VĚDECKÉ SPISY VYSOKÉHO UČENÍ TECHNICKÉHO V BRNĚ
Edice PhD Thesis, sv. 663
ISSN 1213-4198

thesis

Ing. Hana Wouters

Multi-Objective Optimization of Science Parks Based on Qualitative Equationless Relations

BRNO UNIVERSITY OF TECHNOLOGY
FACULTY OF BUSINESS AND MANAGEMENT
INSTITUTE OF ECONOMICS

Ing. Hana Wouters

MULTI-OBJECTIVE OPTIMIZATION OF SCIENCE PARKS BASED ON QUALITATIVE EQUATIONLESS RELATIONS

VEKTOROVÁ OPTIMALIZACE VĚDECKÝCH PARKŮ
ZALOŽENÁ NA KVALITATIVNÍCH TRENDOVÝCH
MODELECH BEZ ROVNIC

Shortened version Ph.D. Thesis

Program: Company management and economics

Supervisor: Prof. Ing. Mirko Dohnal, DrSc.

Opponents: Prof. Ing. Jan Čapek, CSc., Prof. RNDr. Jiří Hřebíček, CSc., Prof. Ing. Vojtěch Koráb, Dr. MBA

Date of Defence: 19.4.2012

Key words:
Science park, qualitative models, equationless relations, scenarios, transition graphs.

Klíčová slova:
Vědecký park, kvalitativní modely, bezrovnicové vazby, scénáře, přechodové grafy.

PhD thesis deposited in: Library of the Faculty of Business and Management

Abstract

The dissertation deals with the Multi-Objective optimization of the Science parks in terms of increasing competitiveness of the regions and the whole country. The main target of this dissertation is to help the investors, who want to implement SP project in different regions of Czech Republic or managers of existing science parks, who want to make another decision. Each science park (SP) is a unique system. It is therefore prohibitively difficult to use traditional methods of analysis e.g. statistical analysis, which require relatively extensive input information. A qualitative description is information non intensive. It is based on three values only – positive, zero, negative (increasing, constant, decreasing).

SP models incorporate variables of different nature and different time behaviours. Therefore slow and fast SP models are studied. A set of 17 slow qualitative equationless relations, among 11 slow variables (e.g. Quality of R&D engineers, Competition status ect.) together with a set of 14 fast qualitative equationless relations, among 10 fast variables (e.g. Cooperation between industries and academics, incentives for investment ect.) is studied.

The individual steps of production of the models are graphically illustrated in the examples.

ISBN 978-80-214-4541-3
ISSN 1213-4198

Content

1 Introduction

Confrontation with needs of adaptation to global challenges, take place in a situation, where the economic level between the different regions in European Union remain significantly different. Many regions in several Member States do not fully exploit the opportunities of the single Internal Market and other projects of European integration.

Competitiveness of Czech economy is declining, competition in markets where our products or services compete, grow. A recent change of competitive position of CR is due to a gradual loss of price competitiveness and slow shift toward more sophisticated production, which would allow to compensate this change in terms of impact on the position of the economy. [32]

At nowadays EU level are three main instruments to support innovation activities. The first is the Cohesion policy (i.e. the Structural Funds (SF) and Cohesion Fund), the second is 7 Research Framework Programme (FP7) and the third is the Framework Programme for Competitiveness and Innovation Programme (CIP). [31]

Furthermore, there are a number of national resources and investment incentives that are annually allocated in science, research and competitiveness.

Science-based industrial parks have been recognized as an effective way of promoting technology development, urban renewal, and economic growth. However, little has been done in discussing the selection strategy of high-tech industries to locate in such a park, see e.g. [6]. However, each science park (SP) is a unique system [5]. It is therefore prohibitively difficult to use traditional methods of analysis e.g. statistical analysis, which require relatively extensive input information [7]. A qualitative description is information non intensive. It is based on three values only – positive, zero, negative (increasing, constant, decreasing) [8].

Analysis/Optimization of ill-known, nonlinear, multidimensional system (INMS) as Science Park (SP) is a difficult task. The reason is that available information is vague, sparse and partially inconsistent. It is therefore difficult to develop meaningful and sufficiently accurate models of any unsteady state SP behaviours. Qualitative quantification of time derivatives, increasing, constant, decreasing, is information non-intensive, as it is based on qualitative values only. Qualitative models can be used to generate all possible dynamic behaviours (qualitative trends/scenarios). The scenarios can be screened against the prescribed trends, maximization or minimization, of objective functions to identify all possible ways of achieving the optimal results.

Human experts, especially at the very beginning of any investigation, do not use mathematical models as the basic framework for their reasoning [19]. Experts draw heavily on knowledge represented by common-sense in evaluating a situation. [10] [4] Numbers are not the only quantifiers.

This disertation takes into consideration the follwoing basic susbystems:

- Human resources (HR),
- Technological resource (TR),
- Investment environment (IE),
- Market development (MD)

The model's solutions i.e. set of slow and fast scenarios and transitions among them, are presented in this dissertation in full details.

The dissertation includes interpretation of the results and benefits for the theory and practice.

2 Research objectives

Managements of a broad spectrum of companies, high tech companies in particular, see identification of trends as the key factor of their competitive advantage. Therefore a deep understanding of the very nature of trends is essential for strategic SPs foresight. [13] [11] [21]. Modern computers are extremely powerful tools in terms of number manipulation. However, their contribution to solving complex problems using common sense has been practically very small. [15]

INMS are such systems which are, by their very nature, difficult to measure/observe and of course to model.

This research is conducted with the intention to develop a qualitative SP models using just trend descriptions.

2.1 Primary objective of this research:

To build up SP modeling/decision making methodologies based on qualitative SP models using just descriptions based on three values, namely positive, zero, negative. Naturally if qualitative information items are used as the only information input into a model then the results are exclusively qualitative ones.

2.2 Secondary objectives of this research:

To verify algorithms which are based on qualitative modeling and built up SP methodology of vague analysis/optimization/decision making.

The basic philosophy is simple - Vague knowledge must not be modified to fit the network of available calculi but the calculi must be made so flexible that they can formalize and integrate vague and inconsistent knowledge with the minimum amount of knowledge loss.

One has to keep in mind the obvious fact that a formalized engineering problem is a solved problem. Thanks to the development of computer hardware and software, the mathematical solution itself does not usually represent a major problem.

However, real life problems often involve data which are vague, inconsistent and sparse. The crucial step towards the final solution is the reconciliation of all relevant data. Human thought is not based on equations and the most powerful tool used by human beings to solve real problems is common sense reasoning.

3 Methods used in this research

This research is closely related to optimization of poorly-known, nonlinear, multidimensional systems as SP. As it was already said it is very problematic to model and optimize SP because available information is vague, sparse and heavily inconsistent. The key problem is information shortage, which has the same reason as any study of a prohibitively complex system. [17] [9] The most difficult aspects are:

- data acquisition problems
  - insufficient numbers of observations
  - prohibitively low accuracy of some observations
  - some variables cannot be measured/quantified and their observations are based on purely subjective evaluations
- knowledge insufficiency
  - process models are oversimplified
  - deep knowledge is limited
  - important relations are not known
  - several principally different explanations of behaviors based on inconsistent pseudo-deep knowledge exist

These scientific methods will be used in this research:

- Qualitative Models
- Unsteady State Qualitative Models
- Qualitative Transitions
- Qualitative Multi-Objective Optimization and/or Decision Making

The details about specifics of each of these methods, is discussed further in the dissertation and future publications. Each use of these scientific methods will be similar to a certain degree of their use in different research, but there are going to be unique and very interesting characteristics. This research is a great challenge that requires the knowledge and expertise of several researchers. The conducted research brings new views to several areas and examines the relations that have not been studied before. The results of this research will be usable in the real world. It is therefore very important to analyze the use of these scientific methods to ensure that no important steps are ignored or incorrect conclusions made.

4 An overview of the current state of the problem, which is the subject of dissertation

4.1 Structural aspects of development

Czech Republic is at the 36th place in the latest comparison of international competitiveness. Especially in last 5 years CR felt in a world and european kontext a noticeable decline in competitiveness, which is necessary to stop and reverse the negative trend. This change can occur only through systemic changes.

Some problems affecting the long-term competitiveness of Czech Republic:

- Increasing regional disparities in performance of regions - significant growth potential of the country is limited to certain urbanized parts of the country, which have objective assumptions for competitive growth with emphasis on strengthening the innovative activities of companies. [22]
- For innovative business was marked as a main problem weak links between companies and scientific/research institutions and workplaces of technology transfer and knowledge transfer. This result corresponds with the low intensity of cooperation between research institutions and innovative infrastructure and regional development institutions. It is not just a question of connection between businesses - research. [1]
- Serious deficit and negative trends were also identified in the public education at all levels.
- Other possible barriers to innovation business is for example the problem of lack of human resources capable of solving innovation in companies and the Higher Education Act and its lack of effect on the motivation of researchers, etc. [1]
- Until recently grant sources for support of innovation activities were poorly drawn and national resources pointed into research and development were not always used for projects with the desired final output.

4.2 Overall assessment of regional competitiveness

Type A - regions with an excellent competitive position

Type B - regions with a good competitive position

Type C - regions with poor competitive position

Type A - regions with an excellent competitive position

In to the first type A was included only Prague and Central Bohemia connected with Prague by intense relationships. These regions have the best conditions for dynamic economic development, ensuring their continuing prosperity and in accordance with the optimal strategy can be considered progressive scenario of their economic development. The dominant economic position of Prague, of course positively affects the surrounding Central Bohemian Region, which is currently the NUTS 2 Central Bohemia Region. Both NUTS 2 regions undoubtedly have a high attraction for locating domestic and foreign investment and the development of economic activities with high added value.

Type B - regions with a good competitive position

To this type B belong the Regions of Plzen, South Bohemia, Hradec Králové, Pardubice, Liberec and South Moravia. Overall, the regions included in this type B have the necessary preconditions for achieving an average economic level of regions of the old EU member states in the time horizon of 15-20 years.

Regions Plzen and South Bohemia, create the Region NUTS 2 Southwest. Region Southwest is undoubtedly an attractive location for investment and development of economic activities with higher added value.

From an administrative point of view, the most structured region at the level NUTS 2 is Northeast Region, which as the only one consists of three regions: Hradec Králové, Pardubice and Liberec. All three included regions (especially Region Hradec Králové) have quite good assumptions to attract investment and development of economic activities with higher added value.

South Moravian Region, together with Vysočina Region create Region NUTS 2 Southeast, which is the only one including regions classified according to the regional competitiveness in different types - Type B in case of South Moravian Region and Type C in the case of the Region Vysočina. In terms of location of investments and the development of economic activities with higher added-value to high added-value is clearly attractive only the Brno agglomeration.

Type C - regions with poor competitive position

In type C were included remaining Regions Ústí nad Labem, Karlovy Vary, Vysočina, Olomouc, Zlín and Moravian-Silesian Region. A suitable default strategy for these regions has adaptive scenario of economic development emphasizing the necessary restructuring of their economic base.

Regions Ústí nad Labem and Karlovy Vary belong to the Region NUTS 2 Northwest. In this context it should be noted, that in both regions have above-average proportion of economically sensitive industries with strong developmental links to level of unemployment, especially mining completed in the Ústí region with the chemical industry. Both regions have appropriate conditions for the localization of investments and development of economic activities with a median value-added and in case of regional or selected cities with more favorable economic profile also activities with higher added value.

Region NUTS 2 Central Moravia is composed of Regions Olomouc and Zlín. Both regions have suitable conditions for localization of investments and economic development activities with median added value. Agglomerations of both county seats have very good conditions for development of activities with higher added value.

Region NUTS 2 Moravia-Silesia, an important factor associated with the problematic economic development of the whole region is fund-consuming economic structure, characterized by great sensitivity to fluctuations in global demand - Moravian-Silesian region has the highest proportion of economically sensitive sectors (metallurgical industry, mining and quarrying). The negative effects generated by the current economic developments affecting especially the heavily urbanized regions of the satellite towns of Ostrava, built originally as a mining settlement with minimal economic base. Moravian-Silesian Region has suitable conditions for localization of investments and development of economic activities with median value-added. In Ostrava and several other mostly larger cities also for localization of activities with higher added value.

From the Region NUTS 2 Southeast belongs to this type C Region Vysočina. The Region Vysočina has suitable conditions for localization of investments and development of economic activities with a median value added, in case of if the county town localization of investments with higher added value. [2]

4.3 Reinforcing priorities of Europe 2020:

- Smart growth: developing an economy based on knowledge and innovation.
- Sustainable growth: promoting greener and more competitive economy less demanding on resources.
- Inclusive growth: promoting a high-employment economy which will deliver social and territorial cohesion.

EU's main objectives:

- 75% of the population aged from 20 to 64 years should be employed,
- 3% of EU GDP should be invested in research and development,
- Climate and energy should achieve objectives "20-20-20" (including an increase commitment to reduce emissions to 30% if the conditions are favorable)
- The proportion of early school leavers should be below 10% and at least 40% of the younger generation should rich tertiary education,
- Number of persons at risk of poverty would drop by 20 million [27]

Top science centers in the Czech Republic

In Brno, grow giant CEITEC Science Center for 5.2 billion Czech crowns. Subsidy was already approved by the European Commission. In CEITEC will work six hundred of scientists, who will invent for example research military robots and nanorobots, special hydrogels that can connect bone fracture using a syringe, dental prosthesis made of ceramic and metal materials or self-cleaning coatings buildings. [28]

Fig. 1 – Ceitec [23]

Besides CEITEC, the European Commission approved grant of seven billion Czech crowns, to build the world's most powerful laser (ELI) in Dolní Břežany near Prague. [24]

A new generation of scientists

ELI device will also create an attractive platform for education of new generation of doctoral students, scientists and engineers. This will significantly increases the prestige of Czech Republic as the host country for top class international research project with open access to scientific community all around the world. ELI will also attract further investment to CR in advanced technologies with high added value. [25]

The approvals by the European Commission are still waiting other four projects in large scientific centers. This applies, for example, Ostrava IT4I centre, which plans to build the largest supercomputer in the center of Central Europe, or center SUNSEN in Řež near Prague, which will develop more advanced nuclear reactors. However, there are critics, who argue, that science centers will not attract enough of scientific research capacity and bold plans will fail. [28]

Critics have analyzed, that subsidies should not be wasted, e.g. to invest in new sites in rural territory and expecting scientist will move there automatically. More logical would be to point brussel´s billions into existing good research facilities rather than building up others.

"Lot´s of money is used for construction of new buildings and equipment“. If funding would be invested into what already exists, it would be more efficient and economical. For the six centres of excelence, which should grow in Czech Republic, will European Union endow only five years. After these 5 years, these centers will have to become financially independent, either by commercial research or by enabling support from state funds. Most centers believe that they will participate in commercial research, cooperation with private entities. However it's without doubt that this will rather be an extra income, but it will not cover overall operations. [30]

Disparities are even wider across EU regions. According to the latest data available, expenditure on R&D in the EU averaged around 1.9% of GDP in 2007. The only exception is Stredni Cechy (the region surrounding Prague) where business R&D expenditure amounts to about 2.5% of GDP.[26]

Business in CR must be more than ever based on the use of innovation, leading to the growth of its productivity. Companies must be progressively more involved in to global division of labor on a higher qualitatively level position in value chains. [29]

5 The results of the dissertation with the introduction of new knowledge

5.1 Foundations of this research

The benefits of Science Parks (SPs) and similar facilities, are well known and relatively well documented, see e.g. [3] However, formal models of SPs, which are inevitable for any application of Operational Research, e.g. Decision support algorithms, forecasts etc., exist just for very few specific tasks [20]. The main reasons, why it is so difficult to develop good models of SPs are typical for any complex systems namely: Uniqueness, Multidimensionality, Interdisciplinary nature of the problem under study [17]. Any forecast related to a SP is therefore inevitably problematic, see e.g. [18] [14].

Qualitative models represent nowadays a tested and trusted formal tool. The following text, hold the basic information for those who are going to use the qualitative models as decision making support tool.

Human experts, especially at the very beginning of any investigation, do not use mathematical models as the basic framework for their reasoning [19]. Experts draw heavily on knowledge represented by common-sense in evaluating a situation. [10] [4] Numbers are not the only quantifiers.
A trend forecast can be downgraded to a choice of the following descriptions:
Increasing, Constant, Decreasing

If the available set of knowledge items does not allow trend forecasts, then nothing can be predicted. In other words, the trend forecast is the least information intensive, see e.g. [10] A certain knowledge/information threshold must be reached to make correct trend evaluations.

This dissertation takes into consideration the following basic subsystems:

- Human resources (HR)
- Technological resource (TR)
- Investment environment (IE)
- Market development (MD)

5.2 Introduction of used methods - tutorial introduction

5.2.1 Qualitative Models

Qualitative models are based just on the following quantifiers:

Values:	Positive	Zero	Negative	Anything	
Derivatives:	Increasing	Constant	Decreasing	Any direction	(1)
Symbol:	+	0	-	*	

A qualitative solution of a qualitative model is specified if all its n qualitative variables,

$$X_1, X_2, \ldots\ldots\ldots Xn \qquad (2)$$

are described by a sequence of qualitative triplets, for details see [21]:

$$(X_1, DX_1, DDX_1), (X_2, DX_2, DDX_2), \ldots (Xn, DXn, DDXn), \qquad (3)$$

where Xi is the i-th variable and DXi and DDXi are the first qualitative and second qualitative derivations with respect to t (which is usually time). Higher derivatives are not considered. They are not known if the INMS are studied.

A qualitative model has m qualitative scenarios. The j-th qualitative scenario is the n-triplet:

$$(X_1, DX_1, DDX_1), (X_2, DX_2, DDX_2), \ldots (Xn, DXn, DDXn)j, \qquad (4)$$

where $j = 1, 2, \ldots, m$.

A typical example of a qualitative knowledge item can be formalized by a certain simple relation between two variables X and Y. Six of them are given in Fig. 2. Each graph represents a certain shape and not numerical values. This is the reason, why the given graphs in Fig. 2 are suitable to formalise such non-numerical information items, which have no forms of traditional equations.

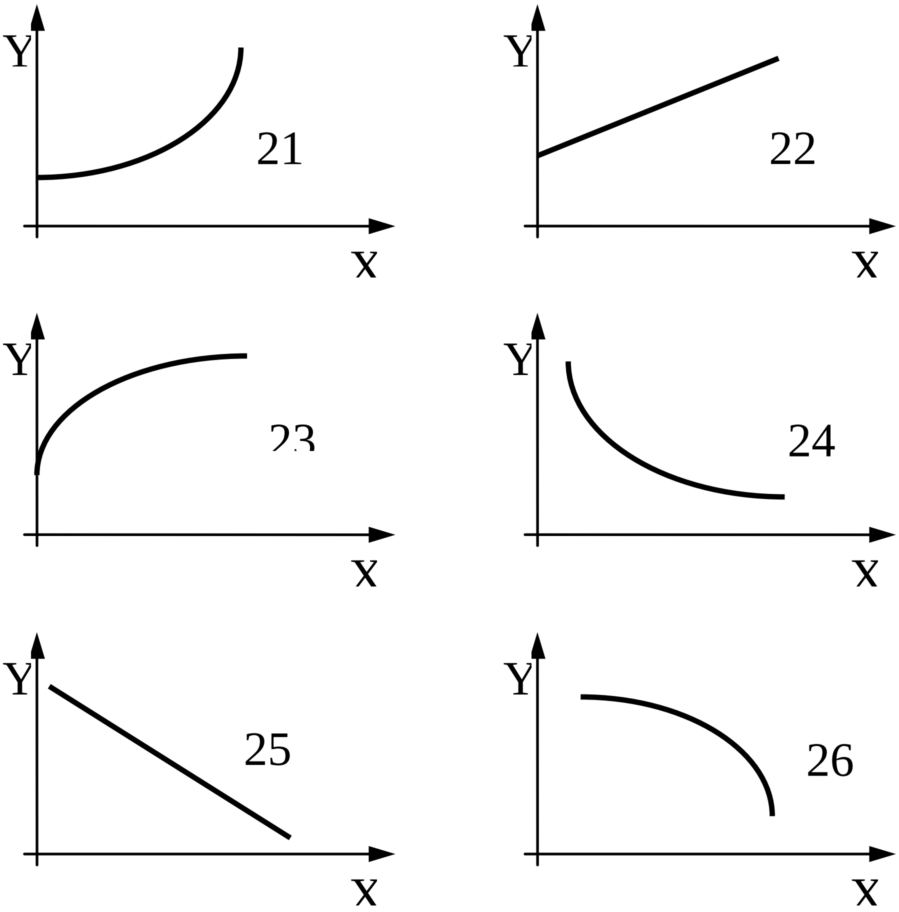

Fig. 2 - Examples of pair wise qualitative relations [21]

All pairwise relations X, Y are qualitative. It means that nothing is qualitatively known.
For example the relation 22 indicates that:

- The relation is increasing
- there is a linear relationship between Y and X
- If X = 0 then Y is positive.

5.2.2 Unsteady State Qualitative Models

Unsteady SPs models are based on the first and second derivatives

DX the first qualitative derivative
DDX the second qualitative derivative (5)

Fig. 3 reflects periodic changes of a variable X_1. If X_1 is e.g. profitability, then DX_1 indicates profitability changes (growing, declining or constant) and DDX_1 indicates, what is happening to the rate of change in profitability.

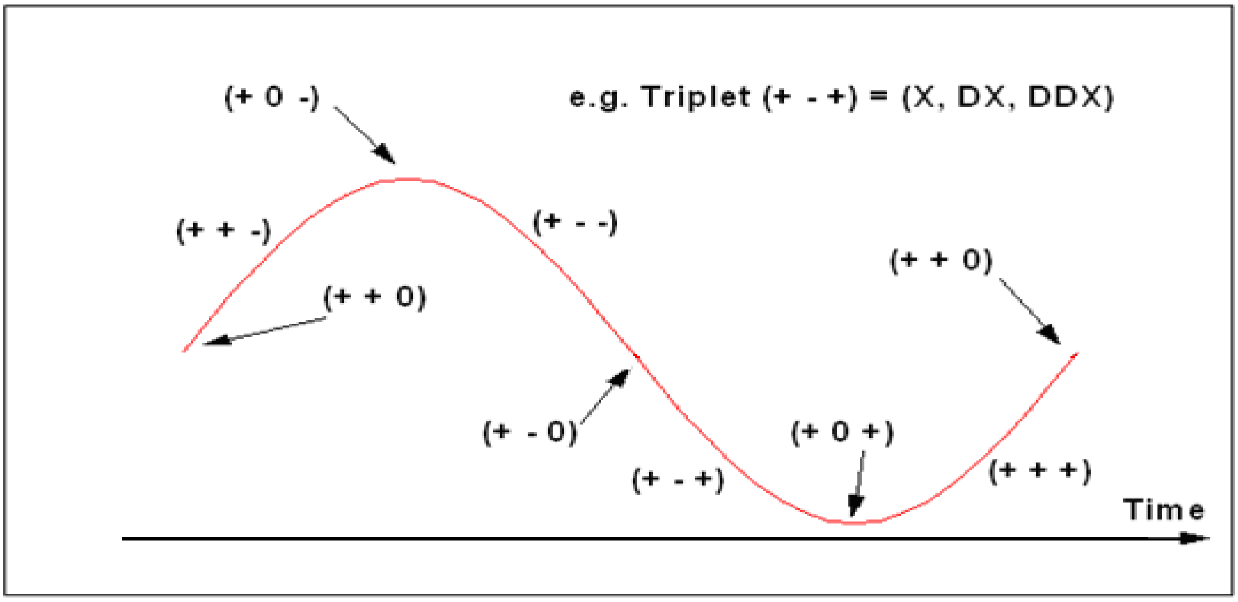

Fig. 3 - Qualitative one dimensional time record

5.2.3 Qualitative Transitions

Unsteady state behaviours of an INMS can be described by a time sequence of its scenarios. A transitional graph gives all possible unsteady state behaviours. If each scenario is represented by a node and all transitions are graphically represented by oriented arks between corresponding pairs of scenarios, the result is an oriented graph of all possible transitions. Any time behaviour of the INMS can be characterized as a path in the transition graph.

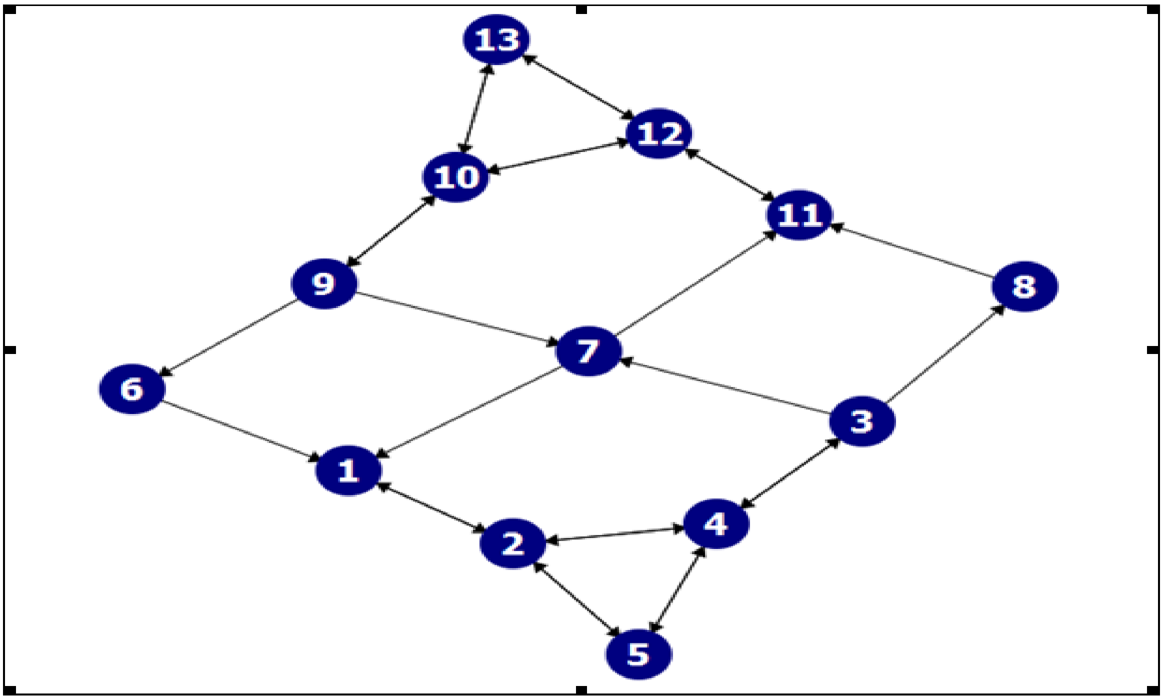

Fig. 4 - Transitional graph

The graph is a human friendly interpretation of all possible dynamic behaviours. The graph gives all possible qualitative sequences of scenarios, which represent all possible dynamic behaviours.

5.2.4 Qualitative Multi-Objective Optimization

Let us suppose that there are two independent variables X1, X2 and two objective functions Q1, Q2. Both objective functions must be maximized because of their nature:

Max Q1 (6)

Max Q2

There is a vector F of constraints represented by a set of equationless relations:

F(X1, X2, Q1, Q2) = 0 (7)

Let the qualitative model have the following set of three scenarios:

	X1	X2	Q1	Q2
1	+++	+++	+--	+--
2	++-	+--	+++	+--
3	+--	+-+	+-+	+++

(8)

Therefore the first qualitative solution is totally unacceptable, see (6), because both objective functions decrease if independent variables X1 and X2 follow the qualitative pattern given in (8). Therefore the qualitative behaviour of independent variables X1 and X2

	X1	X2
1	+++	+++

(9)

is bad with respect to the maximization of two objective functions Q1 and Q2. If there would be a set of scenarios, which contain for example, the following solution,

X1	X2	Q1	Q2
++-	+-0	+++	+++

(10)

then the scenario (10) is highly desirable, because this scenario maximizes both objective functions in the best possible way i.e. both second derivatives are positive.

5.3 Solving the research problem

Team of experts identified two sets of relevant SP variables. The first set is used to characterize variables of slow SP changes and the second one, variables of fast SP changes.

Variables of slow and fast changes are identified on ad hoc bases and there is no a generally applicable rule how to assign a specific variable to either slow or fast set. The following example is just one alternative:

Slow Dynamic Set

Human resource

- Supply of qualified outside personnel SQP
- Human brain cultivation organizations HBC
- Quality of R&D engineers QRD

Technology resource

- Quality of research institution QRI
- Quality of enterprises QE
- Occasion for enterprises cooperating OEC (11)

Investment environment

- Regional development outlook RDO
- Living utilities LU

Market development

- Competition status CS
- Completion of supply chain CSC
- Prospects of industries PI

Fast Dynamic Set

Human resource

- New jobs creation NJC
- Incubator resources IR

Technology resource

- Cooperation between industries and academics CIA
- Circulation of industry information CII

Investment environment

- Scale of industries SI (12)
- Incentives for investment II
- Operation costs OC

Market development

- Benefit of economies of scale BES
- Bargaining power BP
- Reputation RE

A simple common sense analysis identifies an obvious fact, that many of the qualitative relations among variables (11, 12) are ad hoc heuristic valid just for a specific SP currently under study.

It makes no sense to integrate slow and fast variables into one qualitative model as the time horizons are different. No attempts were made to quantify the corresponding time intervals (days, months, years) as it is an ad hoc task.

Qualitative ad hoc SP models are analyzed. Each model has subset of relations within the following subset of variables, see (11, 12):

- Human resource
- Technology resource
- Investment environment (13)
- Market development

and additional relations, which link variables in between the different subsets (13). The following slow and fast models are based exclusively on qualitative proportionalities (+) and (-). In other words just the first derivatives are taken into consideration. It means that the results are based on the first derivatives as well.

5.3.1 Fast model based on the first derivative

Relation within the subsets of variables (12)

+	IR	NJC
+	CIA	CII
-	SI	II
+	BES	RE
+	BES	BP

Relations outside subset of variables (13) (14)

+	RE	NJC
+	BES	IR
+	CIA	RE
+	SI	BES
-	RE	OC
+	CIA	IR

There are three scenarios, i.e. m = 3, see (4) for fast sets.

Fast Scenarios based on first derivation (14):

	CIA	CII	IR	NJC	SI	II	BES	RE	BP	OC	
1	++*	++*	++*	++*	++*	+-*	++*	++*	++*	+-*	
2	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	+0*	(15)
3	+-*	+-*	+-*	+-*	+-*	++*	+-*	+-*	+-*	++*	

Where * means ignore. Therefore the second derivatives are ignored; see the triplets (4).

Fast scenarios result comparison:

Fast scenario sets (15) include steady state scenario as all first derivatives are equal to zero. In fast set (15) it is scenario No. 2. This particular scenario is special because nothing changes (everything is steady state).

If we look at the first scenario of set (15) we find out that incentives for investment and operation costs are decreasing and new jobs creation, incubator resources, cooperation between industries and academics, circulation of industry information, scale of industries, benefits of economies of scale, bargaining power and reputation are increasing.

The more precise information we reflect into the fast model the easier it will become to interpret generated results for the decision maker.

The fast model (15) is based on the first derivates only and therefore the answer is based on the first derivatives as well. Rather often it is possible to identify such set of scenarios by simple common sense reasoning.

Team of experts developed the following fast model, which partially incorporates additional information items based on second derivatives:

5.3.2 Fast model based partially on second derivative

See Fig. 2	X	Y	
23	IR	NJC	
21	CIA	CII	
25	SI	II	
23	BES	BP	
+	BES	RE	
+	RE	NJC	(16)
+	BES	IR	
+	CIA	RE	
+	SI	BES	
-	RE	OC	
+	CIA	IR	

The first four relations of the model (16) is based on the second derivatives, see Fig 2. The first relation is represented in the model (14) just by qualitative proportionality. However the shape 23, see Fig. 2 indicates, that the second qualitative derivative NJC with respect to IR is negative. This additional qualitative information item makes the model (16) much more accurate. The team of experts was not able to make the last 7 relations of the model (16) more precise.

There are 15 fast scenarios:

	CIA	CII	IR	NJC	SI	II	BES	RE	BP	OC	
1	+++	+++	+++	+++	+++	+--	+++	+++	+++	+--	
2	+++	+++	+++	+++	+++	+--	+++	+++	++0	+--	
3	+++	+++	+++	+++	+++	+--	+++	+++	++-	+--	
4	++-	+++	++-	++-	++-	+-+	++-	++-	++-	+-+	
5	++-	++0	++-	++-	++-	+-+	++-	++-	++-	+-+	
6	++-	++-	++-	++-	++-	+-+	++-	++-	++-	+-+	
7	+0+	+0+	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0-	
8	+00	+00	+00	+00	+00	+00	+00	+00	+00	+00	(17)
9	+0-	+0-	+0-	+0-	+0-	+0+	+0-	+0-	+0-	+0+	
10	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	+-+	++-	
11	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	+-0	++-	
12	+-+	+-+	+-+	+-+	+-+	++-	+-+	+-+	+--	++-	
13	+--	+-+	+--	+--	+--	+++	+--	+--	+--	+++	
14	+--	+-0	+--	+--	+--	+++	+--	+--	+--	+++	
15	+--	+--	+--	+--	+--	+++	+--	+--	+--	+++	

The scenario No. 8 is the steady state scenario and it corresponds to the 2nd scenario (15) of the model (14) based on the first derivatives only. The scenarios Nos. 1 – 15 are more accurate qualitative descriptions of the first set of scenarios (15).

If we look closer to set of scenarios (17) based partially on second derivations we find out, that there is no difference between the results (15, 17) although model (16) contains more accurate information. In both fast sets (15, 17) based on the first and second derivation II and OC are decreasing in the first scenario and increasing in the last scenario. The rest of variables is increasing in the first scenario and decreasing in the last scenario (15, 17).

The advantage of the model based partially on the second qualitative derivation is, that the model itself is much more accurate and includes additional qualitative information items in comparison with the model based on first qualitative derivation, where the information is vague. The set of scenarios based on the second derivation shows in detail overview all possible situations, which can occur in reality. Moreover it is possible to convert those complete sets of fast and slow scenarios into the graph of transitions see Fig. 5. This would not be possible if we know only information based on the first qualitative derivations.

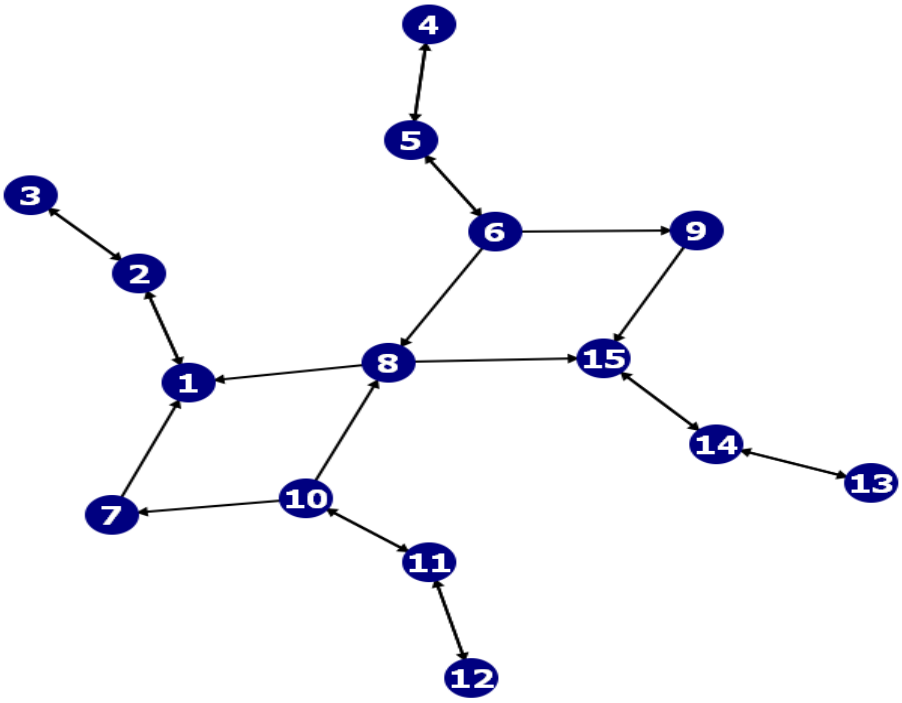

Fig. 5 Graph of transitions among the set of scenarios (17)

The oriented graph is a human friendly interpretation of all possible SP dynamic behaviours. It means that the graph gives all possible qualitative sequences of scenarios, which represents dynamic behaviours.

If CIA is the goal, which must be maximized, then the set of scenarios can be divided into the following subsets, see the first column of the matrix (17):

CIA	Scenario No.	
+++	1, 2, 3	
++-	4, 5, 6	
+0+	7	
+00	8	(18)
+0-	9	
+-+	10, 11, 12	
+--	13, 14, 15	

The best CIA behaviour is described by (+ + +) as it means, that CIA is increasing and the increase is higher and higher. The worst scenario is described by the triplet (+ - -), see the scenario No. 13, 14, 15 (17, Fig. 5).

The following list of possible transitions from and to the set of scenarios with CIA (+++) have four elements:

No.	From	To	
1	1	2	
2	2	1	(19)
3	2	3	
4	3	2	

If a SP is described by the scenario 13, 14, 15, then there is no escape from this bad situation, see Fig. 5. On the other hand if the SP behaviour is represented by a scenario from the set of scenarios (1, 2, 3), then a managerial decision can just transfer SP within this set. It means, that the favourable triplet (+ + +), see (17, 18), will be valid for ever irrespective of any mistakes done by managements.

Interpretation could be:

If the decision maker prefers to maximize cooperation between industries and academics, which will bring him new scientific results and innovations, than he has to expect decrease of incentives for investment and decrease of operation costs (which is always wanted). On the other hand all the rest of variables will increase. This could be good decision, but at the expense of drawing subsidies. The decision maker will have to compromise. This could be a situation of existing and prosperous SP.

However, the realistic transitional graphs are much more complex and more difficult to interpret. If the model (16) is slightly modified, then the number of transitions is relatively high. Just three model's (16) modifications are done:

1 if D (IR) = (+) then 23 IR NJC IR
2 if D (CIA) = (+) then 21 CIA CII CIA (20)
11 if D (CII) = (+) then M+_ CIA IR CII

The macroinstructions Nos. 1, 2 and 11 are conditional. If the first derivatives D of IR, CIA and CII are not positive, then the corresponding macroinstructions (20) replace the original ones. Simple common sense reasoning indicates that the number of scenarios for the modified model (16) will be higher. The reason is, that the macroinstructions (20) are restrictive just for a specific values of three variables and not always.

The modified model (16, 20) has 78 scenarios and 422 transitions among them.

The result of modified model (16, 20) follows:

	CIA	CII	IR	NJC	SI	II	BES	RE	BP	OC	
1	+++	+++	+++	+++	+++	+--	+++	+++	+++	+--	
2	+++	+++	+++	+++	+++	+--	+++	+++	++0	+--	
3	+++	+++	+++	+++	+++	+--	+++	+++	++-	+--	
4	++-	+++	++-	++-	++-	+-+	++-	++-	++-	+-+	
5	++-	++0	++-	++-	++-	+-+	++-	++-	++-	+-+	
6	++-	++-	++-	++-	++-	+-+	++-	++-	++-	+-+	
7	+0+	+++	+0+	+0+	+0+	+0-	+0+	+0+	+0+	+0-	
69	+-0	+--	+-0	+-0	+-0	++0	+-0	+-0	+--	++0	(21)
70	+--	+++	+--	+--	+--	+++	+--	+--	+--	+++	
71	+--	++0	+--	+--	+--	+++	+--	+--	+--	+++	
72	+--	++-	+--	+--	+--	+++	+--	+--	+--	+++	
73	+--	+0+	+--	+--	+--	+++	+--	+--	+--	+++	
74	+--	+00	+--	+--	+--	+++	+--	+--	+--	+++	
75	+--	+0-	+--	+--	+--	+++	+--	+--	+--	+++	
76	+--	+-+	+--	+--	+--	+++	+--	+--	+--	+++	
77	+--	+-0	+--	+--	+--	+++	+--	+--	+--	+++	
78	+--	+--	+--	+--	+--	+++	+--	+--	+--	+++	

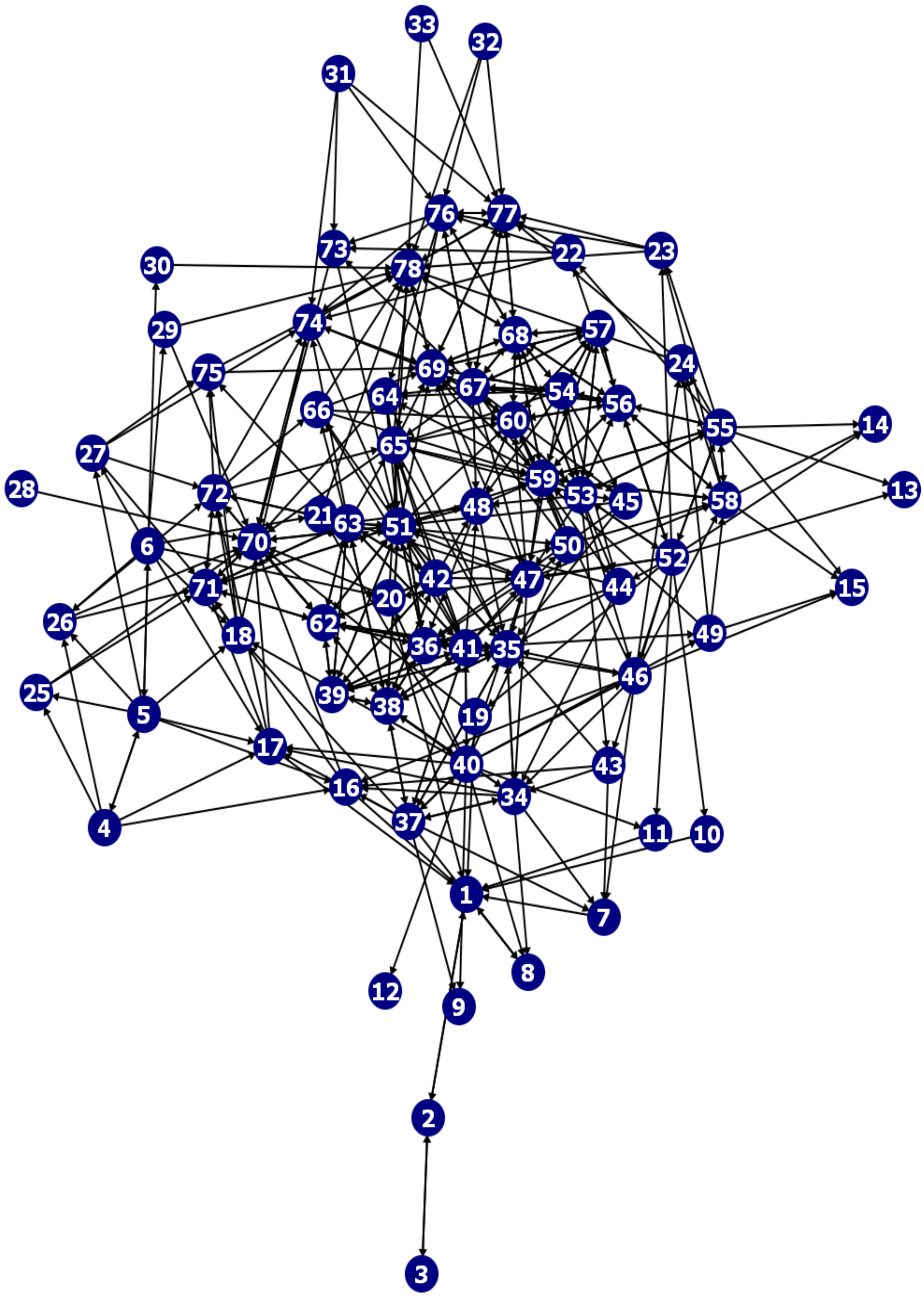

Fig. 6 Graph of transitions among the set of scenarios (21)

It means that the graph is significantly more complex if compared with the transition graph Fig. 5. It is difficult to identify all possible oriented loops in such complex graph.
The optimal CIA triplet (+ + +) have 3 scenarios of the modified model (16, 20), see (21). The following list of possible transitions from and to the set of scenarios with the CIA (+ + +) has four elements.

No.	From	To	
1	1	2	
2	2	1	
3	2	3	(22)
4	3	2	

The interpretation of the set of scenarios (21) depends on the nature of the variables (12). Different variables are controlled by managements (MAN) and government GOV. Some variables are not directly controlled as they are goals (GOA):

		Controlled by	
New jobs creation	NJC	MAN	
Incubator resources	IR	MAN	
Cooperation between industries and academics	CIA	GOA	
Circulation of industry information	CII	MAN	
Scale of industries	SI	MAN	
Incentives for investment	II	GOV	(23)
Operation costs	OC	MAN	
Benefit of economies of scale	BES	MAN	
Bargaining power	BP	MAN	
Reputation	RE	MAN	

There is just one goal to be achieved/maximized namely the Cooperation between industries and academics CIA. It means that the first scenario (21) is desirable. However to achieve this scenario a cooperation of the managements and government is inevitable.

The set of the best CIA scenarios is the set of the first 3 scenarios (21):

	CII	IR	NJC	SI	II	BES	RE	BP	OC	
1	+++	+++	+++	+++	+--	+++	+++	+++	+--	
2	+++	+++	+++	+++	+--	+++	+++	++0	+--	(24)
3	+++	+++	+++	+++	+--	+++	+++	++-	+--	

The set (24) can be characterised as follows**:**

$$\begin{array}{ccccccccc} \text{CII} & \text{IR} & \text{NJC} & \text{SI} & \text{II} & \text{BES} & \text{RE} & \text{BP} & \text{OC} \\ \uparrow & \uparrow & \uparrow & \uparrow & \downarrow & \uparrow & \uparrow & \uparrow\downarrow & \downarrow \\ \text{MAN} & \text{MAN} & \text{MAN} & \text{MAN} & \text{GOV} & \text{MAN} & \text{MAN} & \text{MAN} & \text{MAN} \end{array} \qquad (25)$$

where arrows indicate increase or decrease of the corresponding variables in the set of scenarios (24).

If Incentives for investment II is interpreted as a goal GOA, then two objective functions must be maximized. There are no scenario in (21, 24), which maximizes both objective functions see No. 1, 2, 3 in (21, 24).

$$\begin{array}{cc} \text{CIA} & \text{II} \\ \uparrow & \downarrow \end{array} \qquad (26)$$

Both goals can not be achieved at once.

Interpretation of the result of conditional model (16, 20) could be:

If the decision maker wants to maximize CIA and draw maximum of subsidies, then it seams to be an impossible dream. There is no way how to get maximum of both at the same time.

The best compromise in case the decision maker wants to draw maximum of subsidies scenario No. 4 (21). This scenario shows, that II will gradually increase while CIA will be at its maximum the circulation of industry information will increase and operation costs will also gradually slow decreasing. In the meanwhile IR, NJC, SI, BES, RE, BP will be at its maximum.

6 Conclusion

SPs are typical examples of problems, which are of interdisciplinary nature and unique. The main consequence is, that it is prohibitively difficult to develop relevant quantitative models. It is possible to develop a qualitative SP model using just verbal descriptions. Naturally if qualitative information items are used as the only information input into a model, then the results are exclusively qualitative ones.

The developed algorithms based on qualitative modelling and built up SP methodology of vague analysis facilitate optimization and decision making process about Science Parks in cases, where there are many possible alternative decisions.

The calculi must be made so flexible, that they can formalize and integrate vague and inconsistent knowledge with the minimum amount of knowledge loss. It is then much easier for the decision makers to choose from this well described set of alternative decisions. However the correctness of the results is influenced by the quality of researched informations. The set of scenarios must be provably complete, there cannot be any other qualitative behaviours, that are not generated by the qualitative model. If important details are not taken into account in the qualitative model, then the results may not be precise or may be skewed. Therefore it is essential to input true and complete information and carefully create set of all relevant criteria for the particular decision.

A methodology of vague SP modelling is built up and the basic philosophy can be summarized in the following heuristics:

- SPs knowledge must not be modified to fit the network of available calculi, but the calculi must be so flexible, that they can formalize vague and inconsistent knowledge with the minimum amount of modifications or simplifications of the knowledge.
- The network of calculi must be capable of reasoning based on sparse knowledge and must be at least partially capable of performing not just numerical calculations, but of making logical deductions as well.
- A SP model has to be developed on ad hoc basis.

Any qualitative unsteady state behaviour of a SP is always represented by a path in the transitional graph. This fact allows us to identify, for example:

- a suspicious behaviour of the process, probably a failure
- a shallow quantitative model can be used as a sub algorithm of a decision making support
- behaviours of such variables, that are either not measurable or are not measured

However, real life problems often involve data which are vague, inconsistent and sparse. The crucial step towards the final solution is the reconciliation of all relevant data [12]. Human thought is not based on equations and the most powerful tool used by human beings to solve real problems is common sense reasoning [16]. A qualitative model is the best available calculus, which can be used as a theoretical background to formalize common sense reasoning.

All objectives (main objective and sub-objective) in the dissertation have been properly met. Therefore we can say that the work contains everything what was determined.

7 References

Books

[1] POKORNÝ, O., KOSTIČ, M., ČADIL, V., VALENTA, O., HEBÁKOVÁ, L., VORLÍČKOVÁ, V. *Analýza inovačního potenciálu krajů ČR*. Sociologické nakladatelství, 2008. 137 p. ISBN 978-80-86429-90-8.

[2] VITURKA, M. *Kvalita podnikatelského prostředí, regionální konkurenceschopnost a strategie regionálního rozvoje ČR*. Praha: Grada Publishing, 2010. 232 p. ISBN 978-80-247-3638-9.

Expert articles and papers from conferences

[3] BARROW, C. Incubators: A Realist's Guide to the World's Business Accelerators. *John Wiley & Sons, Chichester*, 2001.

[4] BENAROCH, M., DHAR, V. Controlling the complexity of investment decisions using qualitative reasoning techniques. *Decision Support Systems,* 1995, no. 15, p. 115-131. ISSN 0167-9236.

[5] CHANDLER, G.N., HANKS, S.H., Market attractiveness, resource-based capabilities, venture strategies and venture performance. *Journal of Business Venturing*, 1994, no. 9, p. 331–349. ISSN 0883-9026.

[6] CHENA, CH., HUANG, CH. A multiple criteria evaluation of high-tech industries for the science-based industrial park in Taiwan. *Information & Management,* 2004, no. 41, p. 839 - 851. ISSN 0378-7206.

[7] DAS, T. K., TENG, B. S. Time and entrepreneurial risk behaviour. *Entrepreneurship Theory and Practic,* 1997, vol. 22, no. 2, p. 69–88. ISSN 1042-2587.

[8] DETTWILER, P., BRÖCHNER, J. Office space change in six Swedish growth firms. *Facilities,* 2003, vol. 21, no. 3/4, p. 58–65. ISSN 0263-2772.

[9] DOHNAL, M. A methodology for common-sense model development. *Computers in Industry,* June 1991, 2nd ed., vol. 16, p. 141-158. ISSN 0166-3615.

[10] FORBUS, K.D. Qualitative Process Theory. *Artificial Intelligence,* 1984, vol. 24, no. 1-3, p. 85-168. ISSN 0004-3702.

[11] KRAWCZYK, E., SLAUGHTER, R. New generations of futures methods. *Futures,* 2010, vol. 42, p. 75-82.

[12] LIAO, S. H. Problem solving and knowledge inertia. *Expert Systems with Applications,* 2002, vol. 22, no. 1, p. 21-31. ISSN 0957-4174.

[13] LIEBL, F., SCHWARZ, J.O. Normality of the future: Trend diagnosis for strategic foresight. *Futures*, 2010, vol. 42, Iss. 4, p. 313-327.

[14] MCADAM, M., MCADAM, R. High tech start-ups in University Science Park incubators: The relationship between the start-up's lifecycle progression and use of the incubator's resources. *Technovation*, 2008, vol. 28, p. 277-290.

[15] PARSONS, S., DOHNAL, M. The qualitative and semiqualitative analysis of environmental problems. *Environmental Software,* 1995, vol. 10, Iss. 2, p. 75-85.

[16] PORTER, M. E. Clusters and the new economics of competition. *Harvard Business Review*, 1998, vol. 76, no. 6, p. 77–90. ISSN 0017-8012.

[17] REDMOND, W.H. Form, change, and information: Qualitative dynamics in futures research. *Futures*, 1979, vol. 11, Iss. 5, p. 402-411.

[18] ROTHAERMEL, F., THURSBY, M. University-incubator firm knowledge flows: assessing their impact on incubator firm performance. *Research Policy,* 2005, vol. 34, iss. 3, p. 305-324.

[19] SUC, D., VLADUSIC, D., BRATKO, I. Qualitatively faithful quantitative prediction. *Artificial Intelligence*, 2004, no. 158, p. 189-214. ISSN 0004-3702.

[20] VAN NOTTEN, P.W. F., ROTMANS, J., VAN ASSELT, M.B.A., ROTHMAN, D.S. An updated scenario typology. *Futures*, 2003, vol. 35, p. 423-443.

[21] VÍCHA, T., DOHNAL, M. Qualitative identification of chaotic systems behaviours. Chaos. *Solitons & Fractals,* 2008, vol. 38, no. 1, p. 70-78. ISSN 0960-0779.

Internet resources:

[22] BusinessInfo.cz. *Rozvojové priority ČR pro kohezní politiku EU po roce 2013* [on-line]. HTML [cit. 2011-8-9]. Available from: <http://www.businessinfo.cz/cz/clanek/rozvoj-regionu/rozvoj-priorit-cr-kohezni-politika-eu-13/1001179/61311/>

[23] Ceitec, Středoevropský technologický institut. *Vizualizace* [on-line]. JPG [cit. 2011-6-7]. Available from: <http://www.ceitec.cz/onas/vizualizace/>

[24] Eli, extreme light infrastructure. *Dolní Břežany* [on-line]. HTML [cit. 2011-4-20]. Available from: <http://www.eli-beams.eu/cs/lokalita/ceska-republika>

[25] Eli, extreme light infrastructure. *V kostce* [on-line]. HTML [cit. 2011-4-20]. Available from: <http://www.eli-beams.eu/cs/evropsky-projekt/eli-v- kostce/>

[26] European Union. *Investing in Europe´s future, Fifth Report on Economic, Social and Territorial Cohesion* [on-line]. PDF [cit. November 2010]. Available from: <http://ec.europa.eu/regional_policy/sources/docoffic/official/reports/cohesion5/pdf/5cr_en.pdf >

[27] Evropská komise. *Evropa 2020, Strategie pro inteligentní a udržitelný růst podporující začlenění* [on-line]. PDF [cit. 2010-3-3]. Available from: <http://ec.europa.eu/eu2020/pdf/1_CS_ACT_part1_v1.pdf>

[28] Ihned.cz. *Evropské miliardy na vědu už přicházejí, dostal je brněnský CEITEC* [on-line]. HTML [cit. 2011-6-1]. Available from: <http://zpravy.ihned.cz/c1-51994110-evropske-miliardy-na-vedu-uz-prichazeji-dostal- je-brnensky-ceitec>

[29] Ministerstvo pro místní rozvoj. *Kohezní politika ve vztahu ke Strategii mezinárodní konkurenceschopnosti Ministerstvo pro místní rozvoj, červen 2011*[on-line]. PDF document [cit. červen 2011]. Available from: <http://asocr.cz/dokumenty/2011/110624kohezni.pdf>

[30] Univerzita karlova v Praze. *I-forum, Hledají se tisíce vědců aneb Sazka Areny české vědy* [on-line]. HTML [cit. 2011-5-6]. Available from: <http://tarantula.ruk.cuni.cz/IFORUM-10923.html>

[31] Vysoká škola ekonomická v Praze, Fakulta mezinárodních vztahů. *Význam a rozmístění vědecko-technických parků v Evropě* [on-line]. PDF [cit. 2010-5-12]. Available from: <http://www.svtp.cz/wp-content/uploads/zaverecna_prace.pdf>

[32] Výzkum a vývoj v ČR. *Názvy a stručné charakteristiky jednotlivých panelů expertů* [on-line]. PDF [cit. 2011-4-6]. Available from: <http://www.vyzkum.cz/FrontClanek.aspx?idsekce=612183>

8 List of abbreviations

BES	Benefit of economies of scale
BP	Bargaining power
CIA	Cooperation between industries and academics
CII	Circulation of industry information
CIP	Competitiveness and Innovation Programme
CR	Czech Republic

CS	Competition status
CSC	Completion of supply chain
EU	European Union
HBC	Human brain cultivation organizations
HR	Human Resources
II	Incentives for investment
INMS	Ill-known, nonlinear, multidimensional system
IR	Incubator Resources
LU	Living Utilities
MD	Market Development
NJC	New job creation
OC	Operation costs
OCE	Occasion for enterprises cooperating
OECD	Organisation for Economic Co-operation and Development
PI	Prospects of industries
QE	Quality of enterprises
QRD	Quality of R&D engineers
QRI	Quality of research institutions
R&D	Research and Development
RDO	Regional Development Outlook
RE	Reputation
SI	Scale of industries
SP	Science Park
SQP	Supply of qualified outside personnel
TR	Technological Resource

9 List of Figures

10 Publications

[1] RAUDENSKÁ, L., PAVLÍČEK, M., RAŠKOVÁ, H. Qualitative Models as a Segment of Naive Engineering Design. *Engineering MECHANICS*, 2011, vol. 18, no. 1, p. 43–50.

[2] KREJČÍR, J., RAŠKOVÁ, H., DOHNAL, M. Possibilities of qualitative modeling in bankruptcy predictions. In: *Sborník vědeckých prací University Pardubice.* Pardubice: 2011. ISSN 1211-555X.

[3] REŽŇÁKOVÁ, M., WOUTERS, H., DOHNAL, M. Equationless Qualitative Models of Science Parks: Part I, Individual Scenarios as Models Solutions. *International Journal of Technology Intelligence and Planing, 2012.* ISSN: 1740-2832.

[4] REŽŇÁKOVÁ, M., WOUTERS, H., DOHNAL, M., BROŽ, Z. Equationless Qualitative Models of Science Parks: Part II, Optimization by Time Sequences of Scenarios. *International Journal of Technology Intelligence and Planing, 2012.* ISSN: 1740-2832.

[5] REŽŃÁKOVÁ, M., DOHNAL, M., WOUTERS, H. Multi-Objective Optimization of Science Parks Based on Qualitative Equationless Relation. *The Journal of High Technology Management Research*, 2010. (submitted for publications)

[6] BROŽ, Z., KOCMANOVÁ, A., LUŃÁČEK, J., MELUZÍN, T., RAŠKOVÁ, H. R&D Management of Chemical Engineering Processes versus Complex Socioecological system. In: CHISA. *Process Engineering Publisher.* Praha: 2008, p. 1-4. ISBN 978-80-02-02052-3.

[7] DOHNAL, M., KOCMANOVÁ, A., RAŠKOVÁ, H. Hi-tech microeconomics and information non-intensive calculi. In: Akademické nakladatelství CERM. *Trendy ekonomiky a managementu.* Brno: 2008, p. 20-26. ISSN 1802-8527.

[8] RAŠKOVÁ, H. *New evaluation criteria for the Regional Operational Program Central Bohemia.* (Conference for applicants) Praha: Regional Council of Central Bohemia, 2010. ISBN 978-80-254-9227-7.

[9] RAŠKOVÁ, H. *How to finance your project support of subsidies? Or what beware!.* (Conference for applicants) Praha: Eucentrum, 2008. ISBN 978-80-254-9237-6.

11. Curriculum vitae

Personal details

Name: Ing. Hana Wouters (Rašková)

Date of birth: 7.10.1979

Status: married

Gender: female

Citizenship: Czech Republic

Education

2004–2012 Ph.D. Faculty of business and management, Brno University of Technology

2002 Certificate of Study. Karel de Groote-Hogeschool in Antwerpen, Department of Commercial Sciences and Business Administration

2001-2004 Ing. Faculty of business and management, Brno University of Technology

1998-2001 Bc. Faculty of business and management, Brno University of Technology

1994-1998 high school, Business Academy in Boskovice, Czech Republic

Profesional qualifications

2011 – present Methodologies at Regional Council of the Central Bohemia

2009–June 2011 Project specialist at Regional Council of the Central Bohemia

2008-2009 Business manager at Technoexport a.s.

2007-2008 Business manager at EUcentrum a.s.

2006 Personal secretary to the Minister at the Ministry of Culture Czech Republic

2005-2006 Transport coordinator at Bruhn Spedition N.V. Antwerpen Belgium

2004-2005 Traineeship at Bruhn Spedition N.V. Antwerpen Belgium

2003 Traineeship at Maersk Sealand Antwerpen Belgium

Research interests

Project management, efficiency and optimization, sustainable development, ecology soft computing, fuzzy logic, e-learning, language education.

Languages

Czech: fluent, English: fluent, Neederlands: intermediate, German: intermediate, French: intermediate

Computer skills:

PC: most programs OS Windows, special programs: Benefit7+, MONIT7+, Ginis, internet, Graphics: PhotoShop, Corel