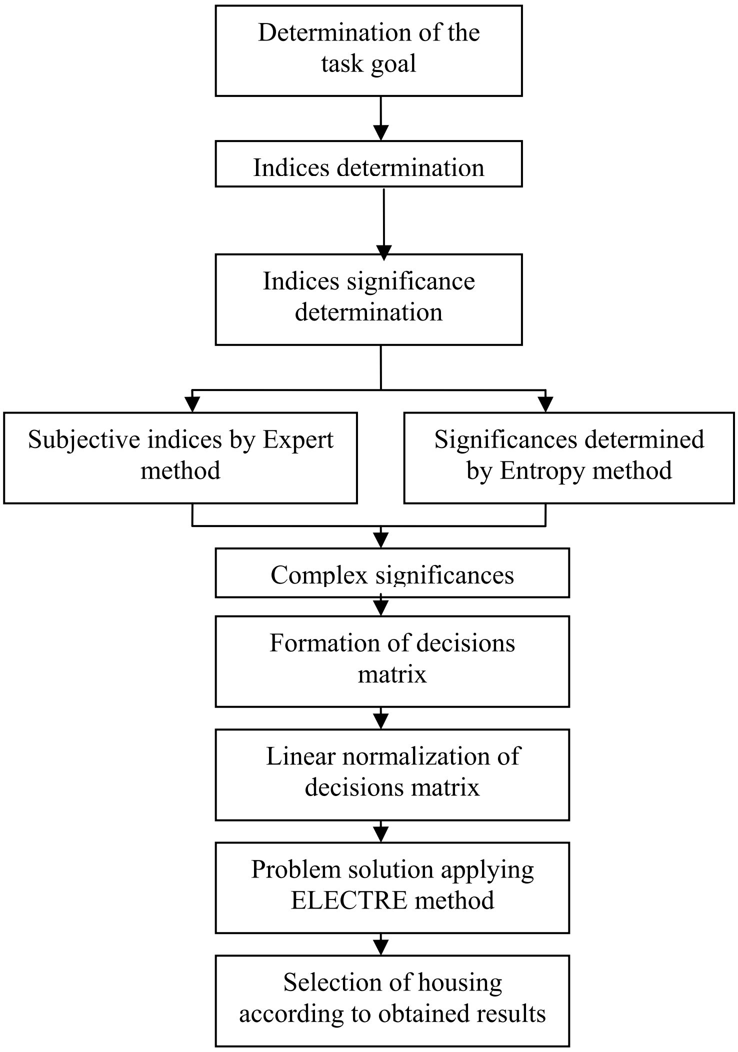


Figure 1. *Problem solution algorithm*

Prof. S. Vanichvatana [3] analyses were done in 3 parts: (1) analysis of frequency ranking of all amenity types, (2) analysis of relationship between amenity types and rents, and (3) regression analysis, test of correlation between rents and types of amenities. The first two Analyses compare amenities among all projects, apartments only, and serviced apartments data sets. To minimize the impact of demand-supply relationship on rent, the test of correlation between rents and types of amenity were done within each zone comparing results among them.

Using a fuzzy multiple attribute decision support R.A. Ribeiro [4] presents an application relevant to civil engineering that deals with the classification of the thermal quality of buildings using a fuzzy multiple attribute decision support tool. The aim of the paper is to demonstrate the potential and flexibility of using these types of tools in the civil engineering area. The application selected follows the Portuguese standards for classifying building insulation construction projects.

M. Cieleback [5] tries to gain insights in the functioning / pricing of the German apartment sector by applying the principles of asset pricing theory to the German residential sector. The analysis is based on rent and price data of apartments in 125 cities in East- and West Germany. The analysis shows how the relation of rents and prices is influenced by the risk free rate (10 year government bond yield) and rental growth expectations, proxied by past rental growth data (backward looking expectation formation of buyers). The results are interpreted against the background of changes in the tax law and government subsidies towards housing.

T. Kauko [6] analysis of the housing market is very fragmented with respect to location; several different house types, age-categories and price-levels, as well as micro-locations, are to be found side by side. It is an extremely patchy and multi-faceted setting, and running the data with neural network modelling techniques, namely the self-organizing map (the SOM) and the learning vector quantification (the LVQ), together with conducting the conceptual level analysis using a heterodox economics framework and some qualitative material, sheds some light about the degree to which the market is affected by physical and socio-demographic characteristics, price and regulation.

Based on data collected in Beijing and Shanghai in autumn by P. Li and A. Karantonis [7] presents how qualitative methods were used, with over 50 in-depth interviews conducted in each of the two cities studied. For deeper understanding of their home-ownership propensities, descriptive data of the interviewees were analysed under five categories, namely: the socio-demographic characteristics; income levels; housing choice; mode of finance; and impact of government policies.

3. SELECTION OF THE SURVEY OBJECT

Vilnius city is the principal administrative centre of Lithuania with the highest concentrated economic potential, the highest number of inhabitants and the leading political, economical, social and cultural centres.

The survey object of the task is desirability of the housing. For this purpose, appropriate residential areas of old construction and new construction were selected. Karoliniskes, Lazdynai, Zirmunai I were attributed to the residential areas of old construction and Zirmunai II (Siaures miestelis), Pilaite, Pasilaiciai were attributed to the residential areas of new construction.

The aim of this task was to highlight the influence of a residential area in selection of housing.

Development of new facilities requires a lot of means and time. One should invest in new water supply and power networks, other services, street building. At present the demand of housing is very high therefore new houses are being built in locations where facilities had already been developed.

It is more convenient to live in buildings that were built until and after 1990 than in new blocks.

4. DESCRIPTION OF INDICES

Prior to obtaining housing the buyer has already formed a certain system of housing quality and desirability indices that is followed in selection of housing by evaluating its quality and life conveniences. For this purpose 45 buyers were interviewed who listed the main indices to be followed in evaluation of the housing prior to its purchase. The buyers indicated 10 principle indices what they take into consideration in purchasing the housing. These principles are as follows:

Housing price, LTL / sq. m – this index indicates the price of 1 sq. m. of the housing they selected (including finishing and cost of repairs of the apartment).

Maintenance costs, points; Administrating Company, points – these indices indicate the level of resident's expenses for living in this housing for a period of one year.

Equivalent noise at the house, dB(A) – this is the level of constant broadband noise expressed in square acoustic pressure in a certain interval of time [8].

Age of construction works, points; Windows, doors (quality), points; Roof (roof structures, roofing quality), points; Exterior finishing (quality), points – is evaluation of quality of the construction works in points; the higher the point the higher the quality of construction works the more desirable is the housing for the buyer. The values of indices were established after interview surveys filled in by experts had been analysed.

Highness of building, floors – highness of building indicates whether the height of the building has influence on the buyer, whether the buyer is concerned about living in a multi-floor building or a low-rise building.

Air pollution, points – reflects evaluation of air pollution in a residential area [9].

5. DETERMINATION OF OPINION COMPATIBILITY AMONG THE RESIDENTS

To determine the significances of the criteria, the expert judgement method proposed by Kendall [10] was used. Zavadskas et al. [11] discussed the application of this method in the construction field.

Having determined the numerical values of indices, the significance (importance) of the indices is determined.

45 customers of Vilnius city were interviewed for determination of significances of the project indices. This expert judgement method was implemented at the following stages [11]:

The values t_{jk} for statistical processing were obtained by interviewing the respondents. The average criterion value $\overline{t_j}$ was calculated by the formula:

$$\overline{t_j} = \frac{\sum_{k=1}^{r} t_{jk}}{r}, \tag{1}$$

where t_{jk} is the ranking of the j criterion by the k respondent and r is number of respondents.

The weights of the criteria were calculated by dividing the sum of the criteria average values by the average value of each criterion:

$$q_j = \frac{\bar{t}_j}{\sum_{j=1}^{n} \overline{t_j}}. \tag{2}$$

The total weight of the criteria must be equal to one:

$$\sum_{j=1}^{n} q_j = 1.0. \tag{3}$$

Reliability of the data can be expressed by the coefficient of concordance (agreement) of the respondents' opinions by describing the extent to proximity of individual views. In cases with reiterated ranks for same parameters, as in our case, the coefficient of concordance is:

$$W = \frac{12S}{r^2(n^3 - n)}, \tag{4}$$

where S is the total square deviation of the rankings of each criterion, T_k the index of reiterated ranks in the r rank, r the number of respondents and n the number of evaluation criteria.

The deviation of the criterion ranking:

$$S = \sum_{j=1}^{n} \left[\sum_{k=1}^{r} t_{jk} - \frac{1}{n} \sum_{j=1}^{n} \sum_{k=1}^{r} t_{jk} \right]^2, \tag{5}$$

where t_{jk} is the rank conferred by the k respondent to the j criterion.

The significance χ^2 of the concordance coefficient is calculated as follows:

$$\chi^2 = \frac{12S}{rn(n+1)}. \tag{6}$$

Kendall [10] has shown that, when $n > 7$, the value $\chi^2 = W \times r \times (n-1)$ has a distribution with degrees of freedom $v = n - 1$, where n is the number of criteria considered and r the number of experts. It has been proved that if the calculated value χ^2 is larger than the critical tabular value $\chi^2{}_{tbl}$ for the pre-selected level of significance (e.g., α = 0.05), then the hypothesis about the agreement of independent experts' judgement is not rejected. If the $\chi_{a,v}{}^2 \rangle \chi^2_{tbl}$ the significance of concordance coefficient exists on α level, then the agreement of experts' opinion is satisfactory and group opinion is established. Otherwise, when $\chi_{a,v}{}^2 \rangle \chi^2_{tbl}$ is obtained, the respondents' opinions are not in agreement, which implies that they differ substantially and the hypothesis on the rank's correlation cannot be accepted.

The concordance coefficient based on the criteria weights is $\chi^2 = 445.86$ greater than $\chi^2{}_{tbl}$, the hypothesis on the rank's correlation cannot be accepted. The degrees of freedom ($v = n - 1 = 11 - 1 = 10$), and pre-selected level of significance is α = 0.01 (or error probability P = 1%), in that case we have the value of $\chi^2{}_{tbl}$ equal to 23.21 [12]. Since 445.86 > 23.21 α = 0.01, and $v = 10$, then, the assumption is made that the coefficient of concordance is significant and expert rankings are in concordance with 99% probability.

6. ENTROPY METHOD

K.E. Shennon entered the concept entropy into the information theory. Entropy is considered as a measure of uncertainty of a random variable. It is possible to use entropy for definition of the importance of parameters of efficiency.

Matrix of decisions must be normalized in such a way [11]:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, \; i = \overline{1,m}\,; \; j = \overline{1,n}\,, \tag{7}$$

i.e. each element of decisions matrix shares for the sum of components of a column in which this element is. The matrix is as a result defined

$$\overline{P} = \begin{array}{c} \\ a_1 \\ a_2 \\ . \\ . \\ a_m \end{array} \begin{array}{c} \begin{array}{cccc} x_1 & x_2 & \dots & x_n \end{array} \\ \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ . & . & \cdots & . \\ . & . & \cdots & . \\ p_{m1} & p_{m2} & \cdots & p_{mn} \end{bmatrix} \end{array}. \tag{8}$$

Level entropy E_j each parameter it is defined under the formula

$$E_j = -k \sum_{i=1}^{m} p_{ij} \ln p_{ij}\,, \; i = \overline{1,m}\,, \; j = \overline{1,n}\,, \tag{9}$$

where $k = \dfrac{1}{\ln m}$.

As it is known, the parameter entropy changes within the limits of an interval (0, 1), therefore we have

$$0 \le E_j \le 1\,, \; j = \overline{1,n}\,. \tag{10}$$

Level of variability j a parameter within the limits of a solved problem, i.e. on set of estimated building variants; it is defined by a parameter

$$d_j = 1 - E_j,\ j = \overline{1,n}. \tag{11}$$

If all parameters are equally important, i.e. there are no subjective or expert estimations of their importance it is defined under the formula

$$q_j = \frac{d_j}{\sum_{j=1}^{n} d_j},\ j = \overline{1,n}. \tag{12}$$

If the subjective sizes of the importance attributed to parameters are known $\bar{q}_j \left(j = \overline{1,n}\right)$ or certain on the basis of expert estimations values of parameters of the complex importance are defined as follows

$$q_j^o = \frac{\bar{q}_j q_j}{\sum_{j=1}^{n} \bar{q}_j q_j}. \tag{13}$$

7. ELECTRE METHOD

Bernard Roy and his collaborators have developed the ELECTRE family of methods for multi-criteria decision-making for the last three decades [13, 14]. Among these methods, ELECTRE TRI [14, 15] has been specifically designed for multicriteria sorting problems.

Many researches and authors used this method in scientific works [17-21]. Various Multiple criteria evaluation methods for assessment of project alternatives and decision-making were applied in many works [22-29].

Method ELECTRE III [30] compared to other comparative preference methods is the most suitable for solving the task of commercial object investment as well as for describing indices of the raised problem. Values of indices may be analysed in more detail, as well as the opinion of an expert, the values of group of indices evaluated in the general context. Comparative preference methods – the group consists of ELECTRE I; ELECTRE IS; ELECTRE II; ELECTRE III; ELECTRE IV; ELECTRE III; PROMETHEE I and II; MELCHIOR; TRICHOTOMIC SEGMENTATION; QUALIFLEX; ORESTE; UTA; PRAGMA; CARTESIA and other methods.

Indices of comparison used in the methods ELECTRE III, IV, etc. allow to valuate inaccuracies of the initial data and measurements of experts [31].

The most typical method of this group is ELECTRE methods (Elimination Et Choix Traduisant la Realite -elimination and choosing reflecting the reality) [31]. Although ELECTRE methods first of all were suggested as heuristic; there are quite a lot of works that serve as the ground of their axiomatic character [32]. ELECTRE methods are implemented in the form of the systems of decision-making [32]. These systems are attractive to the users.

Description of ELECTRE III method.

Benayoun and his colleagues [31] have developed ELECTRE (Elimination et Choice Translating Reality) method. Later Roy, Nijkamp, van Delft [31] developed the method until its present state. ELECTRE uses the principle of "the predominant ratio". Methods of selection of the set of non-predominant variants (ELECTRE) were developed by a group of scientists from France lead by Professor B. Roy. The most effective non-predominant variant is selected in the course of several stages (Fig. 2) [33].

In ELECTRE III method the same indices of two variants are compared, determining the level of index j of variant a being better than index j of variant b expressing this value through the index of conjunction, also the level of discordance of index j of variant a with the index j of variant b expressing this value through the index of discordance [32].

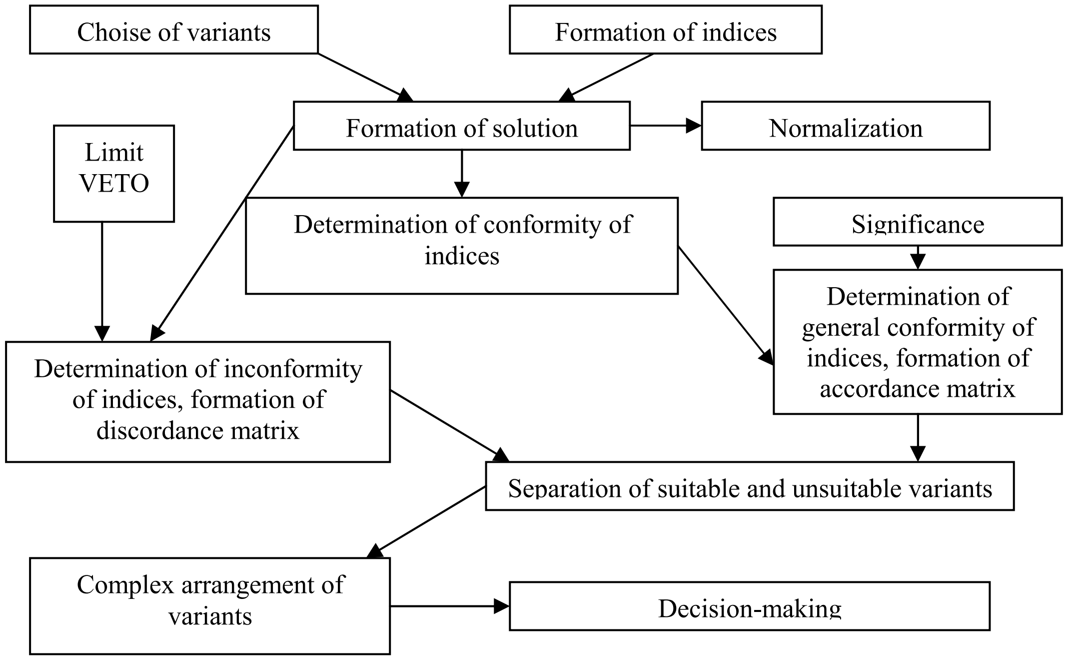


Figure 2. *Model ELECTRE III*

8. PRACTICAL TASK

Characteristic alternatives at the choice of apartments have been chosen according to following criteria: a) a place of the house; b) what house (new construction, old construction). The initial data of the task description are filled in the table developed from the survey. Expert entropy and complex significances were established and filled in Table 1.

Table 1. Initial data of the task and determined significances

Evaluation criteria		Housing price	Main-tenance costs	Administ-rating company	Equi-valent noise at the house	Age of cons-truction works	Windows, doors (quality)	Roof (roof structu-res, quali-ty)	Exterior finishing (quality)	Highness of the building	Air pollu-tion
Unit of measure		1 sq.m	Points	Points	dB(A)	Points	Points	Points	Points	Floors	Points
Min/Max		-	+	-	-	+	+	+	+	-	-
Criteria of significance	Expert method	0.17	0.11	0.04	0.12	0.13	0.07	0.07	0.08	0.08	0.12
	Entropy method	0.000	0.000	0.578	0.009	0.007	0.000	0.03	0.000	0.254	0.149
	Complex	0.000	0.000	0.364	0.017	0.014	0.000	0.003	0.000	0.320	0.281
Zirmunai I	* (v_1)	4500	8	7.53	72	8.46	8.26	8.06	7.33	5	4.42
	** (v_2)	5400	7.93	7.46	72	7.46	8	7.46	7.46	16	4.42
Zirmunai II	* (v_3)	4600	8	7.53	77	8.46	8.26	8.06	7.33	9	4.1
	** (v_4)	5750	7.93	7.46	77	7.46	8	7.46	7.46	5	4.1
Pasilaiciai	* (v_5)	3900	8	7.53	64	8.46	8.26	8.06	7.33	9	5.61
	** (v_6)	4300	7.93	7.46	64	7.46	8	7.46	7.46	5	5.61
Karolin-iskes	* (v_7)	3500	8	7.53	78	8.46	8.26	8.06	7.33	9	5
	** (v_8)	4100	7.93	7.46	78	7.46	8	7.46	7.46	10	5
Lazdynai	* (v_9)	4000	8	7.53	74	8.46	8.26	8.06	7.33	5	4.58
	** (v_{10})	4500	7.93	7.46	74	7.46	8	7.46	7.46	9	4.58
Pilaite	* (v_{11})	4100	8	7.53	67	8.46	8.26	8.06	7.33	5	9.10
	** (v_{12})	4600	7.93	7.46	67	7.46	8	7.46	7.46	7	9.10

** – Old construction; ** – New construction.*

Data describing each alternative have been certain. In a decision matrix we see, that estimations of some parameters for all alternatives, differ a little.

The decision matrix was normalized by application of linear normalization method (Zavadskas, 1987). Thereafter, the value of each index was multiplied to the significance of a respective index. Following the obtained matrix, the task was solved using ELECTRE method. The problem has been solved applying complex significances of attributes.

Having made the calculations the ranks of housing are as follows: $v_4 \succ v_6 \succ v_{10} \succ v_8 \succ v_2 \succ v_{12} \succ v_1 \succ v_9 \succ v_3 \succ v_7 \succ v_5 \succ v_{11}$. New construction: $v_4 \succ v_6 \succ v_{10} \succ v_8 \succ v_{12} \succ v_2$; Old construction: $v_1 \succ v_9 \succ v_3 \succ v_7 \succ v_5 \succ v_{11}$.

CONCLUSIONS

1. Selection of apartments is the sphere of activity requiring strategic (long-term) solutions. Therefore, it is very important to carry out detail research and to analyze the future and past tendencies of the existence of dwelling houses.
2. In order to make research of the apartments, the main environments of research should include: macro-economic situation of the region, micro-economic environment of the locality, modern requirements to the apartments, and management tools of this object.
3. The price of apartments – the main index of competitiveness – is mainly influenced by the following factors: Housing price; Maintenance costs; Administrating company; Equivalent noise at the house; Age of construction works; Windows, doors (quality); Roof (roof structures, roofing quality); Exterior finishing (quality); Highness of the building; Air pollution. However, it is important to match all these elements.
4. Apartments are object, the situated locality of which cannot be changed without changing its designated purpose of use, where dwelling houses activity is executed – living of people of the activity of the subject.
5. Having made the calculations it is obvious that buildings of new construction are more desirable as new construction uses modern, lighter, better heat preserving, more durable, less sound conductive building materials. Services are designed taking into consideration the user's needs and conveniences.
6. Having made the calculations the ranks of housing are as follows: New construction – Zirmunai II, Pasilaiciai, Lazdynai, Karoliniskes, Pilaite, Zirmunai; Old construction – Zirmunai I, Lazdynai, Zirmunai II, Karoliniskes, Pasilaiciai, Pilaite.
7. The calculation shows that location yet plays an important role in housing selection. The location of a residential area in respect of the city centre is important for the residents.

References

[1] Ho D.C.W., Leung H.F., Wong S.K., Cheung A.K.C., Chau K.W., Lau S.S.Y., Wong W.S. and Lung D.P.Y. Assessing the health and hygiene performance of apartment buildings, *Emerald*, Vol. 22, No 3/4, 2004, pp. 58-69. (U.K., Emerald)

[2] Living the highlife? A review of apartment living in inner city Auckland. http://www.building.dbh.govt.nz/e/publish/publications/reports-highlife [revised 02 14 2006].

[3] Vanichvatana S. Relationship between building characteristics and rental to support serviced apartment investment. In: *Proceedings from the PRRES Conference – 2006*, *The 12th Annual Conference of the Pacific Rim Real Estate Society January 22 to 25, Auckland.* New Zealand, 2006, p. 18.

[4] Ribeiro R. A. Fuzzy Evaluation of the Thermal Quality of Buildings, *Computer-Aided Civil and Infrastructure Engineering,* No 14, 1999, pp. 155-162.

[5] Cieleback M. Agency problems in indirect real estate investing. In: *The 11th Annual Conference of the Pacific Rim Real Estate Society January 23 to 27, 2005 held at The University of Melbourne Victoria, Australia.* Victoria, Australia: the University of Melbourne, 2005, p. 5.

[6] Kauko T. The Budapest housing market structure from a heterodox economics perspective and with a neural network classification. In: *The 11th Annual Conference of the Pacific Rim Real Estate Society January 23 to 27, 2005 held at The University of Melbourne Victoria, Australia.* 2005, p. 12.

[7] Li P., Karantonis A. Boom or gloom: A comparative study of the propensity of first home buyers in Beijing and Shanghai. In: *The 11th Annual Conference of the Pacific Rim Real Estate Society January 23 to 27, 2005 held at The University of Melbourne Victoria, Australia.* Victoria, Australia: the University of Melbourne*,* 2005, p. 38.
[8] Traffic noise in Vilnius. http://www.vilniausvsc.lt/aplinka/transportas.priemon_eismohtm [revised 05 14 2006 (in Lithuanian)].
[9] RAIT the residents of Vilnius city, 2005 m. (In Lithuanian)
[10] Kendall M. G. *Rank Correlation Methods*, *4-th ed.* London: Griffin, 1970.
[11] Zavadskas E. K. *Complex estimation and choice of resource saving decisions in construction.* Vilnius: Okslas, 1987. (In Russian)
[12] Kruopis J. *Mathematics Statistics.* Vilnius: Mokslo ir enciklopedijų leidykla, 1993. (In Lithuanian)
[13] Roy B. The outranking approach and the foundations of ELECTRE methods, *Theory and Decision*, 31, 1991, pp. 49-73.
[14] Roy B., Bouyssou D. Aide multicritère à la décision: méthodes et cas, *Économico*, Paris, 1993.
[15] Yu W. 1992. ELECTRE TRI. Aspects méthodologiques et guide d'utilisation. Document du LAMSADE, No. 74, Université Paris-Dauphine.
[16] Zavadskas E.K., Ustinovichius L., Stasiulionis A. Multicriteria valuation of commercial construction projects for investment purposes, *Journal of Civil Engineering and Management*, Vol. 10, No 2, 2004, pp. 151-166.
[17] Dias L.C., Mousseau V. IRIS: A DSS for multiple criteria sorting problems, *Journal of Multi-Criteria Decision Analysis*, Vol. 12, 2003, pp. 285-298.
[18] Roy B., Mousseau V. A theoretical framework for analysing the notion of relative importance of criteria, *Journal of Multi-Criteria Decision Analysis*, Vol. 5, 1996, pp.145-159.
[19] Dias L.C., Mousseau V. Inferring ELECTRE_s veto-related parameters from outranking examples, *European Journal of Operation Research*, Vol. 170, 2006, pp. 172-191.
[20] Mousseau V, Figueira J, Naux J-Ph. Using assignment examples to infer weights for ELECTRE TRI method: some experimental results, *European Journal of Operational Research,* Vol. 130, No 2, 2001, pp. 263-275.
[21] Mousseau V, Slowinski R, Zielniewicz P. A user-oriented implementation of the ELECTRE TRI method integrating preference elicitation support, *Computers & Operations Research,* Vol. 27, No 7-8, 2000, pp. 757-777.
[22] Zavadskas E. K.; Peldschus F.; Kaklauskas A. *Multiple criteria evaluation of projects in construction.* Vilnius: Technika, 1994.
[23] Zavadskas E. K., Kaklauskas A., Banaitienė N. *Multiple criteria analysis of a building life cycle.* Vilnius: Technika, 2001. (In Lithuanian)
[24] Zavadskas E. K. *Multiple criteria solutions in construction.* Vilnius: Technika, 2000. (In German)
[25] Peldschus F., Zavadskas E. K. *Matrix games in building technology and management*. Vilnius: Technika, 1997. (In Lithuanian)
[26] Zavadskas E. K., Ustinovičius L., Turskis Z., Peldchus F., Messing D. LEVI 3.0 – multiple criteria evaluation program for construction solutions, *Journal of Civil Engineering and Management,* Vol. 8, No 2, 2002, pp. 184-191. (Vilnius: Technika); (Statyba)
[27] Peldschus F., Zavadskas E. K., Ustinovičius L., Turskis Z. *Game theory in building technology and management: Monograph.* Vilnius: Technika, 2004. (In Lithuanian)
[28] Peldschus F., Messing D., Zavadskas E. K., Ustinovičius L., Turskis Z. LEVI 3.0 – Multiple criteria evaluation program under uncertainty, *Technological and Economic Development of Economy* (Ūkio technologinis ir ekonominis vystymas), Vol. 8, No 1. 2002, pp. 3-12. (In Lithuanian); (Vilnius: Technika)
[29] Zavadskas E. K., Peldschus F., Ustinovičius L. Development of software for multiple criteria evaluation, *Informatica*, Vol. 14, No 2, 2003, pp. 259-272.
[30] Roy B. Electre III: the algorithm of classification based on dim representation of preferences at presence multi-criteria (Electre III: UN algorithme de classement fonde sur une représentation floue des préférences en présence de critères multiples), *Cahiers du CERO*, 20, 1978, pp. 3-24. (In French).
[31] Roy B. *Multicriteria Methodology for Decision Aiding*. Dortrecht: Kluwer Academic Publishers, 1996.
[32] Vallee D., Zielniewicz P. ELECTRE 3-4, version 3x. Guide d'Utilisation, Document LAMSADE No 85, Paris, Université de Paris Dauphine, 1994.
[33] Zavadskas E.K., Kaklauskas A. *Systemic-technical valuation of constructions.* Vilnius: Technika, 1996. (In Lithuanian)

THE PECULIARITIES OF APPLICATION OF MULTI-ATTRIBUTE DECISION-MAKING METHODS FOR SOLVING THE PROBLEMS WITH A LARGE NUMBER OF ATTRIBUTES AND LIMITED ACCURACY OF ATTRIBUTES' MEANINGS

Edmundas Kazimieras Zavadskas, Zenonas Turskis, Tatyana Vilutienė

Vilnius Gediminas Technical University
Faculty of Civil Engineering
Saulėtekio al. 11, LT–10223 Vilnius, Lithuania
E-mail: Edmundas.Zavadskas@adm.vtu.lt, Zenonas.Turskis@st.vtu.lt, Tatjana.Vilutiene@st.vtu.lt

The article deals with the peculiarities of solving the optimization tasks with incomplete information and aims at determination the influence of possessed attributes number and weights on final result. As a case study applying the methods of game theory the comparative analysis of dwelling maintenance contractors is performed. For solving different problems with incomplete information such as maintenance contractor selection the decision-making methods – Topsis ("Distance to the ideal point"), Wald's rule and Bayes's rule are applied for comparative analysis. To compare the performance of various maintenance contractors, the data from 15 dwelling maintenance organizations is used. Contractors are evaluated by a set of attributes characterizing them from various perspectives. Attributes weights are calculated taking into account the standpoints of building owners. Attributes meanings calculation accuracy is considered before the final number of attributes is chosen. The results of study shows that striving to determine the optimal solution ensuring the reliability of results the number of attributes is to be minimized and the weights are to be attributed to attributes definitely.

Keywords: optimization problems, attributes, game theory, decision-making methods, reliability

1. INTRODUCTION

The problem's solution depends on information we possess, depends on problem's aim and object's model. Advantages or disadvantages obviously are very important to choose the decision-making method for individual problem. However, a question arises about the reliability of results and quality of overall decision-making process. If we scrutinize standard decisions in different fields, we shall become certain that deficiency of information is very often ignored. Experts make use of unfavourable initial data, their values applied are exaggerated, work is executed with poor quality determined models which, in case of need, are a bit corrected on the basis of practical experience, however reflect the actual situation insufficiently. Acting in such a way, experts make allowable decisions, but most often these decisions are unfavourable. For example, insufficient substantiation of projects efficiency under increased risk holds potential investments. State, private businessman, credit institutions financing real investment projects is concerned in quality of evaluation of projects. The main problem of the evaluation decision efficiency is to determine and to ground it and define it as "useful", "profitable" or contrary "useless", "unprofitable", "unreasonable".

In an optimization practice researches often can collide with opinion, that applying methods of optimization it is possible to compare variants with hundreds of attributes. Theoretically the aforementioned methods let to do the operations with many and even hundreds of attributes, however solving the problems with many attributes the doubts about the reliability and practical value of the received results appears. Therefore, striving to determine the peculiarities of solving the problems with many attributes the task of comparison of 15 alternatives according to 20 attributes is selected. The aim of task is to determine the factors, which influence the final result. The assumption is made that the main influence on calculation results has the number of attributes and the presence or the absence and the numerical values of the weights of attributes. The task is solved using two ways: firstly, including the weights of attributes and then, ignoring them. Later, calculation errors are determined and the attributes with the meanings less than attributes errors are eliminated and the calculations applying considered methods are repeated.

The reduction of non-significant attributes is done by elimination of attributes with significance less than 5 percent. The attributes are rated ascribing to them the integer discrete values and considering the 0.5 point accuracy of calculation. In ten-point scale it comprises the 5 percent. Therefore, the attribute, which meanings are less than 5 percent, has less influence on the final result and are eliminated. The less important attributes are eliminated and more important are aggregated so, that their total importance will be higher than the considered maximum allowable 5 percent error of calculation.

The process of problem solution is presented in Figure 1. Hereafter the review of application of decision-making methods in different fields and methodology applied for problem solution is presented.

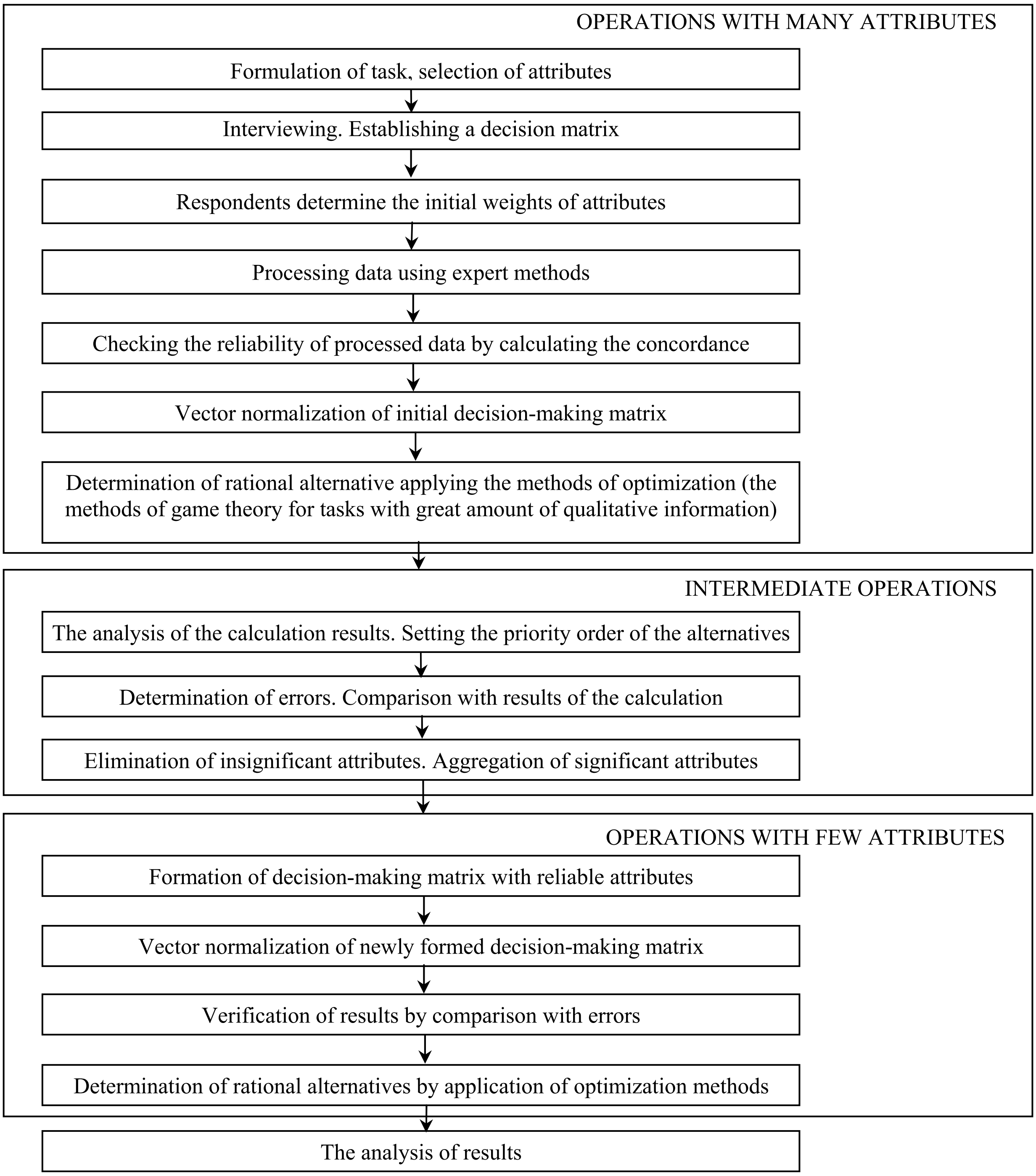


Figure 1. *Decision-making scheme*

2. A REVIEW OF MADM METHODS APPLIED TO SOLVE MULTI-OBJECTIVE PROBLEMS

Classical methods of multi-attribute optimization and determination of priority and utility function were first applied by V. Pareto [1] in 1896. These methods were strongly related to economical theory, concerning the averages of thousands of decisions. Methods of multi-attribute analysis were developed in the 1960's to meet the increasing requirements of human society and the environment. In 1980 F. Seo [2] suggested a multi-attribute decision-making method that was concerned with balancing some conflicting objectives in a hierarchical structure. In 1980 T. Tanino *et al.* [3] analyzed the problem of the coordination of different goals and objectives of various interested parties. R.L. Keeney and H. Raiffa [4] offered the representation theorems for determining multi-attribute utility functions under preferential and utility independence assumptions. R.L. Keeney [5] outlined the essential features and concepts of decision analysis, formulated axioms and major stages. R.L. Keeney and D. Winterfeldt [6] suggested following the prudence principle in decision process, making decisions precisely and evaluating all possible alternatives, the aims of interested parties; subsequence of decision results and value changes, hereby minimizing the decision-making risk. T.L. Saaty [7] in 1977 showed the global importance of solving problems with conflicting goals by using multi-attribute models and presented decision-making models with incomplete information for solving political and economical problems. In his latest works T.L.Saaty analyzed measuring problems in assignments associated with uncertainty conditions and applied the AHP method to solve different problems [8].

Multiple attribute decision-making methods (MADM) have different characteristics; therefore there are different ways to classify them. Multi-attribute methods can be classified by the type of initial information (deterministic, stochastic, fuzzy set theory methods) or by the number of decision-makers (one or group). Scientists classify deterministic MADM methods differently. The classification of MADM methods according to the type of information proposed by O.I. Larichev [9] is given here:

1. Methods based on quantitative measurements. The methods based on multi-attribute utility theory may be referred to this group (TOPSIS – Technique for Order preference by Similarity to Ideal Solution [10, 11], SAW – Simple Additive Weighting [12], LINMAP – Linear Programming Techniques for Multidimensional Analysis of Preference [13] and other new methods).

2. Methods based on qualitative initial measurements. These include two widely known groups of methods, i.e. analytic hierarchy methods [14] and fuzzy set theory methods [15].

3. Comparative preference methods based on pair wise comparison of alternatives. This group comprises the modifications of the ELECTRE [16], PROMETHEE I and II [17], and other methods.

4. Methods based on qualitative measurements not converted to quantitative variables. This group includes methods of verbal decision-making analysis [18].

B. Urli and R. Nadeau [19] emphasized the importance of multi-attribute analysis. Their studies have shown that the area of application of decision-support systems could embrace the most important problems and their significance is underestimated. Researchers examined more than 800 European scientific publications in the period from 1985 to 1996. Since then the amount of articles dealing with multi-attribute analysis has considerably increased. Besides, the researches have noticed the dispersion of multi-attribute analysis to different areas. K. Train [20] presents comprehensive general conclusion of existing methods and certify that at the eighty years of twenty century were delivered main models of qualitative selection analysis methods, defined statistic and economic properties of such methods. Methods were successfully applied in many fields; including transportation, energetic, civil engineering and market (enumerated a few only).

The methods of multi-attribute analysis were tested in many fields and applied to different disciplines as well as to solving many specific problems. In spite of these facts, multi-attribute analysis is not sufficiently developed, the methods are not perfect, and scientists constantly raise the question, "Which is the best method for a given problem?" [21]. Most of the methods enable us to determine the priority rank for comparing the alternatives, not allowing, however, to establish the level at which one alternative can be better than another. Till present time there are not rules how to use multi-attribute evaluation methods and how to interpret results of solution. Therefore the solution must be found to solve these problems.

For multi-attribute selection of an alternative under uncertainty conditions E. K. Zavadskas *et al.* [22] created the software LEVI–3.0 based on different methods for attributes normalization and optimal variant selection. The application of these methods increases the accuracy of determining an optimal decision. With new software it is possible to find solution of rational strategy problem using different methods under risk and uncertainty and to compare the results.

The game theory and its methods are instruments for developing the technological behaviour. Solution results enable to make more exact investigation and to choose more precise solution method.

3. METHODOLOGY OF THE SIMULATION

Every problem to be solved is represented by a matrix, which contains variants (rows) and attributes (columns). The variants represent a set of situations for a problem that really exists. All considered variants are evaluated using the same attributes. The results of the evaluation are put in a matrix.

In order to avoid the difficulties due to different dimensions of the attributes, the ratio to the optimal value is used. That way the discrepancy between the different dimensions of the optimal values is also eliminated. Normalized decision-making matrix can be processed using different methods of multi-attribute analysis. Here we use methods of game theory. A distinction is made between one-sided and two-sided problems for the methods of solution.

The one-sided problems are solved using various well-known methods of the selection of variants and the determination of an order of precedence. For one-sided problems only the method of solution "distance to the ideal point" is considered. Using this method an order of precedence according to the deviation from the ideal variant is determined. The solutions consist of the following steps:

The input matrix is normalized according to formula:

$$a_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}}. \tag{1}$$

When using vector normalization the ratios of the values remain constant and vary in the interval [0; 1]. With these dimension-less values the set a+ (ideal variant) and a- (negatively ideal variant) are calculated.

$$a^{+} = \left\{ \begin{bmatrix} \left(\max\limits_{i} f_{ij} \,/\, j \in J\right), \\ \left(\min\limits_{i} f_{ij} \,/\, j \in J'\right) \end{bmatrix} / \, i = \overline{1, m} \right\} == \left\{ f_1^{+}, f_2^{+}, \ldots, f_n^{+} \right\}, \tag{2}$$

$$a^{-} = \left\{ \begin{bmatrix} \left(\min\limits_{i} f_{ij} \,/\, j \in J\right), \\ \left(\max\limits_{i} f_{ij} \,/\, j \in J'\right) \end{bmatrix} / \, i = \overline{1, m} \right\} == \left\{ f_1^{-}, f_2^{-}, \ldots, f_n^{-} \right\}, \tag{3}$$

Here J is the set of the problems of maximisation and J' is the set of the problems of minimisation. Then the distances between the comparing variant i and both ideal L_i^{+} and negatively ideal L_i^{-} variants are determining:

$$L_i^{+} = \sqrt{\sum_{j=1}^{n} \left(f_{ij} - f_j^{+} \right)^2} \quad ; \quad \forall i; i = \overline{1, m}, \tag{4}$$

$$L_i^- = \sqrt{\sum_{j=1}^{n}\left(f_{ij} - f_j^-\right)^2} \; ; \quad \forall i; i = \overline{1,m} . \tag{5}$$

The relative proximity to the ideal variant is determined according to formula:

$$K_i = \frac{L_1^-}{L_i^+ + L_i^-} , \quad \forall i; \quad i = \overline{1,m} . \tag{6}$$

The calculated values K_i are in the interval [0; 1] and can be ordered in a decreasing sequence, which is the wanted order of precedence. The limits of the interval are obtained from the condition:

$$K_i = \begin{cases} 1 , & if \; a_i = a^+ ; \\ 0 , & if \; a_i = a^- . \end{cases} \tag{7}$$

Using the Game Theory, the two-sided question aims at finding the equilibrium as a result of the rational behaviour of two parties having opposite interests or at the equilibrium in a game against nature. For two-sided problems a distinction is made between games with rational behaviour and games against nature.

The solutions for problems with rational behaviour are found in the ideal case as a saddle point solution (simple min-max principle) or as a combination of strategies (extended min-max principle).

Wald's rule (Wald, 1945) [23], Savage criterion (Savage, 1951) [24], Hurwicz's rule (Hurwicz, 1951) [25], Laplace's rule, Bayes's rule (Arrow, 1949) [26], Hodges-Lehmann rule [27] are the methods represent the group of games against nature.

Wald's rule. By this method it is investigated for the best solutions among the worse ones (Wald, 1945) [23]. The decision-maker acts according to the worst situation occurring, i.e. pessimistic attitude.

$$S_1^* = \left\{ S_{1i} / S_{1i} \in S_1 \cap \max_i \min_j a_{ij} \right\}. \tag{8}$$

Bayes's rule. If the probabilities for the strategies of the opponent are given, the maximum for the expected value can be used (Arrow, 1949) [26].

$$S_1^* = \left\{ S_{1i} / S_{1i} \cap \max_i \left(\sum_{j=1}^{n} q_j a_{ij} \right) \cap \sum_{j=1}^{n} q_j = 1 \right\}. \tag{9}$$

$\lambda = 0$ (no confidence) gives the solution according to Wald's rule. $\lambda = 1$ (great confidence) gives the solution according to Bayes's rule.

To illustrate application of the described methods, we shall consider the task of maintenance contractor selection applying the method "distance to the ideal point" and the two methods from group of games against nature – Wald's and Bayes's rules.

4. CASE STUDY

To illustrate the peculiarities of solving the problems with qualitative information and many attributes the task of maintenance contractor selection is chosen.

Maintenance contractors are evaluated and compared from the viewpoints of building users represented by key maintenance persons. The initial data for comparing the contractors are written down in a decision-making matrix (Table 1). The alternatives n considered in the paper are arranged in columns, while quantitative and qualitative information describing them is given in rows.

A great amount of information characterizes the performance of maintenance suppliers. However, it is not always exactly defined; therefore we must deal with incomplete information.

Alternative maintenance companies are evaluated and compared using mostly qualitative efficiency attributes: quality standard of management services, work organization, certification of company, range of services, reliability of company, staff qualification and past experience, communication skills, geographical market restrictions, etc. (Table 1). Initial data for maintenance contractors' evaluation is put in the table for initial data storage in software Levi 3.0 [22]. Using the scheme presented in Figure 1 by two ways solves the problem:

- Including the weights of attributes;
- Ignoring the weights of attributes.

The attributes involve quantitative and qualitative aspects. As mentioned above, values of the quantitative attributes are taken from the competitive bids of the applicants. The values of qualitative attributes and their weights are obtained from a survey of actual clients of maintenance companies that assessed the provided services and other issues based on experiences gained in cooperating with these firms. The attributes are rated on the ratio-interval scale limited in interval [0; 10] with scores from 0 [none] to 10 [maximum score]. Let the criterion value be denoted by x_{ij}, then $x_{ij} \in [0; 10]$, where x_{ij} is an integer, with the values ranging from 0 to 10 (10 points expressing excellent standard of quality, 9 very good, 8 good, 7 fairly good, 6 satisfactory, 5 poor, 4 mostly poor, repairable defects, 3 poor, non-repairable defects, 2 very poor, the client would like to break the contract with a firm, 1 very poor, defects causing accidents, 0 none). Another important task is as follows – to determine the weights of the attributes. It is done by application of expert's valuation method. Experts assess the level of importance of the qualitative attributes, on the ratio-interval scale limited in interval [0; 10], where the 10 points denote the strongest importance, 9 – very strong, 8 – strong, 7 – mostly strong, 6 – average, 5 – fair, 4 – low, 3 – mostly low, 2 – very low, 1 – none for particular clients, 0 – none. The weights of the attributes are assessed from the standpoint of clients (building's users). Calculated weights of attributes are presented in Table 1. Applying experts' methods the completed questionnaires are processed and the reliability of the expertise is determined by calculating a concordance coefficient that expresses the level of agreement of the experts' judgments. An expert's judgment method is applied when it is impossible to assess elements or their characteristics by objective measurement as well as when the bulk of the initial data is insufficient for statistical processing. In our case, the expert group consists of competent persons – specialists in the area of building maintenance.

Table 1. Initial data for multi-attribute evaluation (values of attributes and initial weights)

No.	Attributes	Units of measure-ments	q_j	Max/ min	Alternatives						
					V1	V2	V3	V4	V5	V6	V7
1.	Cost of building management	Lt^*/m^2	0,038	min	0.064	0.060	0.057	0.058	0.058	0.071	0.110
2.	Cost of common assets management	Lt/m^2	0,088	min	0.110	0.140	0.110	0.120	0.100	0.300	0.140
3.	HVAC system maintenance cost (mean)	Lt/m^2	0,099	min	0.180	0.180	0.370	0.180	0.090	0.180	0.180
4.	Courtyard territory cleaning (in summer)	Lt/m^2	0,105	min	0.310	0.120	0.150	0.150	0.200	0.260	0.120
5.	Total service cost	Lt/m^2	0,335	min	0.670	0.500	0.690	0.570	0.450	0.820	0.550
6.	Length of time in maintenance business (experience)	years	0,016	max	12.000	3.000	12.000	12.000	12.000	13.000	5.000
7.	Market share for each contractor (in Vilnius)	%	0,019	max	11.750	0.390	5.250	7.090	5.560	26.620	2.820
8.	Number of projects per executive	units/ person	0,011	max	4.600	0.330	1.470	2.780	1.390	5.670	1.200
9.	Evaluation of management cost (C_{min}/C_p)	-	0,029	max	0.830	0.885	0.935	0.912	0.912	0.746	0.483
10.	Quality standard of management services	points	0,029	max	9.000	6.500	7.250	7.000	7.500	7.500	9.000
11.	Quality of maintenance of common property	points	0,029	max	6.111	7.111	7.389	6.889	6.889	7.500	8.222
12.	Work organization	points	0,020	max	6.071	4.786	6.114	5.986	6.114	6.500	7.771
13.	The efficiency of information use	points	0,015	max	5.333	4.000	4.500	4.167	5.833	4.333	5.167
14.	Certification of company	points	0,016	max	9.000	2.000	9.000	9.000	9.000	9.000	2.000
15.	Range of services	points	0,024	max	4.000	3.000	3.500	4.300	5.900	3.500	7.500
16.	Reliability of company	points	0,029	max	8.000	6.000	8.000	8.000	8.700	8.000	7.000
17.	Company reputation	points	0,028	max	6.000	5.000	7.500	8.000	8.500	9.000	8.700
18.	Staff qualification and past experience	points	0,029	max	8.400	7.500	8.400	8.400	8.400	8.500	7.700
19.	Communication skills	points	0,025	max	3.000	6.000	7.000	7.000	7.600	8.000	8.500
20.	Geographical market restrictions	points	0,015	min	8.000	8.000	8.500	8.500	8.500	6.000	3.500
			1,000								

The continuation of Table 1

No.	Attributes	Units of measure-ments	Max/ min	Alternatives							
				V8	V9	V10	V11	V12	V13	V14	V15
1.	Cost of building management	Lt^{*}/m^2	min	0.058	0.053	0.071	0.120	0.071	0.078	0.056	0.120
2.	Cost of common assets management	Lt/m^2	min	0.180	0.140	0.260	0.200	0.280	0.200	0.140	0.140
3.	HVAC system maintenance cost (mean)	Lt/m^2	min	0.180	0.370	0.160	0.290	0.090	0.180	0.180	0.090
4.	Courtyard territory cleaning (in summer)	Lt/m^2	min	0.190	0.230	0.230	0.200	0.280	0.300	0.120	0.210
5.	Total service cost	Lt/m^2	min	0.610	0.800	0.730	0.810	0.730	0.760	0.500	0.560
6.	Length of time in maintenance business (experience)	years	max	11.000	11.000	11.000	4.000	12.000	8.000	11.000	3.000
7.	Market share for each contractor (in Vilnius)	%	max	9.480	2.230	13.470	4.700	2.350	5.600	2.660	0.040
8.	Number of projects per executive	units/ person	max	3.030	0.760	9.050	1.500	0.860	3.250	1.700	0.030
9.	Evaluation of management cost (C_{min}/C_p)	-	max	0.916	1.000	0.746	0.443	0.746	0.681	0.948	0.531
10.	Quality standard of management services	points	max	7.500	7.250	8.500	9.000	7.500	7.000	8.350	9.000
11.	Quality of maintenance of common property	points	max	6.389	6.333	7.222	8.444	6.422	5.778	6.611	8.111
12.	Work organization	points	max	6.357	6.700	6.400	8.343	6.571	5.829	6.643	8.100
13.	The efficiency of information use	points	max	5.167	5.167	4.667	8.333	3.833	4.500	5.900	7.167
14.	Certification of company	points	max	9.000	8.000	9.000	9.000	7.500	8.000	9.000	2.000
15.	Range of services	points	max	3.000	4.300	5.000	8.700	5.000	3.000	5.500	6.500
16.	Reliability of company	points	max	8.500	8.500	8.000	8.800	8.000	8.000	8.000	8.000
17.	Company reputation	points	max	8.500	7.900	8.500	9.000	9.000	8.500	5.500	9.000
18.	Staff qualification and past experience	points	max	8.300	8.300	8.300	8.600	8.400	8.000	8.400	7.500
19.	Communication skills	points	max	8.000	7.500	6.000	8.900	9.000	6.000	7.000	8.500
20.	Geographical market restrictions	points	min	8.500	8.000	8.500	3.500	8.600	8.600	8.500	3.500

Note: a basic monetary unit of Lithuania, divided decimally into 100 cents, 1 Lt = 3.4528 EUR (the exchange rate fixed by Lithuanian Central bank (2004-02-12))

4.1. Determination of the Weights of Attributes

The weights q_i of attributes presented in Table 1 were determined by application of the expert judgment method proposed by Kendall [28]. This expert judgment method was implemented at the following stages:

- Calculation of values t;
- Calculation of weights q;
- Calculation of values S;
- Calculation of values T_k;
- Calculation of values W;
- Calculation of values χ^2;
- Testing the statement $\chi^2 > \chi^2_{tbl}$.

The values t_{jk} for statistical processing were obtained by interviewing the respondents. The average attribute ranking value $\overline{t_j}$ was calculated by the formula:

$$\overline{t_j} = \frac{\sum_{k=1}^{r} t_{jk}}{r}, \tag{10}$$

Where t_{jk} is the ranking of the j-th attribute by the k-th respondent: r number of respondents.

The weights of the attributes were calculated by dividing the average ranking value of each attribute by the sum of the attribute average ranking values:

$$q = \frac{t_j}{\sum_{j=1}^{n} \overline{t_j}}. \tag{11}$$

The total weight of the attributes must be equal to one:

$$\sum_{j=1}^{n} \frac{t_j}{\sum_{j=1}^{n} \overline{t_j}} = 1{,}0 \cdot \tag{12}$$

Reliability of the data can be expressed by the coefficient of concordance (agreement) of the respondents' opinions by describing the extent to proximity of individual views. In cases with reiterated ranks for same parameters, as in our case, the coefficient of concordance is:

$$W = \frac{12S}{r^2(n^3 - n) - r\sum_{k=1}^{r} T_k}, \quad W \in [0;1]. \tag{13}$$

Where S – total square deviation of the rankings of each attribute, T_k – index of reiterated ranks in the r rank; r – number of respondents; n – number of evaluation attributes.

The deviation of the attribute ranking:

$$S = \sum_{j=1}^{n} \left[\sum_{k=1}^{r} t_{jk} - \frac{1}{n} \sum_{j=1}^{n} \sum_{k=1}^{r} t_{jk} \right]^2, \tag{14}$$

Where t_{jk} is the rank conferred by the k -th respondent to the j -th attribute.

However, the calculated value W is stochastic; and therefore, the significance of the concordance coefficient has to be calculated.

Kendall [28] has shown that, when $n > 7$, the value $\chi^2 = W \cdot r \cdot (n-1)$ has a distribution with degrees of freedom $v = n - 1$, where n is the number of attributes considered and r – number of experts. It has been proved that if the calculated value χ^2 is larger than the critical tabular value $\chi^2{}_{tbl}$ for the pre-selected level of significance (e.g. $\alpha = 0.05$), then the hypothesis about the agreement of independent experts' judgments is not rejected. In our case, we have $n = 36$, $v = 35$ and the pre-selected level of significance is $\alpha = 0.05$, therefore, the above-mentioned conditions should be satisfactory.

The significance χ^2 of the concordance coefficient is calculated as follows:

$$\chi^2_{\alpha,v} = W \cdot r \cdot (n-1) = \frac{12S}{rn(n+1) - \frac{1}{n-1}\sum_{k=1}^{r} T_k}. \tag{15}$$

If the $\chi^2_{\alpha,v} > \chi^2{}_{tbl}$ the significance of concordance coefficient exists on α level, then the agreement of experts' opinions is satisfactory and group opinion is established. Otherwise, when $\chi^2_{\alpha,v} < \chi^2{}_{tbl}$ is obtained, the respondents' opinions are not in agreement, which implies that they differ substantially and the hypothesis on the rank's correlation cannot be accepted.

The concordance coefficient based on the weights of attributes is W = 0.587. The value of $\chi^2_{\alpha,v}$ calculated by formula (14) is equal to 373.41. This value should be greater than the $\chi^2{}_{tbl}$, which depends on the degrees of freedom v and probability α. In this case, the tabular value was taken from Table IV as given in Fisher and Yates statistical tables [29]. When the degrees of freedom $v = n - 1$ (36 – 1 = 35) and pre-selected level of significance is $\alpha = 0.05$, in that case we have the value of $\chi^2{}_{tbl}$

equal to 49.80. Since 373.41 > 49.80 when $\alpha = 0.05$, and $v = 35$, then, the assumption is made that the coefficient of concordance is significant and expert rankings are in concordance with 95% probability.

4.2. The Analysis of Results after Performing the Operations with Many Attributes

The formed decision-making matrix was normalized using the method of vector normalization. Variants were compared applying the methods Topsis, Wald and Bayes rules. Calculations were made using two data sets: first with included weights of attributes and second – by ignoring weights of attributes. Calculations were made using the software Levi-3.0. Cumulative results are presented in Table 2. The determined priority orders are presented in Table 3. Striving to determine the reliability of obtained results the errors of calculation are determined further.

Table 2. Cumulative results of variants' evaluation considering many attributes

Applied method	Variants														
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15
Topsis (including q)	0,623	0,688	0,465	0,539	0,794	0,419	0,667	0,611	0,380	0,489	0,376	0,495	0,442	0,710	0,687
Topsis (ignoring q)	0,618	0,449	0,498	0,368	0,556	0,675	0,476	0,569	0,469	0,676	0,484	0,487	0,507	0,526	0,454
Wald rule	0,020	0,010	0,090	0,170	0,090	0,110	0,070	0,090	0,060	0,110	0,100	0,070	0,120	0,070	0,000
Bayes rule	0,230	0,186	0,255	0,249	0,199	0,301	0,211	0,239	0,282	0,274	0,288	0,263	0,266	0,207	0,211

Table 3. The priority orders of the variants

Applied method	The weights (q) of attributes	Priority order of variants
Topsis	Included	$Q_5 \succ Q_{14} \succ Q_2 \succ Q_{15} \succ Q_7 \succ Q_1 \succ Q_8 \succ Q_4 \succ Q_{12} \succ Q_{10} \succ Q_3 \succ Q_{13} \succ Q_6 \succ Q_9 \succ Q_{11}$
Topsis	Ignored	$Q_{10} \succ Q_6 \succ Q_1 \succ Q_8 \succ Q_5 \succ Q_{14} \succ Q_{13} \succ Q_3 \succ Q_{12} \succ Q_{11} \succ Q_7 \succ Q_9 \succ Q_{15} \succ Q_2 \succ Q_4$
Wald rule	Ignored	$Q_4 \succ Q_{13} \succ Q_{10} \succ Q_6 \succ Q_{11} \succ Q_5 \succ Q_8 \succ Q_3 \succ Q_{14} \succ Q_7 \succ Q_{12} \succ Q_9 \succ Q_1 \succ Q_2 \succ Q_{15}$
Bayes rule	Included	$Q_6 \succ Q_{11} \succ Q_9 \succ Q_{10} \succ Q_{13} \succ Q_{12} \succ Q_3 \succ Q_4 \succ Q_8 \succ Q_1 \succ Q_{15} \succ Q_7 \succ Q_{14} \succ Q_5 \succ Q_2$

Note: the symbol "$\succ$" means "better than"

The ranking of priority orders presented in Table 3 shows the high level of dispersion of calculation results. All methods show the different priorities of the most reasonable variant.

4.3. The Determination of Accuracy of Calculations and Minimization the Number of Attributes

Solving the multi-objective problems the data is transforming according to certain functional dependencies. When processing the initial data of decision-making matrix the meanings of attributes are determining with certain biases. Therefore the decision results have certain biases. The reasonable implications about the priority order of variants could be done only if the accuracy of calculated final values (the relative importance of variants) is known. Considering the errors of attributes' calculation as random values, the methods of probability theory and mathematical statistics could be applied to evaluate the calculation results. To characterize the accuracy of attributes' values the concepts of dispersion and mean squared deviation (or standard deviation) are used. The dispersion is equal to square root of the mean squared deviation:

$$D(x) = \sigma^2, \tag{16}$$

$$D(x) = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2. \tag{17}$$

In practice processing not large data sets the dispersion measure is changing to mean squared deviation. Scientists often use the term root-mean-square as a synonym for standard deviation when they refer to the square root of the mean squared deviation of a quantity from a given baseline. The standard deviation σ of a probability distribution is defined as the square root of the variance σ^2 [30]:

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2} \ . \tag{18}$$

Whereas the differences of variants' relative importance are not considerable, the statistical significance of these differences and reliability of results in predefined limits of errors have to be determined. To determine mean square deviation the operations were made with vector normalized matrix. The calculation results of dispersion and mean squared deviation presented in Table 4. There we can see that the standard deviation values of some attributes exceed the calculated average values of these attributes. Particularly high errors appear when weights of attributes are ignored. Consequently, the results of calculations performing with many attributes can be inaccurate.

Table 4. Dispersions and deviations of calculation results

Weight		Attributes												
		x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	…	x19	x20
Included	Mean	0,007	0,022	0,035	0,025	0,084	0,005	0,137	0,002	0,012	0,012	…	0,005	0,003
	D(x)	0,000	0,000	0,002	0,000	0,000	0,000	0,186	0,000	0,000	0,000	…	0,000	0,000
	σ	**0,007**	**0,007**	**0,039**	**0,007**	**0,013**	**0,002**	**0,431**	**0,002**	**0,016**	**0,014**	**…**	**0,001**	**0,001**
Ignored	Mean	0,167	0,243	0,229	0,247	0,254	0,241	0,185	0,190	0,252	0,257	…	0,253	0,249
	D(x)	0,029	0,006	0,011	0,004	0,002	0,006	0,025	0,023	0,002	0,001	…	0,002	0,004
	σ	**0,171**	**0,077**	**0,103**	**0,065**	**0,041**	**0,079**	**0,157**	**0,152**	**0,048**	**0,024**	**…**	**0,045**	**0,059**

Striving to increase the precision of solution results authors had reduced the number of attributes by eliminating those with relatively low significance. The same operations with few attributes were done using the considered methods (see Figure 1).

The reduction of non-significant attributes was done by elimination of attributes with weights less than 5 percent. The attributes were rated ascribing to them the integer discrete values and considering the 0.5-point accuracy of calculation. In ten-point scale it comprises the 5 percent. Therefore, the attribute, which meanings were less than 5 percent, has less influence on the final result and it was eliminated. The less important attributes were eliminated and more important were aggregated so, that their total importance would be higher than the considered maximum allowable 5 percent error of calculation.

According to the initial weights presented in Table 1 significant attributes were selected. The attributes 'Cost of building management', 'Length of time in maintenance business (experience)', 'Market share for each contractor (in Vilnius)', 'Number of projects per executive', 'Evaluation of management cost (C_{min}/C_p)' were eliminated. The attributes with the meanings of the weights less than accepted maximum allowable level of error, which were considered by experts to be significant, were aggregated by summarizing the values of their meanings and values of their weights by this way:

- Attributes 'Quality Standard of management services' and 'Quality of maintenance of common property' were aggregated in one attribute named as '*Maintenance and management quality*' (q = 0.029 + 0.029 = 0.058).
- Attributes 'Staff qualification and past experience' and 'Communication skills' were aggregated in one attribute named as '*Staff qualification, skills and past experience*' (q = 0.029 + 0.025 = 0.054).

- Attributes ‘Certification of company’, ‘Reliability of company’ and ‘Company reputation’ were aggregated in one attribute named as ‘*Company reliability, reputation and certification*’ (q=0.016+0.029+0.028=0.073).
- Attributes ‘Work organization’, ‘The efficiency of information use’ and ‘Range of services’ were aggregated in one attribute named as ‘*The efficiency of work organization and range of services*’ (q = 0.02 + 0.015 + 0.024 = 0.059).

After recalculation the following set of attributes was formed: ‘Cost of building management’ (x1), ‘HVAC system maintenance cost’ (x2), ‘Courtyard territory cleaning’ (x3), ‘Total service cost’ (x4), ‘Maintenance and management quality’ (x5), ‘Staff qualification, skills and past experience’ (x6), ‘Company reliability, reputation and certification’ (x7), ‘The efficiency of work organization and range of services’ (x8). Determining the mean of compounded attributes recalculated the values of aggregated attributes. The new-formed decision-making matrix with eight attributes is presented in Table 5. Here the variants presented in lines and the meanings of attributes presented in columns.

The weights of new aggregated attributes were recalculated by summarizing the weights of compounded attributes and presented in Table 5 by marking them as q_{req1}. However, the total weight of recalculated attributes $\sum q_{req1}$ contravenes the condition (12). Therefore, in order to reach the conformity with condition (12), the weights of attributes were recalculated according to formula (11) and in Table 5 presented as q_{req2}. The calculated total value $\sum q_{req2}$ matches the condition (12).

Table 5. New formed initial decision-making matrix with eight attributes and recalculated weights

Variant	Attributes								
	x1(-)	x2(-)	x3(-)	x4(-)	x5(+)	x6(+)	x7(+)	x8(+)	Total
q_{req1}	0,088	0,099	0,105	0,335	0,058	0,054	0,073	0,059	$\sum q_{req1} = 0{,}870$
q_{req2}	0,101	0,114	0,121	0,385	0,066	0,062	0,084	0,067	$\sum q_{req2} = 1{,}000$
V1	0,110	0,018	0,310	0,670	15,100	11400	23000	15400	
V2	0,140	0,180	0,120	0,500	13,600	13,500	13,000	11,800	
V3	0,110	0,370	0,150	0,690	14,600	15,400	24,500	14,100	
V4	0,120	0,180	0,150	0,570	13,900	15,400	25,000	14,500	
V5	0,100	0,090	0,200	0,450	14,400	16,000	26,200	17,800	
V6	0,300	0,180	0,260	0,820	15,000	16,500	26,000	14,300	
V7	0,140	0,180	0,120	0,550	17,200	16,200	17,700	20,400	
V8	0,180	0,180	0,190	0,610	13,900	16,300	26,000	14,500	
V9	0,140	0,370	0,230	0,800	13,600	15,800	24,400	16,200	
V10	0,260	0,160	0,230	0,730	15,700	14,300	25,500	16,100	
V11	0,200	0,290	0,200	0,810	17,400	17,500	26,800	25,400	
V12	0,280	0,090	0,280	0,730	13,300	17,400	24,500	15,400	
V13	0,200	0,180	0,300	0,760	12,800	14,000	24,500	13,300	
V14	0,140	0,180	0,120	0,500	15,000	15,400	22,500	18,000	
V15	0,140	0,090	0,210	0,560	17,100	16,000	19,000	21,800	

Data in Table 5 was processed according to the way used in the first case – by applying the methods Topsis, Wald rule and Bayes rule. Calculations were made also using two data sets: first with included weights of attributes and second – by ignoring weights of attributes. Calculations were made using the same software package. Cumulative results are presented in Table 6. The determined priority orders are presented in Table 7. The dispersion of calculation results processing the data of large number of attributes is presented in Figure 2 and the dispersion of calculation results processing the data of few attributes is presented in Figure 3.

Comparing the results of the calculations with large number of attributes and few attributes, the second case gives more compatible results than first case, the dispersion of results is less and only two alternative variants are shown as the most reasonable.

Table 6. Cumulative results of variants' evaluation considering few attributes

Applied method	Variants														
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15
Topsis (including q)	0,505	0,491	0,285	0,462	0,519	0,576	0,512	0,507	0,214	0,598	0,414	0,641	0,437	0,515	0,554
Topsis (ignoring q)	0,530	0,468	0,309	0,486	0,567	0,543	0,542	0,514	0,261	0,573	0,470	0,616	0,431	0,540	0,600
Wald rule	0,020	0,140	0,160	0,170	0,110	0,220	0,140	0,220	0,200	0,200	0,240	0,110	0,200	0,140	0,110
Bayes rule	0,215	0,192	0,256	0,215	0,202	0,304	0,220	0,244	0,288	0,279	0,307	0,279	0,272	0,214	0,224

Table 7. The priority orders of the variants

Applied method	The weights (q_{req2}) of attributes	Priority order of variants
Topsis	Included	$Q_{12} \succ Q_{10} \succ Q_6 \succ Q_{15} \succ Q_5 \succ Q_{14} \succ Q_7 \succ Q_8 \succ Q_1 \succ Q_2 \succ Q_4 \succ Q_{13} \succ Q_{11} \succ Q_3 \succ Q_9$
Topsis	Ignored	$Q_{12} \succ Q_{15} \succ Q_{10} \succ Q_5 \succ Q_6 \succ Q_7 \succ Q_{14} \succ Q_1 \succ Q_8 \succ Q_4 \succ Q_{11} \succ Q_2 \succ Q_{13} \succ Q_3 \succ Q_9$
Wald rule	Ignored	$Q_{11} \succ Q_8 \succ Q_6 \succ Q_{13} \succ Q_{10} \succ Q_9 \succ Q_4 \succ Q_3 \succ Q_7 \succ Q_{14} \succ Q_2 \succ Q_5 \succ Q_{12} \succ Q_{15} \succ Q_1$
Bayes rule	Included	$Q_{11} \succ Q_6 \succ Q_9 \succ Q_{12} \succ Q_{10} \succ Q_{13} \succ Q_3 \succ Q_8 \succ Q_{15} \succ Q_7 \succ Q_1 \succ Q_4 \succ Q_{14} \succ Q_5 \succ Q_2$

Note: the symbol "$\succ$" means "better than"

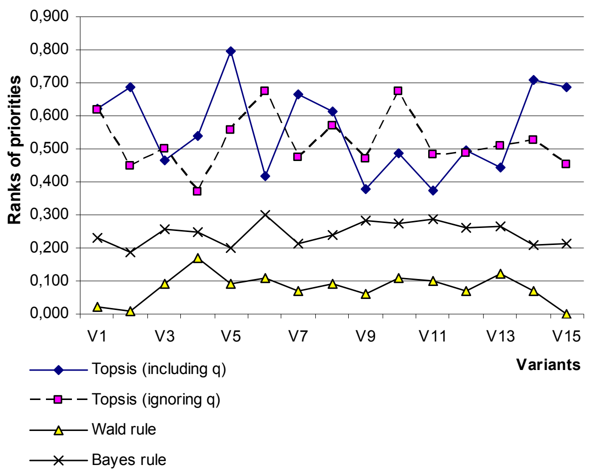


Figure 2. *The dispersion of calculation results processing the data of large number of attributes*

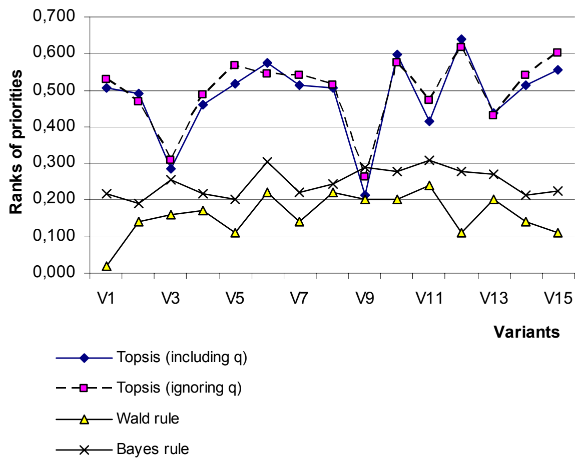


Figure 3. *The dispersion of calculation results processing the data of few attributes*

CONCLUSIONS

The results obtained in solving the problem reveal that considering the large number of attributes and ignoring their weights the less important attributes have high influence on final result. Therefore, the risk exists that irrational decision could be selected. Moreover, when the variants are characterized by large number of attributes rated in 10 points scale with the accuracy of calculation is 0,5 point, or 5% the attributes with significance less than 5% have less influence of final result than the values of possible errors and can be eliminated from decision-making matrix. For the reason to make the efficient decision it is purposeful to use not large number of attributes including their weights.

The results obtained in solving the problem of case study show that the eleventh and twelfth alternatives are more rational than other in satisfying the needs and objectives of the building user. Practical application of the suggested methods for maintenance contractor selection can help all the interested groups to harmonize their diverse interests and objectives and to enhance the procedure of decision-making. The application of multi-attribute analysis to the selection of rational decision helps to take the appropriate decision based on various attributes, which may reduce the risk in the selection process. This confirms an assumption that the above-applied methods can be successfully applied in practice. The suggested methods may be successfully applied not only to planning the maintenance work but also to solve different problems in many other fields dealing with incomplete information.

References

[1] Pareto V. *Manual of Political Economy / A. M. Kelley*. New York, 1971.

[2] Seo F. Organizational aspects of multicriteria decision-making. In: *Lecture Notes in Economics and Mathematical System.* Berlin, Heidelberg, New York, 1981, pp. 363-379.

[3] Tanino T., Nakayama H., Swaragi Y. Methodology for group decision support. In: *Lecture Notes in Economics and Mathematical System*. Berlin, Heidelberg, New York, 1981, pp. 409-423.

[4] Keeney R.L., Raiffa H. *Decision with multiple objectives: preferences and value tradeoffs.* New York: John Wiley & Sons, 1976.

[5] Keeney R.L. Decision analysis: an overview, *Operations Research*, 30(5), 1982, pp. 803-838.

[6] Keeney R.L., von Winterfeldt D. Appraising the precautionary principle – a decision analysis perspective, *Journal of Risk Research,* 4(2), 2001, pp. 191-202.

[7] Saaty T.L. *Mathematical models of conflict situations*. Moscow: Sov. Radio, 1977, p. 304. (In Russian)

[8] Saaty T.L., Vargas L.G., Dellmann K. The allocation of intangible resources: The Analytic Hierarchy Process and linear programming, *Socio-Economic Planning Sciences*, 37, 2003, pp. 169-184.

[9] Larichev O. *Decision-making theory and methods*. Moscow: Logos, 2000. 295 p. (In Russian)

[10] Hwang C. L., Yoon K. S. Multiple Attribute Decision Making. In: *Methods and Applications*. Berlin, Heidelberg, New York: Springer-Verlag, 1981. 259 p.

[11] Arditi D., Gunaydin H.M. Perception of process quality in building projects, *Journal of Management in Engineering*, 15(2), 1998, pp. 43-53.

[12] MacCrimon K. R. *Decision Marking Among Multiple–Attribute Alternatives: A Survey and Consolidated Approach: RAND Memorandum.* RM-4823-ARPA.

[13] Srinivasan V., Shocker A. D. Linear Programming techniques for multidimensional analysis of privileged, *Psychometrics*, Vol. 38, 1973, pp. 337-369.

[14] Saaty T. L. Highlights and critical points in theory and application of the Analytic Hierarchy Process, *European Journal of Operational Research*, Vol. 74, 1994, pp. 426-447.

[15] Zimmermann H.-J. An application-oriented view of modelling uncertainty, *European Journal of Operational Research*, Vol. 122 (2), 2000, pp. 190-198.

[16] Roy B. Multicriteria Methodology for Decision Aiding. Dortrecht: Kluwer Academic Publishers, 1996. 293 p.

[17] Brans J. P., Marschal B., Vincke Ph. Promethean: A new family of outranking methods in multicriteria analysis. In: *Operational Research'84. / J. P. Brans (Ed.).* North Holland: Elsevier Science Publishers B. V. 1984, pp. 408-421.

[18] Larichev O., Moshkovich E. *Qualitative decision-making methods*. Moscow: Fizmalit. 1996. (In Russian)

[19] Urli B., Nadeau R. Evolution of multi-criteria analysis: a scientometric analysis, *Journal of Multi-criteria Decision Analysis*, 8, 1999, pp. 31-43.

[20] Train K. *Discrete Methods with Simulation*. Cambridge: Cambridge University Press Publisher, 2002, 286 p.

[21] Triantaphyllou E. Multi-criteria Decision Making Methods: A Comparative Study, *Applied Optimization,* 44, 2000, p.289.

[22] Zavadskas E.K., Ustinovičius L., Turskis Z., Peldschus F., Messing D. LEVI 3.0 – multiple criteria evaluation program for construction solutions, *Journal of Civil Engineering and Management*, 8(3), 2002, pp. 184-191. (Vilnius: Technika)

[23] Wald A. Statistical decisions functions, which minimize the maximum risk, *Annals of Mathematics*, 1945, pp. 265-280.

[24] Savage L. J. The Theory of Statistical Decision, *Journal of the American Statistical Association*, 1951, p. 55-57.

[25] Hurwicz L. Optimality Criteria for Decision Making under Ignorance. Cowles Commission Paper, *Statistics*, No 370, 1951, pp. 45-52.

[26] Arrow K. J. Bayes and Minimax Solutions of Sequential Decision Problems, *Econometrica,* 1949, pp. 213-243.

[27] Hodges Jr. J. L., Lehmann E. L. The Use of Previous Experience in Reaching Statistical Decision, *Annals of Mathematics Studies,* 1952, pp. 396-407.

[28] Kendall MG. *Rank Correlation Methods. 4-th ed.* London: Griffin, 1970.

[29] Fisher R.A., Yates F. *Statistical tables for biological, agricultural and medical research. 6-th ed*. London: Oliver and Boyd, 1963.

[30] Kenney J. F. and Keeping E. S. *Mathematics of Statistics. 3rd ed.* Princeton, NJ: Van Nostrand, 1962.

AUTOMATED VALUATION MODELS AND KNOWLEDGE-BASED DECISION SUPPORT IN REAL ESTATE VALUATION

Arturas Kaklauskas, Mindaugas Krutinis, Laura Tupenaite, Jurga Naimavičienė, Andrius Gulbinas, Loreta Kanapeckienė

Vilnius Gediminas Technical University
Sauletekio Ave. 11, LT-10223 Vilnius, Lithuania
Arturas.Kaklauskas@st.vtu.lt

In this paper Automated Valuation Models (AVMs) as well as Real Estate's Knowledge and Device-based Decision Support Systems are discussed. The main purpose is to present automated valuation modelling methods that the modern economy requires.

Automated Valuation Models (AVMs) are the latest hot topic for many appraisers, replacing appraisal management companies. AVMs are computer programs that use real estate information, such as demographics, property characteristics, sales prices, and price trends to calculate a value for a specific property. There is a bright future for those appraisers who understand the dynamics in their market and anticipate or always respond to change. More automated valuation processes and products have an important role to play in the future provision of valuation services. The valuation community must rise to the challenge of developing a professional class of appraisers in emerging economies. As in the USA AVMs have been around for at least 20 years in appraising, starting with multiple regression programs used for mass assessments by assessors' offices, in order to form clear understanding of modern valuation and used products, the USA practice in detail is analysed.

The authors of this paper participated in the project Framework 6 "Intelligent Cities" (INTELCITIES). One of INTELCITIES's goals (on the Lithuanian side) was to develop a Real Estate's Knowledge and Device-based Decision Support System (KDDSS-RE). Major KDDSS-RE functions include creating and maintaining customer's personalized real estate objectives, preferences, and evaluation criteria; participation of various stakeholders (buyers, sellers, brokers, etc.) in joint determination of criteria (criteria system, values and weights) defining real estate; market signalling, provide device-based data about indoor microclimates and allergens causing allergy in buildings; searching for real estate alternatives, finding alternatives and making an initial negotiation table, completing a multiple criteria analysis of alternatives, making electronic negotiations based on real calculations, determining the most rational real estate purchase variant, and completing an analysis of loan alternatives offered by certain banks. In order to demonstrate the integration decision support, knowledge and device systems in the real estate sector a Real Estate's Knowledge and Devices-based Decision Support System have been considered in the paper as an example.

Keywords: Real Estate valuation, Automated Valuation Models, Knowledge Based Technologies, Decision Support System

1. INTRODUCTION

The speedy boost of the Internet and intelligent technologies and applications in recent years has driven real estate sector towards adopting innovative e-transformations. Unavoidably, the real estate sector has also clashed with new challenges that moved them forward to implement innovative Internet and intelligent technologies. Developing innovative services is very important for the survival of stakeholders in the real estate sector because of grim market competition and an increase of competitive abilities. The growing demand for information and knowledge-based decision-support facilities that integrate personalized and collaborative needs and requirements in all real estate sector activities has also been noticed further.

There is a bright future for those appraisers who understand the dynamics in their market and anticipate or always respond to change. The consequence of failing to respond is inevitable decline in the long-term. More automated valuation processes and products have an important role to play in the future provision of valuation services. The valuation community must rise to the challenge of developing a professional class of appraisers in emerging economies. Governments should insist on good quality valuation in their jurisdictions as they have a major role to play in consumer protection. The leading professional organizations in the world must ensure that collectively and individually they attract the best possible candidates into it [12].

Throughout the world there are many examples of the adoption of Web-based information and intelligent systems by major players in real estate. Some of them are as follows: e-commerce [28,33], appraisal services [32], brokerage [13,14], facility management [2,10], mortgages [1,8], real estate management [7,29], insurance [5], project development [31], sustainable development [32], real estate finance [33], matching/listing services [6], negotiation [34], real estate's transaction process [9,32], etc. For example, in Forbes's [11] opinion, the forward corporation must successfully integrate facilities management with finance and administrative activities, sales and marketing, human resources, information management, manufacturing, distribution, and these should be Web centric.

Automated valuation, decision support systems were analysed by many authors. Ibrahim et al. [16] constructed automated valuation model to value Housing and Development Board resale flats in Singapore. Gilbertson [12] analysed actions needed to ensure the provision of the valuation services that the modern economy requires. Fisher [9] discussed producing of timely and more reliable estimates of changes in the value of portfolios, price indices based on portfolio of properties, and other aggregate measures of trends in property values. McGreal et al. [27] questioned whether predicted outcomes are within the range of valuation acceptability; and he examines issues relating to potential biasing and repeatability of results. McCluskey and Anand [26] analysed application of intelligent hybrid techniques for the mass appraisal of residential properties. Automated valuations, decision support systems, e-commerce in real estate were extensively analysed by Zavadskas, Kaklauskas at al. [17-24]. Raslanas et al. used multiply regressions for Vilnius and London prices modelling [30].

Researches interest, automated valuation and decision support use in many real estate and other relevant fields shows that this methodology of valuation becomes more and more popular, responding to knowledge society needs. For this purpose Automated Valuation Models (AVMs) as well as Real Estate's Knowledge and Device-based Decision Support Systems are further discussed.

2. AUTOMATED VALUATION MODELS IN REAL ESTATE APPRAISAL

Discussions on AVMs should begin with clear definition. In this paper AVMs are understood as computer programs that use real estate information, such as demographics, property characteristics, sales prices, and price trends to calculate a value for a specific property.

The basis of AVMs is adjustments, whether used as an MRA, neural network (multiple MRA equations) [4], appraiser emulation, hybrid method [3] or other method.

Automated Valuation Models (AVMs) are the latest hot topic for many appraisers, replacing appraisal management companies (AMCs). As with AMCs, AVMs have been around for at least 20 years in appraising, starting with multiple regression programs used for mass assessments by assessors' offices [3].

The key to an accurate AVM valuation is data. According to Fisher [9], it is argued that a traditional market value appraisal of each individual property may not be necessary or optimal when the objective is to value portfolios or get a leading indicator of shifts in market value at an aggregate level. Rather, it is more important to use a critical mass of current market data that captures systematic movements in property values. Although a traditional market value appraisal is always more likely to capture the unique unsystematic characteristics of an individual property, automated valuation models using a database of valuation data may provide the best way to get real time interim updates of real estate portfolios and create more timely real estate indices.

Although many lenders thought AVMs could provide values for all their loans, many areas don't have adequate data. Some states, such as Texas in the USA, are non-disclosure on sales price. Even California, which supposedly has some of the „best“ data, has many counties (including urban counties) that don't provide data on property characteristics or only limited data. Other counties sell their data for very high prices.

According to Lewis Allen, appraiser and AVM consultant, appraisers have never been as accurate as mortgage lenders thought [3]. As appraisers know, values for very similar homes actually fall along a bell shaped curve. For lending purposes, we appraise the probable sales price along a curve or range of possible values. When two (or more) appraisers value one and the same home, seldom are the values the same.

That's one of the reasons lenders like to use AVMs. They don't have the "human" element. In this way automated valuation becomes more objective and easier understandable. But, of course, AVMs can't get any more accurate than the bell shaped curve. Some companies (Real info, for example) provide automated property valuation solutions at a fraction of the cost of traditional appraisal methods in a fraction of the time. By utilizing their proprietary AVM technology, they arrive at a value 80% of the time. The following Table 1 provides further information on some AVMs products.

Table 1. AVMs products descriptions

Product	Description
Q-Val™ Report Automated Valuation Model (AVM)	The Q-Val™ (a.k.a. Quick Value) Report takes advantage of the large database through a rules-based, expert systems model to arrive at a predicted market value for a particular residential property. This tool is useful for home equity lenders, real estate agents, mortgage brokers and bankers, private lenders, homebuyers and many more
***i*-Val™ Report** Automated Valuation Model (AVM)	The *i*-Val™ (a.k.a. Instant Value) Report takes advantage of the large database through a rules-based, expert systems model to instantly arrive at a predicted market value for a particular residential property
realAssessment™ Report Automated Valuation Model (AVM)	The realAssessment™ Report is an estimated value based on assessed value and computer analysed and calculated equalization rate
CASA™ Automated Valuation Model (AVM)	CSW's Characteristics and Sales Analysis ("CASA") Service leverages a very large, meticulously filtered property records database and multiple, market-specific analytic approaches to estimate current market values for individual residential properties (single family and condominium)
ValueSure™ Automated Valuation Model (AVM)	ValueSure™ generates a value estimate, comparable sales listing, and location map, along with a confidence factor that reflects the extent of available data and accuracy of the value estimate
VeroVALUE Automated Valuation Model (AVM)	VeroVALUE is a state-of-the-art automated valuation model (AVM) used for residential property valuation. Veros has combined the reliability of real estate fundamentals with the power of our proprietary advanced predictive technologies resulting in highly accurate valuations
PowerBASE Automated Valuation Model (AVM)	PowerBASE 6.0 combines two proprietary engines (PowerBASE and HPA) to simultaneously calculate a more accurate and reliable property valuation than any single-source process
ValuePoint Automated Valuation Model (AVM)	Provides estimated value; estimated valuation range, date of valuation; a confidence score; last market sale information and prior market sale information along with list of recent market sales
PASS Automated Valuation Model (AVM)	Powered by proprietary data warehousing, PASS delivers highly accurate and reliable valuation results for first mortgage, home equity and high LTV lenders
HPA Automated Valuation Model (AVM)	Home Price Analyser is known throughout the industry for generating precise, immediate and reliable residential property valuations
AVM Insurance	Offered through a national insurance company paying the Insured any covered Loss resulting from a Default of a Loan and a Faulty Original Evaluation. Please contact a sales representative for more information on how our AVM's and insurance can work for you
Flood Certification	This report clearly states whether a particular property is within a flood zone. It uses the Federal Emergency Management Agency (FEMA) flood hazard areas to determine flood hazard levels. 24-hour turn around time
Appraisal Quote	This is a free service that will return the user an estimated cost to complete an appraisal of the property in question. 24-hour turn around time
704 Interior Appraisal Report (Short Form)	This form represents a shortened version of a full report. The interior and exterior of the property is inspected
704 Drive-By Appraisal Report (Short Form)	This form represents a shortened version of a full report. Only the exterior of the property is inspected

Allen sees collateral risk-based pricing, where more accurate values (less „variante“), with a lower range, will get a lower interest rate. Appraisers need to rethink the service they provide, separating the factual data and trends from the final subjective opinion of value. In the Annex 1 automated appraisal report is given. It shows how accurately real estate prices can be predicted by using automated valuation models.

Evolution of AVMs begins with multiple regression analysis methodology. Before the term AVM became widely used, multiple regression analysis (MRA) was the most used term for computer-based valuations.

MRA has been around for many years, in many types of applications, for determining which variables are most important in determining an outcome [15]. In valuation applications, an MRA is used to determine if square footage, lot size, age, quality, etc. affect property values, and by how much. Scientists (and some appraisers) use MRA in other valuation related applications, which are frequently published in appraisal journals. For example Zavadskas, Kaklauskas, Raslanas et al. [23,30] used this methodology for refurbishment decisions support, prices predicting.

Valuation done by using an adjustment grid is the way how MRA or AVM determines value. The MRA or AVM uses mathematical calculations to determine the dollar amount of the adjustments In its simplest form, a regression analysis is a calculation that takes a property characteristic such as square footage and determines a value, similar to a square footage adjustment. For instance, the house of 2,000 sq.ft. multiplying by $100 per sq.ft. gives a value of $200,000. In this example, the equation would be $Y = 100X$, where Y is the value and X is the square footage of the house.

Appraisers can use MRA features in spreadsheet programs or statistical programs such as SPSS, STATISTICA, etc.

Some AVMs use more than one method of calculating a value. Typically MRA and appraiser emulation are used. Appraiser emulation is more like what an appraiser does. The most similar sales are selected and adjustments are made.

No commercially available AVMs let the user know the equations used in calculating values, as the equations are proprietary. Sometimes it is possible to find out which variables are most important. A few let you see adjustments that were made on their appraiser emulation models, where adjustments are made on a grid, like on an appraisal report.

Some AVMs allow user input, such as changing a square footage or inputting a time adjustment, and others don't allow any input. The main reason for not allowing user input is to eliminate the human element from valuation. These AVMs are seen as “pure” without human errors and bias [3].

Public records are the primary data source for all commercially available AVMs. The AVM vendor typically purchases this data. Some vendors collect part of their data, particularly if they work only a few states. Public records data is used for both the subject and the computers. Some vendors use additional enhanced property data, with information from appraisals or other sources. If an address is input and the AVM has no property characteristics or previous sale (for price trending) it cannot be run.

For example, no AVM provider has 100% coverage in the U.S. In many areas, particularly rural areas, no one compiles and sells the data. In such circumstances national AVM vendors compete on how many counties they can cover.

In many states, tax assessment information can be used to determine values. This is particularly useful for a local appraisal firm or lender, who is familiar with local assessment practices. Some assessments are at 100% of market value and some are at 6%.

One of the major weaknesses in AVMs is a lack of a physical inspection of the properties. Methods such as verifying an address of Postal Service and using aerial photography are possible strategies for cutting down on fraud. But there is no substitute for a physical inspection.

It can be concluded that no AVM is perfect. They all have data problems. The best AVM for a user gives the most accurate results with the most “hits”, for their “comfort level” of acceptable risk. Some models perform better than others, but all depend on data to get reliable results. If AVM is used in an area with few sales, it won’t be very reliable. If the AVM database has no property characteristics for the subject property, it won't run if it doesn't allow user input. If AVM runs from a vendor that also provides better data than another equivalent AVM, it will be more reliable.

AVMs can be used for Real Estate Decisions Support. It is discussed further.

3. REAL ESTATE’S KNOWLEDGE AND DEVICE-BASED DECISION SUPPORT SYSTEM

KDDSS-RE is a Real Estate’s Knowledge and Device-based Decision Support System that was developed by the authors and can be found at the following Web address: http://dss.vtu.lt/realestate/. Major KDDSS-RE functions include creating and maintaining customer’s personalized real estate objectives, preferences, and evaluation criteria; participation of various stakeholders (buyers, sellers, brokers, etc.) in joint determination of criteria (criteria system, values and weights) defining real estate; market signalling, providing device-based data about the indoor microclimate and allergens causing allergy in the building; searching for real estate alternatives, finding alternatives and making an initial negotiation table, completing a multiple criteria analysis of alternatives, making electronic negotiations based on real calculations, determining the most rational real estate purchase variant, and completing an analysis of the loan alternatives offered by certain banks.

The KDDSS-RE consists of a Decision Support Subsystem, Knowledge Subsystem and Devices Subsystem. A more detailed description of these Subsystems follows.

Decision Support Subsystem (DSS-RE) consists of a database, a database management system, model-base, a model-base management system and a user interface (see Fig. 1). The Decision Support Subsystem was developed by using methods [22-25,36] that were developed by authors, i.e. a method of complex determination of the weights of the criteria taking into account their quantitative and qualitative characteristics; a method of multiple criteria complex proportional evaluation of the projects; and a method of defining the utility and market value of a real estate.

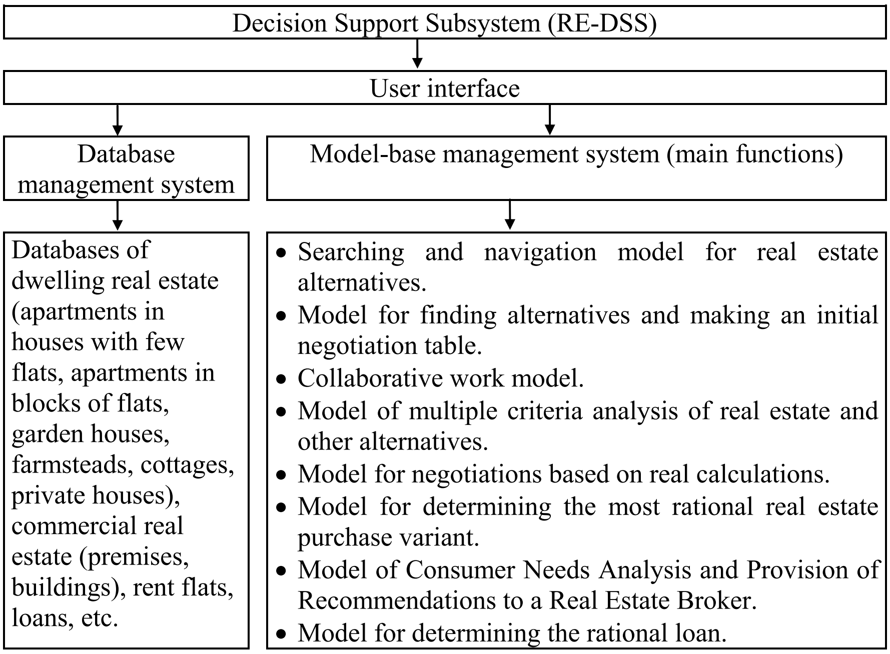


Fig. 1. *Components of Decision Support Subsystem*

Real estate listings are an interface for a seller to post listings. The system provides forms for completion by sellers or real estate on information about their real estate. Real estate brokers wishing to present information on their objects must receive permission from DSS-RE administrator. Having this permission the broker then inserts all the necessary information about real estate objects under sale in the DSS-RE databases according to the system’s requirements (i.e. system of criteria, values and weights of criteria). Access to databases developed personally by brokers is provided only to the broker and to the DSS-RE administrator. At present the developed DSS-RE allows for the performance of nine five main functions. In order to throw more light on the DSS-RE, a more detailed description of some of the above-mentioned Subsystem functions follows.

Data Search and the Navigation Module give a buyer a search and navigational instrument to retrieve and browse exhaustive real estate data and alternatives such as single family house, two, three or four-room flats in different locations and of different quality, etc. Buyers can also choose and keep/save attractive real estate alternatives in a personal preferred list. This real estate search and navigation module is available in the following databases: databases of dwelling real estate (apartments in houses with few flats, apartments in blocks of flats, garden houses, farmsteads, cottages and private houses), commercial real estate (premises, buildings), rented flats and loans, etc. A consumer may perform a search for real estate alternatives from databases with different brokers. This is possible because the forms of data submissions are standardized at a specific level. Such standardization creates conditions that can be applied to special intelligent agents that are performing a search for the required real estate in various databases, and for the gathering information/knowledge.

Consumers specify requirements and constraints and the system queries the information of a specific real estate from a number of online brokers. The system performs the tedious, time-consuming, and repetitive tasks of searching databases, retrieving and filtering information/knowledge, and delivering it back to the user. Search results for a specific real estate are submitted in a textual, photo/video and graphical information on the real estate's alternatives and the initial negotiation table, which may include direct links to a broker's Web page. When submitting such a display, the multiple criteria comparisons will become more effectively supported.

The brokers or sellers offer many different real estate alternatives to the market, while at the same time buyers identify their detailed requirements. First, buyers are offered a system of typical criteria on the basis of which real estate evaluators and buyers evaluate real estate alternatives. Buyers can offer their own system of criteria based on this system of typical criteria and on their needs. Similarly, initial weights of criteria and values of qualitative indicators are determined. Buyers receive typical weights of criteria and values of qualitative criteria describing the analysed real estate. Buyers can change the offered typical weights of criteria and of qualitative indicators on the basis of their experiences and needs. In such a case, each buyer receives a personalized and specifically adjusted decision-making matrix. One person or a group of stakeholders (e.g. the whole family) can participate in the process of determining the system of criteria, their weights and values of qualitative indicators.

The Collaborative Work Module allows different stakeholders (e.g. family members) in collaborative ways to solve common tasks (development of joint criteria system, estimation of criteria weight and qualitative criteria values). The Groupware Module allows stakeholders to share ideas and to vote and select the one with the highest votes as a jointly accepted real estate alternative.

By using Real Estate and other Alternatives Analysis Module buyers may indicate their tasks and preferences by changing criteria systems, criteria values and weight. A buyer can retrieve previously stored information from a previously developed personalized database or directly insert data through an input screen for a concrete case and activate the multiple criteria analysis process. The results are module recommended real estate, loan, brokers, insurance, leasing, work, facilities management and other alternatives that personally match the buyers' tasks and preferences.

While going through the purchasing decision process a customer should examine a large number of alternatives, each of which is surrounded by a considerable amount of information/knowledge (economic, quality-architectural, aesthetic, comfort, infrastructure, and technical, legal, technological) and other factors. Following on from the gathered information and knowledge, the multiple criteria analysis is then carried out. By using multiple criteria methods [22-25, 36] as it is developed by the authors, the buyer (broker) determines the initial priority, utility degree and market value of the analysed real estate's alternatives during this analysis. Clicking the link "Results of Multiple Criteria Evaluation", the results of the multiple criteria evaluation of 3-room apartment's alternatives are thus demonstrated (see Fig. 2). In the lower part of the obtained result's matrix the calculated significance of the real estate's alternatives their priority and utility degree are presented (see Fig. 2). The upper part of the obtained result's matrix shows the numbering of real estate's alternatives (see Fig. 2 (*left*)). By clicking the blue underlined numbers it is possible to calculate the market value of a certain alternative (see Fig. 3). The table presented in Fig. 3 shows the iterations made during the calculation of the real estate's market value. The same information, only in graphical form is presented in Fig. 3. Also, by moving a mouse above any column of the graphical part, the numerical value of the column can be seen. For example, the market value of the eighth alternative was calculated by making 4 iterations (see Fig. 3).

A buyer performing a multi-criteria analysis of all real estate alternatives selects the objects for starting negotiations. For this purpose he/she marks (ticks a box with a mouse) the desirable negotiation objects (see Fig. 4 (*left*)). E-mail negotiations are created by the Letter Writing Subsystem and sent to all real estate sellers after the selection of the desired objects is made and then *Send* is clicked.

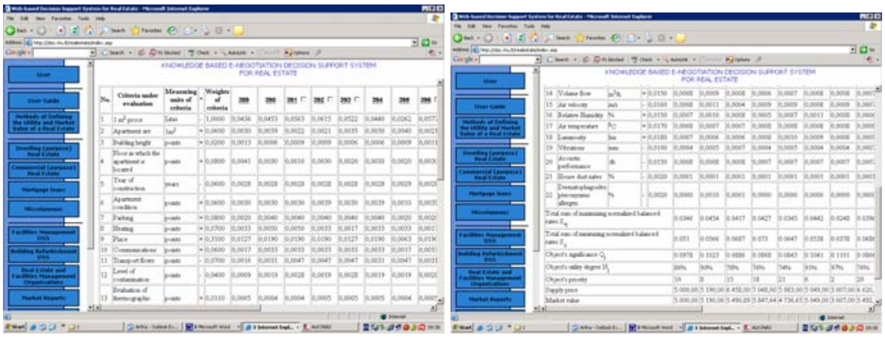


Fig. 2. Results of multiple criteria evaluation of 3-room apartment’s alternatives: upper part of matrix for obtained results (left); lower part of matrix for obtained results (right)

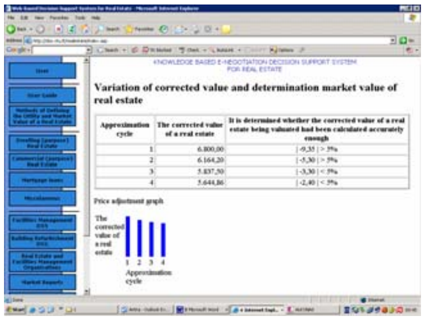


Fig. 3. Calculation of market value: presentation of market value’s calculations in numerical and graphic forms

During negotiations the buyer and the seller with the help of DSS-RE may perform real calculations (utility degree, market value and purchase priorities) of the real estate. These calculations are performed on the basis of characteristics describing the real estate’s alternatives that were obtained during negotiations (explicit and tacit criteria system, criteria values and weights). According to the received results, consequently the final comparative table is developed. Following on from the developed final comparative table, the multiple criteria analysis and selection of the best real estate buying version is carried out by using DSS-RE.

After a variant of the real estate is selected, most often a purchaser has to borrow part of money from a bank. The Loan Analysis Subsystem is created for this purpose (see Fig. 4 (*right*)).

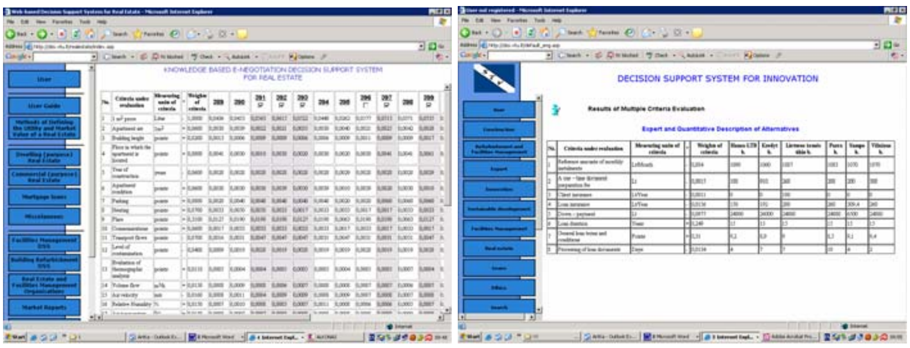


Fig. 4. Selection of real estate objects for automated negotiations (left) and analysis of loan alternatives offered by certain banks (right)

There are five main categories of rules and procedures in the knowledge subsystem (RE-KS):

- Buyer oriented information rules and procedures allow buyers to develop and maintain customer‘s personalized objectives, preferences, and evaluation criteria for analysing and selecting real estate, brokers, related products and services. Editing services for buyers to create personalized real estate Web pages that provide link to directories, annotations and notebooks to analyse related products and services are also integrated.

- Formation of the criteria describing the alternatives. This category consists of rule sets for the formation of the system of criteria that describe the alternatives and provides values and weights of these criteria.
- Development of suggestions with what broker/seller to use and for what reasons further negotiation should be carried out. With the help of a decision support subsystem (RE-DSS) having determined the sequence of priority then the degree of utility and market value of the elements of a renovated building, the rules in knowledge subsystem suggests with what broker/seller to use and for what reasons further negotiation should be carried out.
- Composition of comprehensively reasoned negotiation e-mail for each of the selected broker/seller. By using information inherited from the previous RE-DSS calculations and predefined rules and procedures, the knowledge subsystem composes of a negotiation e-mail for each of the selected broker/seller, where it reasonably suggests that the price of a real estate should be decreased or a real estate of better quality should be sold for the offered price. The e-mail includes references to the calculations performed by KDDSS-RE.

RE-KS also overwhelms a Market Signalling Subsystem. Links to sites with exhaustive information and analytic reviews about the situation in the Lithuanian real estate market and about its development perspectives is provided. Useful information and knowledge is also presented for different stakeholders in the Market Signalling Subsystem: real estate and facilities management organizations, information about collaterals and loans, insurance (real estate, cars, other property), information on companies offering transportation services (furniture transportation, car transportation, etc.; offered services, vehicles and fees), recreational or residential areas for elderly people (sanatoriums, health centres, nursing homes); purchase or lease of furniture, household appliances, audio/video equipment, other household utilities; leasing companies, comparison of alternatives, various announcements, links to job search websites, facilities management services, information and forecasts on the market situation and its changes, information about activities of real estate companies and associations, information about periodical information bulletins, links to other websites and articles.

Devices in the Device Subsystem measure the indoor microclimate parameters (volume flow, air velocity, air temperature, relative humidity, dew point temperature, vibration impulse amplitudes and allergens causing allergy in the dwelling (house dust mites and dermatophagoides pteronysinus allergen etc.). This data is provided in the Decision Support Subsystem and the Knowledge Subsystem.

All members of a real estate market can use the created system. Members are recommended to use as much of their knowledge as possible before making decisions. For example, in order to perform the multiple criteria analysis of a real estate, buyers, sellers, brokers, financial institutions, neighbours and other stakeholders' requirements should be estimated and submitted in a quantitative form.

4. TESTING THE SYSTEM

In order to test the usefulness of the system, final semester master degree students from the Real Estate Management and Evaluation program at VGTU collected more than 250 listings. These students work as brokers in various real estate companies in Vilnius. They have placed information about real estate objects that they are selling at the time into the database. This system was tested by eighteen students for areas that should be improved, e.g. process, interface, navigation, search for alternatives from different brokers' databases, multiple criteria evaluations, calculation of market value and negotiation. A testing of KDDSS-RE was also performed by a designed questionnaire that included four organizations from real estate brokers in Vilnius. The letter that was attached to the questionnaire was as follows 'We would like you to draw on your experience and expertise to help us to test whether the KDDSS-RE can also meet *your* needs as a user. Please read through the following questions circling your response'. A more complete study is underway to find out the satisfaction of users and what current real estate agents have to do in order to survive.

CONCLUSIONS

More automated valuation processes and products have an important role to play in the future provision of valuation services. The valuation community must rise to the challenge of developing a professional class of appraisers in emerging economies.

AVMs are understood as computer programs that use real estate information, such as demographics, property characteristics, sales prices, and price trends to calculate a value for a specific property.

AVMs are preferred by appraisers because they don't have the „human" element. In this way automated valuation becomes more objective and easier understandable.

One of the major weaknesses in AVMs is a lack of a physical inspection of the properties. Methods such as verifying an address of Postal Service and using aerial photography are possible strategies for cutting down on fraud. But there is no substitute for a physical inspection.

No AVM is perfect. They all have data problems. The best AVM for a user gives the most accurate results with the most "hits", for their "comfort level" of acceptable risk. Some models perform better than others, but all depend on data to get reliable results. If AVM is used in an area with few sales, it won't be very reliable. If the AVM database has no property characteristics for the subject property, it won't run if it doesn't allow user input. If AVM runs from a vendor that also provides better data than another equivalent AVM, it will be more reliable.

Integration of neural networks, multimedia, knowledge-based, decision support, devices and other systems in the real estate sector has a very promising future in scientific research. Various forms of the integration of these systems were investigated and several architectures of systems were offered. The authors of the present research have suggested the idea to integrate knowledge-based, devices-based and decision support systems. In order to demonstrate the integration decision support, knowledge and devices systems in the real estate sector a Real Estate's Knowledge and Devices-based Decision Support System have been considered in the paper as an example.

References

[1] *ABN-AMRO Mortgage*. Available: http://www.mortgage.com, (Accessed: 2006, May).

[2] *Archibus, Inc–ARCHIBUS/FM software*. Available: http://www.archibus.com/ (Accessed: 2006, May).

[3] *Automated Valuation Models*. Available: http://www.real-info.com, (Accessed: 2006, May).

[4] *Automated Valuation Models*. Available: http://www.appraisaltoday.com, (Accessed: 2006, May).

[5] *Bankers Insurance Group*. Available: http://www.bankersinsurance.com/index_flash.html (Accessed: 2006, May).

[6] Benjamin J. D., Jud G. D., Sirmans S. G. What Do We Know about Real Estate Brokerage? *Journal of Real Estate Research*, Vol. 20, No 1/2, 2000.

[7] *Draw base software–Facilities management*. Available: http://www.drawbase.com/ (Accessed: 2006, May).

[8] *e-Loan*. Available: http://www.e-loan.com/ (Accessed: 2006, May).

[9] Fisher J.D. Real time valuation, *Journal of Property Investment & Finance*, Vol. 20, Issue 3, June 2000, pp. 213-221.

[10] *FM: Systems, Inc. – FM:Interact and FM:Space software*. Available: http://www.fmsystems.com, (Accessed: 2006, May).

[11] Forbes B.K., Forbes A.R., Forbes J.M. and Zawadski C.M. Facilities Management Automation and Infrastructure Management. In : *The Role of E-Commerce and Business-to-Business Electronic Marketplaces in Facilities Management: Facilities Engineering and Management Handbook. Commercial, Industrial, and Institutional Buildings*. McGraw-Hill, 2000-1. 652 p.

[12] Gilbertson B., Preston D. A vision for valuation, *Journal of Property Valuation and Finance,* Vol. 23, Issue 2, 2005, pp. 123-140.

[13] Guttery R. S., Baen J. S., Benjamin J. Alamo Realty: The Effects of Technology Changes on Real Estate Brokerage, *Journal of Real Estate Practice and Education*, Vol. 3, No 1, 2000, pp. 71-84.

[14] Ham S., Atkinson R. D. *Modernizing Home Buying: How IT Can Empower Individuals, Slash Costs, and Transform the „Real Estate Industry"*. Available: http://www.ppionline.org/documents/Real_Estate_0303.pdf, (Accessed: 2006, May).

[15] Hsia M., Byrne P. Computer assisted valuation: the development of an automated prototype, *Journal of Valuation*, Vol. 7, No 4, 1989, pp.1-17.

[16] Ibrahim M.F., Cheng F.J., Eng K.H. How Eng Automated valuation model: an application to the public housing resale market in Singapore Property Management, *Property Management,* Vol. 23, Issue 5, 2005, pp. 357-373.

[17] Kaklauskas A. Multiple Criteria Real Estate E-Business System. In: *The 2nd International Scientific Practical Conference Information Society '2000. Jump into the new E-Economy. Let's invest into the new E-Economy, October 2000.*

[18] Kaklauskas A., Gulbinas A. Knowledge based decision support system for building refurbishment, Technological and Economic Development of the Country, Vol. XI, No 3, 2005, pp. 176-182.

[19] Kaklauskas A., Zavadskas E. K. and Raslanas S. Multivariant Design and Multiple Criteria Analysis of Building Refurbishments, *Energy and Buildings*, Vol. 37, No 4, 2005, pp. 361-372.

[20] Kaklauskas A., Zavadskas E.K. New Method of Complex Evaluation of Projects Based on Multiple Criteria Analysis and the Principle of Proportionality. In: *5th International Conference "Integrating ... and Human Decisions: Global Bridges into the 21st Century"'. Decision Science Institute, 1999 Athens: Proceedings, Volume 2. / Edited by Dimitris K. Despotis, Constantin Zoporinidis.* Athens-Greece, July 4-7, 1999, pp. 2051-2053.

[21] Kaklauskas A., Zavadskas E.K., Gikys M., Gulbinas A. Efficiency Increase of Property E-Business Systems by Applying Multiple Criteria Decision Support Systems. In: *54th Meeting of the European Working Group "Multicriteria Aid for Decisions": Proceedings*. Belgium, Durbuy, October 4th and 5th, 2001.

[22] Kaklauskas A., Zavadskas E.K., Raslanas S., Krutinis M. Multiple Criteria Property E–Bussiness System. In: *52nd Meeting of the European Working Group. Multicriteria aids for decisions.* Vilnius, Lithuania, October 5-6, 2000. 21 p.

[23] Kaklauskas A., Zavadskas E.K., Vainiunas P., Trinkunas V. Construction Calculators, Analyzers, Software, Experts and Decision Support Systems, Their Integration and Applications. In: *Second International Conference on Information Systems and Engineering and Construction: Conference Proceedings*. Cocoa Beach, Florida, June 13-14, 2002.

[24] Kvederyte N., Zavadskas E. K. and Kaklauskas A. Multiple Criteria Alternative Design of Building Life Cycle, *Journal of Civil Engineering and Management*, Vol. 6, No 2, 2000, pp. 128-142.

[25] Kvederyte N., Zavadskas E.K. and Kaklauskas A. Multiple Criteria Analysis of Semidetached House Life Cycle, *Journal of Civil Engineering and Management*, Vol. 6, No 3, 2000, pp. 179-192.

[26] McCluskey W., Anand S. The application of intelligent hybrid techniques for the mass appraisal of residential properties, *Journal of Property Investment & Finance*, Vol. 17, Issue 3, Aug 1999, pp. 218-239.

[27] McGreal S., Adair A., McBurney D., Patterson D. Neural networks: the prediction of residential values, *Journal of Property Valuation and Investment*, Vol. 16, Issue 1, Jan 1998, pp. 57-70.

[28] Muhanna W. A. E-Commerce in the Real Estate Brokerage Industry, *Journal of Real Estate Practice and Education*, 3(1), 2000, pp.1-16.

[29] "*Peregrine Systems"–SPAN. Facility and Real Estate Management software*. Available: http://sdweb02.peregrine.com/prgn_corp_ap/pstHomePage.cfm?mylanguage=en (Accessed: 2006, May).

[30] Raslanas S., Tupėnaitė L., Šteinbergas T. Research on the prices of flats in the South East London and Vilnius, *International Journal of Strategic Property Management*, Vol. 10, No 1, 2006, pp. 51-63.

[31] *RealData.* Available: http://www.realdata.com/404notfound.html (Accessed: 2006, May).

[32] *Solimar Valuation Technology*. Available: http://solimar.net/products/va-tech.asp (Accessed: 2006, May).

[33] Teicholz E. *The Internet, E-Commerce, and Facilities Management: Facilities Engineering and Management Handbook. Commercial, Industrial, and Institutional Buildings.* McGraw-Hill, 2000. 652 p.

[34] Valley K.L., White S. B., Neale M.A., Bazerman M. H. Agents as information brokers: The effects of information disclosure on negotiated outcomes, *Organizational Behaviour and Human Decision Processes,* Vol. 51, Issue 2, March 1992, pp. 220-236.

[35] *wwwBjmurray.* Available: http://www.bjmurray.com/products/EB_main.html (Accessed: 2006, May).

[36] Zavadskas E.K., Kaklauskas A., Banaitis A. and Kvederytė N. Housing Credit Access Model: the Case for Lithuania, *European Journal of Operation Research*, Vol. 155, No 2, 2004, pp. 335-352.

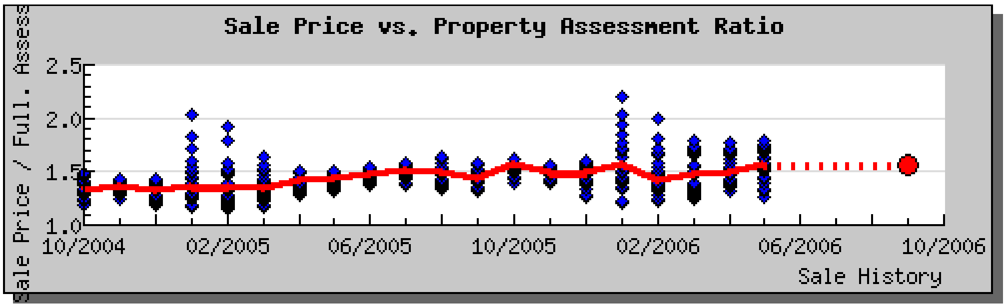
Annex 1

realAssessment™ Report

Real Info Inc.

Automated Valuation Model (AVM)

ABC Bank
Loan# 65451
March 8, 06
v. 1.22



SUBJECT INFORMATION:

OWNER	JOHN DOE	**LAST SALE PRICE**	$ 108,900
ADDRESS	116 CLERMONT ST	**SALE DATE**	06/28/2001
CITY	ALBANY NY	**ASSES. VALUE**	$ 112,600
ZIP	12203	**FULL LAND VALUE**	$ 23,155
COUNTY	ALBANY	**TAX ID**	64.25-2-25
USEAGE	210-SINGLE FAMILY RES		

realAssessment™ VALUE	$ 181,000
MUNICIPAL VALUE	$ 115,879

realAssessment™ VALUE $ 181,000

CONF. SCORE : 94

NEIGHBORHOOD SALES:

FEATURE	ADDRESS	CITY	ZIP	DIST. (Mi)	SALE AMT.	SALE DATE	ASSESSMENT
SALE 1	134 MELROSE AVE	ALBANY	12203	0.00	$ 177,000	09/14/2005	$ 115,900
SALE 2	15 HAWTHORNE AVE	ALBANY	12203	0.18	$ 178,800	10/19/2005	$ 109,900
SALE 3	106 FAIRLAWN AVE	ALBANY	12203	0.21	$ 222,500	09/08/2005	$ 145,000
SALE 4	82 ORMOND ST	ALBANY	12203	0.56	$ 181,000	09/29/2005	$ 111,800
SALE 5	15 HILLCREST AVE	ALBANY	12203	0.58	$ 187,500	09/30/2005	$ 125,100

realAssessment™ VALUE

Based on the sales analysis within the subject's location, full assessments of 210-SINGLE FAMILY RES have been adjusted to 48.55%. This adjusted the full assessments from $ 121,848 to $ 181,000