Do Managers have Enough Quality Information for Decision-Making

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Modern complexity of management is associated with important decision making, confronting a great number of useless information. Selection of information – the choice of only quality, i.e. essential ones, is a big problem in managerial decision-making. Implementation of systemic approach i.e. systemic thinking can help dealing with it.
It is known that decision-making based only on intuition is insufficient, especially nowadays, in the time of global business. Therefore, managers have to operate with adequate knowledge capital. It is synergetic composition of inborn talents, feelings, abilities as well as gained knowledge and experiences. DNT put this capital knowledge into function of management decision-making, thus easier and holistic information management needed for quality and efficient and successful problem solving. It enables managers to be creative, co-operative and interdisciplinary. It opens possibilities for combination of theory and practice in the decision making processes, as presented in our contribution.
Quality, holistic management decision making, create competitive advantages. It can be proved by a practical example of decision making about preventive measures in the winter time (roads gritting and ploughing). Great importance of quality, timely and enough holistic information is presented with the model of Short Term Road Ice Prediction, which gives information for quality decision making.

Key words: requisite holism, management, decision-making, systemic thinking, road safety, combinatorial optimization, algorithm.

Vpliv informacij na kakovost managerskega odločanja

Povzetek: Sodobna kompleksnost managementa je povezana s sprejemanjem (bolj ali manj) pomembnih odločitev. Te so posledica velikega, mnogokrat (žal) neuporabnega števila informacij. Njihovo selekcioniranje – izbor samo tistih kakovostnih, tj. bistvenih za konkretno problematiko managerskega odločanje – je velik problem. Pri tem lahko pomaga sistemski pristop oz. sistemsko razmišljanje.
Vemo, da odločanje zgolj na intuiciji (pa naj bo ta še tako dobra), ni več dovolj, zlasti v času globalnega poslovanja. Zato morajo imeti managerji še ustrezen kapital vednosti in znanja. Ta je sinergijska kompozicija tako prirojenih talentov, čustev, sposobnosti kot tudi pridobljenih znanj in izkušenj. DNT ta kapital vednosti in znanja postavlja v funkcijo managemeta odločanja, tj. za lažje in celovitejše obvladovanju informacij potrebnih za kakovostno, tj. učinkovito in uspešno razreševanje problemov. Pri tem managerjem omogoča, da zmorejo biti (bolj kot sicer) ustvarjalni, sodelovalni in interdisciplinarni. Pomeni, da znajo v procesih odločanja sinergijsko kombinirati teorijo in prakso, takšno, kot je npr. tematika našega članka.
Kakovost, tj. celovitost managerskih odločitev ustvarja konkurenčne prednosti. To lahko tudi potrdimo na praktičnem primeru odločanja o preventivnih (varnostnih) ukrepih v zimskem času (posipavanje in pluženje cest). Slednje kaže velik pomen kakovostnih, tj. pravočasnih in dovolj celovitih informacij za kakovostno odločanje, ki nam jih daje predstavljeni model Kratkoročna napoved nastanka poledice.

Ključne besede: potrebna celovitost, management, odločanje, sistemsko razmišljanje, varnost na cestah, kombinatorična optimizacija, algoritem

1 Introduction

A few decades ago the fathers of the Theory of Systems (L. von Bertallanffy, N. Wiener in Mulej, 2000 and before) saw the meaning of system theory in the development of theoretical approaches (general orientations), methodologies (knowledge about methods) and methods (way of treatment), to support the practice of systemic thinking in research and analysis processes (recognition of hidden essence) This was in preparation and decision implementation, considering the essence of this entangled phenomenon. Mankind would thus be able to think, make decisions, and act holistically instead of one-sidedly, in an overly simplified or dangerously apparent holistic manner[1].

2 Process of quality (sufficiently holistic[2]) decision making in management

2.1 Problems of managerial decision-making

The quality of management depends on creative, dynamic, trained and development-oriented managers, who are eager for interdisciplinary co-operation, provided their way of thinking and decision making is as holistic as necessarily possible. Unfortunately, they do not have enough quality information at their disposal that would enable them to carry out such actions or sufficient information needed for solving more or less complex problem situations and make related decisions[3]. This is extremely important (see Rozman, 1993; Vila, 1994), as the aim of the information lies exactly in the risk reduction that affects each decision, because they are affecting the future. It is not difficult to prepare small amount of data. Difficult, if not impossible, is to prepare adequate and timely information for those who make decisions and take responsibility for them. On the other hand, waiting for information paralyses the decision-making process and related problem solving situations. The quality of information affects the level of risk, where decisions can be divided into decisions made in certainty, decisions made in risk and decisions made in uncertainty.

Decision-making in management (Tavčar 2002) includes routine, analytical and intuitive decision making. Nevertheless, it must be emphasized that routine decision making is done in a normative way (in line with the rules), whereas analytical decision making depends on the knowledge based on studying things in more complex circumstances. Intuitive[4] decision-making is indirect decision making, or when all other possibilities denounce. It is derived from a decision maker's subconscious. From the viewpoint of different managerial levels, a large part of intuitive decision-making is done by the executive management and needs to be supported by appropriate human resource decision makers, i.e. talented, competent and development-oriented managers. At executive level, the percentage of intuitive decision making is sparse. There, the decision-making is managed by a "supervisor and in a normative manner. Overall, in executive management, the break down is as follows: 80 % intuitive, 16 % analytical and 4 % routine decision making. On the other hand, at managerial executive level 2 % is intuitive decision making while 35 % is analytical and 63 % is routine. Between these two extremes one can see the possible relationship of decision making to a particular managerial level. These relationships depend predominantly on the ongoing decision-making activities and their participants.

Here, it is assumed that due to lack of information and presence of one-sided information, a contemporary manager will often have to make decisions based on his or her intuition. This means his or her decision-making is intuitive[5], and can be drastically improved through intuitive techniques and last but not least, although not scientifically proven, the way this affects his or her subconscious. In management or in the features of managing businesses or people inspiration, experience and the knowledge play a vital role when making decisions (see Kralj, 1997). All these managerial skills form the so called capital of knowledge and skills, accumulated in similar situations, where decisions had to be made. In the future this (accumulated) capital will mean a significant competitive advantage, as the management will already have a decision-making model at its disposal that will enable a faster and qualitative, i.e. holistic and therefore more sustainable management (of more and more complicated) decision-making proces-

[1] Due to one-sidedness that can easily be a result of over-specialisation, essential elements being neglected or overlooked in the choice making phase or when a particular managerial decision had already been considered.

[2] Holism as a term is easy to use but difficult to define (for example Bertalanffy, 1968 and before; Checkland, 1981; Schiemenz, 1984; Dyck, Mulej et.al., 1998, 1999; Mulej, 1979; Mulej et.al., 1992, Mulej et.al, 2000; Mulej and Ženko, 2004, Rosi, 2004; Rosi, Mulej & Potočan, 2006 etc.). Holism encompasses everything, all elements and their relationships (connections, relations) that define the term. Naturally, it is impossible to include everything that is why such perfect (total) complexity is not possible, especially not in the working environment and in people's way of thinking as individuals without (inter-specialist) co-operation. At the same time it can be overloading as well. First though, a decision needs to be made as to what level of complexity is sufficient and necessary at the same time and hence suitable for discussion and analysis.

[3] Decision-making and all relevant (human) activities have several meanings: to express will about the following: how it is to (have a right to) make a decision about one's life, work…//to give, have the final opinion or decision about something: management of a company, a person in charge, commission or an institution make such decisions…; to define the result of something: choice of alternative possibilities // to define, direct: something defined someone's destiny ; to make decisions in a way to reach a certain point through thinking, when a person wants to do something, make something happen: one after another they decided to help them; consciously, finding it hard to make a decision, be in a state, when a subject still dwells on making a decision about something etc. (Slovene dictionary SSKJ 1996)

[4] Intuition means to grasp or sense the essence of something indirectly, independently of reason and analytical thinking, an inspiration: to give in to one's intuition, work and create using one's intuition, with intuition, to have a natural capacity for intuition. (SSKJ 1996)

[5] In contemporary management the belief prevails that the majority of managerial decision-making processes (80%) are analytically based on scientific achievements. The practice of the most successful ones shows that their executive managers naively believe in their intuition and make decisions based on it (Kralj, 1997).

ses. (Rosi, 2004; Rosi, Lisec, Kramberger & Kramar, 2006).

When making decisions, managers use their intuition and knowledge in various combinations: first, lack of knowledge called for more intuition, later on it seemed that the only real path was just knowledge (Kralj 1997). It also turned out that in crisis situations, where fast actions need to be taken, inspiration was a successful means of decision-making process, especially as it was supported with already accumulated knowledge and experience. It often makes more sense to solve trivial problems using intuition as the cost of eventual damage proves to be drastically smaller.

However, intuition alone is not enough to make quality decisions. It is necessary to have enough knowledge and skills that are the result of various influences: (inborn and developed) emotions, talents and competences, education, environment, experiences and sometimes also luck. All this helps the managers to reach the necessary and adequately holistic decisions, which means that they are capable of considering all essential elements in the decision making process. Quality decisions are the result of systemic thinking such as DNT and their aim is to solve complex managerial problems.

2.2 Hierarchy and the process of managerial decision-making

In nature everything, including man, is subdued by constant changes, caused by interdependence between the constituent elements. In the process of changing, some things occur before others. The practice says that transfer steps of the process have greater influence that the later ones[6]. The same can be asserted for the managerial decision making process, where the hierarchy of priority decisions is well known. Upper levels define the aims of the decisions, whereas the lower levels implement them. This is the actual hierarchy of sequence and correlation[7] of (alternative) decisions and activities, needed for its realisation. (Mulej, 2000; Rosi, 2004)

The managers' job for instance is not to impose their will but to build the early phases of the process chain, such as to make decisions when there are still too many alternatives, data and messages (unambiguous data) available and hence less meagre information (i.e. influential information that meet information needs). At this point, one needs to consider the numerous correlations, such as the ones between the people at the same organisational and hierarchical level and the ones at different levels, as well as the ones between the events, processes, people in an organisation and its environment. Other than that, the data (could) be available, but there is no (relevant) information. The occurrence of various solutions or alternatives when making decisions means that the same problem can be solved in different ways. The alternative option does not only mean that a decision solves a problem and the other one does not, but that various solutions more or less successfully solve a problem or prevent that it occurs.

The many alternatives available for solving or preventing a problem from occurring call for a measure that could categorize the solutions into more or less successful ones and help us choose the most successful ones. The measure is usually the aim of a subject upon which the decision needs to be made and may differ based on the decision maker or giver and his or her interests (Rozman, 1993).

Here, the so called rationality of the decision making process is being assumed, which means that the person making a decision has all the information, knowledge and skills at his or her disposal needed for the analysis of problems and setting of priorities, the knowledge of measures needed for decision making and problem solving, that he or she can evaluate and foresee all their possible consequences. In practice such examples are rare (the same goes for the perfect holism). That is why in decision making we talk about the so called "restricted rationality" (lack of overview) that often does not provide optimal solutions. For this reason we must often settle for insufficient (single-minded) solutions. The managers can solve this problem through systemic thinking, such as for example dialectic network thinking[8] (Rosi, 2004)

3 An example of tools for supporting managerial decision-making – short-term forecast for the occurrence of consequences

3.1 Starting points for supported decision-making

Today, numerous useful and applicable techniques, methods and tools offer support to decision making. Such

[6] For example in mathematics such experience is expressed by Mark's chain, in ecology by ecological circle flows, in organisations by the circle flows known from the organisational cybernetics etc. (Mulej, 2000; Rosi, 2004).

[7] According to the Laws of Hierarchy of Sequence and Correlation (Mulej, 2000, Rosi, 2004), in a man's working process and related solving of problematic situations the starting points are the most important. The practice of human life and working process shows that there are two (interdependent) subsystems of the starting points. The first one is independent from a man and thus an objective part of the starting points, the other one is subjective, built from the reason and emotional part of a man's personality

[8] Dialectic network thinking can support a sufficient and necessary holistic way of thinking, decision-making and working when solving complex managerial problem situations, for dialectic systematism provides the ability to support and recognise the correlation of the participants of the solution process (from various, yet essential branches, professions, cultures). Based on these findings the managers can easily form (necessary and adequate) potential solutions that will ease their decision-making process.

methods can be based on mathematical models of individual problems or on so called fuzzy logic. As already mentioned, the decisions for wrongly identified problems are more harmful than useful as they give a (misleading) feeling that smart decisions are being made and problems are being solved. In order to avoid such mistakes managers can – if they are familiar with systemic thinking – integrate the knowledge and the power of experts from various fields. The results of such work can today turn into popular software tools that support the decision making processes. Next, we will describe and present the development of the tools that already exists as a prototype. Here, we have mainly focused on the results of our own tests (Kramberger, Lipičnik, Podbregar, 2005) and the already developed optimisation algorithms (Kramberger and Žerovnik, 2005; Kramberger and Žerovnik, 2006).

3.2 Introduction to the problem and its definition

Ploughing and gritting roads during the winter months is an important and costly activity. If in snowy conditions the roads are not ploughed or gritted in time, the road users are exposed to great dangers, traffic standstills can occur, that cause greater economic loss and "at best" can even lead to public disapproval. The optimisation of ploughing and road gritting can, as an occurrence of (more or less complicated) preventive activities, be viewed from two different angles: safety and economy. Safety calls for the most critical points of the road network to be gritted first. These are the points where glazing frost occurs first. From an economical point of view, all the roads are to be gritted in such a sequence that all the vehicles can take the most rational route.

The methods for predicting the occurrence of icing are to a great extent based on the temperature of the roadway, the air temperature and humidity (Schaffar and Hertl, 1995). Some are based only on one of the aforementioned physical quantities, whereas the others depend on the combination of them all. In 1994, Bogren, Gustavsson and Lindqvist presented a model of forecasting temperature changes of chosen road sections. The model is based on the characteristics of temperature oscillation of the roadway that the same authors and D.G Belk have already presented in 1988 and 1992 (Gustavsson and Bogren, 1988; Belk, 1992; Bogren, Gustavsson and Lindqvist, 1992).

The aforementioned models are based on the temperature data of the roadway to which the forecast refers to. They have found out and proven that the sample of the way temperature of the roadway is spread is recurrent. If a sufficient number of measurements and results are divided into three different categories based on the weather, a big correlation between the data series "was seen (Shao, Lister, Hart and Pearson, 1997; Shao and Lister, 1995).

In our research (Kramberger, 2003) it has been shown that this characteristic also refers to smaller samples. In this case, the correlation between the pairs of data series for the measurements along individual points has been studied. Should the correlation between the series of data exist, then it may be assumed that the correlation between the data is from individual measure points from different time sequences.

3.3 The creation of the model

The basic aim for building this model was the fact that from the existing points one or two representative points that at best describe the temperatures on other measure points need to be determined. In order to define these two points mathematically, the following procedure will be described:

- *The algorithm of the procedure*

I. *Calculate coefficient of determination for each among matched pairs of the data series.*
II. *Calculate average coefficient of determination for the same independent x values.*
III. *Mark the measuring spot with the highest average determination coefficient.*
IV. *Calculate the regression lines* $Y = a_0 + a_1 X$*, whereby the values should be measured at individual measurement spots, are the values measured at the reference spot with the highest determination coefficient (see No. II).*
V. *Calculate the standard error for each regression line.*
VI. *Bearing in mind the characteristics of the normal allocation and the estimated 68,26% confidence in the calculated results, check one or more test series, if the measured results can be found in the required interval.*
VII. *Should the required interval, on average, have less than 68,26% of all values, then the reference spot was not well chosen or the correlation links were too weak.*

Should the values calculated on the basis of the defined regression straight line not meet the expectations, we will try the multiple regression calculation. This way we get the regressive straight line in a three dimensional coordination system. Next, we slightly change the course of the algorithm.

- *Modified algorithm*

I. *Of all measured spots three with, on average, the highest determination coefficient are chosen.*
II. *For each trinity* (x_1, x_2, y) *of data series calculate determination coefficient.*
III. *Calculate the average determination coefficient that was calculated with the same independent x values.*
VI. *Mark the measured spot with the highest average determination coefficient.*
V. *Calculate the regression lines* $Y = a_0 + a_1 X_1 + a_2 X_2$ *, whereby the values should be measured at individual measurement spots, are the values measured at the re-*

Figure 1: Measuring points in the area of Maribor

ference spot with the highest determination coefficient (see No. III).

VI. *Calculate the standard error for each regression line.*

VII. *Bearing in mind the characteristics of the normal allocation and the estimated 68,26% confidence in the calculated results, check one or more test series, if the measured results can be found in the required interval.*

VIII. *Should the required interval have approximately 68,26% of all values, then the measured spots are chosen as reference spots.*

The model of temperature distribution of the runway at chosen measure points can be transferred by a linear regression function.

$$Y_j = a_{0j} + a_{1j} X_1 + a_{2j} X_2 ,$$

where Y_j means the calculated temperature value at *j* measure point, and a_{0j}, a_{1j}, a_{2j} mean the calculated regression coefficients for the *j* measure point. X_1 and X_2 represent the value measured at reference measure points. The quality of the estimated value is defined with the expected degree of confidence that is defines from the characteristics of normal distributions. By definition of the model we can trust the estimated data with a risk degree of 31,74 %

■ *Experiment*

In order to place the model into the real-life environment, in this case the road network, an extended experiment had to be undertaken. The basic idea of this experiment was to collect the sufficient amount of data for a serious correlation and regression analysis. Given that the described characteristic is geographically bound (Shao, et. al, 1997; Kramberger, 2003), an adequate spot for the experiment had to be chosen first. It was furthermore one of the aims for the data to be representative for all the roads with different requirements that is why the measuring spots of various types were chosen: On bridges, remote and urban areas. The weather, too, represents certain restrictions. The majority of similar experiments have been undertaken separately, based on various weather types (Shao, et. al, 1997). This way, within the framework of individual types of weather, a stronger correlation link has been reached. In our experiment, the measurements belong to a single weather class, regardless of the weather type. Bearing in mind the assumption that the correlation as such is stronger within the certain types of weather, a sufficient correlation of data will - in our case - mean an even stronger correlation within the certain types of classes.

The measuring spots have been chosen based on the research findings (Kramberger, 2003) and experiences of local winter services from Maribor. The chosen measuring spots were all within the 100 km^2 area, comprising of the city centre, bridges across the river Drava, the hillside of Pohorje and the flat land of Dravsko Polje. The location can be seen in Figure 1.

The measuring spots in the table below are listed based on the data. The data, such as road temperatures were measured manually using the infrared thermometer CALEX ST-8818, with the accuracy of ± 1,5 %, and separability of 0,1° C.

- *Measurements*

The measurements were carried out at dusk of the winter nights. The road temperature is at this time of the day the most stable. The radiation of the energy flow into the atmosphere had just finished, whereas the absorption and hence the warming-up of the road had not yet started. 24 measurement series in different weather conditions have been carried out in two years time. The measured temperatures can be seen in Table 1, the most accurate data from the measurements are listed in the appendices. Of the 24 data series, 20 were chosen randomly for the analysis, the other 4 were used for the test.

Table 1: Measured temperatures chosen for the calculation

spot	1	2	3	4	5	6	7
series							
1	-3,1	-3,0	-3,9	-3,7	-2,7	-3,0	-1,8
2	0,7	0,8	0,5	0,2	0,6	0,4	1,2
3	-1,4	-2,2	-5,2	-2,8	-7,0	-6,4	-5,4
4	7,4	5,7	4,5	4,8	4,8	4,8	4,7
5	-1,1	-1,9	-8,9	-6,7	-7,1	-5,5	-11,1
6	5,4	2,3	2,9	4,8	4,9	4,7	2,3
7	4,8	4,4	4,1	4,1	3,3	2,4	1,2
8	-4,2	-5,2	-11,3	-9,3	-8,8	-9,0	-8,1
9	1,4	-1,5	-5,8	-4,6	-2,9	-4,6	-5,7
10	3,4	0,4	-2,3	-0,9	-3,6	-1,4	-3,4
11	0,3	-3,9	-7,0	-6,9	-5,9	-6,5	-7,7
12	0,2	-4,0	-7,1	-7,1	-6,0	-6,6	-8,0
13	-4,1	-3,4	-16,0	-15,4	-14,8	-14,1	-14,5
14	-4,4	-3,3	-15,9	-15,3	-14,5	-13,9	-14,3
15	-2,9	-4,8	-11,3	-12,1	-12,3	-13,0	-12,1
16	-2,8	-4,9	-11,5	-12,2	-12,4	-13,3	-12,0
17	-6,1	-3,1	-16,1	-15,4	-17,7	-18,7	-15,6
18	-6,4	-3,4	-16,3	-15,4	-17,8	-18,6	-15,6
19	4,8	3,4	-0,1	-1,3	0,7	2,6	0,4
20	4,8	3,4	-0,1	-1,3	0,7	2,6	0,4

- *Calculations*

The calculation was performed using software programme MS EXCEL 2003. The implemented functions for statistics analysis have also been used, most frequently the spreadsheet function LINEST. All regression functions are shown in the Table below:

Table 2: Results from the chosen reference spot 1

Pair	r^2	$y = a_0 + a_1 x$
1-2	0,76564474	y = -1,07202735 + 0,7233684x
1-3	0,85057048	y = -6,08681022 + 1,5481751x
1-4	0,81744667	y = -5,559414012 + 1,5034469x
1-5	0,84559900	y = -5,656944181 + 1,6062107x
1-6	0,84825892	y = -5,820336617 + 1,6156669x
1-7	0,78121902	y = -5,744450533 + 1,3855851x

From the calculation, the value *t* of the statistics and in comparison with the critical value t_c for the size of this pattern that amounts to 1.73, we can predict with a 2.5% risk that the calculated pattern correlation coefficient is not random and is significant to the entire population.

The data from the measured spot *1* are considered to be independent and are compared with the data from all other measured spots. The same calculations are done for all seven measured spots. All parameters and coefficients are calculated and regression equations are determined.

3.4 Test models

Given the measured data, a test model can be performed. The test is performed using the data from the series that have been put to the side for this test. The data is then implemented into the aforementioned regression equations and the estimated value $E(y)$ is calculated. The calculations are further shown in the graph. At this point, the trust interval for the assessment is taken into account, i.e. the measured temperature is with a 68,26% certainty within the interval $E(y) \pm S_{x,y}$.

From the results shown in Table 4 the value of the variable y for individual values x can be calculated. Apart from that, using the equation $E(y) \pm S_{x,y}$ the upper and lower boundary of the trust interval is calculated. The result is:

Table 3: Test calculation for the value of 3,4° C

Values 1						
1	measure.	*calculated*	*measured*	*up.boundary*	*low. boundary*	*Sx,y*
3,4	1	3,4	3,4	4,40	2,40	1
	2	1,4	3,2	4,90	1,50	1,70488993
	3	-0,8	2,1	4,86	-0,66	2,76437020
	4	-0,4	2	5,03	-1,03	3,02667877
	5	-0,2	3,7	6,62	0,78	2,92387224
	6	-0,3	3,7	6,61	0,79	2,91106738
	7	-1,0	4,1	7,22	0,98	3,12366632

The results can be presented graphically. We can see that over 68,26 % of the value falls outside the estimated intervals.

- *Calculation using a modified algorithm*

To put the quality of the gained results to the test we must apply the modified algorithm. To this end some measuring spots will be chosen for which the multiple regression will be calculated. Using the function LINEST the equation of the multiple regression $Y = a_0 + a_1X_1 + a_2X_2$ is calculated for each measured spot separately depending on the pair of the chosen reference spots. The best way to choose the first pair of the reference spot seems to be the choice of the two spots with the highest average determination coefficient when calculating regression in the previous example. In our case these spots are 3 and 5. Their data do not depend on the variables X_1 and X_2.

The line of the multiple regression now gains the following form:

$$Y = 3{,}194498653 + 0{,}31771627X_1 + 0{,}227150141X_2$$

The determination coefficient r^2 has in our case the value r^2 = 0,856731431, which means the strong correlation (regression) connectivity. Having performed the T-test, we can see that the t statistics is higher than the critical value t_c for this size of the sample that includes 20 statistical units. From this we can conclude that the determination coefficient r^2 is not coincidental and is valid for the entire population.

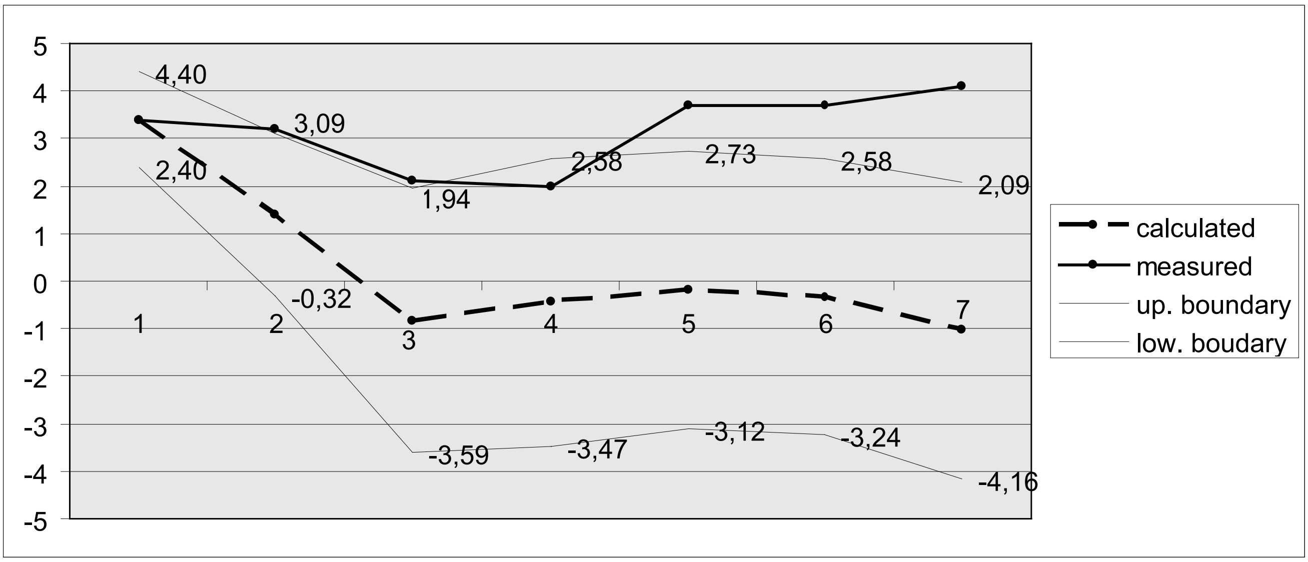

Figure 2: Graphical representation of the calculation for the value 3,4° C

The same calculations are applied for all trinities with referential spots 3 and 5. This way the following values of determination coefficients and the following lines of multiple regression are gained:

Table 4: Regression equations for reference spots 3 and 5

trinities	r^2	$Y = a_0 + a_1X_1 + a_2X_2$
3,5-1	0,85673143	$y = 3{,}19449865 + 0{,}31771627x_1 + 0{,}22715014x_2$
3,5-2	0,71927159	$y = 1{,}55287141 + 0{,}61785402x_1 - 0{,}19822962x_2$
3,5-4	0,97759599	$y = 0{,}32842163 + 0{,}84198149x_1 + 0{,}13437422x_2$
3,5-6	0,96921455	$y = 0{,}03879351 + 0{,}37431781x_1 + 0{,}63353717x_2$
3,5-7	0,97007154	$y = -0{,}47779992 + 0{,}36177685x_1 + 0{,}54045819x_2$

It can be seen that determination coefficients are very high, T-tests also show us the relevance for the entire population, therefore we can assume that between the series of data there is a strong regression (correlation) connectivity.

3.5 Test of the modified model

This model can be testes using the measured data. Bearing this in mind, we can now calculate the intervals of trust with the chosen degree of trust. We will predict that the measured temperature with a 68,26% probability is within the interval . The gained results are the following:

Table 5: Test calculation for the values 2,1 and 3,7° C

	measure.	calculated	measured	up. boundary	low. boundary	Sx_1,x_2,y
x_1=2,1	1	4,85	3,4	6,51	3,19	1,6592060
x_2=3,7	2	3,42	3,2	5,34	1,50	1,9200563
	3	2,10	2,1	3,10	1,10	1,0000000
	4	3,73	2	4,82	2,61	1,0910535
	5	3,70	3,7	4,70	1,75	1,0000000
	6	2,75	3,7	4,10	1,40	1,3492276
	7	2,00	4,1	3,18	0,81	1,1888138

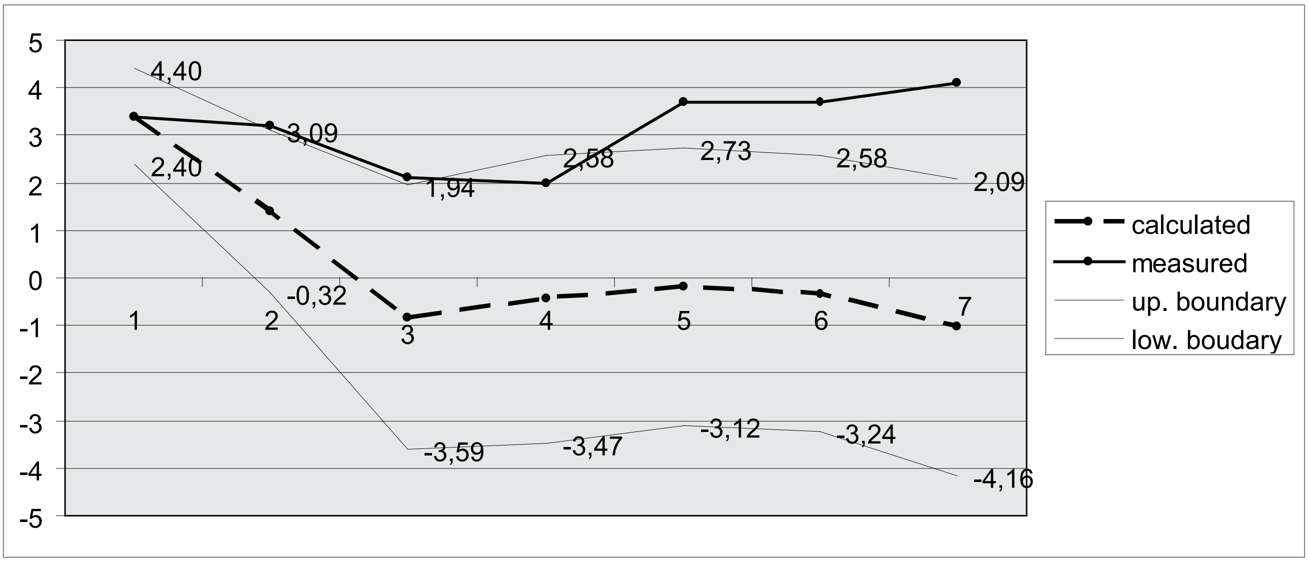

Figure 3: The results for the values 2,1 and 3,7ºC are shown graphically

The results are shown in Figure 3.

The graph from Figure 3 shows that two out of seven values deviate slightly from the interval. However, based on the set demands this is still a pretty good result. Targeted 68,26 % reliability has in this case been reached, as 5 out of 7 makes exactly 71,43 %. A similar result has been obtained from the test series shown below (Figure 4).

Here, only two values deviate from the demanded interval, that is why the demand for 68,36 % reliability has been met.

3.6 Selection of the reference spot

Measures, calculations and statistic tests have shown that there is a strong linear correlation between the temperatures of some measured spots. Determination coefficients and regression lines of an ordinary and multiple regressions have been calculated and analysed. This way, the assumption has been proven that, based on the temperature of the roadway, it is possible to assume the temperature at other measured spots in the road network.

The analysis has shown that the multiple regression provides the best results. For referential spots it is best to consider the spots with the highest average determination coefficient and the lowest average standard estimation mistake.

In our example these are the measure spots 3 and 5. With the constant temperature measures of the roadway on the spots 3 and 5 the temperature development on the other chosen spots in the road network.

4 Application of the model in a decision making process

In winter the road users face a very interesting phenomenon. During minor weather changes and moderate air temperature deviations the road conditions may drastically alter within a very short period of time. Most unpredictable are the circumstances at 0°C, when the water transforms from one aggregate state into another. In such circumstances the water on the roadway turns into ice, the adherence coefficient is drastically reduced and the occurrence of accidents increases. Apart from the appropriate winter equipment and technical motor vehicle roadworthiness, the optimal organisation of winter services seems like the only solution to the problem that could provide the in-time gritting of critical road sections befo-

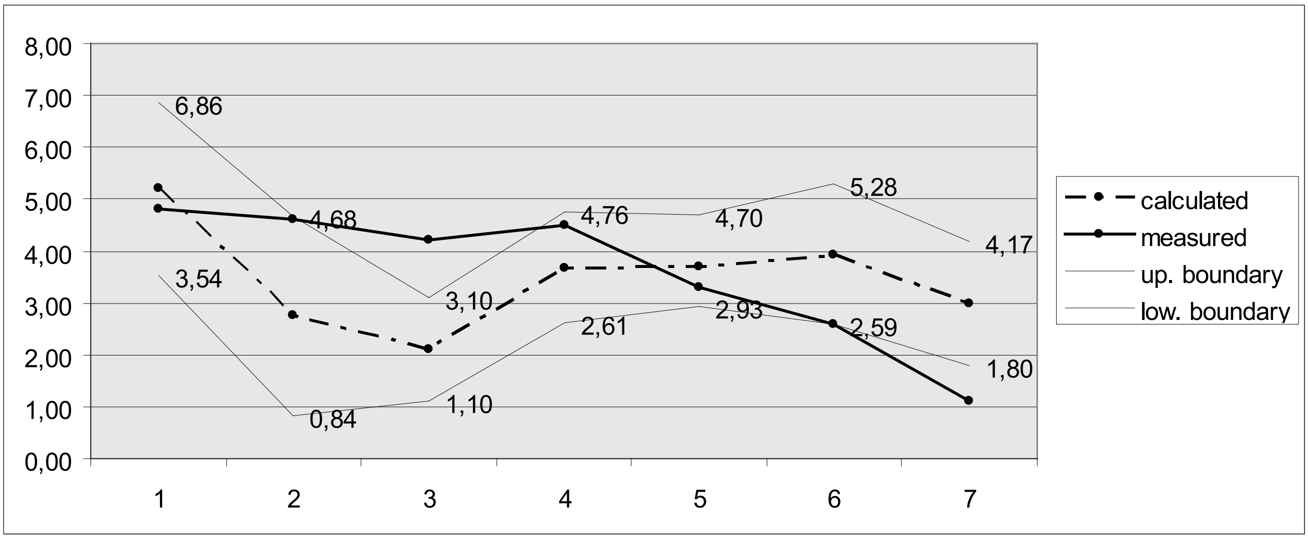

Figure 4: shows the results of the calculation for the following data series – for values 4,2 and 3,3° C.

re they would freeze. Such work must not create high costs and must not damage the environment.

The organisation of winter services in our case gritting of iced road sections, must be tackled using at least three aspects. First, aspect of safety calls for the most critical points to be gritted first, if possible before the icing even occurs. From the economical point of view, all roads are to be gritted so as to enable the most rational route, if possible before the icing even occurs. The environmental point of view demands the gritting of roads to occur as rarely as possible, and only if necessary.

The described problem of optimal organisation of gritting the iced road sections can be further divided into two problems that, at least at the beginning, need to be analysed separately. The first problem refers to setting of the place and time, where the icing is most likely to occur first. The second problem represents an optimal organisation that will take all the aforementioned viewpoints into account.

In the majority of cases the local authorities with the inferred costs are facing difficult problems, for which the constant lack of time and data seems very common for quality decision making when setting the appropriate time for necessary actions. One of their main assignments is preventive gritting of roads that already have glazed or are expected to glaze. Due to increased traffic safety and cost reduction road gritting needs to be planned in advance. In most cases, for example in Slovenia and elsewhere, this is still done manually, with a pencil and a map, often based on the knowledge of the local environment and the experience of operators and drivers that are in charge of this job.

Our model enables the opposite. By applying the model in real environment, on the road network of a specific area, through measuring and analysing quanititatively enough information is gathered to carry out a detailed qualitative analysis of the problem. This way we can determine all potentially dangerous spots within a chosen area. These potentially dangerous spots are not determined by experience but supported by numerous data and qualitative analysis. Such data on dangerous spots are better, more accurate and more reliable.

Furthermore, based on the matrix equation:

$$\begin{bmatrix} y_1 \\ y_2 \\ . \\ . \\ y_j \end{bmatrix} = \begin{bmatrix} a_{11} & a_{21} \\ a_{12} & a_{22} \\ . & . \\ . & . \\ a_{1j} & a_{2j} \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} a_{01} \\ a_{02} \\ . \\ . \\ a_{0j} \end{bmatrix}$$

where are the measured temperatures on the reference spots, is the matrix of estimated temperature at other measured spots and are regression coefficients calculated based on quantitative analysis, from the data of two measured spots, the constant temperature changes on calculated reference spots[9] enable us, to predict the development of temperatures at other measured spots.

Winter services that would use this model when making decisions about the time and organisation of gritting tasks would do the following:

– when air temperatures fall to about 3°C, the operator or the appropriate software would observe the development of the temperature on the roadway at reference spots with the help of the built-in sensor;

[9] Dangerous spots are the spots on which the glazing occurs first. The reasons can be geographical, such as the vicinity of a river, sea or mountains or can depend on the number of inhabitants, the traffic and the like.

– the mathematical model would enable us in each moment to predict the development of temperatures at other measures spots. Such data would provide us with the exact time at which glazing starts on the coldest spots. At the same time we know the temperatures of the roadway at other spots and can thus determine the time continuation of spots where the glazing will occur first.
– At this moment the operator gains two key details to make the right decision: the data about how urgent it is to begin the activity and the information about where this activity should take place first. This way, the route can be constituted that would meet the conditions about the fastest possible gritting of dangerous spots and the economical conditions[10].

5 Findings

For an effective and successful management of organisational and business systems in today's contemporary time, there are many (managerial) theoretical and practical advice, techniques, tools and methods and the like at disposal. Our model of the short-term prediction of glazing occurrence is also a part of them. On the one hand the model provides the managers of winter services with valuable information on the glazing at critical spots and on the other hand improves the safety of all road users.

This procedure enables us, to choose one or more representative spots from all observed spots on a chosed road network. From the data about the temperature measured on those spots we can calculate, using the certain probability from regression equations:

$$Y = a_0 + a_1 X_1 + a_2 X_2 \quad ,$$

the expected temperature values for individual measured spots. This enables us to know when and where the glazing will occur and helps us to react easier, faster and better. Using various functions such information enable us to model and organise winter service operations efficiently, when using the procedure described in chapter 4.

Based on the findings we can conclude that managers should by no means underestimate the contemporary difficulties they are facing in their everyday work. The quality of their decisions depends on the synergy effect of their intuition as well as on knowledge and skills, supported by out tools that need to be directed into a creative systemic thinking and (co)-operation when solving complex problems, typical for an applicative model of a short-term prediction of glazing occurrence.

Here, the knowledge and use of systemic thinking enables the managers to be able to integrate the theory into practice in the so called continuous interdependent dynamic process. These (everyday) processes cause problematic complex decision-making situations that, in most cases, can no longer be solved holistically and thus well enough with the outdated methods.

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[10] Naturally this does not have to be done manually. For this purpose a number of algorithms have been developed to search for shortest possible routes using various price functions. Two of them are analysed in (Kramberger and Žerovnik, 2005; Kramberger and Žerovnik, 2006).

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