Development of Framework for Designing an Analytical Data Warehouse: Case of e-Municipalities

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Abstract: Knowledge sharing is an important aspect in a company's daily life. Transferring practical experience and knowledge (that is required for solution development) among employees is crucial. This improves the development time and quality of software solutions as well as understanding of future projects related to cases with similar concepts and concerns. A framework for designing an analytical data warehouse (FADW) intended for municipalities is proposed. This framework focuses on the usage of patterns that are utilized for knowledge sharing purposes. The paper analyzes a case study and outlines possible solutions to the problems identified. A data warehouse is used to integrate data and to address business data analysis and, with the help of patterns, these solutions are shared among the municipalities.

1 INTRODUCTION

Knowledge sharing is a process of interchanging knowledge, experience, intelligence, understanding and other values, that create awareness and understanding on how to use and apply an existing solution or an approach to help deal with or solve the encountered problem (Nadason et al., 2017). One way to achieve knowledge sharing is with the help of patterns. Pattern in the context of an analytical data warehouse is a general, reusable, and configurable solution to a commonly occurring problem within a given context. With addition to literature review to many patten definitions (Jokste et al., 2019), (Agerbo & Cornils, 1998), (Buschmann et al., 1996), (Fowler, 1997), (Gamma et al., 1995), patterns:

- Can be used as a knowledge base to shorten implementation time and improve quality of solutions;
- Could be shared with other establishments, or in this case – municipalities, to improve the implementation time and quality of a business needs;
- Endure over time, for possible use in the future.

Based on this pattern approach, a framework for designing an analytical data warehouse (FADW) meant for municipality business cases is developed.

The problem addressed in this paper discusses the use of a predefined framework for the development of an FADW. The FADW in this case is meant for the use of e-municipalities that could use other available solutions from other municipalities to create solutions that are necessary for them at that point and time.

The objective of this paper is to elaborate a concept of the FADW by analyzing and researching the requirements and needs for municipal business cases and to show the general idea on using the proposed framework for similar cases. As well as, to propose a way to use patterns for the development of a solution that has similar needs to other cases and are within the same business intelligence (BI) environment.

This research is done as a part of an industrial research project managed by the university and a company that implements the results of the research projects into a system developed specifically for municipalities. The overall objective is to establish BI ecosystem facilitating efficient adoption of BI solutions in Latvian municipalities. Solutions with emphasis on demonstrating the value of information and importance of identifying information for suitable BI application cases.

The rest of the paper is organized as follows. Section 2 provides background information about the research. Section 3 describes the research method used for carrying out the project. Section 4 analyzes a

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case study and describes how to share the attained knowledge with the help of patterns. Section 5 summarizes the analysis and research done in this paper. And Section 6 gives the conclusion and future plans related to this work.

2 BACKGROUND

As the need for municipalities to manage urban and territorial development for cases related to traffic, environmental pollutions, territorial improvements (and other cases) is high, the importance of e-municipalities cannot be over emphasized. The system enhances local governance and democracy, and it makes access to information, that is related to municipalities, easier (Bojang & Bwando, 2018).

For the municipalities of Latvia, there is a Unified Municipality system meant to ease the internal and interinstitutional cooperation processes. This system offers its services to 119 municipalities in total. The company, mentioned in the introduction of the paper, is responsible for the unified municipal system – its maintenance and further improvements.

The company, with the help of the university, has developed a framework meant for designing an analytical data warehouse for the needs of municipalities. This framework is a data warehouse design approach that combines 1) data warehouse technological solutions, 2) implementation of data mining methods (and) 3) methods for independent implementation and improvement of analytical capabilities. The framework describes the concept of a data analytics solution and the technical architecture specifically for case of municipalities. As well as guidelines on how to design and develop these solutions. In the next section, topics related to the FADW development are discussed and the general outline of the framework is described.

3 RESEARCH METHOD

The research analyzes two case studies, based on which the FADW is developed. Both case studies are requests made by two different municipalities to provide a data analytics solution to analyze data with the available information. One of the case studies is about municipality cards, that give the citizens of the municipality a chance to use special services, that require the use of this card. The second case study is about determining the investment index in the municipality and its citizens, to plan future investments and environmental improvements.

To learn from similar BI application cases, literature about the experiences of other countries – their municipalities, was analyzed and reviewed and set as a base, when researching possible solutions for the FADW (Teixeira et al., 2014), (Nycz & Polkowski, 2015), (Hartley & Seymour, 2015), (Hafiz & Faith, 2016), (Adelakun, 2012), (Yadav & Shakya, 2016). The literature describes data warehouse and business intelligence solution implementation potential with the research, planning or development done by the different municipalities. Literature indicates the potential difficulties and benefits of the BI solutions. Largest issues the process of designing BI solutions for multiple municipalities had, was data integration problems between different systems, difficult knowledge sharing between municipalities and that it is financially challenging to provide BI solutions for municipalities en masse. Despite these difficulties, most the country experiences approve the fact that BI solutions provide more benefits than disadvantages.

With the available research materials, questions requiring additional research arose. Questions that required attention and research, before moving on to designing the technological solution:

- What criteria needs to be considered when implementing analytical data warehouses and BI solutions for e-governance purposes?
- What is the role of datamining methods in data warehouse solutions?
- From what kind of components are data warehouses and BI solutions comprised of?
- What kind of already existing component-based data analytics solutions are there?
- Open data in the context of municipality BI platform solutions,
- User cooperation capabilities in already existing BI platforms.

The conclusions made from the research led to understand, that a BI solution meant to satisfy municipality needs requires a stable data warehouse implementation process, the use of datamining methods, geospatial data analysis and visualization tools as well as an integration of data between a variety of different platforms. This study focuses on providing an addition to the already existing data warehouse solutions, by introducing the use of component-based solutions. With an addition of a component-based solution to these data warehouse preconditions, it is possible to design a system, that could help municipalities share knowledge and their existing solutions between themselves and set conditions for the structure of data, that needs to be provided for the BI solutions to work. This would address the issues encountered by other countries and result in cost savings and an efficient way of using already developed solutions.

To understand the implementation possibilities for a component-based approach, reference materials for knowledge sharing (Jokste et al., 2019) within the BI ecosystem and knowledge management (Kampars & Stirna, 2017) are used to make sure that the knowledge is transferred between municipalities. Besides the more common and traditional approaches, when the technological solution of the data warehouse was being designed, multiple reference materials related to data analytics and data warehouses were considered:

- Data extraction from devices, various data format data extraction, data storage and analysis (Ahmed & Shahat Osman, 2019),
- Connecting new data sources to already existing ones and combining new data source data with the already existing data (Hiranandani, 2017),
- Data integrity and control (Ahmed & Shahat Osman, 2019), (Arora & Gupta, 2017),
- Gradual additions and improvements to the data warehouse (Silva et al., 2013), (Felipe et al., 2018),
- Service-oriented approach, configurability, interoperability (Felipe et al., 2018).

With the available information as the base for designing an analytical data warehouse, and a general idea on how to do it, it is still important to consider the two main questions that set the course on how the analytical data warehouse will be build. The main questions that need answers before creating a solution for municipality data analytics needs and knowledge sharing within the BI ecosystem:

- How will it be possible to share knowledge between municipalities,
- How is it possible for different municipalities to use the same solution – they might have similar business objective, but the requirements and needs might differ?

The questions guide the research and creates discussion for possible ways to overcome the problems and issues that these questions highlight. Mentioned reference materials are reviewed for finding possible solutions and approaches for the creation of the framework.

To find an answer to the raised questions, to ease the process of resolving the problems that municipalities encounter and need a solution for, as well as to acquire additional data and information, that could be used to govern the municipality – potential solution, such as an analytical data warehouse, could be proposed. The data warehouse would use data analytics tools, e.g. OLAP (*Online analytical processing*) cube that would be used to analyze the acquired data and provide an overview of the situation regarding the problem. The structure of the data warehouse would differ based on the problem – what kind of data needs to be analyzed and how can this data be stored (in the form of a dimensional data model) in the data warehouse for data analytics purposes.

Once a dimensional data model is structured and implemented for the specific problem in the data warehouse, the data could be uploaded and analyzed with the help of data analytics tools. However, there is a catch. This dimensional data model would require to be universal – to have the most important aspects with a minimalistic touch of the specific problem. The reasoning behind that is so that other municipalities, which would be interested to solve a similar problem, would also be able to use this same dimensional data model for their own purpose. And, if need be, other additional functionalities could be added by themselves later on. At this point, the knowledge management side of the analytical data warehouse solution is proposed.

In order for municipalities to share their experience, knowledge and proposed solutions for respective problems – for this cause, patterns are introduced. Patterns are used together with the pattern repository (Kampars & Stirna, 2017) that provides knowledge management services – create new, find and use already existing patterns. By using the pattern repository, it is possible to track knowledge usage in different applications as well as to aggregate feedback about pattern usage efficiency. With this feedback, it is possible to dedicate, which patterns seem to be more efficient and help with selecting patterns appropriate to solve municipal problems.

The situation is primarily analyzed from the perspective of a consulting company that provides solutions for municipality needs. The FADW serves as guidelines for implementing, maintaining, and sharing possible solutions that are meant to resolve requests made by municipalities.

4 CITIZEN MUNICIPALITY CARD CASE STUDY

As mentioned, the developed framework is based on the two case studies – business requirement cases raised by two municipalities which will be analyzed in this (IV) and the following section (V). The first case study focuses on providing the municipality a way to analyze data that is accumulated by using the municipality cards for different types of services, like public transport, catering, etc. Goal of the case study is to analyze the citizen card – utilization processes, data that is exchanged in the card usage process, data sources, and to design examples for data analysis methods. Based on the case studies, framework for designing an analytical data warehouse is developed.

4.1 Data Warehouse

To be able to use data warehouse for data analytics purposes, a dimensional data model is required. Dimensional models (Kirmani, 2017), (Sherman, 2014) can be used to write reports, use query tools to analyze the data in the data warehouse, provide an easy to understand user interface (helping end user understand the database easier). It can also be extended if there is a need for additional information. The administration of the data warehouse is based on the data structure "Fact-Table". For this case study, a snowflake schema is used for the dimensional data model to ensure, that the data that is acquired in the transaction processes, when using the municipality citizen card, could be analyzed thoroughly and all the required fields for data analysis would be provided in the dimensional data model. To create the dimensional data model, input data for citizen municipality card case study is analyzed.

This input data is not of a complex nature and luckily, all the data provided is already structured without any unnecessary information. This helps avoid any data quality issues. So at first glance the dimensional model does not seem to be too complex itself as well. However, that is not the case. Despite there being only four fields in the provided report – card id, merchandise id, time of the transaction taking place and the transaction amount, many more aspects need to be taken in consideration. Taking the client (citizen purchasing the product with the municipality card) data into account, the dimensional model requires firstly, the standard tables – fact table, time dimension table and client dimension table. To be able to analyze the data, there is additional information that can be related to the client. Which means, that the client will have additional branches to depict "client" in the dimensional data model. In addition, the citizens need to be assigned to a municipality, so dimension tables representing municipalities and their territories must be added as well. Based on this information and these requirements, the dimensional data model, can be structured. A simple representation of dimensional data model can be seen in Figure **1**. The fact table "Utilization_facts" holds the numbers and values that are loaded into the data warehouse for data analysis needs. The other tables are dimensions that provide the necessary data to analyze the fact table data from different perspectives and at different sections.

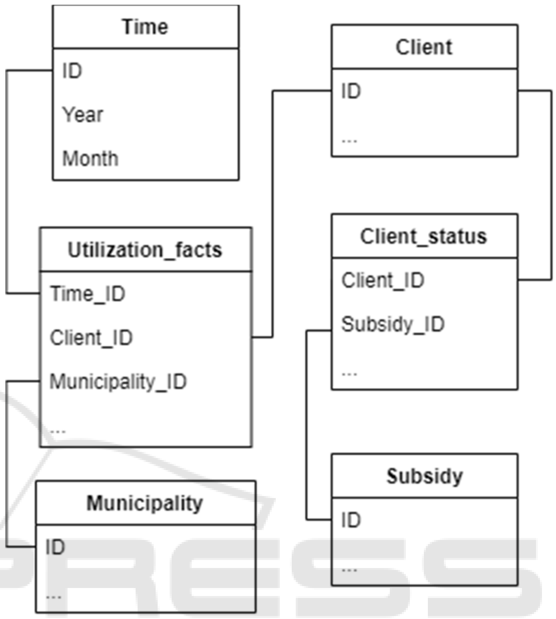


Figure 1: Representation of a dimensional data model for municipality card case study.

4.2 ETL Process

To get the available data into the data warehouse, there are a number of steps, that need to be taken. ETL (*E – extract, T – transform, L – load*) tools and the process of it is responsible for data extraction from many different data sources, cleaning (transforming) the data, for it to be usable and viable for the data warehouse and then inserting the cleansed data into the data warehouse. This data is stored in a snowflake schema which was already described and showed in Figure 1. To fetch data from this schema, many joins are required. That is why it is very important how the data is transformed and then stored during the ETL process in the data warehouse. Based on outcome of this process, the performance of the data warehouse can either improve or diminish (Simitsis, 2005), (Goar et al., 2010), (Hanlin, 2012), (Levene & Loizou, 2003), (Oketunji & Omodara, 2016). So before the data is inserted into the data warehouse, it needs to be analyzed – how it is going to be stored (already provided in Figure 1), and then it can be prepared for the transformation and storing process.

For the municipality citizen card case study, there are two separate data sources. One system provides information about the actual use of citizen cards around the clock, while the other system provides information about citizens – name, surname, other personal information, citizen card assigned to them, and similar information. Citizen card data requires to be collected in real time, while data about the citizens is fixed and rarely changes. Once the input data is acquired, the transformation process of the data may begin.

For this case, in total, there are 3 transformations that need to be performed:

1. Combining data by citizen ID – since the data is acquired from 2 separate data sources, it needs to be combined by using the citizen identification, which is stored in both data sources.
2. Separating data by date and time – to analyze data (for example anomaly identification, which is described later in paper) by time or date, or both for faster data analysis.
3. Calculating citizen (client) age by their birth date – to analyze citizen card usage tendencies according to age groups. The age is acquired by using the citizen birth date from one of the data sources and calculating the actual age of the citizen at the time of the transaction.

Once the data has been processed and transformed it can be loaded into the data warehouse, where further data analysis with respective tools can be performed. As a result, an example of a possible solution, for municipalities to use for their own cases, can be proposed. Based on the needs of the municipalities, different types of data transformations can be made with the available data – therefore different type of data analytics solutions, can be presented. An approach to present these different solutions and to provide the necessary knowledge so that other municipalities could implement them, (as already mentioned in the response for the second question that was raised) is the usage of patterns. Patterns are reusable components, that can help solve problems of a specific context (Alexander et al., 1977), (Agerbo & Cornils, 1998), (Buschmann et al., 1996), (Fowler, 1997), (Gamma et al., 1995), e.g. issues related to municipality governance. These patterns, that can consist of either technical components that ensure that the solution works appropriately to the municipality requirements or consists of knowledge that describes how to use or adjust the patterns for a specific issue. They can be used as a means of sharing knowledge between municipalities.

4.3 Patterns

Traditional patterns for software development consist of three main concepts that are 1) problem description, indicating what type of issues the pattern addresses; 2) definition of the context, describing the conditions and the environment when the pattern can be made use of; 3) solution, describing the achieved results by using the corresponding pattern. However, this is not much to go on, as there is no information on what sort of input data is used or required; how this solution could be implemented for other users; or any indicators on whether or not this pattern provides useful and valid information. Any user, who is unaffiliated with the group of people, who put this pattern together, could have a hard time achieving the same result of the pattern. But it also should be pointed out, that the developed patterns in these cases were not meant for sharing. So, to make knowledge sharing viable with the use of patterns, additional pattern concepts need to be introduced. These concepts are summarized in a pattern metamodel, shown in Figure 2, and a more detailed information follows the figure.

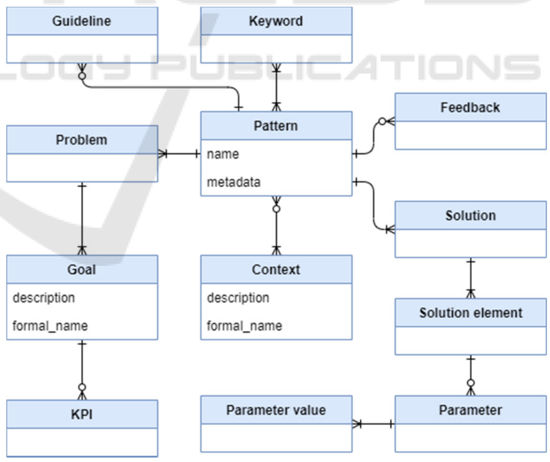


Figure 2: Pattern metamodel.

Pattern is a data analytics solution reusable component, which can be combined with other patterns and it is described by attributes such as a name and metadata. Name referring to the specific pattern and metadata being the concepts described before (problem description, context, solution) and further in the paper. By configuring the concepts of the pattern, an analytical solution for a specific municipality business need can be designed. Besides the problem description, context and solution, that are the main concepts of software development patterns, concepts such as **keywords**, **goal**, **key performance indicators** (KPI), **solution element**, **parameters**, **parameter values**, **feedback**, and **guidelines** are introduced and implemented. **Keywords** are used to find the appropriate patterns in the pattern repository, that is why, each of the patterns have keywords assigned to them, to describe the cases they can be used for. The **goal** describes what can be achieved with the use of the pattern. **Key performance indicators** define the usefulness indicators that indicate how well the pattern performs. **Solution element** is the concepts from which the solution is composed of, e.g. data mining or data processing algorithms. Each pattern is adjustable and so each pattern can have different **parameters** – is it a data source, data extraction query or any other input. **Parameter values** are defined according to the developer, who implements the data analytics soliton by considering parameter types, possible values, and restrictions. **Feedback** is used to evaluate the quality and potential of the pattern. They are acquired from users who have tried the pattern. **Guidelines** that describe how to use patterns and how to integrate them with other patterns. Each one of these concepts is required for knowledge sharing purposes, so it is important give as much information as possible and as detailed as possible.

The aim of the additional concepts is to make it easier for other users of the BI environment (in this case – municipalities) to use and implement the data analytics solutions with the help of patterns. A pattern is described by using the concepts defined in the metamodel (Figure 2) and a pattern template that is represented in the form of a table. By using these supplemented patterns, knowledge sharing in between municipalities is possible.

To demonstrate the pattern approach, one of the possible data analytics solutions encountered in the case study – request for a possible solution from a municipality – will be analyzed and demonstrated in a form of a pattern.

4.4 Pattern Example – First Use Case

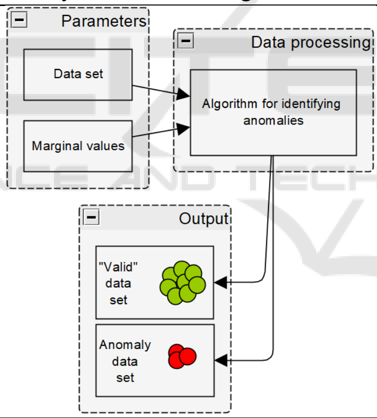
By analyzing the data from municipality citizen cards, it is possible to predict the flow of the citizens that are using public transport services. With these predictions, a plan for the public transport routes – at what times there should be additional units of public transports and when there should be fewer, could be proposed. Therefore, increasing citizen satisfaction levels with the public transport and eliminating inefficient public transport usage. However, there are also public transportations that are functional during nighttime. These are used by fewer people and data analysis for this purpose is not require. But both cases – daytime rides and nighttime rides are noted in the system and are only separated by timestamps. To clean the data from nighttime public transport usage (anomalies) and have a dataset composed only from daytime public transport usage, an anomaly identification pattern could be introduced.

The goal of this pattern is to identify anomalies in the immense amount of available data and separate them from the "valid" data. By defining this goal, one of the pattern concepts – "Goal" can be filled with the respective information. Similarly, the rest of the concepts are also populated with information. By analyzing what is the purpose of the pattern and how the result is acquired, the concepts of the pattern are described. For "key words" – anomaly identification; description about the issue pattern addresses "problem" – distinguish anomalies in data and analyze the reason for the cause of anomalies; and so forth for the rest of the pattern concepts. As a result, we acquire a pattern, in a tabular form, describing the usage and implementation specifics. The example for the anomaly identification case pattern, is shown in Table 1.

The fields "parameter value" and "feedback" have no information, as there is no universal value that could be used for anomaly identification, nor are there any user evaluations available to give a feedback onto the pattern. By understanding under what circumstances the pattern can be used (context) and what the input data should be for the solution to work (parameters), other users may use the same pattern, if the problem they encounter is the same, and the achievable goal matches.

Shown example is only one of the possible pattern types for data analytics purposes – data analysis pattern. In total three pattern types were identified. There is the already mentioned data mining pattern type and three other types – data extraction, transformation, and storage; data analysis; and data visualization and publication. During the data analytics process there are a set of actions that can be (combining citizens in groups by age) or need to be (data extraction from data source) performed. These actions can be described with the pattern types. Therefore, for each of the actions, a respective pattern can be utilized. Meaning, that if there were additional patterns for extracting municipality citizen card public transport data and a pattern for visualizing the "valid" data set, then these patterns could be combined with the anomaly identification algorithm pattern and a complete solution, could be proposed. This would mean, that a complete solution, could be shared with other municipalities, if all the preconditions are made for the solution to work. This shows that patterns have a high potential to not only provide small solutions, but also create larger ones to address more complex issues, by combining different types of pattern solutions.

Table 1: Pattern for anomaly identification algorithm.

Name	Anomaly identification algorithm
Key words	Anomaly identification
Problem	Distinguish anomalies in data and analyze the reason for the cause of anomalies
Goal	Identify anomalies in large amounts of data
KPI	Proportion of anomaly cases in data
Context	• Municipality has access to a large dataset that requires the use of anomaly identification algorithm. • It is important to identify the anomalies in the data, to analyze it further.
Solution	Anomaly identification algorithm
Solution element	
Parameters	• Dataset • Data threshold values
Parameter value	(For this case there is no information, but when used in practice with available data, this field will be populated)
Feedback	(For this case there is no information, but when an actual solution is made and users report on the solution, feedback will be associated with this pattern)
Guidelines	• To implement this pattern, it needs to be integrated with a result visualization pattern. The result can be presented in either the data visualization tool or as a report. The result can be combined with other analytical process patterns.

5 MUNICIPALITY INVESTMENT INDEX CASE STUDY

The second case study focuses on providing information about the investment situation in the municipality – what is the return on investments that were put into the society of the municipality. Goal of the case study is to calculate the current period investment index compared to previous period or multiple periods. This index is composed from the well-being of the municipality citizens – citizen benefits, taxes – taxes paid by citizens or taxpayers, and taxpayers – natural and legal persons of the Republic of Latvia or foreign countries and groups of such persons established on the basis of an agreement or arrangement, or their representatives, who perform taxable activities or who are guaranteed future income. An overall estimation about the current situation in municipality is calculated by using data on these aspects as the main justification of the result.

5.1 Data Warehouse

Compared to the first use case scenario, the input data for this scenario is a lot more complex. The data is acquired in the form of reports that are represented as tables. There is a total of 38 reports – 38 tables representing report data. In these tables, there are only statistical values that are used to inform the municipality about the current situation of the municipality. To use this information, it needs to be normalized and then additional statistical calculations need to be made, to acquire values that can be used to understand the current municipality condition compared to previous periods. Besides this issue, an additional problem is that the well-being of municipality citizens has no correlation with taxpayers. Citizens and taxpayers have correlation with taxes, but between citizens and taxpayers there is no data, that could be used as a possible way to connect these two aspects.

One of the solutions to the mentioned problems could be that the citizens (well-being of municipality citizens) could be separated from taxpayers and made into two data models. This would solve the problem with correlation between citizens and taxpayers. To solve the problem with statistical data, multiple data transformations need to be carried out. As a result of these transformations, final values, used to describe the current situation in the municipality, would be provided and stored in the fact table.

For this use case, two separate dimensional data models need to be designed that contain information related to the well-being of municipality citizens, taxes, and taxpayers. Simplified representations of these data models can be seen in Figure 3 and Figure 4.

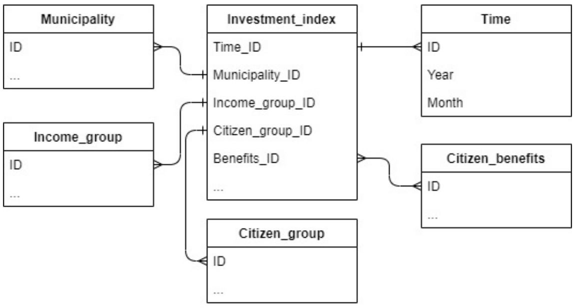


Figure 3: Municipality citizen dimensional data model.

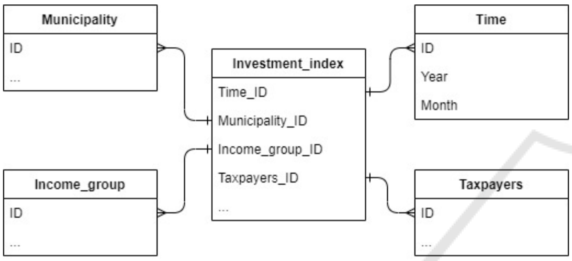


Figure 4: Municipality taxpayer dimensional data model.

For the municipality citizen dimensional data model (Figure 3), similarly to the first use case dimensional data model (Figure 1), information about the municipality and time is required and this information is stored in municipality and time dimensions. As for the other dimensions – *Income_group* stores information about municipality income (types of taxes) that is acquired from citizens; *Citizen_group* stores information about the citizen group for which the statistics data was gathered about; *Client_benefits* stores information about types of benefits citizens get from the municipality.

For taxpayer dimensional data model (Figure 4) same as previous dimensional data models, municipality and time dimensions serve the same purpose. The other dimensions – *Income_group* stores information about municipality income from taxpayers; T*axpayers* stores more specific information about the taxpayer group for which the statistics was gathered about.

Having designed the dimensional data models, the next step is to perform transformations on the data, so that it would be possible to store it into the data warehouse.

5.2 ETL Process – Transformation

To acquire data used to report the situation about the municipality investment index, multiple transformations need to be performed:

1. Report table data normalization.
2. Average values for statistics data values from previous periods of all report tables.
3. Latest period statistics data values against average values (division).
4. Acquiring weights for each of the statistics data values.
5. Indicator calculation by using division results and weights for statistics data values.
6. Aggregating acquired indicators and grouping them to determine the investment index for the corresponding groups - well-being of the municipality citizens, taxes, taxpayers.

As a result, the investment index for each of the groups is acquired and the return on investment can be evaluated based on the outcome. With these transformations, there is no further need for data mining methods. The result can be further used for data analysis and data visualization purposes.

5.3 Pattern Example – Second Use Case

Example of a pattern for this use case is about the ETL process that includes all the calculations mentioned in Section V.B. Just like the first use case pattern example, the representation of the pattern is in tabular form. Each of the concepts is populated with information that is related to this specific use case. As a result, a pattern for a problem – extracting statistical data from report tables to acquire municipality investment index in comparison to previous periods – is proposed. As these reports are available for any municipality in Latvia, this pattern would be useful for other municipalities to use as well, to acquire information about the return on investment into the society.

The proposed pattern for ETL process that transforms data to calculate investment index for municipalities, can be seen in Table 2.

In this pattern concepts “Parameter value” and “Feedback”, same as in first use case, currently have no values, as this is a simple example. But when used with actual data and a data warehouses, information related to data sources, data extraction frequency, data transformation tasks, target storage, as well user feedback – information related to these concepts needs to be provided.

Table 2: Pattern for ETL process for calculating municipality investment index.

Name	ETL process for calculating municipality investment index
Keywords	Investment index; ETL
Problem	ETL process is a mandatory component for data analytics solutions
Goal	To ensure the process of data collection, data transformation and data loading into the data warehouse, that is necessary for the analysis of report statistical data
KPI	Performance • Time efficiency, • Resource utilization.
Context	• Municipality has access to a statistical data about citizens, taxpayers, and paid taxes
Solution	ETL process, that extracts data from the data source, transforms the data and the loads it into the data warehouse
Solution element	1. Data input 2. Data processing 3. Data output
Parameters	1. Data input • Data source, • Frequency of data extraction. 2. Data processing • Data transformation tasks (a set of tasks, that describes how to perform data transformations mentioned in Section V.B.). 3. Data output • Target storage.
Guidelines	• Frequency of data extraction can be adjusted and customized according to requirements

Provided pattern is an example of a data extraction, transformation, and storage pattern type. By combining this pattern with a data analysis pattern and data visualization and publication patterns a complete solution for municipality investment index use case can be proposed.

6 SUMMARY

The framework focuses on the development of patterns that can be used for knowledge sharing between municipalities. By using a data warehouse and ETL process, data is stored, transformed, and analyzed to present a result the municipality is interested in – this can also be called a business analytics solution. Patterns are applied to share the knowledge on how this business analytics solution is achieved. And by using multiple patterns, it is possible to present a bigger solution that can solve a seemingly hard problem in an easy way with the combination of different types of patterns.

A visual representation on how the approach proposed in the framework would work, can be seen in Figure 5.

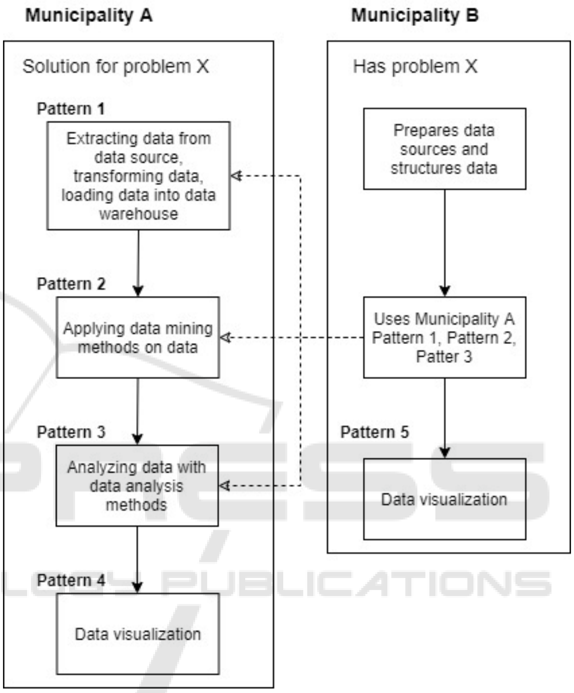


Figure 5: Example for the approach proposed in the framework.

In the example, shown in Figure **5**, there are two municipalities – A and B. Municipality A has implemented a solution for a problem X that they had encountered at some point and time. The solution consists of multiple patterns that each have their own purpose. Municipality B has encountered problem X just recently and wishes to find a solution to solve this issue. Municipality B notices, that municipality A, has a working solution for the same problem, so they decide to use the proposed solution, expect for the data visualization part. Municipality B has decided that it needs to see data in different forms and diagrams, so they will create their own pattern for this purpose. To use the proposed patterns – Pattern 1, Patter 2, Patter 3, Municipality B prepares a data source and structures the data according to the directions provided in Pattern 1, for a successful ETL process. After that, the data is process and analyzed by using Pattern 2 and Pattern 3. After that, all that is left, is for Municipality B to use the output data from Pattern 3 and use it for their own data visualization purposes that is made into a new pattern – Pattern 5.

By using the pattern approach that is at the base of the framework, it is possible to provide a shareable solution for other business cases, that municipalities are interested in (as seen in Figure **5** and described in the example). And not only for municipalities, but for different BI environments as well, where knowledge sharing can be an important factor. Overall, the framework can be used as guidelines to implementing knowledge sharing solutions and understanding how to use or create new patterns with implemented knowledge sharing.

7 CONCLUSIONS AND FUTURE WORK

The groundwork for designing an analytical data warehouse for the use of e-municipalities has been proposed. An approach for knowledge sharing with the help of patterns has been analyzed, research and developed. Based on the results, the pattern approach seems to have potential and could be used to provide complete solutions that are based on multiple smaller solutions derived from patterns.

The results of the research project will be tested, and a demonstration for the pattern approach and the analytical data warehouse will be developed based on the case studies proposed in this paper.

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