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Economic Value of Information Systems in Agriculture: Cohesion and Coupling of Information Elements

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Abstract

Evaluating the economics of information systems is a difficult task. In addition to classical approaches to the economic evaluation of information systems, attention is paid to individual processes and workflows. The quality of information systems functionality is based on a quality workflow processes. A poorly designed workflow of the information system leads to a number of errors and problems in exchanging information within the system. The lower the error rate and the higher the efficiency of individual activities, the higher the economic value of the information system and, as the case may be, of other analytical, expert or decision systems in the organisation. In this paper, known principles of cohesion and coupling are used. The selected real process is evaluated within the framework of the agricultural information system operated by the Ministry of Agriculture of the Czech Republic. In the article is created a design the structure of information elements of the modelled workflow, measured cohesion and coupling and compared with two alternatives.

Keywords

Workflow process, information systems, cohesion, evaluating process, agriculture.

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Introduction

The area of economic evaluation of information systems is a relatively complex issue which is well described in the study (Verstegen et al., 1995). In general, there are two approaches to assessing the economic value of information systems: a normative and positive approach. Normative approaches are based on decision making through theoretical (e.g. decision three analysis (Lahtinen et al., 2017), Bayesian information economics (Kleijnen, 1980)) or analytical approaches (e.g. simulation or linear programming). Positive approaches are based primarily on experimental designs (time series, econometric modelling).

At present, however, there are other methods that may determine the economic value of the information system in the theoretical approaches. Functionality and individual functions of the information system are based on workflow processes. A poorly designed workflow for working with the information system leads to a number of errors and problems in exchanging information within the system. The lower error rate and the higher efficiency of individual activities, the higher the economic value of the information system and, as the case may be, of other analytical, expert or decision systems in the organisation.

According to (Vanderfeesten et al., 2008) there is a similarity between software programs and workflow processes, for which similar quality metrics can be used for the quality workflows area. According to (Troy and Zweben, 1981; Conte et al., 1986; Shepperd, 1993), the quality of the design of programs and the workflow in general is evaluated according to five metrics: coupling, cohesion, complexity, modularity and size. Of these, coupling and cohesion are considered to be the most important as the studies (Troy and Zweben, 1981; Conte et al., 1986; Shepperd, 1993) shows. Coupling is measured by the number of interconnections and cohesion is a measure of the relationships of the elements. Metrics are measured with absolute numbers. Important for evaluation is comparison with another measured workflow.

A loose coupling of activities leads to several information elements that need to be exchanged between activities in the workflow process which reduces the likelihood of process mistakes. Highly cohesive activities are better understood and are better performed by people than large clusters of unrelated work linked together. Since the creation of large activities will reduce the coupling measure and the creation of small activities will increase cohesion, then high cohesion and loose coupling represent the right value that leads to the improvement of the workflow process.

Motivation

There are very specific information systems currently used in the agricultural sector of the Czech Republic (CR). The largest representative is the Farmer's Portal operated by the Ministry of Agriculture of CR (MACR). The Farmer's Portal is intended for agricultural entrepreneurs and agricultural professionals for whom it provides a legal agenda. The basic applications of the Farmer's Portal are the Soil Register, the Animal Register and the Preparatives and Fertilizer Register. The quality of the Farmer's Portal has long been neglected in agriculture although some problems with the use of the Farmer's Portal have long been announced by farmers themselves (Tyrychtr and Vostrovský, 2017; Tyrychtr et al., 2015). Based on the outputs of detailed and systematic analyses, the Farmer's Portal can be adapted to achieve higher service performance, better user-friendliness and efficiency in completing legal electronic forms. Since the principles of cohesion and coupling have not yet been used for the Farmer's Portal, the goal of this article is to demonstrate the use of such measurement on the selected Farmer's Portal workflow. The evaluation of the indicators is presented in the workflow process which deals with the announcement of the sale of the animal. The presented process is a realistic version of the actual procedure. Farmers must undertake according to the legal rules defined by the MACR. First, the author of this article describes this process within the Farmer's Portal. Subsequently, the author illustrates the design of the information element structure and measures cohesion and coupling compared to two alternatives.

Materials and methods

Self-assessment of cohesion and coupling of a real workflow process is preceded by scenario identification and workflow modelling using workflow net notation (Van Der Aalst and Van Hee, 2004). In the framework of cohesion and coupling, the following definitions are used by the author to derive the basic measures: process cohesion, process coupling and process coupling / coefficient ratio (Vanderfeesten et al., 2008):

Definition 1 Operations structure

An operations structure is a tuple (D,W,O) with:

D: the set of information elements that are being processed.

W: the set of resource classes or roles that are available to the process. A relation $\preccurlyeq$ is defined on these resource classes. $v \preccurlyeq w$ means that a person with role w is allowed to do all the work v is allowed to do (and potentially more).

$O \subseteq D \times W \times \wp(D)$: the set of operations on the information elements, such that there are no "dangling" information elements and no value of an information element depends on itself, i.e. the graph (V, E) with $V=D$ and $E = \{(p,c) \in D \times D | \exists (p,w,cs) \in O (c \in cs)\}$ is connected and acyclic.

So, if operation $(p,w,cs) \in O$ for a given operations structure (D,W,O), this means that it is possible for a resource with role w to produce a value for information element p on the basis of values for the set of information elements cs.

Definition 2 Activity

An *activity* T on operations structure (D,W,O) is a tuple $(t,e) \in \wp(O) \times W$ with

t: a set of operations
$(t = \{(p1,w1,cs1),(p2,w2,cs2),\ldots\})$, and

e: the resource that is allowed to execute the activity, fulfilling the following requirement:

$\forall (p,w,cs) \in t (w \preccurlyeq e)$.

Definition 3 Process

A process S on an operations structure (D,W,O) is a set of activities:

$S \subseteq \wp(O) \times W$

Definition 4 Activity relation cohesion

For an activity $T = (t,e)$ on an operations structure (D,W,O), the activity relation cohesion $\lambda(T)$ is defined as follows:

$$\lambda(T) = \begin{cases} \frac{|\{((p1,cs1),(p2,cs2)) \in T^{-} \times T^{-} | ((\{p1\} \cup cs1) \cap (\{p2\} \cup cs2)) \neq \emptyset \wedge p1 \neq p2\}|}{|T^{-}| \cdot (|T^{-}|-1)}, & for |T^{\hat{}}| > 1 \\ 0, & for |T^{\hat{}}| \leq 0 \end{cases}$$

Definition 5 Activity information cohesion

For an activity $T = (t,e)$ on an operations structure (D,W,O), the information cohesion $\mu(T)$ is defined as follows:

$$\mu(T) = \begin{cases} \frac{|\{d \in D \mid \exists (p1,cs1),(p2,cs2) \in T^{-} (d \in ((\{p1\} \cup cs1) \cap (\{p2\} \cup cs2)) \wedge (p1 \neq p2))\}|}{|T^{\wedge}|}, & for|T^{\wedge}| > 0 \\ 0, & for|T^{\wedge}| = 0 \end{cases}$$

Definition 6 Activity cohesion

For an activity $T = (t,e)$ on an operations structure (D,W,O), the activity cohesion $c(T)$ is defined as follows:

$c(T)=\lambda(T)\cdot\mu(T)$

Definition 7 Process cohesion

For a process which consists of a set of activities (S) on the operations structure (D,W,O), the average cohesion, or process cohesion ch, is defined as follows:

$$ch = \frac{\sum t \in S^{-} c(t)}{|S^{-}|}$$

Definition 8 Process coupling

For a process that consists of a set of activities (S) on the operations structure (D,W,O), the process coupling cp is defined as follows:

$$cp = \begin{cases} \frac{|\{(T1,T2) \in S \times S \mid T^{-}1 \neq T^{-}2 \wedge (T^{\wedge}1 \cap T^{\wedge}2) \neq \emptyset\}|}{|S^{-}| \cdot (|S^{-}|-1)}, & for|S| > 1 \\ 0, & for|S| \leq 1 \end{cases}$$

Definition 9 Process coupling/cohesion ratio

For a process which consists of a set of activities (S) on an operations structure (D,W,O), the process coupling/cohesion ratio ρ is defined as follows:

$$\rho = \frac{cp}{ch}$$

Measure tool

The CoCoFlow tool (COhesion-COupling metrics for workFLOW models) is used for measuring cohesion and coupling in the workflow process. The CoCoFlow user interface consists of three different sheets, i.e. a metric sheet, a visualisation sheet and an XML file which is created and enclosed in Appendix B by the author of the article.

Results and discussion

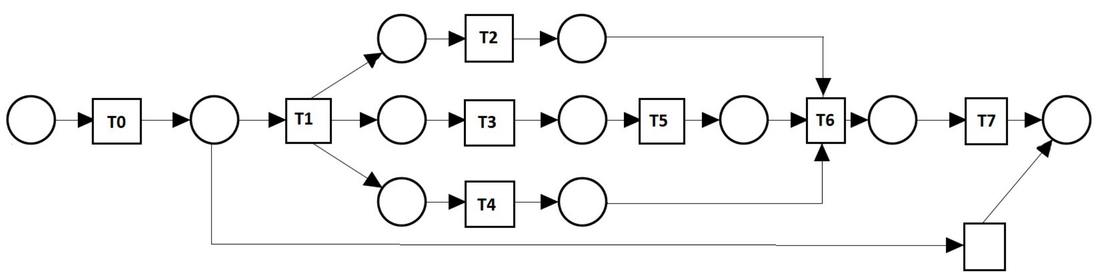
In this section, the author has designed a workflow process, identified information elements and designed their structure including operations. Consequently, cohesion and coupling is measured and the achieved results are evaluated.

Process of reporting the sale of animal

Figure 1 shows the workflow of the sale of the animal through the Farmer's Portal. Seven individual activities are labelled as rectangles that contribute to processing the report of sales as follows. Firstly, the activity T0 determines whether the applicant is entitled to access the register of animals. If this is the case, the animal register will be started and the T1 stables' register will be displayed. In concurrent activities T2, T3 and T4, the type of stables' register is determined. The T5 activity builds on T3 activity and determines the animal or animals that are for sale. In the T6 activity, the submission form for reporting the animal's status change is completed. Finally, in the T7 activity, the form is generated and sent as a report to the Central Register of the MACR.

Structure of information elements and their operations

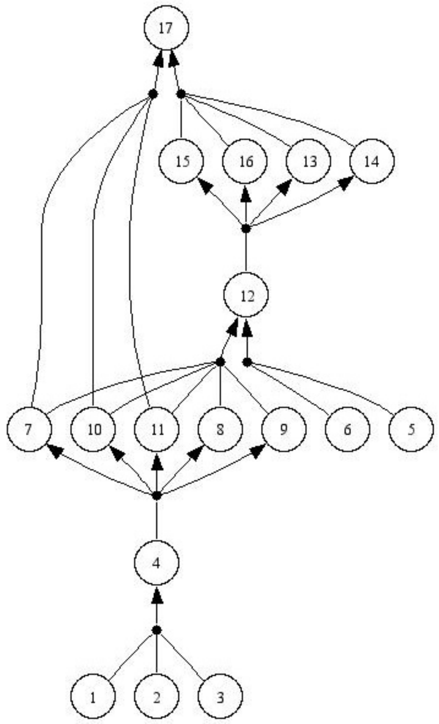
The CoCoFlow tool reads a XML file (see Appendix B) that contains the information element structure and several designs defined for that structure. Figure 2 shows the structure of information elements for the workflow of reporting the sale of an animal. The structure consists of a total of seven operations. Each operation uses different information elements (listed in the table in Appendix A). Operation 1 uses information elements: name of the establishment, cadastral territory, animal species, and stable's register. Operation 2 uses information elements: stable selection, animals by exclusion, and ear-tag number. Operation 3 uses information elements: stable's



Source: own work

Figure 1: The visualisation of information element structure for process.

register, ear-tag number, date of birth, breed, note to the animal, and note on arrival of animal. Operation 4 uses information elements: ear-tag number, date of birth, breed, note to the animal, note on arrival of animal, and list of animals. Operation 5 uses information elements: list of animals, date of departure of animal, tracking code, transfer to zoo, and from/to. Operation 6 uses information elements: ear-tag number, note to the animal, note on arrival of animal and the information that leads to sending the request. The last operation 7 uses information elements: date of departure of animal, tracking code, transfer to zoo, from/to and the information that leads to sending the request. The entire process is divided into several activities that include operations. The first activity concerns the selection of the establishment and the stable's register and includes operation 1. The second activity concerns the display of animals in the register and contains operations 2, 3 and 4. The third activity is related to the completion of a form for reporting the state of the animal, in our case the sale of the animal and contains operation 5. The last activity sends all information in the form of reports to the Central Register, the activity contains operations 6 and 7.



Source: own work

Figure 2: The visualisation of information element structure for process.

Quality metrics

In the next phase, measures are calculated for each activity of the information element structure - information cohesion, relational cohesion and activity cohesion. Information cohesion focuses on all information elements that are used as inputs or as outputs for any operation. This measure determines how many information items are used more than once in relation to all the information elements used. Relational cohesion quantifies how the various operations within a single activity are continuous. This measure for each activity operation determines how many other operations overlap by sharing the input or output. The total activity cohesion is given as a result of information and relational cohesion. This measure explains how much joint operations are interconnected and how information is shared.

	Information cohesion ($\mu(T)$)	Relational cohesion ($\lambda(T)$)	Activity cohesion ($c(T)$)
Activity 1	0	0	0
Activity 2	0.333	0.111	0.037
Activity 3	0	0	0
Activity 4	0	0	0

Source: own work

Table 1: Metrics for available activities.

In the next phase, the designed workflow of the model for the sale of an animal was subjected to heuristic testing. Two alternative models were created for this proposal. The first prefers to combine operations into one major activity and the second one prefers to divide operations into two activities.

	Average activity cohesion (ch)	Process coupling (cp)	Coupling/ cohesion ratio (ρ)
Original design	0.009	0.667	72
Alternative 1	0.018	0.765	42,5
Alternative 2	0.024	0.769	32
Activity 4	0	0	0

Source: own work

Table 2: Cohesion and coupling for information structure.

Table 2 shows cohesion values and coupling metrics for the original design and two alternatives. Due to the desirable low value for the coupling / cohesion ratio, alternative 2 is the best choice. Considering this alternative, it can be noted that it does not contain unnecessarily small or redundant activities. This means that the workflow should not be too complicated. It can be assumed that this alternative design is one that is easier to understand and leads to fewer mistakes in the process. This means that alternative 2 represents a higher economic value of the information system than alternative 1 or the original design.

Conclusion

Cohesion and coupling metrics help designers create workflow models that are superior while carried out and are understood better by people. The aim of this article was to use these measures in the field of information systems in agriculture. For this purpose, the article used the workflow process to report the sale of an animal. This process is part of the Farmer's Portal. The chosen process only demonstrates the possibility of improving the structure of information elements. In case of measuring cohesion and coupling for multiple workflow processes of the Farmer’s Portal, it is possible to improve the workflow of the entire system. It can be assumed that this improvement would have a qualitative and, consequently, economic impact on the value of the information system. More efficient and understandable workflow processes lead to time savings, small error rates and a higher level of satisfaction with the use of the information system.

The limits and constraints of this article are in the use of an already existing metric that has not yet been innovated. The metric itself is rather labor-intensive for evaluating the entire complex information system. At present, there is not study to focus on evaluation the cohesion of workflows in agriculture. The exception is innovation of the modelling workflows. According to the study (Janssen et al., 2017), new types of workflows have been developed for use in visual analysis, including reactive workflows (eg EdiFlow, Manolescu et al., 2009), which specify that every time data and interactive workflows discover a set of operations (e.g., VisTrails, Callahan et al., 2006) that interactively create and run sequences including visualizations. In this article, presented results are only the first step of a more complex research of evaluation information systems in agriculture.

In the next phase of the research of information systems in agriculture it is necessary to:

- Focus on the workflow processes of the entire Farmer’s Portal. The farmer's portal is the most widespread representative of information systems for small and medium-sized farms in the CR.
- Compare these workflow processes with processes of business information systems that are used in CR mainly by representatives of larger farmers.
- Distinguish workflow processes for information, analytical and administrative activities.
- Create a framework for evaluating different types of workflow processes in agriculture.

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Appendix A. Information request for reporting the sale of animal

Number	Description
1	Name of the establishment
2	Cadastral territory
3	Animal species
4	Stable's register
5	Stable selection
6	Animals by exclusion
7	Ear-tag number
8	Date of Birth
9	Breed
10	Note to the animal
11	Note on arrival of animal
12	List of animals
13	Date of departure of animal
14	Tracking code
15	Transfer to zoo
16	From/To
17	The information that leads to sending the request.

Source: own work

Table A.1: Description of information elements of the information element structure.

Appendix B. XML sheet of the information structure (own work)


```
<?xml version="1.0" encoding="UTF-8"?>
<InformationStructure xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
	<InformationElements>
		<InformationElement Identifier="1"/>
		<InformationElement Identifier="2"/>
		<InformationElement Identifier="3"/>
		<InformationElement Identifier="4"/>
		<InformationElement Identifier="5"/>
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		<InformationElement Identifier="13"/>
		<InformationElement Identifier="14"/>
		<InformationElement Identifier="15"/>
		<InformationElement Identifier="16"/>
		<InformationElement Identifier="17"/>
	</InformationElements>
	<Resources>
		<Resource Identifier="Resource1"/>
	</Resources>
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		<ProcessInformationStructure>
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					<InformationElementRef>1</InformationElementRef>
					<InformationElementRef>2</InformationElementRef>
					<InformationElementRef>3</InformationElementRef>
				</InformationElementSet>
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```
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            <InformationElementRef>4</InformationElementRef>
        </InformationElementSet>
        <ResourceRef>Resource1</ResourceRef>
    </Operation>
    <Operation label="Operation2">
        <InformationElementSet>
            <InformationElementRef>5</InformationElementRef>
             <InformationElementRef>6</InformationElementRef>
        </InformationElementSet>
        <InformationElementSet>
            <InformationElementRef>12</InformationElementRef>
        </InformationElementSet>
        <ResourceRef>Resource1</ResourceRef>
    </Operation>
    <Operation label="Operation3">
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        </InformationElementSet>
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<InformationElementRef>10</InformationElementRef>
<InformationElementRef>11</InformationElementRef>
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            <InformationElementRef>11</InformationElementRef>
        </InformationElementSet>
        <InformationElementSet>
            <InformationElementRef>12</InformationElementRef>
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    </Operation>
    <Operation label="Operation5">
        <InformationElementSet>
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        </InformationElementSet>
        <InformationElementSet>
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            <InformationElementRef>14</InformationElementRef>
            <InformationElementRef>15</InformationElementRef>
            <InformationElementRef>16</InformationElementRef>
        </InformationElementSet>
        <ResourceRef>Resource1</ResourceRef>
    </Operation>
    <Operation label="Operation6">
        <InformationElementSet>
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            <InformationElementRef>10</InformationElementRef>
            <InformationElementRef>11</InformationElementRef>
        </InformationElementSet>
        <InformationElementSet>
            <InformationElementRef>17</InformationElementRef>
        </InformationElementSet>
        <ResourceRef>Resource1</ResourceRef>
    </Operation>
<Operation label="Operation7">
        <InformationElementSet>
            <InformationElementRef>13</InformationElementRef>
            <InformationElementRef>14</InformationElementRef>
            <InformationElementRef>15</InformationElementRef>
```

```
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                <InformationElementSet>
                <InformationElementSet>
                    <InformationElementRef>17</InformationElementRef>
                </InformationElementSet>
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        </ProcessInformationStructure>
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                <WorkflowModelElement>Activity 1</WorkflowModelElement>
                <OperationRef>Operation1</OperationRef>
                <OperationRef>Operation2</OperationRef>
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                <OperationRef>Operation6</OperationRef>
    <OperationRef>Operation7</OperationRef>
                <ResourceRef>Resource1</ResourceRef>
            </Activity>
        </InformationStructureDesign>
        <InformationStructureDesign description="Two activities" id="Design 2">
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            <Activity>
                <WorkflowModelElement>Activity 2</WorkflowModelElement>
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