Knowledge Discovery in Case Studies[1]

The Case Insight Method for Case-Based Problem Solving

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Abstract: The topic of this paper is a new method of knowledge discovery in documents called "Case Insight" (abbreviated to CI). The research question that led to this development was "How can we discover knowledge through case studies and make it usable for case-based problem solving?" To answer this question, this research took a Systems Thinking and Networked Thinking qualitative approach. Case-based problem-solving uses knowledge contained in authentic case descriptions (i.e. "good practice" or even "best practice" cases) and adapts it to the requirements of a new problem. Who can use this? Managers and management consultants who are starting out in their careers can benefit in particular from the CI method as it allows them to expand their repertoire of experience in problem-solving on the basis of case studies, i.e. without being involved in projects. All those interested in solving complex management problems in a case-based way also form part of the target audience. Case studies contain a great deal of problem-solving knowledge but only part of that knowledge can be absorbed through simple reading. The rest remains difficult to access, a hidden treasure, so to speak. Why is that? The reason is that knowledge discovery in case studies is made more difficult due to two obstacles: firstly, the texts are not sufficiently *brain-friendly* and secondly, they are not designed *holistically* enough. The CI method makes it possible to overcome these obstacles by means of CI tools and CI models. Firstly, CI tools are used to analyse case studies by comparing concepts, ideas, etc. and combining them into a whole; secondly, CI models make knowledge discovered in this way usable in the form of brain-friendly and holistic knowledge structures. Thus, knowledge discovery through the CI method complies with Immanuel Kant's definition of knowledge as "*a whole of compared and linked ideas*".

Keywords: Case-based knowledge discovery, case studies, case-based problem-solving, case-based reasoning, brain-friendly documents, knowledge visualisation.

1. Introduction

In connection with expertise, which is primarily developed by practising in challenging situations (Ericsson 1993), it is interesting to note that experts, when solving challenging problems (very complex problems and/or in areas where there are no formalisations, e.g. medical diagnosis: ten Cate at al. 2018) strongly draw on a particular type of experience: past cases they have been involved in or know from other sources, in other words, they use *case-based problem-solving* (Zumbach et al. 2008). From these aforementioned past cases, experts search for suitable knowledge, identify it, evaluate its similarity with the new case and if this past knowledge is found to be similar enough, it is adapted to fit the requirements of the new problem. This process of *case-based reasoning* can be divided into two main steps:

1. Cases must be recalled where similar problems have been solved.
2. These earlier solutions must be adapted to the current problem.

But what do you do if you are not (yet) an expert and have not yet been involved in many past cases? One solution to this problem could be using a large repository of *case studies* that can be easily accessed and searched through. In fact, in international academic education, learning from case studies plays a fundamental role and research in cognitive psychology emphasises the importance of *case-based reasoning* for learning (ten Cate at al. 2018; Kolodner 1997; Schmidt & Boshuizen 1992).

Unfortunately, there is a big problem here: although case studies contain a great deal of problem-solving knowledge, only a small part of that knowledge can be absorbed through simple reading. The rest remains difficult to access, a hidden treasure, so to speak. Why is that? This research shows that knowledge discovery in case studies is made more difficult due to two main obstacles: firstly, the case study texts are not sufficiently *brain-friendly* (Probst et al. 2012) and secondly, they are not sufficiently based on *networked, holistic thinking* (Gomez & Probst 1999; Benesch 1987,1988). So the question is: How can we discover knowledge through case studies and make it usable for case-based problem-solving? This is the main research question here. Up until

[1] Bettoni, M. (2022). Knowledge Discovery in Case Studies. The Case Insight Method for Case-Based Problem Solving. Paper to be presented at the 23rd European Conference on Knowledge Management (ECKM 2022), 1-2 September 2022, University of Naples, Naples, Italy. https://www.academic-conferences.org/conferences/eckm/

now, *knowledge discovery* has been considered the process of automatically searching large volumes of data for patterns. This research proposes a completely new and complementary approach. The target data involves carefully selected case studies that an interested individual analyses by applying the new method presented here and which, as a result, leads to the discovery of knowledge hidden within the case study text.

2. Literature Review

About 80% of business-relevant information is encoded in natural language (Wimalasuriya et al. 2010) and therefore unstructured. This is a huge amount of data and explains why, up to now, techniques and processes for knowledge discovery (KD), like text mining (Feldman & Sanger 2007), concept mining (Li et al. 2018), natural language processing (Kurdi 2016), knowledge discovery and data mining (Fayyad et al. 1996) and the like are all focused on the automated processing of large volumes of data: we could call this the "Huge Data KD". Typical tasks of *huge data KD* include text categorisation, text clustering, concept/entity extraction, production of taxonomies, sentiment analysis, summarisation and entity relation modelling. The outputs are long lists of patterns that would otherwise be impenetrable to automated processing and this knowledge – facts, business rules, and relationships – is presented in a machine-readable form for further processing.
In principle all of these functions could be applied also to single, carefully selected documents that someone wants to analyse in detail. But that would contribute only *knowledge fragments* taken out of context, which would not be very useful for case-based problem-solving. Text analysis, for example, aims to derive insight solely from the lexicon of a text itself, without considering semantics. It provides data about frequency of words, presence or absence of words, length of sentences, etc. This makes sense when analysing huge amounts of texts (for example customer conversations over one or more years) to find out keywords relating to the main issues and trends. But when applied only to one document, such an approach would be of little use. Like in text analysis, with other *huge data KD* techniques, outputs are conceived as contributions to statistical evaluations of large volumes of documents; what you get are huge amounts of *knowledge fragments* that have lost their context: this type of knowledge is not very useful for case-based problem-solving.
Case-based problem-solving requires case knowledge in the form of one or more *knowledge models for the case*. This case knowledge is context-related, unbroken knowledge, made up of knowledge items that need to be connected; connections can take many forms, for example feature vectors, production rules, frames, ontologies, semantic nets or other networks (El-Sappagh & Elmogy 2015). This is a very different type of knowledge representation than the one provided by the established *huge data KD* approach.
As a consequence, we need a completely different approach to knowledge discovery, one which does not discover knowledge fragments but rather knowledge models of the cases. This is what the Case Insight method presented in this paper does. Its development is based on research into case-based problem-solving (Zumbach & Mandl, 2008), case-based reasoning for learning (Staempfli 2020; ten Cate at al. 2018; Kolodner 1993; Schön 1983), knowledge externalisation (Probst et al. 2012), knowledge visualisation (Eppler & Burkhard 2004), psychocybernetics (Benesch 1987,1988), networked, holistic thinking (Gomez & Probst 1999; Benesch 1987,1988; Vester 2007) and reverse engineering (Vinesh & Fernandes 2008).

3. Methodology

To answer the main research question (how we can discover knowledge through case studies and make it usable for case-based problem-solving, see above), this research takes a Systems Thinking and Networked Thinking qualitative approach. A Systems Thinking approach is a way of thinking which enables us to better understand and design complex issues. Systems Thinking and Networked Thinking require (Haberfellner 2002; Vester 2007):

1) the systemic definition of concepts: the new concept of *knowledge discovery* is defined in this way;
2) the use of these concepts in the context of a holistic view: the CI method deals with the *document as a whole*, instead of searching only specific parts;
3) the use of systemic models: *CI models*, the outcomes of the CI method, are such models;
4) the use of holistic, interconnected thinking: this has been applied in the *construction of the CI method*.

4. Results

After defining the new concept of knowledge discovery used in this research, three types of knowledge contained in case studies are distinguished and two main obstacles hindering knowledge discovery are specified. Furthermore, the CI method for overcoming these obstacles is presented along with a toolbox for working on both problem and solution case studies and a few application examples from a knowledge management case: a corporate wiki.

4.1 Case-Based Knowledge Discovery: Definition

The approach to knowledge discovery presented here differs in several aspects from all the established techniques of knowledge discovery previously mentioned in the literature review (section 2):

1. *Volume of data*: the number of case studies involved is such that it can be easily managed and scanned through by a person.
2. *Typical task*: the performed analysis is holistic instead of partial: it deals with the whole document, instead of searching only specific parts (like concepts or entities or sentiments, etc.)
3. *Typical objects*: the task objects are single, well-selected documents, not a large collection of written resources (corpus).
4. *Typical process*: the text analysis process is a conscious reasoning process of natural intelligence similar to reverse engineering, not a computational, automatic, artificial intelligence process.
5. *Typical outcomes*: the outputs are a small set of holistic knowledge structures (models) for each task object, not huge lists of similar parts found in a big corpus of many objects.

These characteristics of the concept of Case-Based Knowledge Discovery are summarised in the following definition:

> *Case-based knowledge discovery (CBKD) is the process of examining a case study by means of conscious, natural intelligence reasoning similar to reverse engineering that performs the task in a holistic way, dealing with the whole document and producing as the outcome a small set of holistic knowledge structures (models).*

4.2 Knowledge in Case Studies

Each case study contains much more knowledge than we usually see at first glance. It is a treasure trove of problem-solving knowledge but it is often difficult to access, so it represents a hidden treasure, so to speak. The CI method helps you to discover and use these treasures. On the one hand, it enables you to expand your pool of problem-solving experience - simply by studying case studies and independently of carrying out your own projects. On the other hand, it enables to use this experience and the CI tools for the case-based resolution of new problems.

Figure 1: Knowledge in case studies (adapted from: Paolo Calleri, Ulm, 2010)

The problem-solving knowledge contained in case studies can be divided into 3 types of knowledge:

1. *Problem* knowledge. This is knowledge of the structure of the problem (parts and their connections);
2. *Process* knowledge. This is knowledge of the procedure, i.e. how to find the solution;
3. *Solution* knowledge. This is knowledge on which the implemented solution is based.

Why is the treasure trove of problem-solving knowledge in case studies difficult to access? Two obstacles make knowledge discovery difficult:

- Obstacle 1: case study texts are not or not sufficiently designed in a brain-friendly manner.
- Obstacle 2: Case descriptions are not or not sufficiently holistic.

4.2.1 Obstacle 1

If the case description contains knowledge, then one would perhaps expect that it can be easily accessed by reading the document. Why would we need a method of accessing such knowledge? Let's look at an example of a description: it uses dummy text because at this point the focus is only on the text design.

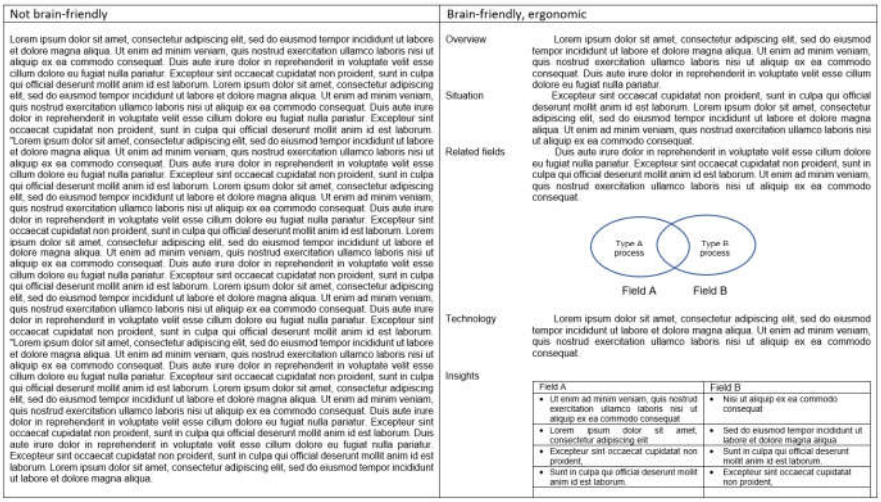

Figure 2: Brain-friendly editing of documents – adapted from Probst, 2012, p. 189.

When textual descriptions resemble the example on the left, then by simply reading such a description, it will be very difficult to use the knowledge it contains. On the right-hand side, the same text has been edited in a brain-friendly manner which makes it somewhat easier to access the knowledge but not easy enough because the document sections still contain a lot of linear text. So we need a method that enables us to access the entire knowledge of the case study in a brain-friendly manner. This is the function of the CI method. Why is linear text not brain-friendly and what is meant here by "brain-friendly"? A description is “brain-friendly” if it is “*oriented towards the processing mechanisms of the human brain*” (Probst 2012 p. 189), especially the brain mechanisms of knowledge processing. How is knowledge processed in the brain? According to a principle by H. Benesch (1987, 1988), the so-called *CPM principle (carrier, pattern, meaning)*, at a basic level, knowledge processing in the brain works like this:

1. Carrier: the processing is carried out by the nerve cells (neurons and others) which are extensively interlinked with one another.
2. Pattern: the activation of the neural networks creates patterns.
3. Knowledge (meaning): is generated and processed through structural pattern formation (so-called “figuration”).

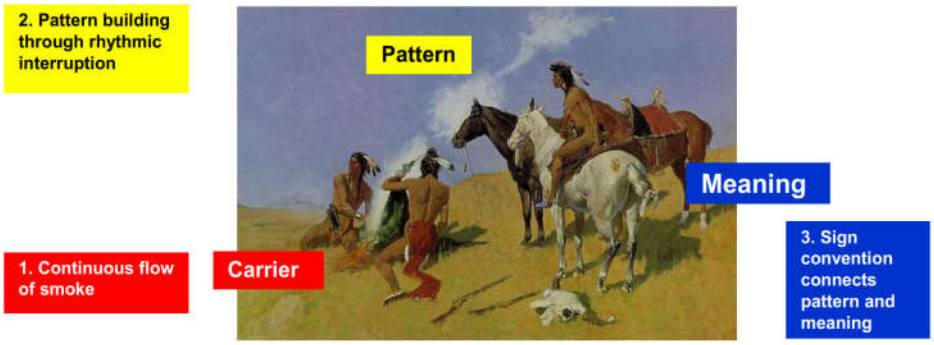

Figure 3: Knowledge processing in the brain: the CPM principle (Benesch 1987, 1988)

In terms of this principle then, a description is “brain-friendly” if it is spatially structured and has patterns because it then supports the structural formation of patterns in the brain.

4.2.2 Obstacle 2

A description is “holistic” if it supports the networked thinking that is necessary for dealing with complexity. How does networked thinking work? I would like to illustrate this with a small exercise (idea by H. Benesch, 1987). Let's consider a short cartoon story about Snoopy and Lucy. The sequence of the 4 pictures is reversed. They should be properly ordered according to the title "The Kiss". To this end, various aspects are to be interpreted within their networked context: a) What does the individual image represent? b) How can the

utterances be arranged? c) What is the effect of Snoopy's kiss? In this way, you reach the logical sequence: 3, 4, 1, 2.

Figure 4: Networked Thinking – adapted from H. Benesch, 1987, vol.1, p. 187

Networked thinking is therefore the integration of:

- Different points of view
- With the networked interrelationship of the parts

4.3 Case Insight (CI) Method

We can overcome obstacles to knowledge discovery in case studies by creating knowledge structures which:

1. Are brain-friendly: spatially structured knowledge structures that support pattern recognition
2. Are holistic: knowledge structures that emphasise the networked interrelationship of the parts and take various points of view into account.

This is exactly what the CI method offers. Case-based problem-solving in management is a two-stage process consisting of knowledge discovery (stage 1) and knowledge use (stage 2):

- *Knowledge Discovery*. This is where the CI method is applied: with the help of *CI tools*, knowledge from authentic case studies is analysed from different perspectives and the knowledge discovered through this processing is made visible and usable in the form of *CI models*, i.e. brain-friendly and holistic knowledge structures.
- *Knowledge Use*. The knowledge structures from stage 1 are adapted to the requirements of new problems and used together with the CI tools for problem-solving.

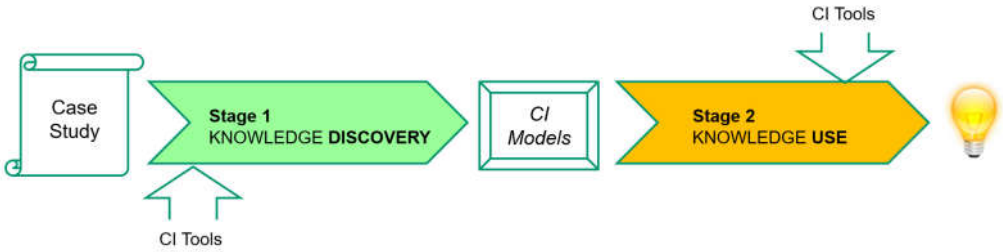

Figure 5: Case-based problem-solving in management with the CI method

Knowledge discovery with CI consists of 4 steps; they are run through several times per tool and are therefore arranged as a circular process, the so-called *CI cycle*. The 4 steps lead from selection of a suitable case study to findings about the problem, the process and the solution from the case study.

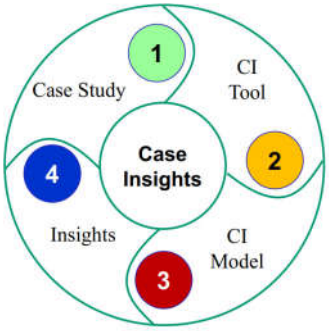

Figure 6: The CI cycle

According to their main subject, the 4 steps can be distinguished as follows:

- Step 1: *Case study*. The case study is at the beginning of the CI cycle, i.e. step 1. You have to look for case studies, define your own criteria for selection, collect suitable case descriptions, select the best one, read it and get a rough idea of the most important characteristics for you. This will take you to step 2 where you will deal with the CI tools.
- Step 2: *CI tool*. First of all, you need to choose a tool. The first will most likely be the project profile (One-Pager, see next). This tool provides orientation knowledge and thus creates good conditions for selecting further tools afterwards. If problem knowledge proves to be important, then you should choose the Triadic Defect Analysis tool. Solution knowledge will certainly always be important: there are several tools available for this that complement each other. After making your selection, you need to make sure that you know the tool well. With this knowledge, you then return to the case study and mark any terms or sections in it that match the chosen tool.
- Step 3: *CI model*. In step 3, you first check whether the marked words can be used as parts of the model. The model, i.e., the knowledge structure, is then iteratively built up and expanded from the appropriate text sections.
- Step 4: *Insight*. Finally, in step 4, the created model is examined carefully and reflected on: what findings does it provide? What questions does it leave open? What information and links are still missing or are redundant? Etc.

So these are the 4 steps of the CI cycle. An important note on this: it is not sufficient to run through the cycle only once per tool; the models would then probably be too rough. To refine it, two types of iterations are necessary: 1) On the one hand, a model-specific iteration through steps 2 and 3 when the first version of a model is created; 2) On the other hand, a cross-model iteration through the various models to ensure the consistency and complementarity of their knowledge structures: they should not contradict or overlap but rather complement one another.

We saw that CI is a method of knowledge discovery. But what is it that is "discovered" in the process? What is knowledge? Immanuel Kant, the famous German philosopher who proposed an innovative theory of knowledge which today is still revolutionary (Bettoni 1997), wrote in his main work that knowledge is: "*a whole made of compared and linked ideas*" (Kant 1781/1966 p. A97). This is exactly what we do with every CI tool: we search for and discover *ideas* in case studies (terms, ideas, etc.), *compare* them and *link* them into a whole. This "whole" is precisely the CI model, a knowledge structure.

4.4 Basic CI Toolbox

The basic toolbox for discovering case-based knowledge by means of the CI method consists of 11 tools, divided into 3 groups:

a) CI tools for problem knowledge: for discovering knowledge about the structure of the problem
b) CI tools for solution knowledge: for discovering knowledge on which the solution is based
c) Generic tools: for discovering generic knowledge

These 11 tools are selected as suitable for working on both problem and solution case studies, namely problems and solutions from any management discipline.

4.4.1 CI tools for problem knowledge

1. The *One-Pager Window* offers orientation knowledge, a panoramic view of the knowledge included in the case study: on a single page, the most important aspects of the project, the what, why, how and who, are described in a few words. This makes it easier to gain an overview of the core idea of the project.

2. The *TDA chain* provides a kind of “bird's eye view” of the problem area which can be very helpful as a basis for formulating the project goals. The focus is on organisational provisions and their consequences, especially with regard to defects. Their links thus provide problem knowledge that is very important for the formulation of the project goals.
3. The *PTO map* focuses on differentiating between important aspects of the main task according to the three categories of people, technology and organisation (Ulich 2011, 2016). The problem knowledge presented here answers the questions: which concept (aspect) in the case study is primarily human, which primarily technical and which primarily organisational and how are these areas structured? References to connections between the parts complete the knowledge structure.
4. The *Stakeholder Window* is an easy-to-understand representation of the main stakeholders in a project who are divided into 4 categories (Pentacle 2015): 1. Are not necessary + benefit; 2. Are not necessary + suffer damage; 3. Are necessary + benefit; 4. Are necessary + suffer damage. This knowledge is very important in order to be able to assess the role of the 4 groups in the project in an individual, appropriate way.

4.4.2 CI tools for solution knowledge

1. The *Means-Ends Hierarchy* makes it easier to oversee and reflect on project goals, especially with regard to weighting and complexity (Haberfellner et al. 2002). Goals are often insufficiently reflected upon or even remain unmentioned. By looking at the goals for a certain hierarchy level, you can see which goals have the same or a similar degree of abstraction; and when looking at all the sub-goals of a goal across different hierarchy levels, you can see, for example, the degree of complexity involved in achieving the goal. This knowledge is very important in the analysis in order to assess the solutions appropriately.
2. In an *SFM Network*, needs, objectives and solutions appear explicitly as independent elements (Bettoni et al. 2013). In addition, they are brought into a recognisable (not hidden, not implicit) connection based on the three connections - meaning (B > Z), achievement (Z> L) and fulfilment (L> B). Units in which all three categories are represented and which link the three elements with one another, so-called triads, are a particularly important knowledge content of the SFM network because they mark the most valuable solutions.
3. The *Structure Network* shows solution knowledge in the form of an order or arrangement pattern and thereby helps to better reflect the principles of order (Haberfellner et al. 2002). It visualises components of the main structure and the associated structural relationships with which the components are connected. When analysing organisational forms, these are leadership relationships, social relationships or command paths. In the case of processes, e.g. information flows, material flows, work sequences, etc., the structure relationships are functions or operations of the process between input and output.
4. The *Causal Network* contains knowledge about mechanisms of action (impact mechanisms). It shows the root of a problem or a solution and supports what is known as “thinking in cycles” which is an important resource for successfully dealing with complexity (Obeng & Gillet 2008). Thanks to the causal network, special effect patterns become visible which are shaped as cycles. Such cycles are like “motors” that drive what happens in the network. These networks thus provide critical knowledge for understanding the mechanisms of action of the system under investigation.
5. The *Time Arc Map* is a mixed diagram: an extension of the project schedule (timeline, Gantt chart) with a breakdown structure plan (task tree, activity tree) and conceptual map (relationships between sub-tasks or sub-activities). This knowledge can be useful when designing (drafting) a new solution to optimise the process of implementation; but also, when analysing an implemented solution, such a mixed diagram can be useful as it helps to better understand the logic of the implementation.

4.4.3 CI tools for generic knowledge

1. The *Mind Map* is a hierarchical diagram used to visually organise thoughts or concepts (Buzan & Buzan 1993). It is always suitable for knowledge discovery when it is not yet clear how the terms are linked to one another (relationships).
2. The *Concept Map* is a diagram that visualises concepts and their relationships (Novak 2004; Sowa 1984). It has the advantage of making all elements of a thought comprehensible at a glance. It thus offers the opportunity to make better use of knowledge e.g. through quick reflection.

4.5 Application Examples

The following figures show CI models obtained by applying the basic CI tools to an authentic management case study, the KAPPA case study (Stocker & Tochtermann 2010) which describes the solution to a problem in the field of knowledge management by means of a corporate wiki.

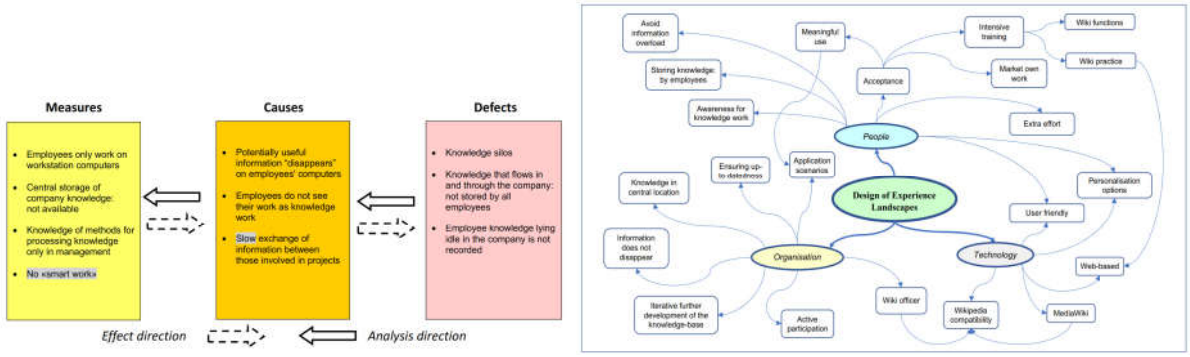

Figure 7: Tool [4.4.1.2 TDA chain], left and tool [4.4.1.3 PTO map], right.

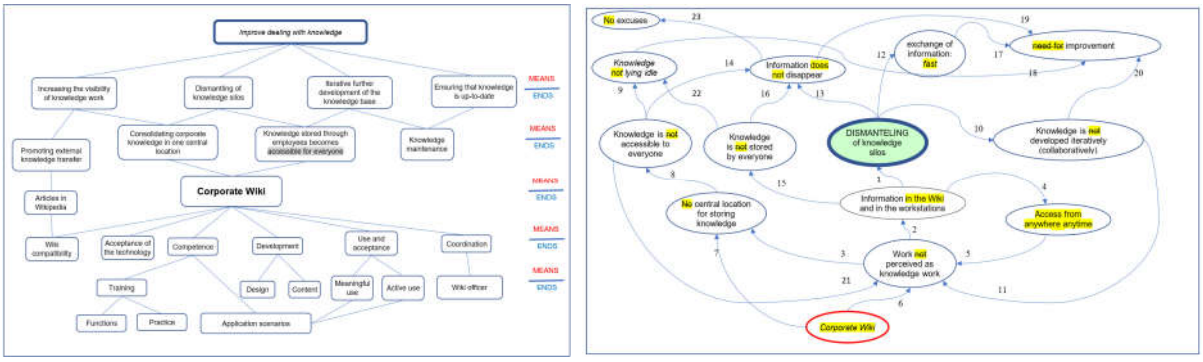

Figure 8: Tool [4.4.2.1 Means-Ends Hierarchy], left and tool [4.4.2.4 Causal Network], right.

5. Discussion

Ksenia, a young knowledge manager who was working at a Ukrainian SME located in Chernihiv until February 2022, had to flee to Poland due to Russian war crimes in her city (killing of civilians and bombing of houses and civilian infrastructure). She now lives with other refugees and is looking daily for a new job. In her spare time, although she is not involved in any business project, she has found a way of expanding her repertoire of management experience on the basis of case studies: using the CI method.

On the internet, Ksenia searches for freely accessible collections of knowledge management case studies: best practice or good practice reports. After defining her own criteria for selection, she selects a suitable description, reads it and gets a rough idea of which aspects of the project are most attractive for her. She then selects four tools from the CI toolbox, updates her knowledge by carefully reading the tools' descriptions and for each tool, marks in the case study terms or sections that match the chosen tools.

For each tool, she then checks whether the marked words can be used as parts of its CI model and iteratively builds up the model with content taken from the appropriate text sections. Finally, she carefully examines the created knowledge structures and reflects on the results: what findings do they provide? What information is redundant or missing? What questions are still open? After this, she repeats steps 2 and 3 for each model. As a last step, she then performs a cross-model iteration across the four models to ensure the consistency and complementarity of the four knowledge structures produced in the process of knowledge discovery.

This use case makes clear three aspects which are crucial to successful application of the CI method. *First* of all, collections of case studies need to be easily accessible. For users in a big company, this can be provided by an internal repository of post project reviews (Carrillo 2010) but for a SME, you need the availability of external repositories. *Secondly,* since the 11 tools of the basic toolbox are probably not sufficient to match the type of knowledge hidden in the case study or the criteria of the user, there is a need for a larger toolbox, perhaps even a big repository of tools. *Thirdly,* the reflection phase could also be supported, for instance, by appropriate evaluation tools.

6. Conclusion

The basic idea of the Case Insights method, abbreviated to CI, which has been presented in this paper is to discover knowledge through case studies and to make it usable for problem-solving. Case-based knowledge is contained in authentic case descriptions i.e. “good practice” or even “best practice” cases. Case-based problem-solving uses this knowledge and adapts it to the requirements of a new problem.

Case studies contain a great deal of problem-solving knowledge but only part of that knowledge can be absorbed through simple reading. The rest then remains difficult to access. The Case Insight method makes it possible to discover this hidden treasure by enabling the creation of brain-friendly and holistic knowledge models of case studies.

The successful application of the CI method presented in this paper depends on three conditions: 1) easily available collections of high-quality case studies; 2) a repository of tools which is large enough to cover a big variety of case studies; 3) evaluation methods for supporting a critical examination of the knowledge discovered. These are points on which future research should concentrate.

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