Volume 63 39 Number 1, 2015
http://dx.doi.org/10.11118/actaun201563010327

KNOWLEDGE SUPPORT OF INFORMATION AND COMMUNICATION TECHNOLOGY IN AGRICULTURAL ENTERPRISES IN THE CZECH REPUBLIC

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Abstract

VOSTROVSKÝ VÁCLAV, TYRYCHTR JAN, ULMAN MILOŠ. 2015. Knowledge Support of Information and Communication Technology in Agricultural Enterprises in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 63(1): 327–336.

Presented article deals with issue of knowledge support of managerial decision making of entrepreneurs with regards to knowledge management principles. Basic idea of proposed solution is such a concept of information management of ICT/IT that would provide appropriate knowledge to decision makers. The core line of the approach is capturing of explicit knowledge relevant to given business activities into multidimensional databases that would become part of utilized ICT/IT. These issues are demonstrated on the agriculture domain where the need to computer storage of relevant knowledge and provide them on-demand is very up to date. Recently, it has become very necessary in frequently discussed agriculture technique called precision agriculture.

Keywords: knowledge support, precision agriculture, knowledge economy, multidimensional database, knowledge management, multidimensional modelling, knowledge rules

INTRODUCTION

In connection with membership of the Czech Republic in the European Union the issue of the competitiveness of Czech agriculture is still increasingly coming to the forefront. While on the one hand opportunities for agricultural exports has significantly opened up offering far greater monetization of farmer's production, on the other hand production of Czech farmers has also begun to be increasingly threatened by imports of cheap food from abroad. Operation of agricultural activities is still more complicated by a number of threats and risks in the form of various diseases, infections and pests. The uncontrolled spread of these negative factors endangers the overall profitability of operating activities. These threats inherently pose challenges to be faced through the increase of immunity of the breedings, growing more resistant crops, improving the gene pool of species, etc., which inevitably requires considerable financial and labour costs, as well as adequate knowledge.

It is equally evident that the worsening of production periods in past years and even better resistant varieties will place increasing demands for timely and effective implementation of the relevant agronomic and veterinary measures. For their optimal choice and proper use the agricultural business then must have an appropriate set of available knowledge. As to many agricultural activities, however, there is the danger that this kind of knowledge that is closely linked with its bearer (a knowledge worker) will be irretrievably lost after his or her retirement. The key priority is finding ways how to prevent losses, store, distribute and use necessary knowledge in a meaningful manner.

For these reasons, recently more and more attention is paid to the issue of *knowledge management.* The increasing popularity of this issue is not accidental and reflects the changes occurring in the vicinity of each individual, business entity, or the entire company. In this regard, some experts formulate the prediction that *in the near future the value of land and capital will completely recede into the background in favour of the value of knowledge. The knowledge then will become a source of wealth for enterprises that poses it.* Leading enterprises are beginning to recognize the value of knowledge, including the ability to pass on this knowledge. The current period of development of human society is characterized as *a transition from the era of competitive advantage based on the information to the era of competitive advantage based on the creation, storage and use of knowledge* by some authors. *The knowledge has become the* only *reliable source of ongoing competitiveness of enterprises*. Enterprise strategies that ignore the matter of storage and other knowledge transfer within an institution that is independent of the presence of their resources (i.e. knowledge workers) are growing unsuitable in this context.

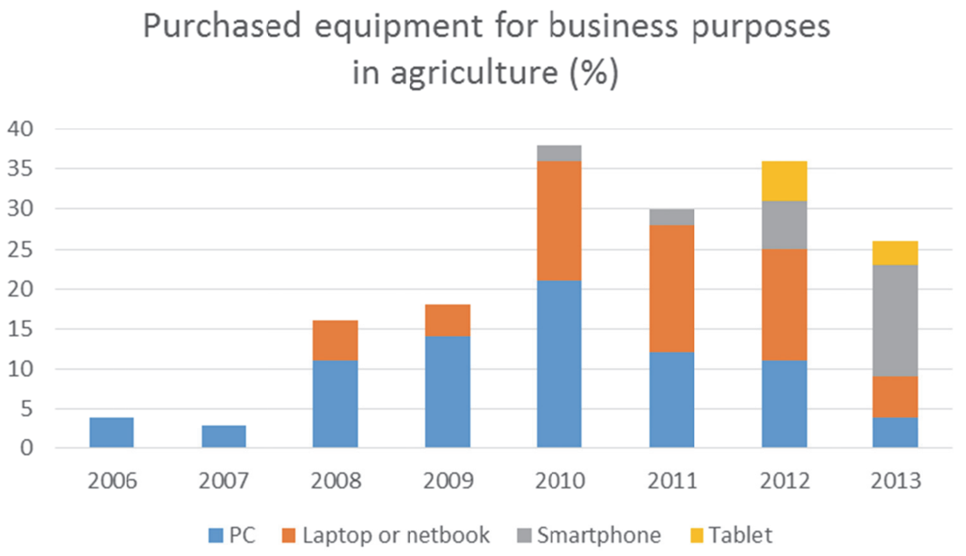
Therefore, knowledge management must focus its attention primarily to creation, formalization, storing, processing, dissemination and use of knowledge. Traditional concepts of this form of management are based on the idea of *the organization collecting all relevant knowledge in one place and employees using this knowledge to support their decisions and solutions for the benefit of the organization*. But the priority should belong especially to *dissemination and further use of knowledge* while the main requirement is to put *that this knowledge not only passively hoarded, but also transmitted and effectively used*. The mechanism that allows the problem solver to reject some variants in the beginning is based on the use of knowledge (Mařík, Štěpánková *et al.*, 1993). Persons who have such knowledge should be approached as highly qualified professionals (i.e. *knowledge workers*) with following basic characteristics:

- *the knowledge worker is very costly,*
- *the knowledge worker is relatively rare* (to form his or her profile takes many years),
- *the knowledge worker cannot be fully substituted* (unplanned departure of the worker poses a loss for the enterprise as the knowledge is gone with the person).

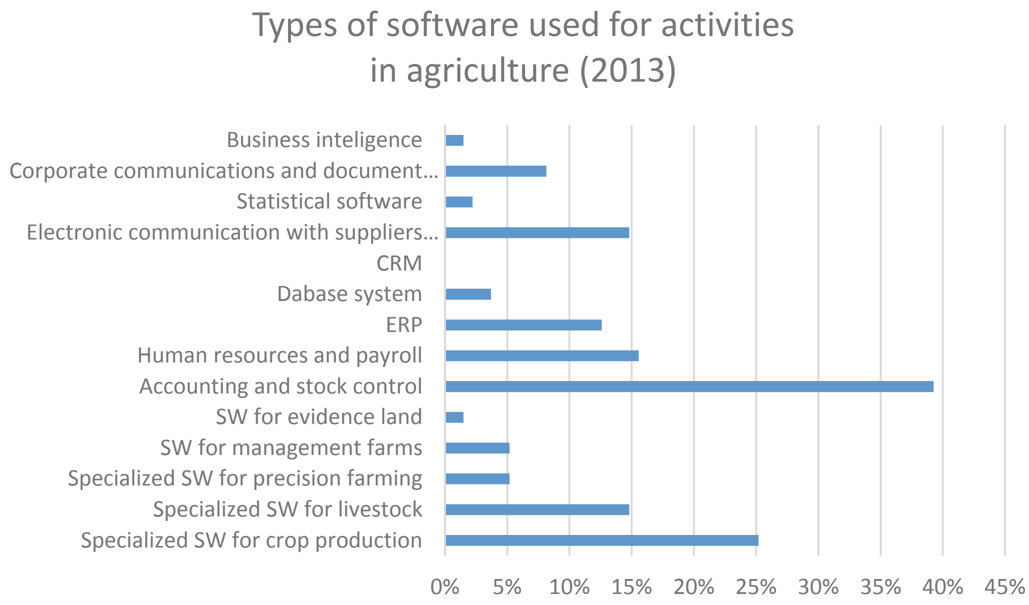
These characteristics imply that there is a need to start immediately with the corresponding *externalization of knowledge* of such workers. The externalization of knowledge is *„the process of formalizing tacit knowledge to explicit knowledge, which allows for their easier storage and subsequent dissemination in the concrete organization“* (Beckman, 1997). The success of any business entity is then predetermined among others by whether it is able to select correctly the appropriate knowledge strategy and apply this strategy in practice. Prerequisite for the success of such strategies must be *meaningful effort to include and subsequently use of knowledge-based solutions in existing information support of these businesses*.

In general we can conclude that the information support of enterprises in the Czech Republic and information and communication technologies that are used by them are on a relatively high level. However, the currents state does not correspond to demands of knowledge economy and knowledge management. Practically, it is needed to provide not only relevant data on demand, but also knowledge to apply it effectively.

There was a research of trends of utilization of information technologies and information systems in Czech agriculture in year 2013 conducted by the Department of Information Technologies and Department of Software Engineering at the Faculty of Economics and Management at Czech University of Life Sciences in Prague (grant no. 2.0131/007). Some of results confirm that there is a good level of both hardware and software equipment among Czech agricultural enterprises (Fig. 1). Agricultural



1: *Purchased equipment for business purposes in agriculture CR (own work)*



2: *Types of software used for activities in agriculture CR (own work)*

entrepreneurs put importance to specialized software for plant or animal production and also to software for accounting (Fig. 2). The fact that agricultural entities perceive information technologies as a necessary facility to reach business goals belongs to further significant finding of the survey. It is obvious that applications for knowledge management were not represented in responses of Czech agriculturists.

The computerized storage of knowledge is fatally missing in current information support of agricultural enterprises. They have sets of data and information available for managerial decisions, but there is no knowledge support for their decision making. The utilization of knowledge management needs to become integral part of current ICT infrastructure of enterprises.

Theoretical Basis of Solved Problems

Knowledge Solutions

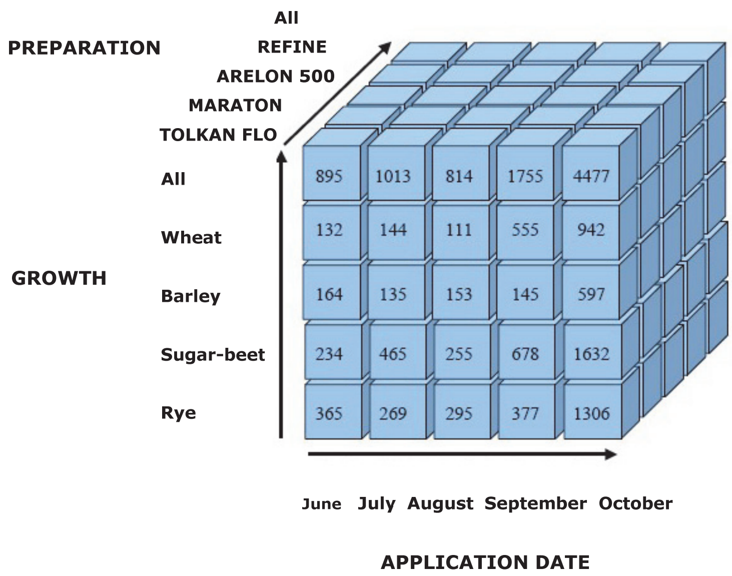
One of the possible methods for facilitating the transformation of knowledge especially in matters of transfer of tacit knowledge to explicit knowledge represents *the knowledge engineering* that is part of artificial intelligence and deals with *methods of obtaining, formalization, coding and testing the knowledge gained from the human source or inductively derived from other information sources* (databases, scholarly texts, etc.) during the creation of the corresponding knowledge base of the knowledge systems. Knowledge engineering was first defined in 1983 Feigenbaum and McCorduck as *„scientific discipline concerned with integrating knowledge into computer systems designed to solve complex problems requiring highly skilled expertise“* (Feigenbaum, McCorduck, 1983).

The computerization of our society currently has penetrated into all areas and could be observed almost everywhere. The decision making processes has been significantly influenced by software tools that improve their efficiency. One of these means are *knowledge-based* systems. The stormy and uncoordinated development of knowledge-based systems in recent years, however, did not contribute to their credibility, and vice versa, lowered the credit to certain extent in the eyes of agricultural users. Now it is necessary to look for new ways and opportunities for further meaningful use in agriculture

Theoretical Principles of Multidimensional Databases

Currently, the knowledge base of explicit knowledge is often implemented as relational databases (Fonkam, 1995; Vaníček, Vostrovský, 2008; Hawryszkiewycz, 2009; Pankowski, 2012). An innovative approach to storing explicit knowledge through multidimensional databases is presented in this paper. *Multidimensional databases* are suitable for storage of (multidimensional) data of the analytical type with which the most common analyses used to support managerial decision are performed. The concept of *multidimensional data* represents data of the aggregated indicators formed by grouping various relational data intended for on-line analytical processing (OLAP). *OLAP* describes an approach for decision support whose goal is to gain knowledge from the data warehouse or data marts (Abelló, Romero, 2009). Way of organizing data in a multidimensional database is enabled through the construct data cubes.

Data Cube is a data structure for storing and analysing large amounts of multidimensional data (Pedersen, 2009b). Generally, it is interpreted as the basic logic structure to describe a multidimensional database, as well as a relation



3: *Example data cube (own work)*

for relational databases. The data cube is an abstract structure, but unlike conventional relational structure (relational data model) is not clearly defined. There are many approaches to the formal definition of operators of the data cube (see article (Vassiliadis, Sellis, 1999)). In general, the data cube consists of dimensions and measures. *The dimension* is a hierarchical set of dimensional values that provide the categorical information describing an aspect of the data (Pedersen, 2009c). *Measures (indicators)* of the cubes are mainly quantitative data that can be analysed.

For physical storage of multidimensional data (and the implementation of OLAP applications) several technologies can be used. The two main ways to store data include so-called *multidimensional OLAP* (MOLAP), *relational OLAP* (ROLAP) (Datta, Thomas, 1999). Access MOLAP physically stores the data in a field like structures that are "similar" data cube shown on Fig. 3. In the approach ROLAP, data is stored in a relational database using a special scheme instead of the traditional relational schema. There are also other approaches, so-called *hybrid OLAP* (HOLAP) that combine the properties of ROLAP and MOLAP (Arshad Khan, 2005) and so-called *desktop OLAP* (DOLAP). DOLAP allows you to connect to a central data store and download the required subset of the cube on the local computer (Novotný, Pour *et al.*, 2005).

For the design of multidimensional databases is to used the multidimensional modelling. *Multidimensional modelling* nowadays is mostly based on a relational model, or on the multidimensional data cube. *Multidimensional models* categorize the data either as facts with associated numerical measure, or as dimensions that characterize the facts and are mostly text. Facts are objects that represent the object of the required analysis, that to be analysed to better understand its behaviour (Pedersen, 2009a).

The multidimensional data model based on the relational model distinguishes two basic types of sessions that are called dimension tables and tables of the facts. They can create a *star structure* [star schema] (Wu, Buchmann, 1997; Chaudhuri, Dayal, 1997; Ballard, Herreman *et al.*, 1998; Boehnlein, Ulbrich-vom Ende, 1999), various forms of *snowflakes* [snowflake schema] (Chaudhuri, Dayal, 1997; Ballard, Herreman *et al.*, 1998; Boehnlein, Ulbrich-vom Ende, 1999) and *constellations* [constellation schema]. The issue of choosing an appropriate structure is solved in the paper Levene *et al.* (2003).

Multidimensional Perspective of Knowledge

Knowledge retrieval in the farm is a very complex and time consuming development stage of an usable knowledge system. If the agricultural business entity stores their explicit knowledge in existing database applications, it can be effectively used such knowledge in managerial decisions of this business entity. These databases can be processed using specialized tools to create the knowledge base (in the form of rules) for applied knowledge system. Creating a knowledge base, however, is a nontrivial problem, because when storing explicit knowledge in database it reverses transformation of knowledge on data. Such an approach of the storing knowledge tends to be incomplete, inconsistent and almost invalid.

Suppose for example the following rule (1):

IF harmful factor (couch grass) AND growth (sugar beet)
THEN protective preparation (TOLKAN FLO) AND dose kg/ha (1.5)
AND application day (postharvest).

(1)

The rule given above can be interpreted such as: To eliminate couch grass in the sugar beet coverage, the protective preparation *TOLKAN FLO with dosing 1.5 kg/hectare in post harvest period*. Such a rule will be useful to add of the indication of the final the efficiency of the recommended product and application site (hunt, soil block). Yet from thus conceived rules stored in the database is not clear whether the rule is still valid and also missing an effective tool for their analysis (analysis of explicit knowledge). The multidimensional approach to storing explicit knowledge allows to analyse knowledge in this context by the various dimensions such as the time, the place, the evolution of the weather, etc. These dimensions in terms of the agricultural sector are very useful since it is possible to determine not only the recommended product (quantity and efficiency), but also to find out how this efficiency has changed in time and in space (i.e. location) compared to other monitored products. In this context it should be noted that the knowledge gained in the past may not be in full force at present (e.g. change of technology preparation, changes in soil quality on specific plot, etc.). And just such an analytical approach allows to edit/create new explicit knowledge to increase (economic, technical) efficiency in the agricultural enterprise.

Finally, the general scheme for the design of multidimensional databases is specified that leads to the elimination of these problems in order to improve the quality of the databases used for storing explicit knowledge.

MATERIALS AND METHODS

For the design of the innovative solution to capture the knowledge of agricultural activities through multidimensional databases we use the prototype database of knowledge published in the paper Vaníček *et al.* (2008). This knowledge base is basically realized as a standard relational table containing the list of registered plant protection products, with details of their application and effectiveness (see Tab. I).

For the design of conceptual schema it is used multidimensional Model Entity Relations (MER model) (Sapia, Blaschka *et al.,* 1999) and schema-type star (Boehnlein, Ulbrich-vom Ende, 1999). For creating of the prototype of the multidimensional knowledge base is used ROLAP technology and applications PowerPivot. The reason for this choice is the flexibility of the solution in creating of ad-hoc queries and the ability to work with relational databases instead of creating a data warehouse. For these purposes the design method by (Rizzi, Abelló *et al.,* 2006) is used. The basic assumption of the designed prototype is that of requirements analysis represents only and just demand for analytical application of the knowledge-based rules in agriculture.

RESULTS

Transforming Knowledge Rules

From the above Tab. I we can derive some examples of knowledge-based rules similar to rule (1). Such rules under which the farm can effectively decide on the use of suitable equipment are beneficial. However, for such knowledge (stored in a relational database) lacks an effective tool for their analysis. Suppose there is a set of knowledge as where and are predicates in implication (according to Vaníček *et al.* (2008) then for multidimensional approach it is needed to limit *H* predicates to those related with observed indicators. Knowledge rule that complies with this condition can look like this:

IF harmful factor (*hair-grass*) ∧ *growth* (*rye*) ∧
protective preparation (*MARATON*) ∧ *dose kg/ha* (4) ∧
soil (1355/1) ∧
application day (*postharvest*) *THEN efficiency* % (75) ∧
cost CZK (11 200).
(2)

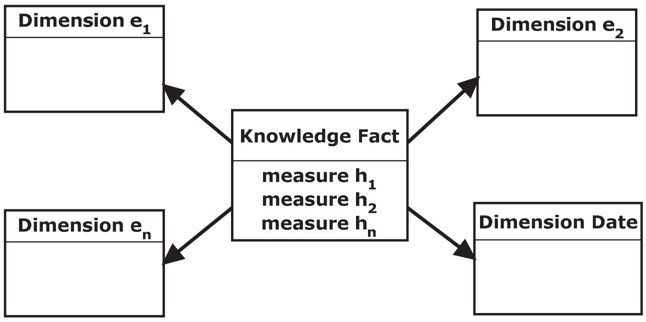
Rule (2) might be interpreted such as: If we use MARATON protective preparation to eliminate hair-grass in rye on land parcel no. 1355/1 in dose 4 kg/hectare in post harvest period, then we can reach 75% efficiency at total costs 112000 CZK.

This type of explicit knowledge will allow the farm management to decide what product to choose in comparison with other criteria such as efficiency and cost. Sometimes it may be advantageous for agricultural enterprise to use cheaper alternatives with lower efficiency, and sometimes vice versa. This given type of explicit knowledge can be transformed into a multidimensional schema for the application of knowledge-based analysis. Further, default conceptual and logical schema for the design a multidimensional database will be created.

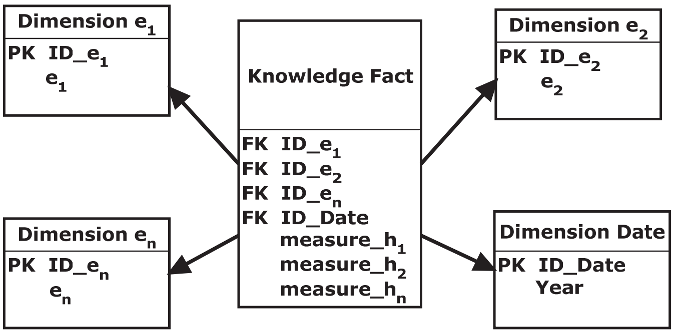
In the first phase of conceptual design of the multidimensional database, must be created a fact table into an empty conceptual schema. Based on the knowledge rule (2) it can be told that *E* predicates will represent dimensional tables while

I: *Relational table containing a set of registered preparations for plant protection*

Protective preparation	Harmful factor	Growth	Dose kg/ha	Protection period	Application day
TOLKAN FLO	couch grass	sugar-beet	1.5	AT	postharvest
MARATON	hair-grass	rye	0.015	AT	during autumn
ARELON 500	catch weed	spring barley	0.25		during spring
REFINE	redshank	meadowland	0.015		during spring



4: *Conceptual scheme of the transformation of the knowledge rules (own work)*



5: *Logical scheme of the transformation of the knowledge rules (own work)*

H predicates are particular measures (indicators) in the fact table. Because there is a predicate on time (Application day) in the knowledge rule (2), therefore the scheme will contain time dimension. Fact table will be associated with roll-up relationship (N:1) with all necessary dimensions. Thus created conceptual scheme is shown in Fig. 4.

During of the transfer to the logical schema, each dimension will be provided with a numerical primary key and will be associated with the foreign key into the fact table (Fig. 5).

At this stage was created the analogy of the knowledge rules with the multidimensional paradigm, and it was possible to transform these rules into conceptual and logic multidimensional data model. The authors of this paper believe that the multidimensional database created through such approach allows to design OLAP applications to the support of the knowledge-based decision of the responsible managers of agricultural businesses.

Creation of Prototype

To get an accurate preview of the future OLAP solution is created through the transformation of knowledge rules the prototype of a multidimensional database. Creating a prototype allows to obtain the advantages and limitations of the proposed process of transforming knowledge into a multidimensional database in the agricultural farm. For the creating of the prototype is used the knowledge-rule by (2):

IF harmful factor $\wedge$ *growth* $\wedge$ *protective preparation* $\wedge$ *dose kg/ha* $\wedge$ *soil* $\wedge$ *application day THEN efficiency %* $\wedge$ *cost Kč.* (3)

Conceptual Design Prototype

Application of transformation of the knowledge rule (3) leads to the identification of measures and dimensions of the conceptual schema. Fact table for the whole diagram is only one (due to the fact that in the methodological approach scheme is

II: *Description of the results of the transformation of knowledge-based rules*

Measure	Dimension	Dimension Date
Efficiency (%)	harmful factor	application day
Cost (CZK)	growth	
	Protective preparation	
	dose	
	soil	

used the type of the star). Identified measures thus represent attributes of the table of the facts.

The result of the transformation of verdicts of knowledge of the rules at the dimensions and measures (Tab. II) allows the creation of conceptual schema.

Logical Design Prototype

The identified dimensions is assigned associations with the table of facts in the logical design. Into the basic logic scheme are complemented the additional attributes dimensions. For dimension HarmfulFactor, Growth and ProtectivePreparation is created attribute specifying the name of the harmful factor and protection preparations. For the dimension Dose is created attribute Quantity, which will contain size dose of protective agent and attribute Measure to indicate of the measurement units For the dimension Soil is created attribute Acreage, which will contain data on the hectares of utilized agricultural land and attribute Plot_number that indicates the number of the parcel. In Dimension Data are added attributes that will allow analysis of both short term (Application_day) and in the long term (Year). For the knowledge analysis is important to implement the analytical processing both the short and long term, since not all knowledge expressions are in a short period unchanged. In this stage of design of the logic scheme prototype is selected the snapshot granularity of data. Data (relating to individual knowledge statements) then will access the database at the same time intervals (e.g. quarterly). The dimension of the time takes into account the year and application period. Just in these intervals is possible to identify changes in each dimension (statements). The resulting prototype logic diagram is shown in Fig. 6.

Physical Design Prototype

The essence of the design phase is complete logical model of the physical characteristics that are typical of the OLAP technology and specific database system. However, during the physical design of the prototype are not important optimum specific settings of proposed database solution, but especially the possibility of the verification the proposed logic model. In our methodological approach is to use for physical design of prototype the software Microsoft® Excel 2013 and PowerPivot, which is sufficient for the creating of this prototype.

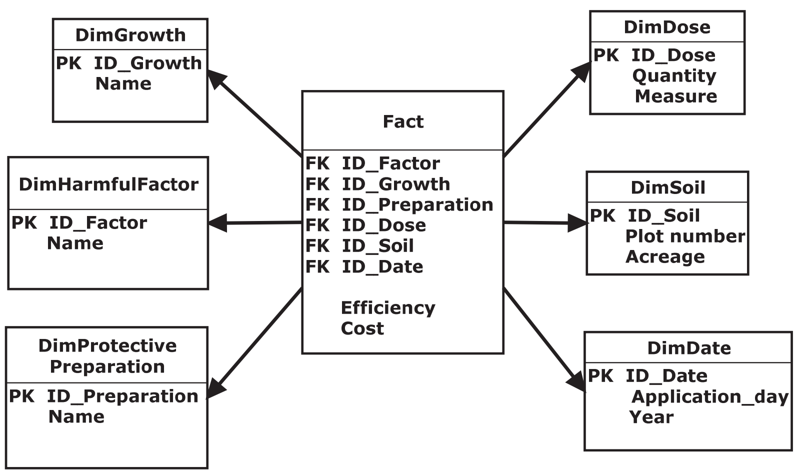
Firstly, relational data are integrated into fact tables and particular dimensions in PowerPivot, then relations are created after proposed logical scheme (Fig 6). Integrated data does not represent specific data of agricultural holding. Data are only theoretical (from Tab. I), represent a small farm farming in the 2013 area of 77 ha. Integrated tables contain attributes designed in the logical schema. Other attributes, especially those that could be added the hierarchy to individual dimensions are not included in the prototype.

Physical design of prototype enables not only to verify that the logical model of our designed approach is realizable, but also verifies whether the solved transformation of knowledge rules into multidimensional databases for OLAP has practical meaning.

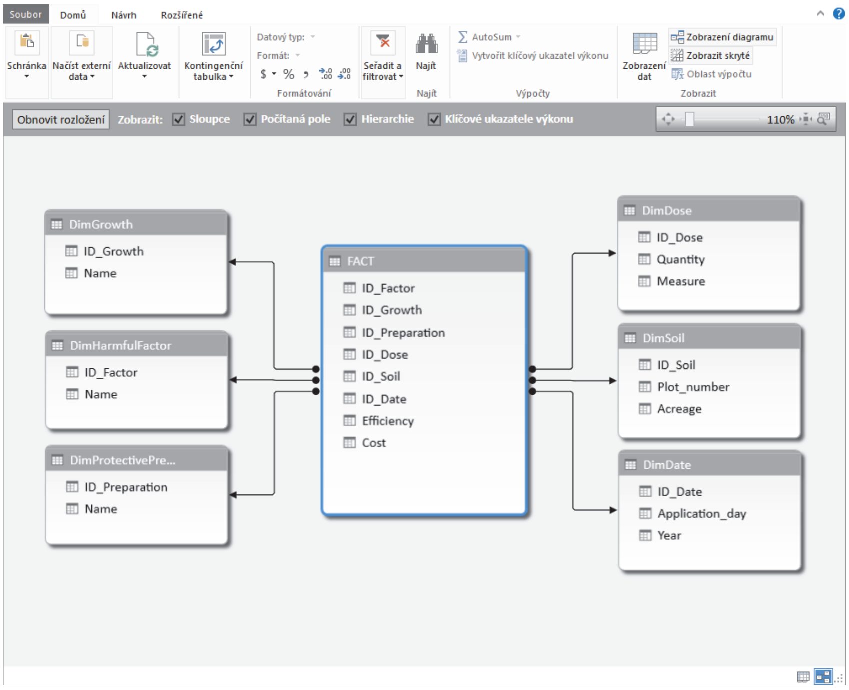
Consider following examples of two analytical questions:

1. What was the average efficiency of the Arelon 500 preparation applied during the spring of 2013?
2. What were the total costs (in CZK) to eliminate harmful factors on individual plots?

To answer these analytical questions and to test prototypes of multidimensional databases in practice the corresponding pivot tables are created in PowerPivot. This type of output is mostly supported by all client applications for OLAP. In the physical design, the rate is selected so that it will be displayed inside the pivot table and dimensions are placed in rows and columns where their values are calculated within. To search for an answer to question 1 the pivot table with the names of the protective agent in rows and application time in columns is created (Fig. 8). Calculated values in



6: *Logical schema of the prototype (own work)*



7: *Multidimensional model in PowerPivot 2013 (own work)*

=AVG('FACT'[Efficiency])

Efficiency	2013			2013	Total
	during autumn	during spring	postharvest		
ARELON 500		72		72	72
MARATON	46		75	60,5	60,5
REFINE		53		53	53
TOLKAN FLO			89	89	89
	46	62,5	82	67	67

8: *PivotTable, preparation – time (own work)*

the pivot table represent an average efficiency of protective agents in form:

Such as approach allows to clearly see what is the individual average size of the efficiency according to the protective agent and time. Thus, it is possible to effectively answer the question No. 1. It is therefore a very effective way to answer question No. 1, ie the average efficiency Arelonu 500 applied during the spring of 2013 was 72%.

For the searching an answer to question No. 2 is created pivot table showing the names of the individual parcel in the rows and damaging agents in the columns (Fig. 9). Calculated values in the pivot table represent the sum of total costs in the form:

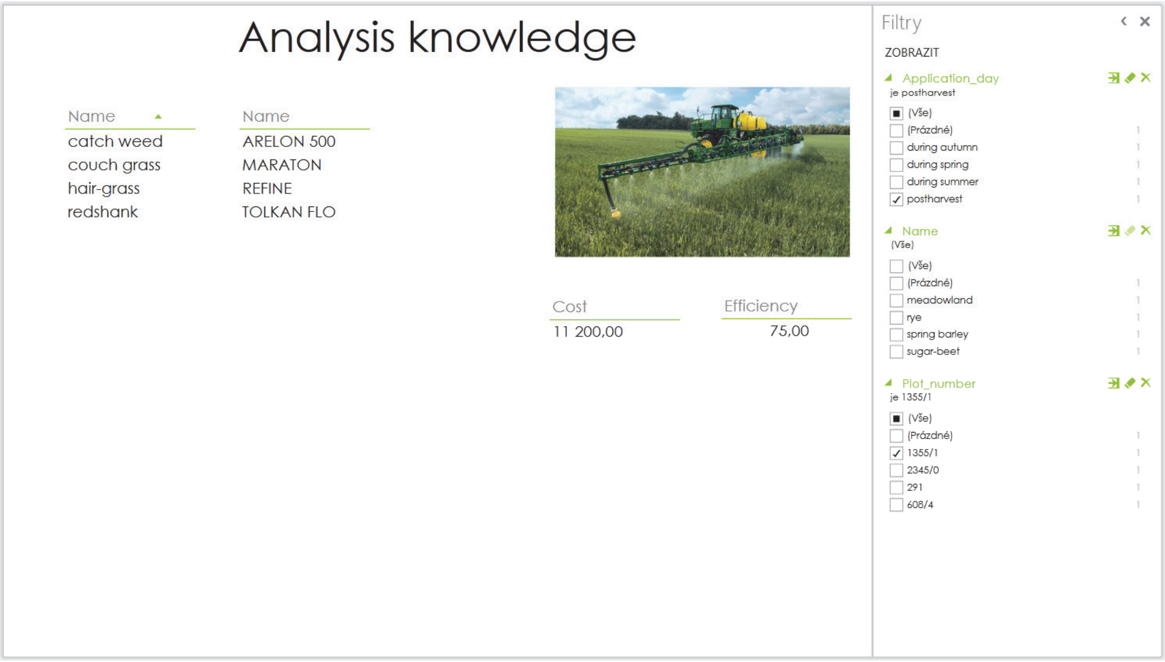
=SUM('FACT'[Cost])

Total costs (in CZK) to eliminate harmful factors on individual plots are thus very clearly summarized.

By creating pivot tables (or graphs) farm management can increase effectiveness in decision making on the basis of available knowledge in

Cost	catch weed	couch grass	hair-grass	redshank	Total
1355/1			11200		11200
2345/0		31500		35800	67300
291	12400				12400
608/4			19200		19200
	12400	31500	30400	35800	110100

9: *Pivot table, factor – factor (own work)*



10: *Pivot Table in PowerPivot (own work)*

the agricultural farm. Outputs in PivotTables allows to summarize and aggregate the data according to different knowledge statements. Technological approach used to design the prototype can be used for the real application of OLAP in agriculture. This is mainly because the software MS Excel with PowerPivot is readily available to users in agriculture and the majority of users controls the work in Excel. The authors consider the selected technological solution useful, mainly because it allows to create a clear analytical views and reports with low entry costs compared to a robust Business Intelligence solutions. Fig. 10 is an example of the view for the research, data visualization and presentation of data from the knowledge. Management of the agriculture enterprise may, on the basis of this created interactive perspective to derive answers to other analytical questions.

Such an approach will find a management of agricultural holding the various combinations of protective agents that lead to approximately the same level of efficiency applications. It will also be possible to identify the maximum cost value in the given period and to deduce the changes of the efficiency of protective agents in time and so on.

DISCUSSION

The designed prototype OLAP application verifies that the present conceptual and logical model is feasible, while also confirms that this new approach dealing with the transformation of knowledge-based rules to multidimensional databases for OLAP has the practical meaning.

Given the nature of the used methods of analogy during the transformation of the knowledge rules as the thinking process, it is clear that conclusions analogues are only probable, not conclusive. Therefore, it may be to exist the other permissible transformation of knowledge rules into the conceptual and logical schema. In further research in this area it must be taken into account and extend knowledge support of activities for the whole area of precision agriculture. In other work of the authors will be created a new method of transformation of knowledge-based rules to multidimensional database for use in precision agriculture. The new method will be created through mathematical apparatus us along with possibility of the measuring the quality of the proposed schemes by scientific methods for measuring data warehouse.

CONCLUSION

The above proposed issues can certainly contribute to a significant increase in the level of knowledge management in the agricultural business entities. The focus of this increase among other things is in a much more detailed attention to factor of time and place, as these attributes often significantly complicate management decisions in the agricultural enterprises. With that corresponds lately very frequently mentioned phenomenon called precision farming, which also related to the fact that decision-making takes into account far more detailed level of the problems. This variant of Agriculture examines the heterogeneity of the plot. The key is getting the maximum amount of information about the plot (soil composition, thickness of the topsoil layer, a supply of nutrients, etc.) and changes of the individual values of the plot. Precision agriculture through knowledge of differences in plot may

access to this place individually. Compared to a single dose for the whole plot is here applied the exact amount in a location where it is needed. This may reduce the number of inputs (e.g. fertilizers, pesticides) and reduce costs. This process is also more environmentally friendly.
The undisputable benefits of multidimensional knowledge solutions however require that higher level of enterprise information technologies such as information tools, applications, databases and user education need to be implemented in agricultural entities. Just the users will have to prove a higher level of ability to work with IT. Unfortunately, recent surveys among agricultural holdings have not brought evidence in all cases. Despite this fact, we can be state that the agricultural sector has the potential for knowledge solutions to become an important source of strategic advantage.

Acknowledgement

The results and knowledge included herein have been obtained owing to support from the Internal grant agency of the Faculty of Economics and Management, Czech University of Life Sciences in Prague, grant No. 20141036: "Analýza a přístupy k řešení informačních a znalostních potřeb v resort zemědělství v kontextu zemědělského eGovernmentu" and grant No. 20141040: "Nové metody pro podporu řídících pracovníků v zemědělství".

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