A System Dynamics Approach for Streamlining the Report Request Process: a Case Study of a Local Healthcare Provider

by
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Thesis submitted in partial fulfillment of the requirements of Master of Philosophy in System Dynamics (Universitetet i Bergen), Master of Science in System Dynamics (Universidade Nova de Lisboa) and Master of Science in Business Administration (Radboud Universiteit Nijmegen)

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AUGUST 2018

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List of Acronyms

FRR	Formal Report Requests
IRR	Informal Report Requests
RRP	Research Request Process
SD	System Dynamics
GMB	Group Model Building
SFD	Stock and Flow Diagram
CLD	Causal Loop Diagram
FRR	Formal Report Requests
LHP	Local Healthcare Provider
CE	Customers' Education
KS	Knowledge Sharing
HMP	Hiring More People
NC	Naming Conventions
NH	Normal Hiring
PC	Productivity Correction
PO	Policy Options
SW	Switches

Acknowledgements

I would first like to thank my thesis supervisor, full professor David Wheat. Whenever I ran into a trouble spot or had a question about my research his ideas, modeling and life experience put me back on the right track. I am very grateful for his support and patience. It is an honor for me to have worked with him.

I am particularly grateful for the assistance given by Arielle Selya, the assistant professor of the University of North Dakota. Without her passionate participation and facilitation of the modeling workshops, they could not have been successfully conducted. As well, I am indebted for her insightful comments and suggestions.

This project would not have been possible unless Ian Watson has suggested the topic for my research. I highly appreciate the time spent by him on this project and his desire to disseminate the System Dynamics. His openness to new ways and ideas made it possible to conduct this project in the best way.

Special thanks to Etiënne Rouwette, professor of Radboud University for his pieces of advice in structuring the workshops. Despite my absence of extensive experience in this field, his insights helped to successfully conduct the model building sessions.

I owe my deepest gratitude to the personnel of an Information Service Department of a local health provider, that found time to participate in the project in spite of their busy schedule. Their interest in the project and willingness to cooperate kept my motivation on a high level.

I would also like to express my gratitude to the Norwegian Centre for International Cooperation in Education and Erasmus Mundus that made possible my participation in the project and in the EMSD program.

I am deeply thankful to my family and friends for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

18/08/2018

Abstract

This thesis describes a modeling project performed by Ekaterina Durova, a student enrolled in European Master Program in System Dynamics, in cooperation with assistant professor Arielle Selya (University of North Dakota) and under the supervision of emeritus professor I. David Wheat (University of Bergen).

This project considers the case of a local healthcare provider. The company faces challenges posed by the considerable backlog of report requests. Due to the backlog of requests, the delivery time for reports has significantly increased, despite the relatively short time needed per report fulfillment. In turn, the inability of medical practitioners and managers to get the completed reports in a timely manner might worsen the productivity of the whole company. Moreover, the problem is exacerbated by the constantly growing rate of report requests that results from the addition of new hospitals under the company structure.

A System Dynamics model was developed to structure the process of requesting and fulfilling reports. Group model building sessions, semi-structured interviews and data analysis were used to determine the key variables of the system.

Hiring more people, naming conventions, knowledge sharing and customers' education were examined as possible policy options. To compare them was conducted the cost-benefit analysis. Based on the analysis and simulation results, it became clear that hiring more people and customers' education provide the best outcomes. Thus, it was recommended to implement one of these policy options.

Key words: report request process, information services, rework, data-based decision making, group model building, system dynamics.

Introduction

The phenomenon of rework has a long history in the System Dynamics field. The first System Dynamics model describing the rework cycle was built in the 1970's to analyze the reasons for the significant cost overrun in a shipbuilding company. From one side this issue was caused by unclear requirements and ever-changing needs of final users. From the other side, attempts to implement the most modern technology produced additional costs. Thus, the shipbuilding company had to make significant changes in the ships and go through the never-ending rework cycle (Cooper, 1980; Sterman, 2000)

The challenges caused by the rework cycle didn't lose their actuality nowadays as proven by the great attention from the business and scientific communities. From System Dynamics perspective this problem has been considered by numerous authors, such as Cooper, Els, Ford, Lyneis and Oliva (Lyneis, Cooper, & Els, 2001; Lyneis & Ford, 2007; Oliva, 2008). Especially the rework cycle is very common for the Information Technologies industry and Information Services departments of any firm (Abdel-Hamid, 1984; Abdel-Hamid & Madnick, 1989).

A local healthcare provider in North Dakota, United States is one of those companies. Established in 1892 as a single hospital, the company currently provides a wide range of medical services. Since then, many other medical organizations in this region were included under its structure; a growth which is expected to continue in the future. Thus, the company seeks ways to maintain a high quality of provided healthcare services across all branches. One of the most promising ways to achieve this is the implementation of clinical decision support and evidence-based decision making (Kawamoto, 2005; Walshe & Rundall, 2001).

These techniques heavily rely on reports from the company’s databases of previously collected healthcare data. Despite the initial success, it is becoming harder and harder to complete reports from the company's databases in a timely manner. The Information Services Department that is responsible for providing the data faces a growing number of report requests, and this is only expected to increase with the addition of new hospitals under the company structure in future years. At the same time, the problem is exacerbated by the increasing complexity of the database and vague requirements of the final users. Thus, the backlog of report requests has grown. That motivated the head of the Information Service department to search for a method that could help to structure the problem, explain its causes and ease the implementation of policy options.

Thus, it was decided to conduct a four-month modelling project that used the System Dynamics methodology to build a simulation model. The personnel of the Information Services Department were actively involved in the modelling process through a series of Group Model Building workshops.

Three workshops were conducted to reach the goal of the project. The first workshop was devoted to the problem definition and building an initial stock-and-flow structure. The second session was aimed at finding possible courses of action and further develop the model structure. The third session was targeted to choose the best solution and test different scenarios of future development.

The project focused on two key issues: growing backlog of report requests and unsatisfactory delivery time of completed reports. During the project, it became clear that the data obtained through ticket tracking system are not reliable. The considerable number of informal report requests received by phone or email, and the time gap between the actual report completion and clicking the completion button in the tracking system are the main causes for the unreliability of available objective data. For that reason, the data were mainly obtained by questionnaires of employees. In turn, that created incentives for better utilization of the tracking system.

This thesis describes the process of the project conduction, its key outputs and challenges. Chapters follow the chronological order in which the project was fulfilled. Description of the company and the issue is presented in the first chapter, the choice of the methodology in the second chapter. Preparation, outputs, and work in between of Group Model Building sessions are described in the next three chapters according to the number of organized workshops. The model structure and behavior are presented in the sixth chapter. In addition to it, a series of model validity tests were fulfilled, which are provided in the seventh chapter. Eight and ninth chapters are devoted to the description and comparison of policy options.

Chapter 1. Report Request Process

This chapter provides a brief overview of the company and describes the key features of the report request process. Also, it includes the graphs describing the behavior of the backlog of open report requests and the reports delivery time, that helps to understand the patterns of the problematic behavior and are prerequisites for the choice of the methodological approach.

1.1. Introduction to the Company

A history of the local healthcare provider dates to 1892 when the healthcare only started its development in this region. in its current form, this healthcare provider was established in 1997 after a merger of the 2 biggest medical organizations. Since this date, many local clinics and hospitals were included under company's structure. Hence the company has facilities to provide a wide range of healthcare services, from general therapy to neurosurgery.

Decreasing the probability of post-surgery complications and exacerbations of chronic diseases are the main priorities of the medical personnel. For that reason, the company wants to implement clinical decision support and evidence-based decision making. These techniques enable healthcare providers to improve the quality of healthcare, but they require an extensive information support.

An Information Services Department is responsible for providing the data and creating reports for the management and health personnel. Reports might contain information about the patients and financial outputs of the company. Sometimes, clients ask to combine clinical and financial data, for instance when they want to understand how much money on average is spent to treat a single patient with a particular disease.

Initially, the report request process worked smoothly. But a couple of years ago, it went out of control due to a growing number of regulatory requests from public services since the government is interested in the reduction of costs on healthcare. In addition, the problem is exacerbated by the inclusion of Critical Access Hospitals in the company's structure. These medical organizations are located in rural areas which don't have their own facilities or experience in providing regulatory reports to the state.

1.2. Types of Report Requests

To further understand this problem the next section explores different types of reports and methods of creation report requests.

Reports can be conditionally divided into the clinical and financial. The first might, for instance, contain data about patients with a certain disease. These reports are usually required by medical practitioners. The second group usually includes information about profits and financial operations. Report requests can be created by management for decision making or regulatory

inspections. Aside from these two groups, mixed reports also occur. They, for instance, can contain numbers showing how much money was spent to treat patients with a certain disease. Generally, report writers are specialized in one type of report request. Thus, the mixed report requests can only be fulfilled by the most experienced staff that know where to find data about both categories.

Requests can be divided into formal and informal. Formal or "ticketed" requests are created through the ticket tracking system "Service Now". This system requires filling out certain fields and provides an opportunity to assign priority and due date. Informal or non-ticketed requests usually are created by old clients or top management. They have direct contact with report writers, thus many of them prefer to use email or phone instead of creating tickets in the tracking system.

1.3. Backlog of Report Requests

The Information Services department is facing the growing number of report requests due to the connection of new hospitals under the company structure. As well it's related to the growing number of regulatory reports required by the public services. Thus, the backlog of open report requests is increasing.

The data regarding the backlog is available starting from April 2014. However, the ticket tracking system has not been used properly until 2016. For that reason, it was decided to exclude the beginning of the dataset from the analyzes and only consider the data starting from January 2016.

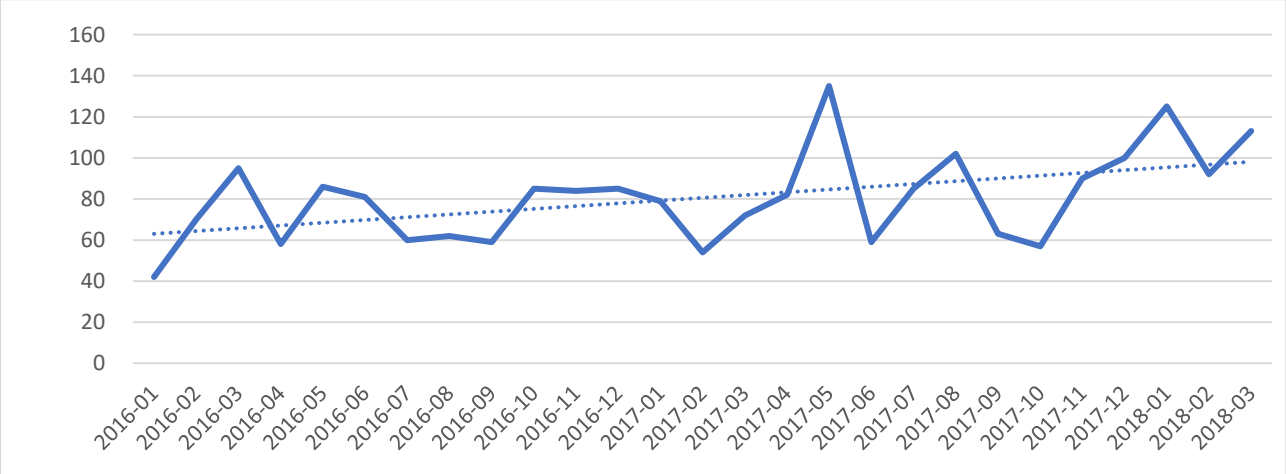


Figure 1. Backlog of Formal Report Requests (“Service Now”)

The backlog starts with 42 reports per month in 2016 and reaching the maximum value of 135 in May 2017. Then it slightly decreases, reaching the value of 113 in March 2018. The data has significant fluctuations over the year, that might be related to changes in the workforce, upgrades of the databases and regulatory check-ups. However, the overall trend line of the backlog of open report requests has been growing.

As it was mentioned earlier, this data is just a partial representation of reality due to a significant share of informal report requests, especially in the earlier years. However, despite the

absence of quantitative data, it's clear that the number of informal report requests is also growing due to the increased number of end-users.

Nevertheless, per se, the growth of the backlog is not necessarily the sign of the problem. It might be related to the growing number of report writers or their increasing productivity. In fact, the number of employees in the Information Services Department is slightly going up and yet the share of experienced employees is declining. For that reason, the management is worried about the growing number of open report requests and would like to decrease this number.

1.4. Average Reports Delivery Time

Methods of creating report requests described before led to the issue of unclear requirements. For a considerable share of reports, they exist only in a verbal form. Even though “Service Now" has a special field for explaining the requirements, many report requestors put vague requirements or, in the worst case, leave this field blank. For that reason, report writers spend quite some time on clarification and communication with customers in addition to their main work. As well, poorly formulated specifications lead to the rework cycle. As a result, on average each report is going through three revisions before it is accepted by the client.

Each revision has a communication delay, which on average takes about a week. Therefore, the report delivery time mainly consists of these communication delays instead of real-time needed for the report fulfilment. In Figure 2 presents the progression of average report delivery time since January of 2016.

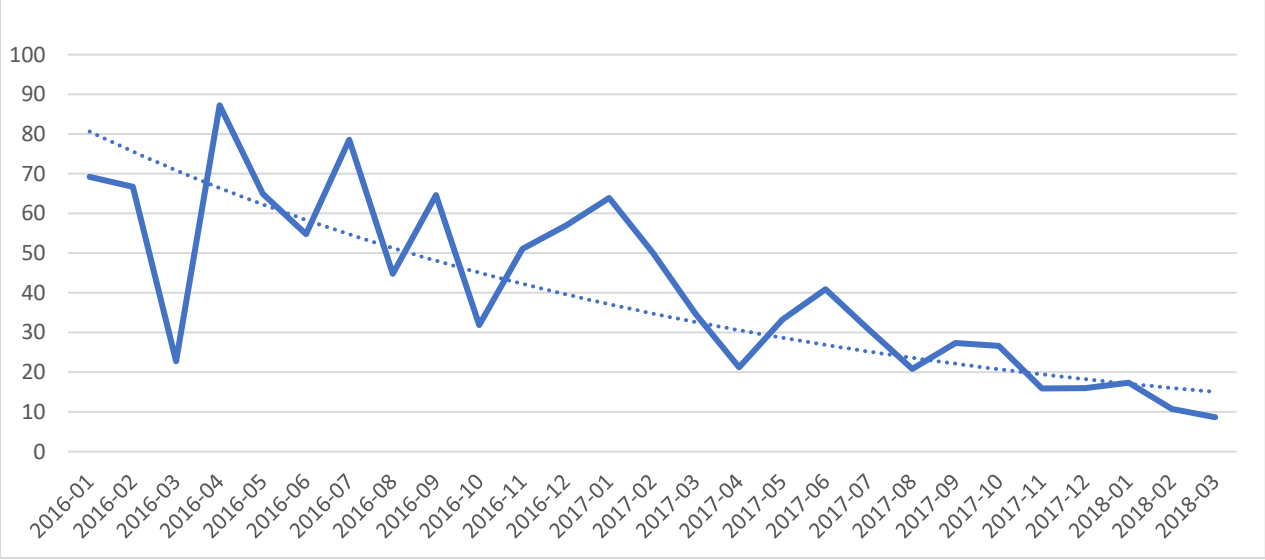


Figure 2. Average Delivery Time for Reports Requested by Formal Procedures (“Service Now”)

According to the graph above, the reports’ delivery time has been going down significantly – from 87 days in April 2016 to 9 days in March 2018. However, this data is severely distorted by the improper use of “Service Now” and by varying number and complexity of report requests.

In the beginning, report writers and customers didn't use the ticket tracking system properly and didn't close tickets on time. Thus, many completed reports remained open in the system for a long time. Report writers have been asked to close fulfilled tickets before each weekly team meeting, starting at the end of 2016. For that reason, it was decided to construct the model for the reality check and use the numbers produced by it as a reference mode for the reports delivery time.

Also, the complexity and number of new report requests are not equally distributed. During some months, simple reports, which require less time on their completion, might prevail. That produces fluctuations in the average reports delivery time fluctuates. But the overall trend is decreasing towards a long-term steady delivery time.

Even though, the management is concerned about outliers that exceed the desired reports delivery time. In addition, the company plans further expanding, and thus, it's not clear how many report requests will come to the Information Services Department and would it be able to fulfill them in a timely manner.

1.5. Reality Check Model

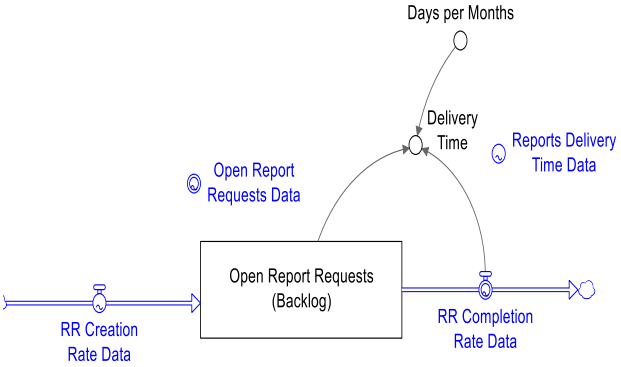


Figure 3. Reality Check Model

Since the data presented in sections above has provoked concerns about their reliability it was decided to conduct the reality check. For that purpose, a single stock model was built, which flows are determined completely by the historical datasets.

With DT equal to 1, the reality check model fully replicates the historical dataset for the backlog of open report requests.

Figure 4. Comparison of the Historical Data with the Reality Check Model

However, it is not the case for report delivery time as presented in Figure 4. As it was mentioned earlier, this might be explained by the changes in the working process and improper use of the ticket tracking system.

Therefore, it was decided to use the simulation results of the reality check model as a constructed reference mode for the reports delivery time instead of the historical dataset. However, the historical data was used as the reference mode for the backlog of open report requests since it less susceptible to distortion and relatively reliable starting from January 2016.

Chapter 2. Methodological approach

The previous chapter describes a few weak areas of the report request process. Based on them it might seem like the problem definition is straightforward, but in fact, there might exist different points of view what the problem is and what we can do about it. Thus, to avoid possible misunderstandings and improve the project output, it is worth thoroughly considering the choice of the methodological approach. Thus, this chapter describes the goal of the project and discusses the suitability of different methodological approaches for its fulfilment.

2.1. Research Aim and Questions

The aim of this project is to improve the efficiency of the Information Services Department of a local health care provider using the System Dynamics methodology to analyze causes and effects of the backlog of report requests and to test possible solutions for further reducing the report delivery time.

To achieve this aim, the following questions need to be answered:

- What are the main causes of fluctuations in the reports delivery time disrupting the delivery of reports in a timely manner in a local healthcare provider?
- Which factors have the most influence on the backlog of report requests in the company?
- What is the most effective way for improving the efficiency of the report request process in a local health care provider that will enable the timely delivery of reports?

2.2. Research Strategy

The following sources were reviewed to show which research strategies could be applied in this field. Dianati and Davidsen (2011) used a case study of a Scandinavian cloud computing company to show how the System Dynamics approach can be applied to plan for data center capacity. This research strategy involves the investigation of a particular contemporary topic within its real-life context, using multiple sources of evidence (Saunders & Lewis, 2012). It helps to get a detailed understanding of the context, which was one of the main goals of this project. Another goal was to decrease risks and costs of policy implementation. For this purpose, a quantitative simulation model was built. Additionally, they investigated how the company decides when to expand the capacity and what prevents the capacity from meeting the demand.

Georgantzas and Katzamas analyze how the System Dynamics approach was applied to information systems by scholars and practitioners by the survey of existing documents in this field (2008). Špicar replicates various System Dynamics archetypes in capacity planning by using a literature review (2014). Both strategies allow identifying common themes across different sources. So, they fit the goals of this research.

The goal of this project is to understand why the current backlog of report requests is higher than its desired level, that would enable a timely delivery of all reports; and how it might be solved. This phenomenon will be observed in real life conditions; therefore, a case study is the most appropriate. This research strategy is closely related to modelling and System Dynamics in particular. Their combination allows getting a better understanding of the matter. For the implementation of policy options based on research findings, a simulation model might be needed. According to De Gooyert (2016: 4), these models "are capable and especially useful to be in the "sweet spot" of theoretical contributions – in between theory-testing and theory-creating". Moreover, they allow the problem to be structured and the effectiveness of various policy options to be compared, in turn decreasing risks of their implementation (Sterman, 2000). Thus, the combination of a case study with System Dynamics quantitative modelling is needed to reach the goal of this project.

2.3. Data Collection and Analysis

Initially, for building the System Dynamics model it was planned to use interviews and document collection as data collection methods. The access to the data was obtained through the head of the Information Services Department of the local healthcare provider in this case study. An interview guide and a list of questions were prepared to conduct semi structured interviews. Participants of the interviews included (1) with five report writers who were chosen based on their expert knowledge of the process and understanding of its workflow, and (2) five report users from other departments. Due to time constraints, there was a need for purposive sampling to select interviewees, based on participants' usage of the report request process and complaints about its quality.

As well, it was planned to use the data from the ticket tracking system to evolve the reference mode of behavior and highlight the vulnerabilities of the system.

The importance of not only relying on written and numeric data was emphasized by Luna-Reyes and Andersen. They point that soft variables severely depend on mental databases and cannot be modelled without stakeholders' participation (2003:2).

Hence, both qualitative data from semi-structured interviews and quantitative data from the report system should be used together. This combination allows modelers to elicit participants' mental models as well as written data, which are essential for the understanding of problem structure.

It was intended to analyze interview data with inductive-coding techniques. According to these methods, a coder looks for common themes in interview text and assigns a code related to the theme of a sentence/paragraph. It might be done manually or with computer-assisted qualitative data analysis software. Based on interview questions and preliminary information, the modelers planned to create a list of pre-set codes with the clarification of the meaning of each code in a codebook.

Originally it also was anticipated to involve a second coder in the project to avoid distortion of information (Andersen et al., 2012).

2.4. Non-participatory System Dynamics Approach

Typically, during the System Dynamics projects without the participation of stakeholders, a problem is defined in bold terms and by a single person. At worst the definition is imposed by a modeler. But, problem definitions might significantly vary among stakeholders, especially when it comes to "messy" problems. That some perceive as an issue, others might view as a benefit. Hence, the non-participatory System Dynamics approach poses risks of solving the wrong problem and policy resistance produced by unsatisfied interests of participants (Vennix, 1996a, 1999).

In many cases, this approach is also characterized by a high complexity of models. Some modelers trying to portray reality build very precise, but extremely complex models that require much time for understanding and modelling expertise. For that reason, many models were never used in practice (Größler, 2007).

In this type of projects, people usually aren't involved in all stages of the modelling process. They might participate in data gathering and testing policy options. But the list of variables in the model and proposed actions highly depends on the modeler's and CEO's points of view.

2.5. Group Model Building Approach

In contrast to the non-participatory approach, Group Model Building (GMB) actively involves stakeholders in all steps of the modelling process. Therefore, models value diverse opinions and represent various points of view. As well, problems are well-defined, which decreases the risk of solving the wrong problem (Rouwette & Vennix, 2008).

Sometimes a model built with stakeholders becomes too complex due to detailed representation of their daily routine. But when it comes to dissemination of modelling results across the company, the modelling group usually realizes the need for simplification (Campbell, 2001). Thus, it is important to find a balance between reality and complexity.

It worth noting that Group Model Building projects help to find a common ground between stakeholders. It might seem like a by-product of modelling, but it has a significant effect on the implementation of a chosen policy option. A research made by Nutt is a clear testament to this. He has analyzed 400 decisions and concluded that decisions imposed by the top-management without a discussion with employees take much longer time for implementation and face stakeholders' resistance (2004, 2008).

2.6. Transition from the Non-Participatory Approach to Group Model Building

Initially, this project implied limited participation of stakeholders, mainly through a series of semi-structured interviews. But during the first meeting with the head of Information Services Department, it was noted that views differ significantly among report writers, and that it would be

beneficial to create a common vision. As well, he was enthusiastic about the System Dynamics approach and wanted to disseminate it in the company. Thus, instead of classic format of modelling projects, it was decided to use a Group Model Building approach.

2.7. Planning of GMB Sessions

The redesigned format of the project led to a question how many Group Model Building sessions should be conducted to build the model. It was decided that the main bulk of the technical modeling work will be undertaken in between workshops due to the limited availability of participants.

It was not clear how many workshops it would be possible to organize. For that reason, their number was brought to a minimum. The possibility of a single two-day workshop was discarded due to the lack of time for model clarification and updates. The idea of organizing a considerable number of workshops also was dismissed due to the limited stay of the author in North Dakota. In the end, it was decided that three workshops would be sufficient to build the model that satisfies the aim of the project.

Based on this number, the project outline presented in Figure 5 was developed. During the first workshop, the chosen goal was to clarify the problem definition and elicit the initial list of variables. The second session was planned to present the updated model and deliberate on policy options. The third workshop was planned to be an interactive learning environment, in which the participants could gain confidence in the model and test various policy options.

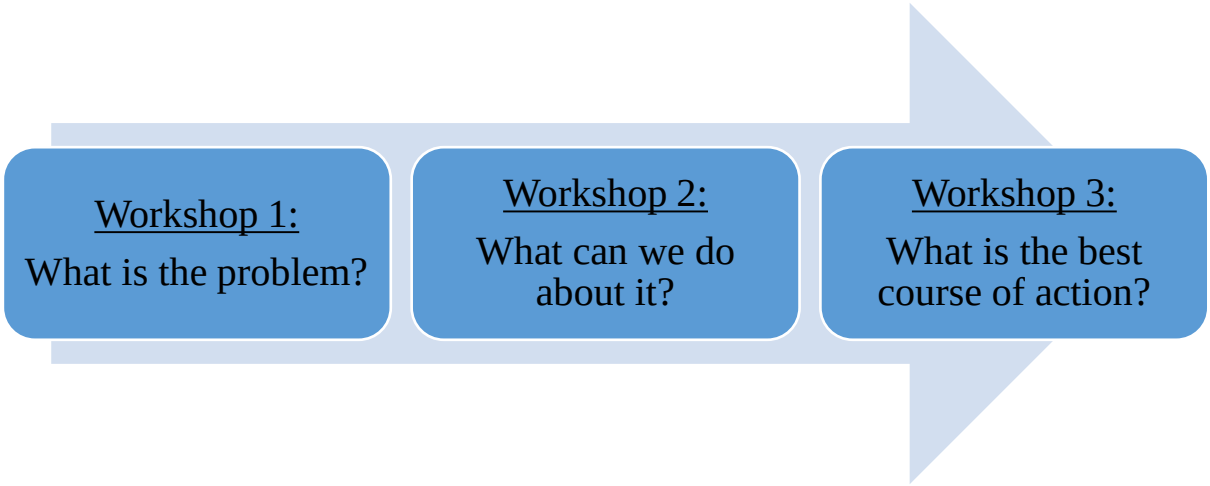


Figure 5. Project Outline

The conducted Group-Model Building workshops are described in the following chapters.

Chapter 3. First Group Model Building Session

In this chapter will be described planning of the first workshop, its outputs and the process of its conduction.

3.1. Preparation of the First GMB Session

Preparation of the first session took longer than the preparation of other sessions since it was necessary to solve many organizational questions. For that reason, the first workshop is described in more detail and the subsequent chapters will mainly focus on differences between sessions.

3.1.1. Room Layout

Room layout has a profound impact on the effectiveness of workshops. In that regard, the meeting space was chosen based on the recommendations provided by Andersen, Richardson, Vennix and Rouwette (Andersen & Richardson, 1997; Rouwette & Vennix, 2008). The room layout of the place where the first workshop was conducted is provided in Figure 6.

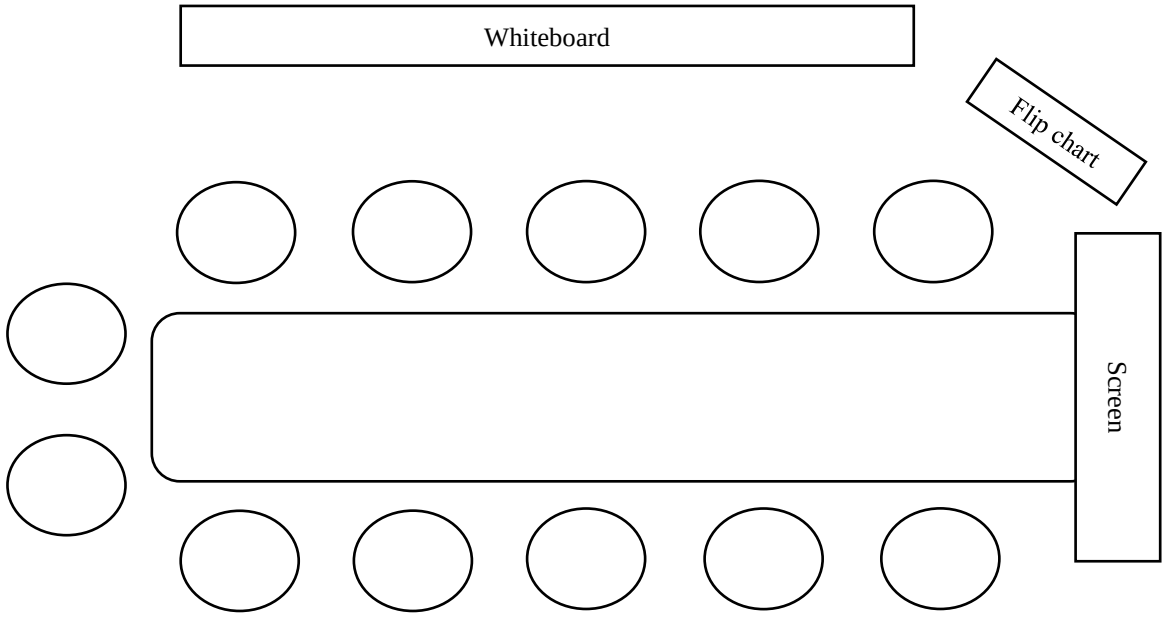


Figure 6. Room Layout

This room layout provides a good atmosphere for eye contact and communication and screen presentation. However, the whiteboard content isn't visible for some of the participants. They have to rotate to see what's going on. It was a bit problematic during the first workshop, but it wasn't possible to adjust room layout or change the meeting room. Nevertheless, it didn't affect much the group productivity and obtained results.

3.1.2. Roles of Team Members

Group Model Building might be challenging to be led by a single person, especially when a simulation model is needed. Thus, the change of the project format has led to a need for forming a modelling team to successfully conduct GMB workshops. Fortunately, Arielle Selya, the assistant

professor of the University of North Dakota and the head of the Information Services Department were interested in the method and helped with the organization and conduction of sessions.

The roles of team members were allocated according to the guidelines provided by Anderson and Richardson (1995) . They distinguish five key roles:

- **Facilitator.** S/he is responsible for group process and actively interact with participants, trying to lead the discussion structured and objective.
- **Process coach.** S/he keeps track of group dynamics and analyses what went right or wrong. It worth noting that the process coach doesn't interrupt the facilitator during the workshop and voices her/his opinion only during breaks.
- **Modeler or reflector.** S/he is mainly responsible for the model construction and its updates. Thus, this team member should have extensive modelling experience. Sometimes modeler might have some content knowledge about the problem that might help to build a more comprehensive structure.
- **Recorder.** S/he is responsible for taking notes that can be used for the preparation of workbooks, model upgrades and the final report.
- **Gatekeeper.** S/he is usually a person that interested in the organization of Group Model Building project in the company and serves as a liaison between modelling team and stakeholders.

But the involvement of five different people in the modelling process quite often might be impossible and irrational in dealing with small groups. In fact, one person can combine several roles (Vennix, 1996).

For these reasons, and because group facilitation might be exhausting, in this project, workshops were divided into two parts, each of them was led either by the author or professor Selya. The person that facilitated the first part was responsible for model building and taking notes during the second part of the workshop, and vice-versa.

Also, it was known that some interpersonal conflicts might occur and that participants tend to go ahead of agenda. Thus, the head of Information Services department served as a gatekeeper and helped to keep the group on the right track.

3.1.3. Purpose of the First Session

The first session was aimed to clarify the problem definition, starting from the combination of different points of view and ending with elicitation of the list of problem-related variables. As well, it was necessary to explain the basics of System Dynamics and introduce the common outline of the project and the format of Group Model Building sessions.

3.1.4. Schedule of the First Session

The schedule of the first session is presented in Table 1.

Table 1. Schedule of the First Session

Time	**Activity**	**Comments**	**Roles**
10:30-10:40	Introduction	Who we are, schedule of the project, agenda of the first workshop	Ekaterina & Arielle
10:40-11:00	Problem definition	To define the problem, Nominal Group Technique was used. Participants were asked to write down on separate lists of paper what do they think the problem is. Afterwards, all ideas were placed on the whiteboard and discussed. Then they were divided into separate clusters. And the group was asked to choose the most critical issue.	Arielle – facilitator, Ekaterina – recorder, Ian – gatekeeper.
11:00-11:20	Problem progression over time	The graph provided in Figure 8 was presented as an example of problem progression over time. It has a solid line from the starting point until the current point of time and two dashed lines representing hoped and feared behaviors. Participants were asked to draw the graphs representing their perception of the reports' delivery time and its development. Then obtained figures were classified and discussed. Afterwards were presented some actual data from the tracking system.	Arielle – facilitator, Ekaterina – recorder, Ian – gatekeeper.
11:20-11:30	Basic notions of System Dynamics	Figure 10 was presented to explain basic notions of System Dynamics. As well, was mentioned the video that was sent out to participants before the workshop.	Arielle – facilitator, Ekaterina – recorder, Ian – gatekeeper.
11:30-11:40	Break	Discussion of the process	-

Time	Activity	Comments	Roles
11:40-11:55	Concept Models	After the break, concept models that were presented to show the accumulation process. They were built on the actual data and represented actual and desired situations.	Ekaterina – facilitator, Arielle – recorder, Ian – gatekeeper.
11:55-12:20	Elicitation of the key variables	To get the list of key variables was used Nominal Group Technic. Participants were asked to write down on separate lists of paper what do they think should be included in the model. Afterwards, all ideas were placed on the whiteboard and discussed.	Ekaterina – facilitator, Arielle – recorder, Ian – gatekeeper.
12:20-12:50	Implementation of the key variables into the concept model	Proposed variables were clustered and implemented into the concept model.	Ekaterina – facilitator-Arielle – recorder and modeler, Ian – gatekeeper.
12:50-13:00	Wrapping up	Outputs of the session were wrapped up. As well, were discussed plans for the upcoming sessions.	Ekaterina – facilitator-Arielle – recorder, Ian – gatekeeper.

3.2. Activities Undertaken During the First Session

3.2.1. Problem Definition

Initially, the problem was described by the head of the Information Services department. He pointed out some weak points of the report request process, including unsatisfactory reports delivery time. As well, he mentioned that the backlog of report requests is constantly growing due to the connection of Critical Access Hospitals and increasing number of regulatory check-ups. He also was concerned about the suboptimal allocation of tasks since report writers mainly choose them on their own. He underlined that it might lead to a low productivity in case if a chosen report turns out to be too complex for an inexperienced report writer.

Group Model Building practice shows that problem definition provided by a single person might significantly differ from the group vision (Vennix, 1999). For that reason, it was decided to clarify the problem definition within the group of participants at the beginning of modelling process.

Initially, was planned to elicit ideas in the round robin fashion, as it supposes Nominal Group Technique (Delp, Thesen, Motiwalla, & Seshardi, 1977). But due to the tight timetable of the meeting, it was decided to save some waiting time to speak by asking participants to write down their own problem definitions instead of voicing it. Communication during the first part of the exercise was prohibited to decrease negative influence of the group pressure on the effectiveness of the meeting was decreased. The list of obtained ideas is provided below. Some of them is occurring multiple times that represents their high actuality and importance.

- Priority
- Number of service-now tickets
- Number of completed service-now tickets
- Time to complete "Service Now" tickets
- Priority (high, medium, low)
- Customer Satisfaction
- Location of Data Needed (correct) in Database
- Phone Calls vs. "Service Now" tickets and incidents
- Call in requests
- "Service Now" User Interface
- End User Expectations
- Communication with end users (via "Service Now")
- Organization/Priority of Tasks
- No clear prioritization of reports requests
- Area of expertise
- Unclear who gets to choose what tickets to work on (priority and experience)
- End User Expectations vs. Current Workload and number of customers
- Application needs work for all users – no way to know where they are in the queue
- How to handle "Service Now" issues more efficiently?
- How to resolve end user requirements more efficiently?
- How to minimize tasks?
- Customers not knowing what they need, or what they state is different than the real report request
- Communication with Customers
- Time to complete report requests
- Time to complete tasks
- Time
- Others' work

Afterwards, proposed ideas were placed on the whiteboard and clarified. Similar proposals were grouped together as portrayed in Figure 7.

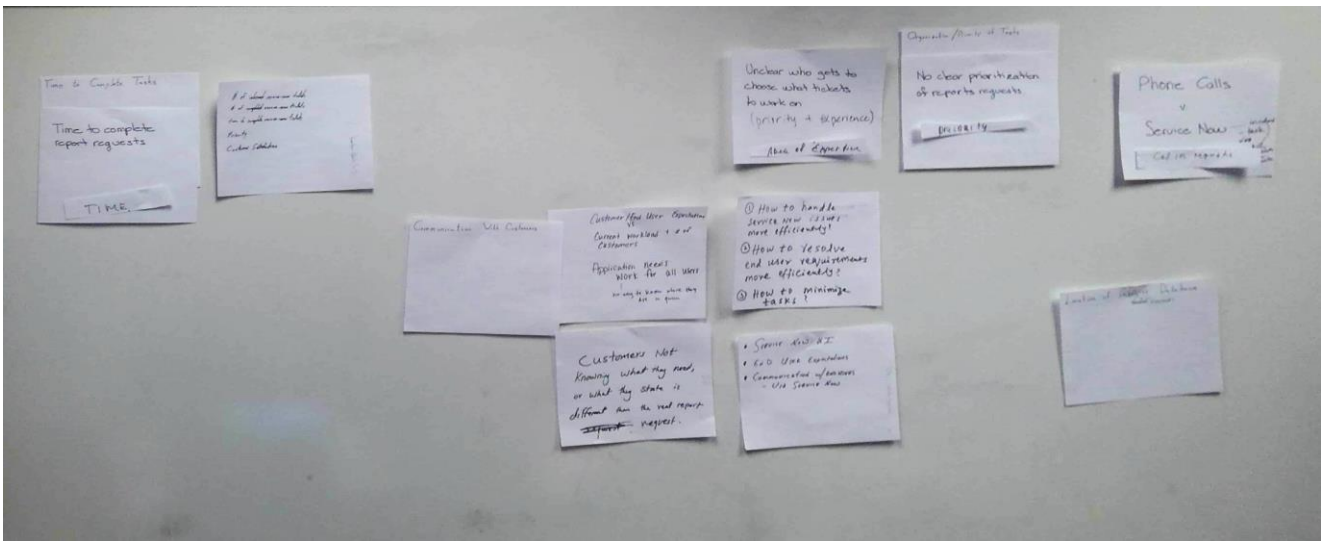


Figure 7. Problem Definition

As a result of the discussion, the group came to a decision that the reports' delivery time is the most critical aspect. In addition, it worth noting that some of the initial concerns of the head of Information Services department didn't occur during the first meeting. For that reason, the focus of the model was shifted from the allocation problem into other areas.

3.2.2. Problem Progression over Time

When the problem was defined, its perceived progression was obtained using Graphs over Time script (Hovmand, Etiënne, Rouwette, Andersen, Richardson, & Kraus, 2013: 23–25). Figure 8 is an example of the problematic behavior over time that was shown to participants before they were asked to draw their own graphs. In this figure, the vertical axis represents an indicator of the problem and the horizontal axis represents the time frame. The solid line shows the progression of the problem until the current moment, and dashed lines describe hoped and feared scenarios of potential future development.

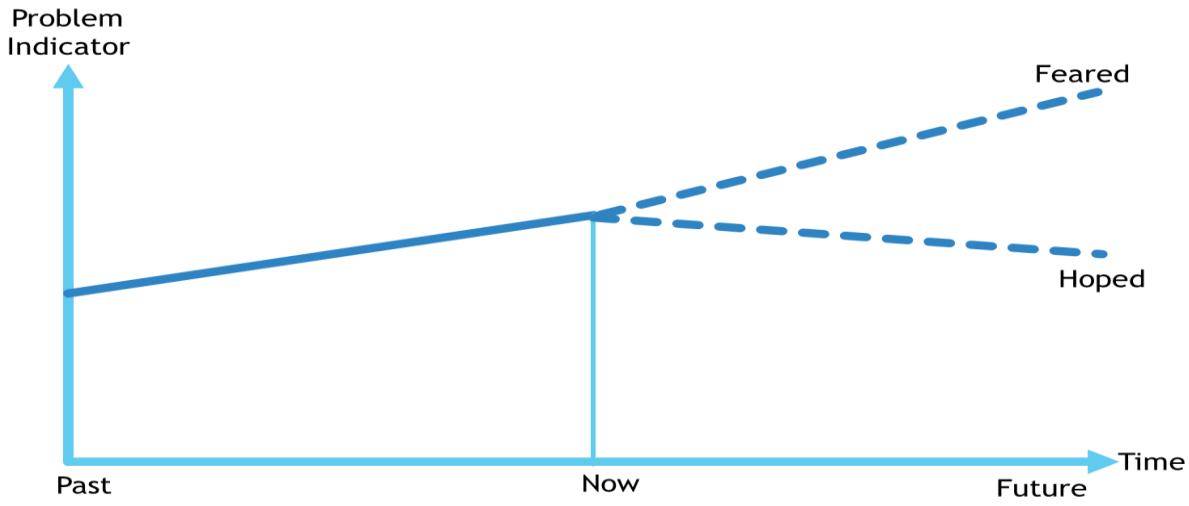


Figure 8. Example of the Problem Progression over Time

After the explanation of this example, participants started to portray their perception of changes in the reports' delivery time. Their graphs are presented in Figure 9.

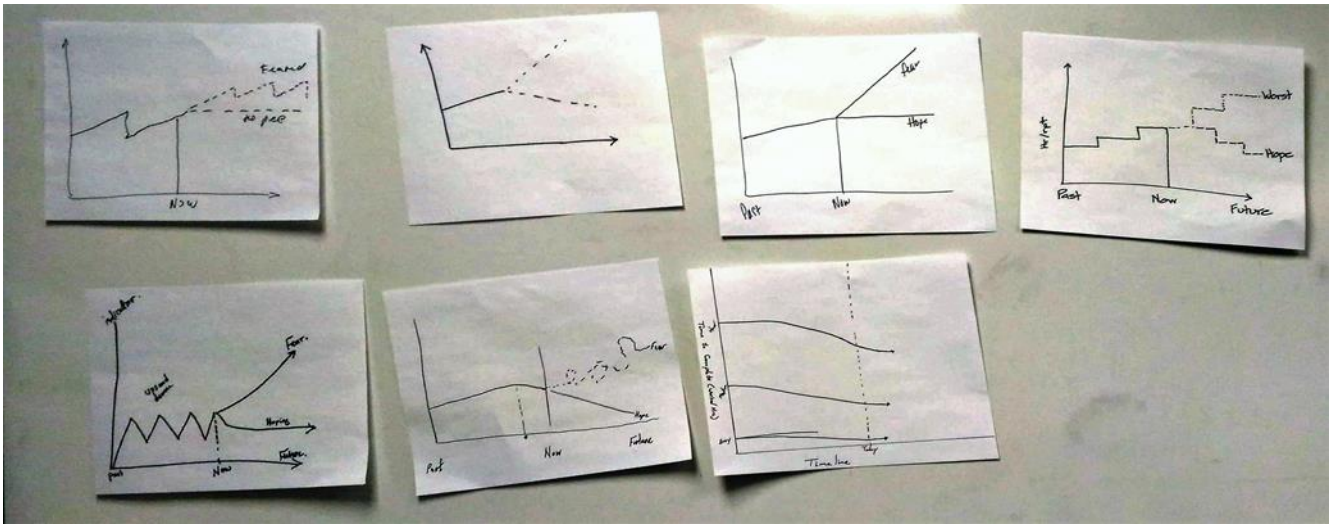


Figure 9. Problem Progression over Time

As we can see from the figure above, most people recognized the increase of reports' delivery time as the feared scenario and its decrease as the hoped scenario. Some graphs also contain fluctuations of this indicator that mainly is caused by routine updates to the database. The last graph represents a learning curve, showing the decrease of time needed for reports' delivery in the process of gaining experience and skills.

Surprisingly, these perceptions significantly differ from the actual data obtained from "Service Now" that are presented in Figure 2. Some reasons for that were already discussed in Chapter 1, such as poor usage of the ticket tracking system and the considerable number of informal requests. But overall, it seems like only one graph proposed by participants that describes the learning curve is not far from the real data.

Based on this insight, it was decided to further investigate the learning effect on productivity and the reports delivery time and include them in the model.

3.2.3. Basic Notions of System Dynamics

After clarifying what is the problem and how is perceived its progression, the basic notions of the System Dynamics were presented. An analogy with a bathtub proposed by Jay Forrester and framed by John Sterman, was used to explain elements of Stock and Flow Diagrams. They have three types of elements: stocks, flows and variables that determine the speed of flows. A stock can be imagined as a bathtub that is filled through a water tap (inflow) and emptied through a drainpipe (outflow). The difference in speed of filling and emptying accumulates in a bath. Variables can be imaged as valves connected to these pipes.

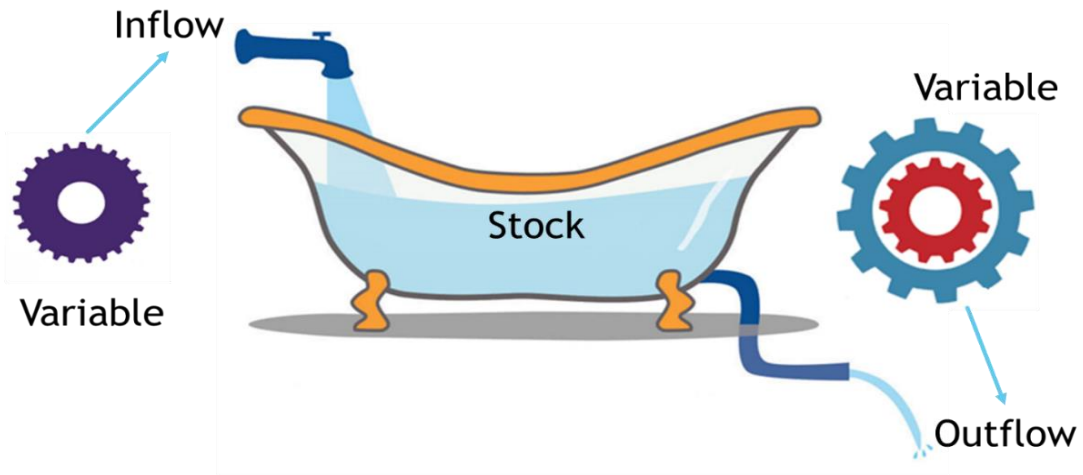


Figure 10. Basic Elements of System Dynamics Models

The described above analogy is presented in Figure 10.

3.2.4. Concept Models

Following the explanation of basic notions of System Dynamics, two small concept models were presented to participants that were built based on the actual data. It assisted to show how Stock and Flow diagrams look in a simulation software and how this approach can be applied to model the problem.

Initially, the use of conceptual models was proposed by Richardson. He argues that they can serve as a good starting point in the Group Model Building projects (Richardson, 2013). However, some authors point out that a group might lose the sense of model ownership. As well, preliminary interviews are prerequisite to building a good concept model. Thus, there is no universal answer to the question should they be applied or not. Nevertheless, if it's planned to build a quantitative model, and the time is limited, many authors recommend to use them (Rouwette & Vennix, 2008; Vennix, 1996b).

Based on these pros and cons, it was decided to use the concept models during the first workshops. It worth mentioning that participants were encouraged to change everything that they don't like or even completely discard them and start over. That was done to prevent the group from losing the sense of ownership.

In Figure 11 is provided the data from the ticket tracking system. They cover the period from January 2016 till March 2018.

Opened tickets	
Total	2,118
Avg/Week	18
Median/Week	17
Max/Week	37
Min/Week	1

Closed tickets	
Total	2,012
Avg/Week	17
Median/Week	17
Max/Week	47
Min/Week	1

Closing time in days	
Total	4,127
Average	36
Median	31
Max	156
Min	1

Figure 11. Data for Conceptual models (“Service Now”)

However, the entire range of data wasn't available by the time when the conceptual model was built. For that reason, the difference between the number of opened tickets and closed tickets was used as the initial stock value instead of the actual number of the backlog of report requests in January 2016. Thus, concept models rather project the future, than replicate the past. As well, it's important to mention, that they represent only formal report requests, created through "Service Now".

Each concept model contains a single stock, that represents the backlog of report requests. As well, they contain one inflow that shows the report request creation rate and one outflow that reflects report requests fulfilment rate. The outflow is determined by the number of report writers and the productivity per writer per week. The inflow is determined exogenously and uses average request creation rate during last two years.

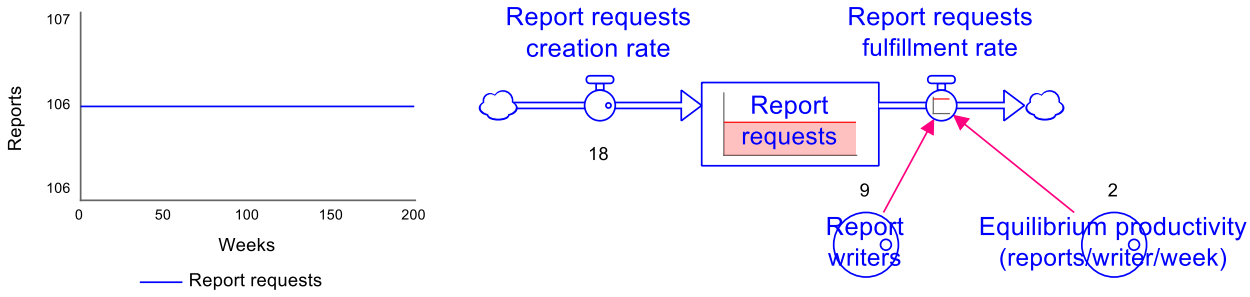


Figure 12. Concept Model in Equilibrium State

The first model that is presented in Figure 12 represents an equilibrium state of the system when the report requests creation rate is equal to the report requests fulfilment rate. Therefore, the backlog of report requests is constant and equal to 106 report requests. The Information Services Department might seek measures to bring this number down, so we can only conditionally count the equilibrium state as desirable.

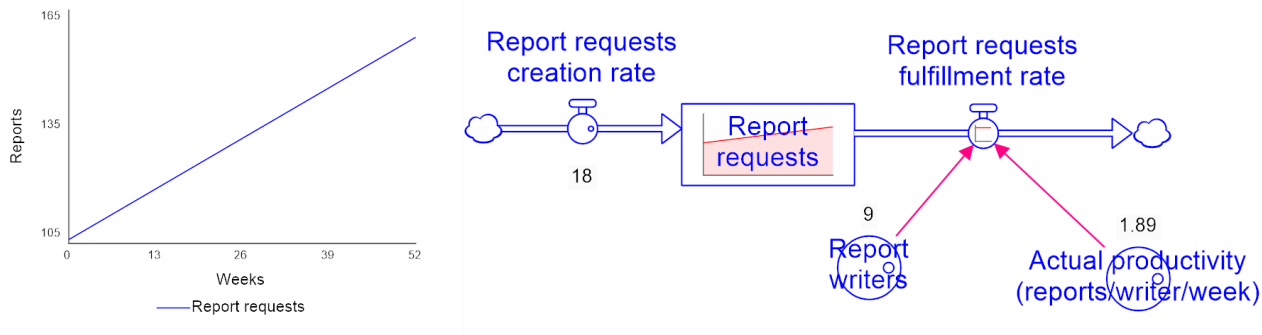


Figure 13. Concept Model

The model in Figure 13 represents the state of the system when the report request fulfilment rate is slightly lower than the report request creation rate. The difference between them is just one report per week, but in a year, it will increase the backlog by 55 percent, from 106 to 165 unfulfilled reports.

These tiny models helped to increase understanding of the accumulation process and served as a starting point for the further model development.

3.2.5. Key Variables

Subsequently, to upgrade the concept models presented above was elicited the list of the key variables. Nominal Group Technique was used to elaborate them. Participants were asked to write down on separate sheets of paper as many variables as they wish without communication with each other.

Afterwards, they were placed on the whiteboard. The discussion helped to clarify some terms that were used by employees of the Information Services Department but were not clear to people outside the company.

The list of ideas is provided below. Some of them is occurring multiple times that represents their high actuality and importance:

- Area of expertise
- Increasing complexity of requests and available data
- Task Difficulty (similar previous tasks, familiarity with Request Needs, Requirements: fields, standardized report filters special display requirements)
- Priority
- Number of Nova Notes (Database upgrades)
- Number of report writers out of office
- Mental Trashing – change from one task to another ->number of tasks
- Non-"Service Now" Request
- Non-reporting requests
- Unexpected projects (i.e. certification, upgrades of the database and urgent requests)
- Unstable/unpredictable tasks/projects with wide scopes of materials and changing requirements
- "Critical" unplanned projects/reports from upper management
- Unknown/Last Minute Critical tasks
- External work to "Service Now" (i.e. teaching users)
- Communication: Language (Vocabulary, Time, Email, Phone)
- Other tasks not reporting (i.e. interfaces)
- Report Pool: Financial, Clinical, Unsure (customers)
- Minutes in meetings per day
- Time
- Minutes answering questions
- Number of report Requests
- Number of Phone Requests
- Number of Email Requests
- Requestor response Time (communication delay)
- Time required by (date by): regulatory deadline, due date

- Time (requested) – requests (entry) date from the customer
- Miscommunication between users and us

Similar ideas were grouped in clusters. The results of clustering are shown Figure 14.

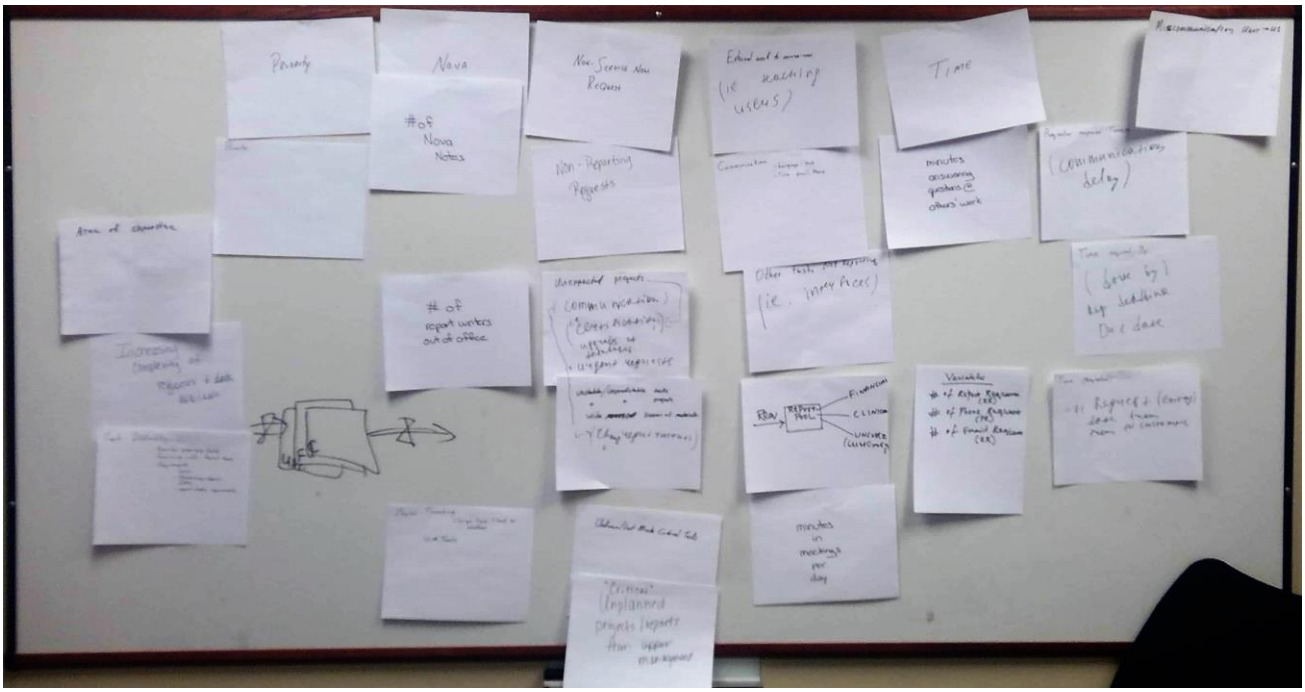


Figure 14. List of Key Variables

Based on these clusters, it became clear that the time available for report writing and time spent on other tasks, as well as the complexity of reports and closeness to the deadline, should be specified in the model in more details.

3.2.6. Model Built During the First Workshop

At the end of the first workshop, the concept model that represents the actual state was combined with the variables proposed by participants. It worth mentioning that most of the links represent “wishful thinking” and requires further elaboration. As well, some elements are just placed in the assumed position, but available time during the workshop was not sufficient to properly include them into the model structure.

The model built the first workshop is presented in Figure 15. It has a chain that represents the process of creation, assignment and fulfillment of report requests. It contains three stocks: number of open reports, report requests in process and number of completed reports. As well, the stock of reports waiting an answer from customers should be added between the stocks of report request in process and completed reports.

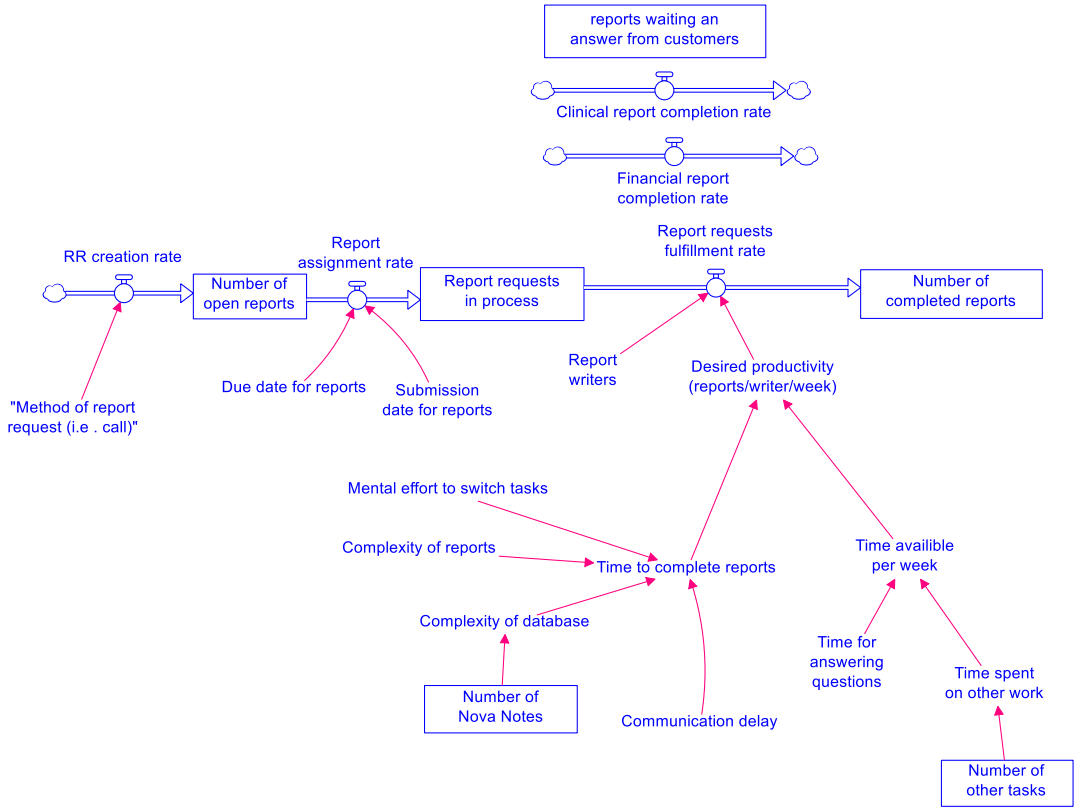


Figure 15. Model Built During the First Session

Participants proposed that methods of report request creation should be divided into separate categories, i.e. “Service Now” requests and Phone & Email requests. At the first glance, that it's not a problem to implement it. However, there was no reliable data for the proper realization.

Created reports are inflowing to the stock of open report request, which has an outflow called the report assignment rate. It sounds logical to connect this rate with the due date for a report and with the submission date. But these dates might differ across reports. Thus, it might be needed to further segregate the stock of open report requests or use a conveyor to properly determine it. As well, the effect of the deadline might be non-linear. Thus, the links between these two variables and the assignment rate are rather "wishful thinking" links.

Assigned reports flows into the stock of the report request in process. Report requests fulfillment rate is the outflow from this stock. This rate is determined by the productivity of report writers and their number, as it was done in the concept models. However, the productivity was further decomposed on time to complete reports and time available per week, to portray the effects of database and report complexity and other tasks and distractors.

It worth noticing, that some participants thought of splitting this flow into financial and clinical reports completion rates. However, because only one report writer works on financial reports, this idea was dismissed.

Also, it was proposed to introduce the stock of reports awaiting an answer from the customer since the report request can only be closed by an end-user, not by a report writer.

3.3. Work After

The model presented in the previous section was clarified and updated. Some elements that were not proposed by participants were added to avoid inconsistency of units and make the model simulate. Based on these updates, a list of questions was created to further improve the model structure and quantify the key variables. The updated version of the model and the questionnaire are provided in the next chapter.

In addition, a workbook was created to wrap up the key outputs of the first session and send out to participants before the second session.

Chapter 4. Second Group Model Building Session

This chapter is devoted to describing the activities undertaken for the second GMB session. It also includes the description of an updated version of the model and a discussion of the answers obtained from the participants' questionnaires.

4.1. Preparation of the Second GMB Session

The preparation of the second session took less time than the preparation of the first session since many of organizational questions, such as room layout and role allocation had already been solved and remained unmodified. The main changes took place in agenda and the purpose of the workshop.

4.1.1. Purpose of the Second Session

The second workshop was aimed to elicit the list of possible policy options that could be implemented in the model structure. Also, it was necessary to present the updated version of the model and clarify if there is a need for its changes.

4.1.2. Schedule of the Second Session

The schedule of the second session is presented in Table 2.

Table 2. Schedule of the Second Session

Time	Activity	Comments	Roles
13:00-13:10	Introduction & Recap	Presentation of the agenda of the second workshop and a brief recap what was done at the first session.	Ekaterina – facilitator, Arielle – recorder, Ian – gatekeeper.
13:10-13:40	Model Presentation	Presentation of the updated version of the model. Clarification of uncertain elements and connections in the model by asking questions to participants (i.e.: What should be added to the model? What elements & connection does not make sense?).	Ekaterina – facilitator &modeler, Arielle – recorder, Ian – gatekeeper.
13:40-14:00	Discussion & Clarification of Responses from Questionnaire	Presentation of aggregated answers and clarification of ambiguous responses (i.e. Do participants include the communication delay in reports completion time? How to distinguish complex & simple report requests?)	Ekaterina – facilitator& modeler, Arielle – recorder, Ian – gatekeeper.

Time	Activity	Comments	Roles
14:00-14:20	Data Incorporation	Incorporation of questionnaire results into the model; presentation of the simulation results.	Ekaterina – facilitator& modeler, Arielle – recorder, Ian – gatekeeper.
14:20-14:35	Break	Discussion of the process among the modelling team.	-
14:35-14:50	Presentation of the data from "Service Now"	Presentation and explanation of the data from "Service Now". Data inconsistency provoked by the poor usage of the tracking system was pointed out and discussed.	Arielle – facilitator, Ekaterina –- recorder & modeler, Ian – gatekeeper.
14:50-15:50	Elicitation of Policy Options	To elicit the list of possible policy options was used Nominal Group Technique. Participants were asked to write down on separate lists of paper what do they think might solve the problem. Afterwards, all ideas were placed on the whiteboard and discussed. Then they were divided into four clusters.	Arielle – facilitator, Ekaterina –- recorder & modeler, Ian – gatekeeper.
15:30-15:50	Implementation of proposed policies into the model	Discussion how the proposed policies can be implemented in the model structure considering their potential costs and benefits.	Arielle – facilitator, Ekaterina –- recorder & modeler, Ian – gatekeeper.
15:50-16:00	Wrapping up	Wrapping up the results of the session & discussion what will be done at the final workshop.	Arielle – facilitator, Ekaterina –- recorder, Ian – gatekeeper.

4.2. Activities Undertaken During the Second Session

4.2.1. Model Presented at the Second Workshop

The second session started with the presentation of the updated version of the model built based on the outputs of the first workshop. To ease the explanation of the changes, white and orange colors were used to portray the elements proposed by participants and the light blue color was used for elements added to avoid unit inconsistency and make the model running. The orange color and

dashed arrows were used to highlight links and variables that need to be further considered or excluded from the model structure.

The updated version of the model will be explained brick by brick, starting from a simple single stock construction presented in Figure 16. The stock of new report requests represents all requests, that were obtained from clients but don't have an author yet. It has the inflow RR creation rate representing how many reports' requests are gotten per a week and outflow RR assignment rate showing the process of reports' allocation.

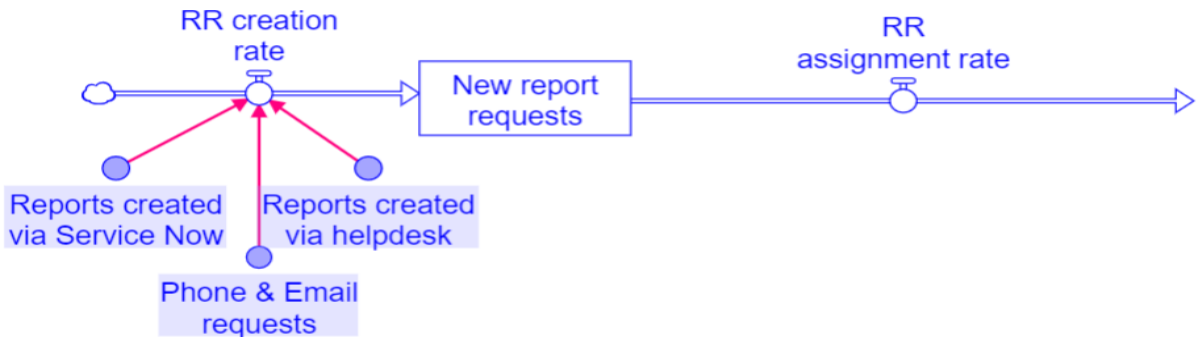


Figure 16. RR Creation Rate

Report request creation rate is determined as the sum of report request created via "Service Now", via email and phone and via Helpdesk. It turned out that the reports created via Helpdesk should not be count separately, because they go into requests created via "Service Now" and phone & email requests.

Figure 17. RR Assignment Rate

On the first workshop, it was proposed to consider the effect of due and submission dates[2]on RR assignment rate. But stock concept assumes perfect mixing of its elements, thus all reports and their deadlines are equal. For that reason, another tasks allocation rule was used. The model assumes that after the completion of a report/ or a bunch of reports follows by choosing a new task/ tasks. Hence, RR assignment rate is equal to RR completion rate.

[2] In the model, they are connected to the assignment rate by dashed lines and highlighted by the orange color. That means that they require further elaboration and might be implemented in the model later (but not necessarily).

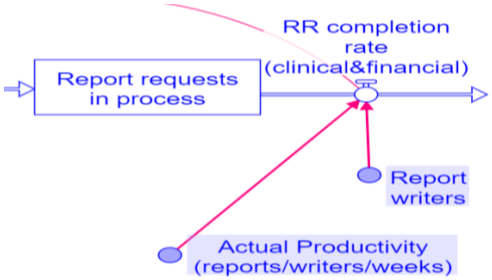


Figure 18. RR Completion Rate

RR completion rate depends on how many writers are available for report writing and their productivity. For simplicity, it's assumed that all report writers have equal productivity. The final model will include the learning curve for new writers.

Productivity is determined by the time available for report writing and time to complete reports. For instance, if 30 hours are available per week on report writing and the completion of a single report request takes 15 hours, two reports can be completed per week.

Also, it's planned to consider the effect of desired productivity on the actual productivity. It might be introduced later along with policy options.

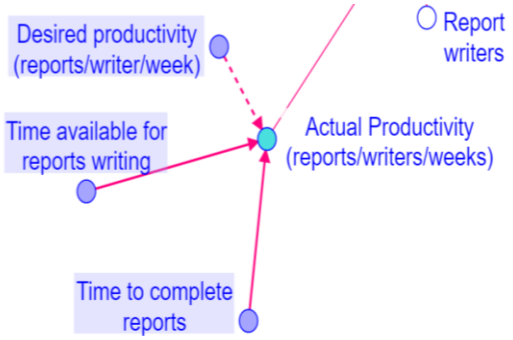


Figure 19. Actual Productivity

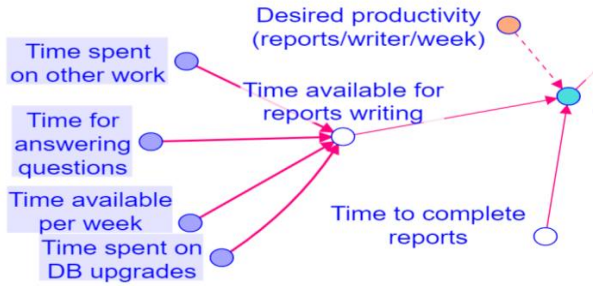


Figure 20. Time Available for Report Writing

In addition to report writing, there are plenty of other things to do, from answering questions to upgrades and maintenance of the database. Hence, it needs to be subtracted from the time available per week to get the time available for report writing.

Time to complete reports might depend on the complexity of database, the complexity of reports and efforts to switch tasks. Also, a learning curve might take place. Their incorporation into the model needs further elaboration.

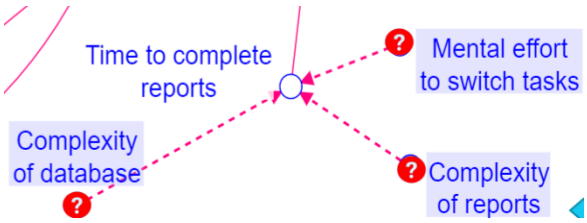


Figure 21. Time to Complete Reports

When reports are completed, they are sent to the customers for revision. Usually, it takes about a week to get a response, which is represented by the communication delay. A client might either accept a report or ask for some corrections. The probability of acceptance determines acceptance and rejection rates.

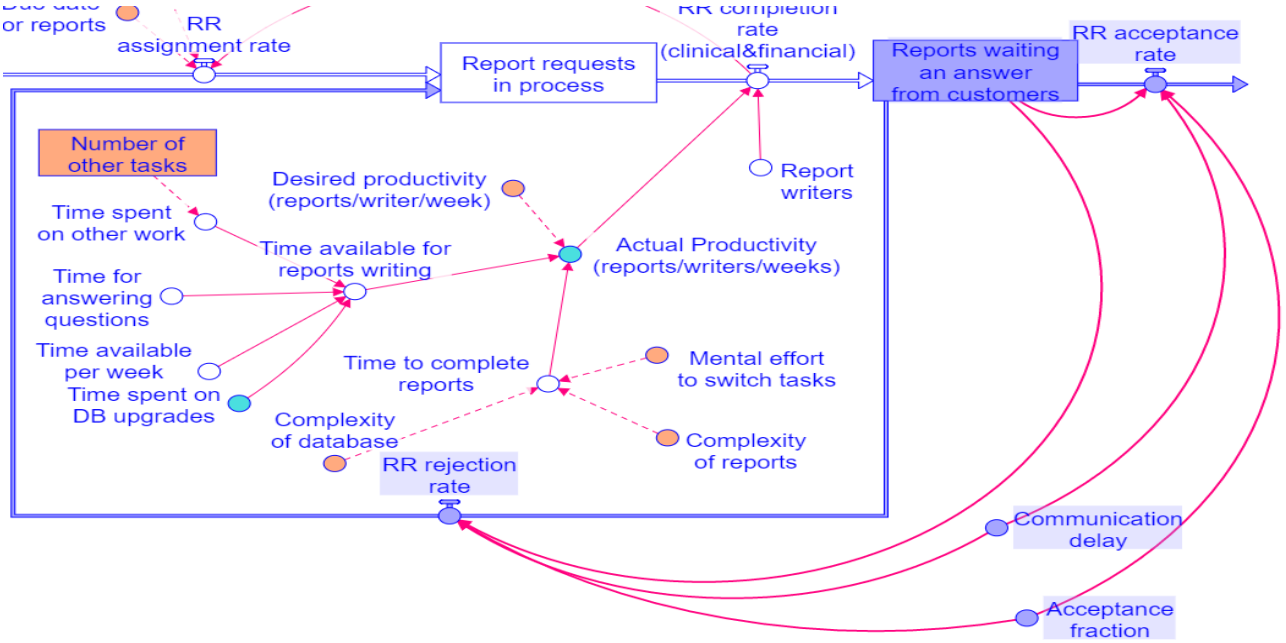


Figure 22. Acceptance and Rejection of Report Requests

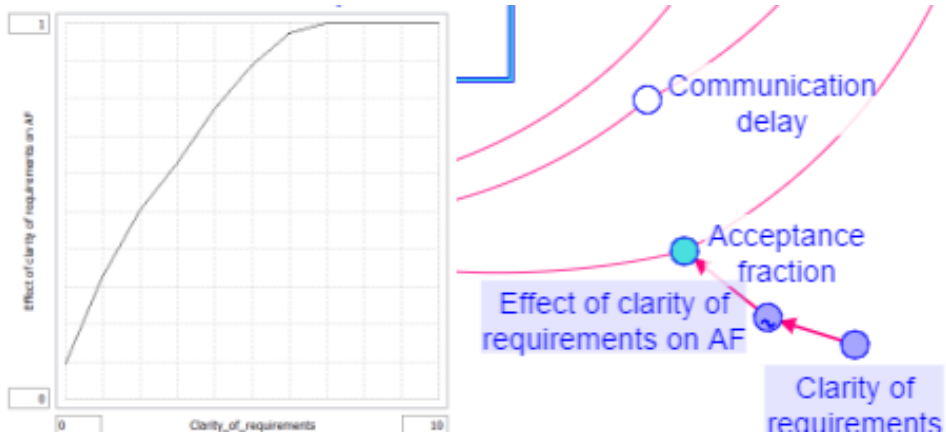


Figure 23. Effect of Clarity of Requirements on Acceptance Fraction

In turn, acceptance fraction depends on the clarity of requirements. The higher quality of requirements the higher probability of reports' acceptance.

Nevertheless, it's hard to measure such a soft and subjective variable. For instance, if a report writer has extensive experience in a specific field, he/she already knows what to put in a report no matter how vague users' needs are. Also, it's challenging to aggregate. Thus, it was decided to exclude clarity of requirements from the scope of the project. However, this is a good direction for further model development.

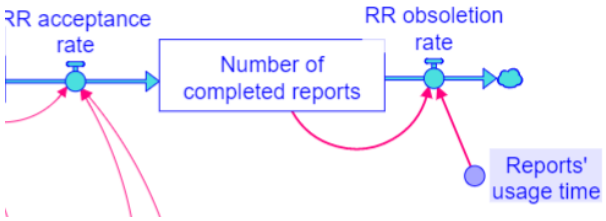


Figure 24. RR Obsoletion Rate

When reports are accepted by customers, they come into the pile of completed reports. Usually, they have certain lifespan, that is driven by data obsoletion and workforce changes. It was agreed that the lifespan is around two or three years.

Hence, only currently used reports will be fixed after the database upgrade. The value for fixing reports per the EPIC update was obtained based on the questionnaire.

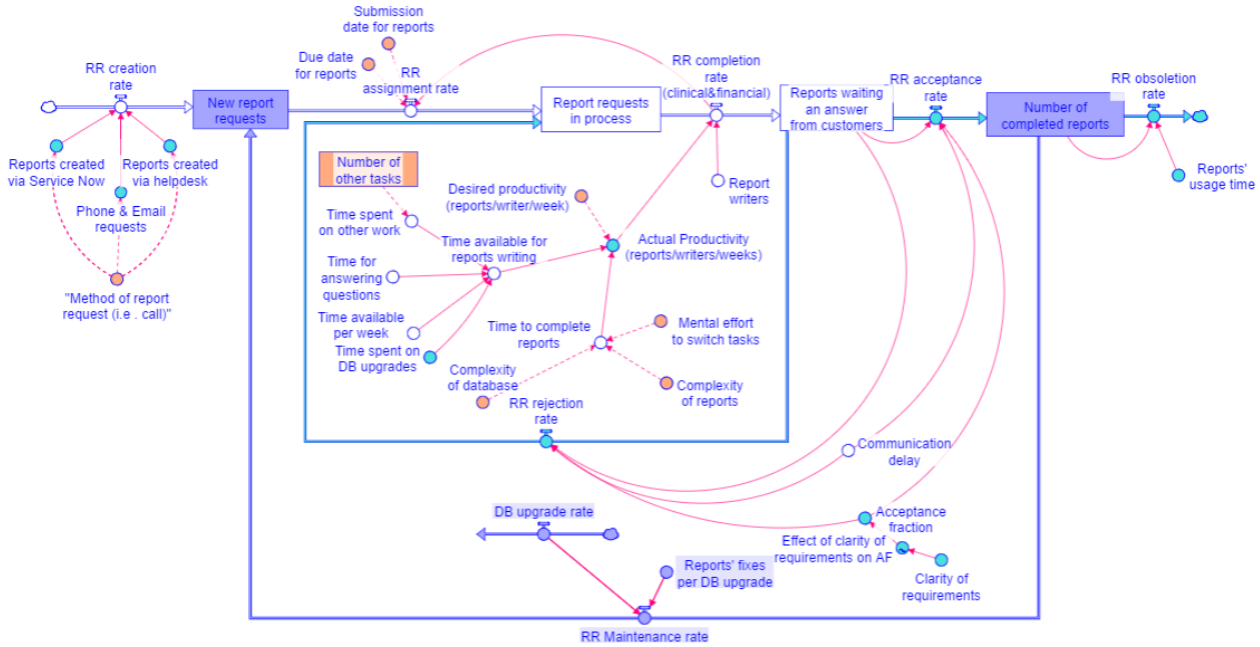


Figure 25. RR Maintenance Rate

However, reports that need to be fixed typically skip the revision process. Thus, in the final version of the model broken reports will go to a different pile than new reports. This was fixed in the final model.

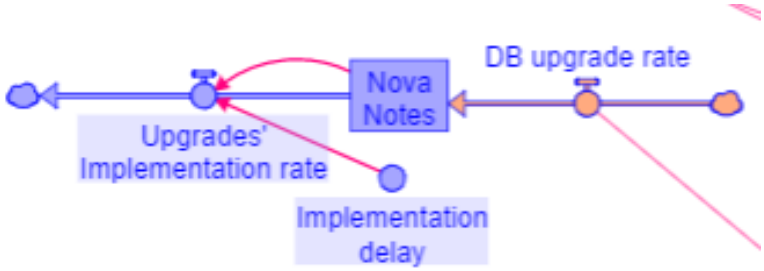


Figure 26. Database Upgrades

In addition, EPIC upgrades also need to be implemented in all related systems. Usually, it doesn't happen immediately, but with a certain delay that might be around 3 - 4 months.

The time spent on database upgrades should be excluded from the time available on report writing. The time spent on a single DB upgrade was chosen based on the assumption that some spend more time due to immediate participation in the implementation process and others only read release notes.

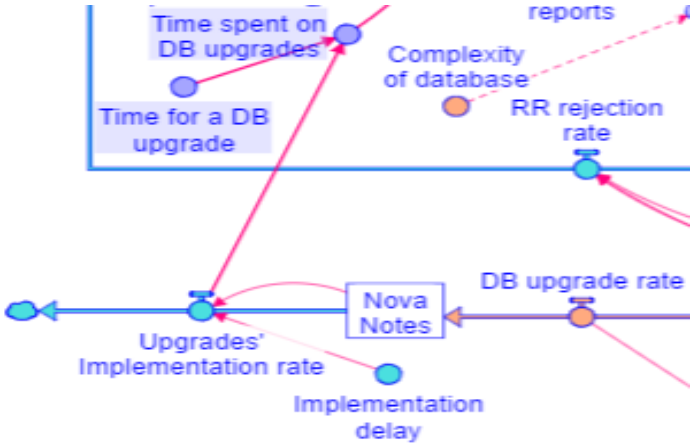


Figure 27. Time Spent on Database Upgrades

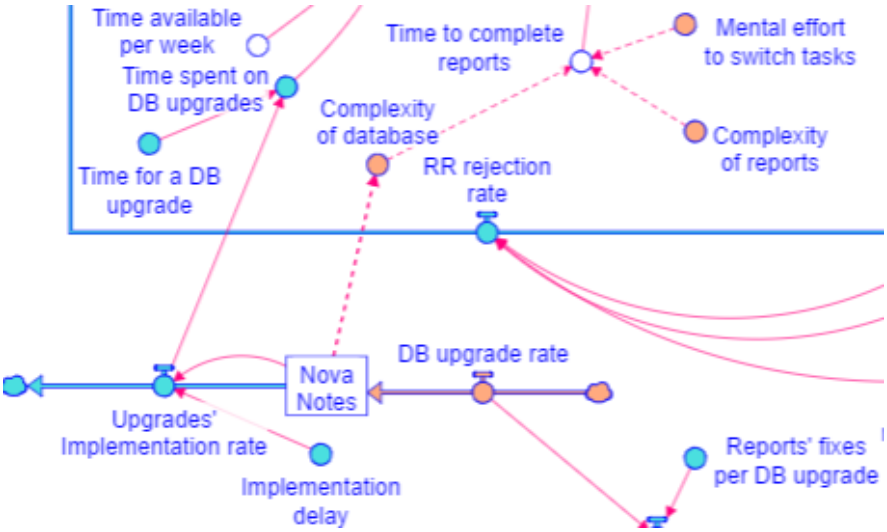


Figure 28. Effect of Upgrades on Database Complexity

Also, there might be a link between the number of Nova notes and database complexity. It may be further elaborated in the future, but not necessarily, since the effect of upgrades is already taken into consideration in multiple ways.

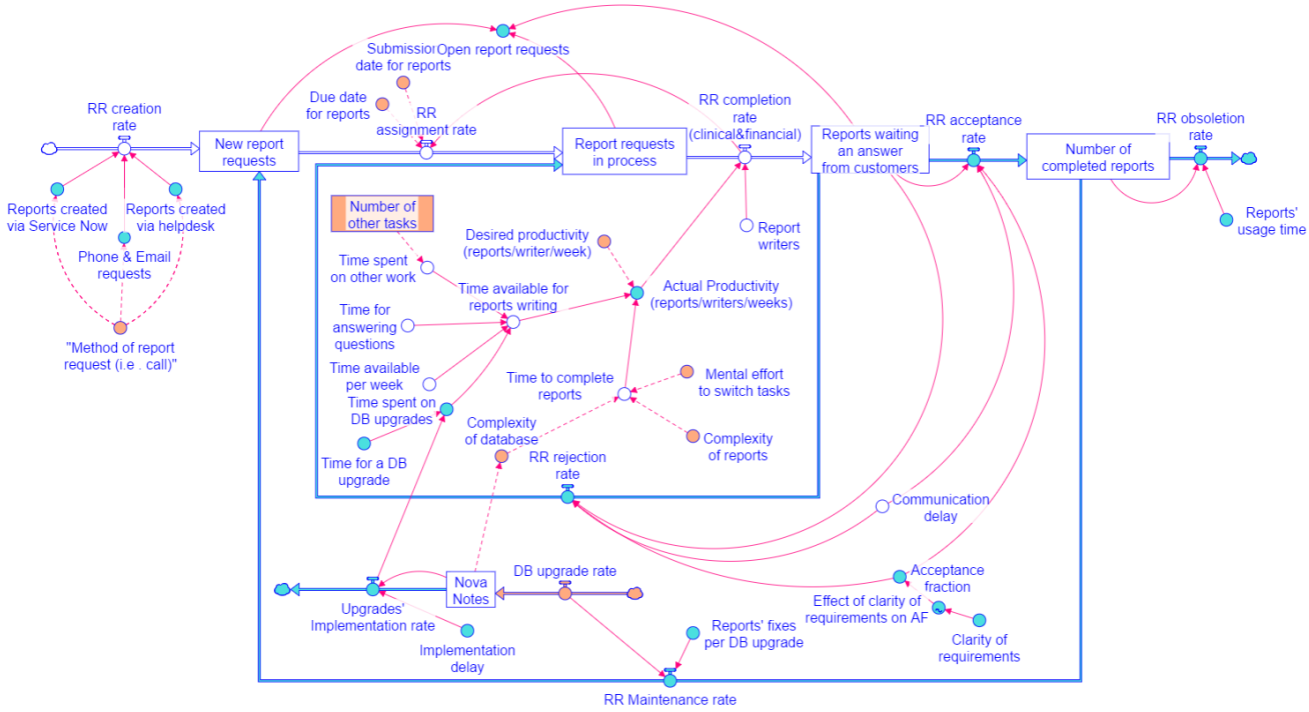


Figure 29. Model Presented at the Second Workshop

Despite some imperfections, the model presented at the second workshop represents key features of the report request process pretty well. The further updates will take into consideration comments and answers to the questionnaire. That will allow the gap between the model and reality to be closed.

4.2.2. Questionnaire

The questionnaire was sent out to participants before the second workshop in order to clarify some elements of the model. During the session, were refined some answers that provoked ambiguity.

Below is provided aggregated responses of participants. Their influence on the further model development is discussed after Table 3.

Table 3. Questionnaire

Questions	**Units of Measure**	**Response**
1. How often do you put requests back into the queue due to unclear customer requirements in the original ticket?	per week	0
2. How many report requests do you get by phone that are NOT in “Service Now”?	per week	1
3. How many report requests do you get by email that are NOT in “Service Now”?	per week	2
4. How much time on average is needed to complete a simple report?	in days	5
5. How much time on average is needed to complete a complex report?	in days	21
6. How long on average does it take to get a reply from a customer?	in days	5
7. On average, how many times do you have to revise a report before the customer says it is finally done?	times	3
8. How much time on average is spent on tasks other than report writing? (e.g. Nova Notes, meetings, fielding questions, testing, etc.)	per week	30 %
9. What is your estimate for how many reports have to be fixed after a major Epic upgrade?	per upgrade	100

10. How can we quantify report complexity? (free text response)	Points the data is needing to come from.	Who is customer. What was requested.
11. How can we quantify the impact of Epic's increasing burden on your time? (free text response)	N.A.	Hours we spend on "User Web"
12. How can we quantify the clarity of requirements? (free text response)	some function based on number of questions needed to clarify the requirements. And number of revisions needed.	Epic recommendation that not reporting analyst get contacted first then they get down to specification INIs (parameters for searching/sorting in the database) items and so on.

The first question helped to clarify what is happening with the reports with unclear requirements. Sometimes clients' needs turn out to be completely different than it seemed by the initial task description. In this regard, was assumed that a report might change an author if it turns out to lie in a different area of expertise. In the model, it would be reflected in splitting the flow of rejected reports into two parts, one would go to the pile of unassigned report requests, and another - to the pile of work in process. But based on the obtained answer, that none of the requests is put back into the queue, it became clear that it's not the case.

Answers on **the second and third questions** showed that the number of informal report requests is twice as much as the number of formal report requests. Also, the discussion during the second workshop showed that it doesn't take so much time to complete the informal requests. For that reason, it was decided to more radically split formal and informal requests and use different stock and flow structures to represent them.

The fourth and fifth questions showed the importance of the right wording to avoid ambiguity and data distortion: it was unclear whether this number should include the communication delay. Fortunately, there was a chance to clarify the obtained answers during the workshop, and it turned out that most authors have included communication delay in their answers for the average report completion time. Finally, the group agreed that excluding communication delay, simple report requests take around a day on completion and complex might take around 3 to 5 days. However, the deliberations led to an uncertainty about what should be considered as simple and complex reports

and how to measure their quantities. Thus, it was decided to use average fulfilment time for both types of reports.

The answer to **the sixth question** helped to determine how long on average it takes to get a response from customers. The obtained number was used to separate the time needed to complete a report from time spent waiting for a customer' response.

The seventh question showed that complex reports might go through several revisions before a customer accepts them. In some cases, a report might be simple, but a customer might be complex. For instance, some customers submit many revision requests for minor changes such as changing the font size or colors, that they can do on their own. For that reason, an attempt to explicitly model the revision process was undertaken, that is presented in Figure 30.

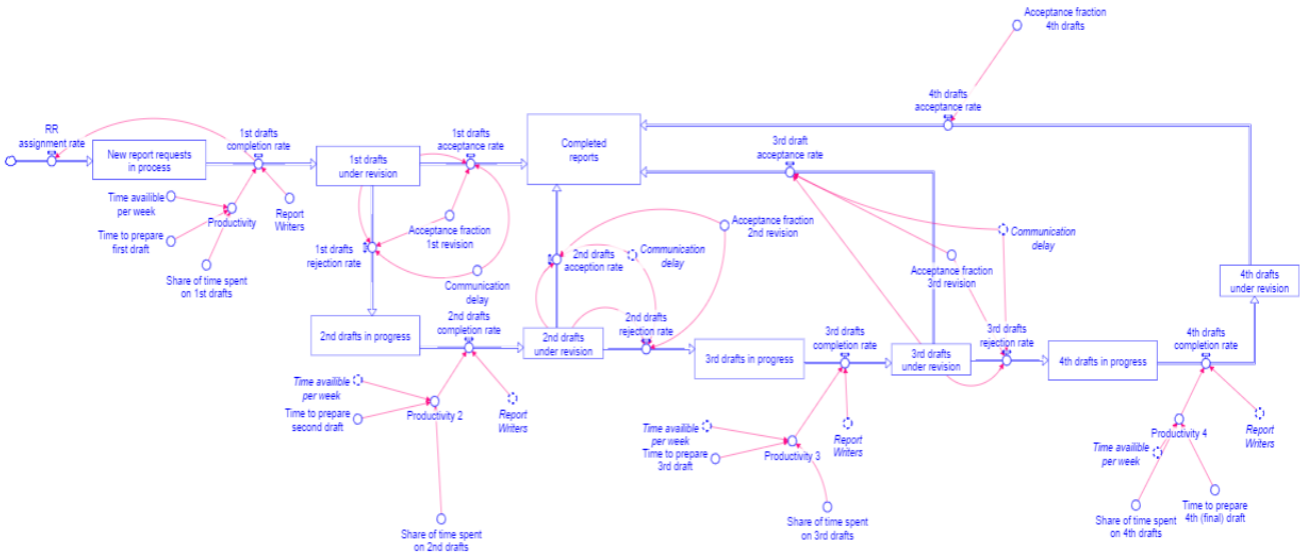


Figure 30. Revision Process

This cumbersome structure doesn't provide deeper problem understanding, and for that reason it was discarded. However, it helped to determine the acceptance fraction used in the model.

Due to the uncertainty of how much time is spent on report completion, the report completion rate from "Service Now" was used, which is presented in Figure 11. It was corrected with the number of report writers and the time spent on other tasks and preparation of informal report requests. With the assumption that 30 percent of time available for report writing is spent on informal requests, the average completion time is about 9 hours for both types of reports (excluding communication delay).

At first glance, the answer to **the eighth question** seemed reasonable. But when this number is considered alongside the average time needed to complete a report and the report completion rate, it became questionable. Either completion of formal reports on average takes less than nine hours or some other tasks might be related to report completion. Thus, there is a need for sensitivity testing of the model parameters. So far in the model, the share of time spent on other tasks is around 12 percent.

The answer to **the ninth question** is relevant for the time when EPIC updates took place once in two years. Recently EPIC has started to release updates more frequently - now they take place once per quarter. Since the number was obtained based on the past experience of report writers when upgrades didn't take place often, we can divide this number by eight since in two upcoming years EPIC is planning to release eight minor updates instead of one major.

Deliberations on report complexity that took place during the discussion of the responses to the **tenth question** showed that it is better to aggregate complex and simple reports together.

The idea to count time spent on "User Web", the website with database manuals, that was proposed in one of responses to **the eleventh question** makes sense, but it's not clear if EPIC can provide this data.

Deliberations on **the twelfth question** showed that clarity of requirements is hardly measurable and might significantly differ. For that reason, this question was excluded from the model boundaries.

4.2.3. Policy Options

During the second part of workshop, the list of possible action to streamline the report request process was developed and similar options were clustered. Results are provided in Figure 31.

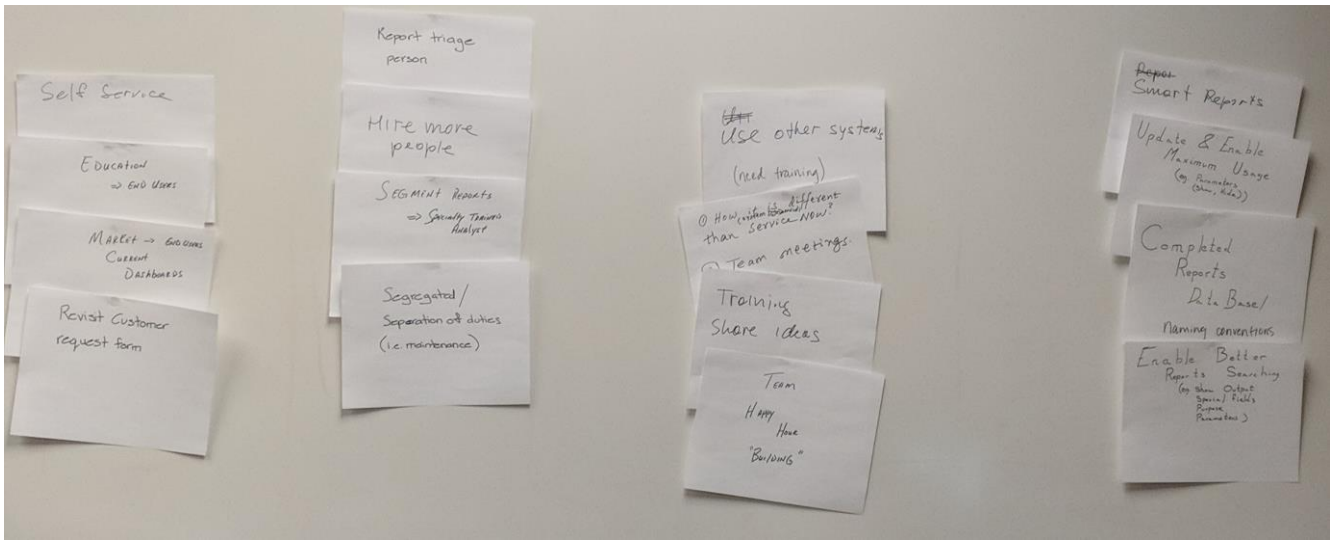


Figure 31. List of Key Policy Options

Afterwards, policies' implementation into the model structure was discussed. Expected positive and negative effects were considered, as is presented in Table 4. Conceptually similar policies were grouped together (shown as Blocks in Table 4).

Table 4. Policy Options and their Effects

	Block I	**Block II**	**Block III**	**Block IV**
Ideas	• Revisit Customer	• Segregation/Separation of	• Team Happy Hour	• Enable better reports searching (e.g. show output;

	Block I	Block II	Block III	Block IV
	request form; • Market -> End Users Current Dashboards; • Education of End Users; • Self Service.	duties (i.e. maintenance); • Segment reports => Specialty Trained Analysts; • Hire more people; • Report triage person.	"Buildin g"; • Training Share Ideas; • Team meetings; • Use other systems (need training).	special fields; purpose; parameters); • Completed reports database /Naming conventions; • Easier Updating (i.e. > Parameters); • Update & Enable Maximum Usage (e.g. Parameters (Show, Hide)); • Smart reports.
Positive effects	The smaller inflow of initial requests	Faster report completion rate	Reduce time spent on reports	Completed reports -> Completion rate
Side effects	• Once per month meeting – for customers; • Use EPIC training staff (?); • Create an online resource.	• Switching tasks; • Budget; • Time to train new person; • Unlikely to happen.	• Increase time required on other things; • Learning curve.	• Increase time spent completing reports as you go (except for naming conventions); • Difficult to implement and enforce.

From each cluster was chosen one policy option for the implementation in the model structure.

4.3. Work After

The model presented at the second workshop was further improved to close the gap between the simulation results and reality. As well, four policy options proposed by participants were implemented in the model structure, as presented in the following chapter. In addition, the key outputs of the session were placed in the workbook for participants.

Chapter 5.

Chapter 5. Third Group Model Building Session

This chapter is devoted to describing the activities undertaken during the third GMB session.

5.1. Preparation of the Third GMB Session

The preparation of the final session took more time than the preparation of the previous sessions, due to the major model upgrade that was needed to implement the policy options. The room layout and role allocation stayed unchanged, as well as the 3-hour duration of the session. The main changes took place in agenda and the purpose of the workshop.

5.1.1. Purpose of the Third Session

The final workshop was focused on choosing the best course of action. To reach this aim were compared simulation results for four policy options. In addition, was fulfilled an analysis of possible impediments and side effects of their implementation.

5.1.2. Schedule of the Third Session

The schedule of the third session is presented in Table 5.

Table 5. Schedule of the Third Session

Time	Activity	Comments	Roles
10:00-10:10	Introduction & Recap	Presentation of the agenda of the third workshop and a brief recap what was done at the second session.	Ekaterina – facilitator & modeler, Arielle – recorder, Ian – gatekeeper.
10:10-10:35	Model Presentation	Presentation of the updated version of the explanatory model.	Ekaterina – facilitator & modeler, Arielle – recorder, Ian – gatekeeper.
10:35-11:00	Knowledge Sharing	Explanation of the policy structure. Elicitation of the possible pros and cons that might take place during the implementation of this policy option using Nominal Group Technique.	Ekaterina – facilitator & modeler, Arielle – recorder, Ian – gatekeeper.
11:00-11:20	Naming Conventions	Explanation of the policy structure. Elicitation of the possible pros and cons that might take place during the implementation of this policy option using Nominal Group Technique.	Ekaterina – facilitator & modeler, Arielle – recorder, Ian – gatekeeper.

Time	Activity	Comments	Roles
11:20-11:35	Break	Discussion of the process among the modelling team.	-
11:35-12:00	Customers' Educations	Explanation of the policy structure. Elicitation of the possible pros and cons that might take place during the implementation of this policy option using Nominal Group Technique.	Ekaterina – facilitator & modeler, Arielle – recorder, Ian – gatekeeper.
12:00-12:25	Hiring More People	Explanation of the policy structure. Elicitation of the possible pros and cons that might take place during the implementation of this policy option using Nominal Group Technique.	Ekaterina – facilitator & modeler, Arielle – recorder, Ian – gatekeeper.
12:25-12:50	Comparison of Policy Options	Simulation results for each policy option were shown to participants. They were not shown before to avoid perception distortion during elaboration of pros and cons. Finally, policy options and their implementation were discussed based on the simulation results and possible side effects.	Ekaterina – facilitator & modeler, Arielle – recorder, Ian – gatekeeper.
12:50-13:00	Wrapping up	Wrapping up the results of the session & project.	Ekaterina – facilitator & modeler, Arielle – recorder, Ian – gatekeeper.

5.2. Activities Undertaken During the Third Session

5.2.1. Model Presented at the Third Workshop

Based on the questionnaire and discussion during the second workshop, the model has undergone major changes that are highlighted in the blue color in Figure 32. Briefly, there are two major alterations: 1) segregation of informal and formal report requests; 2) a separate stock for broken reports since they are skipping revision.

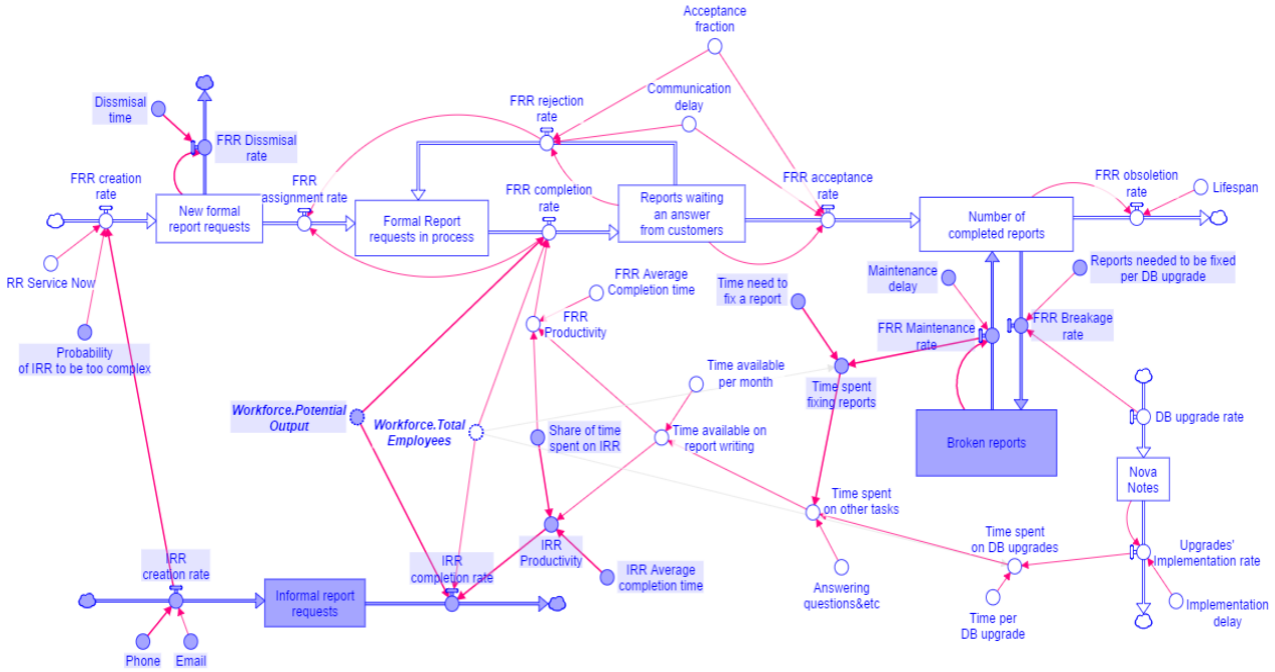


Figure 32. Model Presented at the Third Workshop

Since after the final workshop the model has undergone significant changes, the detailed description of the model, policy options and simulation results will be provided in subsequent chapters.

5.2.2. Analysis of Policy Options

Before presenting the simulation results, were undertaken an analysis of possible pros and cons for each policy that is provided in Figure 33 and in Table 6.

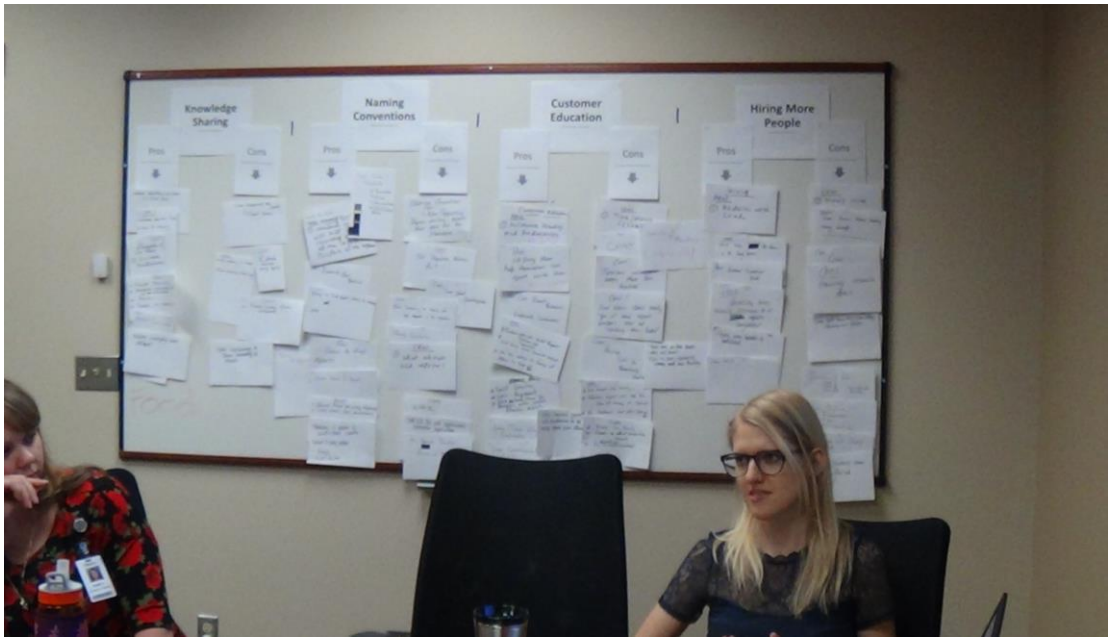


Figure 33. Analysis of Policy Options

After the workshop pros and cons were digitalized and placed in Table 6. Some of them occur multiple times, showing their high relevance and importance.

Table 6. Analysis of Policy Options

	Naming Conventions:	**Customers' Education**	**Hiring More People**	**Knowledge Sharing**
Pros	• Making it easier to review/find reports; • Makes fixing easier; • Tags; • Metadata; • Easier to find existing reports; • Less mess, less workforce (?); • Easier (theory) to Search; • Easier to find reports; • Easier to find report / easy to update; • Reporting Best Practices; • Standard naming will help in report searching and meaning of the report and purpose of the report; • Easier to name; • Copy-Paste Template:	• Less requests coming to us; • Less frustration for the customers; • Make them more efficient; • Communication (will reduce time spend on it); • Helping them help themselves cuts report writer time (less interruptions); • Increase quality and productivity (of Report Writing Team); • Reduce: simple ticket requests; phone calls; emails; • Will have more time for project; • We can utilize the trainers to help us; • Less Communication Needed; • Less Time Educating Customers (answering questions by phone & email); • Less report Requests; • Empower customers;	• Less work; • Long term benefit to workload; • Quality hires would increase number of reports completed; • Increase completion rate; • Will help the team in the long term; • Reduces workload.	• Increase knowledge for team in a long term; • Strengthen the team; • Increase productivity; • Advance the team members; • Send for training; • Faster training; • General knowledge what is available; • Tricks; • Team on same page; • Better communication; • Making everyone more efficient.

	Naming Conventions:	Customers' Education	Hiring More People	Knowledge Sharing
	Parameters, Names, Documentation, Fields/Columns (data).	• Self Service (where customers can create a simple report on their own); • Less Requests; • We'll have time to develop new more flexible reports (i.e. filters).		
Cons	• Time spent developing; • Old reports names fix? • What about old reports? • Following conventions • Non-Reporting Teams writing reports that don't use standards (i.e. financial reports team); • Time consuming to name all the reports in the system • More search results &	• End Users don't really "get it" and report writers end up "holding their hand"; • Turnover with end users that are trained; • Time to train; • Users don't want to learn (and sometimes don't have time to learn); • Reporting to complicated (too many attributes and filter fields); • Update & Maintain (manuals); • Cost; • Time/money issue; • Turnover on their teams; • Who will train? • EPIC is ever changing – always need new training;	• Quality hires are hard to fine; • More people ask for help; • Lower salary & Less: Responsibilities; • Labor; • Time needed to work; • Division of Labor: AA I (beginners), AA II (intermediate), AA III (seniors) – task difficulty specialty; • Time spent sharing knowledge &training new people;	• Time consuming to share knowledge with others; • Setup &Update; • Time consuming for experts; • Time consuming + Cost money (external training) • Time away from projects;

	Naming Conventions:	Customers' Education	Hiring More People	Knowledge Sharing
	Division of Results • Not all fit into applications (crossover applications) • None	• Not everyone like training; • Trainers might not like the idea of training on report; • The customers will still call us; • Possible cuts to reporting staff.	• Training resource drain; • Cost; • None since the company is making money already; • Money issue.	• I don't think any cons; • Time consuming for staff in a short term.

5.3. Work After

After the final workshop, the model was updated according to the comments of prof. David Wheat. Also, some impediments and side effects of policy options implementation that were not considered before were incorporated in the model structure. In addition, the cost benefit analysis was fulfilled for each policy option according to an assumption that in case of untimely delivery of a report the potential price that a customer is ready to pay for it decreases.

As well, a workbook wrapping up the results of the third session was created and sent out to participants.

Chapter 6. Model Structure &Behavior

This chapter describes the final model that was developed through a series of Group Model Building workshops, that has undergone significant changes during the modelling process and its behavior.

6.1. Top-Level Model

For the sake of convenience, the model was divided into five modules, starting from the Research Request Process (explanatory model) and ending with policy switches and historical data sets. The top-level model structure is presented in Figure 34.

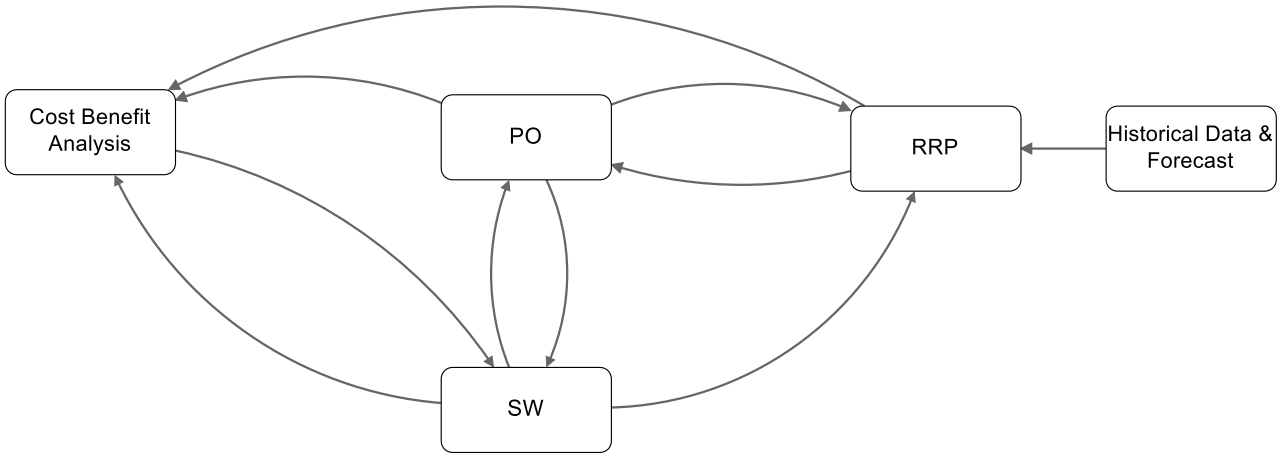


Figure 34. Top-level Model

Research Request Process (RRP) module will be explained in this chapter. Special chapters will be devoted to Policy Options (PO) and Costs-Benefits analysis modules. Historical data & Forecast module will be included in Model Behavior chapter. Module Switches (SW) will be included in Appendix.

6.2. Explanatory Model

6.2.1. Formal and Informal Report Requests

Formal report requests are going through at least three stages before being accepted by the customers. Initially, all requests are coming to the pile of New FRR Requests, that don't have an author yet. A report request might be discarded in case if a requestor doesn't need the report anymore (FRR Dismissal Rate). But most requests are becoming assigned to someone after a while. Usually report writers choose on their own what reports they would like to prepare. Normally it happens when a previous bunch of work is finished. However, there is a risk that reports might be rejected by a customer and will need rework. The actual number of rejected reports might differ from report writers' estimates. For that reason, FRR Perceived Rejection Rate is used in the model to determine FRR Assignment Rate. Thus, FRR Assignment Rate is equal to FRR Completion Rate corrected by FRR Perceived Rejection Rate.

When reports are completed, they need to be reviewed by customers. If they are satisfied, they close the ticket at “Service Now” and reports are going to the stock of Completed Reports and stay in it until they are becoming obsolete.

This process is presented in Figure 35.

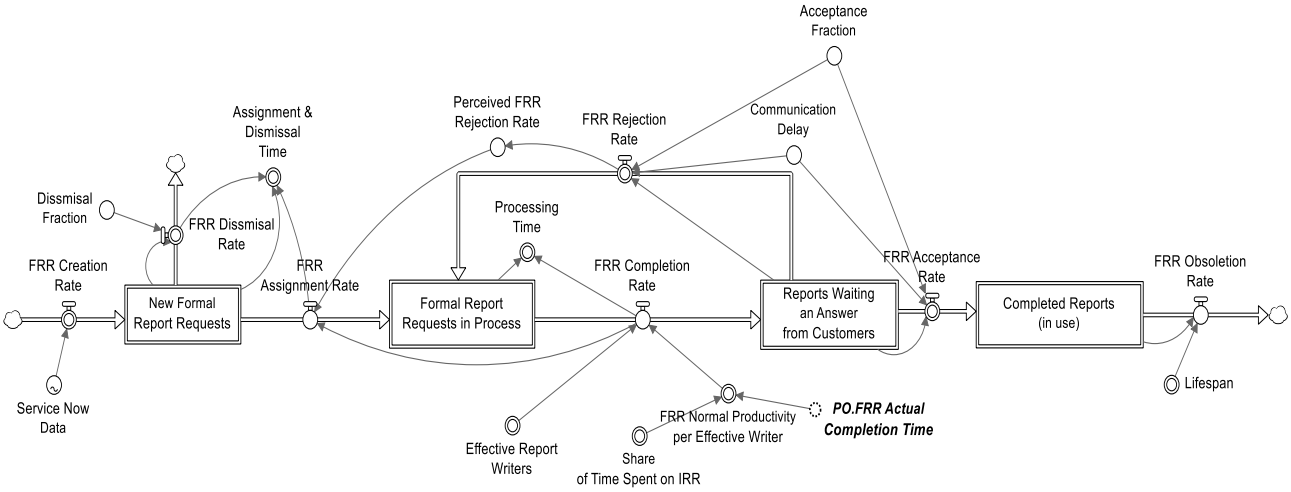


Figure 35. Formal Report Requests

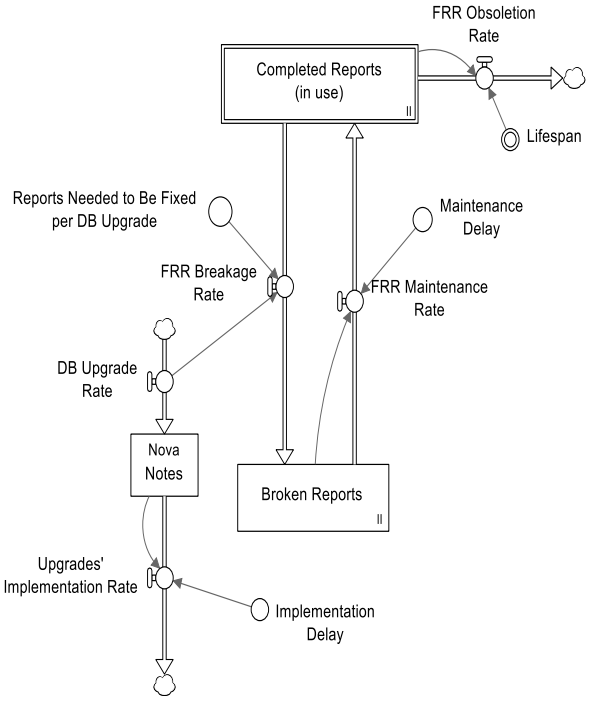


Figure 36. Database Upgrades and Reports’ Maintenance

When database upgrades take place, some of the reports might be broken for instance due to the changes in field names, data structure or data formats. For instance, the reports used the field "date_of_birth" from one table would become broken if in the new version of the database this field was moved to another table or renamed.

A major EPIC upgrade used to take place once per two years and on average resulted in about one hundred reports needing revision. Starting from the autumn of 2018, routine EPIC upgrades will take place once per quarter. Thus, it is expected that now each update might impact about 12 reports. However, this number is hard to predict with a high level of accuracy since upgrades might significantly differ.

Usually, broken reports are discovered and fixed within three months as portrayed in Figure 34.

Time spent on fixing reports and on the implementation of the database upgrades is subtracted from the time available for a report writing. Also, the time spent on answering questions of customers and colleagues is deducted. In addition, working time might be spent on training, knowledge sharing

and customers' education. That will be considered in more details in the Policy Options chapter (Figure 37).

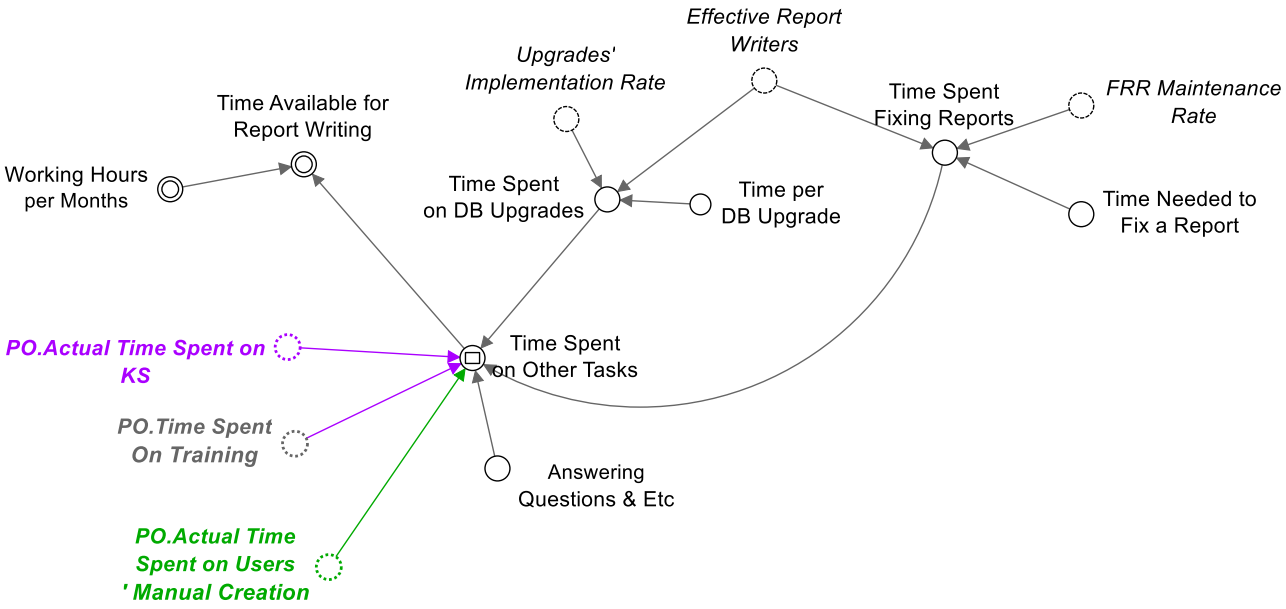


Figure 37. Allocation of Working Time

Some customers are more used to informal ways of requesting reports, such as email and phone. Usually, it takes much less time to complete the informal request. Furthermore, they quite often have a higher level of priority and less time left until the deadline. Thus, report writers usually try first to deal with informal requests and only when they are done switch to formal requests (Figure 38).

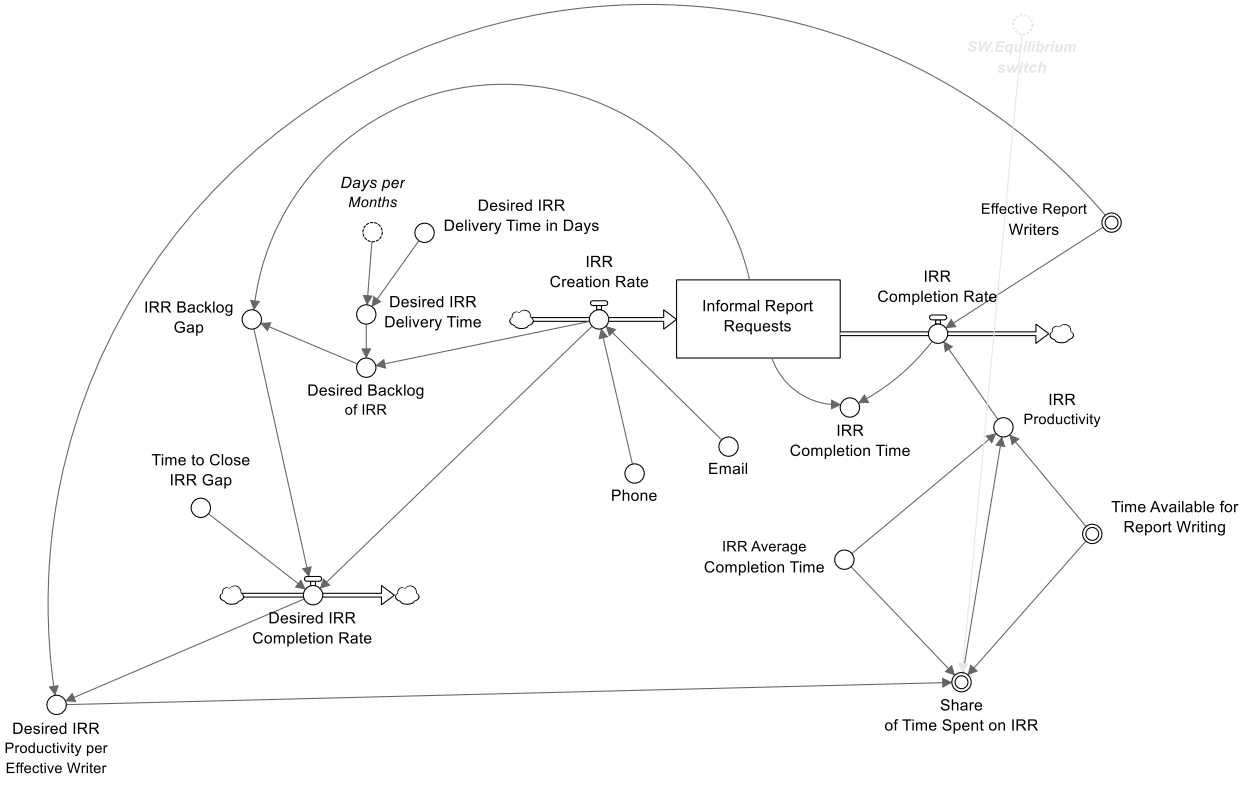


Figure 38. Informal Report Requests

Hence, the employees of the Information Services department sometimes spend too much time dealing with the informal report requests that it might become detrimental for the reports delivery time of formal report requests. Thus, the backlog of the informal requests will highly likely to go down, especially if the number of informal report requests won't significantly change since report writers pay more attention to them. In contrast, the backlog of formal requests will continue to grow with the current workflow.

6.2.2. Workforce

Formal and Informal Reports Completion Rates are determined by how many new and experienced writers work on the report writing that will be considered in this section. Report writing requires specific knowledge, such as the structure of the company's database and the requirements of end-users. Therefore, usually it takes around two years for a writer to reach maximum feasible productivity.

In many companies, people are hired only in replacement to those who decided to leave. However, the need for specific knowledge and impossibility of hiring experienced employees forced the Information Services Department to take into consideration the fact that productivity of new employees is lower. Due to this fact, the company hires slightly more people than leave the company. Thus, during the last two years the number of report writers has increased from 8.5 to 9.5 full time workers - 3 experienced writers left the company and 4 new people were hired in their replacement. It allows the department to keep the number of effective writers at the same level or even slightly increase it (Figure 39).

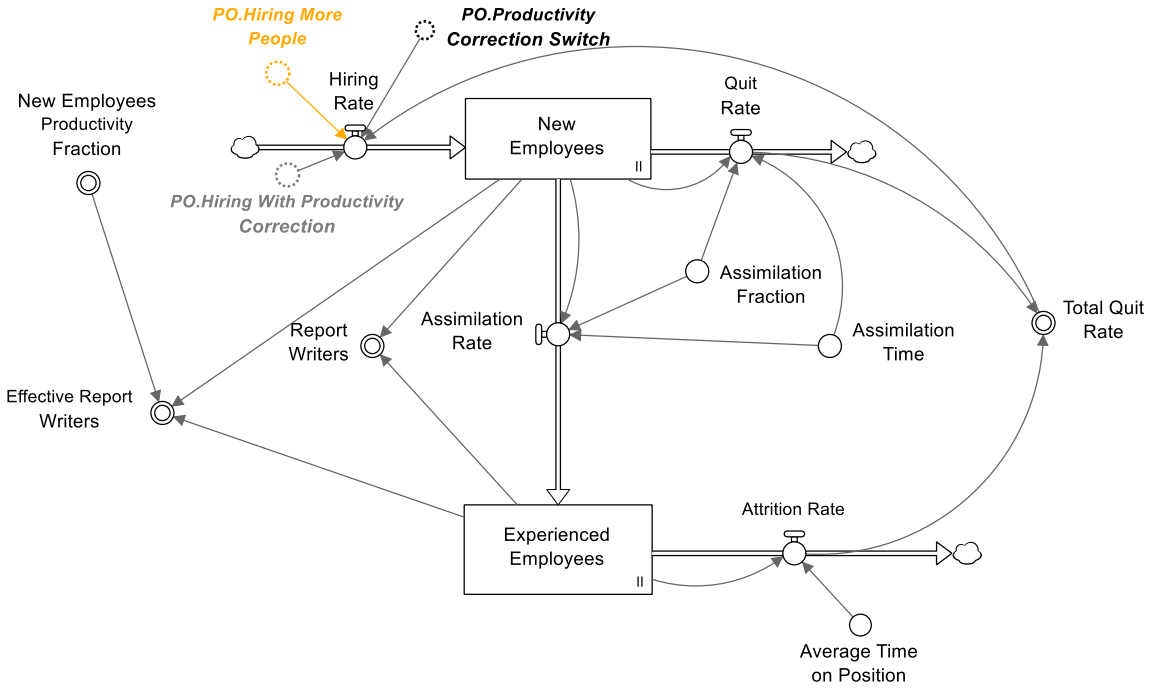


Figure 39. Report Writers

However, the hiring with productivity correction cannot completely satisfy the needs of company and solve the issue of the significant backlog of open report requests. Thus, Hiring More People will be considered additionally as a policy option.

6.2.3. Backlog of Open Report Requests & Reports Delivery Time

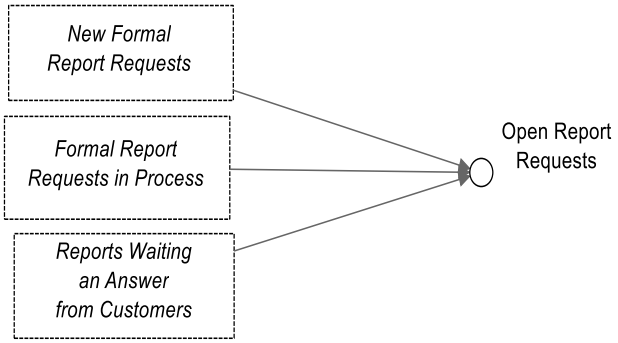


Figure 40. Backlog of Open Report Requests

It worth separate mentioning what kind of reports are considered by the company as a backlog. Requests are coming from the customers and remain open until they close them. Thus, it's not New Formal Report Requests and Report Requests in Process, but also Reports Waiting an Answer from Customers as presented in Figure 40.

Thus, Report Delivery Time consists of three components: Assignment and Dismissal Time, Processing Time and Communication Delay as presented in Figure 41.

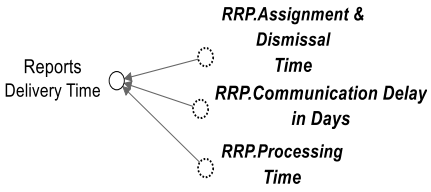


Figure 41. Reports Delivery Time

It worth mentioning that the desired reports delivery time currently is not stated clearly in any of official documents. But according to the estimates of the management of the Information Services department, the delivery of reports should not take more than 7 days. Thus, to enable a timely delivery of reports this number should be clearly stated and communicated to all report writers. In addition, customers should be informed that tickets will be closed automatically if they don't provide feedback within 5 days.

6.3. Model Behavior

6.3.1. Backlog of Open Report Requests

The simulation results for the backlog of open report requests was compared with the data obtained from “Service Now”, the ticket tracking system used in the company. The system initially was implemented in the middle of 2013, but it has not been used properly until 2016. For that reason, only the data for the last two and a half years was used, from January 2016 to May 2018.

In addition, the resulting model was compared with the forecasted data for the backlog of open report requests. The forecast was built based on the historical dataset for upcoming four years, which on one hand allows the results of policy implementation to be considered, and additionally, it's not highly likely that any structural changes related to the Information Services Department will take place. It predicts a growing number of open report requests due to the growing report request creation rate.

The comparison results are provided in Figure 42.

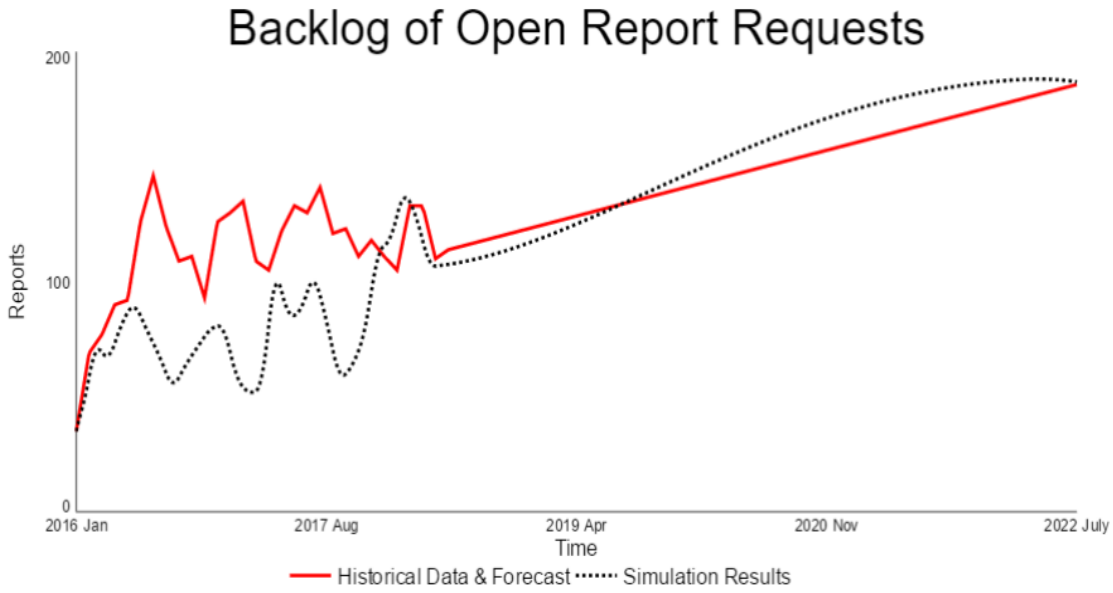


Figure 42. Comparison of the Reference Mode with the Simulation Results: a) Backlog of Open Report Requests

The model partially replicates the historical dataset and the forecasted values for the backlog of open report requests. The discrepancy existing between the actual data and simulation results are not only caused by the model imperfections, but also by the lack of the reliable data. Thus, the extended data collection and proper use of the ticket tracking system are needed to improve the fit between the reference mode and the simulation results.

6.3.2. Reports Delivery Time

Reports delivery time has been significantly distorted by the improper use of the "Service Now" and by the fact that report writers have been asked to close the tickets each week prior to team meetings. For instance, based on the cumulative trends for reports closure, only about 60 percent of opened tickets are closed in the same month when they have been opened (Appendix I. Reports Delivery Time). Hence, the data obtained from "Service Now" is unlikely to be a good representation of the reality.

For that reason, the simulation results for the reports delivery time was compared with the reference mode constructed based on the reality check model (Section 1.5 "Reality Check Model"), as presented in Figure 43.

The model cannot produce exactly the same numbers as the reference mode, especially in the beginning, but follows the overall pattern of behavior. By the end of the considered time horizon, it comes close to the numbers produced by the reality check model.

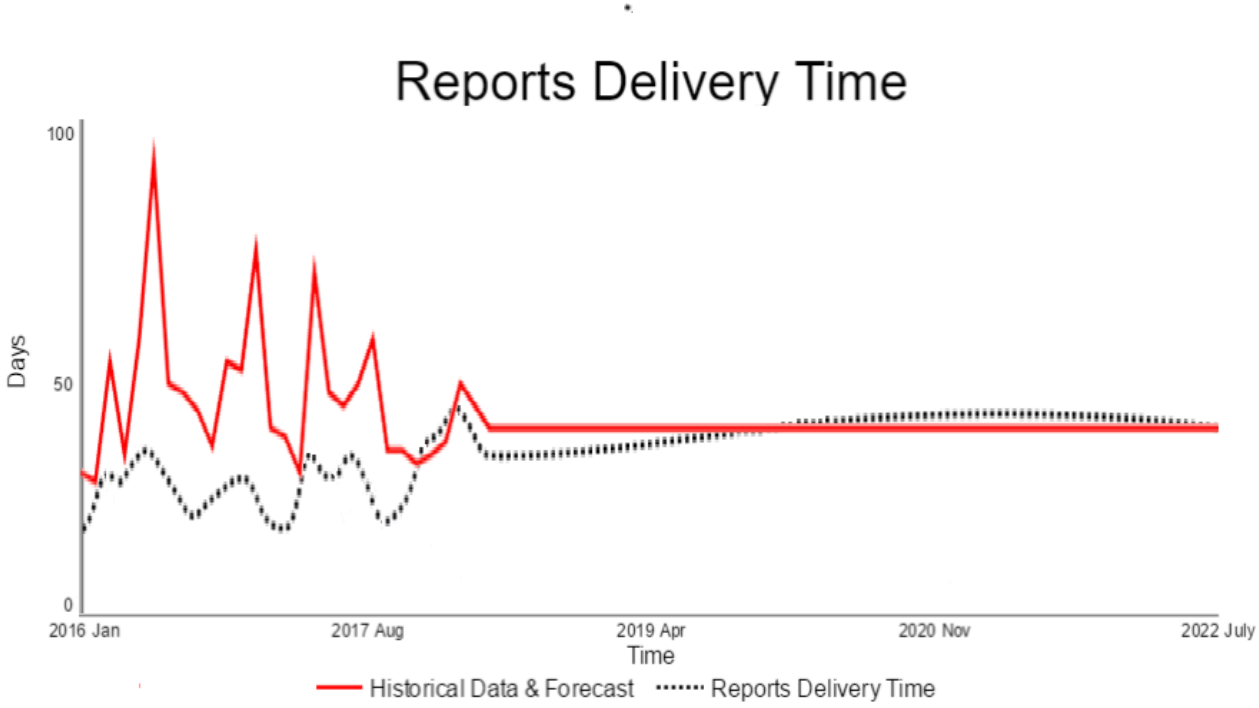


Figure 43. Comparison of the Reference Mode with the Simulation Results: b) Reports Delivery Time[3]

Based on the comparisons presented above, it's clear that the model is able to partially replicate the behavior of the system. As it was mentioned earlier, to improve the fit between the model and reference mode, it's necessary to conduct the extended data collection since a lot of data are missing or don't look reliable.

Overall, in spite of some imperfections, after a conduction of a series of validation tests, the model can be used for the analysis of policy options. Thus, the next three chapters are devoted to the model validation, implementation of the policy options in the model structure and their comparison.

[3] DT in the reality check model is equal to 1.

Chapter 7. Model Validation

To build confidence in the model, a series of validation tests was conducted, described in this chapter. In the first section the general overview of the validation process is described; the second describes the direct structure tests that have been conducted; and the third one describes the structure-oriented tests.

7.1. General Overview of Model Validation

The model validation is necessary to prove the robustness and usefulness of the model for its final users. Stakeholders might be skeptical of the simulation results and thus don't use the model outputs for the decision-making if they are not confident in the model structure and underlying assumptions.

Initially, the issue of model validation was developed by Forrester and Senge (1980). They have pointed out the difference between validity tests in System Dynamics and statistics and proposed the series of tests for the model structure, model behavior and policy implications.

Further the topic was investigated by Barlas (1994, 1996). He divides direct structure verification tests, structure-oriented behavior tests and behavior pattern tests. Also, Barlas proposes the logical sequence of formal steps of model validation and emphasizes that tests should be chosen according to the model purpose.

One of the most recent researches on this issue has been conducted by Groesser and Schwaninger (2012). They have not only considered the process of model validation and the hierarchy of the tests; but also defined the cessation threshold that allows finding a balance between the model validity and validation costs.

Tests used to build the confidence in the model have been chosen based on the sources listed above. Due to time constraints, not all of the recommended tests have been conducted. Since the model has been built with an active participation of stakeholders involved in the Group Model Building workshops, the confidence in the model was achieved based on a small number of tests.

7.2. Direct Structure Tests

Direct structure tests are aimed to check how well the model structure represents the reality. They compare the model structure with verbal descriptions of the system and don't involve simulation. Since this project is a case study, and the literature describing similar models are pretty limited, mainly the structure validation has been conducted through the presentation of the model to the employees of the Information Services Department and incorporating their feedback as needed.

7.2.1. Structure Verification Test

Structure verification test helps to verify the model structure. It's strongly recommended to involve the problem owners in the verification process or conduct an extensive literature research. In

this project, the structure was built with an active participation of report writers and almost all elements of the model were proposed by them. During each workshop, the participants have been asked questions regarding the model structure (i.e. "Do all elements of the model structure make sense to you?").

In addition, the model structure has been multiple times reviewed by the head of the Information Services department, which has a basic knowledge of System Dynamics.

The literature search has been used to verify the structure that is commonly used in models representing the production process. For instance, initially, the model assumed that all report writers have an equal productivity. However, based on the workshop results and the literature search it was decided to disaggregate new and experienced employees and represent the training process.

It worth mentioning that not all elements that were proposed at the workshops have been included into the model structure due to time constrains and the lack of data availability.

7.2.2. Parameter Verification Test

The parameter verification test is closely related to the structure verification tests and aims to check the constant values used in the model with the real life (Senge & Forrester, 1980).

Mainly constants used in the model have been chosen according to the questionnaire of participants and based on the meetings with the head of the Information Services Department. Some of them might not perfectly represent the reality due to the lack of data and difficulties in the measurement of the soft variables. However, overall all parameters of the model lie in the plausible range.

In addition to the data collection, the literature review also has been used to define some parameters. For instance, the productivity fraction of new employees and the assimilation time was chosen based on the numbers used by Sterman in the workforce training model and corrected according to the estimates of the head of the Information Services department (Sterman, 2000).

An analogous procedure has been used to define other parameters of the model. That helped to better determine the model parameters and thus, better replicate the reality.

7.2.3. Dimensional Consistency Test

The most common and basic test that is used to verify the model structure is the dimensional consistency test. This test is automatically performed by the modelling software, Stella Architect. It checks unit consistency for each equation and for the entire model

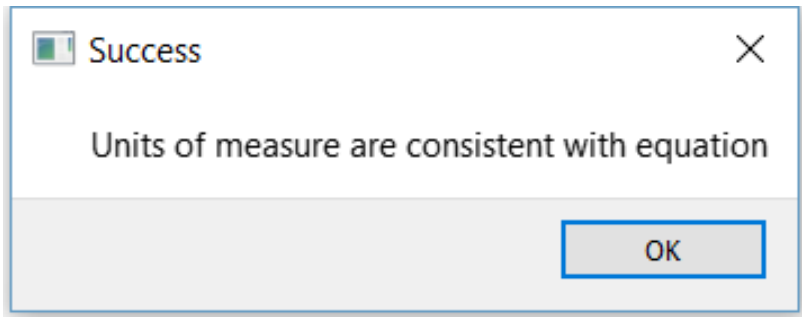


Figure 44. Dimensional Consistency Test, Stella Architect Software

The results of dimensional consistency test are provided in the figure above.

7.3. Structure-Oriented Behavior Tests

Structure-oriented behavior tests involve changing of the model parameters in order to assess its behavior. Thus, the simulation is an integral component of this kind of model validation. Three structure-oriented behavior tests have been conducted: extreme condition test, behavior-sensitivity test and boundary adequacy test as described in the following subsections.

7.3.1. Extreme Condition Test

Extreme Condition Test was conducted to check how the model reacts on the conditions that rarely take place in the reality but theoretically might happen. This kind of testing allows assessing the robustness of the model and the adequacy of used assumptions.

First, was tested how the model reacts to extreme values for FRR Creation Rate. For testing purposes, instead of the data from "Service Now", was used 0 and 10000 report requests per months. The model adequately reacts to them: if the number of report requests is equal to zero, the backlog of report requests becomes zero as well in about a month; if the number is equal to 10000, the backlog is growing up to 2 million open report requests in 6 years.

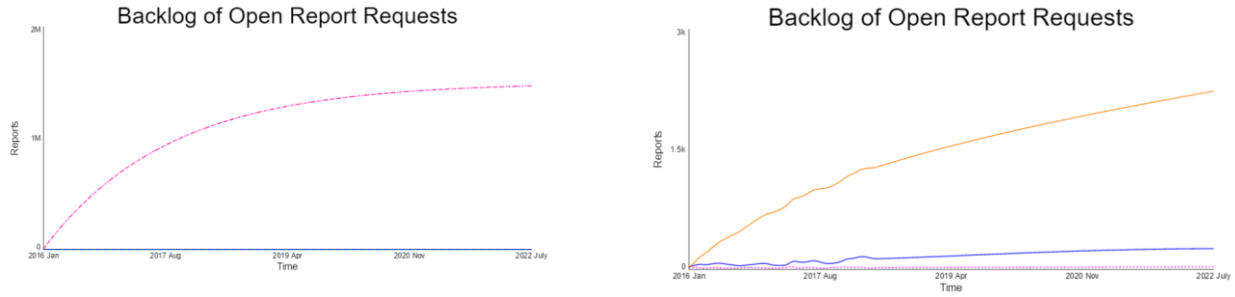


Figure 45. Extreme Condition Test: a) FRR Creation Rate b) Share of Time Spent on IRR

Second, the test was conducted with the extreme values for the share of time spent on informal report requests. Instead of the value endogenously generated by the model and that takes values around 0.3, extreme values of 0 and 1 were used. If the share of time spent on informal report requests is equal to 0, then report writers have more time on completion of formal report requests. Thus, the backlog slightly fluctuates due to the changes in the FRR Creation Rate and is equal to the report

requests waiting for an answer from customers. If the employees spend all their time on informal report requests, the backlog of report requests goes up to 2 thousand in a six-year period.

Based on these two experiments, it might be concluded that the model reacts reasonably under extreme conditions. The same kind of tests might be conducted for other model parameters. Some of them have been considered in the behavior-sensitivity test, that is described in the following section. However, the tests haven't covered the full range of parameters due to the time constraints.

7.3.2. Behavior-Sensitivity Test

The behavior-sensitivity test has been conducted to check how sensitive the model is to parameter changes. This test not only helps to assess the robustness of the model but also shows what elements of the model more sensitive to the external changes, and thus it helps to estimate the effectiveness of policy options.

Since the policy options have been already proposed by participants, it was decided to analyze how sensitive the model is to their implementation. 3 parameters have been chosen for it: FRR Creation rate, that can be decreased by the customers' education; FRR Actual Completion time that might be reduced by knowledge sharing or naming conventions. The effect of changes in hiring on the backlog was not considered in the sensitivity analysis since by default the model assumes that hiring rate is equal to the leaving rate, and thus cannot be determined by exogenous parameters.

First, the effect of changes in FRR Actual Completion Time has been considered. Five values ranging from 3 to 15 hours per report were taken, as presented in Figure 46. The backlog of open report requests doesn’t change if the FRR Actual Completion time is low enough, and equal to 3 or 6 hours per report requests. In this case, the backlog consists only from the reports under customers’ revision. However, if completion time goes up to 9 hours per report, the backlog comes closer to its actual value. Any further changes also affect the backlog, but interestingly that the growth from 9 to 12 hours affects the system behavior more than growth from 12 to 15 hours.

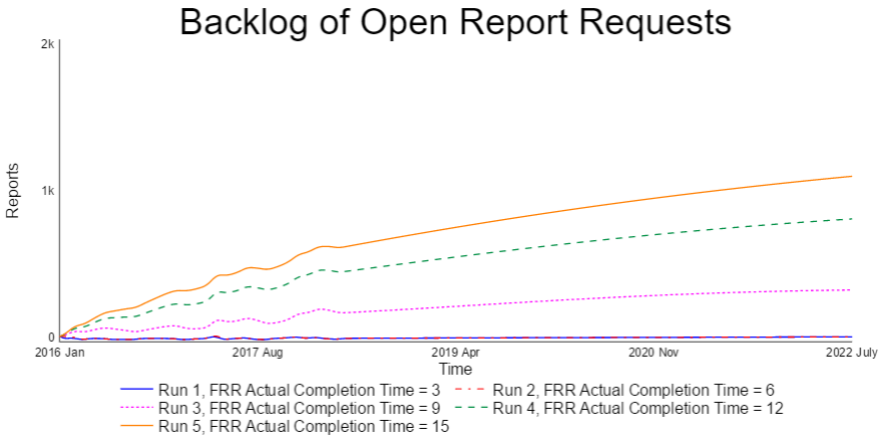


Figure 46. Behavior-Sensitivity test: a) FRR Actual Completion Time

Second, the effect of changes in FRR Creation Rate has been considered. Five values ranging from 50 to 350 report requests per month were taken. If the FRR Creation Rate is equal to 50, the report writers can fulfil all the tasks on time, and thus the backlog is equal to the reports under the customers' revision. If it's equal to 125, the number of reports in progress and the number of unassigned reports is also increasing; the same is true for all other values of the FRR Creation Rate (Figure 47).

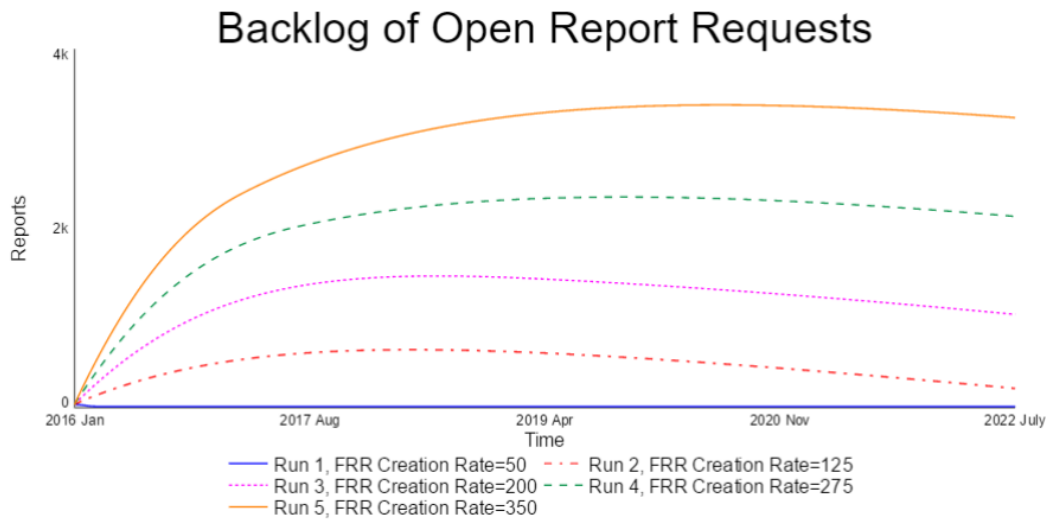


Figure 47. Behavior-Sensitivity test: b) FRR Creation Rate

Based on these two experiments, it might be concluded that the system reacts nonlinearly on changes in the FRR Completion Time and that it's slightly more sensitive to the changes into the FRR Creation rate. Thus, probably the customers' education might provide better results than policies that are trying to reduce FRR Completion Time such as knowledge sharing and naming conventions. Since the sensitivity analysis has not been conducted for the hiring rate due to its endogenous character, it's not obvious what policy more strongly affects the backlog of report requests. For that reason, this question should be also considered through the cost-benefit analysis.

7.3.3. Boundary Adequacy Test

To assess the adequacy of the model boundaries for the aim of the project, the Boundary Adequacy Test has been conducted. The model boundary helps to decide which variables should be included into the model, and whether they should be treated endogenously or exogenously.

Some authors recommend modelling the structure that was excluded from the model scope to check to what extent it affects the model behavior (Barlas, 1996; Senge & Forrester, 1980). Such an attempt has been conducted for the revision process. Despite the significant effect of such a representation on the resulting numbers, it hasn't changed the behavior pattern. In addition, it led to significant growth of the model complexity. For these reasons, it was decided to simplify the structure representing the revision process and thus, exclude its detailed representation out of the model boundaries.

In addition, the key variables used in the model have been divided into exogenous and endogenous, as presented in Figure 48.

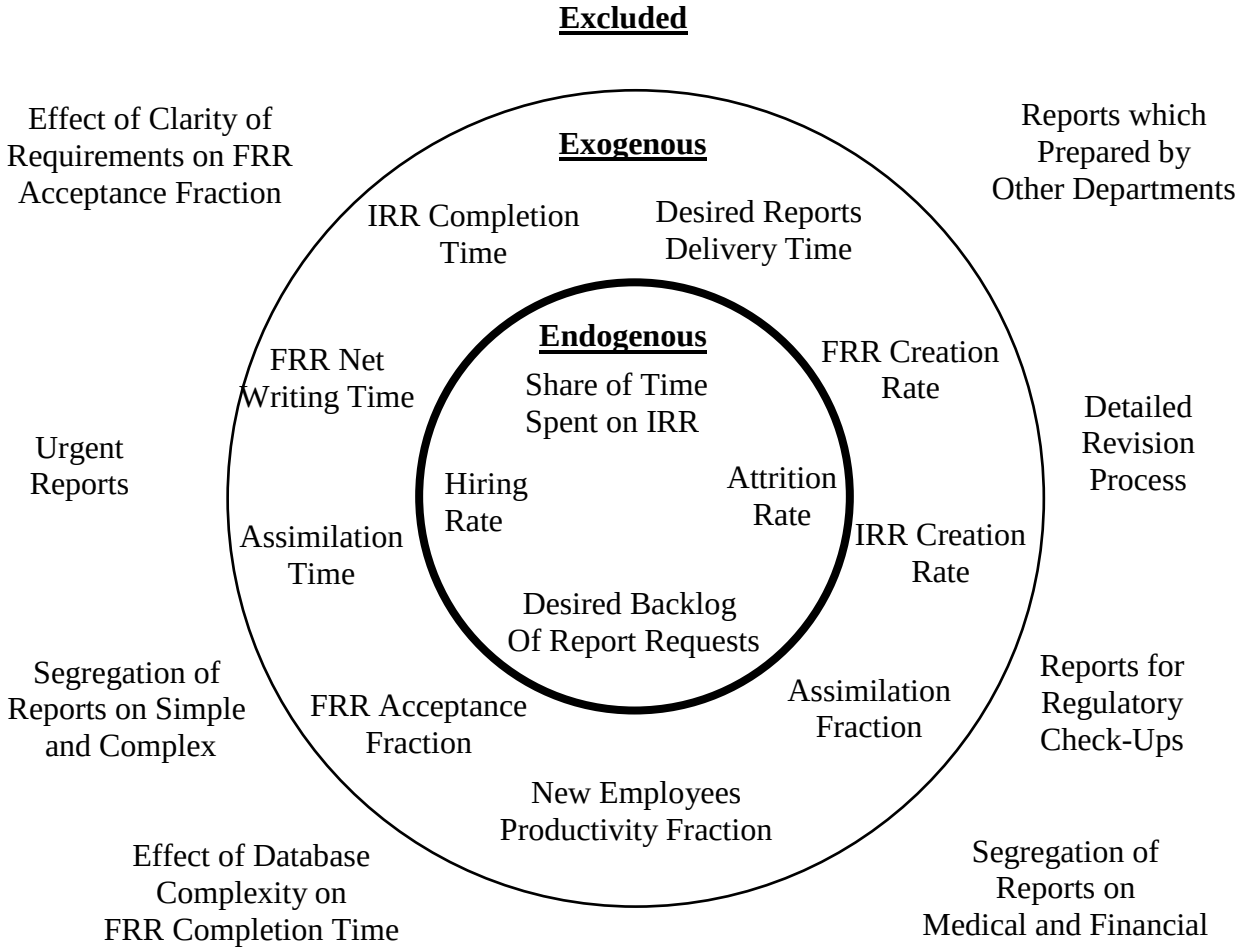


Figure 48. Boundary Adequacy Test

The involvement of the employees of the Information Services Department has helped to focus the model on what is particularly important for them, and thus, adequately set up the model boundaries.

Chapter 8. Policy Options & Feedback Loop Perspective

This chapter describes four policy options that were proposed by participants and implemented in the model structure. Some of them include elements that already take place and thus, should be considered as parts of the explanatory model. For that reason, the model structure from the feedback loop perspective was not considered earlier and is presented in this chapter.

8.1. Link between Policy Options and Desired Reports Delivery Time

Each policy option that was chosen for the implementation in the model structure has a connection to the desired reports delivery time either through FRR Creation Rate or FRR Completion Rates. The majority of policies are connected to FRR Completion Rate, and only one – to FRR Creation Rate.

First, let's consider the desired FRR Completion Rate and its connection to the desired reports delivery time and policy options. It was calculated based on the backlog gap, time to close the gap, the FRR Creation rate and FRR Dismissal and Rejection rates. In, its turn, the backlog gap presents the difference between the actual and the desired backlog. The desired backlog was obtained by multiplication of FRR Creation Rate and Desired Delivery time, that was converted from days to months.

Then the desired FRR Completion Rate was used to determine the desired productivity per effective writer based on the fixed number of effective report writers. For the Information Services Department was important to consider the allocation of the working time to understand how much time is spent on formal report requests and other tasks. For that reason, the productivity in the Report Request module was defined through the time available for report writing, the share of time spent on informal report requests and average completion time. For that reason, the desired productivity was converted to FRR Desired Completion time, as present in Figure 49.

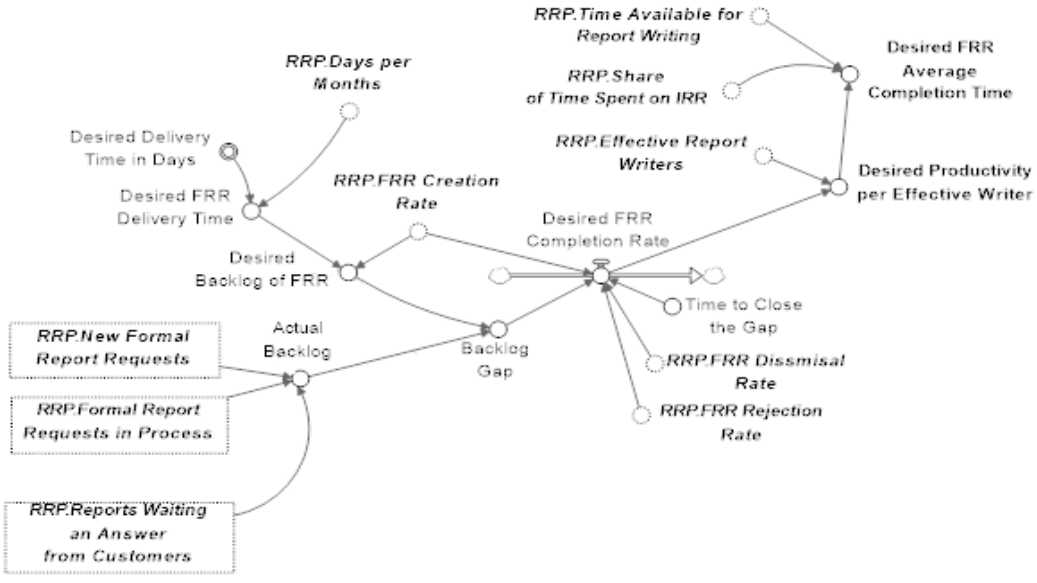


Figure 49. Desired FRR Completion Rate & Desired FRR Average Completion Time

The obtained value was used in the implementation of Naming Conventions and Knowledge Sharing policies into the model structure as presented in the next section.

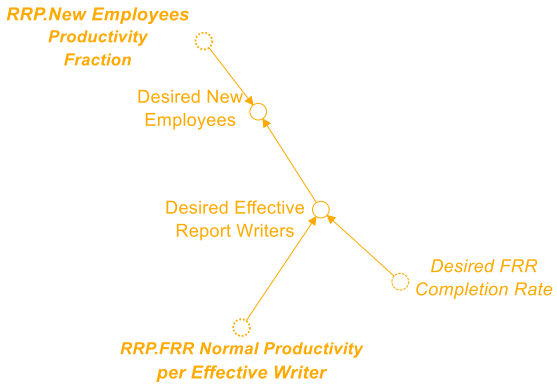


Figure 50. Desired New Employees

The different structure was used to connect Hiring More People policy. For this, the desired number of effective report writers was calculated based on the desired FRR Completion Rate and fixed productivity of report writers. Then this number was corrected by the productivity fraction of new employees to count the number of desired new employees as shown in transferred into the desired number of new employees (Figure 50).

Second, let's consider the Desired FRR Creation Rate. It was calculated based on the gap between actual and desired backlog, time to close the gap and FRR Acceptance rate, as presented in Figure 51.

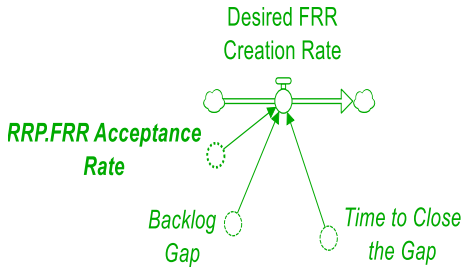


Figure 51. Desired FRR Creation Rate

Only one policy might affect the Desired FRR Creation rate and it is Customers' Education. Its implementation in the model structure is described in the next section.

8.2. Policy Options

8.2.1. Knowledge Sharing

Knowledge Sharing is the first policy option that was proposed to streamline the report request process. Implementation of this policy will increase the knowledge of report writers and it, in turn, will decrease the average time needed to complete a report[4] and increase the productivity of report writers. Thus, this policy influences the outflow of completed report requests.

Knowledge Sharing might be time-consuming since all employees should be involved in the education process. Also, knowledge might become obsolete or become forgotten as time goes by. Thus, to implement this policy into the model structure not only the learning process should be

[4] It worth mentioning that the average time needed to complete a report differs from reports delivery time. Reports delivery time consists of assignment & dismissal time, processing time and communication delay. However, the time needed to complete a report is related only to processing time, but not equal to it due to multitasking.

considered, but also the process of knowledge decay. This part of the model was based on the model built by Gorey and Dobat (1996) that is presented in Figure 52.

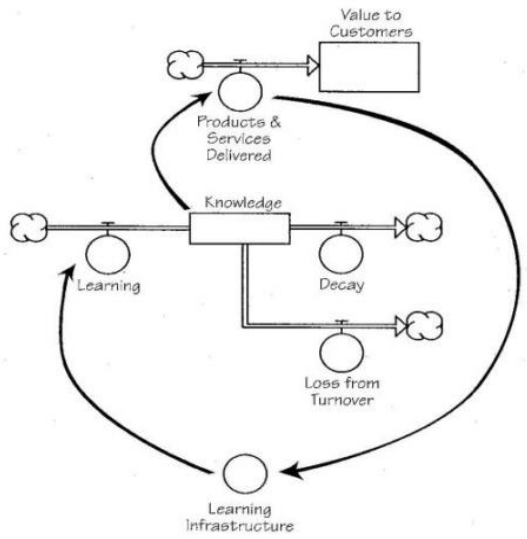


Figure 52. Knowledge: A Structural View

They consider a loss from turnover and decay as the main sources of the knowledge drain. Also, Gorey and Dobat emphasize the importance of learning infrastructure for keeping up the desired level of knowledge and try to estimate the value of company's knowledge for the customers. Thus, their model presents a good structural view of knowledge at the organizational level and can be easily adjusted to the needs of this modelling project. This structure is not only easily transferable to knowledge sharing, but also might be applied to customers' education.

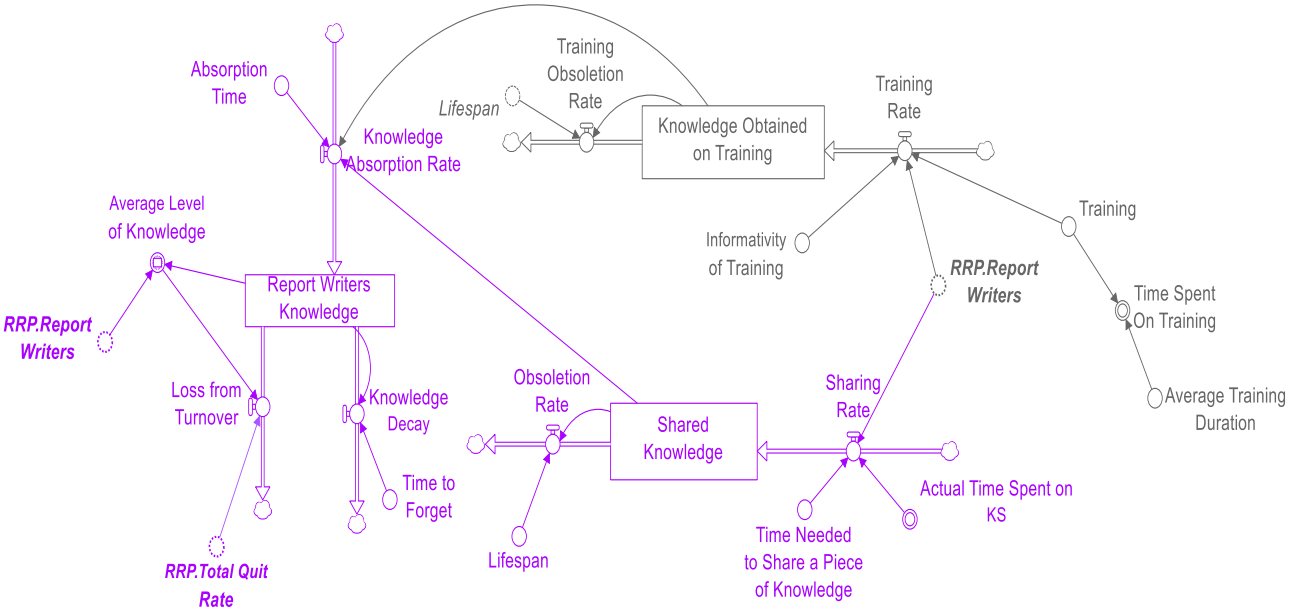


Figure 53. Knowledge Sharing: Structure

In the model presented in Figure 53, were considered two sources of report writers' learning: training and knowledge sharing. The first source is required by Epic, the software provider. Thus, this part of the education process is already taking place and should be considered as part of the explanatory model.

Knowledge sharing takes place only in an ad hoc and incoherent manner mainly through questions. But not everyone likes to answer the same questions again and again, and thus not everyone in the team gets an equal access to the knowledge. Instead of sharing knowledge in a rather individual format, it can be done through the series of report writing guidelines and workshops. Especially, it would be beneficial for new employees, which share in the workforce structure is constantly growing.

However, the shared knowledge and knowledge obtained through training cannot be used forever. Knowledge used in report writing is becoming obsolete in a couple of years due to technology development and changes in the structure of the database. So, to keep up the desired level of knowledge, report writers should be periodically retrained, and the base of shared knowledge must be updated.

Also, the model assumes that it takes some time to absorb the obtained knowledge and start to use it in the daily routine and considers that after a while, the knowledge might become forgotten or a report writer can leave the company.

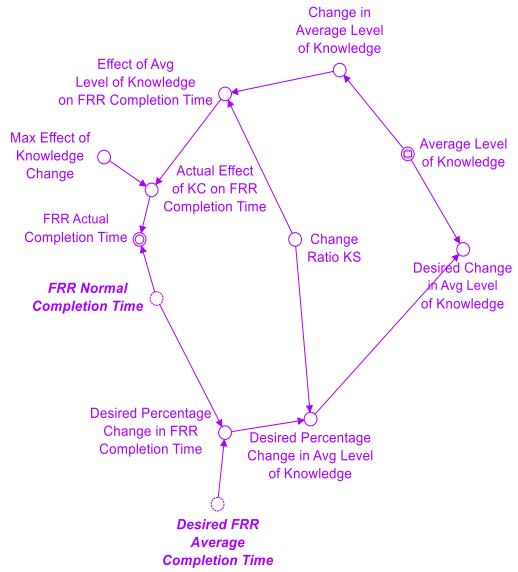


Figure 54. A Link Between Knowledge and Reports Completion Time

The value of report writers' knowledge for the customers is presented through the time needed to complete [5]a report as portrayed in Figure 54. To avoid unit inconsistency, these variables were connected through the desired percentage change in completion time and the percentage change in the average level of knowledge. In addition, was used the change ratio, which assumes that 5 percent growth in the level of knowledge decreases the report completion time by 1 percent. It worth mentioning, that the effect of report writers' knowledge on the completion time is limited. The model assumes that it cannot be decreased by more than 20 percent.

The time needed to achieve the desired level of knowledge was estimated through the time needed to share a piece of knowledge. Also, the time period in which the company is planning to achieve the desired level was taken into consideration. Nevertheless, in some cases it might turn out that all working hours should be spent only on the knowledge sharing. That cannot be the case since the work is needed to be done. Thus, the desired time spent on knowledge sharing was limited by the 20 percent of working time available per months as showed in Figure 55.

[5] The desired reports completion time is connected to the desired backlog and delivery time. This link is presented in "Link between Policy Options and Desired Reports Delivery Time" section.

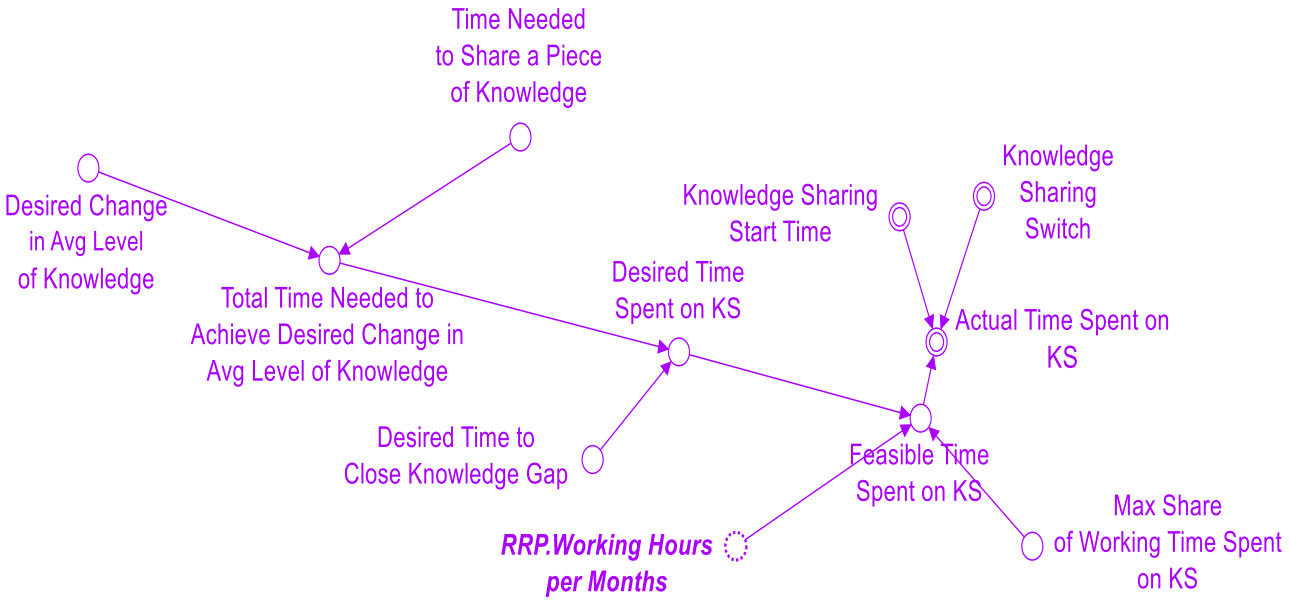


Figure 55. Time needed to achieve the desired level of knowledge

As shown above, the Knowledge Sharing policy might be quite effective in dealing with the backlog of report requests given that it has a direct effect on the reports completion time. However, this policy option may not be able to bring the backlog of report requests to the desired level since not all working time might be spent on knowledge sharing and that reports delivery time can be decreased only to a certain extent through a change in the average level of education.

8.2.2. Naming Conventions

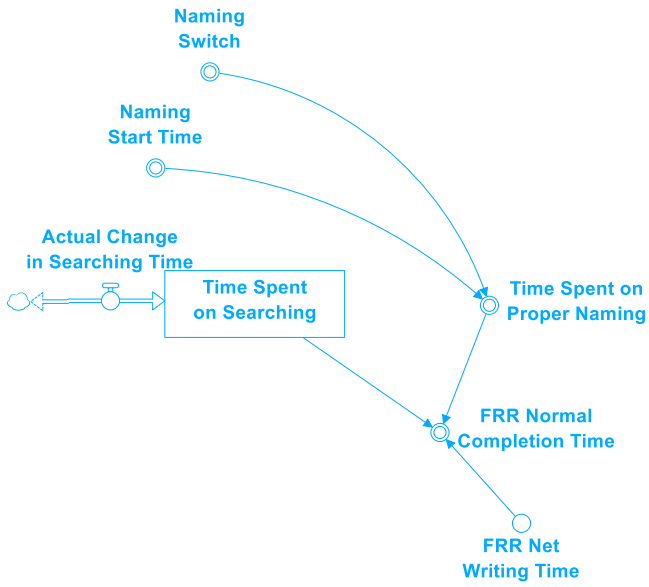


Figure 56. Naming Conventions

Naming Conventions is the second policy that was proposed to streamline the report request process. Its implementation can decrease time spent on searching similar reports and thus, reports completion time. However, it takes more time to properly name reports since it might be needed to double check that a report is named according to naming conventions. Also, the time spent directly at report writing cannot be changed by their implementation as presented in Figure 56.

Implementation of this policy option requires either renaming of old reports or waiting until the share of properly named reports will become prevailed. It's not highly likely that renaming of old reports will take place since everyone are skeptical about it. Thus, the second option looks more realistic: improperly named reports will become obsolete after some time and will be replaced by the properly named reports; as it portrayed in Figure 57.

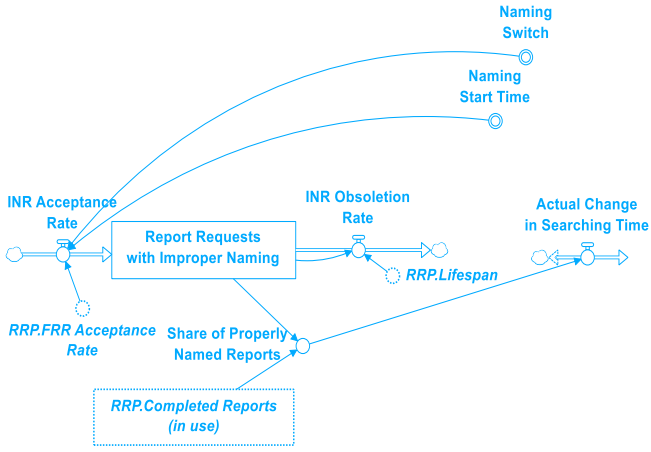


Figure 57. Share of Properly Named Reports

This policy option is also connected to the desired backlog of a report requests and the desired reports delivery time as portrayed in Figure 58.

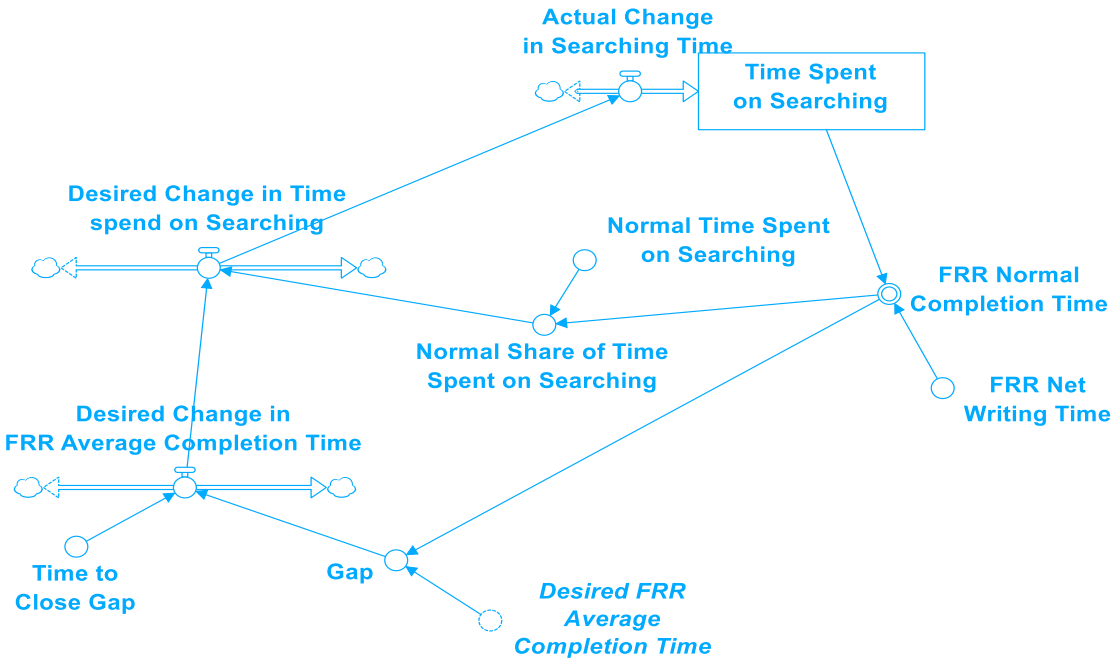


Figure 58. A Link Between Naming Conventions and Reports Completion Time

Since the time spent on searching is only a small part of report completion time, this policy option cannot provide the desired results. However, the expenses on its implementation are small it worth considering this policy in combination with another policy option.

8.2.3. Customers' Education

Customers' Education was suggested as the third policy option. Its implementation allows to decrease report requests creation rate, and in turn, diminish the backlog of open requests. To describe customers' education, the model proposed by Gorey and Dobat (1996) was used, which was described before.

The model assumes that customers might learn how to work with reports not only from the reading of user manuals and attending workshops but also by using the report request process per se. For instance, the more they use reports the easier it becomes to filter the data or show them for a different time horizon. Thus, the learning from usage is the part of the explanatory model. However, the creation of user manuals is the part of the policy model, since now it is taking place only in the unsystematic manner and very seldom.

It worth noticing, that the knowledge acquired by the use report requests and the learning infrastructure might become obsolete as time goes by due to the technology development and changes in the data structure. Thus, periodically they need to be updated.

Also, the model assumes that it takes some time to absorb the obtained knowledge and start its practical application. In addition, some pieces of knowledge might become forgotten or customers can leave the company. Thus, to decrease report request creation rate it's necessary to constantly keep track of the level of customers' education as presented in Figure 59.

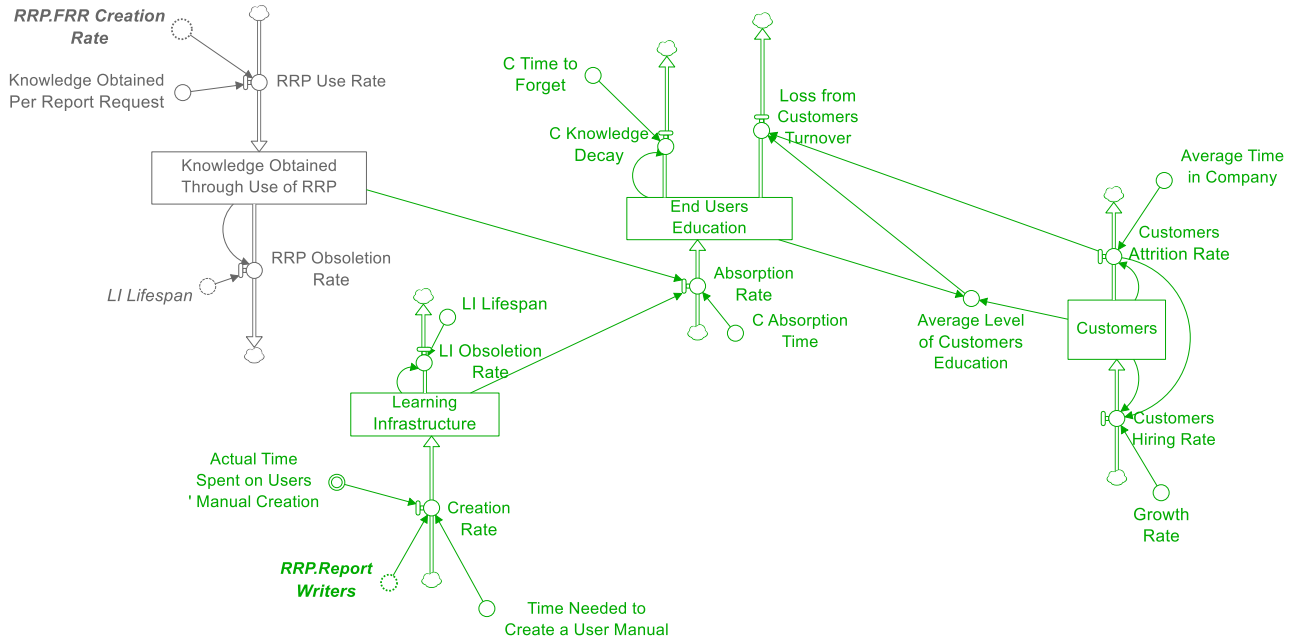


Figure 59. Customers Education

The desired level of customers' education depends on the desired rate of report creation that in turn depends on the desired backlog. To avoid unit inconsistency, these variables were connected through the desired percentage change in FRR creation rate and the percentage change in the level of customers' education. In addition, was used the change ratio, which assumes that 5 percent growth in the level of customers' education decreases the FRR creation rate by 1 percent. It worth noting, that the number of report requests cannot be brought to zero since the effect customers' education on the FRR creation rate is limited. The model assumes that it cannot be decreased by more than 20 percent (Figure 60).

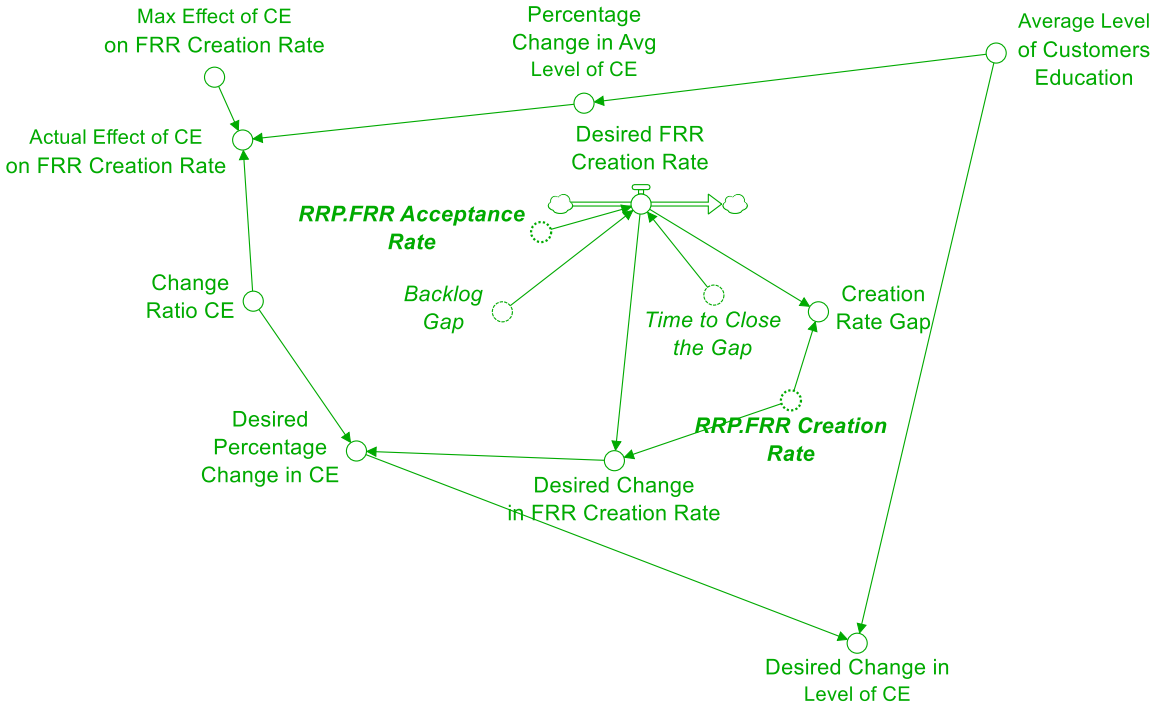


Figure 60. A Link Between FRR Creation rate and Customers' Education

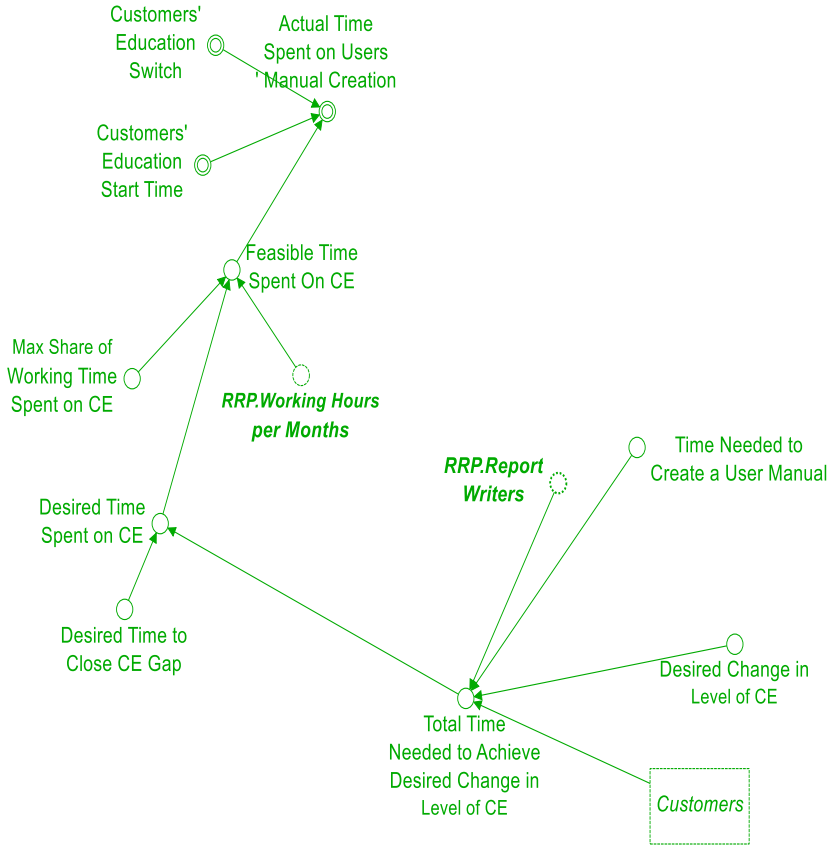


Figure 61. Time needed to achieve the desired level of customers' education

The time needed to achieve the desired level of customers' education was estimate through the time needed to create a user manual. Also, the time period in which the company is planning to achieve the desired level of education was considered. However, in some cases, the desired time spent on user manual creation might be too high and may not leave much time for report writing. Thus, the time spent on customers' education was limited by 20 percent of the total working time as shown in Figure 61.

Therefore, the Customers' Education policy might be policy might be viable for the streamlining the report request process since it can decrease the report request creation rate. Nevertheless, it has some limitations, and is not clear if the implementation of this policy will be able to achieve the desired reports delivery time and the backlog.

8.2.4. Hiring More People & Hiring with Productivity Correction

Hiring is the last policy that has emerged during the discussion. In fact, this policy option is already realized in the company to the certain extent -the company hires slightly more people than leave the company since the new employees are less productive. However, it doesn't represent the actual needs of the company in a workforce and cannot solve the reports delivery time issue.

Thus, the model considers two types of hiring: hiring with productivity correction and hiring more people. The first kind of hiring is a part of the explanatory model, and the last one - the part of the policy model.

It is worth noting that the actual productivity fraction of new employees might be lower than the perceived productivity fraction. Thus, in fact, the number of the effective report writers can even go down despite the attempts to hire more people with productivity correction.

Hiring more people policy also takes into consideration the fact that productivity of new employees is lower since report writing requires knowledge specific to the company. To determine how many people should be hired to streamline the report request process desired FRR completion rate was calculated based on the desired report delivery time. The structure representing the desired FRR completion rate is described in the previous section.

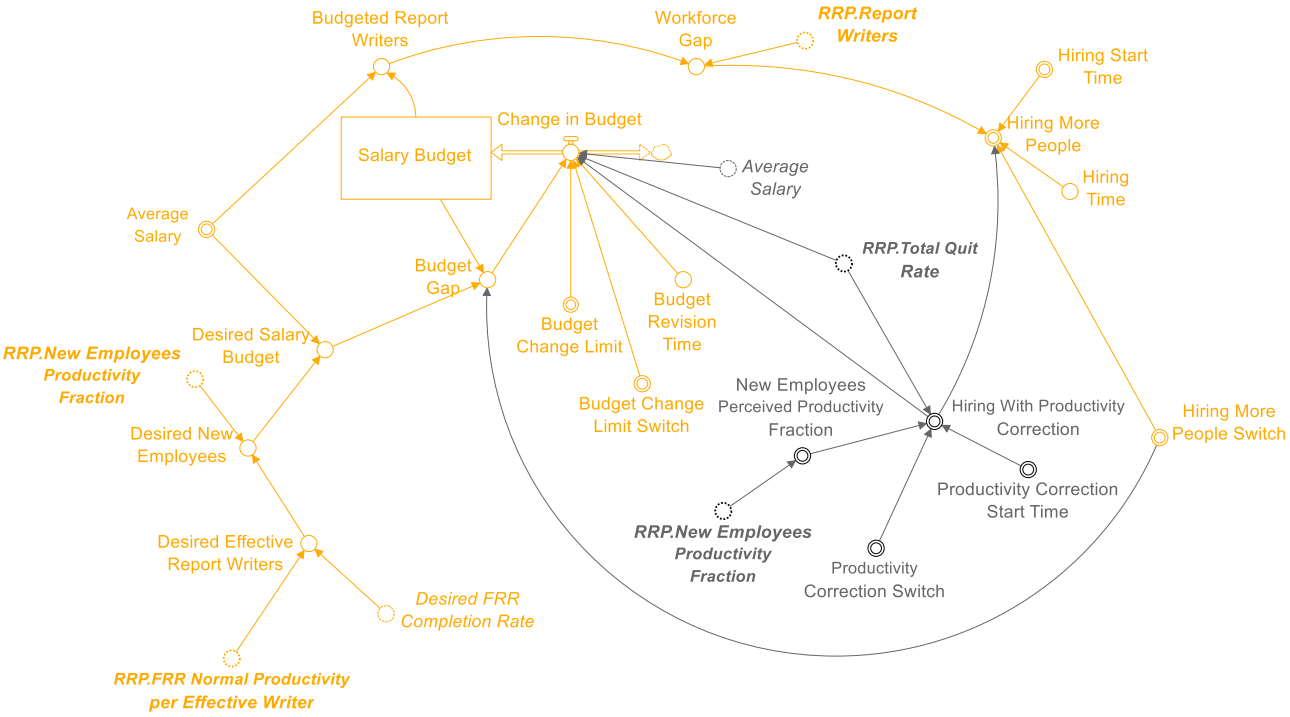


Figure 62. Hiring More People & Hiring with Productivity Correction

In the optimistic scenario, the Information Services Department gets as much financing as needed to hire the desired number of people. In this case, desired report writers are equal to budgeted report writers. However, the company might set up a budget change limit to keep track of the expenses. Thus, it might become impossible to reach the desired level of backlog.

Thus, this policy option might be the most effective in case if the company is ready to provide as much money as needed for hiring more people. However, if the budget change limit take place, it's not clear if it would be possible to reach the goal for the backlog.

8.3. Feedback Loop Perspective

To consider the model from the feedback loop perspective, basic policy options were connected to the structure, representing the report request process. The obtained Stock and Flow Diagram was simplified and rebuilt into the Causal Loop Diagram that is presented in Figure 63.

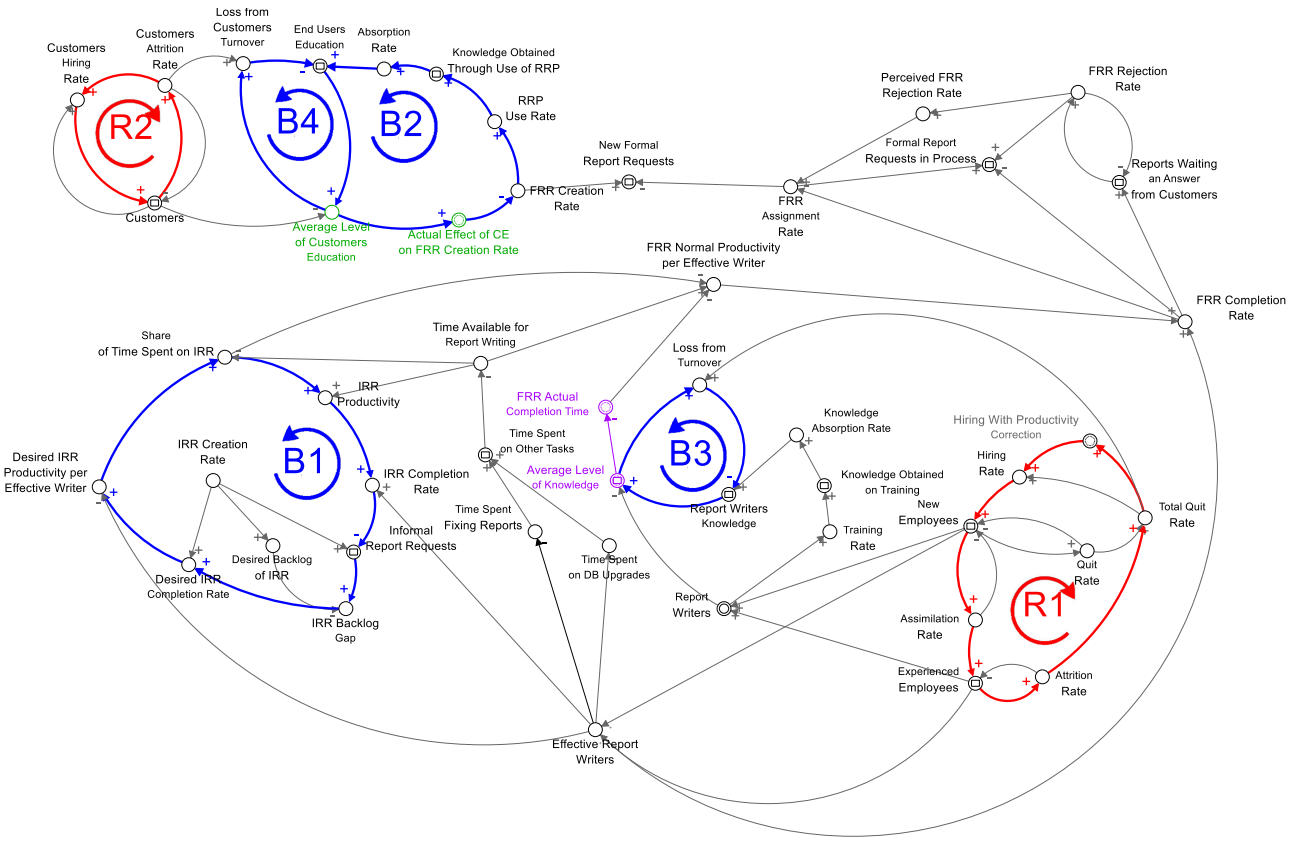


Figure 63. Causal Loop Diagram

The resulting model has 6 major feedback loops: 2 reinforcing and 4 balancing.

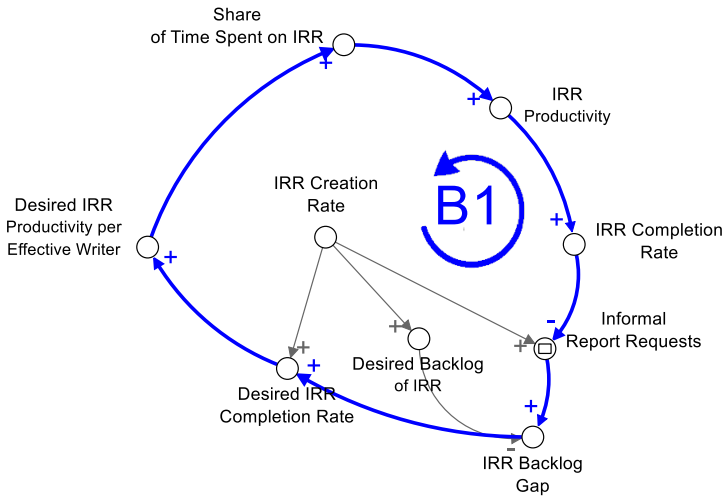


Figure 64. B1: Share of Time Spent on Informal Report Requests

The first balancing loop **(B1)** represents how much time report writers spent on informal report requests. Informal report requests normally have higher priority than formal requests due to the presence of a direct connection between the personnel of the Information Services department and end users. Thus, the desired informal reports completion rate determines the share of time spent on the informal report requests.

The second balancing loop **(B2)** shows the effect of customers' education on FRR creation rate. The higher level of education, the less report requests are coming to the Information Services Department. The model assumes that the more customers use the report request process, the higher their ability to modify and update reports on their own. Thus, the model balances itself, since the low use of the report request process decreases the level of customers' education.

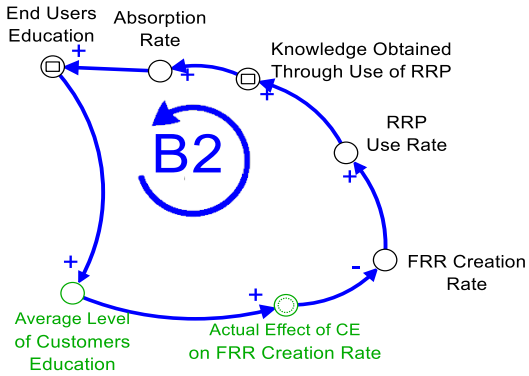


Figure 65. B2: Effect of Customers' Education on FRR Creation Rate

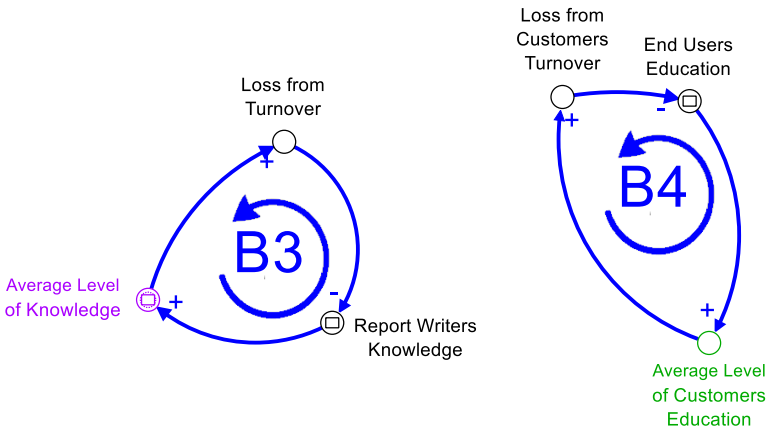


Figure 66. B3&B4: Loss of Knowledge from Turnover

The third balancing loop **(B3)** describes the loss of Report Writers Knowledge from Turnover. The more time and money are invested into the knowledge, the harder it becomes to train new employees to the desired level.

Loss of Knowledge from the Turnover is also actual for the customers' education **(B4).**

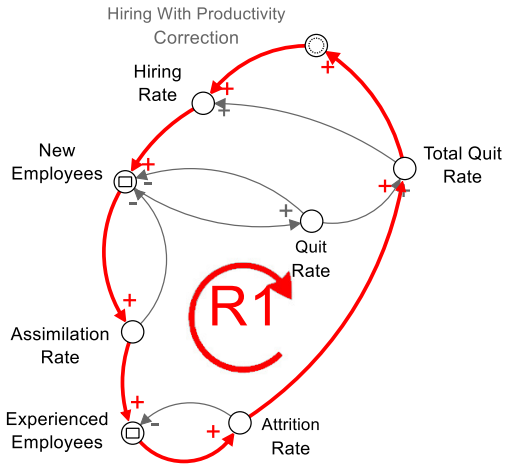


Figure 67. R1: Report Writers

The first reinforcing loop **(R1)** shows the process of hiring new people. The company hires new people to replace employees that have decided to leave the company. Since the productivity of new writers is lower, the management tries to take it into consideration and hires slightly more people. The diagram shows that based on the current system of hiring and training, the number of report writers will constantly go up. The more people work in the company, the higher the attrition rate, and in its turn the hiring rate.

The second reinforcing loop **(R2)** represents the process of hiring users of the report requests in the company. The model doesn't divide the customers at into new vs. experienced, and thus the loop has only three elements: customers, customer hiring rate and customer attrition rate. The more customers work in the company, the more customers leave the company. The more customers leave the company, the more people are hired in their replacement. Thus, the number of customers will always go up.

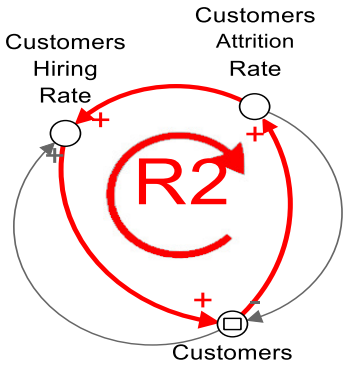


Figure 68. R2: Customers

It worth mentioning that per se the report request process has just a few feedback loops since mainly exogenous parameters were used to define its flows. That is reasonable since the considered time horizon is equal just to several years. However, to further model development it is worth considering possible structural changes that might happen during the more extended period.

Chapter 9.

Chapter 9. Comparison of Policy Options

The tests conducted in Chapter 7 showed that the model is robust enough to use it for choosing the best course of action. Thus, this chapter will focus on the costs of policy options and a comparison of their effectiveness.

9.1. Costs of Policy Options

Each policy option described in Chapter 8, has certain costs and benefits. This section will consider all components of the implementation costs, and the next one – their benefits and net present value.

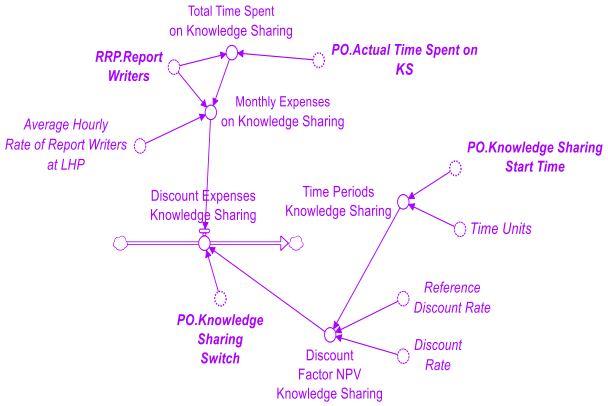


Figure 69. Costs of Knowledge Sharing

The costs of Knowledge Sharing have been considered first. Report writers' working time is the main resource that is needed for its realization. The average hourly rate of the employees of the Information Services Department has been used to transfer the time into the monetary values. And then all expenses for knowledge sharing were discounted and were calculated their value at the current moment as presented in Figure 69.

Secondly, the implementation costs of Naming Conventions have been considered. By analogy with knowledge sharing, working time spent on the proper naming of reports is the main resource that is needed for its realization. Based on the average hourly rate this number was transferred into a money equivalent and discounted as shown in Figure 70.

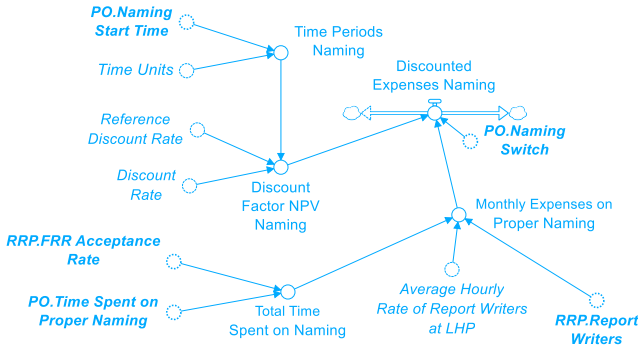


Figure 70. Costs of Naming Conventions

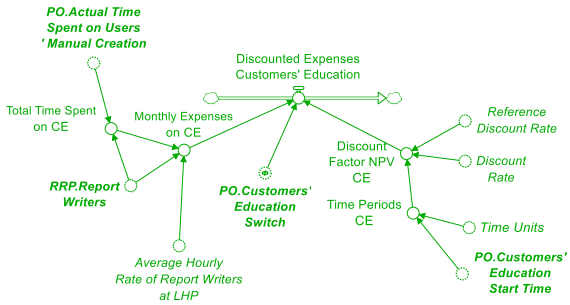


Figure 71. Costs of Customers' Education

Thirdly, the costs of customers' education have been counted. Since it's not clear if it would be possible to delegate customers' education to the specially hired and educated trainers, the model assumes that customers will be educated through the user manuals created directly by report writers. Thus, report writers' working time is once again the main resource that is needed for the policy implementation.

Fourthly, the costs of hiring more people have been considered. At the first sight, this is the most expensive policy option, since it increases the company's expenses at the salary budget. However, it also must be the most effective policy, since all other variants have certain limitations.

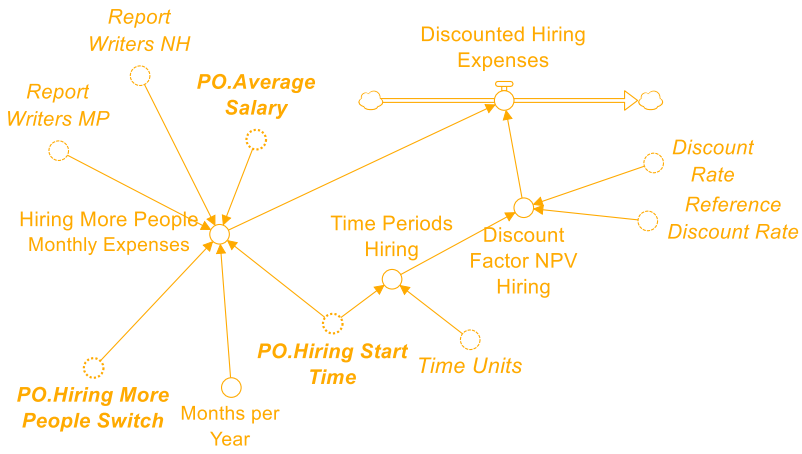


Figure 72. Costs of Hiring More People

Since the company already tries to hire people with the productivity correction, the salary budget and changes in the salary budget has been counted additionally for the basic policy option (Hiring with the Productivity Correction), as presented in Appendix II.

9.2. Benefits of Policy Options and Net Present Value

To calculate the benefits of policy options was considered customers demand on the reports and was developed a conceptual pricing scheme that might be used when working with external clients.

It assumes that the price that customers are ready to pay for reports is going down if they are not delivered in a timely manner. For each day of the delay, the price of the report is going down by 5 percent of its initial value but doesn't go below zero. The initial price of a report that is delivered in a timely manner was determined based on the hourly rate for outsourcing and the average number of hours needed to complete a report.

The structure representing how the price of a report has been calculated is shown in Figure 73.

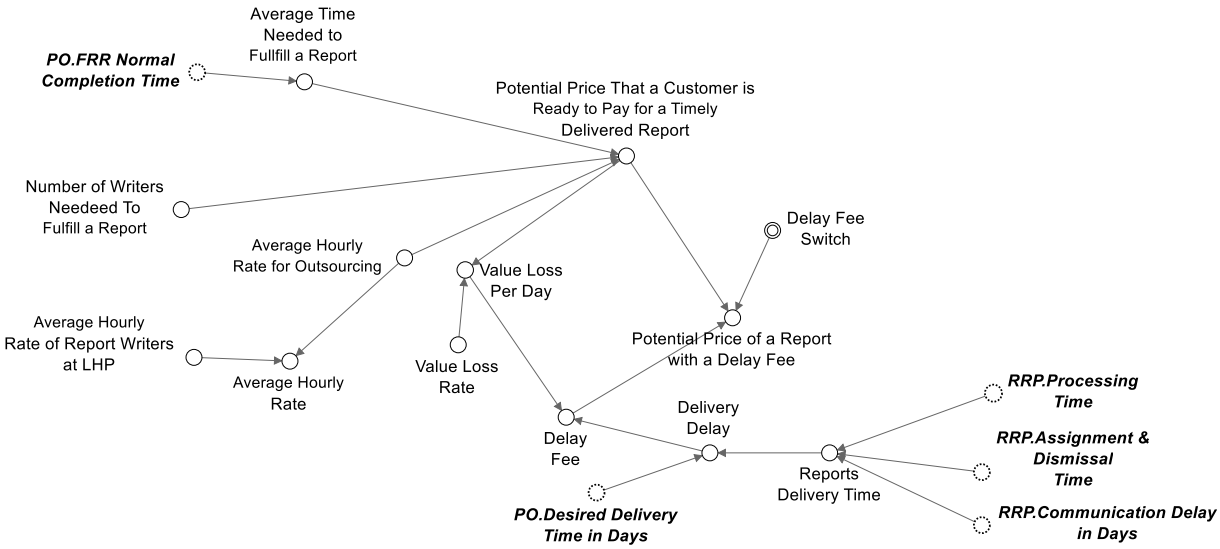


Figure 73. Potential Price of a Report

Then this potential price of a report has been used to calculate the benefits of each policy option. The obtained numbers have been discounted and combined with implementation costs as shown in Figure 74.

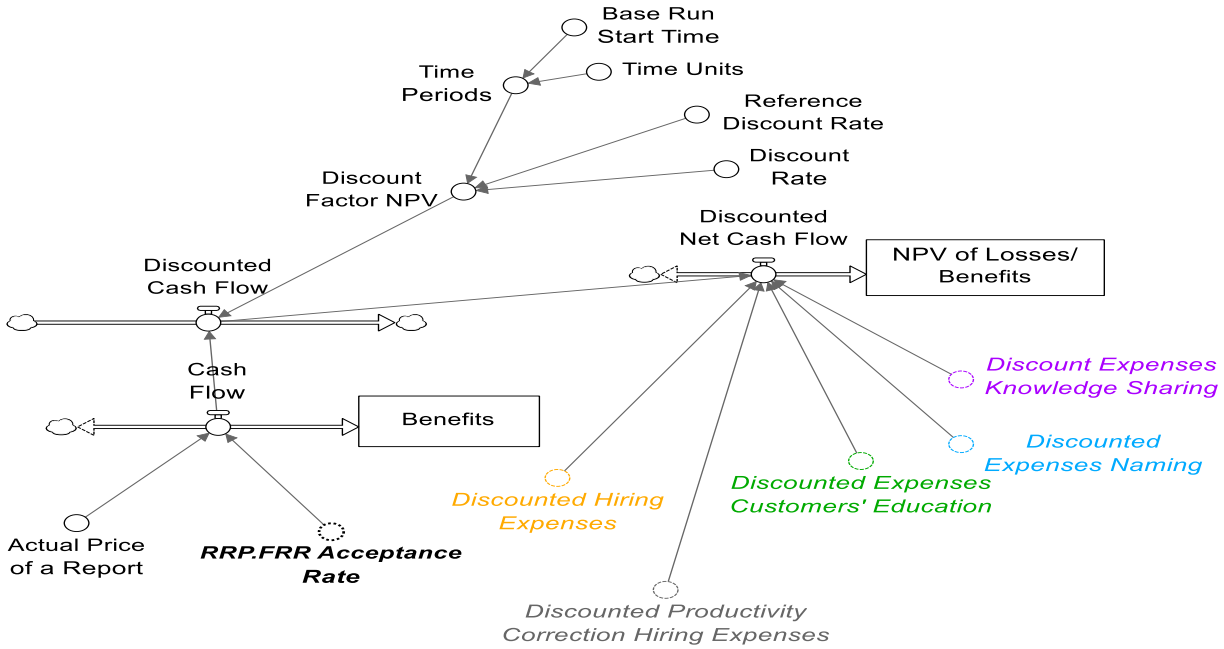


Figure 74. Net Present Value

9.3. Simulation Results

This section describes the effect of policy options on the system behavior and analyzes their effectiveness.

The behavior of the backlog and report delivery time have been considered first. Until the implementation of policies, the backlog goes up and fluctuates due to the changes in the report request creation rate. However, in June 2018, when the model starts to use the forecast instead of the real data for the reports creation rate, the backlog stops oscillating so much but continues to go up in the base run. It reaches the maximum value that is equal to 188 open report requests by March 2022 and slightly decreases by the end of the simulation period.

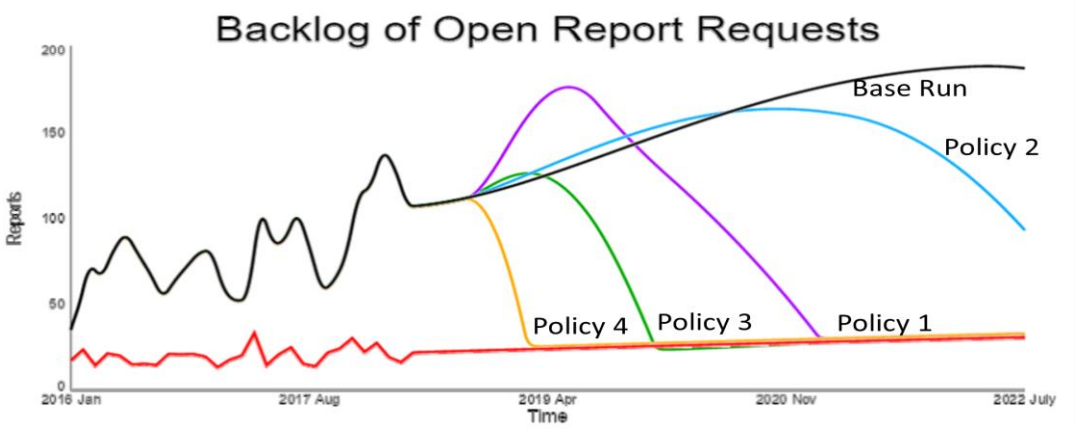
The implementation of the first policy, knowledge sharing, initially increases the backlog of report requests in comparison to the base run since it decreases the time spent on report writing. However, after a delay, the knowledge of report writers rises enough to start affecting the average reports completion time and thus decreasing the backlog. It reaches the desired value by March 2021.

The second policy option, naming conventions, slightly increases the backlog of reports, but starts to decrease it in November 2020, when the share of properly named reports begins to prevail, and thus reducing the time spent on searching similar reports. It, in turn, allows the average time needed to complete a report to decrease, since in many cases it's easier to modify an existing report than create a new one from scratch and thus bringing down the number of open report requests.

However, it has the only limited impact, since the share of time spent on searching is not that high in comparison to the net writing time.

The third policy, customers' education, starts to work faster than naming conventions and knowledge sharing. It slightly brings up the number of report requests, since the time spent on customers education is deducted from the time available for report writing. However, it doesn't require as much time as knowledge sharing and allows the backlog to be decreased to the desired level by January 2020.

The fourth policy, hiring more people, decreases the backlog of reports by February 2019 if there are no budget change limits. Thus, this policy works faster than others.



Policy 1: Knowledge Sharing
Policy 2: Naming Conventions
Policy 3: Customers' Education
Policy 4: Hiring More People

Figure 75. Backlog of Open Report Requests

Now let's consider the behavior of the report delivery time and the effect of policy options on it. In the base run, it reaches the maximum value that is equal to 44 in March 2021 and then starts to slightly go down due to the growing report requests completion rate.

The implementation of the first policy initially increases the reports delivery time to 54 by March 2019 because the time needed for knowledge sharing is deducted from the time used for report writing. But then when the level of customers' education goes up, the report delivery time starts to decrease and reaches the desired level by January 2021.

Initially, the second policy slightly increases the report delivery time in comparison to the base run. However, in March 2020, since the share of properly named reports starts to prevail, the delivery time begins to decline and reaches its minimum value of 19 days by July 2022.

The third policy option raises report delivery time to 40 days by January 2019 due to the reallocation of working time. But soon the customers' education reaches a level that allows decreasing the report request creation rate, and it, in turn, starts to decrease the report delivery time to the desired level, which is reached by January 2020.

The fourth policy, hiring more people, starts to decrease the report delivery time right after its implementation. The desired value is reached in February 2019, which is much faster in comparison to other policies.

Policy 1: Knowledge Sharing
Policy 2: Naming Conventions
Policy 3: Customers' Education
Policy 4: Hiring More People

Figure 76. Reports Delivery Time

Lastly, let's consider the net present value and how it might be affected by the implementation of policy options. In the base run, in the beginning, it's slightly growing, but in November 2017 it begins to decline since the report delivery time completely dissatisfies customers and the price that customers are ready to pay for the report is going down to zero. Thus, expenses on the basic policy option, hiring with the productivity correction, starts to prevail and net present value becomes negative and reaches its minimum value of -550 thousand dollars by July 2022.

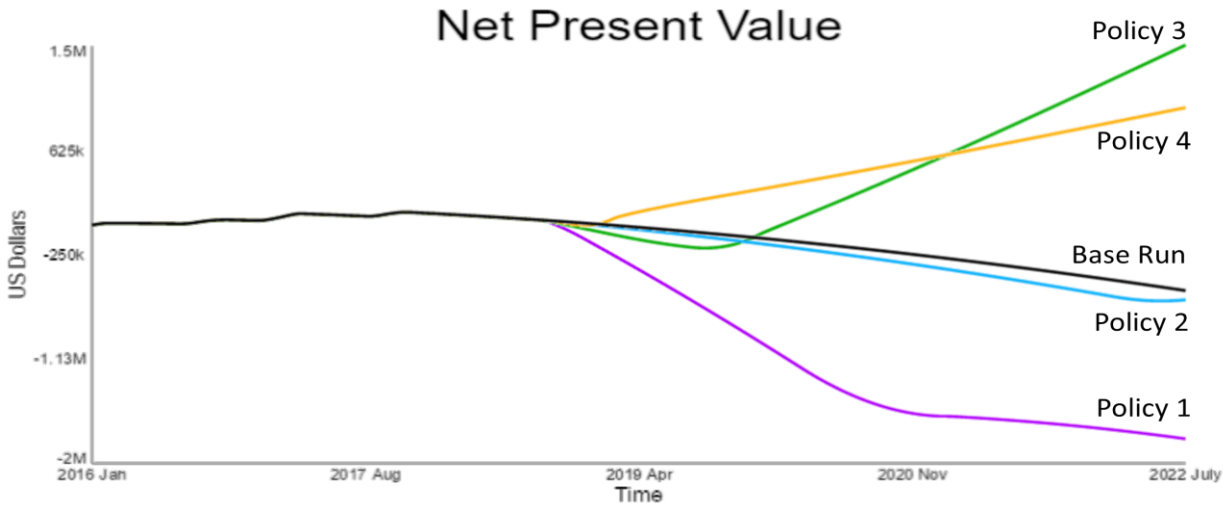
The first policy exacerbates the situation even further since at the beginning it increases the report delivery time and knowledge sharing has certain costs. After reaching the value of -1.58 million dollars in November 2020, the net present value starts to decline less rapidly and reaches the value of -1.8 million dollars by July 2022.

The second policy slightly decreases the net present value. It happens because naming conventions are not able to guarantee the delivery of reports in a timely manner and thus don't increase the value of the report for customers. However, this policy has its costs, and thus it performs even worse than the base run.

The third policy slightly decreases net present value in comparison to the base run at the beginning. But after September 2019, the benefits of the policy start overcome its costs, and net present value begins to grow. It reaches the maximum value of 1.51 million dollars by July 2022.

The fourth policy starts right away to decrease the report delivery time and increase the value of reports for customers. Thus, despite growing costs on the salary budget, the benefits of this policy

prevail. It provides the growth of net present value, which reaches its maximum value of 984 thousand dollars by July 2022.



Policy 1: Knowledge Sharing
Policy 2: Naming Conventions
Policy 3: Customers' Education
Policy 4: Hiring More People

Figure 77. Net Present Value

Based on the graphs above, it's clear that customers' education and hiring more people provide the best results. Implementation of naming conventions is not able to decrease the report delivery time to the desired level and thus this policy should not be considered as a sole solution. However, its combination with other policies might be even more effective than the implementation of only one policy. Knowledge sharing might perform better in a longer time horizon. But it's not highly likely that it will overcome the results of other policies.

Conclusions

The conducted project was aimed to streamline the report request process and improve the efficiency of the Information Services Department, and in turn, the efficiency of the whole company by providing the data needed for the decision-making in a timely manner.

To reach this aim, the participatory System Dynamics modeling has been used. The use of this approach allowed to analyze causes and effects of a late delivery of reports and test possible solutions for reducing the reports delivery time. The direct involvement of the employees of the Information Services department in the modelling process helped to create a shared vision of the problem, build the confidence in the model and develop the list of possible policy options.

Three research questions were answered to achieve the project aim.

The first question is related to the causes disrupting the delivery of reports in a timely manner. Based on the model, it's clear that the constantly growing report request creation rate and the lack of a sufficient workforce are the main causes of reports delivery delay. Another factor, that might exacerbate the problem, in fact, that the company plans further expansion by including rural hospitals in its structure. They usually don't have their own Information Services department; thus, all report requests will come to the employees of the local healthcare provider.

The second question is about factors that have the most influence on the backlog of report requests. Based on the discussion, that took place during the workshops, it turned out that the low level of customers' education is the key factor. However, it worth noticing that the significant backlog might not be a problem if it goes along with the growing number of report writers or their productivity and thus, doesn't cause the delivery delay.

The third question is related to the most effective way of improving the efficiency of the report request process in a local health care provider that will enable the timely delivery of reports. To answer this question, the four policy options proposed by participants have been implemented in the model. Their effects on backlog of open report requests and reports delivery time were considered. In addition, the cost-benefit analysis was conducted.

To evaluate the benefits of policy options, the potential pricing scheme that might be used when working with external customers was developed. It estimates the potential value of the reports depending on the reports delivery time. The model assumes that reports that are not delivered in a timely manner have a lower value for the customers than reports delivered before the deadline.

It turned out that hiring more people and educating customers are the most effective ways that are able to guarantee the timely delivery of reports. However, the solution based mainly on hiring new people might be less effective, when dealing with "complex" customers that don't know exactly what they need. In this case, the reports undergo through the long revision process that might include multiple communication delays. Thus, the company should focus on the customers' education, since

the implementation of any policy option will not be effective without a finding a common ground with customers.

The two other policies that have been considered are naming conventions and knowledge sharing. Implementation of naming conventions is not able to guarantee the timely delivery of reports since it has the only limited effect on the completion time. Knowledge sharing can decrease the backlog of report requests, but costs overcome benefits since this policy requires the significant reallocation of working time.

Also, it worth mentioning that the desired reports delivery time currently is not stated clearly in any of official documents. Thus, in addition to the policies mentioned above, it should be stated clearly and communicated to all report writers. Hence, the report writers will be more aware of the deadline and motivated to deliver reports in a prompt manner. Moreover, customers should be informed that tickets will be closed automatically if they don't provide feedback within 5 days.

Hence, to enable the data-based decision making in the company the Information Services department was recommended to implement customers' education policy and clearly state the desired reports delivery time.

Now let's consider how the use of Group Model Building approach has affected the outputs of the modelling process and how it might affect the further implementation of the policy options.

First, it allowed to better to better represent the reality in the model and at the same time, create a shared vision of the problem among participants. Normally people focus only on their particular tasks, thus, building the model based only on individual interviews might lead to the creation of the "elephant in the room".

Second, according to Nutt, decisions imposed by the management has less chance on being successfully implemented (2004, 2008). They might face significant policy resistance since nobody likes changes. However, the involvement of personnel of the Information Services department in the modeling and decision-making process will significantly increase chances for the successful policy implementation.

Last but not least, the use of Group Model Building approach has helped to disseminate the System Dynamics methodology within the company. Indeed, that has become a project sub goal due to the high interest of the head of the Information Services department.

Limitations and Further Improvements

This section emphasizes what difficulties took place during the project and what can be done to overcome them. Also, it analyzes areas for further model improvement.

Data availability and reliability were the main challenges during the whole modelling project. This challenge has occurred due to the poor use of the ticket tracking system. It has been implemented several years ago and took quite some time before customers and report writers have become accustomed to it. Also, it doesn't contain the full range of data needed for model building. Thus, the questionnaire of employees, interviews with the head of the Information Services Department and the literature review have been used to overcome the challenge with data availability

Another challenge that took place was the availability of stakeholders. Not all participants have attended all Group Model Building workshops. To overcome this challenge, after each workshop a workbook covering the key outputs was prepared to keep the group on the same page. Also, it would be beneficial to include report requestors in the modelling project. They might have a completely different view on what is the problem and might be helpful to model the demand side of the report request process. However, due to the time constrains it was impossible to involve them in the project.

Based on these challenges has been developed the areas for further improvement.

First, the further data collection is needed to increase the data availability. In addition to the ticket tracking system, it would be beneficial to use time tracking system to get a better understanding of how much time is needed for the preparation of a single report.

Second, the time horizon of the model can be extended. It will allow analyzing the long-term behavior of the system and the effects of the policy options. However, during longer time horizon the structural changes might occur. Thus, the model structure and boundaries should be reviewed.

Third, currently, the report request creation rate heavily depends on the exogenous data. However, it would be interesting to define it endogenously, based on the number of customers and the frequency of the use of the report requests. However, it might require the involvement of report users in the modelling process.

Glossary

Rework	is correcting of defective, failed, or non-conforming item, during or after inspection. It includes all follow-on efforts such as disassembly, repair, replacement, reassembly, etc. (“Business Dictionary,” n.d.)
Research Request Process	is the process for requesting, approving, prioritizing, producing and implementing reports from the Information Services department by practitioners and management (the definition is provided by the Information Services department of a local healthcare provider)
Open Report Requests	includes: • new report requests, that are waiting for an assignment of the report writer; • report requests in a process; • reports waiting for an answer from customers.
Reports Delivery Time	includes: • assignment time; • processing time; • communication delay.
Reports Completion Time	Is the only small part of Reports Delivery Time and includes only time needed directly on the completion of report requests. Can be divided on the time needed to find similar reports and net writing time.
Formal Report Requests	are created via “Service Now”, the ticket tracking system. They are usually more complex than informal report requests.
Informal Report Requests	are created via phone and email. They normally do not take much time on the completion and might have higher priority since they are created through a direct contact with report writers.
“Service Now”	is the ticket tracking system, where all formal report requests are registered.
“User Web”	Is the website of the software provider, that contains the description of the major software and database upgrades.
“Nova Notes”	are the notes describing the software and database upgrades. They are published on "User Web" by the software provider.
EPIC	is the provider of the database and software needed for report writing.

Helpdesk	is the mediator between customers and the Information Services Department, that helps clients to create a report request and figure out what should be included in it.
Information Services Department	is the department of the company that is responsible for providing the data requested by management and healthcare personnel for decision-making and regulatory check-ups.
Participatory System Dynamics Modelling	is an approach that involves stakeholders, experts and clients in various phases of the modelling process (Eker, Zimmermann, Carnohan, & Davies, 2017).
Group Model Building	is a specific participatory method that emphasizes the value of directly involving stakeholders in the model development process, in addition to the resultant simulation model (Forrester, 1985).

References

Abdel-Hamid, T. K. 1984. ***The dynamics of software development project management: an integrative system dynamics perspective***. MIT Sloan School of Management, Cambridge, MA.

Abdel-Hamid, T. K., & Madnick, S. 1989. Software productivity: Potential, actual, and perceived. ***System Dynamics Review***. https://doi.org/10.1002/sdr.4260050202.

Andersen, D. L., Luna-Reyes, L. F., Diker, V. G., Black, L., Rich, E., et al. 2012. The disconfirmatory interview as a strategy for the assessment of system dynamics models. ***System Dynamics Review***, 28(3): 255–275.

Andersen, D., & Richardson, G. 1997. Scripts for group model building. ***System Dynamics Review***, 13(2): 107–129.

Barlas, Y. 1994. Model Validation in System Dynamics. ***Proceedings of the 1994 International System Dynamics Conference***.

Barlas, Y. 1996. Formal aspects of model validity and validation in system dynamics. ***System Dynamics Review***, 12(3): 183–210.

Business Dictionary. n.d. . http://www.businessdictionary.com/definition/rework.html, August 10, 2018.

Campbell, D. 2001. The long and winding (and frequently bumpy) road to successful client engagement: One team's journey. ***System Dynamics Review***, 17(3): 195–215.

Cooper, K. G. 1980. Naval Ship Production: A Claim Settled and a Framework Built. ***Interfaces***, 10(6): 20–36.

De Gooyert, V. 2016. Nothing so practical as a good theory; Five ways to use system dynamics for theoretical contributions. ***34th International Conference of the System Dynamics Society***, 1–10.

Delp, P., Thesen, A., Motiwalla, J., & Seshardi, N. 1977. Nominal Group Technique. ***Systems Tools for Project Planning***, 14–18.

Dianati, K., & Davidsen, P. 2011. A System Dynamic Approach to Data Center

Capacity Planning. ***Paper presented at the 29th International Conference of the System Dynamics Society***. Washington.

Eker, S., Zimmermann, N., Carnohan, S., & Davies, M. 2017. Participatory system dynamics modelling for housing, energy and wellbeing interactions. ***Building Research & Information***, 1–17.

Forrester, J. W. 1985. "The" model versus a modeling "process." ***System Dynamics Review***, 1(1): 133–134.

Georgantzas, N. C., & Katsamakas, E. G. 2008. Information systems research with system dynamics. ***System Dynamics Review***, 24(3): 247–264.

Gorey, R. M., & Dobat, D. R. 1996. Managing in the Knowledge Era. ***The Systems Thinker: Building Shared Understanding***, 7(8): 1–5.

Groesser, S. N., & Schwaninger, M. 2012. Contributions to model validation: hierarchy, process, and cessation. ***Dyn. Rev***, vol. 28. https://www.alexandria.unisg.ch/209607/1/233_Contributions to Model Validation_SDR 28-2, 2012.pdf.

Größler, A. 2007. System dynamics projects that failed to make an impact. ***System Dynamics Review***, 23(4): 437–452.

Hovmand, P. S., Etiënne, Rouwette, A. J. A., Andersen, D. F., Richardson, G. P., & Kraus, A. 2013. ***Scriptapedia 4.0.6***, (August): 1–88.

Kawamoto, K. 2005. Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. ***Bmj***, 330(7494): 765–0.

Luna-Reyes, L. F., & Andersen, D. L. 2003. Collecting and analyzing qualitative data for system dynamics: Methods and models. ***System Dynamics Review***, 19(4): 271–296.

Lyneis, J. M., Cooper, K. G., & Els, S. A. 2001. Strategic management of complex projects: A case study using system dynamics. ***System Dynamics Review***, 17(3): 237–260.

Lyneis, J. M., & Ford, D. N. 2007. System dynamics applied to project management:

a survey, assessment, and directions for future research. ***System Dynamics Review***, 23(2–3): 157–189.

Nutt, P. C. 2004. Averting decision debacles. ***Technological Forecasting and Social Change***, 71(3): 239–265.

Nutt, P. C. 2008. Investigating the Success of Decision Making Processes: Success of Decision Making Processes. ***Journal of Management Studies***, 45(2): 425–455.

Oliva, R. 2008. Developing Operational Understanding of Service Quality through a Simulation Environment. ***Article in International Journal of Service Industry Management***. https://doi.org/10.1108/09564230810869711.

Richardson, G. P. 2013. Concept models in group model building. ***System Dynamics Review***, 29(1): 42–55.

Richardson, G. P., & Andersen, D. F. 1995. Teamwork in Group Model Building. ***System Dynamics Review***.

Rouwette, E. A. J. A., & Vennix, J. A. M. 2008. Group Model building. ***Encyclopedia of Complexity and Systems Science***: 4487–4484. Springer.

Saunders, M., & Lewis, P. 2012. ***Doing research in business and management : an essential guide to planning your project***. Financial Times Prentice Hall.

Schein E.H. (1990). A general philosophy of helping. process consultation..pdf. n.d. .

Senge, P. M., & Forrester, J. W. 1980. Tests for building conficence in system dynamics models. ***Studies in the Management Sciences***, 33(6): 209–228.

Špicar, R. 2014. System Dynamics Archetypes in Capacity Planning. ***Procedia Engineering***, 69(C): 1350–1355.

Sterman, J. D. 2000. Business Dynamics: Systems Thinking and Modeling for a Complex World. ***Business Dynamics: Systems Thinking and Modeling for a Complex World***. https://doi.org/10.1057/palgrave.jors.2601336.

Vennix, J. A. M. 1996a. Group Model Building: Facilitating Team Learning Using System Dynamics. ***Journal of the Operational Research Society***, vol. 49. https://doi.org/10.1057/palgrave.jors.2600567.

Vennix, J. A. M. 1996b. ***Group model building : facilitating team learning using system dynamics***. J. Wiley.

Vennix, J. A. M. 1999. Group model-building: Tackling messy problems. ***System Dynamics Review***, 15(4): 379–401.

Walshe, K., & Rundall, T. G. 2001. Evidence-based Management: From Theory to Practice in Health Care. ***The Milbank Quarterly***, 79(3): 429–457.

Appendix I. Reports Delivery Time

Report closing trends: Cumulative closing percentage

Created Tickets		When was it closed																												
Year-Mo	# Opened	2016-01	2016-02	2016-03	2016-04	2016-05	2016-06	2016-07	2016-08	2016-09	2016-10	2016-11	2016-12	2017-01	2017-02	2017-03	2017-04	2017-05	2017-06	2017-07	2017-08	2017-09	2017-10	2017-11	2017-12	2018-0	2018-02	2018-03	2018-04	2018-05
2016-01	42	16.7%	38.1%	54.8%	71.4%	97.6%	97.6%	97.6%	97.6%	97.6%	97.6%	97.6%	97.6%	100.0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2016-02	70		38.6%	57.1%	68.6%	85.7%	87.1%	87.1%	90.0%	90.0%	95.7%	97.1%	97.1%	98.6%	98.6%	98.6%	98.6%	100.0%	-	-	-	-	-	-	-	-	-	-	-	-
2016-03	95			70.5%	78.9%	92.6%	95.8%	97.9%	98.9%	98.9%	98.9%	100.0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2016-04	58				37.9%	53.4%	65.5%	67.2%	70.7%	81.0%	81.0%	91.4%	91.4%	94.8%	96.6%	98.3%	98.3%	98.3%	98.3%	98.3%	98.3%	98.3%	98.3%	98.3%	100.0%	-	-	-	-	-	-
2016-05	86					45.3%	53.5%	57.0%	69.8%	86.0%	95.3%	97.7%	97.7%	97.7%	97.7%	97.7%	97.7%	98.8%	98.8%	98.8%	98.8%	98.8%	98.8%	98.8%	100.0%	-	-	-	-	-	-
2016-06	81						35.8%	54.3%	76.5%	87.7%	92.6%	97.5%	97.5%	97.5%	97.5%	97.5%	97.5%	97.5%	97.5%	97.5%	97.5%	97.5%	97.5%	97.5%	100.0%	-	-	-	-	-	-
2016-07	60							31.7%	58.3%	70.0%	75.0%	88.3%	88.3%	91.7%	91.7%	93.3%	93.3%	93.3%	93.3%	95.0%	95.0%	95.0%	95.0%	96.7%	98.3%	98.3%	98.3%	100.0%	-	-
2016-08	62								54.8%	74.2%	79.0%	87.1%	90.3%	93.5%	93.5%	93.5%	93.5%	93.5%	93.5%	93.5%	93.5%	93.5%	93.5%	95.2%	95.2%	96.8%	96.8%	96.8%	96.8%	96.8%
2016-09	59									44.1%	66.1%	79.7%	84.7%	88.1%	88.1%	88.1%	88.1%	88.1%	88.1%	88.1%	91.5%	93.2%	93.2%	94.9%	96.6%	96.6%	98.3%	98.3%	98.3%	98.3%
2016-10	85										56.5%	83.5%	84.7%	89.4%	90.6%	94.1%	97.6%	98.8%	98.8%	100.0%	-	-	-	-	-	-	-	-	-	-	-
2016-11	84											52.4%	67.9%	79.8%	84.5%	91.7%	94.0%	95.2%	95.2%	95.2%	95.2%	95.2%	95.2%	97.6%	97.6%	98.8%	98.8%	100.0%	-	-
2016-12	85												38.8%	52.9%	70.6%	83.5%	88.2%	90.6%	91.8%	91.8%	92.9%	92.9%	92.9%	95.3%	95.3%	96.5%	96.5%	96.5%	96.5%	96.5%
2017-01	79													49.4%	65.8%	79.7%	83.5%	84.8%	86.1%	86.1%	86.1%	86.1%	86.1%	91.1%	93.7%	98.7%	98.7%	98.7%	98.7%	98.7%
2017-02	54														27.8%	77.8%	85.2%	90.7%	90.7%	92.6%	94.4%	94.4%	94.4%	94.4%	94.4%	98.1%	98.1%	98.1%	100.0%	-
2017-03	72															52.8%	79.2%	87.5%	90.3%	91.7%	91.7%	93.1%	93.1%	93.1%	95.8%	95.8%	95.8%	97.2%	97.2%	97.2%
2017-04	82																62.2%	85.4%	86.6%	95.1%	97.6%	98.8%	98.8%	98.8%	98.8%	98.8%	98.8%	98.8%	98.8%	100.0%
2017-05	135																	61.5%	74.8%	84.4%	85.9%	89.6%	91.1%	94.8%	94.8%	97.0%	97.0%	97.0%	97.0%	97.8%
2017-06	59																		42.4%	69.5%	81.4%	86.4%	88.1%	89.8%	94.9%	96.6%	96.6%	96.6%	96.6%	96.6%
2017-07	85																			56.5%	75.3%	84.7%	88.2%	89.4%	94.1%	97.6%	97.6%	97.6%	97.6%	100.0%
2017-08	102																				58.8%	86.3%	93.1%	97.1%	98.0%	99.0%	####	-	-	-
2017-09	63																					57.1%	81.0%	88.9%	93.7%	96.8%	96.8%	98.4%	100.0%	-
2017-10	57																						47.4%	71.9%	78.9%	87.7%	91.2%	93.0%	93.0%	93.0%
2017-11	90																							64.4%	83.3%	94.4%	95.6%	95.6%	95.6%	95.6%
2017-12	100																								54.0%	84.0%	92.0%	93.0%	93.0%	95.0%
2018-01	125																									54.4%	76.0%	83.2%	90.4%	92.8%
2018-02	92																										63.0%	82.6%	90.2%	93.5%
2018-03	114																											46.5%	64.0%	82.5%
2018-04	80																												52.5%	73.8%
2018-05	68																													60.3%
Total	2,324	0.3%	1.9%	5.6%	7.5%	11.1%	13.2%	14.9%	18.5%	21.7%	25.3%	29.6%	31.9%	35.1%	37.2%	41.4%	45.1%	50.2%	52.3%	56.1%	60.0%	63.6%	65.9%	70.3%	74.3%	80.0%	84.2%	87.9%	91.4%	95.3%

Appendix II. Auxiliary Calculations

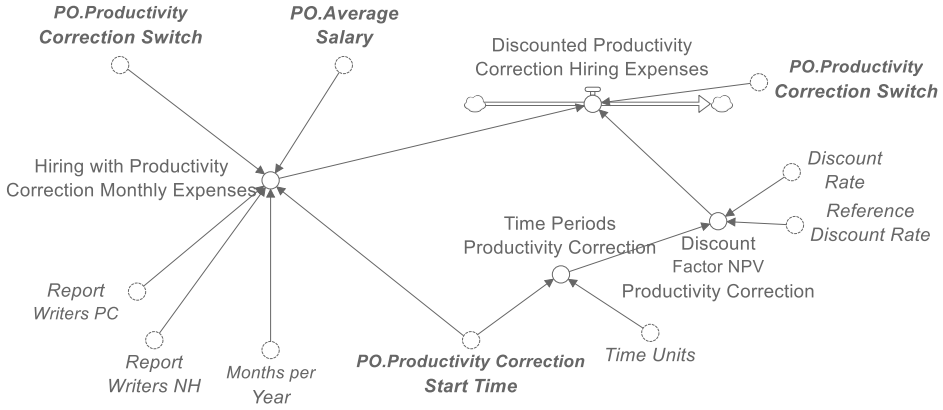


Figure 78. Costs of Hiring with Productivity Correction

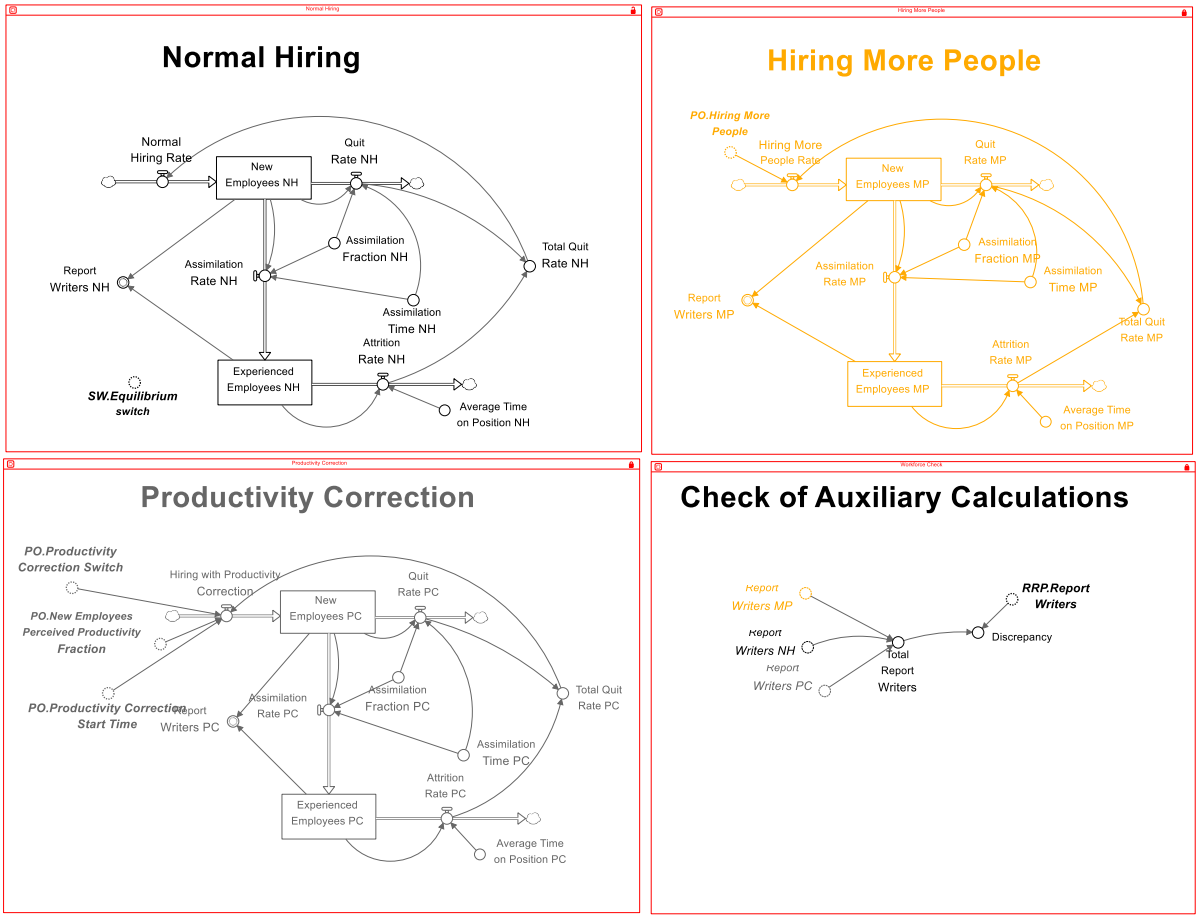


Figure 79. Auxiliary Calculations for Hiring

Appendix III. Switches

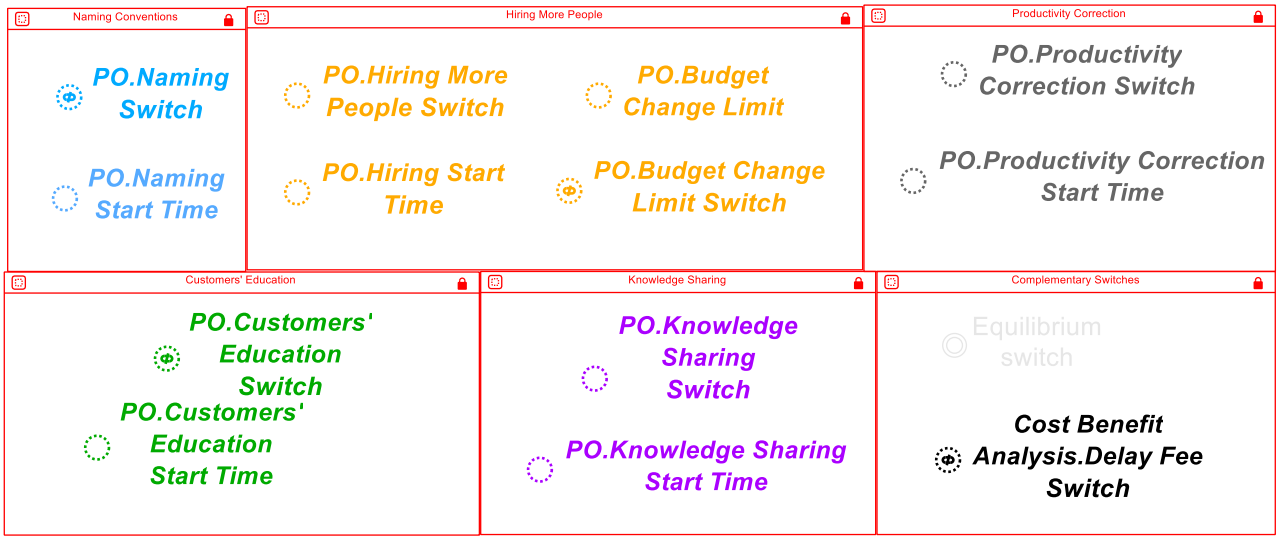


Figure 80. Switches

Appendix IV. Poster Presented at the SD Colloquium

Streamlining the Report Request Process: a Case Study of a Local Healthcare Provider

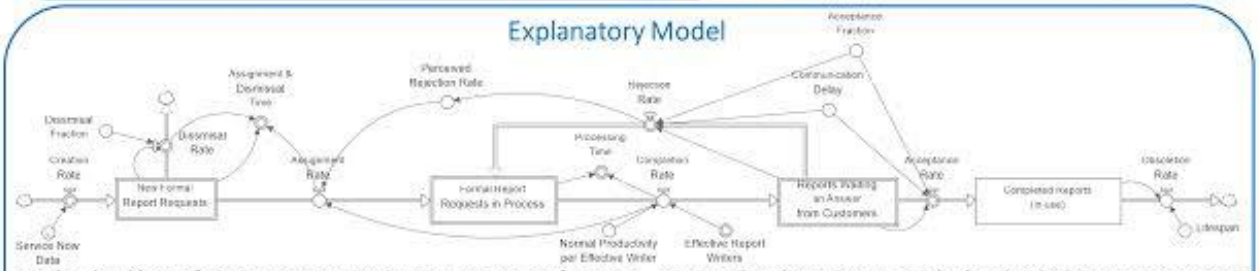
Introduction

A local healthcare is struggling with an increasing number of medical and financial reports, which are essential for evidence-based decision making. Addition of new hospitals under the company structure will exacerbate the problem and increase the rate of new report requests. The Information Services Department that is responsible for completing these reports seeks ways to manage their significant backlog of unfulfilled reports and streamline the report request process.

Modelling Process

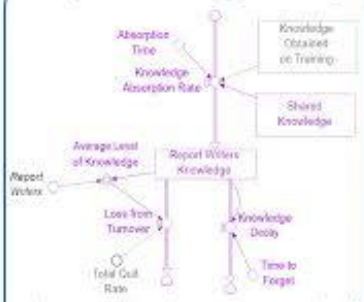
The model was built through a series of Group Model Building workshops conducted with employees of the Information Services Department.

Explanatory Model



- The backlog of Open Report Requests consists of New Report Requests, Reports in Process and Reports Waiting for an Answer from a Customer;
- Reports' Delivery Time might be divided into Assignment & Dismissal Time, Processing Time and Communication delay.

Policy 1: Knowledge Sharing



The growth of Average Level of Report Writers Knowledge can decrease Reports' Delivery Time.

Policy 3: Customers' Education

Customers' education will empower users to modify and reuse reports on their own and thus decrease Creation Rate of report requests.

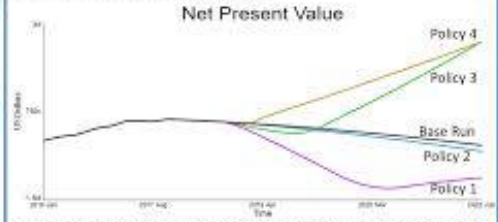
Comparison of Policy Options

Policy 1: Knowledge Sharing **Policy 3: Customers' Education**
Policy 2: Naming Conventions **Policy 4: Hiring More People**

Backlog of Open Report Requests

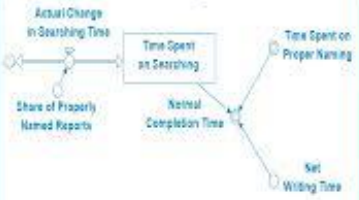
The desired backlog of Open Report Requests is equal to 30 reports. Reaching the desired level of the backlog allows decreasing Reports' Delivery Time to 15 days.

Net Present Value



Net Present Value was counted based on the assumption that the value of reports decreases after the desired delivery time of reports is exceeded.

Policy 2: Naming Conventions



The implementation of naming conventions will ease the process of searching similar reports and thus decrease Reports' Delivery Time since in many cases it's much faster to modify an existing report than to create a new one.

Policy 4: Hiring More People

Hiring More People might help to solve the problem. However, this policy option might be not feasible due to budget limitations.

Conclusions:

- **Naming Conventions and Knowledge Sharing are not able to bring the number of Open Report Requests to the desired level.**
- **Customers' Education and Hiring More People provide the best outcomes.**

Ekaterina Durova
ekaterina.durova@gmail.com

Appendix V. Equations

Top-Level Model:

Cost_Benefit_Analysis:

Benefits(t) = Benefits(t - dt) + (Cash_Flow) * dt

INIT Benefits = 0

UNITS: US Dollars

INFLOWS:

Cash_Flow = Potential_Price_of_a_Report_with_a_Delay_Fee*RRP.FRR_Acceptance_Rate

UNITS: US Dollars Per Month

USED BY: Cost_Benefit_Analysis.Discounted_Cash_Flow, Cost_Benefit_Analysis.Benefits

Experienced_Employees_MP(t) = Experienced_Employees_MP(t - dt) + (Assimilation_Rate_MP - Attrition_Rate_MP) * dt {NON-NEGATIVE}

INIT Experienced_Employees_MP = IF SW.Equilibrium_switch=0 THEN 6.5 ELSE Assimilation_Rate_MP*Average_Time_on_Position_MP

UNITS: writers

USED BY: Cost_Benefit_Analysis.Attrition_Rate_MP, Cost_Benefit_Analysis.Report_Writers_MP

INFLOWS:

Assimilation_Rate_MP = (New_Employees_MP/Assimilation_Time_MP)*Assimilation_Fraction_MP {UNIFLOW}

UNITS: writers/months

USED BY: Cost_Benefit_Analysis.New_Employees_MP, Cost_Benefit_Analysis.Experienced_Employees_MP

OUTFLOWS:

Attrition_Rate_MP = Experienced_Employees_MP/Average_Time_on_Position_MP {UNIFLOW}

UNITS: writers/months

USED BY: Cost_Benefit_Analysis.Total_Quit_Rate_MP, Cost_Benefit_Analysis.Experienced_Employees_MP

Experienced_Employees_NH(t) = Experienced_Employees_NH(t - dt) + (Assimilation_Rate_NH - Attrition_Rate_NH) * dt {NON-NEGATIVE}

INIT Experienced_Employees_NH = IF SW.Equilibrium_switch=0 THEN 6.5 ELSE Assimilation_Rate_NH*Average_Time_on_Position_NH

UNITS: writers

USED BY: Cost_Benefit_Analysis.Attrition_Rate_NH, Cost_Benefit_Analysis.Report_Writers_NH

INFLOWS:

Assimilation_Rate_NH = (New_Employees_NH/Assimilation_Time_NH)*Assimilation_Fraction_NH {UNIFLOW}

UNITS: writers/months

USED BY: Cost_Benefit_Analysis.New_Employees_NH, Cost_Benefit_Analysis.Experienced_Employees_NH

OUTFLOWS:

Attrition_Rate_NH = Experienced_Employees_NH/Average_Time_on_Position_NH {UNIFLOW}

UNITS: writers/months

USED BY: Cost_Benefit_Analysis.Total_Quit_Rate_NH, Cost_Benefit_Analysis.Experienced_Employees_NH

Experienced_Employees_PC(t) = Experienced_Employees_PC(t - dt) + (Assimilation_Rate_PC - Attrition_Rate_PC) * dt {NON-NEGATIVE}

INIT Experienced_Employees_PC = IF SW.Equilibrium_switch=0 THEN 6.5 ELSE Assimilation_Rate_PC*Average_Time_on_Position_PC

UNITS: writers

USED BY: Cost_Benefit_Analysis.Attrition_Rate_PC, Cost_Benefit_Analysis.Report_Writers_PC

INFLOWS:

Assimilation_Rate_PC = (New_Employees_PC/Assimilation_Time_PC)*Assimilation_Fraction_PC {UNIFLOW}

UNITS: writers/months

USED BY: Cost_Benefit_Analysis.New_Employees_PC, Cost_Benefit_Analysis.Experienced_Employees_PC

OUTFLOWS:

Attrition_Rate_PC = Experienced_Employees_PC/Average_Time_on_Position_PC {UNIFLOW}

UNITS: writers/months

USED BY: Cost_Benefit_Analysis.Total_Quit_Rate_PC, Cost_Benefit_Analysis.Experienced_Employees_PC

New_Employees_MP(t) = New_Employees_MP(t - dt) + (Hiring_More_People_Rate - Assimilation_Rate_MP - Quit_Rate_MP) * dt {NON-NEGATIVE}

INIT New_Employees_MP = IF SW.Equilibrium_switch=0 THEN 2 ELSE 3.02108761329

UNITS: writers

USED BY: Cost_Benefit_Analysis.Quit_Rate_MP, Cost_Benefit_Analysis.Assimilation_Rate_MP, Cost_Benefit_Analysis.Report_Writers_MP

INFLOWS:

Hiring_More_People_Rate = PO.Hiring_More_People+Total_Quit_Rate_MP {UNIFLOW}

UNITS: writers/months

USED BY: Cost_Benefit_Analysis.New_Employees_MP

OUTFLOWS:

Assimilation_Rate_MP = (New_Employees_MP/Assimilation_Time_MP)*Assimilation_Fraction_MP {UNIFLOW}

UNITS: writers/months

USED BY: Cost_Benefit_Analysis.New_Employees_MP, Cost_Benefit_Analysis.Experienced_Employees_MP

Quit_Rate_MP = (New_Employees_MP/Assimilation_Time_MP)*(1-Assimilation_Fraction_MP) {UNIFLOW}

UNITS: writers/months

USED BY: Cost_Benefit_Analysis.Total_Quit_Rate_MP, Cost_Benefit_Analysis.New_Employees_MP

New_Employees_NH(t) = New_Employees_NH(t - dt) + (Normal_Hiring_Rate - Assimilation_Rate_NH - Quit_Rate_NH) * dt {NON-NEGATIVE}

INIT New_Employees_NH = IF SW.Equilibrium_switch=0 THEN 2 ELSE 3.02108761329

UNITS: writers

USED BY: Cost_Benefit_Analysis.Quit_Rate_NH, Cost_Benefit_Analysis.Assimilation_Rate_NH, Cost_Benefit_Analysis.Report_Writers_NH

INFLOWS:

Normal_Hiring_Rate = Total_Quit_Rate_NH {IF Switches.Equilibrium_switch=0 THEN Total_Quit_Rate+STEP((Workforce_Gap/Hiring_Time)*Hiring_Switch, 32) ELSE Total_outflow} {UNIFLOW}

UNITS: writers/months

USED BY: Cost_Benefit_Analysis.New_Employees_NH

OUTFLOWS:

Assimilation_Rate_NH = (New_Employees_NH/Assimilation_Time_NH)*Assimilation_Fraction_NH {UNIFLOW}

UNITS: writers/months

USED BY: Cost_Benefit_Analysis.New_Employees_NH, Cost_Benefit_Analysis.Experienced_Employees_NH

Quit_Rate_NH = (New_Employees_NH/Assimilation_Time_NH)*(1-Assimilation_Fraction_NH) {UNIFLOW}

UNITS: writers/months

USED BY: Cost_Benefit_Analysis.Total_Quit_Rate_NH, Cost_Benefit_Analysis.New_Employees_NH

New_Employees_PC(t) = New_Employees_PC(t - dt) + (Hiring_with_Productivity_Correction - Assimilation_Rate_PC - Quit_Rate_PC) * dt {NON-NEGATIVE}

INIT New_Employees_PC = IF SW.Equilibrium_switch=0 THEN 2 ELSE 3.02108761329

UNITS: writers

USED BY: Cost_Benefit_Analysis.Quit_Rate_PC, Cost_Benefit_Analysis.Assimilation_Rate_PC, Cost_Benefit_Analysis.Report_Writers_PC

INFLOWS:

Hiring_with_Productivity_Correction = IF TIME <PO.Productivity_Correction_Start_Time THEN Total_Quit_Rate_PC ELSE (Total_Quit_Rate_PC/PO.New_Employees_Perceived_Productivity_Fraction)*PO.Productivity_Correction_Switch+Total_Quit_Rate_PC*(1-PO.Productivity_Correction_Switch) {UNIFLOW}

UNITS: writers/months

USED BY: Cost_Benefit_Analysis.New_Employees_PC

OUTFLOWS:

Assimilation_Rate_PC = (New_Employees_PC/Assimilation_Time_PC)*Assimilation_Fraction_PC {UNIFLOW}

UNITS: writers/months

USED BY: Cost_Benefit_Analysis.New_Employees_PC, Cost_Benefit_Analysis.Experienced_Employees_PC

Quit_Rate_PC = (New_Employees_PC/Assimilation_Time_PC)*(1-Assimilation_Fraction_PC) {UNIFLOW}

UNITS: writers/months

USED BY: Cost_Benefit_Analysis.Total_Quit_Rate_PC, Cost_Benefit_Analysis.New_Employees_PC

"NPV_of_Losses/_Benefits"(t) = "NPV_of_Losses/_Benefits"(t - dt) + (Discounted_Net_Cash_Flow) * dt

INIT "NPV_of_Losses/_Benefits" = 0

UNITS: US Dollars

INFLOWS:

Discounted_Net_Cash_Flow = Discounted_Cash_Flow-Discounted_Expenses_Naming-Discounted_Hiring_Expenses-Discounted_Expenses_Customers'_Education-Discount_Expenses_Knowledge_Sharing-Discounted_Productivity_Correction_Hiring_Expenses

UNITS: US Dollars Per Month

USED BY: Cost_Benefit_Analysis."NPV_of_Losses/_Benefits"

Discount_Expenses_Knowledge_Sharing = IF PO.Knowledge_Sharing_Switch=0 THEN 0 ELSE Monthly_Expenses_on_Knowledge_Sharing/Discount_Factor_NPV_Knowledge_Sharing {UNIFLOW}

UNITS: US Dollars Per Month

USED BY: Cost_Benefit_Analysis.Discounted_Net_Cash_Flow

Discounted_Cash_Flow = Cash_Flow/Discount_Factor_NPV {UNIFLOW}

UNITS: US Dollars Per Month

USED BY: Cost_Benefit_Analysis.Discounted_Net_Cash_Flow

Discounted_Expenses_Customers'_Education = IF PO.Customers'_Education_Switch=0 THEN 0 ELSE Monthly_Expenses_on_CE/Discount_Factor_NPV_CE {UNIFLOW}

UNITS: US Dollars Per Month

USED BY: Cost_Benefit_Analysis.Discounted_Net_Cash_Flow

Discounted_Expenses_Naming = IF PO.Naming_Switch=0 THEN 0 ELSE Monthly_Expenses_on_Proper_Naming/Discount_Factor_NPV_Naming

UNITS: US Dollars Per Month

USED BY: Cost_Benefit_Analysis.Discounted_Net_Cash_Flow

Discounted_Hiring_Expenses = Hiring_More_People_Monthly_Expenses/Discount_Factor_NPV_Hiring {UNIFLOW}

UNITS: US Dollars Per Month

USED BY: Cost_Benefit_Analysis.Discounted_Net_Cash_Flow

Discounted_Productivity_Correction_Hiring_Expenses = IF PO.Productivity_Correction_Switch=0 THEN 0 ELSE Hiring_with_Productivity_Correction_Monthly_Expenses/Discount_Factor_NPV_Productivity_Correction {UNIFLOW}

UNITS: US Dollars Per Month

USED BY: Cost_Benefit_Analysis.Discounted_Net_Cash_Flow

Assimilation_Fraction_MP = 0.99

UNITS: Dimensionless

USED BY: Cost_Benefit_Analysis.Quit_Rate_MP, Cost_Benefit_Analysis.Assimilation_Rate_MP

Assimilation_Fraction_NH = 0.99

UNITS: Dimensionless

USED BY: Cost_Benefit_Analysis.Quit_Rate_NH, Cost_Benefit_Analysis.Assimilation_Rate_NH

Assimilation_Fraction_PC = 0.99

UNITS: Dimensionless

USED BY: Cost_Benefit_Analysis.Quit_Rate_PC, Cost_Benefit_Analysis.Assimilation_Rate_PC

Assimilation_Time_MP = 24 {Normal_Assimilation_Time*Effect_of_Knowledge_Sharing_on_Assimilation_Time}

UNITS: Months

USED BY: Cost_Benefit_Analysis.Quit_Rate_MP, Cost_Benefit_Analysis.Assimilation_Rate_MP

Assimilation_Time_NH = 24 {Normal_Assimilation_Time*Effect_of_Knowledge_Sharing_on_Assimilation_Time}

UNITS: Months

USED BY: Cost_Benefit_Analysis.Quit_Rate_NH, Cost_Benefit_Analysis.Assimilation_Rate_NH

Assimilation_Time_PC = 24 {Normal_Assimilation_Time*Effect_of_Knowledge_Sharing_on_Assimilation_Time}

UNITS: Months

USED BY: Cost_Benefit_Analysis.Quit_Rate_PC, Cost_Benefit_Analysis.Assimilation_Rate_PC

Average_Hourly_Rate = (Average_Hourly_Rate_of_Report_Writers_at_LHP+Average_Hourly_Rate_for_Outsourcing)/2

UNITS: US Dollars/hours/writers

Average_Hourly_Rate_for_Outsourcing = 100

UNITS: US Dollars/hours/writers

USED BY: Cost_Benefit_Analysis.Average_Hourly_Rate, Cost_Benefit_Analysis.Potential_Price_That_a_Customer_is_Ready_to_Pay_for_a_Timely_Delivered_Report

Average_Hourly_Rate_of_Report_Writers_at_LHP = 30

UNITS: US Dollars/ Hours/Writers

USED BY: Cost_Benefit_Analysis.Average_Hourly_Rate, Cost_Benefit_Analysis.Monthly_Expenses_on_Proper_Naming, Cost_Benefit_Analysis.Monthly_Expenses_on_CE, Cost_Benefit_Analysis.Monthly_Expenses_on_Knowledge_Sharing

Average_Time_Needed_to_Fullfill_a_Report = INIT(PO.FRR_Normal_Completion_Time)

UNITS: Hours/Reports

USED BY: Cost_Benefit_Analysis.Potential_Price_That_a_Customer_is_Ready_to_Pay_for_a_Timely_Delivered_Report

Average_Time_on_Position_MP = 12*4 {5 years in the company in total, including assimilation time. In fact, the number might be lower}

UNITS: Months

USED BY: Cost_Benefit_Analysis.Attrition_Rate_MP

Average_Time_on_Position_NH = 12*4 {5 years in the company in total, including assimilation time. In fact, the number might be lower}

UNITS: Months

USED BY: Cost_Benefit_Analysis.Attrition_Rate_NH

Average_Time_on_Position_PC = 12*4 {5 years in the company in total, including assimilation time. In fact, the number might be lower}

UNITS: Months

USED BY: Cost_Benefit_Analysis.Attrition_Rate_PC

Base_Run_Start_Time = 0

UNITS: Months

USED BY: Cost_Benefit_Analysis.Time_Periods

Delay_Fee = Value_Loss_Per_Day*Delivery_Delay

UNITS: US Dollars/Reports

USED BY: Cost_Benefit_Analysis.Potential_Price_of_a_Report_with_a_Delay_Fee

Delay_Fee_Switch = 1

UNITS: Dimensionless

USED BY: Cost_Benefit_Analysis.Potential_Price_of_a_Report_with_a_Delay_Fee

Delivery_Delay = Reports_Delivery_Time-PO.Desired_Delivery_Time_in_Days

UNITS: Days

USED BY: Cost_Benefit_Analysis.Delay_Fee

Discount_Factor_NPV = ((1 + Discount_Rate) / (1 + Reference_Discount_Rate)) ^ Time_Periods

UNITS: Dimensionless

USED BY: Cost_Benefit_Analysis.Discounted_Cash_Flow

Discount_Factor_NPV_CE = ((1 + Discount_Rate) / (1 + Reference_Discount_Rate)) ^ Time_Periods_CE

UNITS: Dimensionless

USED BY: Cost_Benefit_Analysis.Discounted_Expenses_Customers'_Education

Discount_Factor_NPV_Hiring = ((1 + Discount_Rate) / (1 + Reference_Discount_Rate)) ^ Time_Periods_Hiring

UNITS: Dimensionless

USED BY: Cost_Benefit_Analysis.Discounted_Hiring_Expenses

Discount_Factor_NPV_Knowledge_Sharing = ((1 + Discount_Rate) / (1 + Reference_Discount_Rate)) ^ Time_Periods_Knowledge_Sharing

UNITS: Dimensionless

USED BY: Cost_Benefit_Analysis.Discount_Expenses_Knowledge_Sharing

Discount_Factor_NPV_Naming = ((1 + Discount_Rate) / (1 + Reference_Discount_Rate)) ^ Time_Periods_Naming

UNITS: Dimensionless

USED BY: Cost_Benefit_Analysis.Discounted_Expenses_Naming

Discount_Factor_NPV_Productivity_Correction = ((1 + Discount_Rate) / (1 + Reference_Discount_Rate)) ^ Time_Periods_Productivity_Correction

UNITS: Dimensionless

USED BY: Cost_Benefit_Analysis.Discounted_Productivity_Correction_Hiring_Expenses

Discount_Rate = 0.05/12

UNITS: Per Month

USED BY: Cost_Benefit_Analysis.Discount_Factor_NPV, Cost_Benefit_Analysis.Discount_Factor_NPV_Naming, Cost_Benefit_Analysis.Discount_Factor_NPV_Hiring, Cost_Benefit_Analysis.Discount_Factor_NPV_CE, Cost_Benefit_Analysis.Discount_Factor_NPV_Knowledge_Sharing, Cost_Benefit_Analysis.Discount_Factor_NPV_Productivity_Correction

Discrepancy = Total_Report_Writers-RRP.Report_Writers

UNITS: writers

Hiring_More_People_Monthly_Expenses = IF PO.Hiring_More_People_Switch=0 THEN 0 ELSE IF TIME>PO.Hiring_Start_Time THEN PO.Average_Salary*(Report_Writers_MP-Report_Writers_NH)/Months_per_Year ELSE 0

UNITS: US Dollars Per Month

USED BY: Cost_Benefit_Analysis.Discounted_Hiring_Expenses

Hiring_with_Productivity_Correction_Monthly_Expenses = IF PO.Productivity_Correction_Switch=0 THEN 0 ELSE IF TIME>PO.Productivity_Correction_Start_Time THEN PO.Average_Salary*(Report_Writers_PC-Report_Writers_NH)/Months_per_Year ELSE 0

UNITS: US Dollars Per Month

USED BY: Cost_Benefit_Analysis.Discounted_Productivity_Correction_Hiring_Expenses

Monthly_Expenses_on_CE = Average_Hourly_Rate_of_Report_Writers_at_LHP*Total_Time_Spent_on_CE*RRP.Report_Writers

UNITS: US Dollars Per Month

USED BY: Cost_Benefit_Analysis.Discounted_Expenses_Customers'_Education

Monthly_Expenses_on_Knowledge_Sharing = Average_Hourly_Rate_of_Report_Writers_at_LHP*Total_Time_Spent_on_Knowledge_Sharing*RRP.Report_Writers

UNITS: US Dollars Per Month

USED BY: Cost_Benefit_Analysis.Discount_Expenses_Knowledge_Sharing

Monthly_Expenses_on_Proper_Naming = Average_Hourly_Rate_of_Report_Writers_at_LHP*Total_Time_Spent_on_Naming*RRP.Report_Writers

UNITS: US Dollars Per Month

USED BY: Cost_Benefit_Analysis.Discounted_Expenses_Naming

Months_per_Year = 12

UNITS: Months/Years

USED BY: Cost_Benefit_Analysis.Hiring_More_People_Monthly_Expenses, Cost_Benefit_Analysis.Hiring_with_Productivity_Correction_Monthly_Expenses

Number_of_Writers_Needeed_To_Fulfill_a_Report = 1

UNITS: writers

USED BY: Cost_Benefit_Analysis.Potential_Price_That_a_Customer_is_Ready_to_Pay_for_a_Timely_Delivered_Report

Potential_Price_of_a_Report_with_a_Delay_Fee = IF Delay_Fee_Switch=0 THEN Potential_Price_That_a_Customer_is_Ready_to_Pay_for_a_Timely_Delivered_Report ELSE MAX(Potential_Price_That_a_Customer_is_Ready_to_Pay_for_a_Timely_Delivered_Report-Delay_Fee, 0)

UNITS: US Dollars/Reports

USED BY: Cost_Benefit_Analysis.Cash_Flow

Potential_Price_That_a_Customer_is_Ready_to_Pay_for_a_Timely_Delivered_Report = Average_Hourly_Rate_for_Outsourcing*Number_of_Writers_Needeed_To_Fulfill_a_Report*Average_Time_Needed_to_Fullfill_a_Report

{Average_Hourly_Rate*Average_Time_Needed_to_Fullfill_a_Report*Number_of_Writers_Needeed_To_Fulfill_a_Report}

UNITS: US Dollars/Reports

USED BY: Cost_Benefit_Analysis.Value_Loss_Per_Day, Cost_Benefit_Analysis.Potential_Price_of_a_Report_with_a_Delay_Fee

Reference_Discount_Rate = 0

UNITS: 1/months

USED BY: Cost_Benefit_Analysis.Discount_Factor_NPV, Cost_Benefit_Analysis.Discount_Factor_NPV_Naming, Cost_Benefit_Analysis.Discount_Factor_NPV_Hiring, Cost_Benefit_Analysis.Discount_Factor_NPV_CE, Cost_Benefit_Analysis.Discount_Factor_NPV_Knowledge_Sharing, Cost_Benefit_Analysis.Discount_Factor_NPV_Productivity_Correction

Report_Writers_MP = New_Employees_MP+Experienced_Employees_MP

UNITS: writers

USED BY: Cost_Benefit_Analysis.Total_Report_Writers, Cost_Benefit_Analysis.Hiring_More_People_Monthly_Expenses

Report_Writers_NH = Experienced_Employees_NH+New_Employees_NH

UNITS: writers

USED BY: Cost_Benefit_Analysis.Hiring_with_Productivity_Correction_Monthly_Expenses, Cost_Benefit_Analysis.Total_Report_Writers, Cost_Benefit_Analysis.Hiring_More_People_Monthly_Expenses

Report_Writers_PC = Experienced_Employees_PC+New_Employees_PC

UNITS: writers

USED BY: Cost_Benefit_Analysis.Hiring_with_Productivity_Correction_Monthly_Expenses, Cost_Benefit_Analysis.Total_Report_Writers

Reports_Delivery_Time = RRP.Assignment_&_Dismissal_Time+RRP.Processing_Time+RRP.Communication_Delay_in_Days

UNITS: Days

USED BY: Cost_Benefit_Analysis.Delivery_Delay

Time_Periods = (TIME - Base_Run_Start_Time) / Time_Units

UNITS: Dimensionless

USED BY: Cost_Benefit_Analysis.Discount_Factor_NPV

Time_Periods_CE = (TIME - PO.Customers'_Education_Start_Time) / Time_Units

UNITS: Dimensionless

USED BY: Cost_Benefit_Analysis.Discount_Factor_NPV_CE

Time_Periods_Hiring = (TIME - PO.Hiring_Start_Time) / Time_Units

UNITS: Dimensionless

USED BY: Cost_Benefit_Analysis.Discount_Factor_NPV_Hiring

Time_Periods_Knowledge_Sharing = (TIME - PO.Knowledge_Sharing_Start_Time) / Time_Units

UNITS: Dimensionless

USED BY: Cost_Benefit_Analysis.Discount_Factor_NPV_Knowledge_Sharing

Time_Periods_Naming = (TIME - PO.Naming_Start_Time) / Time_Units

UNITS: Dimensionless

USED BY: Cost_Benefit_Analysis.Discount_Factor_NPV_Naming

Time_Periods_Productivity_Correction = (TIME - PO.Productivity_Correction_Start_Time) / Time_Units

UNITS: Dimensionless

USED BY: Cost_Benefit_Analysis.Discount_Factor_NPV_Productivity_Correction

Time_Units = 1

UNITS: Months

USED BY: Cost_Benefit_Analysis.Time_Periods, Cost_Benefit_Analysis.Time_Periods_Naming, Cost_Benefit_Analysis.Time_Periods_Hiring, Cost_Benefit_Analysis.Time_Periods_CE, Cost_Benefit_Analysis.Time_Periods_Knowledge_Sharing, Cost_Benefit_Analysis.Time_Periods_Productivity_Correction

Total_Quit_Rate_MP = Quit_Rate_MP+Attrition_Rate_MP

UNITS: writers/Months

USED BY: Cost_Benefit_Analysis.Hiring_More_People_Rate

Total_Quit_Rate_NH = Attrition_Rate_NH+Quit_Rate_NH

UNITS: writers/Months

USED BY: Cost_Benefit_Analysis.Normal_Hiring_Rate

Total_Quit_Rate_PC = Attrition_Rate_PC+Quit_Rate_PC

UNITS: writers/Months

USED BY: Cost_Benefit_Analysis.Hiring_with_Productivity_Correction

Total_Report_Writers = Report_Writers_NH+(Report_Writers_PC-Report_Writers_NH)+(Report_Writers_MP-Report_Writers_NH)

UNITS: writers

USED BY: Cost_Benefit_Analysis.Discrepancy

Total_Time_Spent_on_CE = PO.Actual_Time_Spent_on_Users_'_Manual_Creation*RRP.Report_Writers

UNITS: Hours/Months

USED BY: Cost_Benefit_Analysis.Monthly_Expenses_on_CE

Total_Time_Spent_on_Knowledge_Sharing = PO.Actual_Time_Spent_on_KS*RRP.Report_Writers

UNITS: Hours/Months

USED BY: Cost_Benefit_Analysis.Monthly_Expenses_on_Knowledge_Sharing

Total_Time_Spent_on_Naming = PO.Time_Spent_on_Proper_Naming*RRP.FRR_Acceptance_Rate

UNITS: Hours/Months

USED BY: Cost_Benefit_Analysis.Monthly_Expenses_on_Proper_Naming

Value_Loss_Per_Day = Potential_Price_That_a_Customer_is_Ready_to_Pay_for_a_Timely_Delivered_Report*Value_Loss_Rate

UNITS: US Dollars/Days/Reports

USED BY: Cost_Benefit_Analysis.Delay_Fee

Value_Loss_Rate = 0.05

UNITS: Dimensionless/days

USED BY: Cost_Benefit_Analysis.Value_Loss_Per_Day

Historical_Data_&_Forecast:

"Open_Report_Requests_(Backlog)"(t) = "Open_Report_Requests_(Backlog)"(t - dt) + (RR_Creation_Rate_Data - RR_Completion_Rate_Data) * dt {NON-NEGATIVE}

INIT "Open_Report_Requests_(Backlog)" = 35

UNITS: Reports

USED BY: Historical_Data_&_Forecast.Delivery_Time

INFLOWS:

RR_Creation_Rate_Data = GRAPH(TIME)

(0.00, 42.000), (1.00, 70.000), (2.00, 95.000), (3.00, 58.000), (4.00, 86.000), (5.00, 81.000), (6.00, 60.000), (7.00, 62.000), (8.00, 59.000), (9.00, 85.000), (10.00, 84.000), (11.00, 85.000), (12.00, 79.000), (13.00, 54.000), (14.00, 72.000), (15.00, 82.000), (16.00, 135.000), (17.00, 59.000), (18.00, 85.000), (19.00, 102.000), (20.00, 63.000), (21.00, 57.000), (22.00, 90.000), (23.00, 100.000), (24.00, 125.000), (25.00, 92.000), (26.00, 114.000), (27.00, 80.000), (28.00, 68.000), (29.00, 92.000), (30.00, 93.000), (31.00, 94.000), (32.00, 95.000), (33.00, 96.000), (34.00, 97.000), (35.00, 98.000), (36.00, 100.000), (37.00, 101.000), (38.00, 102.000), (39.00, 103.000), (40.00, 104.000), (41.00, 105.000), (42.00, 106.000), (43.00, 107.000), (44.00, 108.000), (45.00, 109.000), (46.00, 110.000), (47.00, 111.000), (48.00, 112.000), (49.00, 114.000), (50.00, 115.000), (51.00, 116.000), (52.00, 117.000), (53.00, 118.000), (54.00, 119.000), (55.00, 120.000), (56.00, 121.000), (57.00, 122.000), (58.00, 123.000), (59.00, 124.000), (60.00, 125.000), (61.00, 126.000), (62.00, 128.000), (63.00, 129.000), (64.00, 130.000), (65.00, 131.000), (66.00, 132.000), (67.00, 133.000), (68.00, 134.000), (69.00, 135.000), (70.00, 136.000), (71.00, 137.000), (72.00, 138.000), (73.00, 139.000), (74.00, 140.000), (75.00, 142.000), (76.00, 143.000), (77.00, 144.000), (78.00, 145.000)

UNITS: Reports/Months

USED BY: Historical_Data_&_Forecast."Open_Report_Requests_(Backlog)"

OUTFLOWS:

RR_Completion_Rate_Data = GRAPH(TIME)

(0.00, 7.000), (1.00, 36.000), (2.00, 87.000), (3.00, 45.000), (4.00, 84.000), (5.00, 47.000), (6.00, 40.000), (7.00, 84.000), (8.00, 74.000), (9.00, 83.000), (10.00, 102.000), (11.00, 52.000), (12.00, 75.000), (13.00, 49.000), (14.00, 98.000), (15.00, 86.000), (16.00, 118.000), (17.00, 48.000), (18.00, 88.000), (19.00, 91.000), (20.00, 83.000), (21.00, 55.000), (22.00, 102.000), (23.00, 93.000), (24.00, 132.000), (25.00, 98.000), (26.00, 86.000), (27.00, 80.000), (28.00, 91.000), (29.00, 88.000), (30.00, 92.000), (31.00, 93.000), (32.00, 94.000), (33.00, 95.000), (34.00, 96.000), (35.00, 97.000), (36.00, 99.000), (37.00, 100.000), (38.00, 101.000), (39.00, 102.000), (40.00, 103.000), (41.00, 104.000), (42.00, 105.000), (43.00, 106.000), (44.00, 107.000), (45.00, 108.000), (46.00, 109.000), (47.00, 110.000), (48.00, 111.000), (49.00, 113.000), (50.00, 114.000), (51.00, 115.000), (52.00, 116.000), (53.00, 117.000), (54.00, 118.000), (55.00, 119.000), (56.00, 120.000), (57.00, 121.000), (58.00, 122.000), (59.00, 123.000), (60.00, 124.000), (61.00, 125.000), (62.00, 127.000), (63.00, 128.000), (64.00, 129.000), (65.00, 130.000), (66.00, 131.000), (67.00, 132.000), (68.00, 133.000), (69.00, 134.000), (70.00, 135.000), (71.00, 136.000), (72.00, 137.000), (73.00, 138.000), (74.00, 139.000), (75.00, 141.000), (76.00, 142.000), (77.00, 143.000), (78.00, 144.000)

UNITS: Reports/Months

USED BY: Historical_Data_&_Forecast.Delivery_Time, Historical_Data_&_Forecast."Open_Report_Requests_(Backlog)"

Days_per_Months = 365/12

UNITS: Days/Months

USED BY: Historical_Data_&_Forecast.Delivery_Time

Delivery_Time = ("Open_Report_Requests_(Backlog)"/RR_Completion_Rate_Data)*Days_per_Months

UNITS: Days

Open_Report_Requests_Data = GRAPH(TIME)

(0.00, 35.0), (1.00, 69.0), (2.00, 77.0), (3.00, 90.0), (4.00, 92.0), (5.00, 126.0), (6.00, 146.0), (7.00, 124.0), (8.00, 109.0), (9.00, 111.0), (10.00, 93.0), (11.00, 126.0), (12.00, 130.0), (13.00, 135.0), (14.00, 109.0), (15.00, 105.0), (16.00, 122.0), (17.00, 133.0), (18.00, 130.0), (19.00, 141.0), (20.00, 121.0), (21.00, 123.0), (22.00, 111.0), (23.00, 118.0), (24.00, 111.0), (25.00, 105.0), (26.00, 133.0), (27.00, 133.0), (28.00, 110.0), (29.00, 113.903997), (30.00, 115.3697939)

UNITS: Reports

Reports_Delivery_Time_Data = GRAPH(TIME)

(0.00, 69.0), (0.948717948718, 67.0), (1.89743589744, 23.0), (2.84615384615, 87.0), (3.79487179487, 65.0), (4.74358974359, 55.0), (5.69230769231, 79.0), (6.64102564103, 45.0), (7.58974358974, 65.0), (8.53846153846, 32.0), (9.48717948718, 51.0), (10.4358974359, 57.0),

(11.3846153846, 64.0), (12.3333333333, 50.0), (13.2820512821, 35.0), (14.2307692308, 26.0), (15.1794871795, 36.0), (16.1282051282, 41.0), (17.0769230769, 37.0), (18.0256410256, 21.0), (18.9743589744, 27.0), (19.9230769231, 27.0), (20.8717948718, 16.0), (21.8205128205, 19.0), (22.7692307692, 22.0), (23.7179487179, 14.0), (24.6666666667, 20.0), (25.6153846154, 10.0), (26.5641025641, 4.0), (27.5128205128, 7.0), (28.4615384615, 7.0), (29.4102564103, 7.0), (30.358974359, 7.0), (31.3076923077, 7.0), (32.2564102564, 7.0), (33.2051282051, 7.0), (34.1538461538, 7.0), (35.1025641026, 7.0), (36.0512820513, 7.0), (37.00, 7.0), (37.9487179487, 7.0), (38.8974358974, 7.0), (39.8461538462, 7.0), (40.7948717949, 7.0), (41.7435897436, 7.0), (42.6923076923, 7.0), (43.641025641, 7.0), (44.5897435897, 7.0), (45.5384615385, 7.0), (46.4871794872, 7.0), (47.4358974359, 7.0), (48.3846153846, 7.0), (49.3333333333, 7.0), (50.2820512821, 7.0), (51.2307692308, 7.0), (52.1794871795, 7.0), (53.1282051282, 7.0), (54.0769230769, 7.0), (55.0256410256, 7.0), (55.9743589744, 7.0), (56.9230769231, 7.0), (57.8717948718, 7.0), (58.8205128205, 7.0), (59.7692307692, 7.0), (60.7179487179, 7.0), (61.6666666667, 7.0), (62.6153846154, 7.0), (63.5641025641, 7.0), (64.5128205128, 7.0), (65.4615384615, 7.0), (66.4102564103, 7.0), (67.358974359, 7.0), (68.3076923077, 7.0), (69.2564102564, 7.0), (70.2051282051, 7.0), (71.1538461538, 7.0), (72.1025641026, 7.0), (73.0512820513, 7.0), (74.00, 7.0)

UNITS: Days

PO:

Customers(t) = Customers(t - dt) + (Customers_Hiring_Rate - Customers_Attrition_Rate) * dt {NON-NEGATIVE}

INIT Customers = 100

UNITS: Customers

USED BY: PO.Customers_Hiring_Rate, PO.Customers_Attrition_Rate, PO.Average_Level_of_Customers_Education, PO.Total_Time_Needed_to_Achieve_Desired_Change_in_Level_of_CE

INFLOWS:

Customers_Hiring_Rate = Customers_Attrition_Rate+Growth_Rate*Customers {UNIFLOW}

UNITS: Customers/Months

USED BY: PO.Customers

OUTFLOWS:

Customers_Attrition_Rate = Customers/Average_Time_in_Company {UNIFLOW}

UNITS: Customers/Months

USED BY: PO.Customers_Hiring_Rate, PO.Loss_from_Customers_Turnover, PO.Customers

End_Users_Education(t) = End_Users_Education(t - dt) + (Absorption_Rate - C_Knowledge_Decay - Loss_from_Customers_Turnover) * dt {NON-NEGATIVE}

INIT End_Users_Education = IF SW.Equilibrium_switch=0 THEN Avg_Level_of_Computer_Skills_Needed_to_Get_a_Job*Customers ELSE 90.9090909091 {https://thesystemsthinker.com/managing-in-the-knowledge-era/}

UNITS: pieces of knowledge

USED BY: PO.C_Knowledge_Decay, PO.Average_Level_of_Customers_Education

INFLOWS:

Absorption_Rate = (Learning_Infrastructure+Knowledge_Obtained_Through_Use_of_RRP)/C_Absorption_Time {UNIFLOW}

UNITS: pieces of knowledge/Months

USED BY: PO.End_Users_Education

OUTFLOWS:

C_Knowledge_Decay = End_Users_Education/C_Time_to_Forget {UNIFLOW}

UNITS: pieces of knowledge/Months

USED BY: PO.Total_Outflow, PO.End_Users_Education

Loss_from_Customers_Turnover = Customers_Attrition_Rate*Average_Level_of_Customers_Education {UNIFLOW}

UNITS: pieces of knowledge/Months

USED BY: PO.Total_Outflow, PO.End_Users_Education

Knowledge_Obtained_on_Training(t) = Knowledge_Obtained_on_Training(t - dt) + (Training_Rate - Training_Obsoletion_Rate) * dt {NON-NEGATIVE}

INIT Knowledge_Obtained_on_Training = Training_Rate*Lifespan

UNITS: pieces of knowledge

USED BY: PO.Knowledge_Absorption_Rate, PO.Training_Obsoletion_Rate

INFLOWS:

Training_Rate = (Training*Informativity_of_Training)*RRP.Report_Writers {UNIFLOW}

UNITS: pieces of knowledge/months

USED BY: PO.Knowledge_Obtained_on_Training

OUTFLOWS:

Training_Obsoletion_Rate = Knowledge_Obtained_on_Training/Lifespan {UNIFLOW}

UNITS: pieces of knowledge/months

USED BY: PO.Knowledge_Obtained_on_Training

Knowledge_Obtained_Through_Use_of_RRP(t) = Knowledge_Obtained_Through_Use_of_RRP(t - dt) + (RRP_Use_Rate - RRP_Obsoletion_Rate) * dt {NON-NEGATIVE}

INIT Knowledge_Obtained_Through_Use_of_RRP = 50

UNITS: pieces of knowledge

USED BY: PO.RRP_Obsoletion_Rate, PO.Absorption_Rate

INFLOWS:

RRP_Use_Rate = RRP.FRR_Creation_Rate*Knowledge_Obtained_Per_Report_Request {UNIFLOW}

UNITS: pieces of knowledge/months

USED BY: PO.RRP_Obsoletion_Rate, PO.Knowledge_Obtained_Through_Use_of_RRP

OUTFLOWS:

RRP_Obsoletion_Rate = IF SW.Equilibrium_switch=0 THEN Knowledge_Obtained_Through_Use_of_RRP/LI_Lifespan ELSE RRP_Use_Rate {UNIFLOW}

UNITS: pieces of knowledge/months

USED BY: PO.Knowledge_Obtained_Through_Use_of_RRP

Learning_Infrastructure(t) = Learning_Infrastructure(t - dt) + (Creation_Rate - LI_Obsoletion_Rate) * dt {NON-NEGATIVE}

INIT Learning_Infrastructure = 0 {learning resources, we pages, manuals, etc}

UNITS: pieces of knowledge

USED BY: PO.LI_Obsoletion_Rate, PO.Absorption_Rate

INFLOWS:

Creation_Rate = (Actual_Time_Spent_on_Users_'_Manual_Creation*RRP.Report_Writers)/Time_Needed_to_Create_a_User_Manual {UNIFLOW}

UNITS: pieces of knowledge/Months

USED BY: PO.Learning_Infrastructure

OUTFLOWS:

LI_Obsoletion_Rate = Learning_Infrastructure/LI_Lifespan {UNIFLOW}

UNITS: pieces of knowledge/Months

USED BY: PO.Learning_Infrastructure

Report_Requests_with_Improper_Naming(t) = Report_Requests_with_Improper_Naming(t - dt) + (INR_Acceptance_Rate - INR_Obsoletion_Rate) * dt {NON-NEGATIVE}

INIT Report_Requests_with_Improper_Naming = INIT (RRP."Completed_Reports_(in_use)")

UNITS: Reports

USED BY: PO.INR_Obsoletion_Rate, PO.Share_of_Proper_Named_Reports

INFLOWS:

INR_Acceptance_Rate = IF Naming_Switch=0 THEN RRP.FRR_Acceptance_Rate ELSE (IF TIME < Naming_Start_Time THEN RRP.FRR_Acceptance_Rate ELSE 0) {UNIFLOW}

UNITS: Reports/months

USED BY: PO.Report_Requests_with_Improper_Naming

OUTFLOWS:

INR_Obsoletion_Rate = Report_Requests_with_Improper_Naming/RRP.Lifespan {UNIFLOW}

UNITS: Reports/months

USED BY: PO.Report_Requests_with_Improper_Naming

Report_Writers_Knowledge(t) = Report_Writers_Knowledge(t - dt) + (Knowledge_Absorption_Rate - Knowledge_Decay - Loss_from_Turnover) * dt {NON-NEGATIVE}

INIT Report_Writers_Knowledge = IF SW.Equilibrium_switch=0 THEN INIT(RRP.Report_Writers)*Average_Level_of_Knowledge_Needed_to_Get_a_Job ELSE 232.568749334

UNITS: pieces of knowledge

USED BY: PO.Knowledge_Decay, PO.Average_Level_of_Knowledge

INFLOWS:

Knowledge_Absorption_Rate = Shared_Knowledge/Absorption_Time+Knowledge_Obtained_on_Training/Absorption_Time {UNIFLOW}

UNITS: pieces of knowledge/months

USED BY: PO.Eq_stock_value, PO.Report_Writers_Knowledge

OUTFLOWS:

Knowledge_Decay = Report_Writers_Knowledge/Time_to_Forget {UNIFLOW}

UNITS: pieces of knowledge/months

USED BY: PO.Total_Outflow_Knowledge, PO.Report_Writers_Knowledge

Loss_from_Turnover = RRP.Total_Quit_Rate*Average_Level_of_Knowledge {UNIFLOW}

UNITS: pieces of knowledge/months

USED BY: PO.Total_Outflow_Knowledge, PO.Eq_stock_value, PO.Report_Writers_Knowledge

Salary_Budget(t) = Salary_Budget(t - dt) + (Change_in_Budget) * dt {NON-NEGATIVE}

INIT Salary_Budget = IF SW.Equilibrium_switch=0 THEN Average_Salary*RRP.Report_Writers ELSE 1087516.01359 {https://www.glassdoor.com/Salaries/grand-forks-analyst-salary-SRCH_IL.0,11_IM340_KO12,19.htm $60,481/yerr , from $42K to $86K}

UNITS: US Dollars Per Year

USED BY: PO.Budget_Gap, PO.Budgeted_Report_Writers, PO.Desired_Salary_Budget

INFLOWS:

Change_in_Budget = (IF Budget_Change_Limit_Switch=0 THEN Budget_Gap/Budget_Revision_Time ELSE (MIN(Budget_Gap/Budget_Revision_Time, Budget_Change_Limit)))+(Hiring_With_Productivity_Correction-RRP.Total_Quit_Rate)*Average_Salary

UNITS: US Dollars Per Year/month

USED BY: PO.Salary_Budget

Shared_Knowledge(t) = Shared_Knowledge(t - dt) + (Sharing_Rate - Obsoletion_Rate) * dt {NON-NEGATIVE}

INIT Shared_Knowledge = IF SW.Equilibrium_switch=0 THEN 0 ELSE 0 {learning resources, we pages, manuals, etc} {28.2 80.6383872}

UNITS: pieces of knowledge

USED BY: PO.Obsoletion_Rate, PO.Knowledge_Absorption_Rate

INFLOWS:

Sharing_Rate = (Actual_Time_Spent_on_KS*RRP.Report_Writers)/Time_Needed_to_Share_a_Piece_of_Knowledge {UNIFLOW}

UNITS: pieces of knowledge/Months

USED BY: PO.Shared_Knowledge

OUTFLOWS:

Obsoletion_Rate = Shared_Knowledge/Lifespan {UNIFLOW}

UNITS: pieces of knowledge/Months

USED BY: PO.Shared_Knowledge

Time_Spent_on_Searching(t) = Time_Spent_on_Searching(t - dt) + (Actual_Change_in_Searching_Time) * dt {NON-NEGATIVE}

INIT Time_Spent_on_Searching = Normal_Time_Spent_on_Searching

UNITS: hours/reports

USED BY: PO.FRR_Normal_Completion_Time

INFLOWS:

Actual_Change_in_Searching_Time = Share_of_Proper_Named_Reports*Desired_Change_in_Time_spend_on_Searching

UNITS: Hours/Reports/months

USED BY: PO.Time_Spent_on_Searching

Desired_Change_in_FRR_Average_Completion_Time = Gap/Time_to_Close_Gap

UNITS: Hours/Reports/months

USED BY: PO.Desired_Change_in_Time_spend_on_Searching

Desired_Change_in_Time_spend_on_Searching = Desired_Change_in_FRR_Average_Completion_Time*Normal_Share_of_Time_Spent_on_Searching

UNITS: Hours/Reports/months

USED BY: PO.Actual_Change_in_Searching_Time

Desired_FRR_Completion_Rate = Backlog_Gap/Time_to_Close_the_Gap+RRP.FRR_Creation_Rate+RRP.FRR_Rejection_Rate-RRP.FRR_Dissmisal_Rate {UNIFLOW}

UNITS: Reports/Months

USED BY: PO.Desired_Effective_Report_Writers, PO.Desired_Productivity_per_Effective_Writer

Desired_FRR_Creation_Rate = RRP.FRR_Acceptance_Rate-Backlog_Gap/Time_to_Close_the_Gap {UNIFLOW}

UNITS: Reports/Months

USED BY: PO.Creation_Rate_Gap, PO.Desired_Change_in_FRR_Creation_Rate

Absorption_Time = 3

UNITS: Months

USED BY: PO.Knowledge_Absorption_Rate

Actual_Backlog = RRP.Formal_Report_Requests_in_Process+RRP.New_Formal_Report_Requests+RRP.Reports_Waiting_an_Answer_from_Customers

UNITS: Reports

USED BY: PO.Backlog_Gap, PO.Desired_Backlog_of_FRR

Actual_Effect_of_CE_on_FRR_Creation_Rate = MAX(Percentage_Change_in_Avg_Level_of_CE*Change_Ratio_CE, Max_Effect_of_CE_on_FRR_Creation_Rate)

UNITS: Dimensionless

USED BY: RRP.FRR_Creation_Rate

Actual_Effect_of_KC_on_FRR_Completion_Time = MAX(Effect_of_Avg_Level_of_Knowledge_on_FRR_Completion_Time, Max_Effect_of_Knowledge_Change)

UNITS: Dimensionless

USED BY: PO.FRR_Actual_Completion_Time

Actual_Time_Spent_on_KS = Knowledge_Sharing_Switch*STEP(Feasible_Time_Spent_on_KS, Knowledge_Sharing_Start_Time)

UNITS: Hours/months/writers

USED BY: PO.Sharing_Rate, RRP.Time_Spent_on_Other_Tasks, Cost_Benefit_Analysis.Total_Time_Spent_on_Knowledge_Sharing

Actual_Time_Spent_on_Users_'_Manual_Creation = Customers'_Education_Switch*STEP(Feasible_Time_Spent_On_CE, Customers'_Education_Start_Time)

UNITS: Hours/Writers/months

USED BY: PO.Creation_Rate, RRP.Time_Spent_on_Other_Tasks, Cost_Benefit_Analysis.Total_Time_Spent_on_CE

Average_Level_of_Customers_Education = End_Users_Education/Customers

UNITS: pieces of knowledge/customers

USED BY: PO.Loss_from_Customers_Turnover, PO.Percentage_Change_in_Avg_Level_of_CE, PO.Desired_Change_in_Level_of_CE

Average_Level_of_Knowledge = Report_Writers_Knowledge/RRP.Report_Writers

UNITS: pieces of knowledge/writers

USED BY: PO.Loss_from_Turnover, PO.Change_in_Average_Level_of_Knowledge, PO.Desired_Change_in_Avg_Level_of_Knowledge

Average_Level_of_Knowledge_Needed_to_Get_a_Job = 25

UNITS: pieces of knowledge/writers

Average_Salary = 60500

UNITS: US Dollars Per Year/writers

USED BY: PO.Desired_Salary_Budget, PO.Budgeted_Report_Writers, PO.Change_in_Budget, Cost_Benefit_Analysis.Hiring_More_People_Monthly_Expenses, Cost_Benefit_Analysis.Hiring_with_Productivity_Correction_Monthly_Expenses

Average_Time_in_Company = 5*12

UNITS: Months

USED BY: PO.Customers_Attrition_Rate

Average_Training_Duration = 5

UNITS: Hours/Training

USED BY: PO.Time_Spent_On_Training

Avg_Level_of_Computer_Skills_Needed_to_Get_a_Job = 1

UNITS: pieces of knowledge/customers

Backlog_Gap = Actual_Backlog-Desired_Backlog_of_FRR

UNITS: Reports

USED BY: PO.Desired_FRR_Completion_Rate, PO.Desired_FRR_Creation_Rate

Budget_Change_Limit = 60500/24 {Average Salary per writer per year}

UNITS: US Dollars Per Year/Months

USED BY: PO.Change_in_Budget

Budget_Change_Limit_Switch = 0

UNITS: Dimensionless

USED BY: PO.Change_in_Budget

Budget_Gap = (Desired_Salary_Budget-Salary_Budget)*Hiring_More_People_Switch

UNITS: US Dollars Per Year

USED BY: PO.Change_in_Budget

Budget_Revision_Time = 12

UNITS: Months

USED BY: PO.Change_in_Budget

Budgeted_Report_Writers = Salary_Budget/Average_Salary

UNITS: writers

USED BY: PO.Workforce_Gap

C_Absorption_Time = 3

UNITS: Months

USED BY: PO.Absorption_Rate

C_Time_to_Forget = 6

UNITS: Months

USED BY: PO.C_Knowledge_Decay

Change_in_Average_Level_of_Knowledge = Average_Level_of_Knowledge/INIT(Average_Level_of_Knowledge)-1

UNITS: Dimensionless

USED BY: PO.Effect_of_Avg_Level_of_Knowledge_on_FRR_Completion_Time

Change_Ratio_CE = -1/5 {5 percent of change in level of customers education leads to 1 percent change on FRR creation rate}

UNITS: Dimensionless

USED BY: PO.Desired_Percentage_Change_in_CE, PO.Actual_Effect_of_CE_on_FRR_Creation_Rate

Change_Ratio_KS = -1/5 {5 percent growth of Average Level of Knowledge decreases FRR Completion Time on 1 percent}

UNITS: Dimensionless

USED BY: PO.Effect_of_Avg_Level_of_Knowledge_on_FRR_Completion_Time, PO.Desired_Percentage_Change_in_Avg_Level_of_Knowledge

Creation_Rate_Gap = Desired_FRR_Creation_Rate-RRP.FRR_Creation_Rate

UNITS: Reports/Months

Customers'_Education_Start_Time = 32

UNITS: Months

USED BY: PO.Actual_Time_Spent_on_Users_'_Manual_Creation, Cost_Benefit_Analysis.Time_Periods_CE

Customers'_Education_Switch = 0

UNITS: Dimensionless

USED BY: PO.Actual_Time_Spent_on_Users_'_Manual_Creation, Cost_Benefit_Analysis.Discounted_Expenses_Customers'_Education

Desired_Backlog_of_FRR = IF SW.Equilibrium_switch=0 THEN RRP.FRR_Creation_Rate*Desired_FRR_Delivery_Time ELSE Actual_Backlog

UNITS: Reports

USED BY: PO.Backlog_Gap

Desired_Change_in_Avg_Level_of_Knowledge = Average_Level_of_Knowledge*Desired_Percentage_Change_in_Avg_Level_of_Knowledge

UNITS: pieces of knowledge/writers

USED BY: PO.Total_Time_Needed_to_Achieve_Desired_Change_in_Avg_Level_of_Knowledge

Desired_Change_in_FRR_Creation_Rate = (Desired_FRR_Creation_Rate-RRP.FRR_Creation_Rate)/RRP.FRR_Creation_Rate

UNITS: Dimensionless

USED BY: PO.Desired_Percentage_Change_in_CE

Desired_Change_in_Level_of_CE = INIT(Average_Level_of_Customers_Education)*Desired_Percentage_Change_in_CE

UNITS: pieces of knowledge/customers

USED BY: PO.Total_Time_Needed_to_Achieve_Desired_Change_in_Level_of_CE

Desired_Delivery_Time_in_Days = 7

UNITS: Days

USED BY: PO.Desired_FRR_Delivery_Time, Cost_Benefit_Analysis.Delivery_Delay

Desired_Effective_Report_Writers = Desired_FRR_Completion_Rate/RRP.FRR_Normal_Productivity_per_Effective_Writer

UNITS: writers

USED BY: PO.Desired_New_Employees

Desired_FRR_Average_Completion_Time = RRP.Time_Available_for_Report_Writing*(1-RRP.Share_of_Time_Spent_on_IRR)/Desired_Productivity_per_Effective_Writer

UNITS: hours/reports

USED BY: PO.Gap, PO.Desired_Percentage_Change_in_FRR_Completion_Time

Desired_FRR_Delivery_Time = Desired_Delivery_Time_in_Days/RRP.Days_per_Months

UNITS: Months

USED BY: PO.Desired_Backlog_of_FRR

Desired_New_Employees = Desired_Effective_Report_Writers/RRP.New_Employees_Productivity_Fraction

UNITS: writers

USED BY: PO.Desired_Salary_Budget

Desired_Percentage_Change_in_Avg_Level_of_Knowledge = Desired_Percentage_Change_in_FRR_Completion_Time/Change_Ratio_KS

UNITS: Dimensionless

USED BY: PO.Desired_Change_in_Avg_Level_of_Knowledge

Desired_Percentage_Change_in_CE = Desired_Change_in_FRR_Creation_Rate/Change_Ratio_CE

UNITS: Dimensionless

USED BY: PO.Desired_Change_in_Level_of_CE

Desired_Percentage_Change_in_FRR_Completion_Time = (Desired_FRR_Average_Completion_Time-FRR_Normal_Completion_Time)/FRR_Normal_Completion_Time

UNITS: Dimensionless

USED BY: PO.Desired_Percentage_Change_in_Avg_Level_of_Knowledge

Desired_Productivity_per_Effective_Writer = Desired_FRR_Completion_Rate/RRP.Effective_Report_Writers

UNITS: reports/writers/months

USED BY: PO.Desired_FRR_Average_Completion_Time

Desired_Salary_Budget = IF SW.Equilibrium_switch=0 THEN Desired_New_Employees*Average_Salary ELSE INIT(Salary_Budget)

UNITS: US Dollars Per Year

USED BY: PO.Budget_Gap

Desired_Time_Spent_on_CE = Total_Time_Needed_to_Achieve_Desired_Change_in_Level_of_CE/Desired_Time_to_Close_CE_Gap

UNITS: Hours/months/writers

USED BY: PO.Feasible_Time_Spent_On_CE

Desired_Time_Spent_on_KS = Total_Time_Needed_to_Achieve_Desired_Change_in_Avg_Level_of_Knowledge/Desired_Time_to_Close_Knowledge_Gap

UNITS: Hours/writers/months

USED BY: PO.Feasible_Time_Spent_on_KS

Desired_Time_to_Close_CE_Gap = 12

UNITS: Months

USED BY: PO.Desired_Time_Spent_on_CE

Desired_Time_to_Close_Knowledge_Gap = 12

UNITS: Months

USED BY: PO.Desired_Time_Spent_on_KS

Effect_of_Avg_Level_of_Knowledge_on_FRR_Completion_Time = Change_in_Average_Level_of_Knowledge*Change_Ratio_KS {5 percent growth of Average Level of Knowledge decreases FRR Completion Time on 1 percent}

UNITS: Dimensionless

USED BY: PO.Actual_Effect_of_KC_on_FRR_Completion_Time

Eq_stock_value = (Knowledge_Absorption_Rate-Loss_from_Turnover)*Time_to_Forget

UNITS: pieces of knowledge

Feasible_Time_Spent_On_CE = MIN(RRP.Working_Hours_per_Months*Max_Share_of_Working_Time_Spent_on_CE, Desired_Time_Spent_on_CE)

UNITS: Hours/months/writers

USED BY: PO.Actual_Time_Spent_on_Users_'_Manual_Creation

Feasible_Time_Spent_on_KS = MIN(Desired_Time_Spent_on_KS, Max_Share_of_Working_Time_Spent_on_KS*RRP.Working_Hours_per_Months)

UNITS: Hours/months/writers

USED BY: PO.Actual_Time_Spent_on_KS

FRR_Actual_Completion_Time = FRR_Normal_Completion_Time*(1+Actual_Effect_of_KC_on_FRR_Completion_Time)

UNITS: Hours/Reports

USED BY: RRP.FRR_Normal_Productivity_per_Effective_Writer

FRR_Net_Writing_Time = 7.5

UNITS: Hours/reports

USED BY: PO.FRR_Normal_Completion_Time

FRR_Normal_Completion_Time = FRR_Net_Writing_Time+Time_Spent_on_Searching+Time_Spent_on_Proper_Naming

UNITS: Hours/Reports

USED BY: PO.Gap, PO.Normal_Share_of_Time_Spent_on_Searching, PO.FRR_Actual_Completion_Time, PO.Desired_Percentage_Change_in_FRR_Completion_Time, Cost_Benefit_Analysis.Average_Time_Needed_to_Fullfill_a_Report

Gap = Desired_FRR_Average_Completion_Time-FRR_Normal_Completion_Time

UNITS: Hours/reports

USED BY: PO.Desired_Change_in_FRR_Average_Completion_Time

Growth_Rate = IF SW.Equilibrium_switch=0 THEN 0.02/12 ELSE 0 {Hiring delay is omitted for the sake of simplicity}

UNITS: Dimensionless/months

USED BY: PO.Customers_Hiring_Rate

Hiring_More_People = IF Hiring_More_People_Switch=0 THEN 0 ELSE STEP(MAX(Workforce_Gap/Hiring_Time-Hiring_With_Productivity_Correction, 0), Hiring_Start_Time)

UNITS: writers/months

USED BY: RRP.Hiring_Rate, Cost_Benefit_Analysis.Hiring_More_People_Rate

Hiring_More_People_Switch = 0

UNITS: Dimensionless

USED BY: PO.Hiring_More_People, PO.Budget_Gap, Cost_Benefit_Analysis.Hiring_More_People_Monthly_Expenses

Hiring_Start_Time = 32

UNITS: Months

USED BY: PO.Hiring_More_People, Cost_Benefit_Analysis.Hiring_More_People_Monthly_Expenses, Cost_Benefit_Analysis.Time_Periods_Hiring

Hiring_Time = 6

UNITS: Months

USED BY: PO.Hiring_More_People

Hiring_With_Productivity_Correction = IF (TIME>Productivity_Correction_Start_Time AND Productivity_Correction_Switch=1) THEN RRP.Total_Quit_Rate/New_Employees_Perceived_Productivity_Fraction ELSE 0

UNITS: writers/Months

USED BY: PO.Change_in_Budget, PO.Hiring_More_People, RRP.Hiring_Rate

Informativity_of_Training = 3.5

UNITS: pieces of knowledge/training

USED BY: PO.Training_Rate

Knowledge_Obtained_Per_Report_Request = 0.04

UNITS: pieces of knowledge/reports

USED BY: PO.RRP_Use_Rate

Knowledge_Sharing_Start_Time = 32

UNITS: Months

USED BY: PO.Actual_Time_Spent_on_KS, Cost_Benefit_Analysis.Time_Periods_Knowledge_Sharing

Knowledge_Sharing_Switch = 0

UNITS: Dimensionless

USED BY: PO.Actual_Time_Spent_on_KS, Cost_Benefit_Analysis.Discount_Expenses_Knowledge_Sharing

LI_Lifespan = 24

UNITS: Months

USED BY: PO.LI_Obsoletion_Rate, PO.RRP_Obsoletion_Rate

Lifespan = 24

UNITS: Months

USED BY: PO.Obsoletion_Rate, PO.Training_Obsoletion_Rate

Max_Effect_of_CE_on_FRR_Creation_Rate = -0.25

UNITS: Dimensionless

USED BY: PO.Actual_Effect_of_CE_on_FRR_Creation_Rate

Max_Effect_of_Knowledge_Change = -0.25

UNITS: Dimensionless

USED BY: PO.Actual_Effect_of_KC_on_FRR_Completion_Time

Max_Share_of_Working_Time_Spent_on_CE = 0.1

UNITS: Dimensionless

USED BY: PO.Feasible_Time_Spent_On_CE

Max_Share_of_Working_Time_Spent_on_KS = 0.1

UNITS: Dimensionless

USED BY: PO.Feasible_Time_Spent_on_KS

Naming_Start_Time = 32

UNITS: Months

USED BY: PO.INR_Acceptance_Rate, PO.Time_Spent_on_Proper_Naming, Cost_Benefit_Analysis.Time_Periods_Naming

Naming_Switch = 0

UNITS: Dimensionless

USED BY: PO.Time_Spent_on_Proper_Naming, PO.INR_Acceptance_Rate, Cost_Benefit_Analysis.Discounted_Expenses_Naming

New_Employees_Perceived_Productivity_Fraction = RRP.New_Employees_Productivity_Fraction*1.75

UNITS: Dimensionless

USED BY: PO.Hiring_With_Productivity_Correction, Cost_Benefit_Analysis.Hiring_with_Productivity_Correction

Normal_Share_of_Time_Spent_on_Searching = Normal_Time_Spent_on_Searching/FRR_Normal_Completion_Time

UNITS: Dimensionless

USED BY: PO.Desired_Change_in_Time_spend_on_Searching

Normal_Time_Spent_on_Searching = 1

UNITS: Hours/Reports

USED BY: PO.Normal_Share_of_Time_Spent_on_Searching

Percentage_Change_in_Avg_Level_of_CE = (Average_Level_of_Customers_Education-INIT(Average_Level_of_Customers_Education))/INIT(Average_Level_of_Customers_Education)

UNITS: Dimensionless

USED BY: PO.Actual_Effect_of_CE_on_FRR_Creation_Rate

Productivity_Correction_Start_Time = 0

UNITS: Months

USED BY: PO.Hiring_With_Productivity_Correction, Cost_Benefit_Analysis.Hiring_with_Productivity_Correction, Cost_Benefit_Analysis.Time_Periods_Productivity_Correction, Cost_Benefit_Analysis.Hiring_with_Productivity_Correction_Monthly_Expenses

Productivity_Correction_Switch = 1

UNITS: Dimensionless

USED BY: PO.Hiring_With_Productivity_Correction, RRP.Hiring_Rate, Cost_Benefit_Analysis.Hiring_with_Productivity_Correction, Cost_Benefit_Analysis.Discounted_Productivity_Correction_Hiring_Expenses, Cost_Benefit_Analysis.Hiring_with_Productivity_Correction_Monthly_Expenses

Share_of_Proper_Named_Reports = (RRP."Completed_Reports_(in_use)"-Report_Requests_with_Improper_Naming)/RRP."Completed_Reports_(in_use)"

UNITS: Dimensionless

USED BY: PO.Actual_Change_in_Searching_Time

Time_Needed_to_Create_a_User_Manual = 5

UNITS: hours/pieces of knowledge

USED BY: PO.Creation_Rate, PO.Total_Time_Needed_to_Achieve_Desired_Change_in_Level_of_CE

Time_Needed_to_Share_a_Piece_of_Knowledge = 5

UNITS: hours/pieces of knowledge

USED BY: PO.Sharing_Rate, PO.Total_Time_Needed_to_Achieve_Desired_Change_in_Avg_Level_of_Knowledge

Time_Spent_on_Proper_Naming = IF Naming_Switch=0 THEN 0 ELSE (IF TIME>Naming_Start_Time THEN 0.1 ELSE 0)

UNITS: hours/reports

USED BY: PO.FRR_Normal_Completion_Time, Cost_Benefit_Analysis.Total_Time_Spent_on_Naming

Time_Spent_On_Training = Training*Average_Training_Duration

UNITS: Hours/months/writers

USED BY: RRP.Time_Spent_on_Other_Tasks

Time_to_Close_Gap = 6

UNITS: Months

USED BY: PO.Desired_Change_in_FRR_Average_Completion_Time

Time_to_Close_the_Gap = 6

UNITS: Months

USED BY: PO.Desired_FRR_Completion_Rate, PO.Desired_FRR_Creation_Rate

Time_to_Forget = 6

UNITS: Months

USED BY: PO.Knowledge_Decay, PO.Eq_stock_value

Total_Outflow = C_Knowledge_Decay+Loss_from_Customers_Turnover

UNITS: pieces of knowledge/months

Total_Outflow_Knowledge = Loss_from_Turnover+Knowledge_Decay

UNITS: pieces of knowledge/months

Total_Time_Needed_to_Achieve_Desired_Change_in_Avg_Level_of_Knowledge = Desired_Change_in_Avg_Level_of_Knowledge*Time_Needed_to_Share_a_Piece_of_Knowledge

UNITS: Hours/writers

USED BY: PO.Desired_Time_Spent_on_KS

Total_Time_Needed_to_Achieve_Desired_Change_in_Level_of_CE = (Desired_Change_in_Level_of_CE*Time_Needed_to_Create_a_User_Manual*Customers)/RRP.Report_Writers

UNITS: Hours/writers

USED BY: PO.Desired_Time_Spent_on_CE

Training = 1/5

UNITS: training/writers/months

USED BY: PO.Training_Rate, PO.Time_Spent_On_Training

Workforce_Gap = Budgeted_Report_Writers-RRP.Report_Writers

UNITS: writers

USED BY: PO.Hiring_More_People

RRP:

Broken_Reports(t) = Broken_Reports(t - dt) + (FRR_Breakage_Rate - FRR_Maintenance_Rate) * dt {NON-NEGATIVE}

INIT Broken_Reports = IF SW.Equilibrium_switch=0 THEN 10 ELSE FRR_Breakage_Rate*Maintenance_Delay {10}

UNITS: Reports

USED BY: RRP.FRR_Maintenance_Rate

INFLOWS:

FRR_Breakage_Rate = DB_Upgrade_Rate*Reports_Needed_to_Be_Fixed_per_DB_Upgrade {UNIFLOW}

UNITS: Reports/Months

USED BY: RRP."Completed_Reports_(in_use)", RRP.Broken_Reports

OUTFLOWS:

FRR_Maintenance_Rate = Broken_Reports/Maintenance_Delay {UNIFLOW}

UNITS: Reports/Months

USED BY: RRP.Time_Spent_Fixing_Reports, RRP.Broken_Reports, RRP."Completed_Reports_(in_use)"

"Completed_Reports_(in_use)"(t) = "Completed_Reports_(in_use)"(t - dt) + (FRR_Acceptance_Rate + FRR_Maintenance_Rate - FRR_Obsoletion_Rate - FRR_Breakage_Rate) * dt {NON-NEGATIVE}

INIT "Completed_Reports_(in_use)" = IF SW.Equilibrium_switch=0 THEN 1500 ELSE FRR_Acceptance_Rate*Lifespan

UNITS: Reports

USED BY: RRP.FRR_Obsoletion_Rate, PO.Share_of_Proper_Named_Reports

INFLOWS:

FRR_Acceptance_Rate = (Reports_Waiting_an_Answer_from_Customers/Communication_Delay)*Acceptance_Fraction {UNIFLOW}

UNITS: Reports/Months

USED BY: PO.INR_Acceptance_Rate, PO.Desired_FRR_Creation_Rate, Cost_Benefit_Analysis.Cash_Flow, Cost_Benefit_Analysis.Total_Time_Spent_on_Naming, RRP.Reports_Waiting_an_Answer_from_Customers, RRP."Completed_Reports_(in_use)"

FRR_Maintenance_Rate = Broken_Reports/Maintenance_Delay {UNIFLOW}

UNITS: Reports/Months

USED BY: RRP.Time_Spent_Fixing_Reports, RRP.Broken_Reports, RRP."Completed_Reports_(in_use)"

OUTFLOWS:

FRR_Obsoletion_Rate = "Completed_Reports_(in_use)"/Lifespan {UNIFLOW}

UNITS: Reports/Months

USED BY: RRP."Completed_Reports_(in_use)"

FRR_Breakage_Rate = DB_Upgrade_Rate*Reports_Needed_to_Be_Fixed_per_DB_Upgrade {UNIFLOW}

UNITS: Reports/Months

USED BY: RRP."Completed_Reports_(in_use)", RRP.Broken_Reports

Experienced_Employees(t) = Experienced_Employees(t - dt) + (Assimilation_Rate - Attrition_Rate) * dt {NON-NEGATIVE}

INIT Experienced_Employees = IF SW.Equilibrium_switch=0 THEN 6.5 ELSE Assimilation_Rate*Average_Time_on_Position

UNITS: writers

USED BY: RRP.Effective_Report_Writers, RRP.Attrition_Rate, RRP.Report_Writers

INFLOWS:

Assimilation_Rate = (New_Employees/Assimilation_Time)*Assimilation_Fraction {UNIFLOW}

UNITS: writers/months

USED BY: RRP.New_Employees, RRP.Experienced_Employees

OUTFLOWS:

Attrition_Rate = Experienced_Employees/Average_Time_on_Position {UNIFLOW}

UNITS: writers/months

USED BY: RRP.Total_Quit_Rate, RRP.Experienced_Employees

Formal_Report_Requests_in_Process(t) = Formal_Report_Requests_in_Process(t - dt) + (FRR_Assignment_Rate + FRR_Rejection_Rate - FRR_Completion_Rate) * dt {NON-NEGATIVE}

INIT Formal_Report_Requests_in_Process = 42*0.5

UNITS: Reports

USED BY: RRP.Processing_Time, RRP.Open_Report_Requests, PO.Actual_Backlog

INFLOWS:

FRR_Assignment_Rate = IF SW.Equilibrium_switch=0 THEN FRR_Completion_Rate-Perceived_FRR_Rejection_Rate ELSE FRR_Completion_Rate-FRR_Rejection_Rate {UNIFLOW}

UNITS: Reports/Months

USED BY: RRP.Assignment_&_Dismissal_Time, RRP.Total_Outflow, RRP.Init_Stock_Value, RRP.New_Formal_Report_Requests, RRP.Formal_Report_Requests_in_Process

FRR_Rejection_Rate = (Reports_Waiting_an_Answer_from_Customers/Communication_Delay)*(1-Acceptance_Fraction) {UNIFLOW}

UNITS: Reports/Months

USED BY: RRP.Perceived_FRR_Rejection_Rate, RRP.FRR_Assignment_Rate, PO.Desired_FRR_Completion_Rate, RRP.Reports_Waiting_an_Answer_from_Customers, RRP.Formal_Report_Requests_in_Process

OUTFLOWS:

FRR_Completion_Rate = FRR_Normal_Productivity_per_Effective_Writer*Effective_Report_Writers {UNIFLOW}

UNITS: Reports/Months

USED BY: RRP.FRR_Assignment_Rate, RRP.Processing_Time, RRP.Init_Value, RRP.Formal_Report_Requests_in_Process, RRP.Reports_Waiting_an_Answer_from_Customers

Informal_Report_Requests(t) = Informal_Report_Requests(t - dt) + (IRR_Creation_Rate - IRR_Completion_Rate) * dt {NON-NEGATIVE}

INIT Informal_Report_Requests = IF SW.Equilibrium_switch=0 THEN 300 ELSE 0

UNITS: Reports

USED BY: RRP.IRR_Completion_Time, RRP.IRR_Backlog_Gap

INFLOWS:

IRR_Creation_Rate = (Phone+Email) {UNIFLOW}

UNITS: Reports/months

USED BY: RRP.Desired_Backlog_of_IRR, RRP.Desired_IRR_Completion_Rate, RRP.Informal_Report_Requests

OUTFLOWS:

IRR_Completion_Rate = IRR_Productivity*Effective_Report_Writers {UNIFLOW}

UNITS: Reports/months

USED BY: RRP.IRR_Completion_Time, RRP.Informal_Report_Requests

New_Employees(t) = New_Employees(t - dt) + (Hiring_Rate - Assimilation_Rate - Quit_Rate) * dt {NON-NEGATIVE}

INIT New_Employees = IF SW.Equilibrium_switch=0 THEN 2 ELSE 3.02108761329

UNITS: writers

USED BY: RRP.Effective_Report_Writers, RRP.Quit_Rate, RRP.Assimilation_Rate, RRP.Report_Writers

INFLOWS:

Hiring_Rate = (1-PO.Productivity_Correction_Switch)*Total_Quit_Rate+PO.Hiring_More_People+PO.Hiring_With_Productivity_Correction*PO.Productivity_Correction_Switch {IF Switches.Equilibrium_switch=0 THEN Total_Quit_Rate+STEP((Workforce_Gap/Hiring_Time)*Hiring_Switch, 32) ELSE Total_outflow} {UNIFLOW}

UNITS: writers/months

USED BY: RRP.New_Employees

OUTFLOWS:

Assimilation_Rate = (New_Employees/Assimilation_Time)*Assimilation_Fraction {UNIFLOW}

UNITS: writers/months

USED BY: RRP.New_Employees, RRP.Experienced_Employees

Quit_Rate = (New_Employees/Assimilation_Time)*(1-Assimilation_Fraction) {UNIFLOW}

UNITS: writers/months

USED BY: RRP.Total_Quit_Rate, RRP.New_Employees

New_Formal_Report_Requests(t) = New_Formal_Report_Requests(t - dt) + (FRR_Creation_Rate - FRR_Assignment_Rate - FRR_Dissmisal_Rate) * dt {NON-NEGATIVE}

INIT New_Formal_Report_Requests = IF SW.Equilibrium_switch=0 THEN 3 ELSE 26.1959592748

UNITS: Reports

USED BY: RRP.FRR_Dissmisal_Rate, RRP.Assignment_&_Dismissal_Time, RRP.Open_Report_Requests, PO.Actual_Backlog

INFLOWS:

FRR_Creation_Rate = IF SW.Equilibrium_switch=0 THEN Service_Now_Data*(1+PO.Actual_Effect_of_CE_on_FRR_Creation_Rate) ELSE 78 {UNIFLOW}

UNITS: Reports/Months

USED BY: RRP.Init_Stock_Value, PO.Desired_FRR_Completion_Rate, PO.Desired_Backlog_of_FRR, PO.RRP_Use_Rate, PO.Creation_Rate_Gap, PO.Desired_Change_in_FRR_Creation_Rate, RRP.New_Formal_Report_Requests

OUTFLOWS:

FRR_Assignment_Rate = IF SW.Equilibrium_switch=0 THEN FRR_Completion_Rate-Perceived_FRR_Rejection_Rate ELSE FRR_Completion_Rate-FRR_Rejection_Rate {UNIFLOW}

UNITS: Reports/Months

USED BY: RRP.Assignment_&_Dismissal_Time, RRP.Total_Outflow, RRP.Init_Stock_Value, RRP.New_Formal_Report_Requests, RRP.Formal_Report_Requests_in_Process

FRR_Dissmisal_Rate = New_Formal_Report_Requests*Dissmisal_Fraction {UNIFLOW}

UNITS: Reports/Months

USED BY: RRP.Assignment_&_Dismissal_Time, RRP.Total_Outflow, PO.Desired_FRR_Completion_Rate, RRP.New_Formal_Report_Requests

Nova_Notes(t) = Nova_Notes(t - dt) + (DB_Upgrade_Rate - Upgrades'_Implementation_Rate) * dt {NON-NEGATIVE}

INIT Nova_Notes = 1 {Nova Notes}

UNITS: upgrades

USED BY: RRP.Upgrades'_Implementation_Rate

INFLOWS:

DB_Upgrade_Rate = 1/4 {Now it's an update per quarter, before 2018 - one major update each 2 years} {UNIFLOW}

UNITS: upgrades/Months

USED BY: RRP.FRR_Breakage_Rate, RRP.Nova_Notes

OUTFLOWS:

Upgrades'_Implementation_Rate = Nova_Notes/Implementation_Delay {UNIFLOW}

UNITS: upgrades/Months

USED BY: RRP.Time_Spent_on_DB_Upgrades, RRP.Nova_Notes

Reports_Waiting_an_Answer_from_Customers(t) = Reports_Waiting_an_Answer_from_Customers(t - dt) + (FRR_Completion_Rate - FRR_Acceptance_Rate - FRR_Rejection_Rate) * dt {NON-NEGATIVE}

INIT Reports_Waiting_an_Answer_from_Customers = IF SW.Equilibrium_switch=0 THEN 11 ELSE 19.6641543682

UNITS: Reports

USED BY: RRP.FRR_Acceptance_Rate, RRP.FRR_Rejection_Rate, RRP.Open_Report_Requests, PO.Actual_Backlog

INFLOWS:

FRR_Completion_Rate = FRR_Normal_Productivity_per_Effective_Writer*Effective_Report_Writers {UNIFLOW}

UNITS: Reports/Months

USED BY: RRP.FRR_Assignment_Rate, RRP.Processing_Time, RRP.Init_Value, RRP.Formal_Report_Requests_in_Process, RRP.Reports_Waiting_an_Answer_from_Customers

OUTFLOWS:

FRR_Acceptance_Rate = (Reports_Waiting_an_Answer_from_Customers/Communication_Delay)*Acceptance_Fraction {UNIFLOW}

UNITS: Reports/Months

USED BY: PO.INR_Acceptance_Rate, PO.Desired_FRR_Creation_Rate, Cost_Benefit_Analysis.Cash_Flow, Cost_Benefit_Analysis.Total_Time_Spent_on_Naming, RRP.Reports_Waiting_an_Answer_from_Customers, RRP."Completed_Reports_(in_use)"

FRR_Rejection_Rate = (Reports_Waiting_an_Answer_from_Customers/Communication_Delay)*(1-Acceptance_Fraction) {UNIFLOW}

UNITS: Reports/Months

USED BY: RRP.Perceived_FRR_Rejection_Rate, RRP.FRR_Assignment_Rate, PO.Desired_FRR_Completion_Rate, RRP.Reports_Waiting_an_Answer_from_Customers, RRP.Formal_Report_Requests_in_Process

Desired_IRR_Completion_Rate = IRR_Backlog_Gap/Time_to_Close_IRR_Gap+IRR_Creation_Rate {UNIFLOW}

UNITS: Reports/Months

USED BY: RRP.Desired_IRR_Productivity_per_Effective_Writer

Acceptance_Fraction = 0.9 {Where 0.8 is an "ideal" acceptance fraction, that might be achieved in case of the absolute clarity of requirements. }

UNITS: Dimensionless

USED BY: RRP.FRR_Acceptance_Rate, RRP.FRR_Rejection_Rate

Answering_Questions_&_Etc = 17

UNITS: Hours/months/writers

USED BY: RRP.Time_Spent_on_Other_Tasks

Assignment_&_Dismissal_Time = ((New_Formal_Report_Requests)/(FRR_Dissmisal_Rate+FRR_Assignment_Rate+0.01))*Days_per_Months

UNITS: Days

USED BY: Cost_Benefit_Analysis.Reports_Delivery_Time

Assimilation_Fraction = 0.99

UNITS: Dimensionless

USED BY: RRP.Quit_Rate, RRP.Assimilation_Rate

Assimilation_Time = 24 {Normal_Assimilation_Time*Effect_of_Knowledge_Sharing_on_Assimilation_Time}

UNITS: Months

USED BY: RRP.Quit_Rate, RRP.Assimilation_Rate

Average_Time_on_Position = 12*4 {5 years in the compsny in total, including assimilation time. In fact, the number might be lower}

UNITS: Months

USED BY: RRP.Attrition_Rate

Communication_Delay = 1/(52/12) {52/12 - the number of weeks per months}

UNITS: Months

USED BY: RRP.FRR_Acceptance_Rate, RRP.FRR_Rejection_Rate, RRP.Communication_Delay_in_Days, RRP.Init_Value

Communication_Delay_in_Days = Communication_Delay*Days_per_Months

UNITS: Days

USED BY: Cost_Benefit_Analysis.Reports_Delivery_Time

Days_per_Months = 365/12

UNITS: Days/Months

USED BY: RRP.Assignment_&_Dismissal_Time, RRP.Processing_Time, RRP.Communication_Delay_in_Days, RRP.Desired_IRR_Delivery_Time, PO.Desired_FRR_Delivery_Time

Desired_Backlog_of_IRR = IRR_Creation_Rate*Desired_IRR_Delivery_Time

UNITS: Reports

USED BY: RRP.IRR_Backlog_Gap

Desired_IRR_Delivery_Time = Desired_IRR_Delivery_Time_in_Days/Days_per_Months

UNITS: months

USED BY: RRP.Desired_Backlog_of_IRR

Desired_IRR_Delivery_Time_in_Days = 5

UNITS: Days

USED BY: RRP.Desired_IRR_Delivery_Time

Desired_IRR_Productivity_per_Effective_Writer = Desired_IRR_Completion_Rate/Effective_Report_Writers

UNITS: Reports/writers/months

USED BY: RRP.Share_of_Time_Spent_on_IRR

Dissmisal_Fraction = 0.05

UNITS: Dimensionless/months

USED BY: RRP.FRR_Dissmisal_Rate, RRP.Init_Stock_Value

Effective_Report_Writers = New_Employees*New_Employees_Productivity_Fraction+Experienced_Employees

UNITS: writers

USED BY: RRP.Time_Spent_Fixing_Reports, RRP.FRR_Completion_Rate, RRP.IRR_Completion_Rate, RRP.Time_Spent_on_DB_Upgrades, RRP.Desired_IRR_Productivity_per_Effective_Writer, PO.Desired_Productivity_per_Effective_Writer

Email = 2*10*(52/12)

UNITS: Reports/months

USED BY: RRP.IRR_Creation_Rate

FRR_Normal_Productivity_per_Effective_Writer = Time_Available_for_Report_Writing*(1-Share_of_Time_Spent_on_IRR)/PO.FRR_Actual_Completion_Time

UNITS: reports/writers/months

USED BY: RRP.FRR_Completion_Rate, PO.Desired_Effective_Report_Writers

Implementation_Delay = 4

UNITS: Months

USED BY: RRP.Upgrades'_Implementation_Rate

Init_Stock_Value = (FRR_Creation_Rate-FRR_Assignment_Rate)/Dissmisal_Fraction

UNITS: Reports

Init_Value = FRR_Completion_Rate*Communication_Delay

UNITS: Reports

Initial_Asimilation_Rate = 0.166159818731

UNITS: writers/months

IRR_Average_Completion_Time = 3

UNITS: Hours/reports

USED BY: RRP.IRR_Productivity, RRP.Share_of_Time_Spent_on_IRR

IRR_Backlog_Gap = Informal_Report_Requests-Desired_Backlog_of_IRR

UNITS: Reports

USED BY: RRP.Desired_IRR_Completion_Rate

IRR_Completion_Time = Informal_Report_Requests/IRR_Completion_Rate

UNITS: months

IRR_Productivity = (Share_of_Time_Spent_on_IRR*Time_Available_for_Report_Writing)/IRR_Average_Completion_Time

UNITS: Reports/writers/months

USED BY: RRP.IRR_Completion_Rate

Lifespan = 3*12 {2 years}

UNITS: months

USED BY: RRP.FRR_Obsoletion_Rate, PO.INR_Obsoletion_Rate

Maintenance_Delay = 4 {Time needed to realise that reports is broken and to fix it}

UNITS: Months

USED BY: RRP.FRR_Maintenance_Rate

New_Employees_Productivity_Fraction = 0.4

UNITS: Dimensionless

USED BY: RRP.Effective_Report_Writers, PO.Desired_New_Employees, PO.New_Employees_Perceived_Productivity_Fraction

Open_Report_Requests = New_Formal_Report_Requests+Formal_Report_Requests_in_Process+Reports_Waiting_an_Answer_from_Customers

UNITS: Reports

Perceived_FRR_Rejection_Rate = FRR_Rejection_Rate*0.8

UNITS: Reports/months

USED BY: RRP.FRR_Assignment_Rate

Phone = 1*(52/12)*10

UNITS: Reports/months

USED BY: RRP.IRR_Creation_Rate

Processing_Time = (Formal_Report_Requests_in_Process/(FRR_Completion_Rate+0.001))*Days_per_Months

UNITS: Days

USED BY: Cost_Benefit_Analysis.Reports_Delivery_Time

Report_Writers = Experienced_Employees+New_Employees

UNITS: writers

USED BY: PO.Workforce_Gap, PO.Training_Rate, PO.Sharing_Rate, PO.Creation_Rate, PO.Total_Time_Needed_to_Achieve_Desired_Change_in_Level_of_CE, PO.Average_Level_of_Knowledge, Cost_Benefit_Analysis.Monthly_Expenses_on_Proper_Naming, Cost_Benefit_Analysis.Total_Time_Spent_on_CE, Cost_Benefit_Analysis.Monthly_Expenses_on_CE, Cost_Benefit_Analysis.Total_Time_Spent_on_Knowledge_Sharing, Cost_Benefit_Analysis.Monthly_Expenses_on_Knowledge_Sharing, Cost_Benefit_Analysis.Discrepancy

Reports_Needed_to_Be_Fixed_per_DB_Upgrade = 100/8 {}

UNITS: Reports/Upgrades

USED BY: RRP.FRR_Breakage_Rate

Service_Now_Data = GRAPH(TIME)

(-1.00, 42.0), (0.00, 70.0), (1.00, 95.0), (2.00, 58.0), (3.00, 86.0), (4.00, 81.0), (5.00, 60.0), (6.00, 62.0), (7.00, 59.0), (8.00, 85.0), (9.00, 84.0), (10.00, 85.0), (11.00, 79.0), (12.00, 54.0), (13.00, 72.0), (14.00, 82.0), (15.00, 135.0), (16.00, 59.0), (17.00, 85.0), (18.00, 102.0), (19.00, 63.0), (20.00, 57.0), (21.00, 90.0), (22.00, 100.0), (23.00, 125.0), (24.00, 92.0), (25.00, 114.0), (26.00, 80.0), (27.00, 68.0), (28.00, 92.0), (29.00, 93.0), (30.00, 94.0)

UNITS: Reports/Months

USED BY: RRP.FRR_Creation_Rate

Share_of_Time_Spent_on_IRR = IF SW.Equilibrium_switch=0 THEN (Desired_IRR_Productivity_per_Effective_Writer*IRR_Average_Completion_Time)/Time_Available_for_Report_Writing ELSE 0.3

UNITS: Dimensionless

USED BY: RRP.IRR_Productivity, RRP.FRR_Normal_Productivity_per_Effective_Writer, PO.Desired_FRR_Average_Completion_Time

Time_Available_for_Report_Writing = Working_Hours_per_Months-Time_Spent_on_Other_Tasks

UNITS: Hours/months/writers

USED BY: RRP.FRR_Normal_Productivity_per_Effective_Writer, RRP.IRR_Productivity, RRP.Share_of_Time_Spent_on_IRR, PO.Desired_FRR_Average_Completion_Time

Time_Needed_to_Fix_a_Report = 4

UNITS: Hours/Reports

USED BY: RRP.Time_Spent_Fixing_Reports

Time_per_DB_Upgrade = 40 {Someone spends more time on it, for instance the person responsible for the maintainence spen 10-15 hours per upgrade, other - 30 mins to read Nova Notes}

UNITS: Hours/upgrades

USED BY: RRP.Time_Spent_on_DB_Upgrades

Time_Spent_Fixing_Reports = FRR_Maintenance_Rate*Time_Needed_to_Fix_a_Report/Effective_Report_Writers

UNITS: Hours/Months/writers

USED BY: RRP.Time_Spent_on_Other_Tasks

Time_Spent_on_DB_Upgrades = Upgrades'_Implementation_Rate*Time_per_DB_Upgrade/Effective_Report_Writers

UNITS: Hours/months/writers

USED BY: RRP.Time_Spent_on_Other_Tasks

Time_Spent_on_Other_Tasks = Answering_Questions_&_Etc+Time_Spent_Fixing_Reports+Time_Spent_on_DB_Upgrades+PO.Time_Spent_On_Training+SMTH1(PO.Actual_Time_Spent_on_KS, 1, 0)+SMTH1(PO.Actual_Time_Spent_on_Users_'_Manual_Creation, 1, 0)

UNITS: Hours/months/writers

USED BY: RRP.Time_Available_for_Report_Writing

Time_to_Close_IRR_Gap = 6

UNITS: Months

USED BY: RRP.Desired_IRR_Completion_Rate

Total_Outflow = FRR_Dissmisal_Rate+FRR_Assignment_Rate

UNITS: Reports/months

Total_Quit_Rate = Quit_Rate+Attrition_Rate

UNITS: writers/Months

USED BY: RRP.Hiring_Rate, PO.Loss_from_Turnover, PO.Hiring_With_Productivity_Correction, PO.Change_in_Budget

Working_Hours_per_Months = 40*(52/12)

UNITS: Hours/months/writers

USED BY: RRP.Time_Available_for_Report_Writing, PO.Feasible_Time_Spent_on_KS, PO.Feasible_Time_Spent_On_CE

SW:

Equilibrium_switch = 0

UNITS: Dimensionless

USED BY: PO.Desired_Backlog_of_FRR, PO.Growth_Rate, PO.RRP_Obsoletion_Rate, PO.Desired_Salary_Budget, RRP.FRR_Creation_Rate, RRP.FRR_Assignment_Rate, RRP.Share_of_Time_Spent_on_IRR

{ The model has 366 (366) variables (array expansion in parens).

In root model and 5 additional modules with 27 sectors.

Stocks: 28 (28) Flows: 64 (64) Converters: 274 (274)

Constants: 87 (87) Equations: 251 (251) Graphicals: 6 (6)

There are also 10 expanded macro variables.

```
}
```