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Title: Next Generation Methods for Development of Enterprise Information Systems
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Instructions

Traditional software development techniques are notoriously expensive and usually do not deliver expected functionality in desired time. Moreover, the legacy systems do not keep up with new requirements and are very difficult to maintain or replace. But who is to blame for that? Are that managers with unrealistic expectations or programmers that do not understand the business needs? A goal of this thesis is to review uprising methods for a requirements engineering and a software development.

Steps to follow:

- Review the state of the art techniques for automated business process discovery.
- Review the state of the art of SharePoint, Low code platforms and iBPMS and compare them with traditional software development.
- Create a proof of concept application by using automated business process discovery and a low code platform.
- Evaluate how much resources can these methods save over traditional software development.

References

Will be provided by the supervisor.

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Master's thesis

Next Generation Methods for Development of Enterprise Information Systems

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Supervisor: Ing. Marek Skotnica

January 10, 2019

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Declaration

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In Prague on January 10, 2019

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Abstrakt

Tradičné techniky vývoja informačných systémov sa môžu stať príliš drahým riešením a často aj nedodať výsledok v potrebnom čase. Táto práca sa zaoberá zhodnotením súčasných metód pre vývoj podnikových informačných systémov. Na prototype aplikácie vytvorenej v jednej z Low code platforiem s použitím automatizovaného hľadania podnikového procesu, bude vyhodnotený, či je možné ušetriť prostriedky použitím takéhoto spôsobu vývoja namiesto tradičných techník.

Kľúčová slova process mining, iBPMS, SharePoint, Low code platformy, Mendix, ProM

Abstract

Traditional software development techniques may become expensive and often did not deliver desired results on time. The objective of this thesis is to review the state of the art methods for development of Enterprise information systems. On the proof of concept application created in one of the Low code platforms and usage of automated business process discovery will be evaluated if resources can be saved by using this means instead of traditional means of software development.

Keywords process mining, iBPMS, SharePoint, Low code platforms, Mendix, ProM

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Introduction

Problem statements

Traditional software development techniques may become excessively expensive and also often fail to deliver required functionality on time. It can also be difficult to keep up with new requirements in legacy systems together with challenging maintenance and replacement. According to [3] approximately 70% of development projects between 2011 and 2015 didn't end successfully. And [4] states that in 2017 failure rates increased, only 29% of projects were delivered on budget, and 20% delivered on planned benefits. The reason for a high percentage of failure can't be known for sure. There are many factors possibly influencing the successful delivery of such system, starting from inappropriate development model, through the late response of IT departments to adjusting to new trends or unrealistic expectations from managers. Success rate of development projects may be essential for business survival because successful development provides organizations with a competitive advantage.

Results from study [5] shows that projects were more successful when agile was used followed by usage of hybrid methods. Also, usage of Six Sigma and managers with software development experience achieved higher project success. According to study [6] management attitude towards IT department is mostly reactive, so the projects are starting after problems occur. This situation may lead to inaccurately defined requirements and unclear budgeting and planning.

Motivation and objectives

The objective of this thesis is to review the state of the art methods for requirements engineering and software development. Namely SharePoint, iBPMS and Low code platforms will be discussed in detail to find benefits which these methods provide in contrast to traditional methods of software development.

The pros and cons will also be covered together with a short summary of advisable use cases of each technology.

The increasing rate of data amounts generated by various information system may open the question of proper handling. This is why data science gained on popularity during last years [1]. Analysis of this data may become very demanding, so the right tools are needed to be used to achieve results, for example by usage of process mining and automated business process discovery.

Finally, automated business process discovery will be used to gain the process from real-life event log covering the handling of applications for contributions for farmers and proof of concept application will be created in one of the low code platforms on the basis of the discovered process. This will be then used as a basis for evaluation of possible save of resources by using these methods over traditional software development.

State of the art development platforms

Through an analysis of the current state of the art technologies mainly Gartner's [7][8] and Forrester's reports [9] were used. Gartner is a research and advisory company providing customers with insights, advice, and tools they need to achieve their goals. They regularly deliver reports covering different topics with a wide range of interests varies from information technologies, innovations, management through finance to sales and legal. For purposes of this thesis, Gartner's magic quadrant report for Information technologies was used [7][8]. Magic Quadrant research methodology uses a competitive graphical positioning of four types of technology providers namely Leaders, Visionaries, Niche Players and Challengers. The report also covers reviews from users in several categories and is delivered a few times a year [10].

Forrester is also solid research and advisory company. They provide their clients with annual reports to help them lead change in their organizations. Forrester offers proprietary research, data and analytics, custom consulting and more. The Forrester Wave report about digital process automation and low-code platforms was used [9]. These reports cover user experiences as well together with an evaluation of platforms current positions on the market [11].

1.1 SharePoint

SharePoint is a collaborative web-based platform provided by Microsoft. Built-in integration with Microsoft office makes Sharepoint a popular tool for using in organizations to share and manage data. Easy access on the web from any device connected to the internet is also a great asset. Nowadays it is also a part of Office 365 or OneDrive for Business, so it is already included in one license with other Microsoft products as Word or Excel. The same user interface as other Microsoft Suite products makes it easier for users to

use SharePoint because many of them are already familiar with how do these products looks and works like. However, there is more, which SharePoint can be used for [12].

1.1.1 Workflows

Workflows can be added to sites for support of the business process. There are several workflows already created in SharePoint, which are covering the absolute basics. These pre-programmed workflows are said to save time and effort and bring consistency and efficiency to tasks performed on a regular basis. Namely, there are[13]:

1. Approval workflow - to pass document or item through approval process between several users, this can be done serial, parallel or combination of both
2. Collect Feedback - to pass document or item between several users to gather feedback, this can be done serial, parallel or combination of both
3. Collect Signatures - to pass document, workbook or form to gather digital signatures of designated people, this can be done serial, parallel or combination of both
4. Three-state - to track an issue, project, or task through three states or phases

These workflows are set to send alerts to users who are contributing to processes.

Users add these workflows from the menu, and then they can use it immediately, no need for programming or modeling their process. If there is a need for more complex workflow, built-in workflows can be customized, or new workflow can be created from scratch. However, for this SharePoint Designer has to be used. SharePoint Designer is a free program which was released in 2013, but creating workflows is not its only functionality, it could also be used to edit external content types for an external data solution based on Business Connectivity Services. Through SharePoint Designer user defines rules that associate conditions and actions with items in SharePoint's lists and libraries. Changing these items then trigger actions in the workflow. The final stage of complexity of workflows is the need of the full programming by users. For this purpose, Visual Studio and knowledge of programming are needed.[14]

1.1.2 Apps

Apps are role-based customized tasks which help users with their day to day work. There are several types of apps, which can be created by app makers. Canvas apps customized aspects of users work and can be connected to

multiple data source; the main aim is to help users complete focused tasks. Model-driven apps are generated from the organization's data, and they are more complex, responsive and highly customizable. Using this type of apps help users to focus on their work by eliminating the need of remembering to perform a set of manual steps. App makers determine which data is relevant for the app and relate them to other data, define a business process to be followed by the app and add and configure components.[15]

After app makers create an app, they can publish it for Android, iOS, Windows and web, so it will be shared among others in their organization. Apps can be created through PowerApps which is a development platform involving support for the development of all app types. Canvas apps are starting like the blank canvas which can be adjusted to users needs. It can connect many different data sources and build for web, mobile and tablet applications. It works on drag and drop system, the user chooses a component and then drag it onto the blank canvas like interface, without the need of understanding classic programming. Model-driven apps are starting with a data model, which are adjusted to core business data and processes, then modeling forms, views, and other components. Unlike Canvas apps, which are created through the user interface, Model-driven apps are designed by components. The automatically generated user interface is responsive across devices. Finally, Common Data Service is a data platform coming with PowerApps which allows storage and modeling of business data. Dynamics 365 applications are also built on this platform. PowerApps is paid service integrated into SharePoint. However, it offers free 30 days trial and free community plan.[14]

1.1.3 Forms

SharePoint also highly supports the creation and managing forms among users. There are several ways of how to create a form on user sites. The most basic one is to use the built-in function of creating Lists. This option is suitable for simple forms. Then there is SharePoint Designer which can be used for workflows creation as was mentioned before. There is possible to create more complex forms through a very intuitive interface. Among others, it is also possible to add rich text and graphics and work directly with the code used by the forms if needed. The third option is InfoPath, even though it works well with structured data and can handle large text fields, calculations, business logic, and integrated workflow, users are limited with its functionality which may need further integration with another three-party paid services. Last option which will be mentioned here is a possibility to develop forms directly in Visual Studio. This way, of course, assume knowledge of programming, which is the only thing limiting the customizing forms here. [13]

1.1.4 Summary

To sum up, SharePoint is not only the platform where organizations can publish data and various documents which are then needed by various employees, but it is also a powerful tool with many possibilities mentioned above. Many of them do not require programming skills as users can create simple or even more complex workflows, forms or apps just by using graphic interface. However, there is still room for improvement by developing highly customized functions by coding in Visual Studio.

1.2 iBPMS

Business Process Management (BPM) is an approach to improving corporate performance. It is not only about process automation, but also about supporting the business initiative and process optimization. To implement BPM in any business successfully, IT support is often necessary for modeling, design, implement and analyze processes within an organization. Implementation of BPM assumes close collaboration between management and IT specialists.[16]

Tools for supporting BPM are evolving during the last years. What started with products for Business Process Modeling is now ending with state of the art technology of Intelligent Business Process Management Suites (iBPMS), which evolved from Business Process Management Suites by adding new functionalities to better cover requirements of users.[17]

Tools for BPM are covering so said basics, which are necessary for successful application of BPM such as modeling tools using standards and notation like BPMN or UML. Optimization of modeled processes is also supported, based on different simulations and metrics analysis. BPMS itself can be defined as application infrastructure for supporting BPM projects and programs, it supports the whole process of process improvement lifecycle starting at process discovery, through modeling, design, implementation, and analysis, ending with continuous improvement.[16]

BPMS came to the end of its capability; it was unable to work with increasing data volumes or complex real-time decision making. Also, the adjustment to rapid changes in business environments was a challenge, so the next evolution was necessary. All these challenges and more were covered by Intelligent Business Process Management Suites (iBPMS).[17]

According to the Gartner Magic Quadrant report from 2017 [7], there are several leaders in the market which provide iBPMS systems, some of them will be discussed next. Few of them also provide low-code platforms, which will be discussed later.

1.2.1 BizAgi

BizAgi has a unique way of licensing its product, BizAgi Modeler and the full BizAgi platform can be downloaded for free, so there is a possibility to try out the functionality before purchasing it. Also, support is on the higher level, thanks to training courses, which led to a high ranking from customer reviews. [18]

It could be confusing that its two design environments for process modeling have different functionality. Comparing to other leading vendors, BizAgi does not offer such strong possibilities in business rules and decision management, operational monitoring, and intelligent mobility as others, which can be essentials for some customers.[7]

1.2.2 IBM

IBM [19] was highly focused on intelligent enterprise processes and robust decision management, but it recently expanded its focus to personal and ecosystem productivity. Its products are available on-premises and also in the cloud.

According to Gartner, IBM is a leader in decision management and analytics. Thanks to broad network and many partners, IBM is more than capable of providing these services globally, thanks to this, it is the second largest vendor of all evaluated in Gartner report [7]. Its products also support integration to software with other vendors, which can be seen as a big advantage. On the other hand, customers rate product below average in the context of easy usage of product suite and dependence on IT developers in maintaining solutions. Even though IBM is working on these problems by expanding its focus, these offerings are evolving too quickly and are incomplete. Among other problems, this may be the main reason, why the growth of IBM has stagnated.

1.2.3 K2

K2 offers an iBPMS platform which includes several possibilities, for example, K2 for Visual Studio, K2 Designer, web-based no-code development environment and K2 Appit for SharePoint. By these means, it is covering a large group of customers. It achieved above average rating in user satisfaction with the overall experience and for the value provided by the product. Strong integration with Microsoft products and with third-party BI tools are also seen as a big asset. To mention some weaknesses - decision management capabilities are limited, which leads to dependency on third-party decision services. The same can be said about process discovery and optimization. In customer rating, it achieved below average score for ease of deployment and integration.

1.2.4 Genpact (PNMsoft)

PNMsoft Sequence - platform, which served as the foundation for Cora, digital business platform offered by Genpact is focused on helping its customers digitally transform; it is available on-premises and as a cloud-enabled bpmPaaS.

A strong asset is the offering consisting of a wide variety of business transformation and digital technology services, besides these, there is other strong functionality such as big data analytics, AI and the IoT, or natural-language processing. Focus on selling and marketing resulted in strong and still growing customer base. As for weaknesses, there is a lack of end-user training and third-party implementation service partners. Also, decision management has not the same quality as other products, and in order to achieve more sophisticated decision automation and analytics, it is necessary to use other Genpact services.

1.2.5 AgilePoint

AgilePoint [20] offers cloud-native BPM PaaS through Microsoft Azure and Amazon Web Services. Thanks to supporting for SharePoint and Office 365, AgilePoint is a good platform choice for businesses already using Microsoft services. According to the Gartner report [7] which also covered user experiences with researched platforms, AgilePoint is seen as a cost-effective alternative for offered services which can scale well to enterprise needs. The work with the platform is rated above average, thanks to the pleasant environment and large scale of drag and drop possibilities in forms creation which are also responsive and reusable in a variety of devices.

To mention some weaknesses, process discovery and optimization are quite limited same as decision management and business rules capabilities. This limitation can lead to additional costs for businesses with more complex needs for business rules and predictive analytics because that may need further integration with another service.[7]

1.3 Low code platforms

Low code platforms allow users to create simple applications without the necessity of deep understanding of programming languages. This development approach is based on a graphical interface, where users can build their own applications by the configuration of preprogrammed parts. Users can produce entirely operational application by using these platforms.

Following definition of the low-code platform was taken from [21]:

That solution is a "low-code" platform, one that allows non-technical staff members to create their own applications without IT involvement and with little to no programming knowledge. By using a

graphical user interface, drag-and-drop modules, and other user-friendly structures, non-programmers can create their own apps for their particular needs. These apps fill the special gaps that business users experience but for which there isn't a standard fix.

Malcolm Ross in [22] used a comparison to box of Legos:

Low-code development platforms should include out-of-the-box functionality that a developer can drop in easily and seamlessly. Think of these pre-built components as a box of Legos. Each block has a specific purpose and can be used in a variety of applications as a piece of a larger puzzle. For example, developers shouldn't need to code UI objects from scratch when they can simply choose from pre-built UI components. Plus, these pre-built components can be easily reconfigured and updated as needs change.

Evaluators of low-code platforms should look carefully at the library of pre-built components and capabilities the platform delivers. For example, if the goal is to build an enterprise contract management system, then you'll want to look for features like document management, business process management, business rules, and the ability to dynamically generate PDF contract documents.

According to Srikanth in [23], low code platforms may become as popular as spreadsheet tool Excel:

Another technology, Low Code App Development Platform, aka Low Code platform, demonstrates an immense future potential. Much like Excel, which has become an essential component of every employee's IT tool-kit, Low Code platforms too hold the promise of becoming equally relevant in the long run.

Combined with a mobile container app approach, Low Code platforms allow for building apps without having to code. With Low Code platforms, even citizen developers i.e. business users with basic HTML knowledge can easily develop apps. The container app, a part of Low Code platform, comes with all the necessary security provisions and features such as hot code updates and upgrades, making app making simple and speedy for all. Typically, these tools also come with strong UXD knowledge built into them, thus, making designing user-interfaces easier for citizen developers.

Platforms are focused on design and development of databases, business processes or user interfaces such as web or mobile applications. Although coding is reduced by using such platform, it can be required to extend the functionality or to handle uncommon or personalized situations. Some of the currently available low-code platforms will be discussed next.

The examples of low-code platforms were chosen according to several properties. The main one was that the platform provides some kind of free trial version to try the functionality. One of these platforms will be chosen for implementation of proof of concept application.

1.3.1 Mendix

Mendix platform provides development of application completely free in the community edition. After sign up for the service, the user is provided with the tutorial, where the main objects and functions of the platform are shown. The tutorial will help the user create a simple application, describe functionalities by click-through process, and then also recommend to participate in their free video tutorial course on several levels.[24]

According to The Forrester Wave report [9], using this low-code platform brings many benefits to the user. Namely its AI and machine-learning development features, which are said to be leading on market, content and collaboration services tooling, support and administration by their development team and last but not least, a specific tool which allows business developers to participate in app-delivery projects.

Although Mendix shows weakness as for cloud security or some advanced reporting and process features, the platform continues to innovate in new use cases and deepen its features. [9]

According to [8], Mendix moved from the visionaries quadrant into the leaders' quadrant in the last two years. It provides high-productivity, model-driven development through its Web modeler or Desktop Modeler used primarily by professional developers. Desktop modeler has an option to customize apps using JavaScript. Mendix also offers SDKs for several platforms to support native iOS and Android apps, which makes mobile app development very approachable. This platform supports the needs of IT staff, but also business staff, which is according to Gartner one of the main strengths.

As for weaknesses, there are few cautions namely for geographic location, because its global presence is mainly in Europe, although it has started to expand in the U.S., and industry strategy, as it does not have industry-specific solutions or certifications, even though it has customers in several industries. [8]

1.3.2 K2

The K2 platform provides a free trial to try out its functionalities. After sign up for this trial, click-through tutorial is provided to help the user get oriented on the modeler page where simple demo process is shown. After this tutorial, the user can watch some demo videos, or start to use the platform. [25]

According to Forester report K2 has strong credentials in several segments. Firstly in low code, but also business process automation. It also has a world-

wide customer base as its goal is to automate enterprise processes without limits. Its strengths are in particular mobile and web UX design, data management, reporting and analysis, and identity, and access management. It also has few solid features as process management, integration, mobile development, and platform administration features. Also, there is some space for innovation, for example in the adoption of new developer technologies in IoT and AI or cloud security certification. [9]

1.3.3 ServiceNow

A new version of ServiceNow's platform called Now Platform solved the problem with over-reliance on scripting, by expanding process tooling an offering a modern developer experience with the significantly large developer community. There should be added another functionality in real-time data processing, predictive analytics, machine learning, and event-based applications. [26] As for the strengths of these platform IoT applications and reporting should be mentioned, also with application scaling and performance tools, artificial intelligence and advanced analytics. Its original focus on IT system administrators was changed, but low-code commercial model stayed weak, offering only limited app-deployment options for customers.

According to the Gartner report, ServiceNow's automated testing framework and security testing dashboard are worthy of mention, together with extending mobile UI, user experience, machine learning, and chatbots. The company also provides users with accelerator programs for applications, components, and integrations. The platform is free of charge during the development phase, which has contributed to significant growth in customers and also in its developer program. Gartner also points to several weak points of Now platform as charging extra for certain services, not included off-line mode for mobile offering, which led to a lower score in users references. [8]

1.3.4 Appian

Appian recently changed its focus from BPM portals to low-code platforms. The company went public with a business model providing easy access and cost visibility. Their next objective should be increasing the number of enterprise customers. There are various features of this platform - process and data-management features are considered very deep. It also offers tools for AI applications, which are planned to be expanded.[27] As for strength, it is one of the few vendors providing tools business-developer involvement and extensive certifications of cloud service. To mention some of the weaknesses - weaker customer control over platform scaling and tools for support of larger web application projects, which involves multiple teams.

According to Forester report, customers considered this platform to be easier for developers to learn how to use it. This brings another benefit because

it takes less time for developers to be fully effective. Ability to design processes in a way that works best for the company could be considered as another benefit, although it also brings a risk because users have to be able to define processes accurately before building an application in Appian. [9] Gartner claims benefits in deploying a few innovative technologies, to mention some: automated parallelizing of application execution, an AI-designer for predictive rules or automated native mobile UI deployment. Reference customers of this report also valued this platform for its functional depth and the end-user experience. On the other hand customers in reviews said, that the pricing model is unsatisfactory compared to other platforms on the market. [8]

1.3.5 TrackVia

The solution which TrackVia offers is workflow-centric focused on unified and easy to use the web and mobile platforms, which is extensible using JavaScript. This platform is priced per user or application and does not offer a free trial version to try out functionalities. [28]

Support for a responsive, real-time reporting and data visualization, together with the possibility for enterprise users to control user access and auditing capabilities are considered as the main strengths of this platform. Customers valued automation of the software development which was rated very highly. High reliability of the service and offline support distinguished TrackVia from its competitors.

According to Forester report, data management features and process are highly productive, although it does not provide users with all the functionalities that Leaders such as Mendix or Appian do, this platform is considered to be a good option for clients who find bigger solutions to be overwhelming. [9]

1.3.6 Summary

During the evaluation of possibilities which are offered by different low code platforms, was found that many of them provide users with very similar functionalities. For purposes of this thesis, the Mendix platform was chosen to create a proof of concept application, due to free of charge use and very detailed tutorials and video tutorials.

Process mining

During last years data science gained on popularity. Nowadays, various information systems across all the fields are generating large amounts of data every second. Data science uses scientific methods, processes, algorithms, and systems to extract knowledge from data produced by these systems. It consists of several techniques and theories drawn from many fields - mathematics, statistics, information science, and computer science. By analysis of data produced by information systems, deep comprehension of the process running on the background can be achieved. Such analysis can add priceless value when the company needs to find places which should be improved or changed in order to get better results. But this often means analyzing huge amounts of data, so the right tools need to be used to achieve results. This is the place where process mining can come in handy.

"Process mining can be seen as a means to bridge the gap between data science and process science."[1]

Because information systems are closely joined with processes they support, large amounts of events are recorded by them. Extraction of value from these data is very problematic. The main aim of process mining is to use event data to extract valuable information and by using this information then automatically discover process model. These models can then serve as reference models or can be used for projection of bottlenecks.

In the picture 2.1 from [1] is shown the relationship between event data and process models on the example of Chinese philosophy of harmony *yin-yang*. The projection of this philosophy into the process mining world describes that data-driven and process-centric forces need to be seen as complementary, interconnected and interdependent. Also, examples of questions, which can be answered by process mining, are shown in the picture.

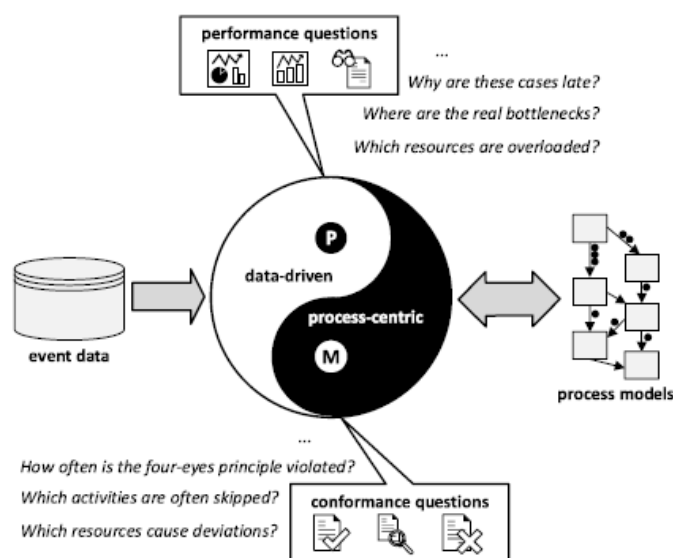


Figure 2.1: Event data and process models [1]

2.1 Process models

Process models are a description of processes on the type level. There are several purposes for using process models, for example:

- to describe the system before implementation, this can be very useful and can serve as an agreement between the developer and end user
- to document the process for instructing people how to use the system
- to comprehend the process properly by all the sides, developers can get deeper insight while modeling the process, and for end users, management or stakeholders can be modeled process easier to comprehend
- to analyze the process looking for various problems like deadlocks, bottlenecks or performance problems
- to provide animation of the process to help see different scenarios and provide feedback
- to configure the system

There are two types of process models: formal and informal. The main difference between them is details, while informal models can be vague because they are aimed for management and end users to present functionality and open discussion about the system. Formal models, on the other hand, may be detailed, on the level to execute the process in a suitable system, these models

can grow very big and become incomprehensible for people. The important thing in process modeling is the alignment of models with reality. Models which were created to describe situation are often idealized, and therefore they do not suit real conditions very well, but models, which served as the basis for some workflow system, can have better alignment with reality, because they usually describe particular sequence of steps, which are needed to be done in order to finish particular task. Thus, the problem here is not only to find balance in details but also in alignment with reality.

2.2 Terminology

As discussed before, information systems log huge amounts of data often in unstructured form, divided into several tables or like a part of subsystems. These data need to be extracted in some structure so the tools can be used to work with them. This is the reason why the data extraction is an essential part of process mining. Each event log consists of sequentially recorded events, while each event refers to an activity, which is well defined one step in the process, and each activity is related to a particular case, which is one instance of the process. Per case, there is recorded trace a sequence of events recorded in order. There are also additional information, which are stored in events to describe the behavior more precisely for example resources - people or devices, which executed or initiated the activity, timestamp of the event or data element recorded with the event. There are three main types of process mining conducted by event logs:

- Discovery - event log is taken, and the model is produced without any a-priory information.
- Conformance - existing process model is compared with event log of the same process.
- Enhancement - existing process model is extended or improved using information gained from event logs of the same process. There are two types of enhancement: repair, model is modified to reflect the reality better, and extension, looking for a new perspective by cross-correlating the model with the log.

Aspects analyzed by process mining can be characterized by perspectives. These perspectives were identified in [1]:

- Control-flow perspective focused on order of activities.
- Organizational perspective focused on information about resources.
- Case perspective focused on properties of cases.

- Time perspective focused on the timing and frequency of events.

At last, but not least the three different terms describing the relation between models and reality will be discussed.

- Play-in - example behavior is taken as input, and then the model is constructed.
- Play-out - referring to classical usage of process models - use the model to generate behavior.
- Replay - this technique uses both, process model and event log, as input. Then the event log is replayed on the process model.

2.3 Process mining techniques

Many of the process mining approaches use heuristic techniques and algorithms which are based on current assumptions on business process patterns. The other way is to use computational intelligence or machine learning techniques, but these techniques are still the minority compared to previous ones or others such as statistical ones.[29]

Several of the commonly used techniques will be discussed next. Some of them will be used later for process mining and be discussed together with results gained from a real-life event log. Before introducing algorithms, some more terms will be defined. By the term noise, the incorrectly logged events are meant. Completeness refers to capturing all possible behavior of the process. And nonfree choice or long-distance dependency means that there is some task X which depends on another task Y to be executed.[2]

- Alpha - this algorithm can automatically extract a Petri net of the behavior discovered from a set of event traces. The assumption is that the traces are complete and without noise. There are also variants of this algorithm which are more powerful, for example, Alpha+, which can discover short loops, and Alpha++, which can mine also nonfree choices.
- Fuzzy Miner - this algorithm mines processes which are less structured by simplifying spaghetti-like models. It works with a variety of techniques: removing of unimportant edges, clustering highly correlated nodes and removing isolated node clusters.
- Flexible Heuristics Miner - this algorithm is suitable also for incomplete traces and traces containing noise. It computes edge frequency due to the indication of confidence in an edge. It also applies heuristic rules which rely on the frequencies of the edges to correct ordering of relation. All this determine the semantics of the underlying process model captured by the traces.

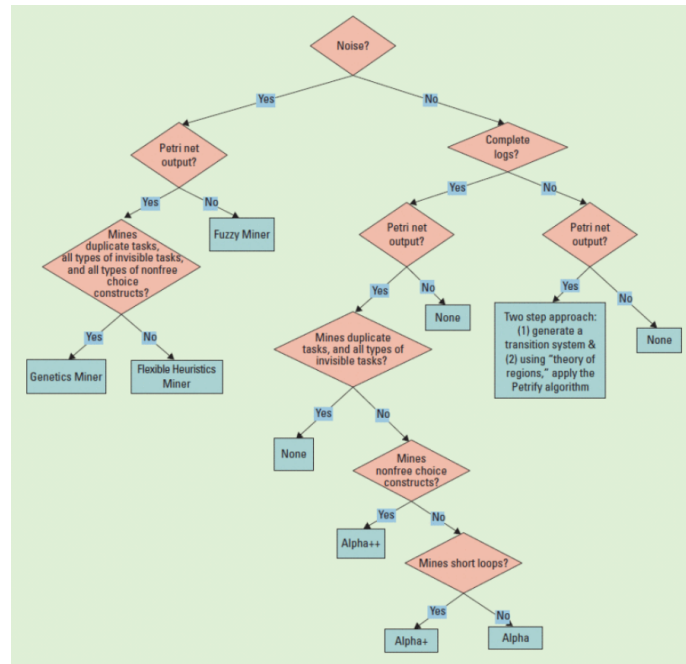


Figure 2.2: Decision tree of mining algorithms[2]

- Genetics Miner - genetic algorithm is used here to mine a Petri net representing the process model from execution traces. Search technique used by this algorithm simulates the evolution of biological systems. This algorithm can mine a wide variety of processes and also handle noise; it requires a large amount of computational time.
- The Two-Step Approach - targets the discovery of processes with complicated dependencies. It involves the construction of a transition system and then folding this system via Petrify algorithm to produce Petri net. It can also be used for incomplete traces.

Each of the presented algorithms is suitable for different situations, even the fact if the data log contains noise makes the clear split in the mining algorithms that can be used. The picture 2.2 from [2] describes possible decision tree according to several criteria.

2.4 Process mining frameworks

Some of the process mining tools can be limited to measurement and analysis of performance indicators as frequencies or flow times. But process mining involves the construction of models and should not be limited to simple metrics. Due to these limitations, some of the process mining tools are unable

to discover non-trivial models. At the Eindhoven University of Technology, several mining tools have been developed lately and have been integrated into the ProM framework[30]. This framework will be used for process mining for purposes of this thesis.[31] Several techniques will be described later together with outputs directly from ProM. More examples can be found in the appendix of this thesis.

Enterprise information systems development techniques

3.1 Methodologies

3.1.1 Waterfall

Waterfall model of the software development process was for the first time announced by Dr. Royce in 1970. This model is mainly oriented on the logical progression of the development process. There are steps, which should be taken through the software development life cycle, these steps are interlocking with others in a defined order, one by another until the whole process end. [32]

1. Requirements - Initial phase is aimed at analyzing the requirements of the application. Specification document is created, it then serves for all future development. This document should define what will application do, but not how it will do it.
2. Analysis - In the next phase, all the requirements will be analyzed to generate models and business logic according to all needs collected before.
3. Design - This step is oriented on technical design, decisions about the programming language, data layers, services, and others are made. Another document is created during this stage; technical specification covers how will all the items from the first specification be technically implemented.
4. Coding - Source code of the application is written during this stage using specification documents as guidelines.

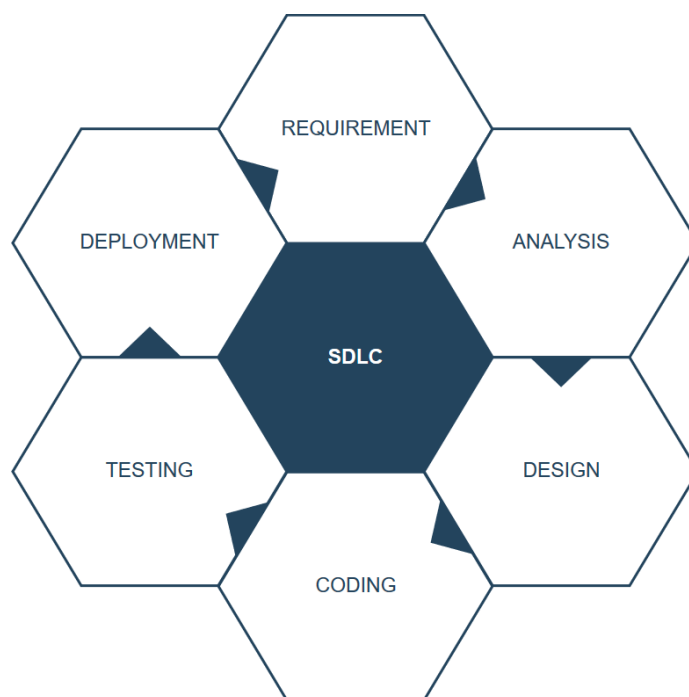


Figure 3.1: Software Development Life Cycle

5. Testing - Issues are discovered and reported in this step. It is possible that the Coding phase will be repeated for all issues to be resolved properly.
6. Operations - In this phase is application ready for deployment. Subsequent support and maintenance are provided to keep the application functional and updated.[33]

As a result of this step-by-step process of development, there is well-prepared documentation of the whole project; it can be seen as an advantage of this approach because it is well suited for big teams where people are often changing.[34] Early design changes are also possible because of a quite late phase of actual coding. During the first two phases, communication between development team and client is established on a regular basis, so when some problem occurs in the design phase, it can be resolved without the necessity of interference into code. However, this advantage becomes a disadvantage later, from another point of view, if there will be some major issue, which will be discovered not until the testing phase, it could cause problems with resolving. It can lead to a delay in delivery of application due to the need of getting back in the process, fix the problem on the level where it occurs for the first time and then repeats other phases.[35] Also, the lack of client feedback may cause problems, in this way is waterfall model non-adaptive.

Feedback from the client comes quite late, after the coding and testing phase in the deployment step. Required change this late in the process is very time and resource consuming again due to the need of repeating earlier phases.[36]

3.1.2 Agile

Agile development started to gain attention in the 1990s as a reaction to more rigid Waterfall model. As described sooner, the Waterfall model is considered non-adaptive in many ways, so there were a need and more importantly room for a new approach.[37] The term Agile Software Development covers a set of methods and practices based on principles described in Agile Manifesto.[38]

This approach consists of several methods having a different combination of old and new ideas, focusing on collaboration between development teams and business stakeholders, frequent delivery of business value, self-organizing teams and smart ways to write, confirm and deliver code. The term Agile was for the first time applied to this set in 2001 after meeting of various software developers in the United States. The Agile Manifesto was also written at this meeting.[39]

As the main characteristic of this approach can be seen the fact, that product development work is broken into small cycles, which leads to minimization of the amount of up-front planning and design. These iterations are called sprints and last typically from one hour to four weeks. Each sprint consists of all the development life-cycle stages, in this case: planning, analysis, design, coding, testing, and acceptance. To achieve this, a cross-functional team is needed to cover all the functions. This should minimize the risk and allows quick adaptation to changes. [40]

3.2 Custom development and off-the-shelf software

Custom software development is a way of development of software that suits all needs of end users. It is often a good solution for organizations that have very specific requirements. Custom software is designed to address the needs of specific users or group of users very precisely. The other possibility, which is used often is to buy software which is already developed so called off-the-shelf software.[41]

The custom development can be seen as an expensive kind of software development. But companies can get quite a lot for their money. To mention some pros of this approach, custom software is well suited for user's needs, because it is designed specifically for unique circumstances in the company. Modification and expansion are possible when needed and can be started in a short time. It could also be seen as an advantage over competitors as the company produces something very own to support their processes precisely and effectively. As for cons, it is very likely that the company will have to make the larger upfront investment. Also, the delivery of this solution

takes more time than buying already developed software. And there is always a possibility that company could become depended on the custom software provider, which can be very inconvenienced if provider become unavailable for some reasons.[42]

On the other hand, buying an off-the-shelf software also brings some pros and cons. It suits well for companies which need the solution in a smaller amount of time because there is no need to develop all the functionality. Companies can also see it as a cheaper solution for them, but this may not always be the truth. Off-the-shelf software is developed to cover a wide range of requirements; it is highly possible that company does not need everything that is offered, but they have to pay for it because it is already part of the solution. It is also harder to get an adaptation of software if there is some specific process or requirement in the company. Essential thing which has to be considered is that by using an off-the-shelf solution, the company can lose an advantage over the competitors because the same solution is available to all of them. If they have the same possibilities, there is a risk of replicating innovative business ideas. To mention some pros, the fact that the solution is already available on the market can be seen as a big advantage, because company can do research in advance. There are reviews and feedback from other users already using it. There is often a possibility to give a software test run, to try out all the functionality before purchasing it. If some issues occur, it is highly possible that some other users have or had the same problem, which may be already solved.[43]

3.3 Development using iBPMS

Intelligent Business Process suites include functions of basic BPM platforms, analytics, and business intelligence tools. Basic BPM platform provides users with executable models. Development of such BPM application starts with process model in BPMN which is then used as a guideline for an application. Executing of process model can be seen as flowing of data through some stages from start to end. This could be done with submitting forms, assigning jobs to colleagues, reminding of jobs to be done and so on. Platforms offer own standard front-end visuals for all features. If there is a need for more functionality, BPM Suites can be used. It is built on basic BPM platform, but there are more possibilities, for example, automatizing of routine and also some nonroutine work, support of collaboration between business and IT and also adding continuous intelligence into process performance. Intelligent BPM suite is the most advanced tool built on previous ones. It offers the most complex functionality including dynamic and ad hoc types of nonroutine work, analysis of in-process performance and external data, real-time data presentation and support for decision making. [16] Some of these platforms also include process templates, accelerators or frameworks to make development easier. The

undeniable advantage of this solution is the capability of endless process refactoring and improvement. If BPM was deployed successfully in the company and it is suitably supported with iBPMS the process of company's adaptation to a constantly changing business environment may be more comfortable and faster.

All these benefits come with a paid license; there are many possibilities on the market, which varies with the amount paid for their service. Usually, there is a fixed amount for month and user, but it is also possible to buy application licensing with an unlimited number of users. The particular amount differs between platforms, but with the high number of possibilities, it is very probable that the company will find the most suitable option for them. Among the functionality presented above, there is also support and training of employees. By buying a license for iBPMS is the company buying some kind of off-the-shelf product, but with the possibility to personalize it according to specific needs.

Some of the vendors also offer parts of the solution for free. For example, BizAgi is offering Modeler and the full platform for free. By this way, the company can try out functionality before buying the product. The license is then needed when the application is ready for production. As for scalability of the product - the utmost majority of platforms are deployed in the cloud, so as the company grows bigger and needs more space for their data, there is no need for buying new hardware and place to store it. But there are also other possible environments: public cloud, on-premises or hybrid.

3.4 Development using Low Code Platform

Low code platforms can also be seen as something between custom development and off-the-shelf solution. Unlike the iBPMS, low code platforms are more on the side of custom developed software. As mentioned above, low code platforms allow users to create an application without the necessity of programming. The philosophy is based on the creation of an app consisting of pre-programmed building blocks of different kinds; for example several typing boxes, lists, forms, buttons, timelines, and others. Building blocks are adjustable by setting their properties choosing from several options, and also by connecting them to entities in the database. A simple application can be created relatively fast if something more complex is needed, it is possible to use process models, which will regulate the flow of data on the background. Platforms often include also databases with simplified creation of particular tables for entities. It is always possible to add new parts of the data model, so the applications can grow bigger with the company. Programming, or better said, creating of application, is done by creating pages of an app, by dragging and dropping blocks to the desired place. Because of this, there is no particular necessity for highly skilled and experienced developers. Power users

can be trained to create simple or even complex applications, so the resources of the IT department can be saved. If there is a need for expansion of the app, it can be done by adding new pages, new blocks or new entities into the database model. Also, if the developer does not find needed functionality in the offering, it could be customized by programming it by himself.

The development of such application can be done using an agile development approach. Several providers also offer tools for support some kind of simplified scrum by adding use-case stories to project, planning tools and place for discussion between team members. Co-working developers can then take the task from the pool of user stories and start working on it. Others will know, that somebody already started the development of that feature and won't be doing the same thing. Developers then can give feedback on the features or edit them. Low code platforms usually work as a web applications, but some of them also provide desktop versions, which can be synchronized with the cloud, so all developers have the same data. As a big advantage can be seen, that one application can be used for various platforms, the developer only needs to create one app and then deploy it for the web, iOS or Android. By this way, resources for specialized developers can be saved.

As a disadvantage can be seen possible vendor lock-in. If the company started to develop the application in some particular platform, it could be difficult to move it to another solution. So the research of the market is very important before making a decision. Low code market is growing instantly; it is expected to double its size in the next two years, with increasing potential of data and the need to process them. Low code platforms can be a suitable option for helping with creating means to help to manage and process a large amount of data. [8]

Licensing and scalability are very similar to iBMPS; there are many possibilities which varies in pricing and offering. Many of the providers offer several pricing plans, free trials or completely free development, paid after deployment. Environments for application are also various: private or public cloud solutions, on-premises or hybrid.

3.5 Development using SharePoint

SharePoint can be seen as a kind of low code platform. Functionality was described in chapter 1.1. The main reason why to use SharePoint for application development can be the relatively easy access to the platform because it is already included in Office 365 license. Thanks to that, all data is available among users and other Microsoft products. As for overall evaluation of possibilities, SharePoint offers similar benefits as other low code platforms including pre-programmed box and possibility to develop customized functionality by programming it in Visual Studio. But because of its wide range of possibilities, it could be seen as a blind and robust tool, which can be a big

obstacle for beginners.

3.6 Summary

The main pros and cons of development techniques using several means were described above. Several factors influencing the decision of choosing the best option suitable for the company needs are described below. Custom development was not included because using this way of developing products is not limited by conditions of third-party providers.

1. Suitability

iBPMS Connection of processes in organization
Automation, monitoring, measurement, and improvement of processes
Business intelligence

Low code Rapid application development and delivery
Build end-to-end business apps
Modernization of old applications
Test business ideas and concepts at low cost

SharePoint Automation of often repeated steps in processes
Creation of specific workflows (four types)
Data management

2. Functionality

iBPMS Process discovery, specification, integration specification, development, test and roll out

Low code Declarative visual modeling, test deployments, user tests, rollout

SharePoint Shared data storage, data management, forms creation and management

3. Needed experts

iBPMS Business analysts, process experts, professional developers, integration experts

Low code Business users, citizen developers, existing IT, integration experts

SharePoint Power users, platform administrator, professional developers if highly customized functionality is needed

4. Used technology

3. ENTERPRISE INFORMATION SYSTEMS DEVELOPMENT TECHNIQUES

iBPMS Process engine, electronic forms, business activity monitor, integration connectors, process simulator, predictive analytics, rules engine

Low code Application engine, resource manager, integration connectors

SharePoint Application engine, spreadsheet program, instant integration with other Microsoft products and products from Microsoft store, modeler for workflows and simple applications

5. Example use cases

iBPMS Workflow centric applications, underwriting, processing systems, approval processes, customer servicing

Low code End/to/end business applications, CRM systems, custom ERP systems, management systems

SharePoint Simple applications to support processes, approval processes, forms, shared data storage

6. Pricing models

iBPMS High installation fees plus yearly subscription

Low code various, average 10€/per user/month

SharePoint Already included in Office 365 Premium subscription which is 12,50€/per user/month up to 300 users

As can be seen in the summary above each development method has its pros and cons. It is on the company to choose which tool will be best suited for the purpose. For the purpose of this thesis, the Low code platform is adequate to create proof of concept application due to these reasons: it is not a big project with need for real-time analysis and processing of data, supported business process is not very complicated and is well described, the most of the functionality should be covered by built-in functions, integration with Microsoft product is not needed. Low code platform should provide everything necessary for this type of application.

A proof of concept - Integrated Administration and Control System

Datalog used in this thesis covers the handling of applications for EU direct payments for German farmers from the European Agricultural Guarantee Fund (EAGF) [44]. In this process, workers of several departments evaluate the claim for financial contribution according to several criteria.

Member states of the European Union are required to ensure that transactions financed by EAGF are handled properly. National authorities operate the Integrated Administration and Control System [45] for this purpose. This system covers unnecessary administration connected to the process of the farmer's application and the whole deciding process of fund distribution.

4.1 Automated business process discovery

Process mining tool ProM will be used for automated business process discovery. At first, few examples from the platform will be presented; then the particular actions will be executed in order to analyze the event log.

4.1.1 Data log analysis

After import of data log into ProM tool, several possibilities are offered to analyze data. By this means better comprehension of the process is provided. In the picture 4.1 is the frequency of events contained in cases shown. The next possibility is the list of all events ordered by the time of execution provided for each instance of the process, together with the set of attributes.

Then in another bookmark of Log Inspector - Explorer is the frequencies described again together with other additional information. The situation can be seen in the picture 4.2. In the last bookmark - Log Attributes are the

4. A PROOF OF CONCEPT - INTEGRATED ADMINISTRATION AND CONTROL SYSTEM

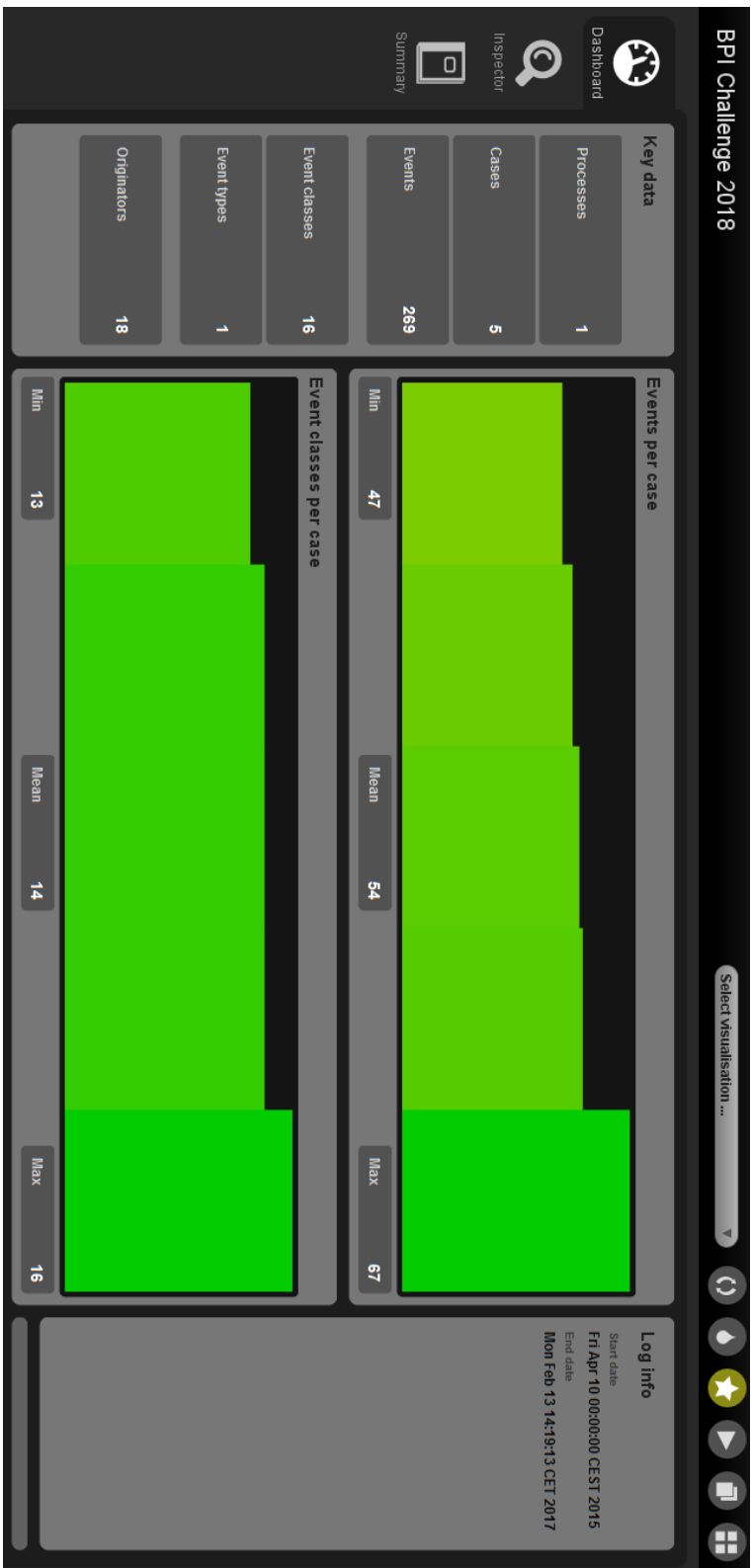


Figure 4.1: Prom data visualisation - Events frequency

4.1. Automated business process discovery

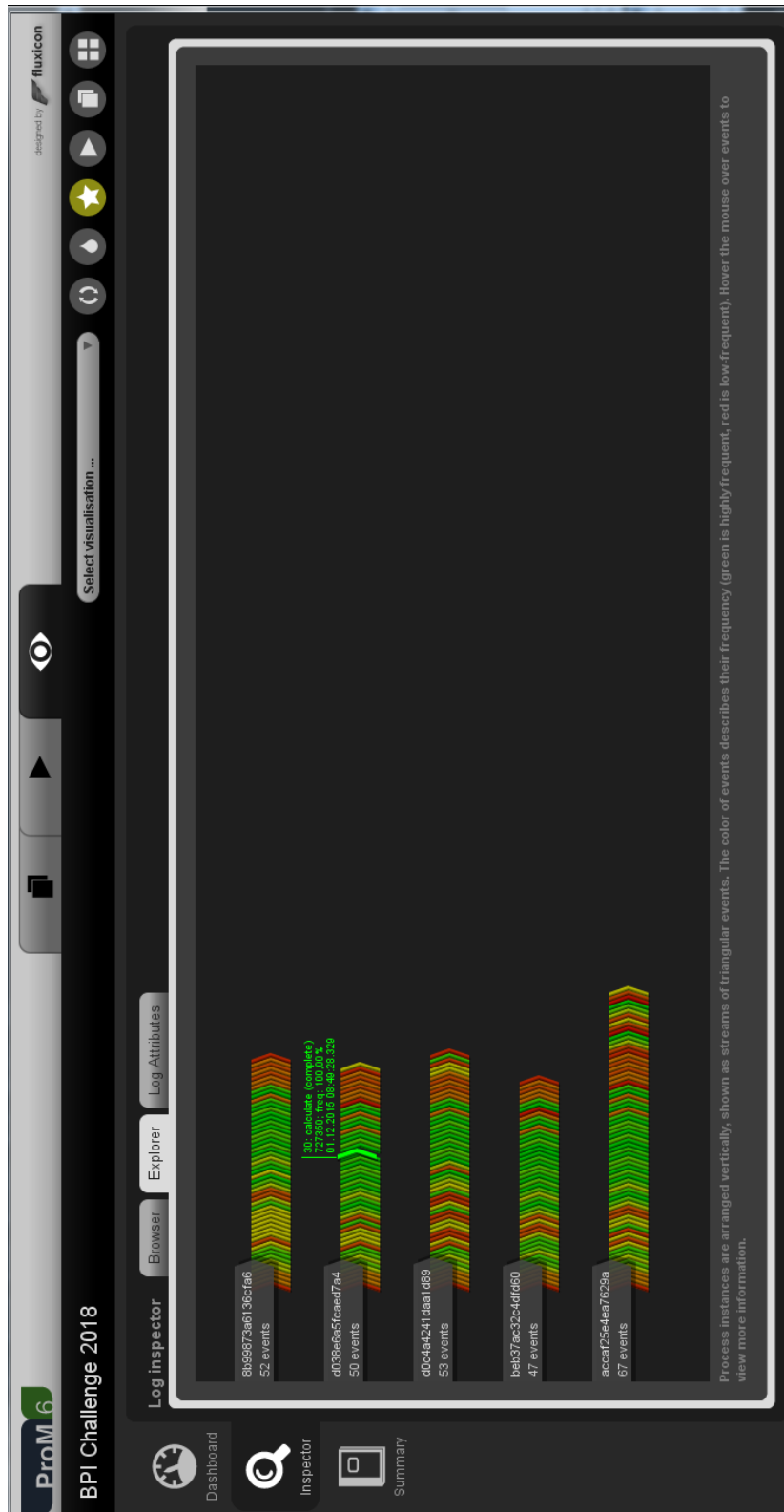


Figure 4.2: ProM data visualisation - Log Inspector Explorer

attributes shown similarly as in the bookmark Browser, but in the form of a summary, where all the occurrences of particular events are counted together with identified start and end events.

4.1.2 Actions

In the section Actions, represented by the play button in the top menu, can the algorithms be chosen and then executed. As can be seen in the picture 4.3, ProM shows the input and output for each action. For action chosen in the example only the data log is required as input, but for some actions, more inputs are needed, for example, Petri nets, which can be gained as outputs of other actions. Drivers and settings can be managed only through the other framework - ProM PM, which is provided together with the ProM tool.

4.1.3 Used techniques

Short description of used techniques with the results will be next. Due to high complexity of data log, results and mined models are very extensive. Several build-in action of ProM were used in order to discover the process.

Alpha Required input is Event log. The Alpha algorithm is basic for process mining; it reconstructs causality from a set of sequences of events, each transition in the net corresponds to an observed task. For example, one particular task might always precede another particular task in every execution trace - this would be very useful information. The output of this algorithm is Petri net, which can be used as an input in other actions. The result is shown in the picture 4.4, due to the high complexity of the mined model, a detail was zoomed and put into the picture.

PomPom View Required inputs are Event log and Petri net generated out of this log. Then this view shows a combination of given inputs. The size of the transitions corresponds to the frequency of activities. Significance cutoff can be selected by the user, so it is possible to filter smaller transitions and by this means reduce the model as much as possible. The result is shown in the picture 4.5, significance cutoff was set to 50%.

Inductive visual Miner Required input is Event log, then the Petri net or a process tree can be generated. In this case, Petri net was generated, together with usage frequency of activities and edges, the result is shown in the picture 4.6, the significance of activities was cut off by half. Replay is also provided directly in this model, together with visualization of deviations in the model, or times needed for the activities to be done. Deviations visualization is shown in the picture 4.7 on the very simplified model for better visibility.

4.1. Automated business process discovery



Figure 4.3: ProM - Actions

4. A PROOF OF CONCEPT - INTEGRATED ADMINISTRATION AND CONTROL SYSTEM

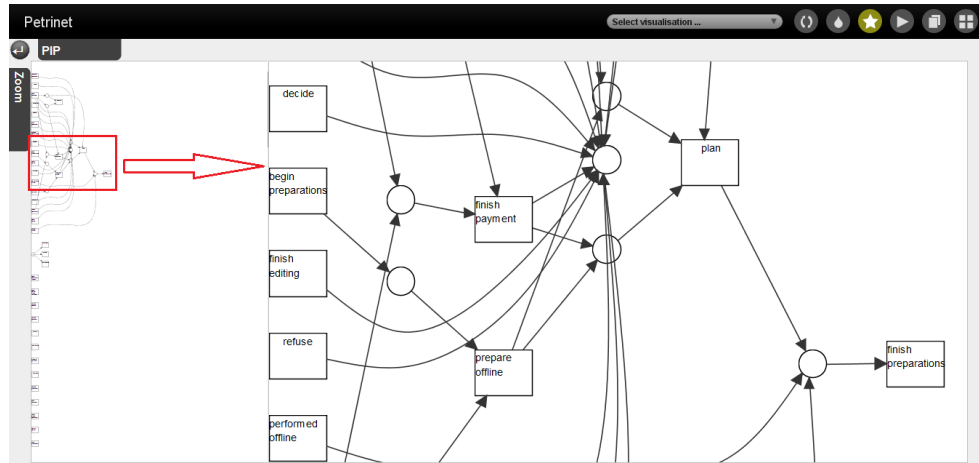


Figure 4.4: Result of Alpha algorithm

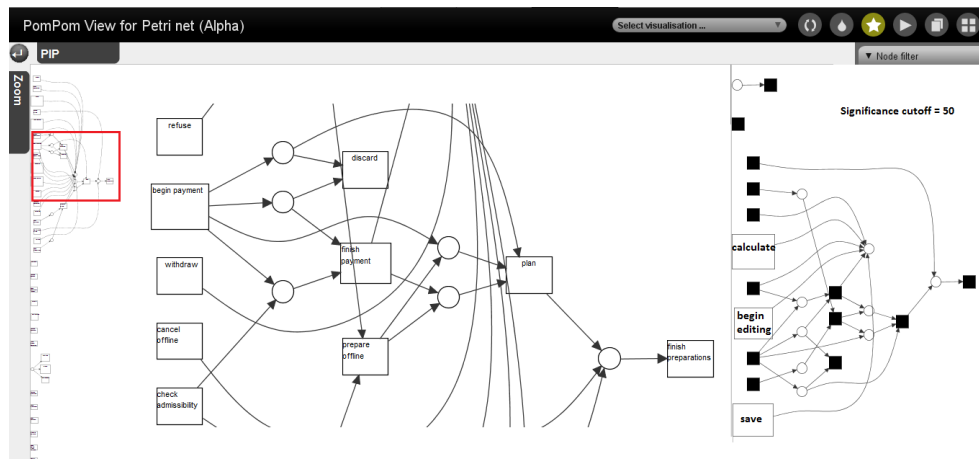


Figure 4.5: PomPom View

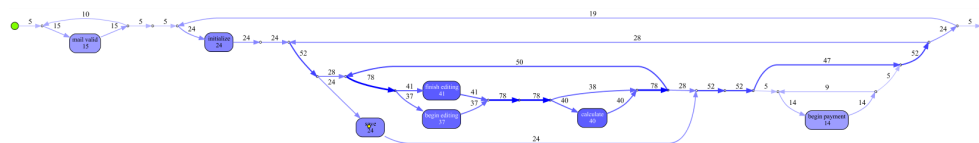


Figure 4.6: Result of Inductive visual Miner

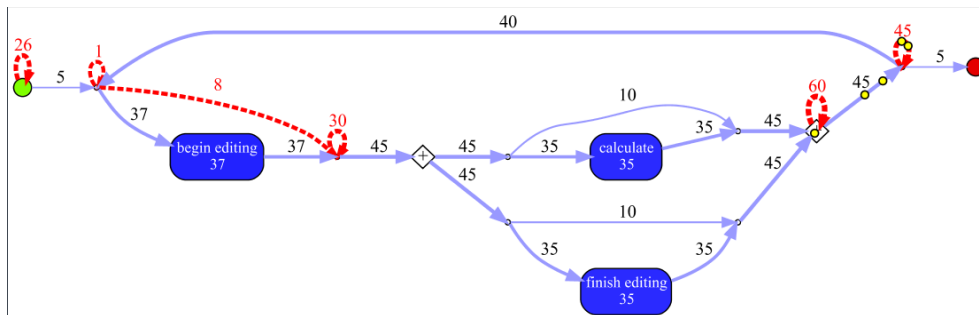


Figure 4.7: Deviations using Inductive visual Miner

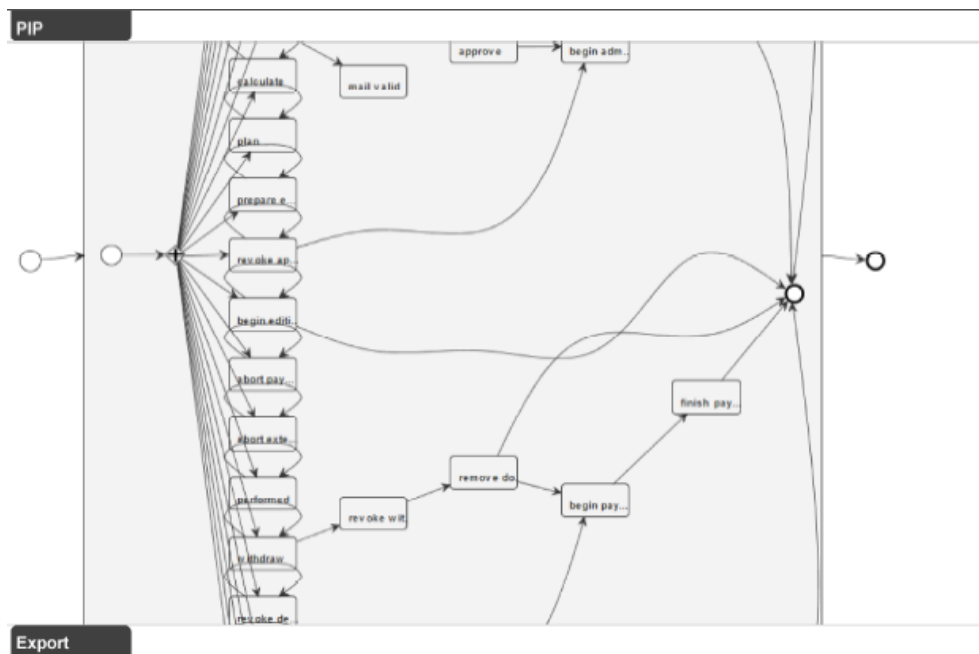


Figure 4.8: Example of mined BPMN diagram

BPMN diagram There are several possibilities of getting a BPMN diagram in ProM. For example, generated Petri net can be converted into BPMN, or heuristic miner can be used to mine BPMN. The example shown in the picture 4.8 was mined using Casual Net Miner.

4.1.4 IACS Business process

As can be seen in previous pictures, activities included in the process were discovered and modeled as a Petri net. These activities were then put into BPMN manually. The results from Inductive visual Miner provides a better

4. A PROOF OF CONCEPT - INTEGRATED ADMINISTRATION AND CONTROL SYSTEM

comprehension of the sequence of these activities, as it is ordered and aligned. Possible loops are visible together with frequencies of how many times was the particular path taken. Using the replay on this model showed a possible sequence of activities and according to this was found that the decision about computed amount can be made repeatedly. This fact was later included in proof of concept application.

Event log also contains information about resources in each activity. Thus, during the analysis of log, like it was described at the beginning of this section, can be found who perform these activities. Different visualizations directly from ProM actions can show the same information, but this was not tried.

After collection of sufficient amount of information about the process, namely: actions, sequence of actions, loops, deviations, and resources; model was created in BPMN as it is shown in the picture 4.9. On the basis of this model, the proof of concept application was designed and developed. Design and further specification will be discussed next.

4.2 Design

Information about IACS and rules for direct support schemes for agricultural funding was acquired from [45]. Information relevant for the design of proof of concept application will be discussed next.

4.2.1 Rules for direct support

There are several requirements, which farmers need to ensure to get a financial contribution. The deciding process of relevant EU department consists of an evaluation of several criteria. At first, there are minimum requirements for farms:

1. area of the farm has to be big enough to be eligible for the contribution; these thresholds may differ from country to country
2. farmer has to be active and located in EU
3. farmer has to own an agricultural land that is used for an agricultural activity
4. farmers have to apply every year to receive direct payments, declaring every parcel of their farm.

Then there are several criteria which affect the rate of contribution. Farmers have to respect other EU rules, failure to do so results in a cut of the support. The size of the cut depends on which of the rules were failed to comply with. These rules are known as cross-compliance and are divided into two sets.

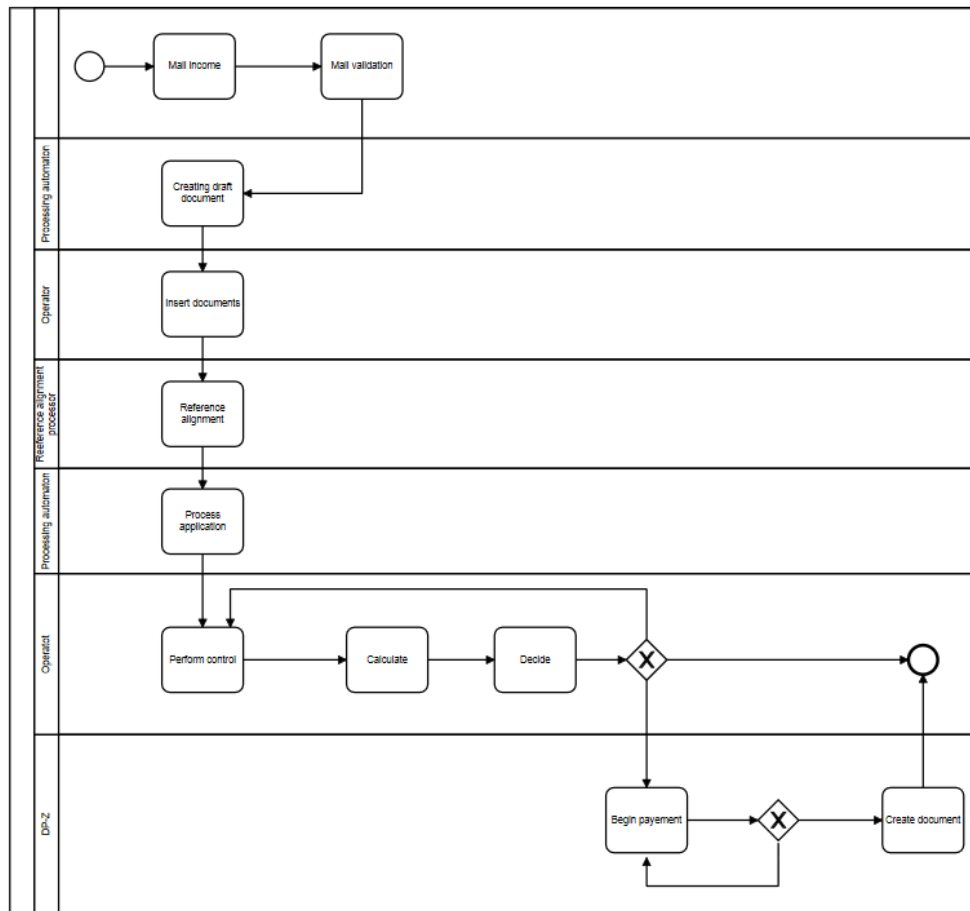


Figure 4.9: BPMN diagram

1. Statutory management requirements
 - a) public, animal and plant health
 - b) animal welfare
 - c) environmental protection
2. Good agricultural and environmental conditions
 - a) prevention of soil erosion
 - b) maintenance of soil organic matter and soil structure
 - c) preserving of biodiversity and ensure a minimum level of maintenance
 - d) protection and management of water

4. A PROOF OF CONCEPT - INTEGRATED ADMINISTRATION AND CONTROL SYSTEM

Finally, the final amount of contribution is complemented by other support schemes, which targets specific objectives or types of farmers:

1. a green direct payment for agricultural practices beneficial for the climate and the environment
2. a payment to young farmers - farmers who are starting their business and are 40 or under at the time of applying, young farmers have priority in receiving direct payments
3. a payment to provide improved support for small and middle-size farms
4. payments for areas with natural constraints where farming conditions are difficult
5. a small farmers scheme - a simplified scheme for small farmers
6. voluntary support to help certain sectors undergoing difficulties.

4.2.2 Functional requirements

Functional requirements were identified according to discovered business process and information about funding.

Registration of new application system provides the user with the registration of the new application, which was sent by the farmer to the relevant department. The incoming application is firstly validated, stored in the system and then passed into the next steps of the process.

Adding required documents required documents can be added manually by the user, or the user specify which documents should be added, and it will be added automatically.

Show of required documents user is able to review any of the added documents at any time in the process.

Computing of penalties penalties are computed automatically according to set rules.

Review and edit of penalties penalties can be manually reviewed and edited by the user.

Create payment user is able to create a payment. Required information will be provided, and payment will proceed to the relevant department.

Export of application document user generates a document, which consists of all information about the application, which was collected during the process.

Review of application user can review applications.

4.2.3 Use cases

Use case 1: Registration of new application User received an email from farmer. The system displays an email, the user visually checks it. System check if email includes all required information. If not, the system displays which information are missing, the user can fill them or send an email back to the farmer. This email contains an example how to apply correctly. If yes, the system adds the application to database and display overview information for the user.

Use case 2: Adding the required documents - manually The user picks an option for adding documents. System display form for uploading the document. User upload document. System display information if uploading was successful. If not, the user can try to upload the document again or cancel the process.

Use case 3: Adding the required documents - automatically The user picks an option for adding documents. System display form for uploading the document. The user chooses an option - add automatically. System display form with available documents. User pick which documents should be added. System display information if adding was successful. If not, the user can try to upload the document manually or cancel the process.

Use case 4: Show of required documents The user looks up an application and asks for detail. System display application overview. The user chooses option documents. System display list of documents added to this application. The user can choose from these documents. The system displays the chosen document.

Use case 5: Computing of penalties The user chooses an option Penalties. The system displays a new page with the table of penalties and its values. If no penalties were computed yet, the table is empty. The user can choose between two possibilities, edit penalties or edit rules on which are computing based. System display a new page, either rules settings or manual setting of penalties. The user can set rules on his own, or choose from preset rules, which can be modified. System display overview of set rules. The user confirms settings. The system computes penalties and displays result for the user.

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The user can confirm the validation, modified penalties manually or start the process again by modifying the rules settings. System save penalties after confirmation.

Use case 6: Review and edit of penalties The user looks up an application and asks for detail. The system displays an application overview. The user chooses option penalties. The system displays the table of penalties which were computed before. The user can modify penalties or start the process of computing penalties again.

Use case 7: Create payment After penalties were computed, payment can be created. The user chooses the option to create a payment in application overview. The system displays information about computed penalties and amount of contribution which should be paid. The user can confirm the information, or start the process of modifying penalties. After confirmation, the system displays an overview of the created payment and send a request for payment to the relevant department.

Use case 8: Export of application document The user chooses the export option in the application overview. The system generates a document in pdf, which will be saved in the application overview. The user can save the document to his computer.

Use case 9: Review of application The user looks up an application from the main page. This could be done by the number of the application generated by the system or by the name of the farmer. The system displays a list of application which matches the criteria if there is only one match, system display application overview. The user can review the application and execute some actions if the application is still active. If the application is archived, only action export document is possible.

4.2.4 Wireframes

Wireframes can be found in the appendix of this thesis, however short description of functionality will be provided next:

Home page On the home page is shown a list of added applications. User can filter through applications by its number or farmer name. By click on the application, the application overview is open. On all pages connected to the actual application, basic information is shown on the top of the page - the number of application and name of the farmer.

Application overview Application overview consists of information about a farmer, farm, and application divided into separate boxes for better orientation in data. From this page it is possible to start four main activities by clicking on buttons: documents, penalties, create payment or export. The application can be active or archived if it is archived only option export is possible.

Documents By clicking on button Documents on Application overview page, the user is redirected to page Documents, where can be documents added to application managed. The user can upload documents from his computer, or add some documents manually from other sources if it is possible.

Penalties Each application consists of the same penalties which are computed from information gained from different documents. The user can set rules for computing penalties automatically, or set penalties manually. Previously set penalties can be modified.

Create payment On Create payment page list of the computed penalties is shown together with amount computed for the application. The user can confirm the amount or choose to recalculate when the process of computing penalties is started again by redirecting the user to penalties page. After confirmation, payment is created and send to the relevant department.

4.2.5 Database model and Architecture

The database model is shown in the picture 4.10. Architecture can be seen in the picture 4.11 as a client-server architecture secured with the proxy server and separated database.

4.3 Mendix low code platform

Proof of concept application will be developed in the Mendix platform as it was discussed earlier. Mendix platform provides users with many tools for business collaboration and several tutorials to do work with platform easier.

4.3.1 Mendix functionality

Particular functionality of Mendix and examples of usage will be described next.

4.3.1.1 Tutorials

Mendix provides users with very comprehensive tutorials. There are several ways how to learn basic or more advanced functionality. First one is learning

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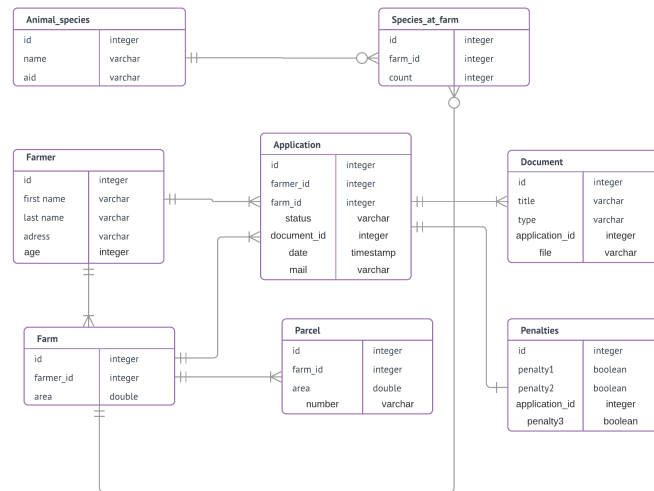


Figure 4.10: Database model

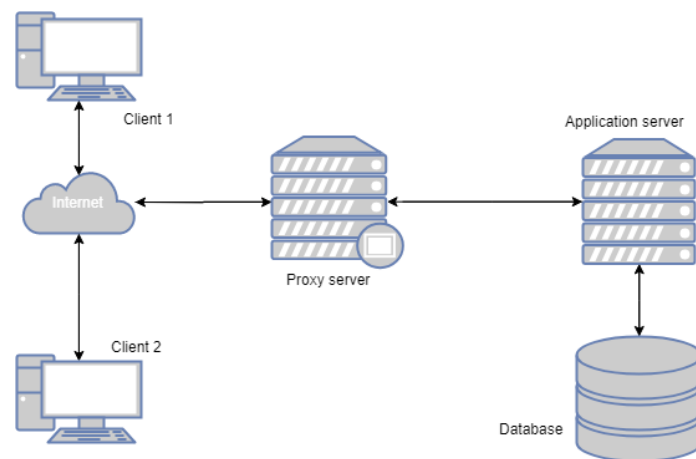


Figure 4.11: Architecture

4.3. Mendix low code platform

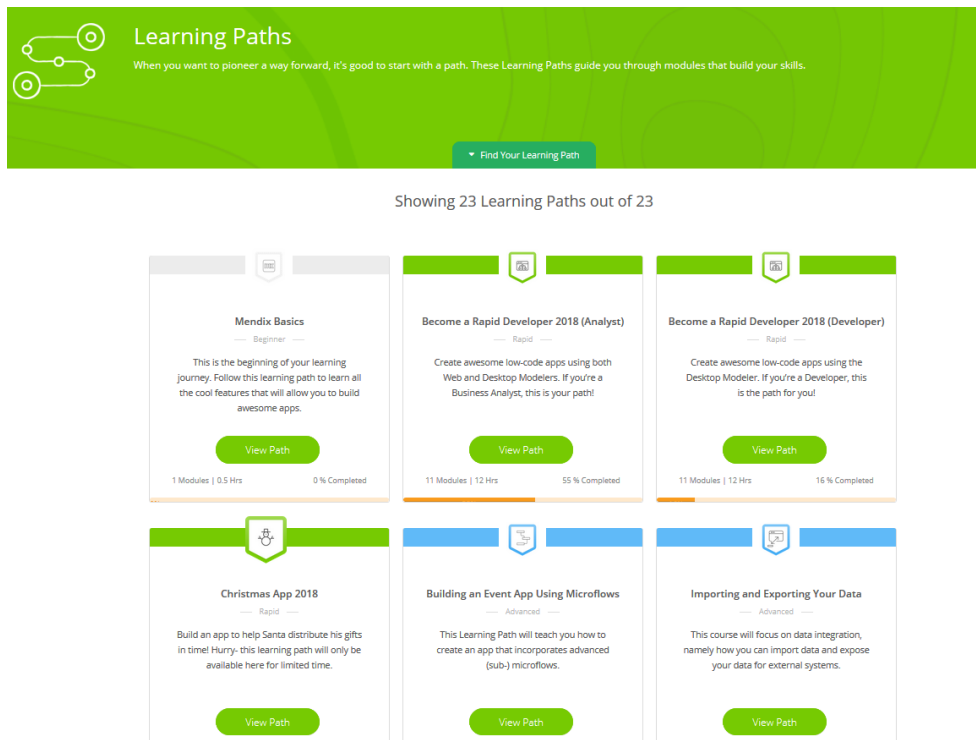


Figure 4.12: Mendix - Learning Paths

paths. As can be seen in the picture 4.12, paths are divided into blocks according to the scope of interest.

In Mendix Basics learning path, users can get an introduction to basic use of platform just in half an hour. Each concept is explained in short video, so users can see the usage and try it by themselves during the tutorial. According to the description of this path, users will learn more about:

- The Mendix development process
- Building pages using the Web Modeler
- The domain model
- The team server
- Microflows
- Data validation and consistency
- Application security
- Building mobile applications

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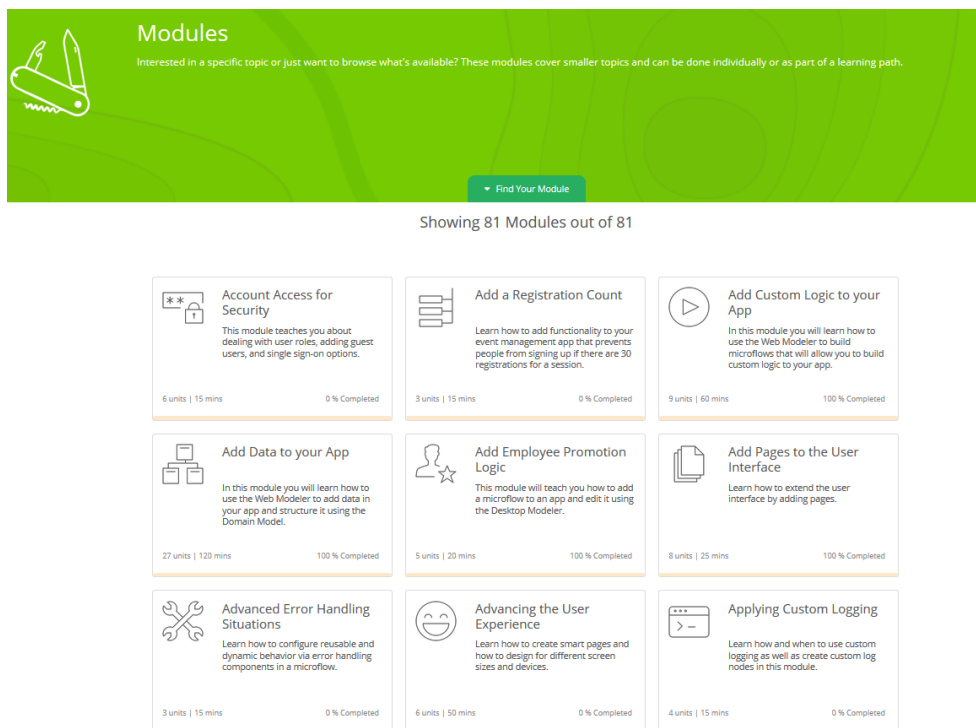


Figure 4.13: Mendix - Modules

After completing this learning path, a deeper comprehension of these topics can be accomplished by another learning path - Rapid Developer. There are two versions available, for Analysts and Developers. The main difference between them is the platform on which are the functionality described. Version for analysts is aimed at Web modeler, and Desktop modeler for some advanced functionality and version for developers is aimed only on Desktop modeler. During this twelve hours long learning path, the example application is created from scratch and user should gain skillset broad enough to create own advanced application in the Mendix platform. Other learning paths are focused on particular topics, so when the user needs an even deeper explanation, these paths are available together with modules shown in the picture 4.13, webinars, and classrooms. Mendix also has very extensive documentation pages and discussion pages with other developers.

4.3.1.2 User Stories

One of the tools for business collaboration allows users to import user stories. The developer responsible for some part of the system will get one or more user stories which characterize one or more functions of the system. User stories can be added into sprints, which is way how Mendix supports agile means

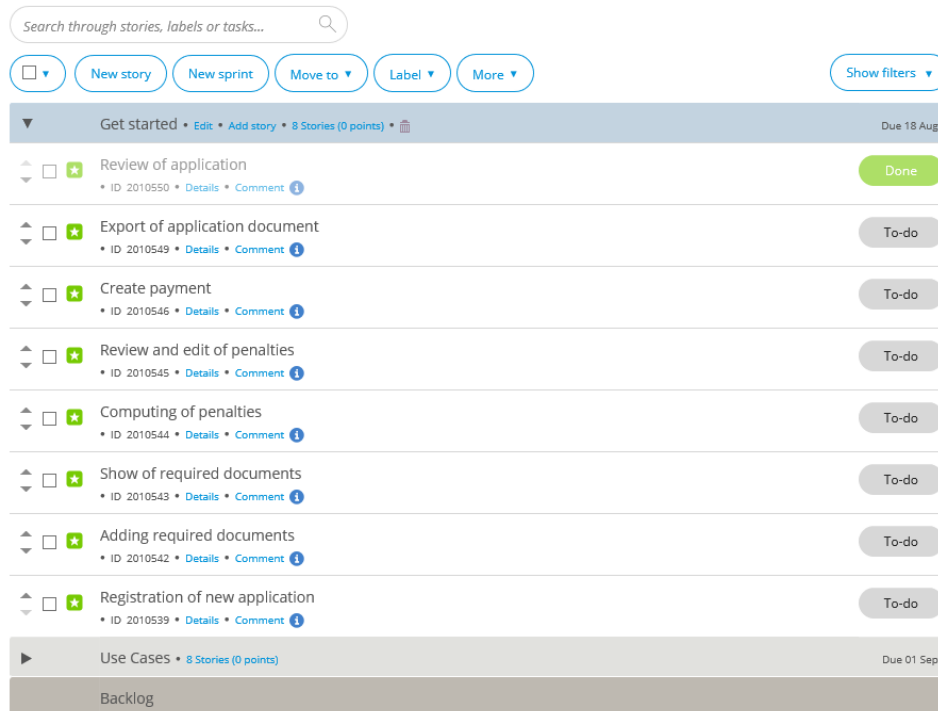


Figure 4.14: Mendix - Use cases

of application development. Sprint consists of several user stories and is terminable, so developers know how much time they have left to create required possibilities. For the purposes of this thesis, use cases defined during analysis were entered into Mendix, just for easier orientation in system requirements. A use case is picked from the summary of user stories of actual sprint and then developed. A developer can mark particular user stories as done, so it will be immediately visible which functionality is already developed and which have to be added into the application. An example is shown in the picture 4.14, where the use cases were added and the first one was marked as done.

4.3.1.3 Support for development teams

Mendix itself provides development teams with several useful tools. User stories were already described above, but there is also a place for discussion between team members, list of team members with their roles, place for feedback. In feedback section, users can write issues, ideas and questions, which will be available for other team members, they can then contribute to the discussion about the topic, mark it as accepted, handled or closed. The whole list of feedback items can be exported into Excel. In the picture 4.15 the example of such feed is shown. There are three topics, one of each, all of them

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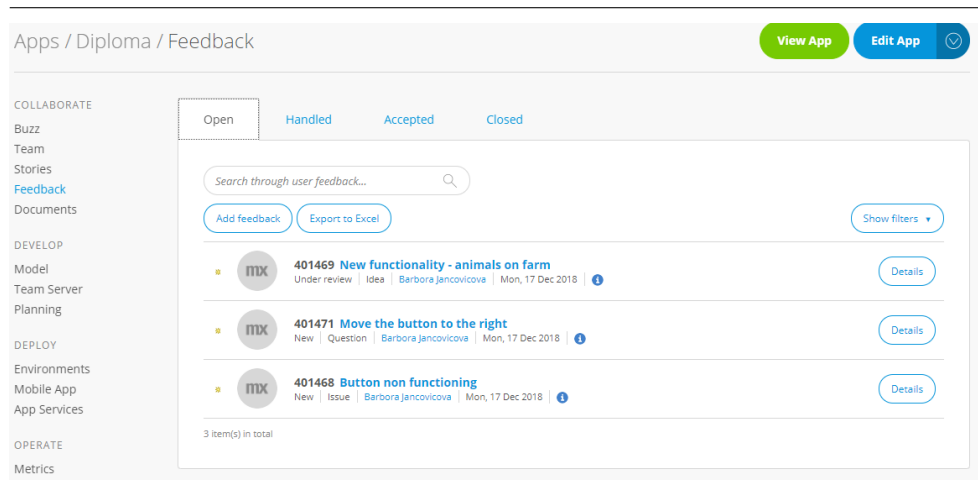


Figure 4.15: Mendix - Feedback page

currently marked as open.

4.3.1.4 Database model

Mendix offers two ways how to create a database model. It could be done either during the process of functionality development or in Domain Model section, where is possible to create the whole model at once or easily modify model when needed. During the process of development it is possible to create an entity right when it is needed, then it is automatically added into the domain model, where it can be modified later. Mendix automatically creates unique identifiers for entities, so it is not necessary to add it as one of the attributes during the creation of the entity. Each entity represents one table in the database. After modification of model, tables are automatically updated after deployment of the application. In the picture 4.16 is the final database of proof of concept application shown. This database was created step-by-step during the process of creating an app.

4.3.1.5 Pages

Pages are the end-user interface of the created application. A page consists of building blocks, which are predefined to make work with them easier. Each page has its layout or snippet, and in them, widgets are arranged. There are several types of widgets grouped into categories, to name some of them: menu widgets, data widgets, layout widgets, container widgets, button widgets and more.

In the picture 4.17 an example of such page is shown. The layout chosen for this page states that there are two layout grids, one for the header and the other for the content of the list. So in the header, there is static text

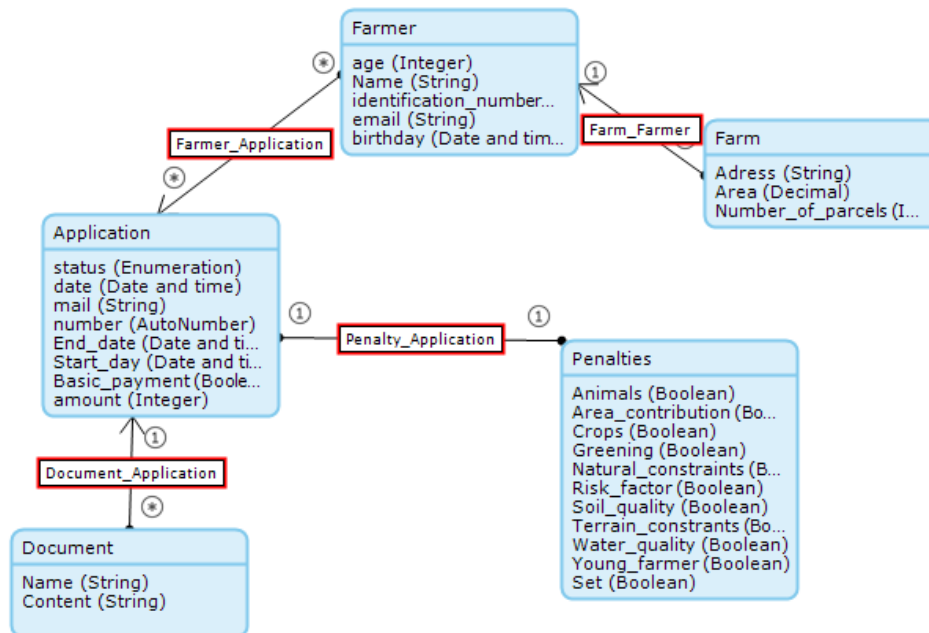


Figure 4.16: Mendix - Database

and button widget, and in the bottom layout grid, there is a data widget containing the list of all applications which will be in the database. This is just a template of the page, in the picture 4.18 is shown, how this page looks like after deployment with some data in the database.

4.3.1.6 Microflows

In microflows, all the logic of the application is implemented, for example, actions for creating and updating objects, showing pages or making choices. In other words, microflow can be described as a simplified model of the process, it visually represents logic, or logical steps need to be done, to perform some task successfully. This microflow is then represented as code by Mendix, a user just models the situation in the editor, and it is then revoked after clicking on the button or from another microflow. A graphical notation is based on BPMN, so each microflow can consist of elements: events, flows, gateways, activities, artifacts, and error handlers. In the picture 4.19 is shown an example of creating a new object associated with another object using microflows. In this particular case, the new Farmer object is created within the object of Application, and they are associated together, in the next step of this microflow the page with the form for creation of new Farmer profile will be shown.

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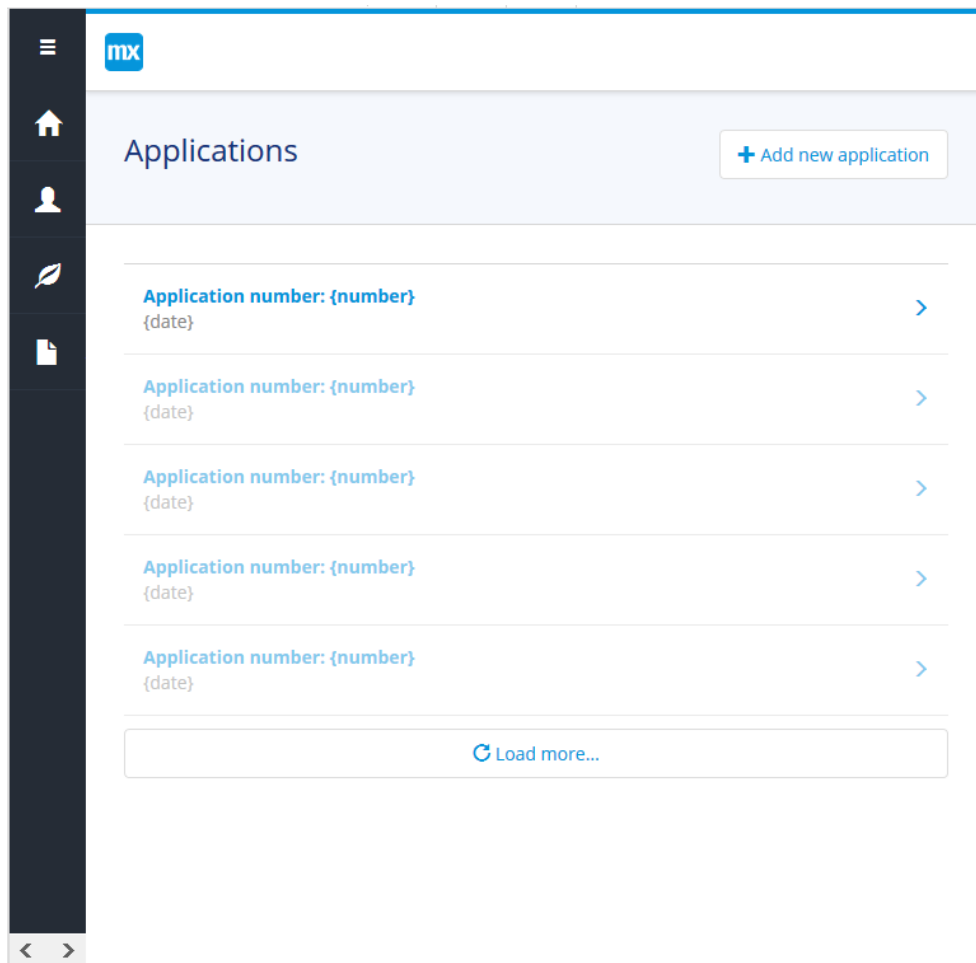


Figure 4.17: Mendix - Page example

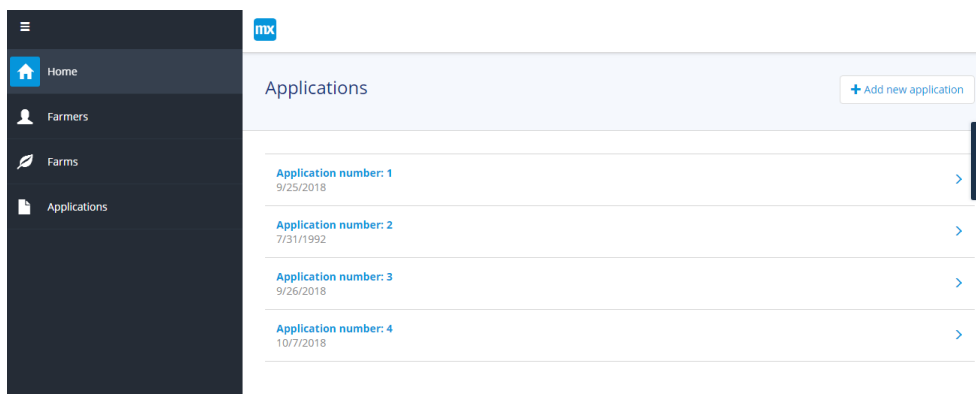


Figure 4.18: Mendix - Page example after deployment

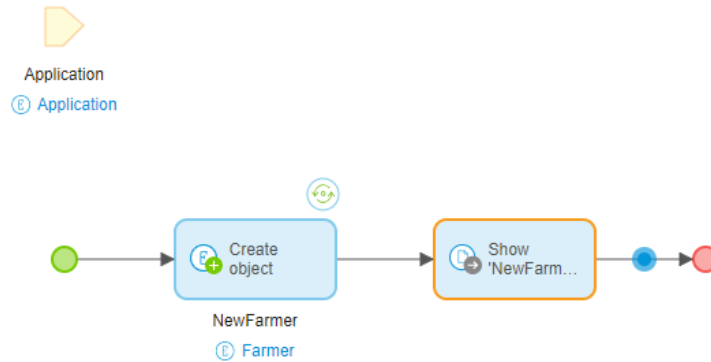


Figure 4.19: Mendix - Microflow

4.3.2 Proof of concept application

Application IACS was developed according to a process discovered from event logs and further specification described in chapter 4. Not all described functionality is covered by proof of concept application. Few differences can also be seen between database models. Model from the analysis in the picture 4.10 is more detailed, database implemented in Mendix as it can be seen in 4.16 is simplified by excluding of species and animals at the farm and also parcels. Some more changes occurred during the process of creation of the proof of concept application, so also the visual side is different as compared to wireframes.

Finally, because the exact rules and process of computing the rate of the contribution are not known, the rules were chosen as a combination of complying with penalties. The amount computed by this application is not real neither comparable to the amount which would be computed by relevant authorities.

4.3.2.1 Pages

Several pages were created according to specification and wireframes. Each page is related to at least one of the entities according to the database model. As mentioned above entities in the database can be added to the model during the creation of the pages or before, both means end with the same result. Also, the changes in database model can be realized anytime, particular tables of the database are then modified during deployment. However, some errors

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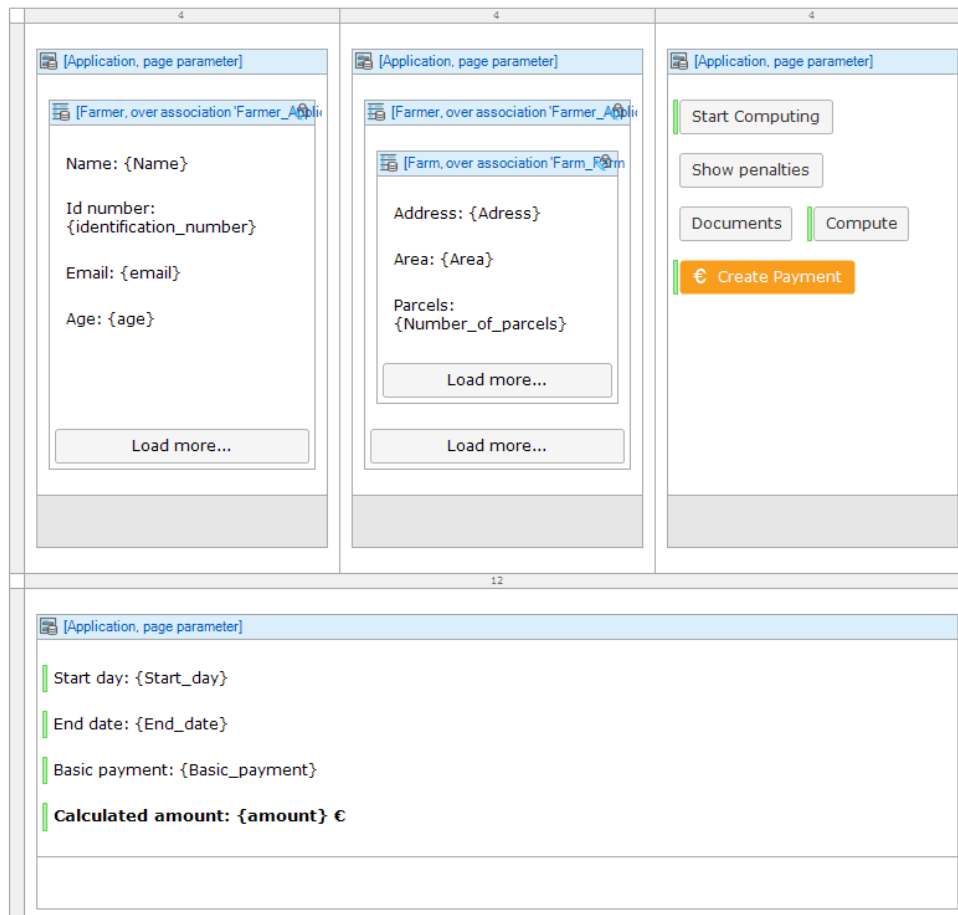


Figure 4.20: Layout of page Application detail

may occur, if the tables already contain some data, mainly if the associations between entities are modified. The solution to this problem is to delete data, so Mendix can generate new foreign keys between entities, considering that all unique ids are completely in its management.

Creation of pages was described above together with an example of one of the more simple pages in the picture 4.17. The most complex page is Application detail where are all data associated with the application provided. The layout in edit mode is shown in the picture 4.20.

Pages in proof of concept application are related to these entities and are then divided into other parts providing more details like so:

- Application
 - Applications - list of all applications existing in database, shown in the pictures 4.17 and 4.18

- Application detail - detail of one application chosen by user, shown in the picture 4.20
- New Application - adding a new application from scratch
- New Application Farmer - adding a new application to existing farmer
- Farmer
 - Farmers - list of all farmers existing in database
 - Farmer detail - detail of one farmer chosen by user
 - New Farmer - adding a new farmer
- Farm
 - Farms - list of all farms existing in the database
 - Farm detail - detail of one farm chosen by a user
 - New Farm - adding a new farm, this is possible only from a farmer detail, so the association between entities is automatically set
 - Farmer Farms - list of all farms associated with particular farmer
- Penalties
 - Penalties - overview of penalties set to a particular application with the possibility of edit
 - Set Penalties - initial set of penalties, when the computing of application is started
- Document
 - Documents - list of all documents attached to particular application
 - New Document - adding a new document to particular application

Pages are connected and possible navigation through the entire application is demonstrated in the picture 4.21. In Mendix is also possible to create different user profiles, where can be defined which pages will be available for the particular user. This topic will be discussed later, but in the picture 4.21, is already depicted which page is available for which user profile.

4.3.2.2 Microflows

The majority of microflows in proof of concept application is for creation and association of objects, but there are also some for setting the attributes of objects including the one responsible for computing of amount based on penalties. Microflows are named according to Mendix policy as it was presented in the provided tutorial:

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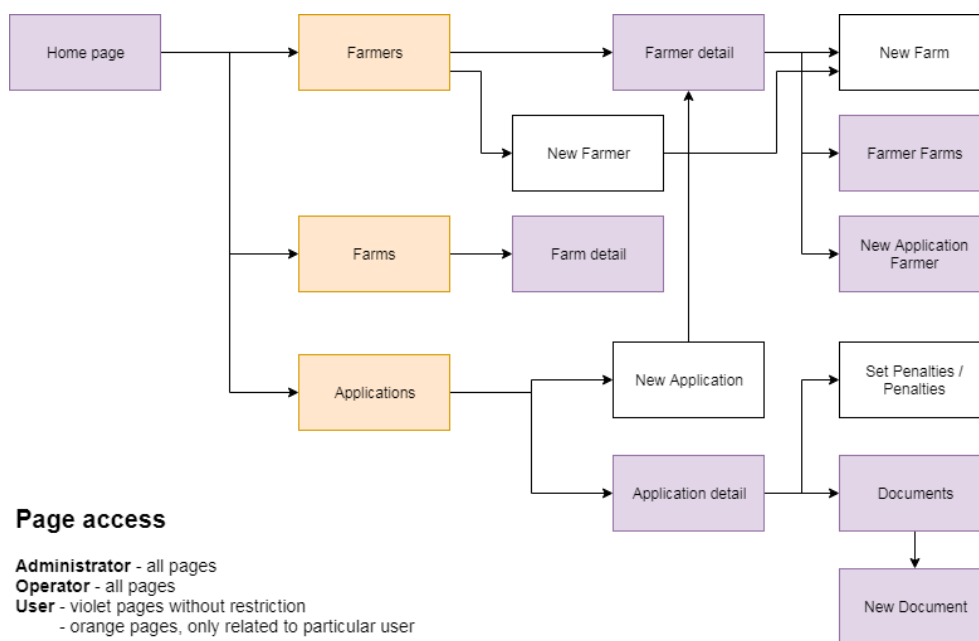


Figure 4.21: Pages navigation and access

- ACT_Application_AddDocument - creates and adds new instance of Document to instance of Application and shows page New Document where the form needs to be filled.
- ACT_Application_AddFarmer - creates and adds new instance of Farmer to instance of Application and shows the page New Farmer, where the form needs to be filled. This microflow is shown in the picture 4.19.
- ACT_Application_Compute - the most complex microflow responsible for computation of the rate of contribution. The logic is as follows and also shown in the picture 4.22:
 - Set amount in application to zero, to allow multiple computations.
 - Retrieve instance of penalties associated with the application.
 - Compute amount answering to the rate of contribution according to set penalties
 - Show information about the completed calculation
 - Show page Application detail
- ACT_Application_CreateNew - creates a new instance of Application and shows page new Application where the form needs to be filled.
- ACT_Application_CreatePayment - sets attribute status in Application to completed, shows information about application completion, sets end

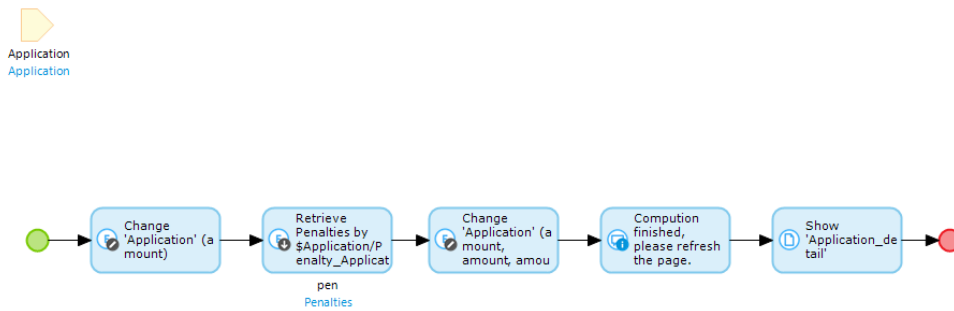


Figure 4.22: ACT_Application_Compute Microflow

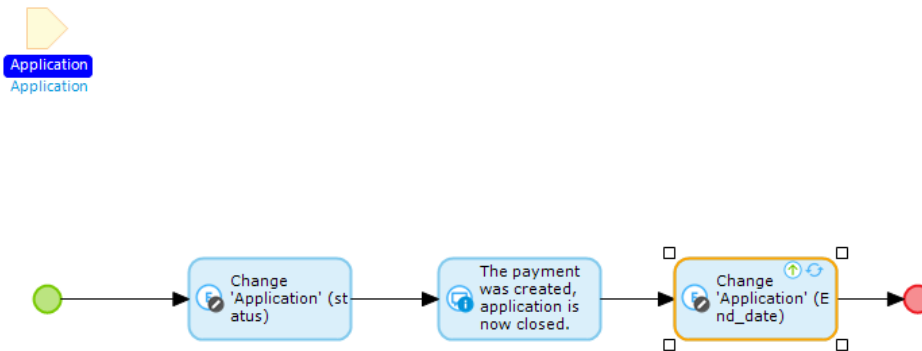


Figure 4.23: ACT_Application_CreatePayment Microflow

date to current date and closes application for further changes. Microflow is shown in the picture 4.23

- ACT_Application_StartComputing - sets attribute status in Application to calculating, sets start date to current date, creates a new instance of penalties and shows the page Set Penalties, where penalties should be set for the first time.
- ACT_Farmer_AddNewFarm - creates and adds new instance of Farm to instance of Farmer and shows the page New Farm, where the form needs to be filled.
- ACT_Application_CreateApplication - creates a new instance of Application and adds it to the existing instance of Farmer, then shows page New Application Farmer where the gathered information is shown for review.

Only selected Microflows are presented in the pictures, because of high similarity between them. The others are listed in the appendix of this thesis.

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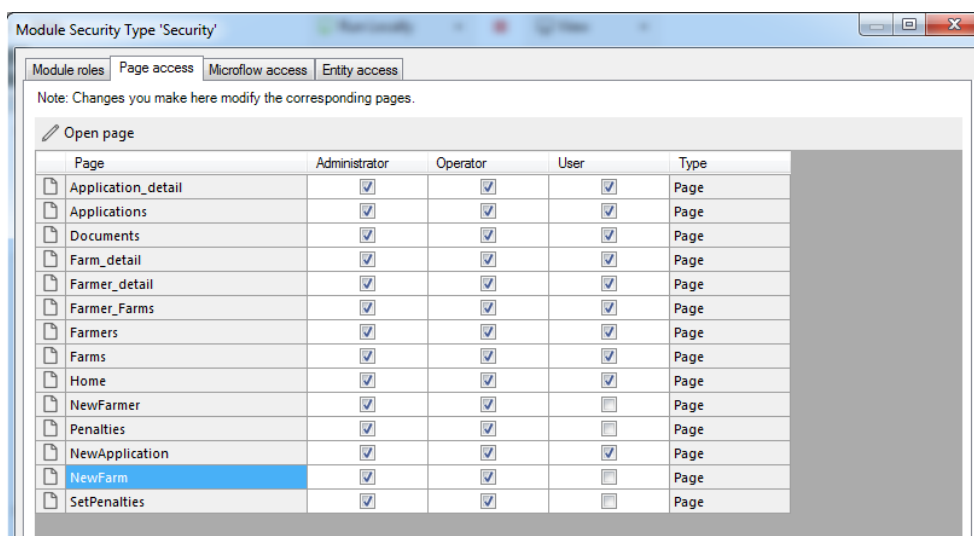


Figure 4.24: Security - page access

4.3.2.3 User profiles

Mendix provides an interface for security where user roles can be defined. As mentioned above, in proof of concept application different user roles were created with different access to pages. There are three user roles: Administrator, Operator, and User. Regarding to page access, Administrator and Operator have the same privilege, but the Administrator has more authority regarding to user accounts management, as it is defined automatically by Mendix. Restrictions for the pages where are instances of Farmer, Farms, and Applications from database listed, were planned, but due to the high complexity of such functionality, this was not implemented.

In the picture 4.24 the interface for setting the page access is shown. In the bookmarks on the top of the windows can be seen that the similar access can also be set to microflows and entities in the database. In the picture 4.25 is the setting of entity access shown, according to this setting User has no right to delete any data from the application.

4.3.2.4 Other used functionality

Other used functionality will be described on the example of page Application detail 4.20.

Buttons and text boxes visibility is possible to set according to some rule, condition or value of the attribute. Buttons with this setting are situated on the right side of the page and have the green stripe to distinguish them. All of them have visibility set according to the status of the application. The

Entity	Module roles	Create	Delete	Member access	XPath constraint
Application	Administrator, Operator	Yes	Yes	Full Read, Full Write	
Application	User	Yes	No	Full Read, Full Write	
Document	User	Yes	No	Full Read, Full Write	
Document	Administrator, Operator	Yes	Yes	Full Read, Full Write	
Farm	User	Yes	No	Full Read, Full Write	
Farm	Administrator, Operator	Yes	Yes	Full Read, Full Write	
Farmer	Administrator, Operator	Yes	Yes	Full Read, Full Write	
Farmer	User	Yes	No	Full Read, Full Write	
Penalties	Administrator, Operator	Yes	Yes	Full Read, Full Write	

Figure 4.25: Security - entity access

button Start Computing is visible only if the status is set to new because after selecting this action, the microflow ACT_Application_StartComputing is called. In this microflow, the status is changed to calculating, which hide this button, but makes the buttons Compute and Create Payment visible. The similar situation will follow with this two buttons, where Compute calls microflow ACT_Application_Compute, where the rate of contribution is calculated, and after selecting Create Payment, the status is again changed to closed, what hides both buttons.

Text boxes with this setting are situated in the bottom of the page also according to attribute status. They are visible only after computation is started, but stay visible also after closing the application.

Nesting data is used to show data which are associated with other entity's data. As can be seen in the picture 4.20, only the information about farmer and farm associated with this application are desired to be shown. So at first data from the instance of Application are gained from the database over page parameter, and inside of this data container, the instance of Farmer over association is retrieved from the database. The same principle is used with information about associated Farm, where one more data container is inserted into Farmer data container. This is the only option how to do so using building blocks of pages. However, the same results can be achieved using microflows.

4.4 Summary

Mendix functionality and creation of proof of concept application was described in this chapter. The majority of the application was created using the desktop modeler with deployment to the local machine, due to better usability of desktop modeler comparing to web modeler. Also, the desktop modeler provides more functionality than the web version. Versions of the application

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can be merged into one and then be also displayed in the web version, but the user won't be able to edit some functionality directly in web modeler.

Before the development started, it was necessary to go through several learning paths. At first the beginner one and then also Rapid Developer learning path for both web modeler and also desktop modeler. Some more concepts were then studied separately, mainly about data management and microflows.

The application was created only in one version, as a web application, but in responsive web design for desktop, tablet and mobile view, which Mendix provides automatically. The mobile application for Android and iOS can be created in project properties, together with publishing it directly to App Stores. This option was not tried.

Finally, the short video was made to preview functionality of the proof of concept application. It can be found on the medium enclosed to this thesis or at <https://youtu.be/6ME2Jm-cu3c> .

Evaluation of findings

5.1 Resources estimation

The estimation of the resources needed to create the application as it was specified in chapter 4 by traditional methodologies, was done by consultation with Ing. Jakub Chlup, Android developer. He estimated resources needed for web application as follows in the table 5.1.

Table 5.1: Resources estimation - Web application

Task	Man hours
Specification	180
Database model, Model of architecture	50
Technical background, database, access management	40
User management	20
Listing data from database	25
Interface for adding data to application	35
Applications management	80
Interface for operators including calculating	70
User profiles	30
UX design	80
Deployment	30
Summary	640

A process of creating a software specification using traditional software development techniques and estimated resources as it is stated in the table 5.1 includes collecting requirements from customer and then creating specification according to that information. If there is data log provided, as it was for IACS, the needed resources can be decreased as it is shown in table 5.3. Resources estimation for specification using automated business process discovery with ProM tool includes data log preparation; data log analysis and execution of

5. EVALUATION OF FINDINGS

actions as described in 4, process model and studying of additional information provided by IACS web page.

Resources needed for the creation of Android application for users (farmers), after the web application was created, was estimated as follows in the table 5.2.

Table 5.2: Resources estimation - Android application

Task	Man hours
Project preparation	8
Farmers and farms management	56
Listing data from database	40
Summary	104

Time spent on the development of proof of concept application together with the estimation of time needed to finish the application as was specified in chapter 4, will be considered in comparison to the previous estimation. There are very small additional resources needed for the creation of separate applications for mobile platforms, due to in-built Mendix functionality. Only the upload of application to App stores by the user is needed, together with filling required information about the project. The estimation is presented in table 5.3.

Table 5.3: Resources estimation - Mendix

Task	Man hours	Implemented
Specification	40	yes
Database model, model of architecture	3	yes
Technical background, database, access management	2	yes
User management	8	no
Listing data from database	1	yes
Interface for adding data to application	2	yes
Applications management	10	yes
Interface for operators including calculating	10	yes
User profiles	10	no
UX design	10	no
Deployment	1	no
Summary	159	

Additional costs connected to the operation of application are stated in table 5.4. These costs include rental of the server, hosting and service level agreement which covers support and up-time guarantee. On the other hand, all these items are already included in the Mendix licensing plan. In table

5.4 ate two different licensing plans stated, and the only difference between them is the number of applications. Mendix - Single App provides only one application, while Mendix Pro provides an unlimited number of applications.

Table 5.4: Other costs connected to operation of application per month

	Traditional techniques	Mendix - Single App	Mendix Pro
Server (rental)	500 €	incl.	incl.
Hosting	20€	incl.	incl.
Service level agreement	1000€	incl.	incl.
Summary	1520€	1640€	4700€

The results of estimation are brought together and presented in table 5.5. As can be seen, it is estimated that development of this particular application as web application would need almost 80% fewer resources.

Table 5.5: Resources estimation - Summary

	Traditional techniques	Mendix
Web application	640	159
Android application	104	1
iOS application	104	1

The cost of man hour for this size of the project was estimated to 80€/hour. After multiplying needed resources by this estimation, the final amount will be **67840€** for web application and application for Android and iOS. As was presented in table 5.4, costs of Mendix license are **1640€** or **4700€** monthly depending on licensing plan. But also custom developed application has more monthly costs, this amount was estimated to **1520€** monthly.

The initial time needed for a developer to get know the platform and be able to create in it was not included, because the training of developers is needed for every required task. But to mention how much time was spent on studying the topic before the development of proof of concept application, estimation can be made according to the learning paths provided by Mendix. As was mentioned in chapter 4, provided tutorials also have the time needed for completion. Basic learning path and Rapid developer paths were taken, in a duration of half an hour, 12 hours and 12 hours. Then documentation was used during the development when a deeper understanding of some particular functionality was needed; this can be estimated to approximately 15 more hours. So after little less than 40 hours, which is one work week, developer able to create basic and also more complex applications in Mendix platform, can be trained. However, some technical background is needed to full comprehension of all concepts; it is not necessary to have advanced programming skills.

5.2 Overall summary

During the development of proof of concept application and then estimation of resources needed to create such application also using traditional methods of software development, was discovered, that there is room for saving resources. Pre-build blocks of functionality which can be used without deep knowledge of programming undoubtedly can save time during the development. The developer can focus on the logic behind the functions and workflows instead of creating communication with the database, retrieving needed data or creation of application front-end. However, the development of high customized functionality can be more difficult than in whole custom application, because it must be done in a particular way to ensure the right communication with other parts of the application. Thus, if the developed application needs too much customization, using the low code platform may not be the easiest neither the right way.

The fact, that there is no need to create a separate application for Android and iOS because one application is supported by several devices is also a bonus which can save resources. As was stated in table 5.5, the difference between traditional techniques and low code platform, in this case, Mendix, is most notable. There are possibilities of turning a web application into Android application without the need for further programming only with small adjustments, but the web version of such application must counts with a highly responsive design from the beginning.

Mendix provides very explicit documentation and user-friendly tutorials in many different forms, what may be seen as a pleasant bonus, but also as a necessity. Although the work in Mendix was not always easy, the solution to almost all problems could be found in provided documentation.

Monthly costs connected to the application presented in the table 5.4 are lower for custom made application, but initial investment into the application is almost five times higher than in the case of development in Mendix. Also, all the changes, which will be necessary for the future, will have to be developed with additional costs. Application deployed in Mendix can be changed anytime by almost anyone.

Conclusion

The state of the art platforms for software development of Enterprise information systems was reviewed in the first part of this thesis. SharePoint from Microsoft, iBPMS and Low Code platforms from several providers considered as leaders on the market were reviewed together with pros and cons. According to this analysis, the Mendix platform was chosen for the development of proof of concept application, because of a strong position on the market, free version for development and extensive tutorials and documentation. Summary of development techniques is introduced in chapter 3, together with an overall evaluation of suitable usage of each platform - SharePoint, Low code and iBPMS in several categories including example use cases. While SharePoint is most suitable for business which is dependent on other Microsoft Office products and needs mainly automation of processes or extended data management, Low code platforms, and iBPMS are suitable for process management support or business intelligence. Low code platforms and iBPMS are each best options for different kind of applications what is indeed connected to pricing models. iBPMS demands higher initial investment plus yearly subscription, Low code platforms have various pricing models with payment for user/month, and SharePoint is already included in Office 365 Premium subscription.

In the next chapter 2 process discovery was described together with real results from tool ProM on event log from systems for support calculation of contribution for farmers in European union - IACS. Process mining as a tool for analysis of event logs generated by large information systems may come handy in the extraction of valuable information as bottlenecks or process deviations. This can make the process optimization easier and move the process management cycle in organizations on the next level. According to results from automated process discovery and information about the process of calculation of contribution, the information system for support this process was designed and specified in chapter 4. This design was then used for development of proof of concept application in Mendix low code platform.

Experience with development in low code platform can be rated as interesting. Concepts used in Mendix were similar to programming but not completely. Learning paths and documentation was sufficient enough for getting know how to use the Mendix platform. The training time estimated in chapter 5 for usage of Mendix is much lesser than the in which a good programmer can be trained - this can take years of studying and gaining experience. Although the best results may be possible to get if a person with at least some IT background is trained, it is not necessary as was mention several times.

For applications where are no complex logic, large databases, high level of security or customized functionality needed, is low code platform suitable option. Many concepts currently used in developing information systems are already developed, programmed somewhere or figured out. By using construct, where the developer can focus on other things than creating something over and over again only in slight mutation, resources needed for already existing functionality can be saved. The developer can then use this time for other activities, for example, to create bulletproof logic behind process models or other functions which were marked as nice-to-have. Even though some technical background is required for full comprehension of all concepts of low code programming, it is not necessary to have advanced programming skills.

In the last chapter of this thesis 5 the resources needed for development of application as was designed in chapter 4 were evaluated. The result of this evaluation is that using low code platform for this particular task could save more than 80% of resources as is stated in table 5.5. This could be an amazing finding, but the application as it was designed didn't need anything highly customized. Almost all functionality could be covered by usage of building blocks of Mendix, which means that choosing to create this application in the low code was a good decision. It should be carefully considered if the application needs to be developed is suitable for low code, and if this consideration ends with a negative answer, there can still be other suitable task for the low code; for example, creation of application preview as more elaborated wireframes or to test new business ideas and concepts at low cost.

Bibliography

- [1] van der Aalst, W. *Process Mining: Data Science in Action*. Springer, second edition, 2016, ISBN 978-3-662-49851-4.
- [2] Lakshmanan, G. T.; Khalaf, R. Leveraging Process-Mining Techniques. *IT Professional*, volume 15, no. 5, Sep. 2013: pp. 22–30, ISSN 1520-9202, doi:10.1109/MITP.2012.88.
- [3] Hujainah, F.; Bakar, R. B. A.; et al. Stakeholder quantification and prioritisation research: A systematic literature review. *Information and Software Technology*, volume 102, 2018: pp. 85 – 99, ISSN 0950-5849, doi:<https://doi.org/10.1016/j.infsof.2018.05.008>. Available from: <http://www.sciencedirect.com/science/article/pii/S0950584917302422>
- [4] Obrand, L.; Augustsson, N.-P.; et al. The interstitiality of IT risk: An inquiry into information systems development practices. *Information Systems Journal*, volume 29, no. 1, 2019: pp. 97–118, doi:10.1111/isj.12178, <https://onlinelibrary.wiley.com/doi/pdf/10.1111/isj.12178>. Available from: <https://onlinelibrary.wiley.com/doi/abs/10.1111/isj.12178>
- [5] Williams, C. *A quantitative comparative and correlational study of critical success factors for information technology projects*. Dissertation thesis, 2013, copyright - Database copyright ProQuest LLC; ProQuest does not claim copyright in the individual underlying works; Last updated - 2016-03-12. Available from: <http://ezproxy.techlib.cz/login?url=https://search-proquest-com.ezproxy.techlib.cz/docview/1412660187?accountid=119841>
- [6] Berghout, E.; Nijland, M.; et al. Management of lifecycle costs and benefits: Lessons from information systems practice. *Computers in Industry*, volume 62, no. 7, 2011: pp. 755 – 764, ISSN 0166-3615, doi:

- <https://doi.org/10.1016/j.compind.2011.05.005>. Available from: <http://www.sciencedirect.com/science/article/pii/S0166361511000704>
- [7] Dunie, R.; Kerremans, M.; et al. Magic Quadrant for Intelligent Business Process Management Suites. Oct 2017. Available from: <https://www.gartner.com/doc/reprints?id=1-4J4JD9Z&ct=171024&st=sb>
- [8] Vincent, P.; Baker, V.; et al. Magic Quadrant for Enterprise High-Productivity Application Platform as a Service. Apr 2018. Available from: <https://www.gartner.com/doc/reprints?id=1-4XKJ1MZ&ct=180426&st=sb>
- [9] Rymer, J. R.; Mines, C.; et al. [Forrester Wave] Low-Code Development Platforms For AD&D Pros, Q4 2017. Oct 2017. Available from: https://lb.appian.com/low-code-2016/ar-forrester-wave-low-code-q42017?utm_source=email&utm_medium=drip&utm_campaign=low-code&utm_content=ar-forrester-lowcode-wave-2017
- [10] About Gartner. Available from: <https://www.gartner.com/en/about>
- [11] Home Forrester. Available from: <https://go.forrester.com/>
- [12] SharePoint, Team collaboration software tools. Available from: <https://products.office.com/en-us/sharepoint/collaboration>
- [13] Jaaskelainen, J. R. O. *SharePoint Development with the SharePoint Framework: Design and implement state-of-the-art customizations for SharePoint*. Packt Publishing, 2017, ISBN 978-1787121430.
- [14] Smith, T. *SharePoint 2016 User's Guide: Learning Microsoft's Business Collaboration Platform*. Apress, fifth edition, 2016, ISBN 978-1484222430.
- [15] What is PowerApps. Available from: <https://docs.microsoft.com/en-us/powerapps/powerapps-overview>
- [16] Fanning, K.; Centers, D. P. Intelligent Business Process Management: Hype or Reality? *Journal of Corporate Accounting & Finance*, volume 24, no. 5, 2013: pp. 9–14, doi:10.1002/jcaf.21870. Available from: <https://onlinelibrary.wiley.com/doi/abs/10.1002/jcaf.21870>
- [17] Palmer, N.; col. *iBPMS - Intelligent BPM Systems (BPM and Workflow Handbook Series)*. Future Strategies Inc., 2013, ISBN 978-0984976461.
- [18] Bizagi - Digital Transformation & Business Process Management BPM. Available from: <https://www.bizagi.com/>
- [19] Home - BPMDev. Available from: <https://developer.ibm.com/bpm/>

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- [20] BPMS - AgilePoint. Available from: <http://agilepoint.com/bpms-2/>
- [21] Sambandam, S. Where low-code development works and where it doesn't. *InfoWorld.com*, Aug 09 2018. Available from: <http://ezproxy.techlib.cz/login?url=https://search-proquest-com.ezproxy.techlib.cz/docview/2086018587?accountid=119841>
- [22] Ross, M. 4 essential features of modern low-code development platforms. *InfoWorld.com*, Jul 04 2018. Available from: <http://ezproxy.techlib.cz/login?url=https://search-proquest-com.ezproxy.techlib.cz/docview/2063977891?accountid=119841>
- [23] Srikanth, R. P. Will Low Code platforms be the next Excel? *Express Computer*, Oct 01 2018. Available from: <http://ezproxy.techlib.cz/login?url=https://search-proquest-com.ezproxy.techlib.cz/docview/2114683193?accountid=119841>
- [24] Low-code Application Development Platform - Build Apps Fast & Efficiently — Mendix. Available from: <https://www.mendix.com/>
- [25] K2—Digital Process Automation. Available from: <https://www.k2.com/>
- [26] Cloud Services for Enterprise by ServiceNow - Works for you. Available from: <https://www.servicenow.com/>
- [27] Appian: Enterprise Low-Code Application Development & BPM Software. Available from: <https://www.appian.com/>
- [28] Workflow Software: TrackVia Work Management & Automation. Available from: <https://www.trackvia.com/>
- [29] Maita, A. R. C.; Martins, L. C.; et al. A systematic mapping study of process mining. *Enterprise Information Systems*, volume 12, no. 5, 2018: pp. 505–549, doi:10.1080/17517575.2017.1402371. Available from: <https://doi.org/10.1080/17517575.2017.1402371>
- [30] Process Mining. Available from: <http://www.processmining.org/prom/start>
- [31] van der Aalst, W.; Reijers, H.; et al. Business process mining: An industrial application. *Information Systems*, volume 32, no. 5, 2007: pp. 713 – 732, ISSN 0306-4379, doi:<https://doi.org/10.1016/j.is.2006.05.003>. Available from: <http://www.sciencedirect.com/science/article/pii/S0306437906000305>
- [32] Sommerville, I. *Software Engineering 10th Edition*. Pearson Education, 2015, ISBN 1292096136.

- [33] Leach, R. J. *Introduction to Software Engineering*. Champman and Hall/CRC, second edition, 2017, ISBN 978-1498705271.
- [34] Davis, B. *Going Beyond the Waterfall: Managing Scope Effectively Across the Project Life Cycle*. J. Ross Publishing, 2014, ISBN 978-1604270907.
- [35] Lal, M. K. *Knowledge Driven Development: Bridging Waterfall and Agile Methodologies*. Cambridge University Press, 2018, ISBN 978-1108475211.
- [36] Chong, J. *Knowledge Sharing in Software Development: Comparing XP and Waterfall Methods*. VDM Verlag Dr. MÄijller, 2008, ISBN 978-3639100846.
- [37] Leffingwell, D. *Agile Software Requirements: Lean Requirements Practices for Teams, Programs and the Enterprise (Agile Software development Series)*. Addison-Wesley Professional, 2011, ISBN 978-0321635846.
- [38] Manifesto for Agile Software Development. 2001. Available from: <http://agilemanifesto.org/iso/en/manifesto.html>
- [39] Stellman, A. *Learning Agile: Understanding Scrum, XP, Lean, and Kanban*. O'Reilly Media, 2013, ISBN 978-1449331924.
- [40] Institute, P. M. *Agile Practice Guide*. Project Management Institute, 2017, ISBN 978-1628251999.
- [41] Sawyer, S. Packaged software: Implications of the differences from custom approaches to software development. *European Journal of Information Systems*, volume 9, no. 1, 03 2000: pp. 47–58. Available from: <http://ezproxy.techlib.cz/login?url=https://search-proquest-com.ezproxy.techlib.cz/docview/218734279?accountid=119841>
- [42] Wang, E. T. G.; Barron, T.; et al. Contracting structures for custom software development: The impacts of informational rents and uncertainty on internal development and outsourcing. *Management Science*, volume 43, no. 12, 12 1997: pp. 1726–1744. Available from: <http://ezproxy.techlib.cz/login?url=https://search-proquest-com.ezproxy.techlib.cz/docview/213234729?accountid=119841>
- [43] Ayala, C.; Hauge, O.; et al. Selection of third party software in Off-The-Shelf-based software development: An interview study with industrial practitioners. *Journal of Systems and Software*, volume 84, no. 4, 2011: pp. 620 – 637, ISSN 0164-1212, doi:<https://doi.org/10.1016/j.jss.2010.10.019>, the Ninth International Conference on Quality Software. Available from: <http://www.sciencedirect.com/science/article/pii/S0164121210002864>

- [44] Dongen, v.; Borchert; et al. Jan 2018. Available from: <https://doi.org/10.4121/uuid:3301445f-95e8-4ff0-98a4-901f1f204972>
- [45] Integrated Administration and Control System (IACS)—Agricultural and rural development. Available from: https://ec.europa.eu/agriculture/direct-support/iacs_en

Additional pictures from ProM and Mendix

A. ADDITIONAL PICTURES FROM PROM AND MENDIX



Figure A.1: Prom data visualisation - Log Inspector Browser

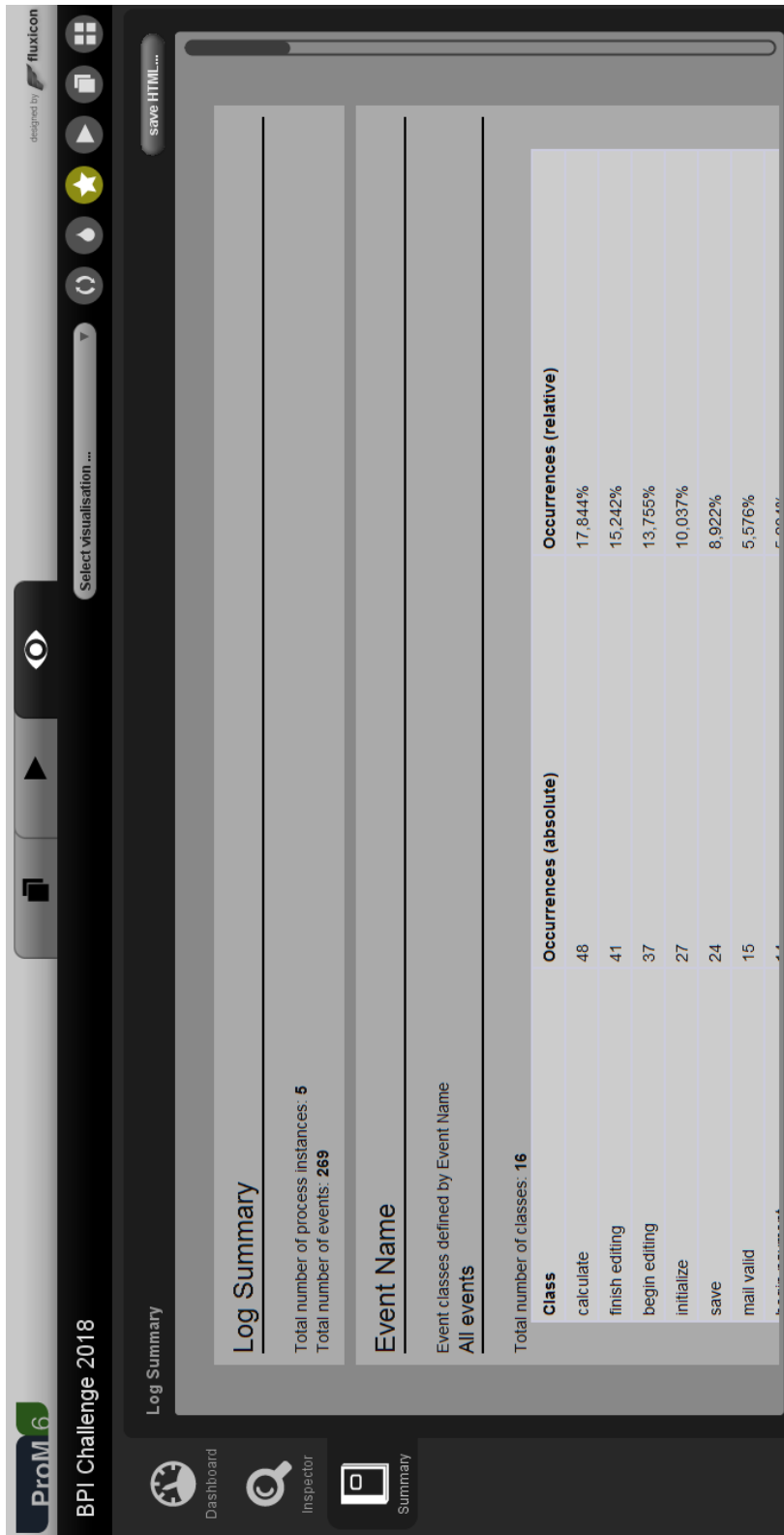


Figure A.2: ProM data visualisation - Summary

Wireframes

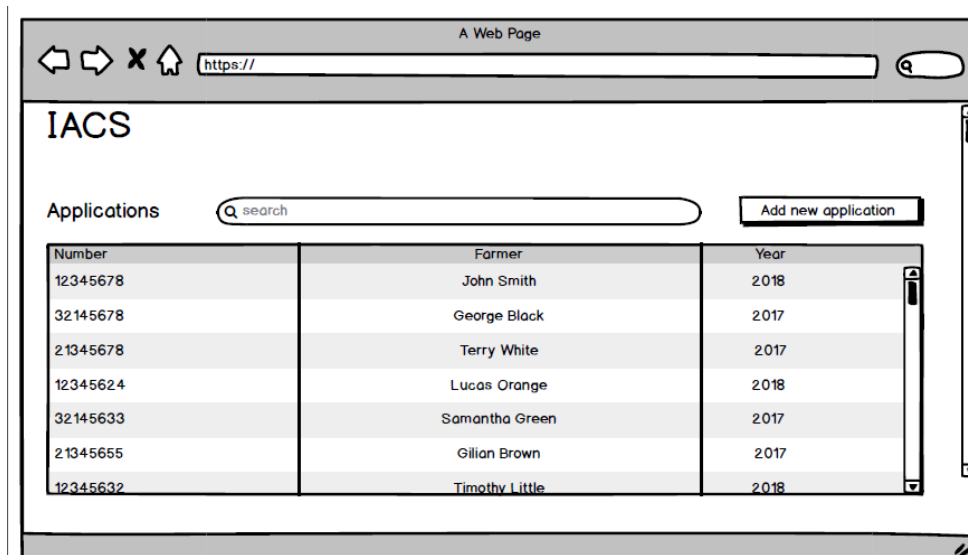


Figure B.1: Wireframe Home page

B. WIREFRAMES

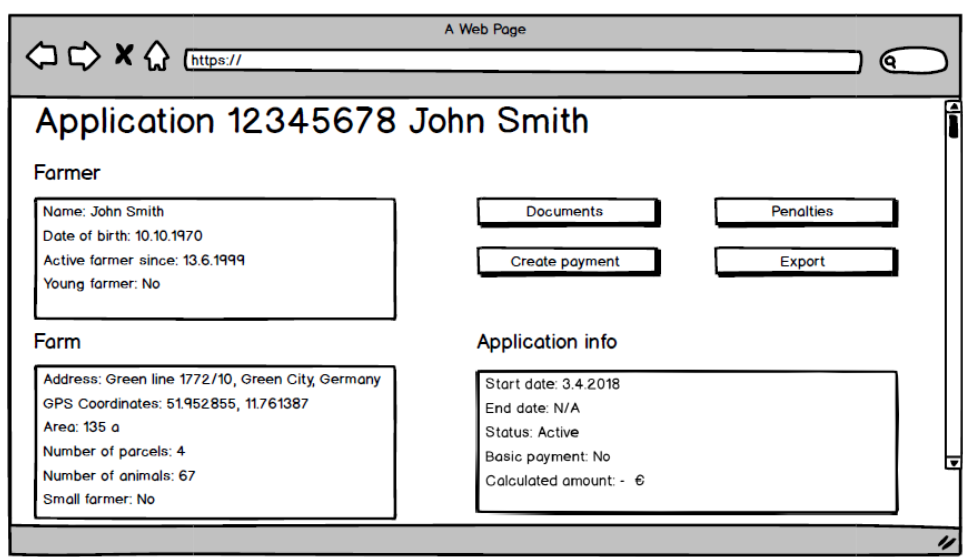


Figure B.2: Wireframe Application detail

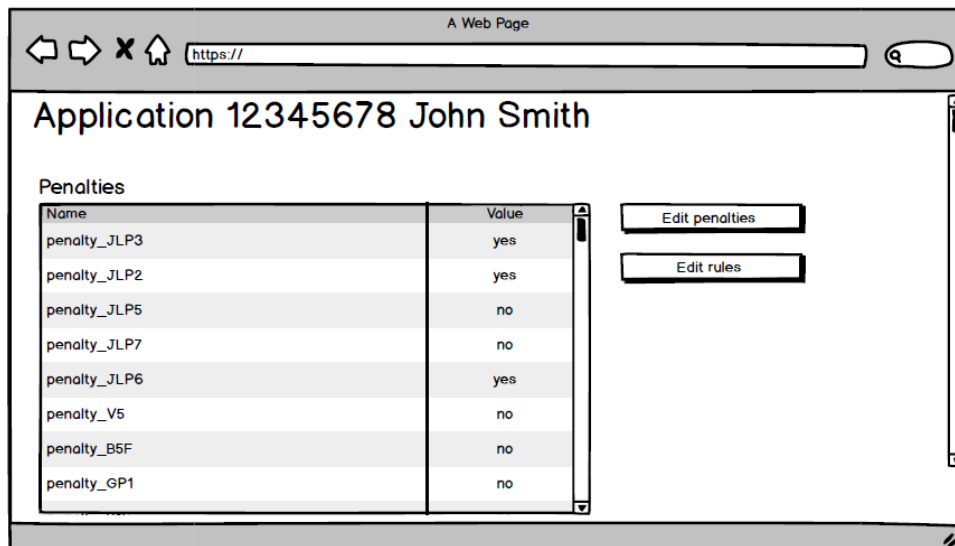


Figure B.3: Wireframe Penalties

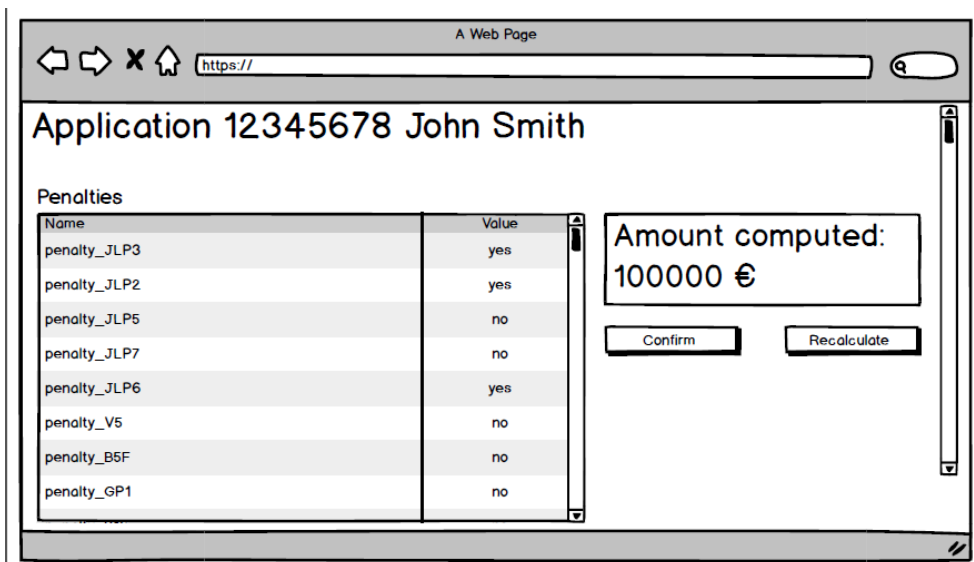


Figure B.4: Wireframe Penalties detail

Acronyms

iBPMS Intelligent Business Process Management Suites

MS Microsoft

IACS Integrated Administration and Control System

Contents of enclosed USB

readme.txt	the file with USB contents description
src	the directory of source codes
├─ wbdcm	implementation sources
├─ thesis	the directory of \LaTeX source codes of the thesis
text	the thesis text directory
├─ thesis.pdf	the thesis text in PDF format
├─ thesis.ps	the thesis text in PS format