MASTER

A methodological business process redesign approach for documented processes
a case study within ASML

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A Methodological Business Process Redesign Approach for Documented Processes:

A Case Study within ASML

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Abstract

In this Master's project, a *Redesign Project* for the *"Training"* processes of *ASML* was conducted. A methodology, which was developed specifically for the case study examined here was followed. According to the methodology, the project started with analysing the existing processes. The existing processes were the process models developed within the organization by using the *"swimlane"* notation. These documented processes were analysed and mistakes were discovered. The conceptual models were created by fixing the mistakes. The validated conceptual models were the bases for the redesign scenarios. A number of redesign scenarios were developed by the researcher and approved by the process owners. As a last step, the existing and redesigned process models were simulated to assess the effects of the redesign scenarios. The scenarios, which were proved to provide gains, were selected and suggested to the organization. As a result of the project, the *throughput time* of a process and *workload* of resources were reduced and the methodology was validated with the case study.

"Mens Agitat Molem"

"The mind brings matter into motion"

The Motto of TU/e

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Chapter 1

Introduction

Hammer and Champy (1993) defined the term *Business Process Reengineering* as *"the fundamental rethink and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed"*.

In today's world, companies and organizations are trying to improve one, more or all of the measures of performance metrics mentioned in the statement of *Business Process Reengineering (i.e. Business Process Redesign, or in a short form, BPR)* to gain competitive advantage against their rivals in their competitive industries. The concept *BPR* may help companies and organizations to achieve their goals by enabling them to redesign the business processes within their companies or organizations. In their paper, *Jansen-Vullers and Reijers (2005)* have discussed that one of the approaches to derive such an improved process design is an evolutionary approach, making use of the redesign heuristics (i.e. best practices) developed by *Reijers (2003) (see Appendix A)*. Moreover, in another paper of theirs *(Jansen-Vullers and Reijers, 2005)*, it is seen that the redesign heuristics were used as a checklist to redesign the *"intake"* process in a healthcare case. The usage of the redesign heuristics as a checklist has provided practitioners with a way to evaluate different redesign scenarios by following a structured approach. The goal in the project was to decrease the throughput times and service times by applying the redesign heuristics.

Similarly, in this Master's project, the goal was to redesign and improve the business processes within *ASML Holding N.V. (hereafter referred to as "ASML")* by applying the redesign heuristics. The business processes that were in the scope of this project are as follows. The main process is called *"Manage ML Skill & Learning"* process and the subprocesses are called *"Manage ML Skill Carousel"* and *"Manage ML Training Forecast" (hereafter they altogether will be referred to as "the processes" or "Training processes")*. The related processes for the Master's project were selected due to the importance of the trained employees for such a high-tech company. Moreover, a redesign project, which was about a training process that has not been elaborated in other redesign projects, made our Master's project important as well.

Before starting the Master's project, *a literature review on BPR* was conducted *(Arkilic, 2011)*. With this review, it was aimed to obtain some information from the related works done by the authors over a long period of time. Due to the fact that the background of *BPR* dates back to 1990s, the accumulated knowledge allowed the researcher of this Master's project to see the directions of the authors in this domain. Although the redesign heuristics were in the focus of this Master's project, the literature study was inspiring to search for the new directions. Common ideas and shared thoughts of the authors helped the researcher to see the main interest areas of such projects and come up with new ideas for the *BPM* literature. Finally, discrepancies between the different views of the authors made the researcher to see the conflicting parts and evaluate them in a constructive way.

The case study that was analysed in this Master's project consists of three parts. These three parts and their brief descriptions are as follows.

1. **Methodology:** The methodology shows the steps that were followed during this project. Some of the steps in the methodology were formulated specifically for this project due to its distinct characteristics *(e.g. the processes were already discovered by the business engineers of ASML)*. Therefore, the methodology played a guidance role to conduct this redesign project.
2. **Development of Redesign Scenarios:** The development of redesign scenarios starts with discovering and analysing the existing situation *(i.e. the processes that were used within ASML)*. However, as it was mentioned in the previous statement, the processes were already discovered by some of the employees within *ASML*. Therefore, a different approach was followed to analyse and understand the existing processes. After this step, redesign scenarios were developed with the aim of improving the existing situation.
3. **Validation of Redesign Scenarios:** After developing the redesign scenarios, the researcher must ensure that the redesign scenarios will really improve the existing processes. For this purpose, simulations were performed both for the existing and improved processes to evaluate the effectiveness / ineffectiveness of the redesign scenarios.

These parts will be explained in detail throughout this Master's project.

1.1 Context

Problem Definition

The subject of this Master's project and the related problem definition were decided after a meeting with the company supervisor, Master's project supervisor, and the researcher carrying out the Master's project. Since the Master's project was carried out within *ASML* and contained a case study, the requirements of *ASML* played an important role in this project. The content of the project was balanced according to the needs of *TU/e* and *ASML* since it was important to add value to both of the organizations and balance the academical and practical parts.

Based on the discussions with the company supervisor when a subject for a Master's project was being searched, the *BPR* concept was explained by the researcher and the researcher's interest was shown to conduct a project in this subject. Luckily, the company supervisor stated that the processes which are in charge of him needed further investigation and could be optimized and improved to deliver a better performance. The reasons for such a need is stated as follows.

The related processes are quite important for *ASML* since trainings (along with the resources) are scheduled, new hires are trained, and the defined skills are managed based on these processes. Moreover, since the semiconductor industry is a fluctuant field in terms of the customer demand *(Tan & Mathews, 2007)*, *ASML* dismisses many people from employment and also employs many people at once. When many people are hired by *ASML* at once, *ASML* does not want to spend too much time to train these people because there may be a downturn in the semiconductor industry soon and all the efforts may be wasted. As the company supervisor stressed, the duration of these processes is vital for a company that is in a highly fluctuant field and therefore, the characteristic of industry makes these processes more important than ever. As a result, *BPR* was selected as a solution and was intended to be applied to redesign the processes to allay the problems in these processes.

Research Questions

In this project, the aim was to develop and validate a set of redesign scenarios (supported by the redesign heuristics) for the processes followed within *ASML*. Although this was the main direction of our research, there were other directions that supported the research in this project. The research question that reflected the main direction of this project and the research subquestions that reflected the auxiliary directions of the project are presented as follows.

The Research Question

Which redesign heuristics can be applied to the related processes within a high-tech organization like ASML?

The Research Subquestions

Can the current methodologies be applied to the case study in this project or should the researcher propose a new methodology that suits the case study better?

How can the researcher assess the effectiveness / ineffectiveness of the redesign scenarios before putting them into practice in the real world?

Goal of the Project

The goal of the project was shaped by two studies. These studies and their relationships to the Master's project were visualized as follows.

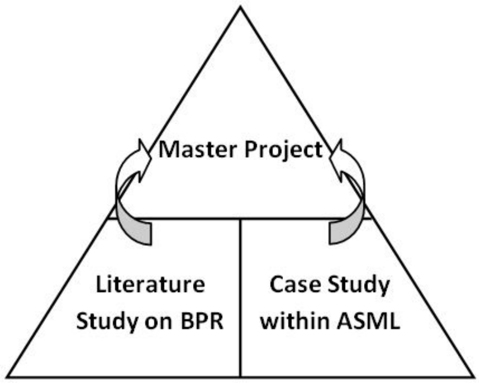

Figure 1.1: The Relation of the Master Project to the Literature Study and Case Study

The *literature study on BPR* helped the researcher to see the directions of the similar studies and understand how more value can be added to the project. However, due to the fact that the directions should be in alignment with the project, the case study within *ASML* played an important role as well.

Some of the points that were found in the literature study and needed further investigation in the project are as follows.

First of all, although mostly the papers with the case studies were selected for the literature study, there were no projects that focused on a *"Training"* process that *ASML* is currently following. Therefore, there is a lack of researches in the literature that may help practitioners to improve their processes related with the processes investigated in this project.

Second, the methods and techniques, in the papers the literature study covered, to redesign the business processes did not follow a structured approach to redesign the processes and just focused on specific parts of the whole process. This point was also reflected by *Jansen-Vullers and Reijers (2005)* where a limitation was found by the authors in the healthcare domain. The authors claimed *"Some of the researchers start reengineering projects from a certain starting point such as the goal of implementing an Electronic Health Record. As a disadvantage, this approach prevents other redesign practices to be used in the project and thus, makes the scope narrower."* Moreover, based on this analysis, it can be proposed that most of the redesign techniques stayed distant from the analysis of a business process and focused on the other aspects that did not fully use the power of process models. For instance, deploying a computerized system to track vegetable products (this was one of the redesign projects in the literature study *(Arkilic, 2011)*) was a project that just focused on the technological aspect of the project other than different ways for improvement such as redesign heuristics *(Reijers, 2003)*.

Third, the methodologies used in the papers were too general that they may not be applied to other studies which contain distinct characteristics. Therefore, practitioners who may encounter a similar project investigated in this project, may be in quandary which steps to follow while performing a redesign project.

And finally, a *quantitative validation* of the redesign scenarios lacked in most of the papers. The authors preferred to present *qualitative* rather than *quantitative* results. Presenting qualitative results may not be wrong, however, convincing other people (and especially stakeholders in a redesign project) may play an important role and it may be hard to get a redesign solution applied within an organization. Moreover, a quantitative validation such as performing a simulation makes the practitioners confident about the outcome of a redesign scenario.

As a result of these observations, the goals of this project were categorized into research *(for TU/e)* and practical *(for ASML)* goals as follows.

For TU/e:

- Being able to show that the processes *(and especially related with "Training")* within a high-tech organization can be improved by using the *redesign heuristics*.
- Offering a methodology for redesign projects when the processes were already discovered (documented) within an organization.
- Presenting a way for assessing the effectiveness / ineffectiveness of redesign scenarios based on quantitative approach.

For ASML:

- Making *MMT* department be accounted with *Business Process Management / Redesign* subject which will be beneficial for the operation of the department *(and also ASML)* in the future.
- Offering *"corrected"* process models to *MMT* department which will run smoothly and reflect the existing situation better.
- Providing redesign scenarios to *MMT* department to show how they can tune their existing processes to get better performances in terms of *throughput time* or *workload* of the resources.

1.2 Background of the Subject

The Business Process Redesign Framework

Before taking an action to make a process better, it might be useful to think about the context that will be affected by this action. Moreover, by doing this, the redesign practitioners may have a deeper understanding whether they are selecting the correct best practice to improve the specific context of a process they proposed to do.

For this purpose, *Reijers and Mansar (2005)* presented a *Business Process Redesign (BPR) framework* in their paper. However, their framework did not emerge at once, but evolved from different frameworks that have been developed throughout the time.

For example, *CIMOSA framework*, which is the work of *Berio and Vernadat (2001)*, offered three modeling levels for business process-centered enterprise modeling. The levels are defined as the requirements definition level, the design specification level and the implementation description.

Alter (1999) suggested the work-centered analysis framework *(WCA)*. This framework consists of six linked elements. The elements are ordered as follows: *the internal or external customers of the business process*, *the products (or services) generated by the business process*, *the steps in the business process*, *the participants in the business process*, *the information the business process uses or creates and finally the technology the business process uses*. This framework can be seen in the figure below.

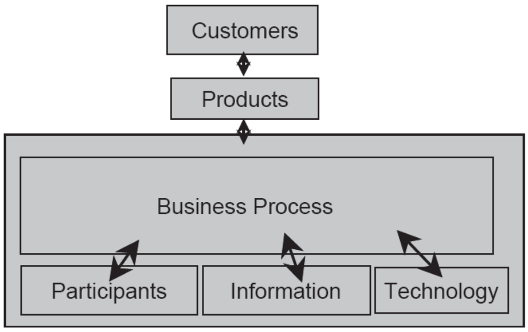

Figure 1.2: The WCA Framework

Other frameworks that influenced the final work of *Reijers and Mansar (2005)* are the *MOBILE model*, which is the work of *Jablonski and Bussler (1996)* and the work of *Seidmann and Sundarajan (1997)*.

Jablonski and Bussler focused on the context of workflow management in which they presented two categories, namely the *factual perspectives* and the *systemic perspectives*. Last but not least, *Seidmann and Sundarajan* pointed out the effects of some best practices on workflow redesign in their work.

Reijers and Mansar (2005) offered the final framework of *BPR* by synthesizing the frameworks mentioned above to present a guidance to redesign practitioners to understand which topics should be taken into account when implementing *BPR*.

This framework is presented below.

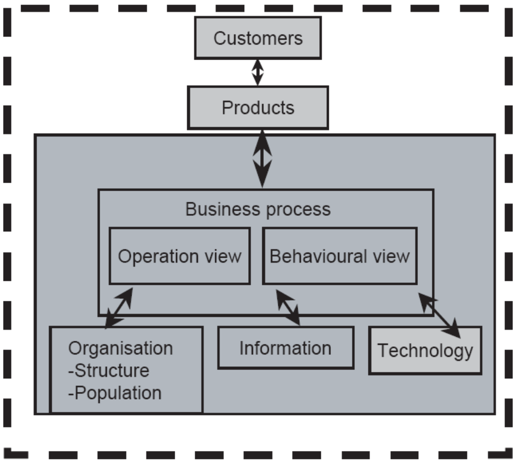

Figure 1.3: The Final Framework for BPR

Finally, in their paper, *Reijers and Mansar (2005)* presented six elements which are linked to each other. These are:

- the internal or external *customers* of the business process,
- the *products* (or services) generated by the business process,
- the business process with two views,
  - *the operation view*: how is a workflow operation implemented? (number of tasks in a job, relative size of tasks, nature of tasks, degree of customization), and
  - *the behavior view*: when is a workflow executed? (sequencing of tasks, task consolidation, scheduling of jobs, etc.),
- the *participants* in the business process considering:
  - the organization structure (elements: roles, users, groups, departments, etc.) and
  - the organization population (individuals: agents which can have tasks assigned for execution and relationships between them),
- the *information* the business process uses or creates,
- the *technology* the business process uses and, finally,
- the *external environment* other than the customers.

The Evaluation Framework (Devil's Quadrangle)

The paper in which best practices that are used to improve a process are mentioned, *Reijers and Mansar (2005)* presented a framework to assess the possible effects of these best practices. The framework based on the work of *Brand and Van der Kolk (1995)* where they presented four main dimensions used to evaluate the effects of best practices. The main dimensions are presented as *time*, *cost*, *quality* and *flexibility*.

The evaluation framework can be seen below.

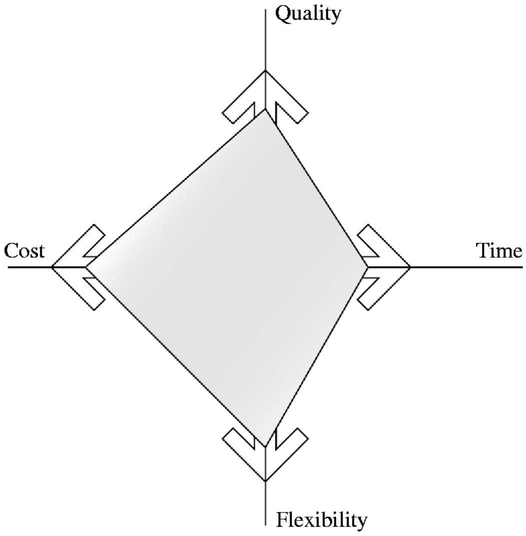

Figure 1.4: The Devil's Quadrangle

This evaluation framework helps redesign specialists (and also the other stakeholders in a redesign project) to think about the possible outcomes of a best practice before implementing it. This is quite important because most of the reengineering specialists just think about the possible effects of such a best practice, but miss the negative effects caused by it. They do not take tradeoffs into account that may take away the positive sides of that best practice. This framework makes analysts think about not only the positive, but also negative effects of the best practices. Moreover, it is quite important to evaluate the effect of a best practice since it is known that we cannot improve what we cannot measure.

Actually, the framework is called as the *"Devil's Quadrangle"* to reflect this tradeoff.

Reijers and Mansar (2005) stated this tradeoff in their paper clearly:

> *"Ideally, a redesign of a business process decreases the time required to handle an order, it decreases the required cost of executing the business process, it improves the quality of the service delivered and it improves the ability of the business process to react to variation. The attractive property of their model is that, in general, improving upon one dimension may have a weakening effect on another."*

For instance, the *parallelism* best practice proposes to reduce the throughput time. However, as drawbacks, if an activity in one of the parallel branches goes wrong, it does not prevent other activities to be stopped and all the activities are executed even if the process delivers no benefit. Therefore it costs more than the sequential flow. Moreover, since parallelism incorporates more complex structures, the possibility of errors during the execution may increase the cost and decrease the quality. It is also possible that flexibility (in term of adaptation) becomes harder due to complex structure of parallelism.

In conclusion, it can be said that the *Devil's Quadrangle* attracts the attention of the stakeholders in a redesign project to assess the advantages and tradeoffs of a reengineering practice and see that whether the proposed practice will deliver the benefits as it was supposed to do.

The Redesign Heuristics (Best Practices)

A best practice is a technique or methodology that, through experience and research, has proven to reliably lead to a desired result[1].

In the context of *BPR*, the description above is also valid since a redesign practitioner can rely on the *best practices* collected over the last twenty years when s/he needs to redesign a business process. The best practices help redesigners to tackle the *technical challenge of BPR*.

Although the redesign heuristics were created by different researchers for different domains, in their paper *Reijers and Mansar (2005)* brought them together.

The redesign heuristics were explained in detail in *Appendix A*. In this appendix, the redesign heuristics were categorized according to their characteristics whether they are related with *task, routing, allocation, resource, external parties* or *internal process*. The effects of the redesign heuristics on *quality*, *cost*, *time* and *flexibility* and other details are not discussed for simplicity. For the details, one can refer to the paper of *Reijers and Mansar (2005)*.

[1] `http://searchsoftwarequality.techtarget.com/definition/best-practice`

Chapter 2

A Case Study within ASML

In this chapter, the aim was to realize the goals of this project by applying the steps mentioned in the *Introduction* chapter to the case study. With this case study, the original processes of *ASML* were fixed, the redesign heuristics that could be applied to the existing processes were presented, a simulation approach to evaluate the redesign scenarios was suggested, and the applicability of the proposed methodology was tested. It is important to note that the documented processes of *ASML (see Appendix B)* played a significant role in this project.

2.1 Company & Department Profile[1]

ASML, founded in 1984, is the world's leading provider of lithography systems for the semiconductor industry, manufacturing complex machines that are critical to the production of integrated circuits or chips. Headquartered in Veldhoven, the Netherlands, *ASML* is traded on Euronext Amsterdam and NASAL under the symbol *ASML*.

ASML is located in 16 countries around the world, including the Netherlands, the United States, China, France, Germany, Ireland, Italy, Japan, Korea, Taiwan, Singapore, and the United Kingdom. *ASML* supplies most of the world's major chip manufacturers its products.

The department in which the case study was carried out is called *Means, Methods & Training (MMT)*. The position of this department within the *Manufacturing & Logistics (ML)* department is depicted as follows. Note that only the departments that were in the context of this Master's project were presented.

[1] Most of the information presented in this section was collected from the company documentation of ASML.

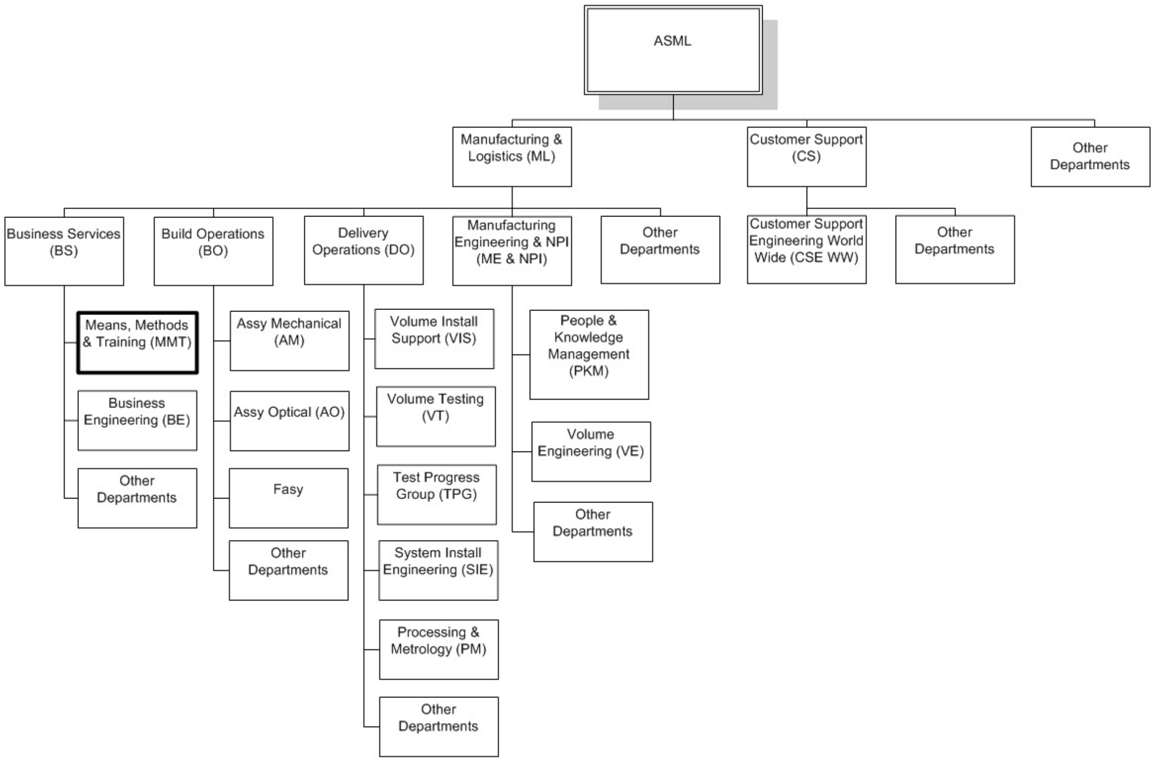

Figure 2.1: A Part of the Organizational Chart of ASML

MMT is a department with the goal to support the *Manufacturing & Logistics (ML)* by providing means, methods, and trainings for the most effective work environment. The competencies of the group are described below.

1. **Document Management Systems:** This competency is responsible for systems / tools which manage (contain) documents *(e.g. technical work instructions)*.
2. **(SAP) Support:** This competency is responsible for managing masterdata and troubleshooting, including 1st line support for SAP and SAP related tools.
3. **Knowledge Management:** This competency is responsible for maintaining, improving, communicating, and supporting knowledge about improvement tools / knowledge, lean / flow and standardization.
4. **Skill & Learning Management:** *Support the Skill & Learning Management process within ML to secure the availability of defined skills within manufacturing.*
   - Give insight into actual and target skill level based on pre-defined skill frameworks.
   - Coordinate training development and delivery to enable employees to move from actual to target skill level.
   - Support of the Learning Management System (LMS)[2] as key-user and control masterdata in LMS.

The case study focused on the fourth competence of *MMT* since the processes related with *"Training"* are managed here.

[2]The LMS software tool is an online tool that provides employees control of their own skills development, both technical and non-technical. By individual learning plans the employee can measure and plan the own skills development. LMS enables team supervisors and team leaders to balance the skills within their teams.

The overall purpose of the *"Manage ML Skill & Learning"* process is to secure the availability of defined skills within manufacturing as requested via the *Capacity Resource Planning (CRP)* and *Rolling Financial Forecast (RFF)* driven by the *Master Planning Schedule (MPS)*. The following statements give more detailed information about this process.

- The process gives insight into actual & target skill level of employees based on pre-defined skill frameworks.
- The process makes learning events available to enable employees to move from actual to target skill level by learning.

The overall purpose of the *"Manage ML Skill Carousel"* subprocess is to secure the effective execution of the *"Manage ML Skill & Learning"* process by controlling / managing the actual versus new skill targets of the employees.

The overall purpose of the *"Manage ML Training Forecast"* subprocess is to manage and control the identification and anticipation on current and future training needs within *ML*. The following statements are managed in this subprocess.

- Actual training need & actual availability of training material and resources (trainers, rooms, equipment) based on pre-defined individual learning plans & requests.
- Training forecast in time for training need.
- Long term training need based on Process & CRP input.
- Training Forecast review moments: Every 3 months (quarterly) forecast with an 18th months window.

2.2 Methodology

The methodology for the case study was developed to *redesign the processes of organizations that have already discovered their processes by themselves*. Since most of the people who were responsible for the process discovery within the companies were not as experienced as the people who are just focused on process redesign projects *(e.g. practitioners, consultants)*, there was a need to follow a different approach to understand and analyse the current situation in the case study. Since the goal was to determine whether the methodology could be applied to real world cases, the methodology was validated within *ASML*. Before presenting the methodology for the case study and Master's project, it should be shown why a new methodology was necessary.

This was done by presenting the existing methodologies from the *BPR literature* and mapping the steps in these methodologies to the steps in the proposed methodology. Through this approach, the aim was to show the missing parts in the current methodologies that did not fit to the case study.

Table 2.1: Current Methodologies in the Literature

Furey (1993)

1. Identify the process's customer-driven objectives *(INI)*
2. *Map and measure the existing process* (DIS)
3. Analyze & modify the existing process *(DEV)*
4. Benchmark for innovative, proven alternatives *(DEV)*
5. Reengineer the process *(DEV)*
6. Roll out the new process *(IMP)*

Muthu et al. (1999)

1. Prepare for BPR *(INI)*
2. *Map & analyze As-Is process* (DIS)
3. Design To-Be processes *(DEV)*
4. Implement reengineered processes *(IMP)*
5. Improve continuously *(MAN)*

Castano et al. (1999)

1. Definition of the reengineering project *(INI)*
2. Reverse engineering of the existing system (if needed) *(DIS)*
3. Construction of the system vision *(INI)*
4. *Modeling and analysis of system processes* (DIS)
5. Redesign of system processes *(DEV)*

Lee & Chuah (2001)

1. Investigate and select the problematic processes *(INI)*
2. *Study the process architecture / flow and understand the operating activities* (DIS)
3. Define and measure the operation performance *(DIS)*
4. Improve the problematic tasks performance to the level of desired states *(DEV)*
5. Evaluate the improvement results *(EVA)*

Adesola & Baines (2005)

1. Understand business needs *(INI)*
2. *Understand the process* (DIS)
3. Model & analyse process *(DIS)*
4. Redesign process *(DEV)*
5. Implement new process *(IMP)*
6. Assess new process & methodology *(EVA)*
7. Review process *(MAN)*

Jansen-Vullers & Reijers (2005)

1. *Understand & model the existing process* (DIS)
2. Measure the existing process *(DIS)*
3. Develop redesign scenarios *(DEV)*
4. Evaluate the redesign scenarios *(EVA)*

When the steps of each of the methodologies are analysed in detail, it can be easily seen that some of the steps are almost similar. A similar approach was also used by *Kettinger et al. (1997)* where *25 BPR methodologies* were analysed and *6* stages were extracted, together with *21* steps in these stages. It was seen that *25* methodologies, that are used to conduct redesign projects, followed almost similar steps. For the case study analysed in this project, *6* methodologies, which reflected the importance of understanding the existing *(i.e. As-Is)* processes, were selected.

The similar steps in these *6* methodologies were presented as follows.

Table 2.2: Steps in the Current Methodologies

Abbrev.	Step
INI	**1.** Initiate the redesign project
DIS	**2.** Discover, map, analyse & measure (optional) the existing process
DEV	**3.** Develop redesign scenarios
IMP	**4.** Implement redesign scenarios
EVA	**5.** Evaluate redesign scenarios
MAN	**6.** Manage the redesigned process

Table 2.3: Mapping the Steps to the Current Methodologies

Methodology	INI	DIS	DEV	IMP	EVA	MAN
Furey (1993)	1	2	3, 4, 5	6	-	-
Muthu et al. (1999)	1	2	3	4	-	5
Castano et al. (1999)	1, 3	2, 4	5	-	-	-
Lee & Chuah (2001)	1	2, 3	4	-	5	-
Adesola & Baines (2005)	1	2, 3	4	5	6	7
Jansen-Vullers & Reijers (2005)	-	1, 2	3	-	4	-

The new methodology in this project differed in the second step *(i.e. Discover, map, analyse & measure (optional) the existing process)* because the current methodologies proposed that the existing processes should be discovered and mapped by practitioners. However, the new methodology in this project followed a different approach. To this end, there was a need of a deeper analysis for this part. Although there are more than one step in some of the methodologies related with the second step, the analysis in this project focused on the modeling of existing processes *(these steps are in italic in the methodologies)*. The authors of the methodologies reflected the importance of this point as follows.

Furey (1993) stated *"Companies that have successfully reengineered themselves made the effort to gain a detailed understanding of the current process before they decided on possible solutions. The tools they used include mapping or flow-charting the existing process, and then measuring the results in terms of cost, quality, and time."*

Muthu et al. (1999) stated *"Before the reengineering team can proceed to redesign the process, they should understand the existing process. Many people do not understand the value of an As-Is analysis and rather prefer to spend a larger chunk of their valuable time on designing the To-Be model directly. The main objective of this phase is to identify disconnects and value adding processes* (Mayer & Dewitte, 1998). *This is initiated by first creation and documentation of Activity and Process models making use of the various modeling methods available."*

Castano et al. (1999) stated *"Processes to be analyzed have to be properly modeled to obtain a for-*

mal description of their properties. Steps of this phase of the methodology are (a) Process workflow modeling: devoted to the construction of a comprehensive description of different process aspects (i.e., technological, human, macro-organizational) at different levels of abstraction (b) Process workflow analysis: devoted to a deep analysis of activity execution and coordination, of the exchanged information, and of the employed organizational resources."

Lee & Chuah (2001) stated *"In this phase, the PIT (Process Improvement Team) is going to study the process architecture/flow and understand the operating activities involved in the selected processes. This process analysis should include the tasks and sub-tasks, so that the PIT can make effective changes to the processes. The main activity in this phase is to identify and clearly map out the process tasks and sub-tasks. Problems or process weaknesses may come from a few small tasks within the process. Process mapping is an effective way to chart the process sequence of each task (AS-IS model)."*

Adesola & Baines (2005) stated the substeps as *(a) identify the business process architecture (b) scope and define the process (c) capture and model the AS IS process information (d) model the process. XPat process, IDEF0, walkthrough, Process flowchart, ABC, and cause and effect analysis are the techniques used to carry out these steps*.

Jansen-Vullers & Reijers (2005) stated the benefits of As-Is process model regarding redesign heuristics as *(a) for each redesign heuristic, consider which part(s) of the process may benefit from this particular heuristic (b) for each process fragment, decide which (combination of) heuristic(s) is interesting (c) based on the redesign heuristics for the relevant process fragment, change the original process model and create a new one*.

As can be seen, the *importance of the modeling and analysis of the existing situation and processes* is undeniable in the redesign projects. Specifically, the most important point from the aspect of the research is how to map and model the existing process within an organization. The methodologies above (and also many other methodologies in the literature *(Harrison & Pratt, 1993; Fitzgerald & Murphy, 1996; Motwani et al., 1998; Wastell et al., 1994; Xenakis & Macintosh, 2007)*) proposed that the researchers should discover, map, and model the existing processes before developing the redesign scenarios to identify and understand problems. Therefore, there is a *gap* in the literature that investigates *what researchers should do if existing processes were already discovered and mapped within organizations*. With this research, a new methodology was proposed that aimed to fill this gap. The steps in the proposed methodology are as follows.

Table 2.4: Our Methodology

1. Transformation of the business processes *(DIS)*
2. Checking the processes in terms of correctness *(DIS)*
3. Developing the conceptual models (if needed) *(DIS))*
4. Validation of the conceptual models (if needed) *(DIS)*
5. Development of redesign scenarios *(DEV)*
6. Data collection for simulation and simulating the existing processes *(EVA)*
7. Validation of the simulation result *(EVA)*
8. Evaluation of the redesign scenarios through simulation *(EVA)*

Table 2.5: Mapping the Steps to Our Methodology

Methodology	INI	DIS	DEV	IMP	EVA	MAN
The Proposed Methodology	-	1, 2, 3, 4	5	-	6, 7, 8	-

As it is seen, the new methodology made a big difference in the first two steps because it proposed that the processes should be transformed to another modeling language and also fixed to create the conceptual models *(by using the documented processes within an organization)* instead of just discovering them from scratch. In the following parts, each of the steps of this methodology were explained in detail to tell why a different methodology was needed for the case study.

Finally, the steps in this methodology can be grouped, summarized, and visualized into three basic steps as follows.

Figure 2.2: Three Basic Steps in the Methodology

Chapter 3

Discovery Phase

3.1 Transformation of the business processes

The starting point of this step was reflected in the current methodologies clearly: *Understanding the existing processes of an organization before redesigning them.* Therefore, it can be proposed that the transformation is useful not only to detect and correct the mistakes, but also to understand the actual execution of the processes. Transformation of the business processes to the business process modeling language that the researcher is familiar with, plays an important role here.

The current methodologies discussed that the researchers should map & model the existing processes to understand them better. Although it was not explicitly stated, it was not hard to predict that the researchers model the existing processes with their preferred modeling language due to numerous modeling languages *(e.g. Petri-net (Aalst & Hee, 1996), BPMN (Wohed et al., 2006), EPC (Kim, 1995), UML Activity Diagrams (Dumas & ter Hofstede, 2001), Swimlane diagrams (Bhongale et al. (2010)), and IDEF (Yan-ling et al. (2004))*.

Based on the case study in this project, since the existing processes were documented as *swimlane diagrams* within *ASML (see Appendix B)*, the researcher decided to make use of these documented processes rather than discovering them from scratch. The reasons behind this approach as follows.

- The process owners (i.e. the people who were in charge of the related processes) developed these processes by sitting together with the task executors and common consent. Therefore, considerable time and effort were spent to discover and document the existing situation.
- In the limited time frame of this project, it would be almost impossible to contact all the task executors and remodel the processes. Therefore, it was timesaving to use the documented processes.
- In the simulation phase, the researcher contacted the task executors and therefore, had a chance to be sure about the correctness of the processes.

The goal was to remodel the existing processes in a way that the process will be easier to understand than the original one for the researcher. Therefore, a remodeling approach was conducted to the processes of *ASML* using the *Petri-net* modeling language. *Petri-net* was selected as a modeling language due to the familiarity of the researcher. It was also beneficial to model the processes in the *Petri-net* notation since the simulation was carried out with the same modeling language.

Finally, PROTOS 5.0.6[1] was selected as a process modeling tool.

[1]PROTOS is a modeling software developed by Pallas Athena BV for the purpose of recording, analysing, and managing business processes.

While developing the business process models, *ASML* had the following goals.

- Clarifying the way of working through providing a documentation.
- Ensuring that the employees are following the same way of working to improve the quality.
- Using the models to communicate with the employees for explanations and/or discussions.
- Standardizing the way of working within the organization to obtain certificates such as ISO.

Swimlane diagrams were specifically selected as a modeling language to make the responsibilities clear for the employees who were executing the tasks in the processes. The idea was that since there was no *Workflow Management System (WfMS)* at the organization, task executors should have easily seen the tasks they would execute. The tasks might be executed daily such as in the *"Manage ML Skill & Learning"* process or less frequent such as in the *"Manage ML Training Forecast"* subprocess.

The process models within *ML* were started to be developed *2* years ago and in the initiative of the *"ML Quality Assurance Manager"*. In the current situation, each department develops their own process models. The models are being developed by the people who are in charge of the responsibilities of that department such as team leaders.

The idea of using swimlane models was working well for *ASML* because each task executor had a chance to open the documentation and see the tasks that could be executed by him/her. However, it was not a very good idea for the researcher who needed to understand the whole processes in detail in order to improve them. This can be shown in the figure below. The figure also states why there was a need for a remodeling approach.

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Figure 3.1: Swimlane Diagram vs. Petri-net

The process fragment, which is on the left side, was modeled in the *"swimlane"* notation. In this notation, each column represents the tasks and responsibilities of the resources. Therefore, all the activities of a resource should be fitted to the resource's *"swimlane"* which causes disorder in the process model. On the other hand, the process fragment, which is on the right side and modeled in the Petri-net notation, offers more freedom to the modeler. The lack of the *"swimlanes"* in the model makes the processes and the flow of cases easier to understand from the aspect of the researcher.

These two different points from the aspects of *ASML* and the researcher can be summarized as follows.

For ASML:	For the researcher:
Who executes the tasks?	How are the tasks executed?

As it was intended, the process owners such as team leaders within *ASML* were interested in the *resource-based* view of the processes. The models were designed to show the tasks and by whom they would be executed. Therefore, when the employees need to execute the tasks, they open the documentation (process models) and find the activities easily.

On the other hand, the researcher was interested in the *control-flow (i.e. which task is executed when)* view of the processes.

The difficulty of understanding the existing process fragment which was modeled within *ASML* required the transformation of the processes.

In *Appendix C*, all the existing processes modeled in the Petri-net notation can be seen. Note that the subprocess *"Manage ML Skill Carousel"* was not modeled as a subprocess but as a separate process and given a reference to the the process *"Manage ML Skill & Learning"* in the company documentation *(see Appendix B)*. However, to make the whole process easier, it was modeled as a subprocess.

3.2 Checking the processes in terms of correctness

After the processes were remodeled, a detailed analysis was performed to understand how they were executed. This step was quite important to create the conceptual models since semantical and syntactical correctness were checked here. A semantical check was made to see that the process owners could reflect the actual situation and expected ways of executing the tasks to the process models. A syntactical check was made to see that the rules of business process models were ensured (e.g. absence of deadlock, livelock). The findings regarding the process models were presented under these categories.

The checks were conducted in cooperation with the process owners due to their knowledge about the related processes. Bi-weekly meetings in the first four months of the project[2] were organized to discuss the correctness of the models.

Although the checks and related fixes ended up with *"corrected"* processes, it will also provide benefits to the *MMT department* in the future. Periodic meetings revealed that a *Workflow Management System (WfMS)* was not being used for these processes but the communication was provided through e-mails between the task-executors *(i.e. executors receive / send e-mails when they start / finish their works)*. Therefore, this project acted not only as a redesign project, but also a basis for future improvements such as deploying the processes to a *WfMS*.

Before presenting the findings about the existing processes, it is important to note that the findings were based on the processes in *Appendix B* as *swimlane* notation and in *Appendix C* as *Petri-net* notation. The visual representations of the findings can be found in *Appendix D*.

[2]The project was completed in six months. Last two months were spent for the simulation and writing the thesis.

Syntactical Problems:

Finding -1-

In their book, *Sharp & McDermott (2009)* stated *"The process name, at its simplest, must be in the form verb-noun (e.g. Assign Inspector). It might be in the form verb-qualifier-noun (e.g., Assign Backup Inspector) or verb-noun-noun (e.g., Assign Inspector to Route)."*

These statements are also valid for tasks (or activities) that exist in processes. When the existing processes were checked, it was seen that 20 out of the 48 (41.67%) tasks' names were not compliant with the related proposal. Three of them can be seen in *Appendix D*.

This problem was solved by transforming the names of the tasks into proper names.

Finding -2-

Van der Aalst (2000) stated *"A workflow is sound if and only if, for any case, the process terminates properly, i.e., termination is guaranteed, there are no dangling references, and deadlock and livelock are absent."* and *"A Petri net which models the control-flow dimension of a workflow, is called a WorkFlow net (WF-net). It should be noted that a WF-net specifies the dynamic behavior of a single case in isolation.. A WF-net has one input place (i) and one output place (o) because any case handled by the procedure represented by the WF-net is created when it enters the WFMS and is deleted once it is completely handled by the WFMS, i.e., the WF-net specifies the life-cycle of a case."*

Our finding for the case study as is follows.

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Figure 3.2: A Deadlock in the Process

It is clear that *AND-Join* requires two tokens for *"Search offering"* task to be executed. If the outcome of the *"Offering acceptable?"* task becomes *"No"*, *"Make request in LMS to MOS Training"* is executed and a token is placed to the place *"41"*. This action introduced a deadlock to the system after *"Manage offerings"* task was executed. Note that this was the only violation of soundness in the models created within *ASML* and this was fixed by eliminating the left branch of the parallelism since it is not related with any activities.

Finding -3-

As it was mentioned in the previous finding, *van der Aalst (2000)* stated that a process has to have one output place.

If the paths are selected in a way that a token is placed to the place *"17"* in the *"Manage ML Skill Carousel"* subprocess, the token reaches to the end state. However, this is not the actual end step of the process. In this case, the process has two end places which is considered as a violation of the rule. This was fixed by discussing the next step with the stakeholders after the *"Escalate to Director (*)"* task.

Semantical Problems:

Finding -4-

In the existing *"Manage ML Skill & Learning"* process, it is seen that when an employee cannot pass a training, s/he has to go back and book another training. However, booking another training is not logical without searching all other training offers because the training dates / places might be changed. This may cause a confusion for the new hires. This problem was fixed by directing the new hires to the *"Search offering"* task instead of the *"Book offering"* task.

Finding -5-

The other finding was related with the mapping of the resources to the related tasks. For some of the tasks, *"MOS Training"* was used to indicate the responsibilities of the employees within *MMT* department; however, for different tasks, *"BS MMT Engineer"* was used to indicate the same role. It was revealed that *"BS MMT Engineer"* is the new name of *"MOS Training"*. Therefore, the processes were updated by considering the new name of the resource. The finding was presented in *Appendix D*.

Finding -6-

This finding was related with updating of a training status by the *"BS MMT Engineer"* in the *"Manage ML Skill & Learning"* process. In the existing process, the status of a training is stored when the outcome of a training of an employee is considered successful. However, in reality, the status is updated even if the outcome of a training is unsuccessful. This was fixed by adding the task *"Update training status in LMS or Online Academy"* after both of the decisions.

Finding -7-

In the existing *"Manage ML Skill & Learning"* process, *"Manage LMS masterdata"* task seems to be executed for each of the cases *(i.e. each of the incoming new hires)*. However, it is an extensive task that is executed by the *"Direct Manager"* and in reality, it is just executed semi-annually *(once in every 6 months)*. This situation is the same for the *"Execute offering"* and *"Update LMS learning history"* tasks since they are executed bi-weekly or monthly and on fridays at 15:00, respectively. The periodical parts of these activities were not presented to the process model. The related problems were fixed by adding a *"time trigger"* to both of the activities.

Finding -8-

There are two types of trainings that are taken by the new hires / employees. One of them is the training in a classroom environment *("Normal training")* and the other is on a computer *("CBT")*. If a new hire / employee takes a *"CBT"*, s/he does not have to follow all the steps required for a normal training *(e.g. "Search offering", "Accept offering", "Book offering", etc.)* because *"CBTs"* can be immediately taken. In the existing *"Manage ML Skill & Learning"* process, no distinction was made to handle these different types of trainings and therefore, the flow of new hires who have to take *"CBTs"* was ignored *(see the "Finding 4" in Appendix D for a visual representation)*. This was fixed by adding the related routes for the new hires who have to follow *"CBTs"*.

Finding -9-

This finding is in concern with the hierarchical structure of a group of tasks. In the *"Manage ML Skill Carousel"* subprocess, it seems that *"Control/manage actual vs new skill target (Carousel meeting)"* task is a task executed by the resource to produce an outcome. However, in reality, it is a task which notifies the stakeholders that the *"Carousel meeting"* will start. Therefore, it is not a real task but a subprocess. The same structure was used in the *"Manage ML Training Forecast"* subprocess for the tasks *"Skill and Learning Management Tango 159988"*. These problems were fixed by using just the subprocesses and moving the tasks into the related subprocesses (just the subprocesses were presented).

Finding -10-

This finding does not represent an actual problem but clearly worthwhile to mention. At the beginning of the *"Manage ML Skill Carousel"* subprocess, three tasks are executed in parallel (*"Determine required skill framework changes"*, *"Determine required CRP/RFF & skill targets"*, and *"Update skill status reports"*). This is an important observation that some tasks went in parallel but *swimlane* diagram could not capture it very well.

Syntactical and Semantical Problems:

Finding -11-

Considerable amount of time was spent to analyse and understand the processes. This helped the researcher to elicit small details regarding the actual execution of the processes. One of them stands in the *"Manage ML Training Forecast"* subprocess.

Although it seems that one of the routes *(i.e. "Yes" or "No")* is followed after the *"ML Training"* task, in reality it was revealed that both of them can be followed if there are training requests for both *"ML Training"* and *"CS Training"*. This is a violation of soundness because the subprocess ends up with two tokens at the end. This problem also causes a wrong representation of the subprocess for the stakeholders. These were fixed by synchronizing the tokens at the end of the subprocess and also reflecting the existing situation to the subprocess.

Based on these findings, the processes were fixed and conceptual models were created (*see the next section*). As a result, the conceptual models acted as bases to allow the researcher to develop redesign scenarios and also perform simulations.

3.3 Developing the conceptual models (if needed)

Process Model

The issues found in the previous step were discussed with the process owners to develop the conceptual models of the existing processes. Each of the findings was explained in detail and feedbacks were collected. As a result, all of the findings were accepted by the process owners and mentioned solutions to fix the process models were applied. Note that the documents (input to tasks and outputs from tasks) were not taken into consideration while developing the process models. The documents are available beforehand when the tasks need to be executed *(i.e. the documents are created in the previous steps and delivered through an e-mail or published on the intranet of ASML immediately)*. Therefore, redesign heuristics such as *Integration (INT)* and *Technology (TECH)* were not needed for the documents used in these processes. In conclusion, there was no benefit to present them in the process models *(actually it will make the models more complicated due to extensive exchange of documents)* and therefore, they were ignored in the conceptual models.

The conceptual models are presented below. Beware that in the *"Manage ML Skill Carousel Meeting"* subsubprocess, there are two end places. The place *"19"* represents a *"Port Out"* to the *"Manage ML Skill Carousel"* subprocess and therefore, is not a real end place.

Figure 1: Manage ML Skill & Learning Process (Conceptual)

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Figure 3.3: Manage ML Skill Carousel Subprocess (Conceptual)

Figure 3.4: Manage ML Skill Carousel Meeting Subsubprocess (Conceptual)

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Figure 3.5: Manage ML Training Forecast Subprocess (Conceptual)

Resources

In this section, the resources of the related processes are presented. The resources were depicted from two aspects: *roles* and *groups*. The resources were presented as *"resource classes"* which are a group of resources *(van der Aalst & van Hee, 2002)*. A role represents a functionally-based resource class *(each resource has a number of specific skills such as a counter staff or junior doctor)* and a group represents the place of a resource in the organization such as a sales department or Atlanta Branch *(van der Aalst & van Hee, 2002)*. The resources classes for the case study's process models can be seen below. Note that because of the limited space, abbreviation of the departments were used (detailed information can be found in *Section 2.1*).

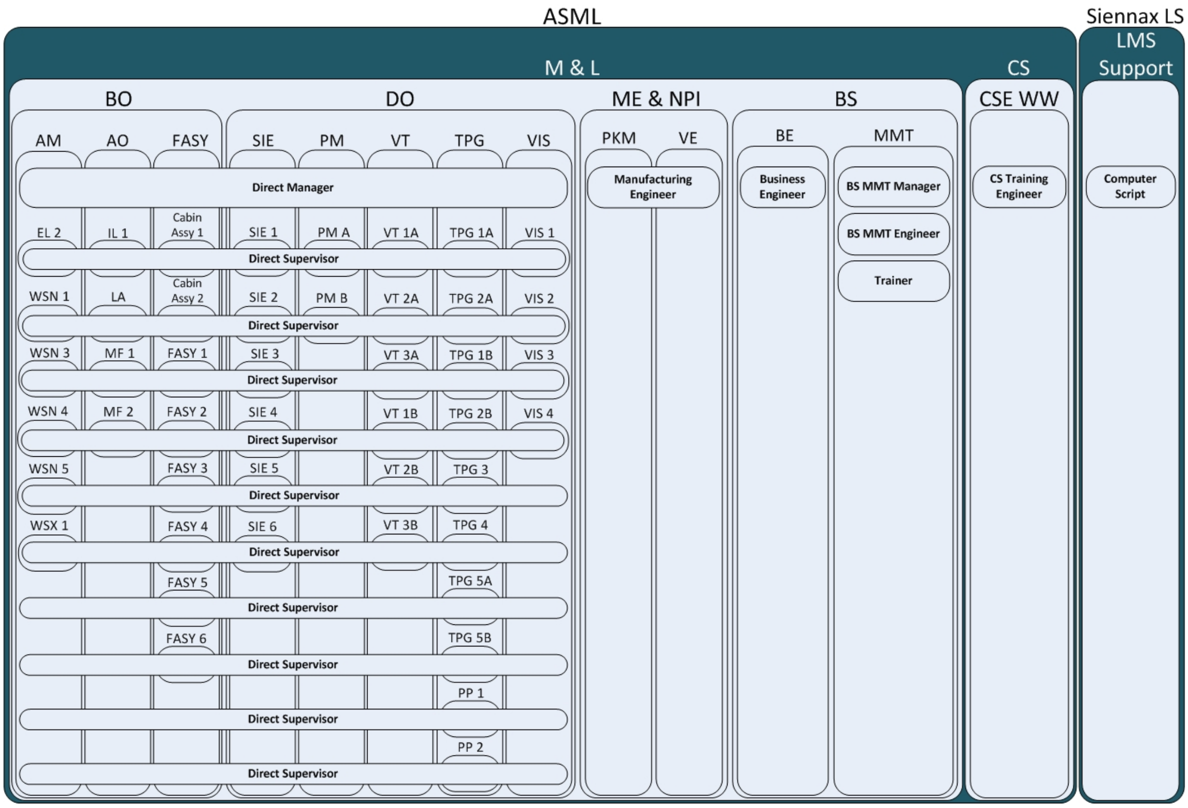

Figure 3.6: Resource Classes

Finally, the number of the resources was presented in the table below[3]. Note that there were more than one supervisors at most of the departments. Because of this reason, the subdepartments which were led by these supervisors were presented explicitly.

[3] Although there are other departments at *ASML*, only the departments who follow the *"Training"* processes were taken into account due to the Master's project scope

Table 3.2: Available Resources

Resource	# of Resource
Direct Manager (BO - AM)	1
Direct Manager (BO - AO)	1
Direct Manager (BO - FASY)	1
Direct Manager (DO - SIE)	1
Direct Manager (DO - PM)	1
Direct Manager (DO - VT)	1
Direct Manager (DO - TPG)	1
Direct Manager (DO - VIS)	1
Direct Supervisor (BO - AM)	6
EL 2, WSN 1, WSN 3, WSN 4, WSN 5, WSX 1	
Direct Supervisor (BO - AO)	4
IL 1, LA, MF 1, MF 2	
Direct Supervisor (BO - FASY)	8
Cabin Assy 1, Cabin Assy 2, Fasy 1, Fasy 2	
Fasy 3, Fasy 4, Fasy 5, Fasy 6	
Direct Supervisor (DO - SIE)	6
SIE 1, SIE 2, SIE 3, SIE 4, SIE 5, SIE 6	
Direct Supervisor (DO - PM)	2
PM A, PM B	
Direct Supervisor (DO - VT)	6
VT 1A, VT 2A, VT 3A, VT 1B, VT 2B, VT 3B	
Direct Supervisor (DO - TPG)	9
TPG 1A, TPG 2A, TPG 1B, TPG 2B, TPG 3	
TPG 4, TPG 5A, TPG 5B, PP 1&2	
Direct Supervisor (DO - VIS)	4
VIS 1, VIS 2, VIS 3, VIS 4	
Manufacturing Engineer (ME & NPI - PKM & VE)	189
Business Engineer (BS - BE)	3
BS MMT Manager (BS - MMT)	1
BS MMT Engineer (BS - MMT)	5
Trainer (BS - MMT)	2
CS Training Engineer (CS - CSE WW)	2

3.4 Validation of the conceptual models (if needed)

In this section, the conceptual models were validated. This step was needed before developing the redesign scenarios and conducting the simulations since it was important to be sure that the conceptual models reflect the existing processes and actual execution of the activities without any syntactical problems. The problems remain in the conceptual models propagate to other steps *(e.g. improved* *processes, simulations)* which may fail the whole project.

To validate the conceptual models, a meeting *(which took around 2 hours)* was held with the process owners. In this meeting, the models created based on the findings and related solutions were discussed with them and it was asked whether the conceptual models were correctly modeled to reflect the reality. There was no need to have individual meetings with task executors since they were done by the process owners while developing the business process models within *ASML*. Moreover, during the data collection of the simulation part, the researcher contacted each of the task executors individually. This was helpful to fix the small mistakes / misunderstandings in the process models.

As a result of this section, the conceptual models were validated for further investigation *(e.g. developing the redesign scenarios and simulations)*.

Chapter 4

Development Phase

4.1 Development of the redesign scenarios

As the importance of socio-cultural challenges was mentioned in our literature study *(Arkilic, 2011)*, special attention was paid to the development of the redesign scenarios in this project. Since the socio-cultural aspects are as important as the technical aspects in redesign projects and missing these aspects may result in failure of the whole project, a collaborative approach was followed. To overcome the socio-cultural challenges and make the project successful, it was decided to arrange two workshops with the process owners and other stakeholders.

In the first workshop, the aim of the project, the background information *(i.e. the BPR and Evaluation Frameworks, Redesign Heuristics)*, and which steps would be carried out to complete the project *(i.e. the proposed methodology)* were described. In this workshop, the redesign heuristics were explained in detail one by one to make the people think about possible improvement scenarios and give insights about the *BPM* concept.

In the second workshop, more technical and detailed information was given to the stakeholders. For instance, information related to why and how a transformation of the business processes needed, which problems were discovered in the existing processes, and finally which redesign scenarios were developed to improve the existing processes were explained. The redesign scenarios were validated by the process owners in this workshop. It was asked if the redesign scenarios developed by the researcher could be applied to the conceptual process models and put into practice in the real world.

Both of the workshops took around *2* hours and some members of the *MMT* department (including the manager of the department and process owners) and *ML Quality Assurance Manager* participated the workshops *(totally 6-7 participants)*. With these workshops, the researcher aimed to incorporate the stakeholders in the project to prevent the resistance of them for the changes which will be the result of the project. Moreover, keeping the *ASML* employees up-to-date for the *BPM / BPR* concept that might be useful for their work was also aimed during the project.

While developing the redesign scenarios, the process fragments were analysed in detail and the researcher tried to find suitable redesign heuristics *(best practices)* that would fit to these fragments. This approach allowed the researcher to follow a structured approach because best practices were used as a guideline *(Jansen-Vullers & Reijers, 2005)*. The scenarios developed for the processes were independent of each other and there were no overlaps.

Finally, the redesign scenarios are presented as follows. These redesign scenarios were evaluated in terms of the *throughput time* of the processes and *workload* of the resources by conducting simulations in the next chapter.

Redesign Scenario -1-

In the existing *"Manage ML Skill & Learning"* process, an employee decides his / her level based on his / her skills through a self assessment *(see "Define actual skill level by self assessment")*. Further, this level is approved by his / her direct supervisor *(see "Approve actual skill level")*. If the skill level is not approved, the employee has to decide his / her skill level again and again until it is approved. This authorization step takes time, especially when it is rejected. Based on *Empower (EMP)* and *Task elimination (ELIM)* heuristics, the decision can be taken by the employee himself / herself and the control task might be removed. Before this scenario was accepted by the process owner, data collected during the *"data collection"* phase taken into account because of the risk of deteriorating the quality of the process *(because of the removal of the control task)*. Since the actual skill level is approved 90% of the time, the scenario was accepted to be evaluated.

This scenario is expected to reduce the *throughput time* of the *"Manage ML Skill & Learning"* process and *workload* of the *"Direct Supervisor"*. As a disadvantage, the quality of the skills of the new hires may reduce.

Redesign Scenario -2-

In the existing *"Manage ML Skill & Learning"* process, a *"Direct Supervisor"* sets a role and targets to his / her employee *(see "Assign role" and "Set target (short & long term)")* before the employee defines his / her actual skill level *(see "Define actual skill level by self assessment")*. However, it can be more efficient that the actual skill level of an employee is defined before the role and targets are assigned by the *"Direct Supervisor"* since the actual skill level may affect the targets of the employee. Based on *Resequencing (RESEQ)* heuristic, the places of the tasks can be replaced.

This scenario is expected to change neither the *throughput time* of the process nor *workload* of the resources, but have a positive effect on the *quality* of the process in terms of the skills of the *"New Hires"*.

Redesign Scenario -3-

In the existing *"Manage ML Skill & Learning"* process, a *"Direct Supervisor"* assigns a role to his / her employee *(see "Assign role")*. After this step, the *"Direct Supervisor"* sets targets for his/her employee's further responsibilities based on the role *(see "Set target (short & long term)")*. These two tasks are executed by the same person and also consecutively. Based on *Task composition (COMPOS)* heuristic, these two tasks can be combined into one task.

This scenario is expected to reduce the *throughput time* of the *"Manage ML Skill & Learning"* process and *workload* of the *"Direct Supervisor"*. As a disadvantage, the *flexibility* of the resources may reduce and *quality* of the process may deteriorate since the tasks become one big task.

Redesign Scenario -4-

In the existing *"Manage ML Skill & Learning"* process, the training forecast is conducted quarterly *(see "Manage Training Forecast")*. Moreover, for each of the *"New Hires"* who follow a normal training, learning events are managed based on the training needs *(see "Manage offerings")*. Our discussions with the stakeholders revealed that the duration of managing the training forecast is too long, which may affect the quality of the training forecast (some information may be outdated after three months). Although the periodic restriction cannot be eliminated due to its burden in terms of throughput time and workload of the resources *(see Appendix E)*, its frequency can be decreased *(i.e. weekly instead of quarterly)*. By doing so, the need of managing the learning events can be eliminated for all the cases since a similar task is executed in the *"Manage ML Training Forecast"* subprocess. However, when the training offer is rejected and a request in *"LMS"* made by an employee *(see "Make request in LMS to BS MMT Engineer")*, managing the learning events may still be needed due to the change in the plans. Based on the *Case types (TYPE)* and *Resequencing (RESEQ)* heuristics, *"Manage offerings"* task can be specifically used for the cases where the training offer is rejected.

This scenario is expected to improve the *quality* of the *"Manage ML Skill & Learning"* process because up-to-date information will be provided about the training needs. Moreover, it is expected to reduce the *throughput time* of the same process. However, as a disadvantage, the *workload* of the resources responsible for the *(see "Manage Training Forecast")* subprocess *(see Appendix E)* may increase.

Redesign Scenario -5-

In the existing *"Manage ML Skill & Learning"* process, an employee (or new hire) searches the training offering and decides if the offering is suitable for him / her. If the offering is suitable, s/he books the offering *(see "Search offering", "Accept offering", and "Book offering")*. Based on the *Task composition (COMPOS)* heuristic, *"Accept offering"* and *"Book offering"* tasks can be combined into one task.

This scenario is expected to reduce the throughput time of the *"Manage ML Skill & Learning"* process and workload of the *"New Hire"*. As a disadvantage, the flexibility of the *"New Hire"* may reduce and quality of the process may deteriorate since the tasks become one big task.

Redesign Scenario -6-

In the existing *"Manage ML Skill & Learning"* process, if a training is successfully completed by an employee, the outcome is stored in *"LMS"* or *"Online Academy"* based on whether the training was performed in a classroom environment *(i.e. "Normal training")* or on the computer *(i.e. "CBT") (see "Update training status in LMS or Online Academy")*. If the outcome is stored in *"LMS"*, there are no additional steps required. However, if the outcome is stored in *"Online Academy"*, the outcome is not reflected to *"LMS"* immediately. Instead, a computer script is run every friday afternoon (specifically, at 15:00 hrs) to transfer the outcomes from *"Online Academy"* to *"LMS"* in batch. Based on *Cased-based work (CASEB)* heuristic, each case can be processed individually (other options such as updating LMS every hour, every day, and two times in a week can also be evaluated).

This scenario is expected to reduce the *throughput time* of the *"Manage ML Skill & Learning"* process. However, the cost of modifying the current system should also be considered.

Redesign Scenario -7-

In the existing *"Manage ML Skill Carousel Meeting"* subsubprocess, two reports are created by the *"BS MMT Engineer" (see "Update skill status reports" and "Update learning status reports")*. These tasks consume a considerable amount of time due to the fact that they are created manually. It is important to mention that existing information in the databases is used to create these reports. Moreover, although there is no direct relation between them, they are executed in sequence *(the sequence of creating the reports is not important because they will be used in the following task, which is "Analyse deviations with* *respect to targets").* Based on *Task automation (AUTO)* and *Parallelism (PAR)* heuristics, a software program can be developed to create these reports automatically and also at the same time.

This scenario is expected to reduce the *workload* of the *"BS MMT Engineer"* and improve the *quality* of the reports. However, the *cost* of developing such a software program should also be considered.

Redesign Scenario -8-

In the existing *"Manage ML Skill Carousel Meeting"* subsubprocess, three decisions are given and their outcomes are executed in sequence *(see "Decide: Role assignment, skill target impact by new MPS", "Define actions: Team role assignment & targets setting [1-2]", "Decide: Skill growth as planned", "Define actions: -1- Adjust skill targets [2] -2- Execute ILP*[1] *[7-11]", "Decide: Skill framework changes needed" and "Define actions: -1- Master data changes").* During our discussions, it was revealed that there may be a combination of decisions and also their outcomes. The decision *"Decide: Skill framework changes needed"* is based on the other two decisions; therefore, it should be executed after the other ones. Based on *Task composition (COMPOS)* and *Resequencing (RESEQ)* heuristics, decisions *"Decide: Role assignment, skill target impact by new MPS"* and *"Decide: Skill growth as planned"* can be combined into one and outcomes *"Define actions: Team role assignment & targets setting [1-2]"* and *"Define actions: -1- Adjust skill targets [2] -2- Execute ILP [7-11]"* can be combined into one as well since decisions are executed by the *"Direct Manager"* and outcomes are executed by the *"Direct Supervisor"*.

This scenario is expected to reduce the *throughput time* of the *"Manage ML Skill Carousel Meeting"* subsubprocess and *workloads* of the *"Direct Manager"* and *"Direct Supervisor"*. As a disadvantage, the *flexibility* of the resources may reduce and *quality* of the process may deteriorate since the tasks become one big task.

Redesign Scenario -9-

In the existing *"Manage ML Training Forecast"* subprocess, *"Create training request overview"* and *"Analyse availability (including resources A*)"* tasks are executed by the *"BS MMT Engineer"* and in sequence. Based on *Task composition (COMPOS)* heuristic, these two tasks can be combined into one task.

This scenario is expected to reduce the *throughput time* of the *"Manage ML Training Forecast"* subprocess and *workload* of the *"BS MMT Engineer"*. As a disadvantage, the *flexibility* of the resource may reduce and *quality* of the process may deteriorate since the tasks become one big task.

Redesign Scenario -10-

As it was mentioned, the communication of the stakeholders in the processes is facilitated through e-mails and no sophisticated technology is being used to assign the work items to the related resources. It was revealed that this type of communication introduces synchronization and workload problems. Based on *Technology (TECH)* heuristic, a *Workflow Management System (WfMS)* can be deployed.

This scenario is expected to reduce the *throughput time* of all the processes, reduce the *workload* of all the resources and improve the *quality* of the work done. However, the *cost* of deploying such a system should also be considered.

[1] ILP: Individual learning plan

Based on the redesign scenarios above, the redesigned process models can be seen below. The parts that were affected by the redesign scenarios were presented as a circle with the scenario numbers. Moreover, the modified tasks and executors can be found in *Appendix F*.

All the redesign scenarios, except the last one *(Redesign Scenario 10)*, were evaluated by using the results of the simulations in the following chapter. Due to the extensive research and burden, the simulation of *Redesign Scenario 10* was out of the scope of this project.

Finally, it was investigated whether a new redesign heuristic *(e.g. Extra resources (XRES))* can be applied based on the results of the simulations. The results are important to decide for such a best practice because the queue time is an important criterium for the researcher to see if additional improvement can be achieved by introducing additional resources.

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Figure 4.1: Manage ML Skill & Learning Process (Redesigned)

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Figure 4.2: Manage ML Skill Carousel Subprocess (Redesigned)

Figure 4.3: Manage ML Skill Carousel Meeting Subsubprocess (Redesigned)

Figure 4.4: Manage ML Training Forecast Subprocess (Redesigned)

Chapter 5

Evaluation Phase

5.1 Data collection for simulation and simulating the existing processes

After developing the redesign scenarios, it is important to determine if they really delivered benefit to the organization in terms of performance metrics (i.e. *workload of the resources* or *throughput time*). To accomplish this, related data about the existing and redesigned processes should be collected and then compared. One approach to do so is to put the redesign scenarios into practice and measure the performance metrics. Each of the scenarios should be implemented in real life through redesigning the existing processes. If a scenario is regarded not efficient, it should be skipped and the existing process should be redesigned to measure the metrics for the next scenario. This approach is quite cumbersome due to the workload of redesigning and measuring the existing process according to each scenario in real life.

The second approach proposes that the repeated execution of a process can be done through simulation with the aid of a computer to analyse a workflow *(van der Aalst & van Hee, 2002)*. Therefore, the simulation is the realization of a real-life scenario by the help of a computer and in our case study and context, real-life scenarios are represented by the processes *ASML* uses. In this approach, the process is modeled and measured on the computer without the hassle of putting the process into practice. A study that followed this approach was performed by *Jansen-Vullers & Reijers (2005)* for a redesign project in healthcare.

In order to compare the performance metrics of the existing process and redesigned processes, data should be assigned to simulation models. However, at this point, the following problems emerged.

- No event logs were available to deduct useful information about the cases.
- Data regarding the duration of service, waiting, queueing and throughput times were not available.
- Data regarding the routing probabilities were not available.

Because of these problems, it was decided to use the subjective estimates of task executors. *Golenko-Ginzburg (1988)* stated that *PERT analysis*, which assumes the activity-time distribution as a beta distribution, can be used to estimate the mean and variance of the activity time by taking into account the pessimistic, most likely, and optimistic completion times determined by an analyst subjectively. The *Beta distribution* is also often used in simulation and several application areas *(Farnum & Stanton, 1986)*.

Finally, the mean, standard deviation, and shape factors which can be estimated using the *PERT approximations*, are presented below.

$$mean = \frac{min + 4mode + max}{6}$$

$$stdev = \frac{max - min}{6}$$

$$\alpha_1 = \left(\frac{mean - min}{max - min}\right)\left(\frac{(mean - min)(max - mean)}{stdev^2} - 1\right)$$

$$\alpha_2 = \left(\frac{max - mean}{mean - min}\right)\alpha_1$$

The routing probabilities for the decision tasks were also determined on the basis of estimates instead of objective data. It was asked that what percentage of the cases followed which routes. Based on these questions, meetings were conducted with two task executors for each of the tasks to collect the relevant data for the simulation purpose. For some of the tasks, the data was collected from one executor instead of two because there was just one person responsible to execute specific tasks *(see "BS MMT Manager" resource)* or the second executor was not available for a long time. The forms used during the meetings and data that was collected for the simulation purpose can be seen in *Appendix G*.

Furthermore, there are other decisions have to be made regarding the allocation of tasks. The allocation principles were discussed by *van der Aalst & van Hee (2002)*. These are as follows.

- ***In what order are the work items[1] transformed into activities[2]?:*** Sometimes a task cannot be transformed into an activity immediately due to the fact that there may be more work items than resources who need to execute them. Therefore, the order that specifies which work item is transformed into an activity should be decided.
- ***By which resource are the activities carried out?:*** Since there are different types of resources, it should be decided that which work item is executed by which resource.

For our case study, the decisions above were also made because of their effect on the simulation models. Regarding the execution order of work items, it was decided that when there are more work items than resources, the resources picked up the work items randomly. Regarding the allocation of resources to activities, tasks and related executors were presented in *Appendix E*.

Other assumptions related with the simulation are as follows.

[1] A work item is a combination of a task and case.

[2] An activity is a combination of task, case, and resource (i.e. a work item is transformed into an activity when it starts to be executed by a resource).

1. A working day starts at 9 am and continues until 5 pm. Therefore, a work day is equal to 8 hours (or 480 minutes). One week consists of 5 work days. Therefore, a week is equal to 40 hours (or 2400 minutes).

2. A year is equal to 52 weeks. Therefore, a month consists of 4.33 weeks and is equal to 173.20 hours (or 10400 minutes).

3. The simulation starts at the beginning of a week (monday morning at 9 am).

4. All the resources are available 8 hours a day (from 9 am to 5 pm).

5. The number of incoming *"New Hires"* according to each department (and subdepartment) can be found in *Appendix G*. This is important in the simulation because *"Direct Managers"* and *"Direct Supervisors"* of each department take care of their own new hires while executing the tasks (e.g. a target is set to a new hire by a direct supervisor from his / her own department). These numbers show the number of *"New Hires"* who attended the trainings in a class environment between January and July 2011 period (totally 134 new hires). The other type of training is *"CBT"* (computer-based training) and that constitutes 60% of all trainings. Therefore, 335 cases are handled by the simulation (134 cases in a class environment and 201 cases in a computer environment) in a 6 month period. Therefore, 12.98 cases flow through the process on average each week.

6. Two *"Trainers"* are responsible for the trainings (which are conducted in a class environment). However, when both of them are busy with other tasks, a *"BS MMT Engineer"* can act as a trainer.

7. A training (which is conducted in a class environment) is given when there are at least two *"New Hires"*. When there is just one *"New Hire"*, s/he has to go back and search for the new offerings.

8. The *"Manage ML Skill Carousel"* subprocess is executed by specific departments. These departments are *BO - AO*, *DO - SIE*, *DO - VT*, and *DO - VIS*. Although other departments also follow *LMS*, they do not have *"Carousel Meetings"*.

9. The *"Carousel Meeting"* is conducted with a *"Manager"* of a department, *"Direct Supervisors"* of subdepartments and a *"BS MMT Engineer"*. For a specific department, a meeting with a *"Manager"* and a *"Direct Supervisor"* is followed by another meeting with the same manager and other supervisor (e.g. if there exist four subdepartments of a department, four separate meetings are conducted between a manager and a supervisor sequentially). In these meetings, resources are not allowed to do other tasks which are out of the scope of these meetings.

10. The combination of *"Assign role"* and *"Set target (short & long term)"* tasks reduces their total service time by 25%[3] *(see RS3)*.

11. The combination of *"Accept offering"* and *"Book offering"* tasks reduces their total service time by 50%[3] *(see RS5)*.

12. When the *Cased-based work (BASEB)* heuristic is applied, the duration of reflecting the outcome of *Online Academy* to *LMS* is reducted to Min: 0 min., Most Likely: 1 min., and Max: 2 min[3] *(see RS6)*.

13. The automation of the related reports reduces the service time to Min: 1 min., Most Likely: 2 min., and Max: 3 min. for each of the reports[3] *(see RS7)*.

[3]This was decided by the stakeholders.

14. The combination of *"Decide: Role assignment, skill target impact by new MPS"* and *"Decide: Skill growth as planned"* tasks does not reduce their total service time[3]. However, the combination of *"Define actions: Team role assignment & targets setting [1-2]"* and "Define actions: -1- Adjust skill targets [2] -2- Execute ILP [7-11]" tasks reduces their total service time by 15%[4] *(see RS8).*

15. The combination of *"Create training request overview"* and *"Analyse availability (including resources A*)"* tasks reduces their total service time by 10%[4] *(see RS9).*

Moreover, decisions considering the *replication length* and *replication number* were evaluated. These parameters are important in a simulation because they affect the reliability of statistics deducted from a simulation model. It is important to balance the reliability of the statistics and the need of the computing resources used to calculate the statistics *(T. Altiok & B. Melamed, 2007).* Therefore, the *replication length* was selected by observing the stabilization of the statistics of interest and also the reliability of the statistics and *replication number* was selected by observing the reliability of the statistics *(T. Altiok & B. Melamed, 2007).* In *Appendix H*, the simulation results with different *replication lengths* and *numbers* can be seen. As a result, the *replication length* was selected to handle *10000 new hires* and *replication number* was selected as *100* to safeguard the reliability of the statistics.

Finally, CPN Tools 3.0.4[5] was selected as a simulation tool. The simulation results can be found below.

[4]This was decided by the stakeholders.

[5]CPN Tools is a tool, which was developed at Aarhus University, for colored petri nets to edit, simulate, and analyse them.

Results

The result of the simulations for the existing processes was analyzed from two aspects: *Throughput time* and *workload* of the resources. *Throughput time* gives information about the duration of the cases including service, queue, and waiting times. *Workload* of the resources gives information about the time the resources spend on their activities and their utilization rates. The redesign heuristics were evaluated to see if they reduce the *throughput time* and *workload* of the resources.

To give more detailed information about the existing situation, *queue time* and *waiting time* were also monitored. *Queue time* gave information about the bottlenecks (e.g. a case is ready to be executed but there is no available resource) in the process. It was useful to see whether more resources were needed and a new redesign heuristic (i.e. *Extra resources (XRES))* could be applied. Finally, *waiting time* showed where large amounts of time were spent in the processes due to the structure of the process. It is important to note that activities that were out of the scope of the process were not modeled in the simulation.

Table 5.1: Simulation Result with 99% Confidence Interval (Throughput Time)

Process	**Throughput Time (in hours)**		
	Left Bound	**Mean**	**Right Bound**
Manage ML Skill & Learning Process	50.56	50.76	50.96
Manage ML Skill Carousel Subprocess	21.52	21.63	21.74
Manage ML Training Forecast Subprocess	45.21	46.34	47.46

The throughput times represent the average duration of the cases between the starting point of a process and ending point of a process. It is composed of the *service time* (i.e. actual time spent on the tasks / activities, *queue time* (i.e. the time that elapsed when a case was ready to be executed but there were no resources available), and finally *waiting time* (i.e. the time that elapsed other than service and queue times)). Since *"Manage ML Skill Carousel"* and *"Manage ML Training Forecast"* subprocesses are executed separately, the *throughput times* were presented separately as well.

Table 5.2: Simulation Result with 99% Confidence Interval (Waiting Time)

Manage ML Skill & Learning Process			
Task	**Waiting Time (in hours)**		
	Left Bound	**Mean**	**Right Bound**
Execute offering (Normal)	65.27	65.72	66.16
Update LMS learning history	19.95	20.00	20.04

There are two waiting times in the *"Manage ML Skill & Learning"* process. The *"New Hires"* wait before taking *"normal trainings"* because normal trainings are offered bi-weekly or monthly. The new hires that take *"CBTs"* also wait before the outcomes are reflected to *"LMS"* because the computer script is run at a specific time during a week.

Table 5.3: Simulation Result with 99% Confidence Interval (Queue Time)

Manage ML Skill Carousel Subprocess (together with Carousel Meeting Subsubprocess)			
Task	**Queue Time (in minutes)**		
	Left Bound	**Mean**	**Right Bound**
Determine required CRP/RFF & skill targets	66.43	66.60	66.77
Decide: Role assignment, skill target impact by new MPS	174.50	180.09	185.68
Escalate to Director (*)	35.93	41.58	47.23

It is clear that *queue time* forms the bottlenecks in a process. Although it gives good insights how to improve a process, the results should be interpreted in the context of the process. In our process, *three bottlenecks* were discovered which were caused by the unavailability of resources. One of them was caused by a *"Business Engineer"* and the others were by a *"Direct Manager"*. When the process was analysed in detail, it was seen that the waiting times caused by the *"Direct Manager"* do not represent the real bottlenecks in the process. To understand it, the *"Carousel Meeting"* should be analysed. Carousel meetings started with the task *"Decide: Role assignment, skill target impact by new MPS"* and they were conducted by the *"Direct Manager"* and *"Direct Supervisor"*. However, since there is one *"Direct Manager"* of each department but may be more than one *"Direct Supervisor"*, the meetings were conducted one by one. A *"Direct Supervisor"* should wait the previous meeting completed to start his/her meeting with the same *"Direct Manager"*. Therefore, they are not real bottlenecks but the time that should elapse in the process. The situation is the same for the task *"Escalate to Director (*)"*. There exist two outcomes at the end of each meeting. A *"Direct Manager"* may escalate the issues to a *"Director"* or finish the meeting without escalation. However, it is important to note that the escalation is out of the carousel meeting. Therefore, after a meeting, a *"Direct Manager"* either proceeds with other meetings or escalates the issues to a director. If s/he decides to proceed with other meetings, *queue time* emerges which is not a real bottleneck again. If these were real bottlenecks, no solutions would be offered (e.g. *Extra resources (XRES)) redesign heuristic)* because there cannot be more than one *"Direct Manager"* for each departments.

However, the task *"Determine required CRP/RFF & skill targets"* which is executed by a *"Business Engineer"* represents a real bottleneck. This task is executed in the beginning of the *"Manage ML Skill Carousel"* subprocess and for each of the departments who has a *"Carousel Meeting"*. Three *BS Engineers* take care of this task and it is obvious that there is more resources needed. In this case, another redesign scenario emerges. This is as follows.

Redesign Scenario -11-

In the existing *"Manage ML Skill Carousel"* subprocess, *"Determine required CRP/RFF & skill targets"* task is executed by the *"BS Engineer"* but the number of resources (*currently, it is 3*) is not satisfactory to execute this task without a *queue time*. Therefore, based on *Extra resources (XRES)* heuristic, extra resources can be added (*the number of resources will be increased to 4*).

This scenario is expected to reduce the *workload* of the *"BS Engineer"*. However, the *cost* of introducing an additional resource should also be considered.

Table 5.4: Simulation Result with 99% Confidence Interval (Workload per Resource)

Resource	Workload of Resources for One Year (in hours)			Average Utilization Rate
	Left Bound	Mean	Right Bound	Mean
Direct Manager	56.31	56.58	56.84	2.72%
Direct Supervisor	11.06	11.07	11.08	0.53%
Manufacturing Engineer	4.16	4.17	4.19	0.20%
Business Engineer	78.26	78.48	78.70	3.77%
BS MMT Manager	11.33	11.74	12.15	0.56%
BS MMT Engineer	38.29	38.56	38.82	1.85%
Trainer [6]	127.07	127.84	128.61	6.15%
CS Training Engineer	73.05	75.26	77.48	3.62%

The *workload* of the resources was calculated in a one-year time period. Therefore, the time shows the duration a resource spent on his/her activities in one year. The utilization rates are small because the number of incoming new hires are based on the number of the departments that were following the related processes (*see Appendix G*). In reality, the number of new hires were more than the ones presented here (e.g. Some new hires were hired by some of the departments that were out of the scope of the processes investigated in this project). Therefore, the resources were busier than presented.

Table 5.5: Simulation Result with 99% Confidence Interval (Workload of a New Hire)

Resource	Workload of a New Hire (in hours)			Average Utilization Rate
	Left Bound	Mean	Right Bound	Mean
New Hire	8.49	8.51	8.53	16.76%

The workload of the *"New Hire"* shows the duration and percentage s/he took part in the activities throughout the processes. The numbers also contain the durations of the trainings *(both "Normal" and "CBT")*.

5.2 Validation of the simulation result

In this step of the methodology, the simulation results of the existing processes were communicated to the process owners. A meeting was organized with the process owners for this purpose and results were discussed. The process owners had no statistical information about the processes before this project because no similar studies were conducted. Therefore, the validation of the simulation results were based on the correctness of the models and data collected. At the end of the meeting, the process owners agreed on the results of the simulation and therefore, the results were validated.

As a next step, the redesign scenarios were simulated and their results were compared with the existing situation.

[6] The trainer belongs to *"BS MMT"* department.

5.3 Evaluation of the redesign scenarios through simulation

As it was mentioned, a similar simulation approach was followed to get the performance metrics of the redesign scenarios. The existing process was modified according to each of the redesign scenarios and then simulated. The *throughput time* and *workload of the resources* were in the focus again.

The results of the simulations can be found below.

Results

Table 5.6: Simulation Results of the Redesign Scenarios

RS [7]	**Avg. Throughput Time Gain**	**Avg. Workload Gain**
	Value	**Value**
RS1*[8]	<1% (Skill & Learning)	38.28% (Direct Supervisor)
RS2	0% (Skill & Learning)	0% (Direct Supervisor) 0% (New Hire)
RS3*	<1% (Skill & Learning)	8.17% (Direct Supervisor)
RS4	<1% (Skill & Learning) -4.23% (Training Forecast)	-16.88% (Direct Supervisor) -1180.28% (BS MMT Manager) -385.23% (BS MMT Engineer) -1201.55% (CS Training Engineer)
RS5	<1% (Skill & Learning)	<1% (New Hire)
RS6* (Immediate) RS6* (Every hour) RS6* (Every day) RS6* (Two times a week)	23.62% (Skill & Learning) 23.26% (Skill & Learning) 19.25% (Skill & Learning) 11.80% (Skill & Learning)	- (Siennax LS) - (Siennax LS) - (Siennax LS) - (Siennax LS)
RS7*	0% (Skill Carousel)	11.62% (BS MMT Engineer)
RS8	<1% (Skill Carousel)	<1% (Direct Supervisor)
RS9	<1% (Training Forecast)	<1% (BS MMT Engineer)
RS10[9]	?	?
RS11*	0% (Skill Carousel)	21.66% (Business Engineer)

The simulation results of the redesigned processes gave important information because some of the results were hard to anticipate without conducting simulations. Below, the explanations of the results for each of the scenarios can be seen.

RS1: The effect of *RS1* on the *throughput time* of the *"Manage ML Skill & Learning"* process is too little. Compared to the *throughput time* of the process, the elimination of the related task in terms of *service time* did not make any improvement. However, the effect on the *workload* of the *"Direct Supervisor"* is satisfactory.

RS2: *RS2* did not have any effects on the process in terms of the *throughput time* and *workload* of the resource. The reason is that the related tasks in the redesign scenario were resequenced and there was no change in the way of executing the tasks themselves.

[7] RS: Redesign Scenario

[8] The results with considerable gains were marked with (*).

[9] This redesign scenario needs further investigation and thus, out of the scope of this project.

RS3: The combination of the related tasks in *RS3* did not reduce the *throughput time* of the *"Manage ML Skill & Learning"* process to a large extent, but had an positive effect on the *workload* of the *"Direct Supervisor"* (8.17%).

RS4: Putting *RS4* on practice had enormous negative effects on the *throughput time* of the *"Manage ML Training Forecast"* subprocess and also on the *workload* of the resources. This is due to the fact that there is a big difference on the frequency of executing the subprocess after the redesign scenario. The reason why there is a gain on the *throughput time* of the *"Manage ML Skill & Learning"* process is that the task *"Manage offerings"* was executed less frequently. However, it was not a considerable gain.

RS5: In this scenario, the combination of the related tasks did not provide any gain on the *throughput time* of the process or *workload* of the resource.

RS6: The analysis of *RS6* needs further investigation due to the big gain it provided. The scenario offered that the computer script should be run immediately to eliminate the batch handling. However, there are other options such as running the script *every hour, every day, and two times in a week* were also analysed. Although the decision should be given based on the balance between the gain provided and the applicability of the scenario by the IT department within *ASML*, all of the options provided considerable gains.

RS7: Although *RS7* cut the *service times* of getting the reports to be created substantially, it did not affect the *throughput time* of the *"Manage ML Skill Carousel"* subprocess. To understand it, the duration of the tasks situated in the other two branches of the parallelism should be analysed. Data collection phase of the simulation showed that the task *"Determine required skill framework changes"* took the longest duration in the parallel branches. Therefore, it is obvious that reducing the durations in the other branches had no effect on the *throughput time* because the duration was decided by the branch that took the longest time in the parallelism. However, the scenario reduced the *workload* of the *"BS MMT Engineer"* because of the elimination of the manual creation of the reports.

RS8: The result of *RS8* is similar to the result of *RS5*. The composition of the related tasks added very little value in terms of *throughput time* and *workload* of the resource.

RS9: The result of *RS9* is similar to the results of *RS5* and *RS8*. The composition of the related tasks added very little value in terms of *throughput time* and *workload* of the resource.

RS10: As stated previously, the simulation of *RS10* could not be conducted because this scenario needed an extensive research. It proposed that a *Workflow Management System (WfMS)* should be deployed to the organization to facilitate the communication between the stakeholders and flow of the work items. Although it is obvious that the scenario will add a lot of benefits, the analysis of its result is out of the scope of this Master's project.

RS11: This scenario emerged after conducting the simulations and analyse the simulation results. Because of the *queue time* before the task *"Determine required CRP/RFF & skill targets"*, it was revealed that additional resources might be added to the *"Business Engineer"*. The simulation result showed that the scenario provided no gain on the *throughput time*. The reason is the same as with *RS7*. Although the *queue time* was eliminated through adding an extra resource, the duration of the parallelism was decided by the branch that took the longest time (i.e. *"Determine required skill framework changes"* task). On the other hand, the *workload* of the related resource reduced. Since there is no gain on the *throughput time* and the utilization rate of the *"Business Engineer"* is low, introducing an additional resource would not provide benefit to the organization (instead, it would introduce a cost to the organization).

Table 5.7: Simulation Results of the Redesign Scenarios (Combined)

RS	**Avg. Throughput Time Gain**	**Avg. Workload Gain**
	Value	**Value**
RS1&RS3&RS6&RS7	24.54% (Skill & Learning)	46.31% (Direct Supervisor) 11.96% (BS MMT Engineer)

Finally, the redesign scenarios that were proved to be useful in terms of the *throughput time* or *workload* of resources were selected and implemented all together in the same process. The result of this step can be found in the table above.

Chapter 6

Conclusion

In this chapter, the final remarks of this Master's project were presented. To this end, this chapter was divided into three parts. In the first part, the Master's project was summarized. The most important points and the results of the project were addressed.

In the second part, the limitations of the Master's project and the assumptions related with these limitations were stated.

In the final part, the future research of this Master's project were discussed and possible directions were suggested.

6.1 Summary

In this project, a *Business Process Redesign (BPR)* project was successfully implemented to improve the processes of the *MMT department* within *ASML*.

Although the project was conducted within *ASML*, it was not completely an industrial project. The unique characteristics of the project made this study academically important as well. The steps followed in this project can be summarized as follows.

The project started with analysing the existing processes of the *MMT* department. The existing processes were documented within the department; therefore, there was no need to discover and map the processes from scratch. The existence of the documented processes within the department was the different part of this project compared to the other redesign projects in the literature. Therefore, a methodology was developed to provide a step-wise approach to conduct similar redesign projects. In this methodology and project, following actions were taken.

In the *Discovery Phase*, the researcher decided to benefit from the documented processes (the process models modeled in the *"swimlane"* notation) developed within the organization. Despite the existence of the documented processes, a transformation was needed to understand the processes better. The *swimlane* diagrams were converted to *Petri-net* diagrams. The transformation phase allowed the researcher to see the mistakes in the models. Identified mistakes in the processes were discussed with the process owners and the researcher fixed these mistakes to develop the conceptual models. The conceptual models were validated by the process owners to be sure that they were free of the syntactical and semantical mistakes. The conceptual models acted as bases for the next steps such as developing the redesign scenarios and evaluations of them.

After this step and based on the correctly-modeled models, the *Development Phase* started. By analysing the fragments of the processes in detail and using the redesign heuristics presented by *Reijers (2003)*, totally *10 redesign scenarios* were developed. The applicability of these scenarios were approved by the process owners. *9* of the redesign scenarios found to be evaluated in the *Evaluation Phase*, but *1* of them, which proposed to deploy a *Workflow Management System (WfMS)* to the organization, was not found suitable to be evaluated. Moreover, the applicability of a new redesign scenario, which was about introducing additional resources, was planned to be decided in the *Evaluation Phase*.

As the last step, the *Evaluation Phase* considered the statistical information of the existing situation and also the outcomes of the redesign scenarios. A simulation was conducted for the existing processes and they were evaluated in terms of the *throughput time*, *waiting time*, *queue time*, and *workload* of the resources. These parameters gave important information about the existing processes. The *queue time* revealed one *bottleneck* in the *"ML Skill Carousel"* subprocess, which resulted a new redesign scenario *(i.e. Extra resources (XRES))*. By the help of the simulations, the original and proposed models were compared and performance metrics were presented. At the end of the simulations, *4* redesign scenarios were found to be useful in terms of *throughput time* or *workload* of the resources. These *4* scenarios were combined together to see their effects on the processes and it was revealed that there was a gain of ***24.54%*** on the *throughput time* of the *"Manage ML Skill & Learning"* process. Moreover, the combination of the redesign scenarios resulted a gain of ***46.31%*** of the *workload* of the *"Direct Supervisor"* and ***11.96%*** of the *workload* of the *"BS MMT Engineer"*.

As a result of this project, following goals were achieved and values were delivered to the related organizations discussed in the *Introduction* Chapter.

- A new methodology that considered a redesign project for documented processes was developed and successfully validated with the case study of *ASML*.
- It was shown that the redesign heuristics provided by *Reijers (2003)* could successfully be applied to a *"Training"* process within a high-tech organization.
- An evaluation approach that formed the simulations of the business processes was followed to provide the *quantitative* and *objective* results of the redesign scenarios.
- The processes in this project were analysed in detail and related corrections were made to provide the *"corrected"* business process models to the *MMT* department.
- Gains in the *throughput time* and *workload* of the resources were achieved for the processes of the *MMT* department and *ASML*.
- The knowledge related with the concepts *BPM* and *BPR* were conveyed to the *MMT* department and *ASML*

6.2 Limitations & Assumptions

The processes developed within the *MMT* department were supposed to be followed by the related departments. However, it was the case that not all the departments and employees complied with the steps stated in the processes. The models which were on the papers and the lack of a *WfMS* also caused the incompliances within *ASML (there was no control system that was forcing the employees to follow the steps)*. In this project, it was assumed that the processes were being followed by the stakeholders as they were modeled in *Appendix B*.

The second limitation concerns the departments who were following the departments. The departments who were following the related processes were stated in *Appendix G*. As this project was being conducted, the *MMT* department was trying to extend the processes to the other departments. With this extension, the number of new hires that would follow the processes will also be affected. The number of the new hires following the related processes was important for the *Evaluation Phase* because the statistics produced by the simulations will also be affected. In this project, a fixed number of new hires, who were the employees of the departments following the related processes during this project, was taken into account *(see Appendix G)*.

The last limitation was about the data collected for the simulation approach. As stated in the *Evaluation Phase*, no objective data was available regarding the *service times*, *waiting times*, *queueing times* of the tasks and *throughput times* of the processes. The routing probabilities of the decisions also lacked. In this project, the *subjective estimates* of these parameters were decided to be used *(see Appendix G)*.

6.3 Recommendations & Future Research

In this project, the conceptual models of the processes were developed and based on them, the redesign scenarios were offered. The redesign scenarios were evaluated through simulations *(except one of them)* and it was seen that considerable gains can be achieved with this project. Referring to these results, the process models should be put into practice by the *MMT* department.

Although the project can be considered successful, this should not be the final destination for the *MMT* department and *ASML*. The processes analysed and improved in this project and followed by the employees are still on the papers. Therefore, there is still room for a future improvement. One of the redesign scenarios presented such an improvement and offered a *Workflow Management System (WfMS)* to the organization. Although this project provided the basis for such an improvement by offering the process models, because of the limited scope of this project, the effect of that scenario could not be evaluated.

Therefore, as a future research, the results of such a scenario can be evaluated. If the scenario can be proved to provide gains, it should be put into practice by the *MMT* department as well.

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Appendix A

BPR Best Practices *(Reijers, 2003)*

Task best practices
Task best practices focus on optimizing single tasks within a business process.

1. Task elimination ***(ELIM)***: delete tasks that do not add value from a client's viewpoint.
2. Task addition ***(ADD)***: check the completeness and correctness of incoming materials and check the output before it is send to clients.
3. Task composition ***(COMPOS)***: combine small tasks into composite tasks and divide large tasks into workable smaller tasks.
4. Task automation ***(AUTO)***: introduce technology if automated tasks can be executed faster, with less cost, and with a higher quality.

Routing best practices
Routing best practices try to improve upon the routing structure of the business process.

5. Resequencing ***(RESEQ)***: move tasks to more appropriate places.
6. Knockout ***(KO)***: execute those checks first that have the most favorable ratio of expected knock-out probability versus the expected effort to check the condition.
7. Control relocation ***(RELOC)***: relocate control steps in the process to others, e.g. the client or the supplier, to reduce disruptions in the process.
8. Parallelism ***(PAR)***: introduce concurrency within a business process to reduce lead times.
9. Triage ***(TRI)***: consider the division of a general task into two or more alternative tasks.

Allocation best practices
Allocation best practices involve a particular allocation of resources to activities.

10. Case manager ***(MAN)***: make one person responsible for the handling of a specific case.
11. Case assignment ***(ASSIGN)***: let workers perform as many steps as possible for single cases.
12. Customer team ***(TEAM)***: consider assigning teams out of different departmental workers that will take care of the complete handling of specific sorts of cases.
13. Flexible assignment ***(FLEX)***: assign resources in such a way that maximal flexibility is preserved for the near future.

14. Resource centralization ***(CENTR)***: treat geographically dispersed resources as if they are centralized.
15. Split responsibilities ***(SPLIT)***: avoid assignment of task responsibilities to people from different functional units.

Resource best practices
Resource best practices focus on the types and availability of resources.

16. Numerical involvement ***(NUM)***: minimize the number of departments, groups and persons involved in a process.
17. Extra resources ***(XRES)***: if capacity is not sufficient, consider increasing the number of resources in a certain resource class.
18. Specialist-Generalist ***(SPEC)***: consider making resources more specialized or more generalized.
19. Empower ***(EMP)***: give workers most of the decision-making authority and reduce middle management.

Best practices for external parties
This type of best practices tries to improve upon the collaboration and communication with the client and third parties.

20. Integration ***(INT)***: consider the integration with a process of the client or a supplier.
21. Outsourcing ***(OUT)***: relocate work to a third party that is more efficient in doing the same work, to reduce costs.
22. Interfacing ***(INTF)***: consider a standardized interface with clients and partners.
23. Contact reduction ***(REDUC)***: combine information exchanges to reduce the number of times that waiting time and errors may show up.
24. Buffering ***(BUF)***: subscribe to updates instead of complete information exchange.
25. Trusted party ***(TRUST)***: replace a decision task by the decision of an external party.

Integral process best practices
This type of best practices applies to the business process as a whole.

26. Case types ***(TYPE)***: determine whether tasks are related to the same type of case and, if necessary, distinguish separate processes and case types.
27. Technology heuristic ***(TECH)***: try to elevate physical constraints in a process by applying new technology.
28. Exception ***(EXCEP)***: design processes for typical cases and isolate exceptional cases from normal flow.
29. Case-based work ***(CASEB)***: get rid of constraints that introduces batch handling may significantly speed up the handling of cases.

Appendix B

Existing Processes (ASML Documentation)

CONFIDENTIAL

Figure B.1: Manage ML Skill & Learning Process

CONFIDENTIAL

CONFIDENTIAL

Figure B.2: Manage ML Skill Carousel Subprocess

CONFIDENTIAL

CONFIDENTIAL

Figure B.3: Manage ML Training Forecast Subprocess

CONFIDENTIAL

Appendix C

Existing Processes in Petri-net

Figure 1: Manage ML Skill & Learning Process

CONFIDENTIAL

Figure C.1: Manage ML Skill Carousel Subprocess

CONFIDENTIAL

Figure C.2: Manage ML Training Forecast Subprocess

Appendix D

Findings about Syntactical / Semantical Correctness

CONFIDENTIAL

Figure D.1: Finding -1-

CONFIDENTIAL

Figure D.2: Finding -3-

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Figure D.3: Finding -4-

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Figure D.4: Finding -5-

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Figure D.5: Finding -6-

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Figure D.6: Finding -7-

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Figure D.7: Finding -9-

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Figure D.8: Finding -10-

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Figure D.9: Finding -11-

Appendix E

Tasks and Related Executors in the Conceptual Models

Table E.1: Tasks and Related Executors

Manage ML Skill & Learning Process	
Task	**Executor**
Manage ML Skill Carousel	(Subprocess)
Manage LMS Masterdata	Direct Manager
Assign Role	Direct Supervisor
Set target (short & long term)	Direct Supervisor
Define actual skill level by self assessment	Employee
Approve actual skill level	Direct Supervisor
Manage ML Training Forecast	(Subprocess)
Decide: CBT or normal training	(Dummy Task)
Manage offerings	BS MMT Engineer
Search offering	Employee
Accept offering	Employee
Make request in LMS to BS MMT Engineer	Employee
Book offering	Employee
Accept: Invitation offering	Employee
Execute offering [1]	Trainer
Decide: Training passed	Trainer or LMS Support (Siennax)
Update training status in LMS or Online Academy (1)	Trainer or LMS Support (Siennax)
Decide: CBT or normal training (1)	(Dummy Task)
Update training status in LMS or Online Academy	Trainer or LMS Support (Siennax)
Decide: Learning stored in Online Academy	LMS Support (Siennax)
Update LMS learning history	LMS Support (Siennax)
Manage ML Skill Carousel Subprocess	
Task	**Executor**

[1] In the original document, "Employee" was stated as an executor. However, "Trainer" is responsible for teaching the training content.

AND-Split1	(Dummy Task)
Determine required skill framework changes	Manufacturing Engineer
Determine required CRP/RFF & skill targets	Business Engineer
Update skill status reports	BS MMT Engineer
Update learning status reports	BS MMT Engineer
Analyse deviations with respect to targets	Direct Supervisor
AND-Join1	(Dummy Task)
Control / Manage Actual vs New Skill Targets (Carousel Meeting)	(Subprocess)
Escalate to Director (*)	Direct Manager
Manage ML Skill Carousel Meeting Subsubprocess	
Task	**Executor**
Decide: Role assignment, skill target impact by new MPS	Direct Manager
Define actions: Team role assignment & targets setting [1-2]	Direct Supervisor
Decide: Skill growth as planned	Direct Manager
Define actions: -1- Adjust skill targets [2] -2- Execute ILP [7-11]	Direct Supervisor
Decide: Skill framework changes needed	Direct Manager
Define actions: -1- Master data changes	BS MMT Engineer
Agree with defined actions	Direct Manager
Escalate	Direct Manager
Make required changes	Direct Manager
Manage ML Training Forecast Subprocess	
Task	**Executor**
Create training request overview	BS MMT Engineer
Analyse availability (including resources A*)	BS MMT Engineer
AND-Split2 (Decide: ML Training and/or CS Training)	BS MMT Engineer
Route (ML Training)	(Dummy Task)
Route (CS Training)	(Dummy Task)
Decide: All offerings available	BS MMT Engineer
Manage CS Training (TBD)	CS Training Engineer [2]
Accept CS proposal	BS MMT Engineer
Manage offering resource claim (A*) (including time-frame, possible solutions)	BS MMT Engineer
Manage offering resource claim (A*) (including time-frame, possible solutions) (1)	CS Training Engineer
Approve offerings	Direct Supervisor
Decide: CS proposal correction possible	CS Training Engineer
Escalate best effort offerings	BS MMT Engineer
Escalate: Discuss with staff M&L	BS MMT Manager [3]
Check/Update LMS	BS MMT Engineer
Check/Update LMS (1)	CS Training Engineer
AND-Join2	(Dummy Task)

[2]The resource was renamed "CS Training Engineer" instead of "CS Training."

[3]The resource was renamed "BS MMT Manager" instead of "Manager BS MMT."

Appendix F

Modified Tasks and Related Executors in the Redesigned Models

Table F.1: Tasks and Related Executors

Manage ML Skill & Learning Process	
Task	**Executor**
Assign role and set target (short & long term)	Direct Supervisor
Accept and book offering	Employee
Manage ML Skill Carousel Subprocess	
Task	**Executor**
AND-Split2	(Dummy Task)
Update skill status reports	Computer
Update learning status reports	Computer
AND-Join2	(Dummy Task)
Manage ML Skill Carousel Meeting Subprocess	
Task	**Executor**
Decide: Role assignment, skill target impact by new MPS and skill framework as planned	Direct Manager
Define actions: Team role assignment & targets setting [1-2] and -1- Adjust skill targets [2] -2- Execute ILP [7-11]	Direct Supervisor
Manage ML Training Forecast Subprocess	
Task	**Executor**
Create training request overview and analyse availability (including resources A*)	BS MMT Engineer

Appendix G

Simulation Data

Table G.1: Number of New Hires According to the Departments (between January 2011 and July 2011)

Department	Number of New Hires
BO - AM - EL 2	1
BO - AM - WSN 1	7
BO - AM - WSN 3	4
BO - AM - WSN 4	7
BO - AM - WSN 5	4
BO - AM - WSX 1	4
BO - AO - IL 1	5
BO - AO - LA	2
BO - AO - MF 1	2
BO - AO - MF 2	1
BO - FASY - Cabin Assy 1	1
BO - FASY - Cabin Assy 2	1
BO - FASY - Fasy 1	2
BO - FASY - Fasy 2	2
BO - FASY - Fasy 3	3
BO - FASY - Fasy 4	4
BO - FASY - Fasy 5	1
BO - FASY - Fasy 6	2
DO - SIE - SIE 2	2
DO - SIE - SIE 6	32
DO - PM - PM A	1
DO - PM - PM B	2
DO -VT - VT 1A	1
DO -VT - VT 2A	1
DO -VT - VT 2B	2
DO -VT - VT 3B	1
DO - TPG - TPG 1A	2
DO - TPG - TPG 2A	2
DO - TPG - TPG 1B	1
DO - TPG - TPG 2B	1
DO - TPG - TPG 3	3
DO - TPG - TPG 4	4
DO - TPG - TPG 5A	4
DO - TPG - PP 1	9

DO - TPG - PP 2	4
DO - VIS - VIS 1	3
DO - VIS - VIS 2	2
DO - VIS - VIS 3	3
DO - VIS - VIS 4	1

Table G.2: Simulation Data for *Manage ML Skill & Learning* Process

Task	Service Time (in minutes)			Routing Probability
	Min.	**Most Likely**	**Max.**	
Manage LMS masterdata	240	960	2400	-
Assign role	5	6	15	-
Set target (short & long term)	5	6	15	-
Define actual skill level by self assessment	15	25	30	-
Approve actual skill level	5	15	30	Yes: 90% No: 10%
Decide: CBT or normal training	-	-	-	CBT: 60% Normal: 40%
Manage offerings	5	10	15	-
Search offering	10	18	20	-
Accept offering	2	3	5	Yes: 50% No: 50%
Make request in LMS to BS MMT Engineer	5	6	10	-
Book offering	2	3	5	-
Accept: Invitation offering	2	4	5	Yes: 80% No: 20%
Execute offering (Normal) Execute offering (CBT)	959 60	960 90	961 120	- -
Decide: Training passed (Normal) Decide: Training passed (CBT)	0 0	1 0	2 0	Yes: 99% No: 1% Yes: 80% No: 20%
Update training status in LMS or Online Academy (Normal) Update training status in LMS or Online Academy (CBT)	1 0	2 0	3 0	- -
Update training status in LMS or Online Academy (1) (Normal) Update training status in LMS or Online Academy (1) (CBT)	1 0	2 0	3 0	- -
Decide: CBT or normal training (1) [1]	-	-	-	CBT: 60% Normal: 40%

[1] The percentage is based on "Decide: CBT or normal training" task.

Decide: Learning stored in Online Academy [2]	0	0	0	Yes: 60% No: 40%
Update LMS learning history	1	2	3	-

[2] The percentage is based on "Decide: CBT or normal training" task.

Table G.3: Simulation Data for *Manage ML Skill Carousel* Subprocess

Task	**Service Time (in minutes)**			**Routing Probability**
	Min.	**Most Likely**	**Max.**	
Determine required skill framework changes	480	960	1920	-
Determine required CRP/RFF & skill targets	180	300	480	-
Update skill status reports	20	30	45	-
Update learning status reports	60	90	120	-
Analyse deviations with respect to targets	15	20	30	-
Escalate to Director (*)	5	7	10	-

Table G.4: Simulation Data for *Manage ML Skill Carousel Meeting* Subsubprocess

Task	**Service Time (in minutes)**			**Routing Probability**
	Min.	**Most Likely**	**Max.**	
Decide: Role assignment, skill target impact by new MPS	5	8	10	Yes: 20% No: 80%
Define actions: Team role assignment & targets setting [1-2]	15	20	30	-
Decide: Skill growth as planned	20	28	35	Yes: 50% No: 50%
Define actions: -1- Adjust skill targets [2] -2- Execute ILP [7-11]	15	20	30	-
Decide: Skill framework changes needed	5	8	10	Yes: 20% No: 80%
Define actions: -1- Master data changes	5	10	15	-
Agree with defined actions	1	2	3	Yes: 95% No: 5%
Escalate	1	2	3	Yes: 5% No: 95%
Make required changes	5	10	15	-

Table G.5: Simulation Data for *Manage ML Training Forecast* Subprocess

Task	**Service Time (in minutes)**			**Routing Probability**
	Min.	**Most Likely**	**Max.**	
Create training request overview	5	10	15	-
Analyse availability (including resources A*)	10	20	30	-
AND-Split2 (Decide: ML Training and/or CS Training)	0	1	2	-
Route (ML Training)	-	-	-	Yes: 100% No: 0%
Route (CS Training)	-	-	-	Yes: 100% No: 0%
Decide: All offerings available	1	2	3	Yes: 5% No: 95%
Manage CS Training (TBD)	240	360	480	-
Accept CS proposal	15	30	60	Yes: 20% No: 80%
Manage offering resource claim (A*) (including time-frame, possible solutions)	30	45	60	-
Manage offering resource claim (A*) (including time-frame, possible solutions) (1)	60	90	120	-
Approve offerings	10	20	30	Yes: 10% No: 90%
Decide: CS proposal correction possible	5	10	15	Yes: 99% No: 1%
Escalate best effort offerings	10	15	30	-
Escalate: Discuss with staff M&L	5	30	60	-
Check/Update LMS	180	240	360	-
Check/Update LMS (1)	120	180	240	-

Appendix H

Determining the Replication Length and Number of the Simulation

Table H.1: Simulation Results (Throughput time in minutes) with Different Replication Numbers (Number of New Hires = 1000)

# Replication	**Simulation Duration**	**Skill & Learning**		**Skill Carousel**		**Training Forecast**	
Value	*Average*	*Average*	*99% CI*	*Average*	*99% CI*	*Average*	*99% CI*
10	312144.76	3088.97	107.76	1280.82	56.49	2618.44	642.52
30	308019.60	3029.63	47.94	1280.18	17.99	2823.02	384.71
50	289699.62	3037.13	40.63	1278.20	12.02	2671.33	294.93
100	320260.34	3057.35	31.72	1284.73	9.09	2849.94	236.47

Table H.2: Simulation Results (Throughput time in minutes) with Different Replication Numbers (Number of New Hires = 3000)

# Replication	**Simulation Duration**	**Skill & Learning**		**Skill Carousel**		**Training Forecast**	
Value	*Average*	*Average*	*99% CI*	*Average*	*99% CI*	*Average*	*99% CI*
10	680389.73	3060.69	100.74	1287.48	30.26	2781.23	434.75
30	667871.64	3029.40	36.65	1294.51	8.46	2792.30	263.34
50	649132.08	3063.30	32.09	1295.30	9.39	2844.92	196.56
100	663499.33	3037.34	16.13	1293.55	7.91	2736.91	126.32

Table H.3: Simulation Results (Throughput time in minutes) with Different Replication Numbers (Number of New Hires = 5000)

# Replication	**Simulation Duration**	**Skill & Learning**		**Skill Carousel**		**Training Forecast**	
Value	*Average*	*Average*	*99% CI*	*Average*	*99% CI*	*Average*	*99% CI*
10	1073420.81	3028.85	45.31	1285.58	14.24	2744.62	296.61
30	1038080.10	3053.84	33.98	1292.30	9.31	2922.99	236.75
50	1008553.13	3045.03	25.70	1292.15	9.30	2738.06	143.64
100	1041609.58	3039.13	16.53	1293.18	6.18	2821.34	102.22

Table H.4: Simulation Results (Throughput time in minutes) with Different Replication Numbers (Number of New Hires = 10000)

# Replication	**Simulation Duration**	**Skill & Learning**		**Skill Carousel**		**Training Forecast**	
Value	*Average*	*Average*	*99% CI*	*Average*	*99% CI*	*Average*	*99% CI*
10	1990788.71	3067.94	43.62	1304.70	25.12	2792.44	322.30
30	1982446.22	3028.50	19.32	1298.74	10.57	2882.17	113.38
50	1947066.84	3039.70	16.56	1295.42	8.78	2847.36	106.51
100	1958927.68	3045.35	12.05	1294.94	6.29	2800.67	71.33

Table H.5: Simulation Results (Throughput time in minutes) with Different Replication Numbers (Number of New Hires = 15000)

# Replication	**Simulation Duration**	**Skill & Learning**		**Skill Carousel**		**Training Forecast**	
Value	*Average*	*Average*	*99% CI*	*Average*	*99% CI*	*Average*	*99% CI*
10	2889380.73	3041.18	31.54	1297.40	32.22	2898.43	278.48
30	2893485.56	3045.73	17.64	1300.54	14.78	2790.83	119.39
50	2880541.48	3035.18	11.03	1292.46	7.61	2821.84	82.84
100	2888688.86	3040.43	9.18	1295.50	5.78	2842.02	62.25

Appendix I

CPN Tools

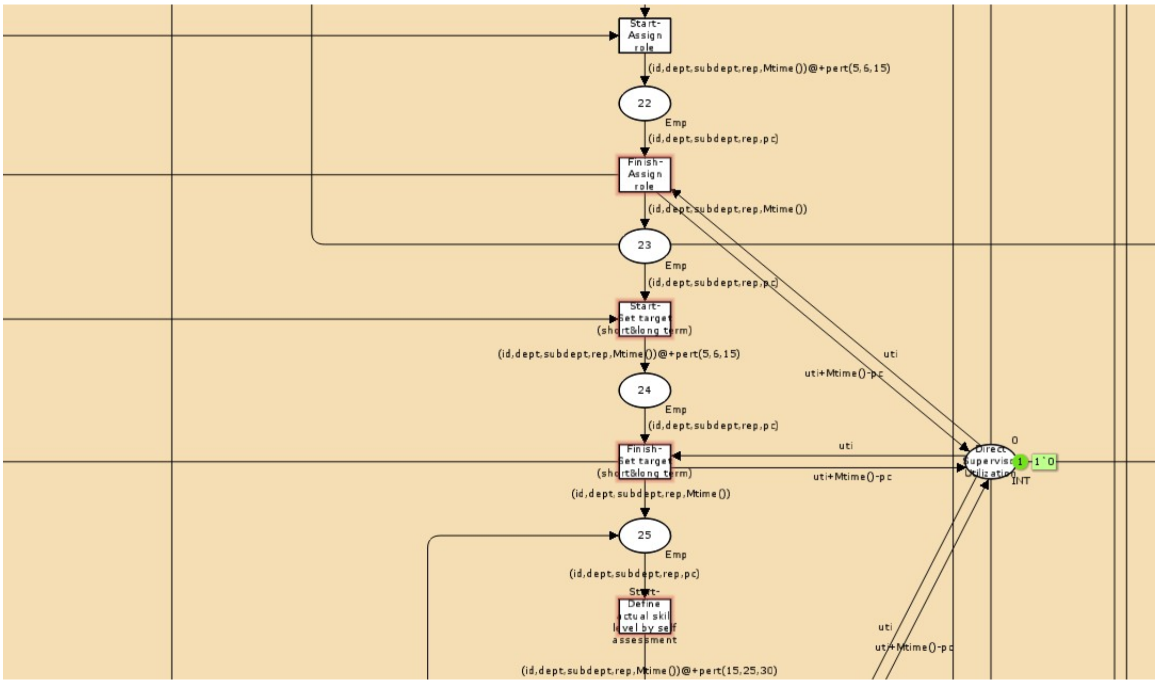

Figure I.1: Screenshot -1-

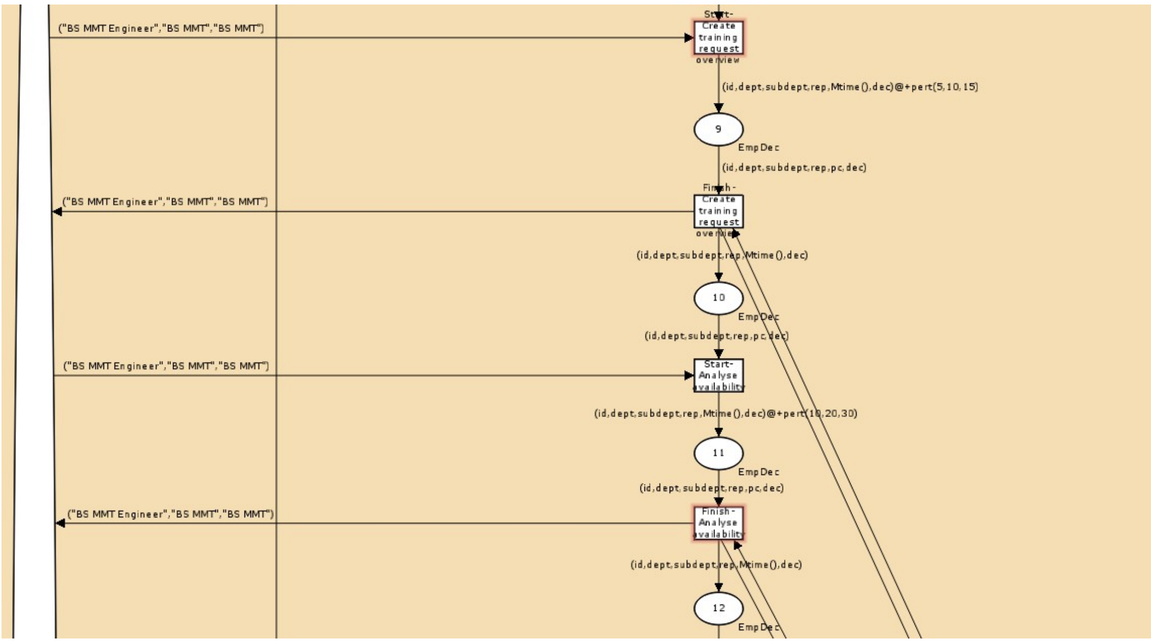

Figure I.2: Screenshot -2-

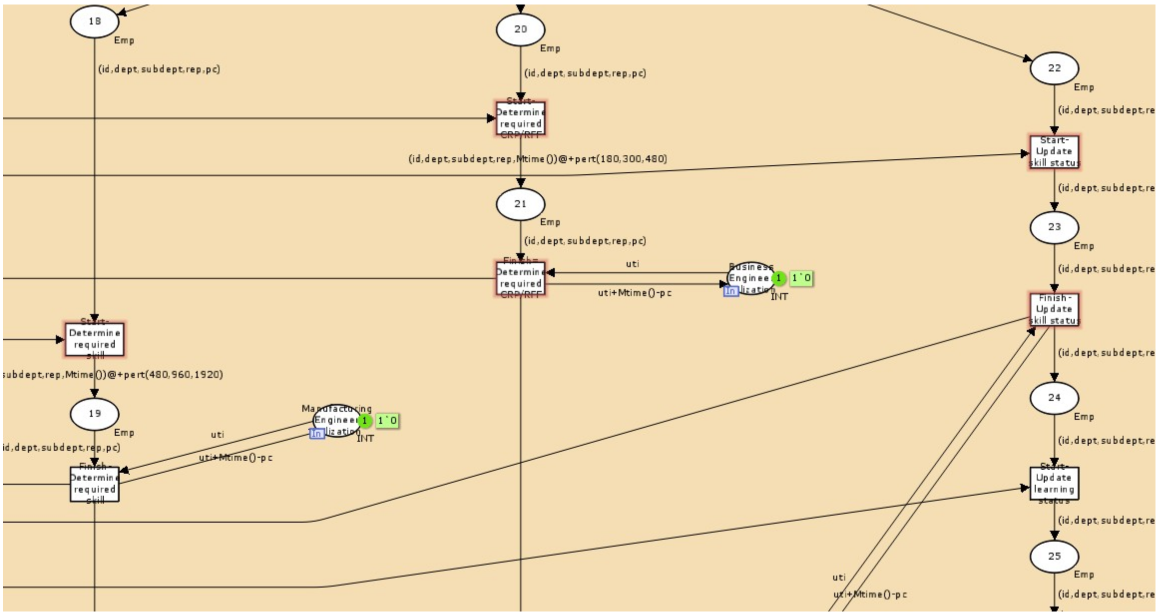

Figure I.3: Screenshot -3-

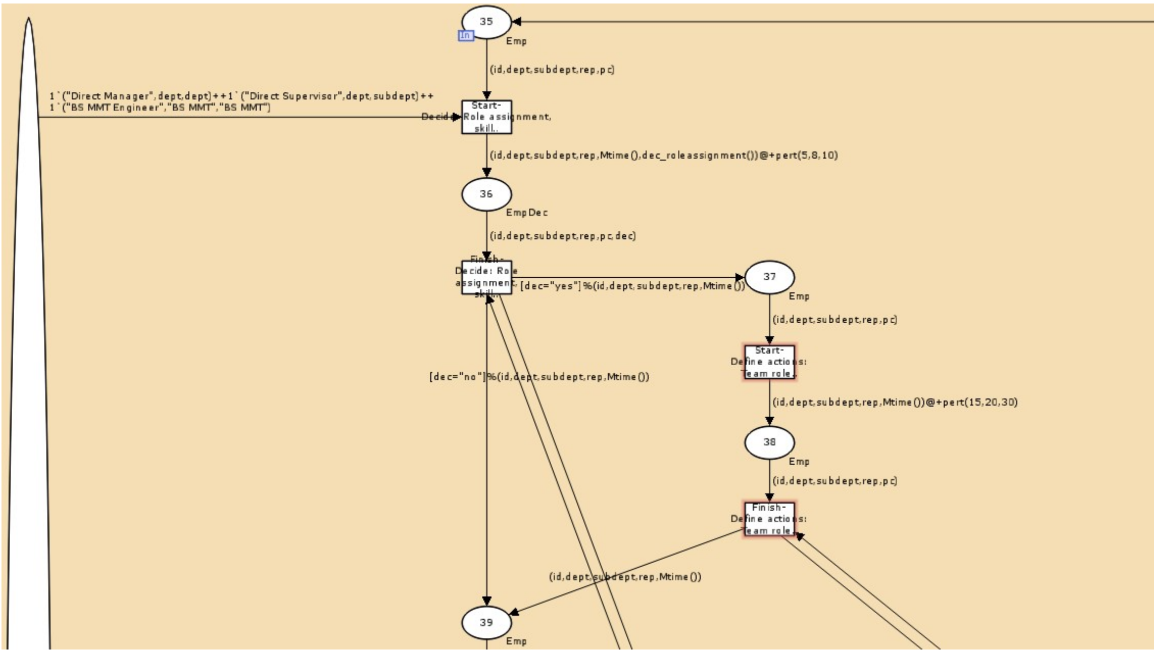

Figure I.4: Screenshot -4-

```
fun undefined() = 1.0/0.0 and erlang_treshold() = 0.0000000000000001 and
beta_pert(l, h, m) = if l<m andalso m<h then beta(l, h, (l+4.0*m+h)/6.0, (h-l)*(h-l)/36.0) else undefined() and
beta(l, h, m, v) = if l<h then l+(h-l)*beta_std((m-l)/(h-l), v/((h-l)*(h-l))) else undefined() and
beta_std(m, v) = if m*(1.0-m) > v then beta_01(m*(m*(1.0-m)/v-1.0), (1.0-m)*(m*(1.0-m)/v-1.0)) else undefined() and
beta_01(a,b) = if a<2.0 andalso b<2.0 then pow2beta(Math.pow(uniform(0.0,1.0), 1.0/a), Math.pow(uniform(0.0,1.0),1.0/b), a, b)
else gamma2beta(gamma(1.0, a), gamma(1.0, b)) and
pow2beta(x, y, a, b) = if x+y>1.0 then beta_01(a,b) else x/(x+y) and
gamma2beta(a, b) = a/(a+b) and
gamma(l, k) = gamma1(l, k, 1.0) and
gamma1(l, k, r) = if k>1.0-erlang_treshold() then gamma1(l, k-1.0, r*uniform(0.0,1.0))
else ((if k>erlang_treshold() then 0.0-beta_01(k, 1.0-k) else 0.0)*Math.ln(uniform(0.0,1.0))-Math.ln(r))/l;
```

Figure I.5: Pert Analysis

```
fun producenew(id:INT)=
let
  val d = discrete(0,133);
in
  if (d<1) then (id+1,"AM","EL2","No",Mtime()) else if (d>0 andalso d<8) then
 (id+1,"AM","WSN1","No",Mtime()) else if (d>7 andalso d<12) then
 (id+1,"AM","WSN3","No",Mtime()) else if (d>11 andalso d<19) then
 (id+1,"AM","WSN4","No",Mtime()) else if (d>18 andalso d<23) then
 (id+1,"AM","WSN5","No",Mtime()) else if (d>22 andalso d<27) then
 (id+1,"AM","WSX1","No",Mtime()) else if (d>26 andalso d<32) then
 (id+1,"AO","IL1","No",Mtime()) else if (d>31 andalso d<34) then
 (id+1,"AO","LA","No",Mtime()) else if (d>33 andalso d<36) then
 (id+1,"AO","MF1","No",Mtime()) else if (d>35 andalso d<37) then
 (id+1,"AO","MF2","No",Mtime()) else if (d>36 andalso d<38) then
 (id+1,"FASY","CABINASSY1","No",Mtime()) else if (d>37 andalso d<39) then
 (id+1,"FASY","CABINASSY2","No",Mtime()) else if (d>38 andalso d<41) then
 (id+1,"FASY","FASY1","No",Mtime()) else if  (d>40 andalso d<43) then
 (id+1,"FASY","FASY2","No",Mtime()) else if (d>42 andalso d<46) then
 (id+1,"FASY","FASY3","No",Mtime()) else if (d>45 andalso d<50) then
 (id+1,"FASY","FASY4","No",Mtime()) else if (d>49 andalso d<51) then
 (id+1,"FASY","FASY5","No",Mtime()) else if (d>50 andalso d<53) then
 (id+1,"FASY","FASY6","No",Mtime()) else if (d>52 andalso d<55) then
 (id+1,"SIE","SIE2","No",Mtime()) else if (d>54 andalso d<87) then
 (id+1,"SIE","SIE6","No",Mtime()) else if (d>86 andalso d<88) then
 (id+1,"PM","PMA","No",Mtime()) else if (d>87 andalso d<90) then
 (id+1,"PM","PMB","No",Mtime()) else if (d>89 andalso d<91) then
 (id+1,"VT","VT1A","No",Mtime()) else if (d>90 andalso d<92) then
 (id+1,"VT","VT2A","No",Mtime()) else if (d>91 andalso d<94) then
 (id+1,"VT","VT2B","No",Mtime()) else if (d>93 andalso d<95) then
 (id+1,"VT","VT3B","No",Mtime()) else if (d>94 andalso d<97) then
 (id+1,"TPG","TPG1A","No",Mtime()) else if (d>96 andalso d<99) then
 (id+1,"TPG","TPG2A","No",Mtime()) else if (d>98 andalso d<100) then
 (id+1,"TPG","TPG1B","No",Mtime()) else if (d>99 andalso d<101) then
 (id+1,"TPG","TPG2B","No",Mtime()) else if (d>100 andalso d<104) then
 (id+1,"TPG","TPG3","No",Mtime()) else if (d>103 andalso d<108) then
 (id+1,"TPG","TPG4","No",Mtime()) else if (d>107 andalso d<112) then
 (id+1,"TPG","TPG5A","No",Mtime()) else if (d>111 andalso d<125) then
 (id+1,"TPG","PP","No",Mtime()) else if (d>124 andalso d<128) then
 (id+1,"VIS","VIS1","No",Mtime()) else if (d>127 andalso d<130) then
 (id+1,"VIS","VIS2","No",Mtime()) else if (d>129 andalso d<133) then
 (id+1,"VIS","VIS3","No",Mtime()) else (id+1,"VIS","VIS4","No",Mtime())
end
```

Figure I.6: Distribution of Incoming New Hires

```
fun interarrivaltime() =
 round(exponential(12.88/24000.0));
```

Figure I.7: Interarrival of Incoming New Hires

```
fun dec_approveactualskilllevel() =
let
  val d = discrete(0,99);
in
  if (d<90) then "yes"
  else "no"
end
fun dec_acceptoffering() =
let
  val d = discrete(0,99);
in
  if (d<50) then "yes"
  else "no"
end
fun dec_acceptinvitationoffering() =
let
  val d = discrete(0,99);
in
  if (d<80) then "yes"
  else "no"
end
```

Figure I.8: Routing Probability Sample

```
▼Monitor ML Skill and Learning Process Throughput Time
  ▶Type: Data collection
  ▶Nodes ordered by pages
  ▶Predicate
  ▼Observer
     fun obs (bindelem) =
     let
      fun obsBindElem (Manage_ML_Skill'Calculate_Throughput_Time (1,
                        {counter,dept,id,pc,pc1,rep,
                        subdept})) = Mtime()-pc1
        | obsBindElem _ = ~1
     in
      obsBindElem bindelem
     end
  ▶Init function
  ▶Stop
```

Figure I.9: Monitoring of a Throughput Time Sample

```
▼Monitor Update LMS learning History Waiting Time
  ▶Type: Data collection
  ▶Nodes ordered by pages
  ▶Predicate
  ▼Observer
     fun obs (bindelem) =
     let
      fun obsBindElem (Manage_ML_Skill'Calculate_waiting_time (1,
                        {dept,id,pc,rep,subdept})) = Mtime()-pc
        | obsBindElem _ = ~1
     in
      obsBindElem bindelem
     end
  ▶Init function
  ▶Stop
```

Figure I.10: Monitoring of a Waiting Time Sample

```
▼Monitor Accept Invitation Offering Queue Time
  ▶Type: Data collection
  ▶Nodes ordered by pages
  ▶Predicate
  ▼Observer
     fun obs (bindelem) =
     let
      fun obsBindElem (Manage_ML_Skill'Start (1,
                        {dept,id,pc,rep,subdept})) = Mtime()-pc
        | obsBindElem _ = ~1
     in
      obsBindElem bindelem
     end
  ▶Init function
  ▶Stop
```

Figure I.11: Monitoring of a Queue Time Sample