Knowledge Sharing in BI Ecosystems: Case of E-Municipalities

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Abstract. The paper investigates the ecosystem perspective of business intelligence and data analytics with emphasis on knowledge sharing. It is argued that knowledge sharing is an efficient way of justifying and promoting usage of business intelligence solutions and that municipalities are particularly well-suited for collaborating in the business intelligence ecosystem. The paper proposes a preliminary conceptual model of the business intelligence ecosystem. The model considers formalized representation of knowledge in a form of reusable patterns, supports accumulation of feedback information about value of the patterns and distinguishes usage of open and proprietary data items. Examples of business intelligence knowledge sharing are provided.

Keywords: Business intelligence, knowledge sharing, e-municipalities, patterns metamodel

1 Introduction

BI (BI) and data analytics is being widely adopted in providing smart municipal services [1]. Municipalities have similar objectives and functions, driven by principles of openness and transparency and often have limited capabilities to adopt digital technologies. Therefore, a collaborative data and BI ecosystem approach [2] is particularly appealing to them for implementation and exploitation of BI and data analytics solutions.

Knowledge sharing is one of the key areas of concern in current BI research and the ecosystem is the most widely considered architectural pattern [3]. Cross-company comparisons are considered one of the main advantages of knowledge sharing. One of the main challenges of wider adoption of BI and data analytics is lack of convincing business cases with clear justification of expected returns on investment. Sharing knowledge about successes and failures of BI and data analytics usage is a potential solution to this problem in the e-municipalities framework.

This research is done as a part of the industrial research projects conducted jointly by the university and the company. The overall objective of the projects is to establish the BI ecosystem facilitating efficient adoption of BI solutions in Latvian municipalities with emphasis on demonstrating information value and identification for suitable BI application cases. The research process follows the action design research (ADR) methodology [4]. ADR addresses real world problems which require strong organizations stakeholders and research community collaboration [5]. Our research is collaborative work between company that develops software and services to municipalities and researchers who help to find the most appropriate solution for proposed problem.

The objective of this paper is to propose an initial version of conceptual model for sharing knowledge of developing and using BI solutions. The conceptual model defines key actors involved and mechanism for knowledge sharing based on patterns. The model emphasizes on open and proprietary data and information items. It is used to analyze several BI application cases in municipalities and potential for knowledge sharing. The contributions of the proposed research are expansion of BI solutions with components for ecosystem-wide knowledge sharing and proposing to use patterns for definition of reusable BI components.

The rest of the paper is organized as follows. Section 2 provides background information. An early version of the conceptual model is proposed in Section 3. Section 4 shows several examples of potential scenarios of knowledge sharing among the municipalities.

2 Background

Modern data analytical solutions are characterized by their diversity and centralized data analysis patterns such as data warehousing are no longer sufficient. That has caused rise of analytics ecosystems [2], where various parties collaborate and exchange data processing and analysis services. There are various modes of collaboration depending on entities shared. The highest level of collaboration is achieved if data, analytical services as well as value attained are shared among the members of the ecosystem. There are various actors involved in data ecosystems [6]. Their examples are data providers, service providers, application developers, infrastructure and tools providers as well as data users.

BI and data analytical solutions are typically developed according to commonly used reference architectures. Dimensional storage centered architecture is used in data warehousing, lambda architecture is used to combine stream and batch processing for big data and [7] combines structured and unstructured data processing and analytics. Rao et al. [8] provide an extensive review of constituent parts of BI and data analytics solutions. Data warehousing components are formally defined in the Common Warehouse Meta model [9] though the model has not been updated recently.

In last decade implementation and usage of BI solutions in local governments and municipalities are evolving rapidly. BI technology allows to quickly analyze data into reliable information which can be further used for decision-making process [10] and allows to ensure better services for citizens [11]. Municipalities' innovation plans often include modernizing decision-making process which proves the need for BI solutions for municipalities [12]. [13] point out that there are not many existing solutions that can be applied for municipalities, which leads to the need for customizable solutions for local government units. [14] have in depth researched the need for BI solutions in different organizations. The main value acquired from BI solutions is based on data that organization generate on daily bases which means that for municipalities BI solutions are important regarding data about citizens, tourists, legislations, laws, territorial aspects and municipality itself. [15] emphasize that BI solutions for municipalities serve as mechanism for identifying citizens' needs so services provided by municipality can meet the needs of citizens thus ensuring maximum benefit of such services.

The ecosystem perspective and open data collaboration in particular has been formalized in the data ecosystem model [16]. The ecosystem model shows its actors, relationships among the actors and resources exchanged. There is a gap between research done on BI and data analytical solutions and data ecosystems. The former still treats these solutions as relatively self-contained with mainly inwards flows of data and resources and the latter focuses on interactions among players in the ecosystem while neglecting data processing and analysis features.

Recently a capability-based approach to support mixed open and proprietary data ecosystems has been proposed [17]. This approach distinguishes among raw data measurements, meaningful business information and knowledge. The business information drives digital companies, the raw data measurements provide situation specific data sources to extract the necessary information and knowledge describes reusable data processing solutions. All these items are either open or proprietary and reasoning about data sharing possibilities can be performed. The capability-based approach is supported by appropriate tools and a pattern repository is a component responsible for knowledge management. The pattern repository [17] provides knowledge management services for knowledge creation, discovery and usage. The main feature of this pattern repository is that it is able to track knowledge usage in different applications and to aggregate feedback about usage efficiency. This feedback can be used in knowledge discovery to guide selection of appropriate patterns.

Using patterns is a promising approach how to "improve something", because patterns by their definition state that they offer instructions how to achieve the desired result [18]. According to [19] patterns are "a three-part rule, which expresses a relation between a certain *context*, a *problem*, and a *solution*. [20] also define *forces* as forth major pattern component. [18] have developed business process improvement patterns metamodel which defines the structure of the patterns and serves as the basis for selecting an appropriate pattern and its proper application. In Addition to typical pattern components, their metamodel includes building blocks, mechanisms, effects and performance indicators.

3 General Approach

The BI ecosystem is primarily analyzed from the perspective of an IT company implementing BI solutions at various organizations, e.g., municipalities. The IT company proceeds with gradual and evolving roll-out of these solutions starting at one user site and transferring the implementation knowledge to other users. In the case of municipalities, they have similar functions though their organization architectures, BI readiness and technological landscapes are very different. Lack of understanding about value of BI and proven returns on investment are the most significant impediments of BI implementation. While literature often emphasizes collaboration as a progressive chain starting with data sharing [2], knowledge sharing is the most important aspect for the municipalities.

3.1 Conceptual Model

Interactions among parties involved and relevant concepts are defined to establish foundations of knowledge sharing in the BI ecosystem. The interactions are modeled (Fig. 1) by expanding the open data ecosystem model [6]. The User needs a BI solution to analyze its business. The solution is provided by the Consulting company, which uses services provisioned by the Service provider and the Infrastructure and tool provider. The solution operates with data provided by the Data provider. However, users often do not have knowledge about BI utilization opportunities and consulting company has possibilities to reduce implementation effort by reuse. Therefore, an actor referred as to the Sage is introduced and it is responsible for knowledge management. The Sage maintains BI implementation and usage knowledge. Users like municipalities inquire the knowledge base about BI solutions used by similar users and get inspirations and suggestions. The Consulting company uses the knowledge base to retrieve technical information (i.e., design patterns) about the implementation of relevant features. The users provide feedback on usage success of the implemented features. This information could be shared with other members of the ecosystem, notably, data and service providers to improve data quality and services.

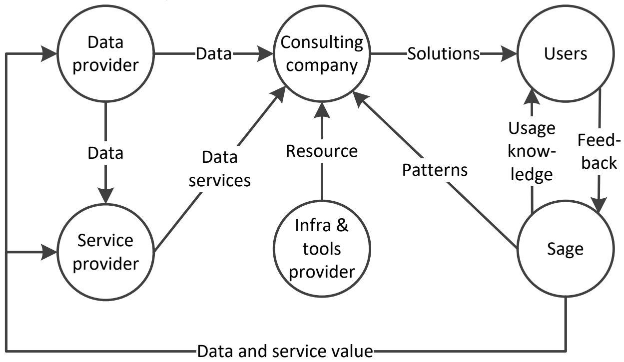

Fig. 1: Actors of the knowledge sharing in the BI ecosystem.

The main concepts of the knowledge sharing in the BI ecosystem are defined in Figure 2. It is assumed that users (e.g., municipalities) have some data processing and analysis needs expressed as goals. A BI solution is to be provided or updated to support fulfilment of these goals. It consists of various components as prescribed by various reference architectures. Examples of the components are data storage, reports, dashboards and ETL activities. These components operate with data items. The differentiation between data and information is made. The former refers to raw data supplied by data providers and the latter represents information created within the BI components by means of processing. Information is directly applicable in business processes and decision-making. It is expected that information needs are relatively similar within the ecosystem while data sources and raw data could be quite variable.

Knowledge of using BI and data analytics is represented as patterns. The patterns are rated according to feedback obtained during usage of the BI solution. The feedback might be qualitative such as users' ratings or quantitative such as process efficiency measurements. The quantitative evaluation is supported by key performance indicators (KPI) defined according to the goals. Members of the ecosystem use the aggregated feedback to identify appropriate BI application cases. The patterns are assumed as open within the ecosystem while data and information can be either open or proprietary. That influences the ability to reuse patterns and a degree of configuration required.

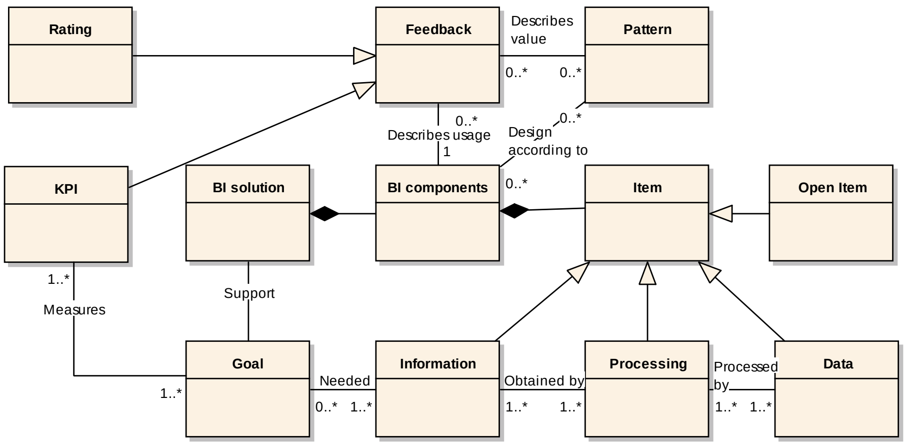

Fig. 2: Key concepts of the BI ecosystem with knowledge sharing.

The knowledge of using BI and data analytics is represented in a form of patterns metamodel (Fig. 3). Metamodeling has been recognized as suitable way of describing patterns completely and consistently [18]. Metamodel was developed based on existing identification of pattern components [17],[18] by adding additional components specific for knowledge sharing patterns such as Guidelines for pattern application and usage and Feedback for performance indicators retrieval. The problem and context are defined in a formalized manner as goal models and context models, respectively [18]. That allows users to match their business requirements and context to knowledge stored in the pattern repository.

The solution can be represented in various formats depending on the type of problem. It can be a data structure for data storage purposes, a query for data retrieval purposes, data mining algorithm for data analysis purposes, dashboard design for data presentation purposes or analytical model (e.g., in XML format) for analytical purposes.

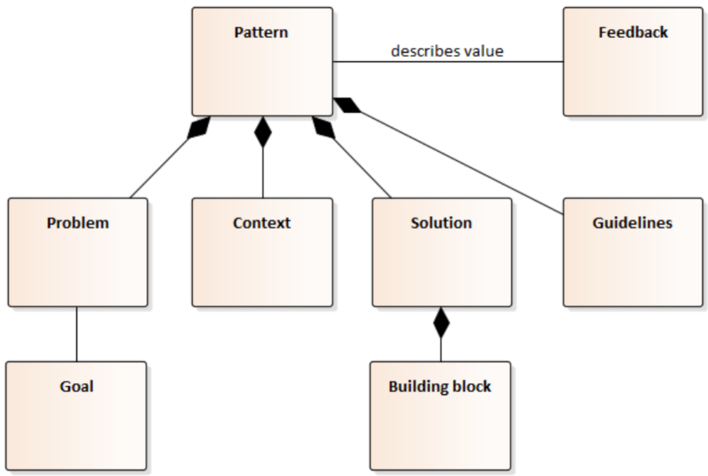

Fig. 3: Knowledge sharing patterns metamodel

3.2 Technical Architecture

The BI and data analytics solution consists of typical components characteristic to this type of solutions [6]. It is expanded by adding components responsible for requirements and knowledge management (Figure 4).

The data capture module is responsible for extraction of raw data from their sources. The data forwarding component is responsible for channeling data for further processing and performing data transformations. Classical ETL processing can be used as well as data streaming for real-time processing. There are various ways for storing data including dimensional data storage, data cubes and data lakes. These types are combined according to the business needs. The computational module is responsible for computationally intensive data processing and calculations. The data analytics module concerns interactive presentation and analysis of data. The data analysis can be performed using data coming directly from the forwarding module or from the storage.

The additional components to support knowledge sharing are the requirements and knowledge management modules. The requirements management module is used to specify customer's goals and context. That is used to find appropriate BI usage knowledge maintained by the knowledge management module. Patterns provided by the knowledge management module are used to setup up the BI solution. The patterns used are registered in the knowledge management module to enable accumulation of customers' feedback. Semantic consistency of the goal and context definitions as well as pattern definitions should be ensured.

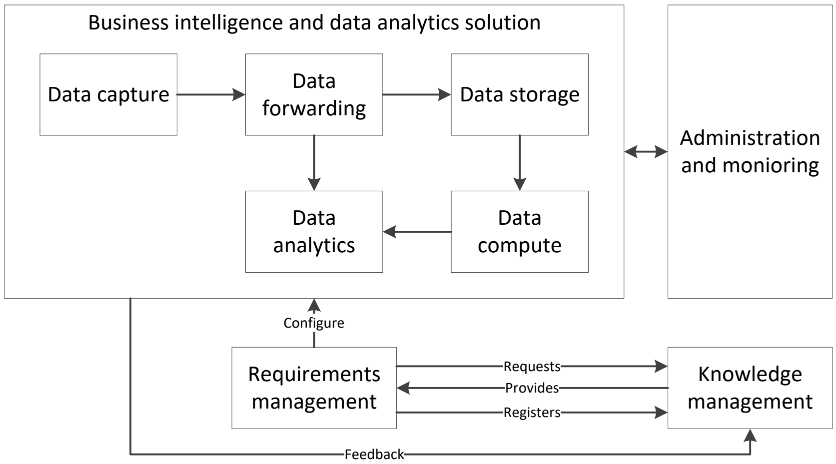

Fig. 4: Components of BI solution with knowledge sharing support.

4 Sample Application Cases

Several BI application cases are identified and tentatively formulated as patterns. These cases arise in municipalities pioneering BI application is these areas and are assumed as candidates for reuse in other municipalities. Cases were identified together with IT company which is developing software for municipalities and is aware of municipalities' needs for analytical solutions. Reusable BI components are identified for each case as building blocks which can help for other municipalities to build similar BI solutions. Patterns are described in tabular form and follow the structure of Knowledge sharing patterns metamodel given in figure 3. Identification of BI application cases also serves as the preliminary validation of knowledge sharing patterns metamodel. Patterns structure was initially validated by software development and business analysis experts from IT company by evaluating patterns structure from both – software development and implementation and business analysis adequacy perspectives.

4.1 Road Maintenance Case

Municipalities are responsible for maintenance of local roads including winter maintenance. Tracking of maintenance activities is a complex task and touches multiple concerns such as cost efficiency, environmental impact and road safety. Reporting solution has been developed for one of the municipalities and pattern has been defined specifying this solution (Table 1).

Table 1: Pattern defining BI component for providing winter road maintenance overview.

Item	Description
Goal	To know status of winter road maintenance work performed

	To calculate cost of winter road maintenance work performed To calculate environmental impact of winter road maintenance work performed To summarize customer feedback
Context	Road network; Climate conditions
Solution	Information: km traveled, km plowed, km de-ice, liters of de-icing liquid consumed, kg of salt consumed, customer feedback Data: GPS data, de-icing liquid tank sensors, customer feedback BI component: Winter road maintenance overview dashboard (could be provided in a machine readable format).
Feedback	KPI: km plowed; KPI: liters of de-icing liquid consumed; KPI: number of customer complaints
Guidelines	1. GPS data should be mapped to GIS data 2. De-icing liquid tank sensors are not always available and could be substituted by number of refills.
Reusable BI building blocks	1. Calculation algorithms 2. GPS to GIS data mapping 3. Sensor data gathering and processing 4. Winter road maintenance overview dashboard components 5. Changes in Municipalities Business data model (new attributes etc.) 6. Changes on BI Dimensions model (new facts in facts tables, new relationships etc.)

The goal and context can be represented using models as described in [21]. The solution can be specified using data processing and analytics standards or widely used formats, for instance, the dashboard can be represented using Grafana JSON model[1]. Other municipalities search the pattern repository and might find this pattern useful. If that is the case, usage guidelines are followed to configure the BI solution for the new application case.

4.2 Pubic Services Applications Delivery Analysis Case

Municipalities are responsible about public services delivery to their citizens. Different channels are established for citizens applications handling, services delivery and consultations. Traditional channels can include face-to-face contact, telephone or postal mail. Digital channels encompass websites, mobile-based services and public access points such as kiosks. Each channel effectiveness measurements are needed to meet legalization requirements and resources planning (citizens service centers locations, working hours etc.). Data can be used also for cities scoring[2]. Reporting solution has been developed for one of the municipalities and pattern has been defined specifying this solution (Table 2).

[1] https://grafana.com/docs/reference/dashboard/
[2] https://www.boston.gov/cityscore

Table 2: Pattern defining BI component for providing public services delivery overview.

Item	Description
Goal	To know amount of delivered public services (per each service and channel) To know amount of received services applications and consultations on each channel To measure public services that are delivered on time To calculate cost of one service application handling and consultation on each channel To plan citizens service centers locations and working hours To summarize customer feedback
Context	Citizens service centers locations; Citizens movement
Solution	Information: number of delivered services on each channel, public services delivery time (defined and actual), public services delivery costs, citizens flow, customer feedback Data: E-services platforms data, call centers data, queue machines data, accounting data, customer feedback, cameras BI component: Public services delivery dashboard, API for data sending to government centralized Public services platform and other sources (as municipality website)
Feedback	KPI: delivered public services (per service, per channel); KPI: public service delivery costs (per service, per channel); KPI: number of public services delivered on time; KPI: number of customer complaints
Guidelines	1. Camera data should be mapped to approx. numbers of citizens in different locations on different times 2. Public services delivery data from different channels and data sources must be aggregated in unified format 3. Statistics data must be sent to Public services platform once per year
Reusable BI building blocks	1. API for data sending to Public services platform 2. Changes in Municipalities Business data model (new attributes etc.) 3. Changes on BI Dimensions model (new facts in facts tables, new relationships etc.) 4. Data aggregation algorithms for camera data 5. New dashboards

4.3 Spatial Analysis of Municipal Investments Case

Each Municipality of Latvia vary in area and population which leads to different population density both between municipalities and within different territorial units of one municipality. Municipalities have to invest financial resources to evolve road infrastructure, recreation infrastructure and to create territorial improvements. In the same time municipalities gain territorial income from real estate taxes, personal income taxes, rent for land and buildings owned by municipality and company taxes. Municipalities want to determine investments efficiency, by territorially comparing investments made against the income received. This analysis can further help to plan territorial investments. Reporting solution has been developed for one of the municipalities and pattern has been defined specifying this solution (Table 3).

Table 3: Pattern defining BI component for spatial analysis of municipal investment.

Item	Description
Goals	Geospatially display data of financial resources investments made by the municipality Geospatially display data of income from taxes and rent In Geospatial Information System (GIS) split municipality territory in smaller analyzable units (parish authorities, villages, populated areas etc.) Calculate Return on Investment (ROI) index for each analyzable unit
Context	Citizens population in municipalities territorial unit
Solution	Information: citizens population in each territorial unit, financial resources investments, income from taxes and rent Data: Data from municipalities financial systems (rent and real estate tax incomes, planned and made investments in territorial units), anonymized data on the amount of Personal Income Tax residing in the planning territorial units from State Revenue Service data warehouse, data from municipality population accounting system BI Component: Investment, income and calculated ROI data displayed in GIS
Feedback	KPI: Financial resources investments per territorial unit; KPI: Income (taxes, rent) per territorial unit; KPI: Citizens population density per territorial unit; KPI: ROI index per territorial unit
Guidelines	1. Municipality's territory in GIS should be splatted into smaller analyzable units 2. ROI should be calculated in annual terms, because rent and taxes incomes can vary depending on season
Reusable BI building blocks	1. ROI calculation algorithm 2. Displaying investment, income and ROI data in GIS 3. Data extraction from municipality systems 4. Changes in Municipalities Business data model (new attributes etc.) 5. Changes on BI Dimensions model (new facts in facts tables, new relationships etc.)

5 Future Work and Conclusion

The preliminary version of the knowledge sharing BI and data analytics ecosystem has been proposed in the paper. Several application scenarios for municipalities are identified jointly with a BI consulting company. The scenarios show that knowledge sharing is important for the municipalities and patterns need to be configured to fit particular data and enterprise architecture of individual municipalities.

The conceptual model will be further elaborated and the technical solution will be developed in the framework of the research and innovation project. Additional BI application scenarios will be identified jointly with the IT company stakeholders and municipalities, BI application patterns will be defined and potential for reuse will be identified. The analytical cycle will be proceeded by the build and evaluation cycles, where the main emphasis will be devoted to feasibility of the pattern evaluation feedback loop. The knowledge sharing mechanisms will be piloted with participating municipalities and field observation will made of functioning of the ecosystem. More thorough validation of knowledge sharing patterns metamodel and BI ecosystem for municipalities will be carried out during the practical development, implementation and evaluation of this project.

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