MASTER

Business process simulation in healthcare
an initial characterization to model resources in healthcare processes

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Business process simulation in healthcare: An initial characterization to model resources in healthcare processes

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Preface

This report is the results of my graduation project of the Master study Operations, Management and Logistics, at the Eindhoven University of Technology (TU/e). This project is carried out within the Information Systems group of the department Industrial Engineering & Innovation Sciences. The master thesis project is conducted within the "Libra Zorg Groep". I would like to thank the Libra organization to give me the opportunity to carry out a real life case in my graduation process. Also, the opportunity of the vacation job during the summer period helped me to come acquainted with the organization.

I would thank the employees of Libra which are involved in this project. Especially, I would thank Marika Trieling. Her contribution to this project was very valuable for me. Also, her criticism opinion during the project helped me to improve this end product. Further, many thanks to Angela Bod and Liesbeth Tienkamp. Both helped me, when I had questions about the processes of Libra or about the data that was needed in the simulation model.

Next, I would thank my supervisors of the TU/e. Firstly, I would thank Irene Vanderfeesten for her support and input during my graduation project. Also, her critical feedback was valuable to improve my graduation project. Secondly, I would thank my second supervisor Pieter Van Gorp for his objective review during the project.

Finally, many thanks to my family and friends. Their support, interests and faith helped me to finish this master thesis project.

Roel Sillekens
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Abstract

In the past simulation is not used much for healthcare processes. The main reasons are that simulation was not developed for healthcare and that healthcare processes are more complex than processes in manufacturing. One of the differences between these sectors is the active resources. In healthcare processes the active resources are humans and in manufacturing these active resources are machines. Humans are more difficult to model since these are more dynamic and thus less straightforward than machines. The behavior of the machines can be estimated by a probability distribution. In this project a research is carried out to identify the most important characteristics of active resources in healthcare processes. Since no concrete information is available in the literature, it is not clear which characteristics of the active resources should be taken into account in a healthcare simulation study. Therefore, an initial simulation study is carried out to get some first ideas to what important characteristics are of active resources in healthcare processes. Also, two other healthcare cases are used to identify the most important characteristics of resources in healthcare processes. The three cases are analyzed using the typology for resource profiling and modeling of Jenkins and Rice (2007). The result is an initial characterization (framework) that consists of the most important characteristics of the active healthcare resources that are needed to develop good simulation models. The most important characteristics in the characterization are implemented in two well-known simulation programs to show that these characteristics can be modeled adequately in existing simulation tools.

Glossary and definitions

- Libra – Libra Care group (in Dutch: Libra Zorggroep)
- RCB – Rehabilitation Centre Blixembosch
- Team VI – Team that treated patients with chronic pain complaints
- PBS – Patient discussion meeting (in Dutch: patiënten bespreking). All involved therapists discuss the progress of the patient(s) in a meeting during the observation phase and treatment phase.
- Capacity of therapist – Number of hours that the therapist is available for care giving (direct and indirect patient bounded hours)
- Availability of therapist- Weekly scheme that consists the working days and times of the therapist
- DBC – Diagnose treatment combination (in Dutch: Diagnose Behandel Combinatie). The new way to calculate the cash Libra gets from the insurances. The calculation method is given in appendix B.
- RBU – Rehabilitation treatment hour (in Dutch: Revalidatie Behandel Uur). The old way to calculate the cash Libra gets from the insurances. The calculation method is given in appendix B.
- Patient bounded hours – The amount of time that the therapist has to spend to patients. This can be divided into two groups: direct and indirect.
    - Direct time is the time that therapists are busy for a patient and the patient is present.
    - Indirect time is the time that therapists are busy for a patient, but the patient is not present.
- As-is situation – Current situation
- To-be situation – Possible future situation
- FT – Abbreviation for the work discipline physiotherapy
- ET– Abbreviation for the work discipline occupational therapy
- MW– Abbreviation for the work discipline social worker
- PSY– Abbreviation for the work discipline psychology
- BA– Abbreviation for the work discipline movement therapy (in Dutch: Bewegingsagogie)
- RA– Abbreviation for the work discipline physician
- LB – Lower bound of confidence interval
- UB – Upper bound of confidence interval
- MDL – Gastroenterology (in Dutch: Maag, Darm en Lever)

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1. Introduction

This chapter first introduces the objective and motivation of this master thesis project. Next, it provides an overview of the work that has been done throughout the project. Finally, the structure of the remainder of this report is discussed.

1.1 Motivation and objective

Before the mid-1990s, there was a lot of resistance to use simulation for healthcare processes. One reason was that simulation was designed for manufacturing and not for healthcare (McGuire, 1998). In recent years simulation is used more and more for decision making in healthcare processes (Jahangirian et al., 2010), however a few healthcare simulation studies are implemented (Brailsford, 2007). In this master thesis project attention is given to improve the simulation of healthcare processes. Processes in healthcare are uncertain and complex processes with a lot of interacting parts (Brailsford, 2007). One cause of the complexity is the interaction among the entities involved in healthcare processes. In this research, entities are seen as concrete or abstract items that are involved in a process. Examples of entities in healthcare processes are patients, employees, rooms, medicines, treatments and equipment material. Two categories of entities are introduced by Jenkins and Rice (2009): passive entities and active entities. The focus of this project is on healthcare processes with passive clients that are served by active servers. Passive entities go through the process and are involved in activities till the end of the process. Active entities remain in the process and are used to carry out activities. (Jenkins and Rice, 2009)

More specifically, this master thesis project focuses only on the active entities in healthcare processes. These active entities are called resources. The resources in healthcare are different than the resources in manufacturing. A deviation can be made between active resources and passive resources. Active resources are resources which are actively involved in the activities of the process. Passive resources are resources that are involved, but are not actively involved in the activities of the process. Examples of passive resources are rooms and equipment. These resources are similar in healthcare and manufacturing and thus the same characteristics are important in both sectors. Of course, these passive resources can be important in simulation models, but larger differences can be found in the active resources of healthcare and manufacturing processes. Therefore, active resources are more interesting to study and the passive resources are neglected in this study.

The focus of this project is given to the modeling of the active resources in healthcare simulation models. Before these active resources can be modeled should be known what important characteristics are of these resources that should be modeled. The differences between active resources in healthcare and manufacturing are caused by the characteristics of the resources. Active resources in healthcare processes are mostly human beings (physicians, therapists, nurses etc.). In manufacturing the active resources are mostly machines. Humans are much harder to model, because of the difference between characteristics of humans and machines. For example, humans have feeling and emotions what determines their behavior. Also, the situation can influence the behavior of a human. That is why humans are more dynamic than machines and thus human are not as straightforward as machines. Another difference in characteristics of humans and machines is that cognitive abilities and the availability of the resources are more important in healthcare processes than in manufacturing processes. Machines are not dependent on cognitive abilities and are full time available in contrast to human. On the other hand machines can better be described by a probability distribution because machines are more regular and thus predictable. According to this comparison it seems that other characteristics of active resources are important in healthcare processes than in manufacturing processes. These characteristics can be important for the development of good healthcare models. That is why it is important to know which characteristics of healthcare resources are involved in the process.

The aim of this master thesis project is to identify the most important characteristics of active resources in healthcare processes to improve healthcare simulation models. An initial framework (also called characterization) is developed to characterize and define resources in healthcare processes for healthcare simulation models.

The characteristics of the resources in this framework should be easy implemented in the simulation tools. A short evaluation is given about the implementation of this initial characterization into some well-known simulation tools. This should help to improve the modeling of resources in healthcare simulation models in the future.

1.2 Contents of the project

According to the literature review of Sillekens (2011) no concrete information seemed available about healthcare resource characteristics. Also, a relative low number of papers are available that discussed real-life cases in a simulation study compared to the manufacturing sector (Eldabi, 2009). Therefore, it is hard to make a complete overview of the characteristics of healthcare resources. Multiple steps are performed to develop a general framework for healthcare resources. These steps can be found in figure 1. The deliverables are drawn as ovals and the activities are drawn as rectangles. The rectangles in the figures can be related to the chapters in this report.

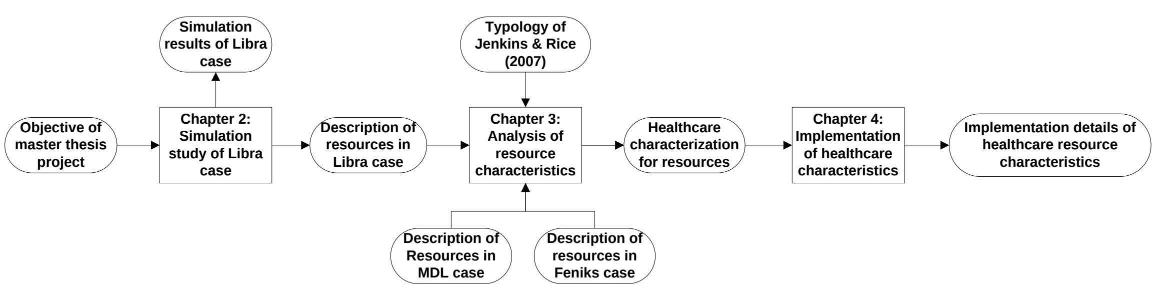

Figure 1: Contents of the project

The starting point of this master thesis project is the objective of this project: the development of a characterization of healthcare resources to improve modeling of future healthcare simulation models. Since no concrete literature is available about characteristics of resources in healthcare, a simulation study is performed to get some initial knowledge and experiences in the important characteristics of resources in healthcare processes. Also, the results of this simulation study can indicate potential important characteristics of healthcare resources. One single case is not enough to get a healthcare broad framework, because there are several types of healthcare processes (core and support) and also the contents of these processes are different (case specific). Therefore, two other healthcare cases are analyzed to develop an initial framework for resources in healthcare processes in general. The framework build on the typology of Jenkins and Rice (2007) is the most important contribution of this master thesis project. The characteristics of this framework are implemented in some well-known simulation tools as a prototype implementation. This implementation shows how these characteristics can be implemented in simulation tools and should help the modeling of healthcare resources in simulation models in the future.

1.3 Structure of report

The structure of the report is related to the contents of the project. The simulation study of a healthcare case is discussed in chapter two. In this chapter the conceptual model, executable model, simulation results and a conclusion is given where a description of the important characteristics of the resources of the case is given. In chapter three, the knowledge of the simulation study, two extra healthcare cases and the typology of Jenkins and Rice (2007) are combined in the analysis to develop an initial framework for healthcare resources. Then, the implementation of this framework into two simulation tools is described in chapter four. Finally, in chapter five the conclusions of this master thesis project are discussed. Also, limitations, future research and reflection of this project are given in this chapter.

2. Case study

This chapter deals with a simulation study with which insights are obtained of important characteristics of active resources in healthcare processes. The simulation design used in this study can be found in appendix A. First, the motivation for this case is described. Then, a description of the Libra organization is given to indicate the involved departments. Next, the problem description is given. Also, the conceptual and executable models of the Libra process are discussed. Then, the results of the simulation study are given. Finally, the lessons learned about the characteristics of resources in healthcare from this simulation study are given.

2.1 Motivation for case study

Simulation of healthcare processes is not used a lot, because of several reasons as described in the introduction. Healthcare are dynamic processes and simulation is appropriate to analyze such dynamic processes (Baldwin, Eldabi & Paul, 2004) Therefore, simulation should be helpful in the analysis of healthcare processes, but the practice shows that is quite difficult to model healthcare processes in a desired way. A possible cause of the bad models is that characteristics of resources in healthcare and manufacturing are different from each other. It is not known which characteristics of the resources are important in healthcare processes. Also, no concrete literature exists with this information. A simulation study is performed to get some initial ideas, knowledge and experiences of the characteristics of resources in healthcare processes. Besides, the simulation study can deliver valuable information for the organization where the simulation study is performed.

The case study analyzed in this project is a process in the rehabilitation care. The rehabilitation care focuses on the quality of life for people with disabilities at all life stages. These disabilities can be physical or cognitive. Rehabilitation organizations provide specialized diagnosis, treatment, care, support and advice to patients in order to improve the lives of the patients (Missie, visie Libra zorggroep, n.a.). This rehabilitation process consists of two phases: observation and treatment phase. In the observation phase the patient is observed to identify whether the rehabilitation center can help the patient and what treatment should be given in the treatment phase. The observation and treatment phase consists of a number of treatments from several disciplines (like physiotherapy, occupational therapy, social work and psychology) during a number of weeks. The involvement of resources from several disciplines gives the rehabilitation care a multidisciplinary character and makes the rehabilitation process complex. In this case study, the involvement of resources in a rehabilitation process of the Libra Care Group (further called Libra), is analyzed. The aim of Libra is to get insights in the consequences on the production results if processes (parameters) of the employability of the resources are changed, since these are unclear at this moment.

2.2 Background

This case study is focused on the rehabilitation organization called "Libra Zorg Groep". Several institutions are part of the Libra organization: Audiology Centre Brabant, Rehabilitation centre Blixembosch (RCB), Gemini care and services and Rehabilitation centre Leijpark (Over ons, n.a.). The organizational chart of Libra is given in appendix B.

The case study is carried out for the department "Kenniscentrum Onderzoek, Innovatie en Kwaliteit". This department is involved in research, innovation and quality (Kennis, onderzoek en innovatie, n.a.).

- The research part focuses on promoting of evidence based practice in care giving, treating and counseling.
- The innovation part focuses on improving and renovating existing products, processes and services. The innovation part also focuses on the use of knowledge, skills and expertise for innovation of (co-) partners.
- The quality part focuses on continuous improvement, implementation and securing of work methods and treatment methods.

This case study is carried out in a part of RCB. The care giving in RCB is divided into a number of teams. Each team treats their own patient groups (including, among others, chronic pain patients, acquired brain injury patients and neurologic patients). This project focuses on the team that treats patients with chronic pain complaints, also called team VI. Three types of patients are treated in this team: heart patients, lung patients and pain patients. The focus in this project is on the group of pain patients.

The care giving in team VI is outpatient. Patients have to come to the rehabilitation centre when they take part in a treatment. Care packages are assigned to patients using predefined care programs (also called treatment programs or programs). A care program is a program that consists of treatments from the several work disciplines and is largely the same for all patients. Some optional treatments (treatments not involved by all patients) can result in differences in a treatment program. The care programs are introduced in September 2010 in order to improve the care giving to patients. In the planning process of these treatment programs the patient aspect is taken into account with respect to the number of treatment days per week and the time between two treatments on a day.

2.3 Problem statement

The process of the care giving in rehabilitation is complex due to the multidisciplinary character of the rehabilitation processes. This multidisciplinary character causes that a good coordination in care contents aspects and in organizational aspects is necessary (Braaksma, n.a.). To improve the coordination of the care contents and the organizational aspects during theses phases, team VI of RCB has been involved in healthcare logistic changes last years.

In March 2008 the first changes were implemented. The focus was to organize processes and to describe the treatment components. Throughput times for patients in observation phase and treatment phase were determined. A year later it turned out that the waiting times between the end observation and start treatment programs went up. Even, it seemed difficult to steer available treatment capacity in advance and the communication with patients needed further optimization. In September 2010 the team started working with the care programs. Some student projects are carried out at the Eindhoven University of Technology to give Libra more insights in the process. It seemed that the simulation tool used in these student projects has their limitations in especially the modeling of the availability of therapists.

Objective

After the analysis of the last year production figures of team VI it seemed that, given the available treatment capacity of the therapists, the production of the team was too low. This low production is caused by the gaps within the treatment schedules of the therapists. The availability of the therapists is very important in this case, because in some treatments multiple therapists are involved. The planning of these treatments is difficult and is probably a reason for the gaps in the treatments schedules of the therapists. The objective of this case study for Libra is to get more insights on the production results in combination with changed process (parameters) redesigns. Libra wants some insights on changes of the employability of the resources on the production results so that Libra can anticipate adequately in the future.

Performance indicators

The performance indicators are the variables that indicate the performance of the process. Multiple performance indicators are relevant in this project. Some of these performance indicators are not in line with each other. For example, if the capacity needed increases, the capacity used will not change necessary with the same level due to the limited available capacity. The performance indicators used in this project are:

- Capacity of therapists needed per discipline to carry out all planned treatments of the patients during a week (in hours)
- Capacity of therapists needed per discipline to carry out all planned treatments of the patients during a year (in hours)
- Average utilization of the work disciplines per year (in percentage)
- Capacity of the therapists used per discipline for the continued treatments of the patients during one week (in hours)
- Capacity of the therapists used per discipline for the continued treatments of the patients during one year (in hours)
- The production level during a year (in DBC and RBU level)
- Percentage of missed treatments (in percentage)
- Average production per patient per treatment program inclusive observation (in DBC and RBU level)
- Average waiting time per patient per treatment program (in weeks)
- Number of patients finished per program in a year (in patients)

Decision variables

The decision variables are the parameters that can be changed in the experiments to analyze the performance of a system. The performance is measured by means of the performance indicators listed above. The decision variables of this study are parameters which Libra can manage. For this case study the decision variables, which has effects on the employability of the therapists, are important (direct or indirect). Changed capacity has direct effect on the employability of the resources. The start of the programs has indirect effect on the employability of the resources. When the start of the programs is changed, the capacity needed of the therapists will also change. Possible decision variables in this project are:

1. Number of patients in a group treatment program
2. Capacity per week of the therapists
3. Work schedules of the therapists
4. Arrival rate of patients
5. Start weeks of programs
6. Maximal number of observations per week
7. Amount of treatments in an observation or treatment program

Not all decision variable are used in this simulation study, because of time limitations in this project it is not possible to run multiple simulations of every decision variable. Next to these decision variables, redesigns of the process can be made in which the resources are employed differently. This change in the employability of the resources can have also consequences on the process.

2.3 Conceptual model

The conceptual model is an important part in a simulation study (Sillekens, 2011). The conceptual model describes in an abstract way the real process. The model for the treatment of the patients with chronic pain complaints is given in figure 2.

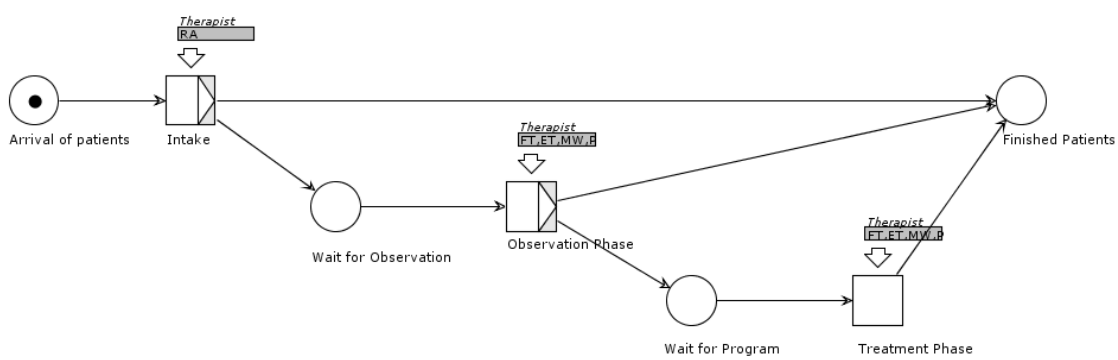

Figure 2: Conceptual model of process of team VI

Three parts can be distinguished in the process of pain patients: intake meeting, observation phase and treatment phase. Patients are the input of this process. Patients are sent to the rehabilitation centre by a referrer. An intake occurs by a physician. The patient is referred to the observation phase when the physician thinks that the rehabilitation centre can help the patient. Otherwise the patient is send back to the referrer. Every week seven observations can start. The observation is carried out to decide whether rehabilitation is appropriate for the patient. If rehabilitation is appropriate for the patient the observation results are used to decide which care and thus which program (I, II, III, IV or V) can help the patient best. Then, the patient has to wait till the program start. The start weeks of the treatment programs are predefined and limited to a maximum number of patients. After the start of the program, the patients do several activities dependent on the program they are referred. After the treatment phase is finished the patients are ready with the rehabilitation process. It is also possible that after the observation phase no further treatment is necessary. Then the patient is ready after the observation phase.

In the observation and treatment phase several types of activities are carried out. Note that not all activities are present in the observation phase or treatment phase. Possible activities of the observation or treatment phase:

- Introduction: Initial meeting in program I, II and III to start the treatment phase.
- Individual treatment: Activities in observation and treatment phase in which one patient is treated by one therapist.
- Group treatment: Activities in program I, II and III in which several patients are treated by one or two therapists.
- Optional treatment: Activity in program III, IV and V that a part of the patients carry out.
- Administration: Therapists report the treatment process of the patient after the observation phase and treatment phase.
- Patient discussion: All involved therapists discuss the progress of the patient(s) in a meeting during the observation phase and treatment phase.
- Control session: Final session at the end of the observation and treatment phase to finish the phase.
- Come-back hour: Meeting with the patient a couple of weeks after finishing program I and II as kind of aftercare.

To carry out these activities resources are used. Resources in this process are the therapists of Libra. The availability, capacity and discipline are important characteristics of the resources in the case study. It is important when and how much the therapists can carry out treatments. Also, the treatments cannot carried out by all therapists, but is dependent of content of the treatment. Therapists of the following disciplines are involved in the activities of this process:

- Physiotherapy (FT)
- Occupational therapy (ET)
- Social Work (MW)
- Psychology (PSY)
- Movement therapy (BA)
- Physician (RA)

The production in this process is calculated in DBC and RBU. DBC and RBU are terms to calculate the amount of money Libra can declare from the care assurances. The DBC is a new calculation method that replaces the RBU method. The level of DBC and RBU is dependent on the amount of the treatment that the patient has followed. In the DBC calculation the direct (patient present in the treatment) and indirect (patient not present in the treatment) patient bounded time are counted. In RBU only the direct patient bounded hours is counted. In the RBU also a group factor (extra compensation for treatments in a group) is used for the group treatments. This group factor is not available in the DBC. The formulas to calculate the DBC and RBU level can be found in appendix C.

2.4 Scope

As discussed in the background section, this project focuses on the observation and treatment phase of the patient with chronic pain complaints (team VI) in RCB. In this team, three types of patients are treated: heart patients, lung patients and pain patients. The focus of this project is only the group of pain patients. The other patients groups are out of the scope of this project, because the design of the treatment process is different from the treatment process of the pain patients.

In the previous section the conceptual model for the pain patients is discussed. For this project not the complete process is relevant, because not all resources are within the scope of this project. The focus is on the therapists of the disciplines FT, ET, MW and PSY. The therapists of BA have unlimited capacity, because it seemed that therapists of BA are available when they are needed. Also, these therapists of BA are employed in all teams of RCB and are planned differently. However, the BA is included to calculate the level of DBC and RBU and therefore the therapists of BA are also taken into account in this model. Resources of RA (physicians) are left out of the scope, because it is hard to determine the capacity of these resources for the only the pain patients of team VI. The reason is that resources of RA are involved in other activities, like the treatments of the heart and lung patients. The resources of RA are only involved in the intake, patient discussion and control session in the pain process. The activities in which only a resource of RA is involved will be neglected. Thus, the intake and some control sessions are neglected in this model. The patient discussion and the other control sessions are taken into account, because also other therapists are involved in these activities. Note that the absence of the resources of RA in the model will bias the DBC and RBU level. These levels will be higher if the resources of RA are included in the model

The body group treatment is also left out of the scope. This is a separate module of treatments that can be followed by patients of team VI, but also by patients of other teams. Only patients of team VI are modeled in this model and therefore the body group is left out of the scope. Also, the therapist of the body group treatment is only involved in this treatment and is not involved in the other activities of this team. Note that the absence of the body group will also bias the DBC and RBU level. This level will be higher if the body group treatment is included in the model.

Further, illness of therapists is left out of the scope. Illness cannot taken into account in the planning, because this will occur unexpectedly. Of course this has effects on the real results, but the expectation is that illness is similar in all situations and thus not relevant for this simulation study.

Finally, the rooms are left out of the scope. This can be an important aspect in the treatment process, since rooms should be available for a treatment of a patient. However, the rooms in RCB are used by all teams and not only by team VI. The absence of the usage of the rooms in the other teams causes that the rooms are neglected in this project. The rooms are more frequently occupied than only for team VI and thus the rooms is not relevant when modeling the process of team VI only.

2.5 Executable model

In this section the executable model is described. The model described in this section will mostly approach the as-is situation and is called further *base model*. ARENA is chosen as simulation tool in this case study. The explanation for this choice can be found in appendix D. In this section the important characteristics and design choices of the executable model are given. Then, the assumptions of the executable model are given. Finally, some limitations of the model are mentioned. The verification and validation of this model can be found in appendix E and F. This section gives a first idea in which characteristics of the resources are important in this healthcare process and how these can be modeled in the simulation model. It is also possible that the modeling of the characteristics results in assumption in the simulation model or even limitations of the simulation model.

2.5.1 Characteristics and design choices

The flow of the patients, employability of therapists, observation phase, treatment phase and calendar are discussed in more detail. Also, the design choices used to model the characteristics are discussed in this section.

Patients

The patients arrive to the rehabilitation centre according to a Poisson distribution. The calculation of the inter-arrival time can be found in appendix G. All patients that arrive to the system go to the observation phase. Every week a maximum of seven observations can start. When there are more patients waiting these are waiting until they can start. The content of the observation phase is explained below in more detail. After the observation the patient has two possibilities. The first possibility is that the patient is referred to a treatment program. The distribution of patients over the treatment programs is given in appendix H. The treatment programs start on predefined weeks with a maximum number of patients. If more patients are waiting these patients have to wait till a next start of the program. The treatment phase is also discussed below in more detail. The patient is ready when the treatment program is finished. The second possibility is that no treatment program is needed after the observation. Then, the patient is finished. For each patient the DBC, RBU and waiting time between end observation and start treatment phase are stored.

The patients are as follows modelled in ARENA. Individual patients arrive to the system. These patients are individually sent through the observations and individual programs. However, in the group programs multiple patients are sent through the program as one group. Before an individual treatment (in the group program) the group is split so that individual patients can execute this treatment. After the individual treatment the group is regrouped for the rest of the group treatment phase.

Therapists
The therapists of disciplines FT, ET, MW, PSY and BA are the resources of the model. For each resource it is important to know in what discipline the therapist works and thus what kind of activities the therapists can carry out. Therapists of BA are unlimited available and are modelled with unlimited capacity. For each therapist of the other disciplines the individual work times are modelled (see appendix I). Also, the capacity that is assigned to the therapists for the pain patients is modelled, because the therapists also perform other activities during the work times. These other activities fell out of the scope, like heart and lung treatments. The capacity of the therapists consists of direct and indirect patient bounded hours and can be found in table 1. The calculation method of these times can be found in appendix J. Also, the total available hours per discipline are given. The performance indicator for the resources is the utilization.

Therapist	**Capacity (hours)**	**Therapist**	**Capacity (hours)**	**Therapist**	**Capacity (hours)**	**Therapist**	**Capacity (hours)**
FT1	**13.76**	**ET1**	**18.17**	**MW1**	**15.17**	**PSY1**	**11.07**
FT2	**19.13**	**ET2**	**10.56**	**MW2**	**7.58**	**PSY2**	**11.38**
FT3	**11.38**	**ET3**	**13.04**			**PSY3**	**2.84**
FT4	**20.76**	**ET4**	**17.70**				
FT10	**1.75**	**ET5**	**2.00**				
Total	66.78	Total	61.48	Total	22.75	Total	25.29

Table 1: Capacity hours per therapist per week

For the modelling of the resources a design choice is made. Due to general activities, like discussion and study hours, the work times of the therapist are larger than the capacity of the therapist per week. To model these aspects separate this will approach the reality more, but has also some limitations. This limitation will be discussed in the section 2.5.3.

Observation phase
The start weeks of the observation program are given in an Excel-file. In this case every week observations are started and thus every week number is in the Excel-file. Then, the fixed therapists are stored in the attributes of the patients. Therapists are chosen according to their availability. Not all therapists can do activities in all programs. Therefore, the chance that the therapists is chosen is the capacity of the therapists divided by the capacity of the therapists who can carry out the activity (see appendix K for the table in which the therapists per program are given). If the patient is assigned to the therapists, the observation phase can start. In week one and two the observations take place. The observations that should be carried out are read from an Excel-file. In appendix L an overview of the treatments per week is given. The routing of the treatments does not really matter, but two same treatments may not occur on one day. This is as follows modeled in ARENA. Randomly, a treatment is chosen. For this treatment is checked whether it has still to be done in that week, whether the therapists are available and that the treatment is not carried out on that day already. If this is not the case the treatment can be carried out, otherwise a new treatment is chosen. To prevent a deadlock, a maximum of 50 iterations is allowed. If no appropriate treatment is found the model proceeds 15 minutes and the process of treatment selection starts again. When the patients have no treatments left, the patient will wait till next week before the patient can

proceed. If not all treatments can be carried out in that week, the missed treatments are stored and the patients proceeds in the next week. In week 3 the therapists do the administration activities. During these activities the patient is not present. In week 4 the PBS is executed with all therapists that are involved in the treatments (also without patient). Actually a control session is carried out after the PBS, but since the control session is carried out by a physician this is left out of the model. In this phase is determined whether the patients is referred to the treatment phase or that the patient is finished. 346 observations are started in 2012.

Treatment phase

If in the observation phase appears that the patient can be helped at the rehabilitation centre the patient is referred to one of the five treatment programs. Program I, II and III are group programs. The size of the group is the number of waiting patients at the start of a new treatment program with a maximum of 9, 8, 6 for program I, II and III respectively. Program IV and V are individual programs. The treatment programs start on predefined weeks. The planning of 2011 and 2012 is used in this simulation study (see appendix M). This planning is made using the expected number of patients in combination with the deviation over the programs. In an Excel-file the start weeks are specified. Fixed therapists are assigned to the patients in the same way as in the observation phase. In program I, II and III an introduction meeting starts the program. Then the treatments are carried out during 10 weeks in program I, II and III and 12 weeks in IV and V. In every week the treatments that has to be done are read from an excel files. In appendix L, an overview is given of the treatments that should be carried out per program. Note that three types of treatments are in the programs: optional, individual and group. The routing of the treatments is determined in the same way as in the observation phase. Note that the PBS is included in these treatment weeks in the group programs. The optional treatments are modelled using two random numbers between (for MW and PSY) one and hundred for all patients. If the values is higher than 50, the optional treatment will be given. Otherwise the patient will not get the individual treatment. The administration is done in the week after the treatments in all programs. One week later the PBS of the individual programs is done and the control session is carried out if a therapist of PSY is involved (otherwise the control session fell out of the scope). In program I and II a return session is organized ten weeks after the control session. The number of program starts in 2012 can be found in table 2.

Treatment program	Number of starts in 2012
Program I	**8**
Program II	**7**
Program III	**7**
Program IV	**31**
Program V	**37**

Table 2: Number of program starts

Calendar

The last design choice relates to the time of the model. The work hours of the therapists are different from each other. To put the work hours of the therapists in the model chosen is to model 12 hours per day (from 6.00h till 18.00h). This ensures that for all therapists the correct work times can be modeled. Therefore, also an own calendar function is made, instead of using the calendar of ARENA. The main reason is that signals will be sent when a new week starts, performance indicators can weekly written to Excel and the weekly parameters can be reset using the developed calendar function. This is not possible using the ARENA clock.

2.5.2 Assumptions

During the development of the model a number of assumptions are made. These assumptions are listed below.

1. The arrival of patient to the observation is approached using a Poisson processes. The inter-arrival time is exponential distributed with mean 9.02 hours (see appendix G for this calculation). An exponential distribution is a good option to model the arrival of patients in healthcare (lowery, 1996).
2. All treatments will start in work time of the therapist, but can be finished in non-work time. In the case that a treatment will not be finished in work time, the therapists works some time longer to finish the patient. As compensation, the therapists will start this time later the next time the therapist starts. One precondition is that the therapists will have enough capacity left in that week. This assumption is acceptable since the therapists are not working more than in their contract and the overtime hours will be compensated on another day. In reality is expected that the therapists are indeed flexible with their work times and overtime will incidentally accepted.
3. The assignment of the fixed therapists is based depending on the weekly capacity of the therapist. A therapist that is working more has a larger chance to be chosen than a therapist who works fewer hours per week. This assumption prevents that therapists with a small contract will have to do the same as the therapists with large contract. This assumption is made to divide the work over the therapists in this model. In reality the planning employee knows which therapists has still place and can do the treatment, but that is not possible in the model.
4. The patient wishes are left out of the scope of this project. Absence, time between treatments, number of treatment days or preference days are not taken into account, because the main objective of the study is to get insights in the performance of the system in several situations. Therapists (of the disciplines FT, ET, MW and PSY) are more important than the wishes of the patient. This assumption is acceptable, because in reality it is indeed more important to proceed all treatments with the therapists. If possible, the wishes of the patient can be added.
5. Only one swimming pool is available, because otherwise a lot patient can swim at the same time, because the therapists for swimming (BA) are unlimited available. In reality the other rooms could be a problem, but are left out of scope of this project.

6. Missed treatments will not be overtaken. When a patient missed a treatment during a week this treatment is not overtaken in a later stadium. Otherwise the missed treatments can be stacked. Such stacked treatments causes that the planned treatments will be postponed and it can take some time to finish a complete treatment program. The throughput time will increase and that is not allowed in this process. Therefore, the number of missed treatments are counted and taken into account in the results. This assumption is acceptable when the percentage of missed treatments is low. If the percentage of missed treatments is too high this will result in problems in reality.
7. No patients will leave RCB during the observation or treatment phase. Only after the observation phase a patient can leave when no further treatment is necessary. This assumption is reasonable, because all patients that need the care of a treatment will finish the treatment phase. However, in reality patients will stop during the observation or treatment phase.
8. No replacements of therapists are allowed in the model. When the fixed therapist is not available it is not possible that another therapist will carry out the treatment. The condition that the patients have fixed therapists per treatment is not met if treatments are overtaken. If one therapists of a group is absent this therapist will also not replaced and the treatment will be missed. This is not completely according to the real situation, because in reality treatments will proceed with fewer therapists if possible. However, since illness of therapists is out of the scope this will not affect the results.
9. The transportation time between several treatments is zero. All treatments are carried out at RCB. The rooms of the therapists are close to each other and therefore, no transportation time is counted. This assumption is acceptable and reliable, since the distances are very short. Also, since the throughput time is fixed for the treatment programs, this will have no effect on the results.
10. The capacity of the therapists is assumed. The contract of a therapist consists of direct hours, indirect hours and other time. In the RBU only the direct hours are important. In the DBC also the indirect hours are important. It is not known exactly which percentage of the contract are direct and indirect patient hours and which percentage is other time. Therefore, an assumption (estimation) is made for the percentage of direct and indirect hours per discipline. A deviation of this percentage can prejudice the results of the study. The estimation of percentage direct and indirect hours of the total contract hours can be found in appendix J.

2.5.3 Limitations

The model, as specified in the previous sections, has a number of limitations. These aspects can be improved further to approach the reality more. However, this will also add a lot of complexity to the model.

- Waiting time between treatments and the number of treatment days are not taken into account. These variables should be minimized as much as possible, but in the model these are neglected. These conditions make the planning more difficult, but will not directly affect the outcome parameters. Therefore, this limitation is less important in this case.
- Holidays of therapists are not taken into account (like Easter and Christmas day). In practice RCB is closed on these days and no treatments are carried out. In the planning of the as-is situation these days are taken into account when they make the planning of the year. Therefore, these days are not specifically modelled.
- It is not possible for therapists to get free days in the model. The design choice of the separate work times and capacity made it not possible to give a therapist a specific day free. In reality this is possible, but it is not possible for Libra to take these into account during the planning of the treatment programs during the year.
- The choice of fixed therapists for the patients depends on the capacity per week available (direct and indirect). As discussed before, depending on the therapist that is available and the capacity of the therapist the chance that the therapist is chosen will be calculated. The limitation is that the already capacity used is not taken into account. However, the arrival of patients and the maximal number of patient that can start with the observation phase will prevent that too much new patients can arrive and start with the treatment program at the same time.
- The routing of treatments is a limitation of this model. In reality the planning employee determines the order and can change the planning several times (iterative process). The disadvantage is that this cannot be modelled in ARENA. A design choice is made to model the routing based on chances. In the model a treatment is chosen and if the therapist is not available or the treatment is already carried out, another treatment is chosen. Determination of the order using chance will not result in an optimal solution and the amount of missed treatments in this model will be too high. Another routing method may results in better results.
- In program I and II the MW individual treatments are for all patients planned in one week. In reality these are divided over three weeks. For some treatments it is possible that some treatments can be better carried out a week later. This is not taken into account in the model.
- The RA activities and the body group module are left out of the scope. This will have effect on the level of DBC and RBU. The real value will increase due to the absence of the RA and body group module.
- PBS is carried out with all therapists that are involved in the treatments. In reality the PBS will also occur when some therapists are not available. So, in the model more PBS are missed than in reality.

2.6 Experiments and results

In the modelling of the executable model some first indications are obtained of what important characteristics are of the active resources in healthcare processes. Also, can be seen how some characteristics can be modelled in the simulation tool. The question is what effects some of these characteristics have on the results of the process. Therefore, some simulation experiments are described to analyze the importance of the characteristics of the healthcare resources. The scenarios are based on some research questions of Libra on the employability of resources in the process. These research questions can be found in appendix N. Finally, the results of the simulation study are discussed. The conclusions on these research questions for Libra can be found in appendix O.

2.6.1 Experiments

The research questions are especially related to the employability of the resources in the process. The simulation model has a number of decision variables (section 2.3) whereby the employability of the resources changed. A lot of experiments can be made using a combination of these decision variables. Also, experiments can be made by making a redesign of the process. In this master thesis project ten interesting experiments for Libra are studied in more detail. Each experiment can be described using scenarios. A scenario is a new situation in which new parameter values are used for the decision variables or a redesign of the process is made. These scenarios are interesting for Libra, because these scenarios will help to give answer on the research questions and thus insight in the consequences of the changes. All scenarios are compared to the base model, except scenario 10. This scenario is compared to scenario 9. The base model describes the as-is situation of the model. The ten scenarios describe a new situation in which Libra wants more insights. Below, these scenarios are discussed. The specific changes in parameters values of all scenarios can be found in appendix P.

Scenario 1 – Change in number of patients in a treatment program: This scenario can only applied to the group programs. The size of the individual programs cannot be changed. In this scenario the number of patients in program III is changed. The reason is that a relative small number of patients are send to this group program compared to the other group programs. Therefore, the consideration between the group size and waiting time is extra important. Groups will not be full when the program is started too much and if too less groups are started this will increase the waiting time of a program. The other group programs get more patients and thus groups are faster complete. It is also not really possible to increase the number of patients in these groups, because the workload of the therapists becomes too high. The scenario consists of two sub scenarios. In this scenario two decision variables are changed. A change of the number of patients in a treatment program (decision variable 1), will change the planning of the treatment programs (decision variable 5). An increase in the number of patients in a program will reduce the number of program starts. This will cause that less capacity is needed to carry out all activities. A decrease in the number of patients per program will increase the number of program starts and thus also the capacity that is needed during the year. Dependent on the expected number of program starts needed in the new situation, new start weeks are equally divided over the year.

- **Scenario 1a:** In this scenario the number of patients in treatment program III is decreased from 6 to 4 patients. Since more programs III are needed to treat the same amount of patients, three more programs III are started.
- **Scenario 1b:** The number of patients in treatment program III is increased from 6 to 8 patients. Since fewer programs III are needed to treat the same amount of patients, two less programs III are started.

Scenario 2 – Reduced capacity due to vacations: Capacity of all therapists is reduced (decision variable 2) partly in some vacation weeks (25% in week 9; 50% in week 18 and 42) and reduced to zero in other vacation weeks (in week 1, 28, 29, 30 and 52). In the weeks that no therapists are available the treatment program are postponed. Also, no observations are carried out in these weeks. If the capacity is only reduced (with 25% or 50%) the observations and programs will continue. The capacity in the other weeks will be the same. Libra wants to know the effect of the reduced capacity of the therapists due to the vacation periods.

Scenario 3 – Administration time not planned: In this scenario a redesign of the treatment process is made to make the process more flexible. As a consequence the capacity of the therapists decreases (decision variable 2). In the as-is situation time periods are arranged for the therapist to carry out their administrative tasks. This planned time can be within time that other therapists are available for patients that results in an inefficient planning. Another strategy is that the therapists have to do the administration in "own" time. The therapists have still the same work days and have thus more time to carry out the other treatments. The capacity of the therapists available per week is reduced with 10% of the contract to compensate the administration time during "own" time.

Scenario 4 – Absence of therapists: This scenario describes four sub-scenarios with reduced capacity of a therapist (decision variable 2). In contrast with scenario 2, the capacity is decreased during the whole year. One specific therapist is dropped out of the model. The reasons to drop a particular therapist are contracts with just a few hours and expected absence in reality.

- **Scenario 4a:** The discipline ET has a therapist who has a really small contract in team VI (ET5), because this therapist is hired from another team. Libra wants to know the effect when this 'extra' therapist is not hired anymore. In this scenario the ET with the small contract is dropped out of the model and thus the capacity of the discipline ET is decreased 3.25% (2 hours) per week compared to the base model.
- **Scenario 4b:** The discipline FT has also a therapist with a small contract (FT10). This therapist works normally in another team, but is hired for a couple of hours per week. In this scenario this therapist is left out of the model whereby the capacity of FT is decreased 2.62% (1.75 hours) per week in this scenario compared to the base model.

- **Scenario 4c:** The discipline MW has no therapists of another team, but one therapist will be unavailable for a while (MW1). Libra wants to know what the effect is of the absence of this employee. In other words, the capacity of MW is decreased with 66.68% (15.17 hours) per week compared to the base model. The result is that MW2 has to do all activities of the MW discipline.
- **Scenario 4d:** The discipline PSY has also a therapist with a small contract (PSY3). This therapist is not hired from another team, but has just a small contract. Libra wants to know if this therapist is needed. In this case capacity of PSY is decreased with 11.23% (2.84 hours) per week compared to the base model by dropping PSY3 out of the model.

Scenario 5 – Dynamic starts of treatment programs: In this scenario no decision variable is changed, but a redesign of the treatment process is made. In the as-is situation the treatment programs start on predefined weeks. In advance it is not known how many patients will arrive to the different treatment programs. This causes that the start of the programs are probably not convenient in reality (waiting queues or incomplete groups). To be more flexible a redesign of the process is made. The start of the treatment programs is determined using a different strategy. Instead of the predefined weeks, the treatment program starts when a treatment program is complete (maximal one group can start per week). The availability of the therapists will not change. Two sub scenarios are analyzed.

- **Scenario 5a:** This sub scenario starts when a treatment program is complete instead of the predefined start weeks. The aim is that Libra can react better on the arrival of patients.
- **Scenario 5b:** In this sub-scenario an increase in the number of patients that arrive in a year will be increased with approximately 50 patients (decision variable 4). To treat these patients the number of observation per week is increased to maximal eight. The available capacity will be the same. In this scenario the flexible start is maintained and thus, due to the arrival of more patients, more treatment programs will start during the year. Therefore, more capacity is needed.

2.6.2 Simulation results

Now, the results of the simulation study are discussed. The simulation parameters (replication length, warm-up period and number of replications) used in this study can be found in appendix Q. An overview of the capacity needed per week per discipline in the base model is given in figure 3. In this figure can be seen that in the planning for 2012 the summer period is taken into account (red rectangle). In this period fewer treatments are planned, to give Libra the opportunity to give the therapists vacation. The average capacity needed is compared with the capacity of the therapists per discipline. The capacity needed per week is, on average, less than the available capacity per week for FT (52.8 hours needed and 66.78 hours available) and ET (52.35 hours needed and 61.48 hours available). However, for MW (25.55 hours needed and 22.75 hours available) and PSY (26.65 hours needed and 25.29 hours available) the available capacity per week is, on average, somewhat lower than the needed capacity per week. This will suggest that FT and ET has no capacity problems, but MW and PSY needs extra capacity to carry out all activities of these disciplines in 2012.

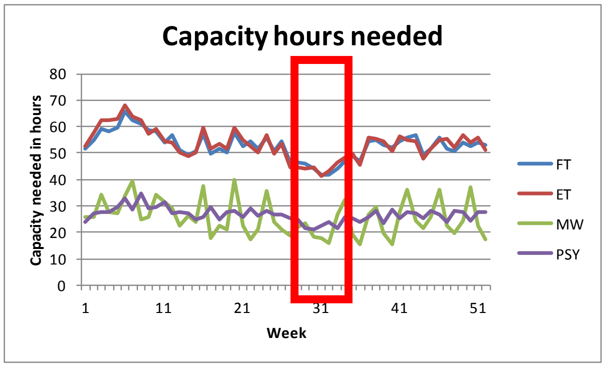

Figure 3: Capacity hours needed per discipline per week - Base model

The other performance indicators are compared in the scenarios using confidence intervals. A significant difference is found when the confidence intervals will not cross each other. The results tables of all performance indicators can be found in appendix R. For each scenario the expectations are discussed followed by the simulation results.

4.6.2.1 Scenario 1 – Change in number of patients in treatment program III

The two sub-scenarios are discussed separately. Note that these two scenarios show opposite behaviour.

Scenario 1a – Decrease in number of patients in program III: The amount of patients in treatment program III is decreased from 6 to 4 patients. Three more starts of program III are needed to treat the same amount of patients. The expectation is that this will increase the capacity that is needed during a year, because more treatments will be carried out. On week level no large differences are expected, because the capacity per week needed in program III is relatively low per discipline. Due to the increase of the capacity needed, the capacity used of the therapists will increase if enough capacity is available. The waiting time between the end observation and start program III will decrease, because of the increase of starts of program III. The level of DBC and RBU of program III will increase, since the same DBC and RBU is divided over fewer patients. In the other programs no changes are expected.

The capacity needed per discipline per week is changed a little due to the increase of program III starts. However, in the overview no clear distinction is found as expected (see appendix S for the figure of the overview of capacity needed), because the differences in capacity needed per discipline per week are too small to indicate in this figure. On year level, bigger differences can be found. It seems that the capacity hours needed in 2012 of all disciplines together is indeed higher in scenario 1a compared to the base model, but no significant difference is found (figure 4). However, in the disciplines FT and ET a significant difference is found (figure 4). The decrease in the number of patients in program III cost more capacity of FT (1.3 hours per week) and ET (1.4 hours per week), but will have fewer effects on the disciplines MW (0.2 hours per week) and PSY (0.3 hours per week). Apparently are these disciplines less involved in this program.

Nevertheless the overall capacity increases approximately with 175 hours per year (3.2 hours per week).

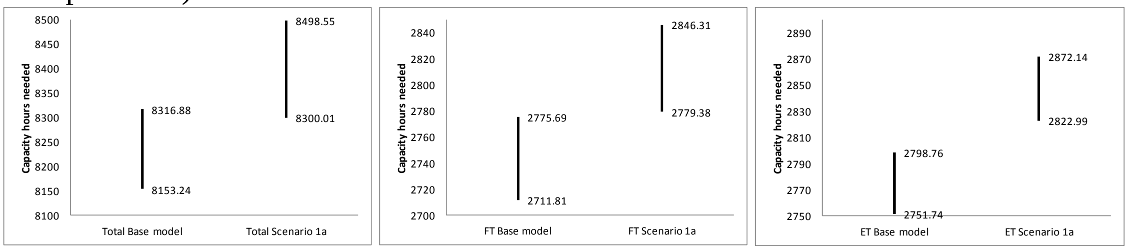

Figure 4: Capacity hours needed in 2012 – Base model compared to scenario 1a – (Left: All disciplines together; Middle: FT; Right: ET)

The capacity used per year per discipline shows similar results. The total capacity used per year seems larger (as expected), but no significant increase is found in one of the disciplines (or all disciplines together) compared to the base model. This suggests that not more capacity is used per year. Nevertheless, the total capacity used seemed increased with approximately 122 hours per year (2.35 hours per week). Thus, the increase in capacity needed is not completely picked up by the therapists. Probable, because the capacity of the therapists is too low.

The increase of capacity used causes an increase in the DBC (177) and RBU (244) level of 2012 (see figure 5). This suggests that Libra can get more money from the care assurances if the number of patients in treatment program III is reduced.

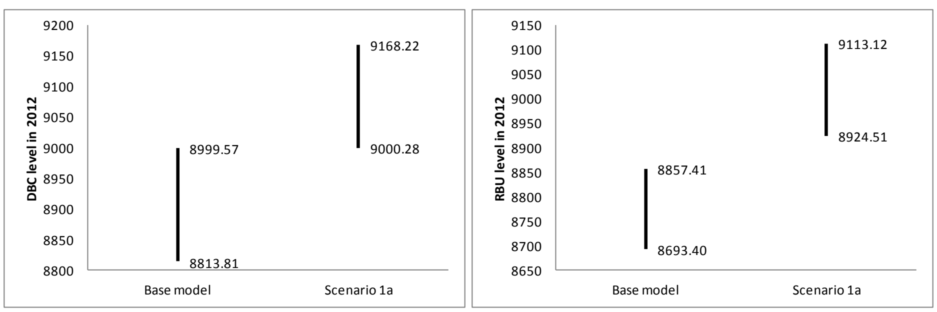

Figure 5: Level of DBC (left) and RBU (right) in 2012

In program III an increase in average amount of DBC (3.5) and RBU (4.8) level is found per patient. This is caused because the same amount of DBC and RBU of a program III is divided over four patients instead of six patients. Therefore, the DBC and RBU level in program III increases and more money can be obtained for this program. The waiting time was expected to decrease due to the increase of number of starts, but no significant difference is found (see program III results of appendix R). Therefore, more program III starts will have no positive effect on the waiting time of program III. A possible reason is that the treatment program is has reached the limit and patients have to wait till a next start of program III.

Scenario 1b - Increase in number of patients in program III: The amount of patients in program III is increased from 6 to 8. The expectations are the opposite of the expectations in scenario 1a. To treat the same amount of patients less starts of program III are needed. Less starts of program three will reduce the capacity needed during a year, because fewer treatments will be carried out. On week level no changes are expected. The DBC and RBU level in 2012 of the therapists will decrease. The expectation is that the waiting time for program III will increase, because it takes longer before the program will start. The DBC and RBU level in program III will decrease, because the total DBC and RBU of program III is divided over more patients.

The capacity needed per discipline is changed a little in 2012 due to the decreased number of program starts. However, in the overview figure of 2012 no clear distinction can be made with the base model (see appendix S for the overview figure of the capacity needed per week in 2012). The total capacity of all disciplines together in 2012 shows as expected a decrease of 218 hours per year (4.2 hours per week) in the capacity needed, but the decrease is not significant (see figure 6). A significant decrease is found for the disciplines FT (1.96 hours per week) and ET (1.83 hours per week). The decrease of starts in program III results in more available capacity in the disciplines FT and ET. The increase in number of patients in program III has fewer consequences on the disciplines MW and PSY. Therefore, the increase of the number of patients in program III saves more capacity of therapists in the discipline FT and ET than in MW and PSY.

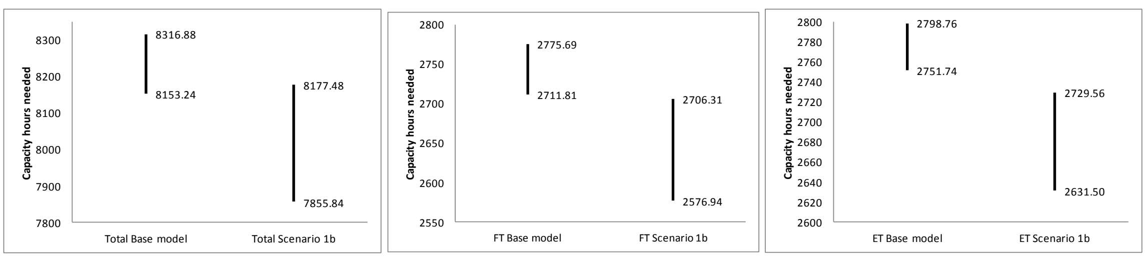

Figure 6: Capacity hours needed in 2012 - Base model compared to scenario 1b – (Left: All disciplines together; Middle: FT; Right: ET)

Similar results are found for the capacity used by the therapists (see appendix R). The overall capacity used of the therapists in 2012 seems decreased with 160 hours per year (3.08 hours per week), but no significant decrease is found compared to the base model. The decrease of capacity used is caused by the decrease in program starts and thus in the decrease of capacity needed. For the disciplines FT and ET a significant decrease is found in the capacity used. The capacity needed decreases harder than the capacity used. Possible reason is that resource will get more capacity and thus can carry out more other treatments.

The DBC (211 hours) and RBU (273 hours) level in 2012 decreases significantly (see figure 7). This decrease can be declared by the decrease of program III starts. So, fewer treatments are carried out in 2012 what reduced the DBC level and RBU level and thus less money can be declared by the assurances.

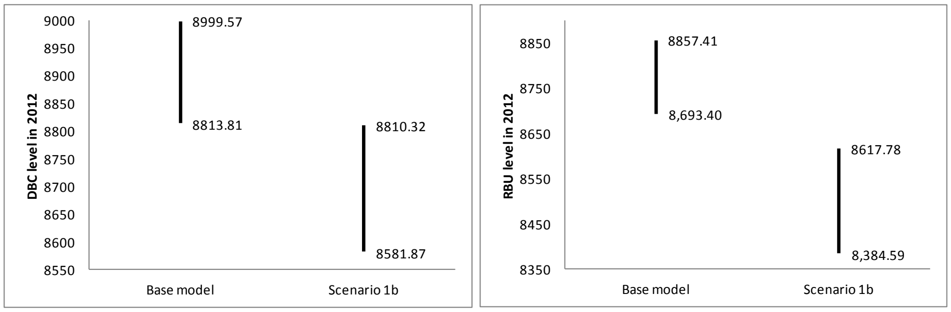

Figure 7: Level of DBC (left) and RBU (right) in 2012

The DBC (4.65 hours) and RBU (6.7 hours) decreases in program III. The reason is that the same amount of DBC and RBU is divided over more patients. The decrease in starts of program III caused an increase in waiting time for program III of approximately 3.65 weeks (see figure 8). Also, the distribution of the waiting time is larger in the new scenario. More patients in a program will have a negative effect on the waiting time of a program.

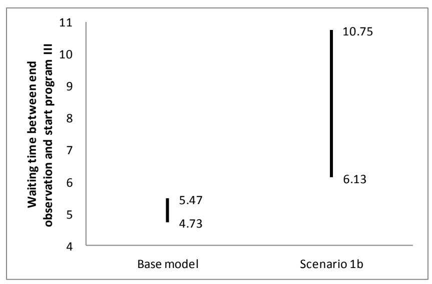

Figure 8: Waiting time in weeks between end observation and start program III

4.6.2.2 Scenario 2 – Reduced capacity due to vacations

Capacity of all therapists is reduced partly in some vacation weeks (25% in week 9; 50% in week 18 and 42) and reduced to zero in other vacation weeks (in week 1, 28, 29, 30 and 52). In the weeks that no therapists are available the treatment program are postponed. Also, no observations are carried out in these weeks. If the capacity is only reduced (25% or 50%) the observations and programs will continue. The expectation is that capacity of therapists used, DBC and RBU will decrease, because less treatments are carried out during the year. The percentage of missed treatments will increase, because therapists are less available in the partly vacation periods. The waiting time of a program will increase slightly due to the vacation weeks when no therapists are available.

The overview of the capacity needed during the year can be seen in figure 9. In the vacation period where no therapists are available no treatments are planned and thus no capacity is needed. If therapists are partly available the treatments will proceed and thus this will have no consequences for the capacity needed. A disadvantage is that in the predefined planning the vacation periods are taken into account. The time that is lost due the vacation should be overtaken in the other weeks, so that the capacity over the year will not change. This is not done in this scenario and therefore, the weeks after the summer breaks too less capacity is employed. In this case the vacations are two times taken into account. If these fixed vacation periods are used in the future the predefined planning should be adapted to increase the capacity needed after the vacation breaks, otherwise the production results will decrease.

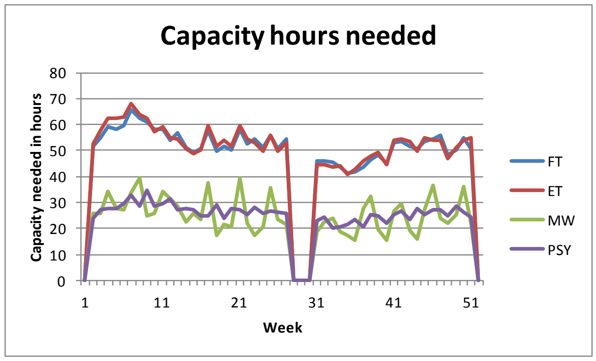

Figure 9: Capacity hours needed per discipline per week - Scenario 2

In the overview of the capacity used per week in 2012 can the vacation weeks be identified. The capacity used is reduced in these weeks (see figure 10). In the weeks that the rehabilitation centre is closed the capacity used is reduced to zero. In the other vacation periods (week 9, 18 and 42) the capacity used is decreased, but still treatments are carried out.

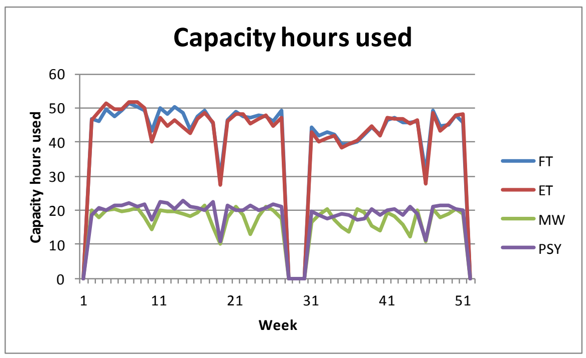

Figure 10: Capacity hours used per in 2012 – Scenario 2

The capacity that is needed of all disciplines together in 2012 is significant lower than in the base model (see figure 11). Also, for each discipline separately the capacity needed is decreased. This is a logic consequence, because five weeks no treatments are planned. The decrease in capacity needed can be reduced to change the predefined planning. As explained before, the vacation is two times taken into account.

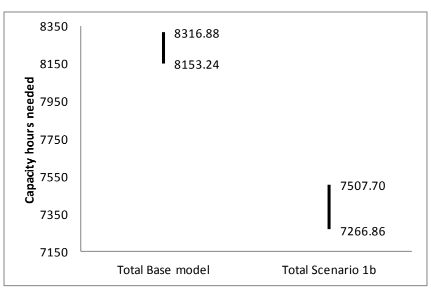

Figure 11: Capacity hours needed in 2012 (all disciplines)

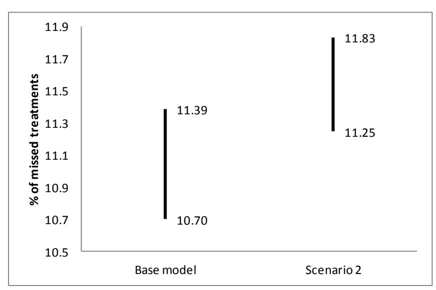

Figure 12: Percentage of missed treatments

Also, the capacity hours used decreased significantly for all disciplines. That is logic consequence, since the therapists have significant less work to do in the same time period. That is why also the utilization of the therapists and the DBC and RBU level decreases significantly. These results can be found in the tables of appendix R.

The percentage of missed treatments seems increased due to the weeks that the therapists are partly available (see figure 12). This is also expected, but no significant difference is found. Apparently, the partly vacation periods have just a minor effect on the percentage of missed treatments. This corresponds to approximately 104 treatments missed during the year due to the partly vacation periods.

In the most performance indicators of the observation and treatment phase no significant differences are found. However, the waiting time of the programs seems increased due to the vacation periods. Only the average waiting time of program III increases significantly with approximately 1.5 week (see figure 13). Patient before the vacation periods have to wait longer before they can start with program III.

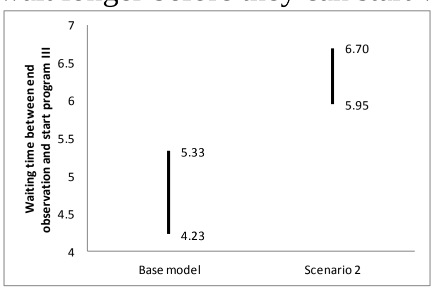

Figure 13: Waiting time of program III

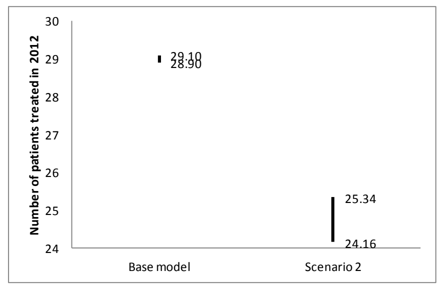

Figure 14: Number of patients treated in program IV

The amount of patients that are finished in program IV reduces significantly with approximately 4 to 5 patients per year (see figure 14). Also, in the other programs seems that fewer patients are treated, but no significant differences are found. The vacation weeks have no positive effect on the number of patients that are finished during the year, but the consequences are limited. Possibly, this can be improved if the predefined planning is changed so that vacation is not two times taken into account.

4.6.2.3 Scenario 3 – Administration time not planned

In this scenario the administration time is not planned anymore. This is done to prevent that therapists carry out administration activities in time they can treat patients with other therapists. Administration should be done on times when the therapist has nothing else to do. A fraction of the contract (10 % of net factor; see appendix J) is assigned to administration time whereby the capacity of the therapists for treatments is decreased to compensate this administration time. Of course the capacity that is needed per discipline and the capacity used will decrease, because no administration activities are carried out in this scenario. Fewer activities are carried out during the year. However, this will have no effect on the RBU, because no administration time is compensated in this method. The DBC level in this model will decrease per year and per program. In reality administration time will also be compensated when carried out and thus the DBC level will not change but in this model it will decrease. The percentage of missed treatments is expected to decrease, because more opportunities of treatments are created due to the absence of administration in work times.

The capacity needed per discipline per week looks similar to the base model. The capacity needed per discipline per week is decreased some time, because the administration time is dropped of the model (see the figure in appendix S). The administration time of all disciplines together is on average approximately 20 hours per week. Per therapists this will be just a couple of hours per week. This decrease is in fact not really a decrease, because the administration time is carried out on different moments. Therapists are compensated to do the administration in other time and the capacity of the therapists per week is decreased. The DBC level per year decreases significantly with also approximately 20 DBC hours per week (see figure 15). The RBU level seems decreased, but not significant change is found. A decrease is strange because administration time is not compensated in the RBU compensation method (see figure 16). A possible reason of this decrease is that more treatments are missed due to the decrease of the capacity of the therapists.

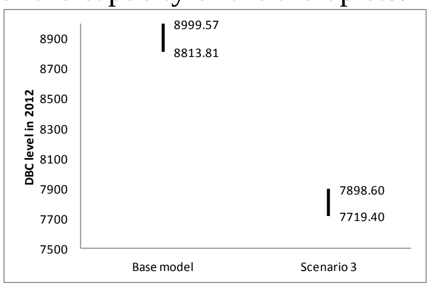

Figure 15: DBC level in 2012

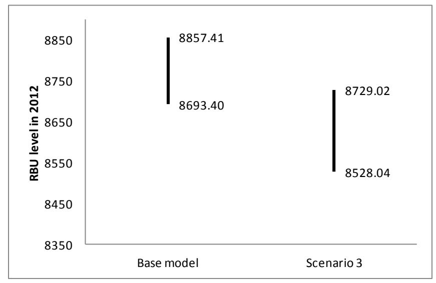

Figure 16: RBU level in 2012

The percentage of missed treatments is increased significantly with approximately 2% (see figure 17). This are corresponds to 6-7 treatments per week. No clear reason for this increase is found. However, it is possible that this is caused by the decrease in capacity of the therapists or by the decrease of the amount of treatments planned (due to the absence of administration activities). The first reason is more plausible, because also more treatments are missed when the administration activities are not included in the calculation of the percentage of missed treatments. This can also declare the decrease in the RBU level. However, the percentage missed treatments is smaller (approximately 1%) if all administration tasks are neglected (see figure 18). Probably, a combination of the two reasons will declare the increase of the percentage of missed treatments.

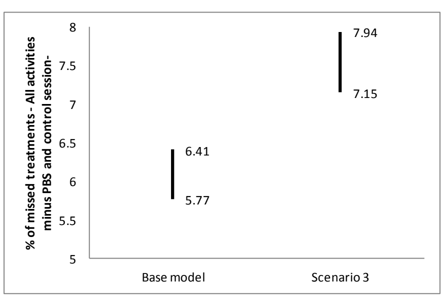

Figure 17: % of missed treatments in 2012 -All activities minus PBS and control session-

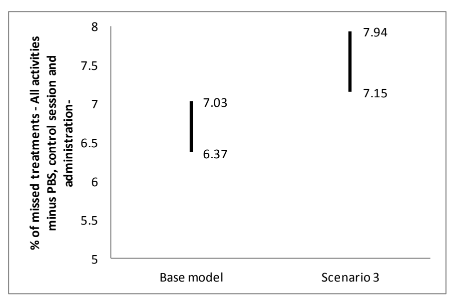

Figure 18: % of missed treatments in 2012 -All activities minus PBS, control session and administration-

The DBC level per program seems decreased in all programs, but in program III this decrease is not significant (see appendix R). This decrease is expected, because administration activities are not calculated in the model.

4.6.2.4 Scenario 4 – Absence of therapists

In this scenario is analyzed what the effect is of the absence of some therapist on the production results. The planning is not affected in this scenario. Therefore, the same amount of treatments should be carried out and the capacity needed is similar to the needed capacity of the base model (see figure of scenario 4 of appendix S). Also, the waiting time of the program will not change, since the planning is not adapted.

Scenario 4a – Absence of ET5: In this scenario therapist ET5 is dropped out of the model. Expected is that the changes will be small, because the therapist is just two hours per week involved in the process. The utilization of the ET discipline will increase a little because the same work has to be carried out with less available capacity in the ET discipline. Therefore, the percentage missed treatments will increase if the ET discipline is involved. Capacity used, DBC and RBU will be approximately the same. Also, on program level the expectation is that the DBC and RBU will be approximately the same.

The capacity used of all therapists during the year is not significant different to the base model. This confirms our expectation that this scenario has no large consequence compared to the base model. Only, the utilization of the ET discipline increases significantly (see figure 19). The other therapists of ET have to overtake the lost hours. This is maximal two hours per week.

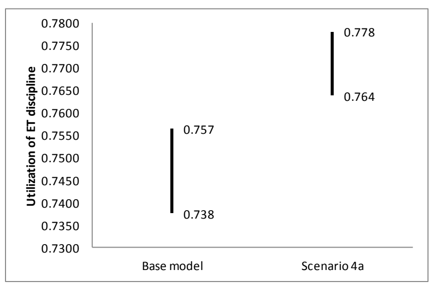

Figure 19: Utilization of the ET discipline in 2012

The absence of ET5 has no consequence of the DBC and RBU level per year and the percentage of missed treatments per year. Also, no differences are found in the performance indicators of the observation and treatment phase. This is in line with the expectations. According to the results of this model compared to the base model the therapist has no added value to the model. Only the utilization of the ET discipline is increased, but still acceptable.

Scenario 4b – Absence of FT10: In this scenario therapist FT10 is dropped out of the model. The changes in this scenario will be similar as scenario 4a. Expected is that the changes will be small, because the therapist is little involved in the process. Utilization of FT will increase a little because the same work has to be carried out with less available capacity. Therefore, the percentage missed treatments will increase if the discipline FT is involved. Capacity used, DBC and RBU will be approximately the same, because the therapist is not much involved in the process.

The absence of FT10 results not in significant differences according to the model. In contrast with the expectations, the utilization of the FT discipline is not changed. The reason is that the contract of this therapist is too small (maximal 1.75 hours per week) and thus not used a lot in the model. Thus, according to the results this therapist has also no added value to the model and the treatments can be overtaken by the other therapists of FT.

Scenario 4c – Absence of MW1: In this scenario therapist MW1 is dropped out of the model. This is a large difference, because almost 67% (15.17 hours per week) of the capacity in this discipline is lost. Utilization of MW will increase because the same work has to be carried out with less capacity of the MW discipline. The percentage missed treatments will increase if the discipline MW is involved. Capacity used, DBC and RBU will decrease, because this therapist (MW1) is much involved in the process and thus a lot of treatments are missed.

The capacity used decreases in the MW (10.7 hours per week) and PSY (1.3 hours per week) discipline (see figure 20 and 21). The decrease in MW is logical since approximately 66% of the capacity in the MW discipline is lost. The decrease in capacity of PSY is more a surprise. However, there is a treatment in which a combination of a MW therapist and a PSY therapist is involved (ACT Cursus). When these treatments cannot be carried out due to the absence of the MW the capacity used in PSY also decreases.

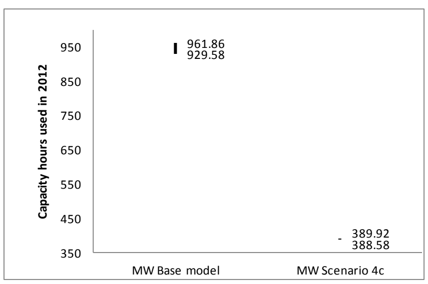

Figure 20: Capacity hours used in 2012 for MW discipline

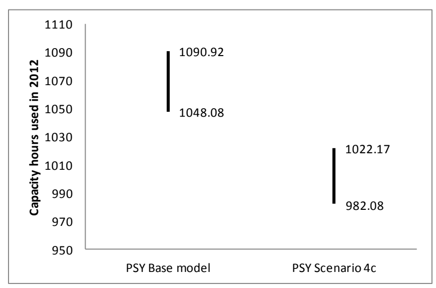

Figure 21: Capacity hours used in 2012 for PSY discipline

The utilization of the MW discipline increases (see figure 22). This is no surprise, because one therapist has to do all treatments of the MW discipline. The capacity of this therapist is too small to carry out all activities of MW, but the therapists will do as much as possible what increases the utilization of the MW discipline. The utilization of the PSY seemed decreased (see figure 23). More mixed treatments of the MW and PSY are carried out. This decreases the capacity of PSY used. The utilization of the PSY discipline decreases, because less capacity of PSY is used with the same capacity of PSY is available. However, this decrease is not significant.

Due to the absence of MW1 the amount of missed treatments increased from approximately 44 missed treatments to 82 missed treatments. The result is that the treatments missed will be approximately doubled. For the capacity of MW and PSY the amount of missed treatments almost tripled from 15 missed treatments per week to 40 missed treatments per week.

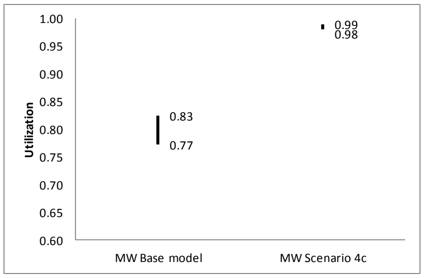

Figure 22: Utilization of the MW discipline

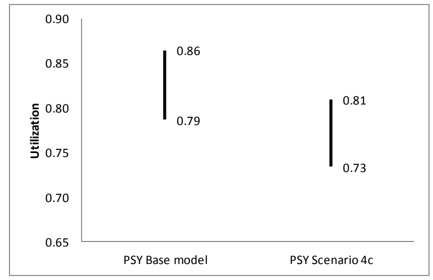

Figure 23: Utilization of the PSY discipline

Scenario 4d – Absence of PSY3: In this scenario therapist PSY3 is dropped out of the model. Expected is that the differences will be small, because the therapist is involved for 2.84 hours per week in the process. However, since the total availability of the discipline PSY is much larger as the disciplines FT and ET this will have larger influence on the results than in scenario 4a and 4b. Utilization of the PSY discipline will increase, because the same work has to be carried out with approximately 11% less capacity. Therefore, the percentage missed treatments will increase if the PSY discipline is involved. These missed treatments caused that the capacity used, DBC and RBU level per year will decrease a little.

The capacity used in the PSY discipline seemed decreased, however the decrease is not significant and is less than one hour per week. Also, no significant difference is found in the DBC level, RBU level, and percentage of missed treatments. These values are indeed expected to change, but the change is too small to get significant differences. A difference is found in the utilization of the PSY. Due to the absence of a PSY therapist, the other therapists have to do significant more work (see figure 24).

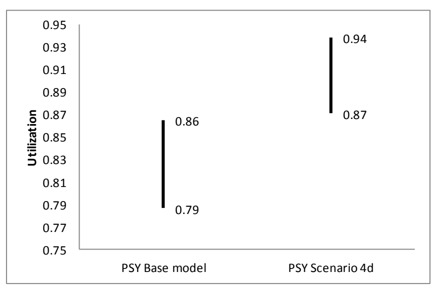

Figure 24: Utilization of the PSY discipline in 2012

In the results of the observation phase and treatment phases, the DBC and RBU level seemed decreased, but are not significant different. The waiting time between end observation and start treatment shows also no significant changes, as expected. According to the results, this therapist is not needed. However, according to the capacity needed and the capacity available this therapist is needed. Apparently, the differences between the two scenarios are too small to get significant differences.

4.2.6.5 Scenario 5 – Dynamic starts of treatment programs

The treatment programs starts in this scenario when the maximum amount of patient is the treatment program is reached instead of the predefined start weeks. This change is made, so that Libra can better anticipate on the real arrival of patients.

Scenario 5.1 – Dynamic start: In this scenario the starts of the treatment programs is changed. The same amounts of patients arrive to the system. The expectation is that the same amount of capacity is needed during the year. The advantage is that programs are started when these are needed. The expectation is that the utilization per discipline, capacity used and percentage of missed treatment, will not change, because the same number of patients arrives to the system and thus approximately the same programs shall be started (if the predefined planning is realistic). However, the capacity needed is expected to decrease since the programs are not complete in the base model and thus fewer programs are needed in 2012. The level of DBC and RBU per patient per program will decrease in some programs due to the fact that groups are complete (not all groups are complete in the base model). The same level of DBC and RBU is divided over more patients what caused the decrease. The waiting times of the programs will decrease a little. Now a program is started when a program is complete. Complete groups have not to wait till a predefined start week. In the old situation must be waited on the predefined start week.

The capacity needed per discipline per week in 2012 is in the case of dynamic starts different compared to the base model. Vacation periods are not taken into account when the programs can only start if the maximum amounts of patients are waiting for the treatment program. The overview of the capacity needed per week in 2012 can be found in figure 25. According to this figure and section 2.5.1, it seems that there is enough capacity available per week for the disciplines FT and ET, but not for MW and PSY.

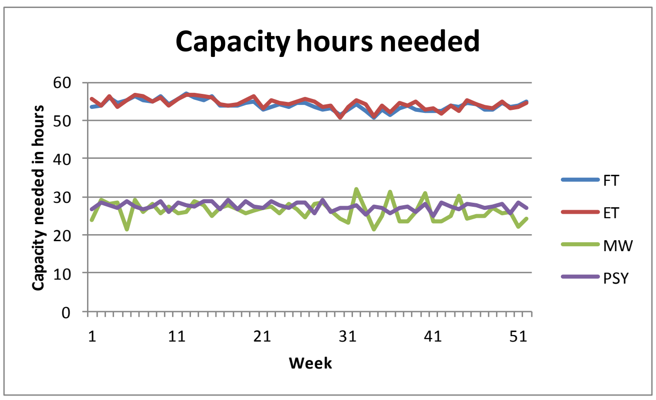

Figure 25: Capacity hours needed per discipline per week – Scenario 5a

The overall capacity needed (all disciplines together) seems approximately 3.75 hours higher, but no significant difference is found. For the disciplines MW (0.75 hour per week) and PSY (0.79 hour per week) the capacity needed increased significantly (see figure 26 and 27). Thus it seems that MW and PSY are planned too less in the 2012. A disadvantage is that the capacity of these disciplines is not available. For MW and PSY approximately 27.5 hours are needed on average per week, but approximately 23 and 25 hours are available per week. These results are not expected, because complete treatment programs should save capacity compared to incomplete programs. More starts are needed to treat the same amount of patients. A possible reason for this unexpected behaviour is that the wrong programs are started in the predefined start weeks. It is possible that individual programs or program I (this program is nearly always complete) are started too less using the predefined start weeks.

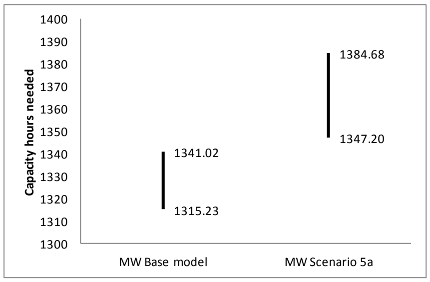

Figure 26: Capacity hours needed of MW in 2012

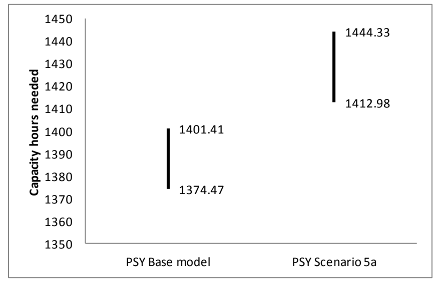

Figure 27: Capacity hours needed if PSY discipline in 2012

Similar results are found for the capacity used. The capacity used increases approximately 2.3 hours per week. Approximately, 1.5 hours of extra capacity needed is not carried out in this case. That is not strange, because if more treatments can be carried out also more treatments are carried out if enough capacity is available. However, not all capacity that is needed is used. The reason is that more treatments are missed in the new situation. Further, no significant result is found anymore for the capacity needed of the PSY discipline. The reason is probably that the capacity of the PSY cannot deal with the increase the capacity needed of the PSY discipline.

No significant increase is found in the utilization of the therapists. More treatments should be carried out, but the disciplines works not significantly more. Therefore, the percentage of the missed treatments increases. As can be seen in appendix R the percentage of missed treatments indeed increases significantly. The number of missed treatments increased from approximately 45 per week to 55 week. Especially, treatments of MW and PSY are missed. The cause is that FT and ET has more capacity unused than MW and PSY. Also, a lot of patient discussions will not proceed. The reason is that all involved therapists should be available at the same time. This was hard to reach in the model, without a real planning.

In program I, II, IV and V no changes are found in the DBC and RBU level per patient. In program III a decrease of 3.55 DBC and 4.95 RBU is found. The cause is that program III is on average not complete in the base model. In the new situation all groups are complete. Therefore, the DBC and RBU are divided over more patients, what caused the decrease in DBC and RBU level of program III.

The introduction of the dynamic starts reduces the waiting time between end observation and start program I, II, IV and V enormous. The change on the average waiting time for program I and II is shown in figure 28 and 29. The average waiting time decreases in program I with approximately 13 weeks, in program II with approximately 7 weeks, in program IV with approximately 16 weeks and in program V with approximately 2 weeks.

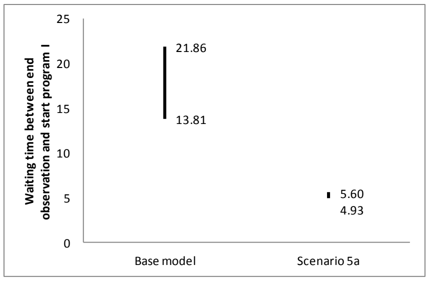

Figure 28: Waiting time in weeks for program I

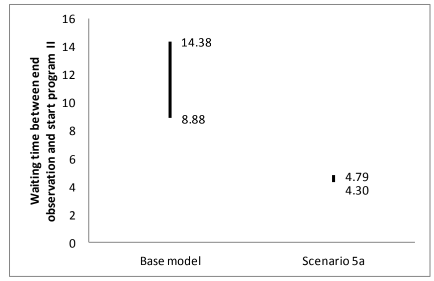

Figure 29: Waiting time in weeks for program II

In program I, II and IV significant more patients are finished in 2012 when the dynamic start is introduced. For the observation, program III and V the number of finished people seems also increased, but no significant increase is found. However, no real conclusion can be drawn, since the patients over multiple years should be analyzed. The start of the programs can influence the number of patients that are finished during the year. So it is possible that in the next year fewer patients are treated, because several patients are finished just before or just after the year.

Scenario 5.2 – Dynamic start and increased number of arriving patients: In this scenario also the dynamic start is used, but now more patients arrive to the system. This scenario is compared to scenario 5.1. More patients (approximately 50) arrive to the system and therefore is expected that the more capacity is needed. The utilization per discipline, capacity used DBC per year and RBU per year will increase, because more patients will be treated. Also, the percentage of missed treatments will increase, because more treatments will be carried out in the year using the same capacity. The level of DBC and RBU per patient per program will decrease a little due to the fact that more treatments are missed. The waiting times of the programs will decrease, because groups are faster complete. Further is expected that more patients are finished in this year, because also more patients arrive to the system.

The increase of arriving patients and observations per week caused that more observations and programs are carried out during the year. Of course this result in an increase of capacity needed. The overview of the capacity needed per week can be found in figure 30. Approximately 22 hours extra capacity (all disciplines together) is needed to treat these extra patients. For the disciplines FT enough capacity is available. FT needs 61.54 hours per week and has 66.78 hours per week available. For ET just a little extra capacity is needed. ET needs 62 hours per week and has 61.48 hours per week available. For MW around 7 extra hours per week are needed with this amount of patients. For PSY around 5 extra hours per week are needed to treat all patients.

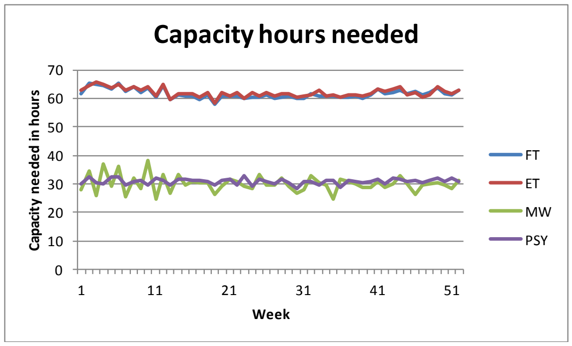

Figure 30: Capacity hours needed per discipline per week – Scenario 5b

Nevertheless, the production increases according to the results (see appendix R). In the utilization of the scenario 5a some capacity is left and thus more treatments can be carried out. Therefore, the capacity used is increased with around 9 hours per week (all disciplines together) in this scenario. So, 13 hours of the extra needed capacity is not used in this situation.

The DBC and RBU per patient per program decreases significantly with approximately 2 hours (see appendix R). The reason is that the amount of missed treatments increases from 55 per week to 87 treatments and the patients get fewer DBC and RBU during the program.

2.7 Lessons learned

One aim of the simulation study was to get some initial insights in possible important characteristics of active resources in healthcare. The focus of this section is on the acquired knowledge during the simulation study. This knowledge will be used in the analysis of the three healthcare cases in the next chapter. The availability of the resources seems extremely important, because in the Libra process treatments should be planned within the work schedule of the therapist. Machines in manufacturing are full time available, but therapists are less available (approximately 40 hours per week). This characteristic is extra important due to the group activities in which more therapists should be available at the same time. If the patient wishes are taken into account the planning becomes more difficult again. However, patient wishes are out of the scope of this project. In manufacturing resources are less dynamic since machines are more steady and also the order have no wishes.

The capacity of the resources is important in this case study too. If the therapist is available it is important to know whether the resource has some capacity left to treat patients. Not all availability is available for the core activities of the therapists, but resources also carry out some support activities. Team discussions or study days are such support activities and will of course cost capacity. During this time the resource is not available for care giving. These support activities are carried out somewhere in the work week, but are not on the same time every week. Since, these activities are sometimes and irregular these are often neglected in simulation models. Therefore, it is important that both capacity and the work schedule of the resource are available in healthcare models. Manufacturing models are less complex, because machines in manufacturing do not have such support activities.

Further, the identification of individual resources is important, because more therapists can be involved in a healthcare process. All different resources can have a different function in the process. Another reason why it is important in the case study to have individual identifiable resources is that fixed therapists are assigned to the patients. During the treatment process this therapists must be found to carry out a treatment. Also, for the capacity and availability (work schedule) it is important that individual resources can be found.

The behaviour of therapists is more dynamic than the behaviour of machines. Therapists should behave according to rules. For machines these rules are not relevant since the behaviour the machines is programmed. The behaviour of a machine is thus more predictable and thus can better be estimated by for example a probability distribution.

Not only characteristics of the resources are important in healthcare models. Also, the structure of the process is important. The design choices of the routing of the treatments and the choice of the fixed therapists for the patients have reasonable effects on the results. The routing of the treatments is a lot more difficult in healthcare than the planning of the orders in manufacturing (mostly just a queue). The availability (work week) is important for resources in healthcare. Patients will not wait in a queue till the therapist comes available. A real planning is needed. In reality this is an iterative process, but that is not possible in a simulation tool. Also, the group treatments make the process more complex, because more patients and resources should be available on the same time.

3. Characteristics of healthcare resources

In the literature no concrete information is available about characteristics of resources. However, a typology for profiling and modeling resources is given by (Jenkins and Rice, 2007). This typology is quite abstract, because it describes resources in general. Despite, this typology is used as starting point for this analysis. The three healthcare cases (Libra, Feniks and MDL) are used to qualitatively identify the most important characteristics of active resources in healthcare processes using the typology of Jenkins and Rice (2007). For each case the most important characteristics of the active resources are identified separately. Afterwards, the three cases are compared to each other to determine whether the active resources of the three cases have different characteristics in healthcare processes. The most important characteristics of the active resource in healthcare are combined to a first indication of a general characterization of active resources in healthcare.

3.1 Typology

(Jenkins and Rice, 2007) have made a general typology to describe resources of several domains. No distinction is made in active and passive resources. However, in this research part this typology is used to analyze the active resources. Resources can be described using four categories: existential, availability, utility and implementation. The typology is applicable to several domains and therefore the definitions of the characteristics are quite abstract. The four categories are shortly discussed including the definitions of all characteristics (Jenkins and Rice, 2007).

- **Existential:** The first category describes the existential characteristics of a resource. It describes the properties of a single independent resource in terms of whom or what the resource is (person or thing). This category is described using the following characteristics including definition:
    - **Identity:** This characteristic describes the identity of a resource. Using this characteristic, resources can be distinguished from other resources and are therefore individually identifiable.
    - **Origin:** This characteristic describes the source of a resource. Using this characteristic, properties of a resource are assigned.
    - **Living:** This characteristic describes whether a resource is living or non-living. A living resource is more dynamic than a non-living resource and is therefore less predictable.
    - **Consumption:** This characteristic describes whether resources are consumed during an activity. The resource is consumed when the quantity of the resources is decreased after the activity. If the quantity of the resources will not change after the activity the resource is not consumed. These resources are re-usable.
    - **Make-up:** This characteristic describes the composition of a resource. A resource can be made using several other (partial) resources.

- **Traits:** This characteristic describes the relative fixed characteristics of the resources. Examples are gender, birthday and ethnicity for human beings. These characteristics will normally not change in the future.

- **Availability:** The second category describes the availability of a resource. It describes when and where and to whom the resources can provide their service. This category is described using the following characteristics including definition:
  - **Status:** This characteristic describes the possible states of a resource. Examples of possible states are in-service, out of service, idle and busy
  - **Location:** This characteristic describes where the resource can be found and where they can deliver their service. If the resources are working on several places it can cost some transfer time to go to another workplace.
  - **Schedule:** This characteristic describes the time periods that a resource is available to perform services to the system.
  - **Delivery mode:** This characteristic describes whether the resource delivers discrete or continuous service to the system. The resources (therapists) in healthcare are discrete. A therapist treats one (or more) patient(s) for a specified time. After the treatment the therapist can do something else.
  - **Failure mode:** This characteristic describes whether a resource can fail, and is not available for service any more. Failures can be limited by maintenance, rest or replacement.
  - **Selectivity:** This characteristic describes whether a resource can choose the clients it will serve.
  - **Exclusivity:** This characteristic describes whether more than one client can get service of one resource at the same time.
- **Utility:** The third category describes the utility characteristics of a resource. It describes what and how well the resources can provide their service. This category is described using the following characteristics including definition:
  - **Competencies:** This characteristic describes the services that the resource can deliver. It describes the tasks that a resource can execute.
  - **Size:** This characteristic describes the amount of services the resource can deliver at one time.
  - **Performance:** This characteristic describes the performance of a resource. The performance can be measured on several aspects. Six aspects of performance are discussed: deliverability, reliability, effectiveness, efficiency, cost, quality.
  - **Cognition:** This characteristic describes the cognitive abilities of a resource. These abilities are influenced by the IQ, educational level, attitude, commitment and personality.

- **Implementation:** The last category describes the implementation characteristics of a resource. This describes how the resources provide their service. Resources can have the same goal, but a different way to reach their goal. The way how the resources provide their service is described using the following characteristics including definition:
    - **Adaptability:** This characteristic describes the ease with which a resource can be changed so that they can better perform their activities.
    - **Activity:** This characteristic describes the extent to which resources are actively or passively involved in the process.
    - **Interactivity:** This characteristic describes the amount of interaction between the clients and resources during the service.
    - **Autonomy:** This characteristic describes the extent to which resources control their own processes or that the resources are influenced by other resources.
    - **Coupling:** This characteristic describes the extent to which a resource will influence another resource when it is modified. Resources can influence other resource a little bit (loosely coupled) or enormously (tightly coupled).
    - **Isolation:** This characteristic describes the extent to which a resource knows that other resources exist.
    - **Discoverability:** This characteristic describes the ease of which a client knows that the resource exists.
    - **Composition:** This characteristic describes whether a resource is build from several resources
    - **Centralization:** This characteristic describes the extent to which the resources are available on one or more locations.
    - **Mobility:** This characteristic describes whether a resource can be moved from one location to another location.
    - **Forgetfulness:** This characteristic describes the amount of information the resource contains after service.
    - **Preemptibility:** This characteristic describes whether a resource may be interrupted to do other things.
    - **Standardization:** This characteristic describes the extend in which a resource adheres to a standard.
    - **Risk:** This characteristics describes the extend in which the resource will cause a threat for the clients.
    - **Policy:** This characteristic describes whether the preferences of a resource and their constraints can be changed.

3.2 Healthcare cases

To get a general characterization for active resources in healthcare more than one case is analyzed. One case is not representative for the whole healthcare sector. Better is to do all possible types of processes, but that is impossible in the time span of this project. A broad range of healthcare processes is included in this research to get a first indication of a general characterization for active healthcare resources. Three healthcare processes are used: Libra, MDL and Feniks. These cases are selected because of three reasons. The first reason is that these cases are documented and modeled before. So, these cases are available and this will thus not result in more work and can be analyzed easily. Further, the cases describe a totally different healthcare process (core and support). To make a general characterization for active resources in healthcare it is important that more types of processes are included. Also, the processes are of different type of organizations (hospital and rehabilitation). The last two reasons will ensure that a lot of different healthcare aspects are taken into account. The main points of these three cases are described shortly in this section.

Libra

In this case the focus is on a rehabilitation process for patients with chronic pain complaints. The case describes a core process in healthcare. As described in the business part, the aim is to improve the lives of the patients by giving a number of treatments. These treatments are planned beforehand. The treatments are carried out by active resources, in this case the therapists. These therapists work according to a work schedule. The patients arrive to the rehabilitation centre and start an observation phase. During this phase the patients are observed by therapists. If necessary, the patients are referred to an appropriate treatment program after the observation. Then, the patients have to follow a complete program. The observation and treatment program consists of the treatments that are given per week. Note that in a rehabilitation process, treatments by multiple disciplines are involved, like physiotherapy, occupational therapy, social work and psychology. The routing for the treatments is not necessarily the same. The amount of treatment days per week and the time between treatments on a day should be acceptable for the patient. Also, several types of treatments are given in a rehabilitation process, like individual treatments, group treatments, indirect activities (without presence of the patient) and optional treatments (not for all patients). The amount of therapists that are involved in is dependent on the treatment. More information about the Libra case can be found in the business part of this project.

MDL

Habif (2011) discussed the process model of endoscopy on the gastroenterology department at “Academisch Ziekenhuis Maastricht”. This process is a core process at a hospital. The active resources in this process are the physicians and nurses. The rooms are also an important resource for this process, but since this is a passive resource this is left out of the scope in this project. The routing of the activities in the process is clear. The main points of the process are discussed. A more detailed description can be found in (Habif, 2011)

The process is dependent on the type of endoscopy procedure, type patient (from wards or outpatient) and whether sedation is used. However, the core of all processes is the same. Appointments are arranged for the patients to undergo the endoscopy. Nurses ensure that the patient is coming to the operating room and prepares the patients for the procedure. Parallel, the physician checks the information of the patient. Eventually an extra activity is needed when sedation is used. Then the procedure can be carried out. There are many types of procedures. (Habif, 2011) divided these into four categories: colonoscopy, gastroscopy, sigmoidoscopy and 'other'. The procedure is carried out by the physician and a nurse. An extra nurse is needed when the patient is sedated. Afterwards some activities are carried out to finish the endoscopy procedure (like cleaning the room and administration). When the patient is sedated the patients has to go to another room to recover. If the patient is from a ward the patient can recover there, otherwise the patients will recover at the daycare unit. After this recovery the patient can leave the hospital. An extensive version of the MDL processes can be found in (Habif, 2011).

Feniks

The Feniks process is a study of "Maastricht Universitair Medisch Centrum". This study analyzed the mistakes in the preparation and the administering of parenteral medication. A lot of mistakes were caused by giving wrong medicines, incorrect doses, calculation errors, dissolving errors, inadequate hygienic actions or the absence of double checks. The aim of the project was to improve the medication safety, improvement of quality due to specialization, the transfer of pharmaceutical tasks to the pharmacy assistants to give nurses more time giving care to the patients and to realize cost savings. Feniks is a process that supports core processes in healthcare. Patients are not direct involved in this process. Other characteristics of resources may be important in this process than in core processes. The procedure of medication in "Academisch Ziekenhuis Maastricht" is given in four steps:

1. The physician prescribes electronically the medication for the patient.
2. The hospital's pharmacy does the medication monitoring.
3. The nurses or the hospital's pharmacy does the preparation for administration (VTGM).
4. The nurses give the medication to the patients.

In the Feniks project the preparation of the medicines (step three) was important. This process is carried out by the pharmacy assistants. The pharmacy assistants are the active resources in this process. The pharmacy of the hospital receives a request for medicines electronically. The inventory of stock is checked and a planning is made for the requests. Then, the preparation process is started by printing the protocols and labels, preparing the supplies and filling the protocols. Next, the medicines are prepared, checked and labeled. Finally, the final product is double checked and released. These tasks are carried out by three pharmacy assistants. All assistants can carry out all activities of this process. When the final product is released can go to the departments of the patients. More information about the Feniks case can be found on the brochure of Feniks. (Brochure feniks, n.a.)

3.3 Important characteristics of healthcare resources

In this section the results of the qualitative analysis of the typology on the three healthcare cases are discussed. The typology of (Jenkins and Rice, 2007) is applied to the three healthcare cases. An overview of the results can be found in table 3. A “+” sign indicates that the characteristic is important. A “-“ sign indicates that the characteristic is not important. If it is not clear whether the characteristic is important a “+/-“ sign is used. The result of the table is explained for each case separately.

Aspect	*Characteristic*	*Libra*	*MDL*	*Feniks*
Existential	Identity	+	+	-
	Origin	-	-	-
	Living	-	-	-
	Consumption	+	+	+
	Make-up	+	+	+
	Traits	-	-	-
Availability	Status	+	+	+
	Location	-	+	-
	Schedule	+	+	+
	Delivery mode	+	+	+
	Failure mode	+/-	+/-	-
	Selectivity	+	-	-
	Exclusivity	+	+	+
Utility	Competencies	+	+	-
	Size	+	+	+
	Performance	+	+	+
	Cognition	-	-	-
Implementation	Adaptability	-	+	+
	Activity	-	-	-
	Interactivity	+	+	+
	Autonomy	-	-	+
	Coupling	-	-	-
	Isolation	+	+	+
	Discoverability	-	-	-
	Composition	+	+	+
	Centralization	-	+	-
	Mobility	-	+	-
	Forgetfulness	-	-	-
	Preemptibility	-	-	+
	Standardization	-	-	-
	Risk	-	+/-	+
	Policy	+	+	+

Table 3: Identification of important characteristics in the three healthcare cases

3.3.1 Libra

The active resources in this case are the therapists of the FT, ET, MW and PSY disciplines. In this section the most important characteristics of the resources are discussed. In appendix T all characteristics of the typology of Jenkins and Rice (2007) are discussed to identify the most important characteristics. A summary is given in this section.

Some existential characteristics are important. In the Libra case it is important to distinguish individual therapists. Therapists should be identified individually, because the characteristics of resources are individual. Examples of cases that individual therapists should be identifiable are: patients should be treated by the same therapists, therapists are working for one discipline and therapists have different (own) work times. These are characteristics that will have influence on the process. Also, it is important that multiple resources can be selected in a treatment if the treatment is given by more therapists. After a treatment, the resource is released and available to other patients.

A number of characteristics in the availability aspect are important. So, the status of a therapist important. Therapists can only treat patients in working time and if they are not busy already. Further, the work schedule is important to know whether the therapists are available for patients or that the therapist is absent. Also, it is important to know whether the therapist delivers discrete services or continuous service. This helps to select the correct simulation method (discrete event simulation or system dynamics). Resources must treat the same patients, because therapists know the history of the patient and can help the patient faster. Then, it is important to that the resource can deliver service to multiple patients at one time moment, in the group processes.

From the utility aspect also some characteristics are important. The competency of the therapists is important to know what treatments the therapists can carry out. Note that a therapist (or a combination of therapists in groups) can carry out just one treatment per time unit. Of course, the performance of the therapists plays a role in the results of the process.

The implementation aspect is less relevant, because this discusses how the resources reach their goals. This is already defined by the treatment programs. Nevertheless, some characteristics are important for the resources. Interactivity among therapists and between therapist and patient are important to help the patient as good as possible. Since the process is multidisciplinary the therapists should know each other activities. This will improve the treatment of a patient. Also, the composition characteristic is important, because in group treatments multiple individual resources will treat a number of patients at the same time. Therefore, the therapists in this process should collaborate. Finally, the policy plays a role for the resources. A policy should exist when therapists want to have a free day. This free day should be taken into account in the planning of the treatments. Especially for group treatments it is necessary that multiple therapists are available on the same time.

3.3.2 MDL

The active resources in this process are the nurses and physicians. These resources are involved in the endoscopy procedures. In appendix U all characteristics of the typology are analyzed whether the characteristic is important for the active resources. A summary of this analysis is given in this section.

The existential aspect is of interest, because multiple types of resources are in the model. Individual resources should be identified, because there are several types of endoscopy procedures. Physicians are specialized in specific procedures. Also, the work times of these physicians are different. It is less important to identify individual nurses, because all nurses should be available to do all types of nurse activities. The resources of the MDL process become available for other patients if an endoscopy session is finished. The make-up of the resources is even important in this process, because dependent on the process characteristics the composition of the resources is determined. For example, an extra nurse should be available if sedation is used.

The availability aspect is also important in this process. The correct therapists should be available when an endoscopy procedure is planned for a patient. The status of the physicians and nurses should be all free before the procedure can be started. Thus, the work times of the physicians and nurses are needed in the process. In this process the location is important, since specific rooms are assigned to this process. The transport from one room to another room will cost time. Further, it is important to know how the resource will deliver the service to choose an appropriate simulation tool. The exclusivity characteristic should also be in mind. The physician and nurse can do one thing at one time unit.

The utility aspect is also important for resources in the healthcare process, especially for the physicians. Nurses have to do several types of activities. However, the physicians have their own specialization and thus specific competences. Note that multiple resources will treat one patient per procedure. Of course, the performance of the resource is plays a role in reality.

The implementation characteristics are less important in the MDL process, because the treatment process is already predefined. It is fixed how the resources should reach their target. However, in these resources it can be interesting when a resource can adapt easily to carry out other types of endoscopy procedures. Interactivity between physicians and nurses must ensure that the procedures run smoothly. Therefore, the isolation characteristic is also important, so that the collaboration among the resources will help to optimize the process. The composition is important, because multiple resources should help just one patient at one time unit. The activities of this process are carried out on several locations of the hospital. Patients go from one room to another, and thus is mobility important in this process. Also, policies for the resources are needed in this process. Enough resources should be available, and the procedures should be finished before the end of the day.

3.3.3 Feniks

The final case is Feniks. This is a totally different process. The active resources in this process are the pharmacy assistants. In appendix V all characteristics of the typology applied to the Feniks case to check whether the characteristic is important for pharmacy assistants. A summary of this analysis is given in this section.

The existential characteristics are less important in this case. It does not matter which assistants are involved in the process. All assistants are able to do all activities of the process. After an activity the assistants becomes available for the next activity. The make-up has a role in this case, because multiple assistants are involved in the preparation of one medicine.

The availability aspect is important for the resources in this case. Enough resources should be available to carry out the preparation of medicines. So, the work times of the resources should be available. Also, the status of the resource plays a role in this case. Assistants should be free when they start preparing a medicine. The assistant can work on one request at the same time. How the service is delivered of the resources is also an important characteristic, because this will help to choose an appropriate simulation method.

The utility aspect is less important in this case than in the other cases. The reason is that the competencies of the assistants are not really relevant in this case, because all assistants have to do the same activities. One request can be carried out by the assistants at one time unit, because other mistakes are made. The performance of the assistants plays a role in the case, because all requests should correctly finished at the moment that the medicines are needed.

Some characteristics of the implementation aspect are important for the assistants. Adaptability is important, because several medicines should be prepared. Assistant should switch easily among these preparation methods. Multiple assistants prepare one request. Thus, the communication among the assistants is important to prevent making mistakes and thus assistants should help each other. Assistants make a planning of the request, but this planning can be disturbed due to emergency cases. In this case the risk is also important, because mistakes in the preparation can have enormous consequences for the patients. A policy should be available in which is described how the emergency cases will be handled.

3.4 Framework of healthcare resource characterization

The most important characteristics of the active resources in the three healthcare cases are identified in the previous sections. The three cases are completely different from each other. Also, different characteristics of the typology of (Jenkins and Rice, 2007) are important in the cases. In the Libra case specific information for all individual resources is needed, because specific resources carry out the treatments. In the other cases the specific resources are less important. In the MDL case the transportation times are important, but this is not essential in the other cases. This makes it hard to the make a general characterization to model resources in healthcare processes, because it depends also on the process that will be modeled. Differences are found in core healthcare processes and support healthcare processes. Identification of individual resources is more important in core processes than in support processes. The reason is that in support processes it does not matter which resources the activities carries out. In core processes this is more important.

Nevertheless, an initial characterization for active resource in simulation of healthcare studies is made. This new typology is based on the important characteristics of resources in healthcare of the previous chapter. The aim of the characterization of the healthcare resources is to improve the modeling of healthcare processes in simulation tools. In this typology the modeling possibilities in simulation tools are taken into account. Several important characteristic in a real process cannot be modeled in simulation tools, like interactivity between resources or between patient and resource. Other characteristics are descriptive and too much in detail to model these characteristics in a simulation model, like isolation (knowledge that other resources exists). Therefore, in this typology is taken into account whether the characteristic of the resource can be modeled in simulation tools.

In general, the existential and availability aspects of the typology are important in healthcare processes. However, not all specific characteristics of these aspects are important to all resources. It is important to know which resource is involved in the process and when, to whom and where the resource is available. In manufacturing the availability aspect is less important. A machine in manufacturing is full time available (neglecting failure). Therapists in healthcare are available just some hours a day (neglecting illness). Therapists can also not available all days of the week. Therefore, it is also important to distinguish individual resources in healthcare processes. Each therapist has other work times and carries out different activities. This characteristic is less important if all resources in a process have to do the same activities, like machines.

The utility and implementation aspect describes what, how well and how the resources will deliver their service. For simulation modeling this is not important. In simulation the activities are a kind of "black box". The details of what activity the resource does and how the resource does the activity are not relevant in a simulation study. Due to the fact that these characteristics are descriptive, these characteristics are not possible to model. Therefore, characteristics of these aspects are not taken into account for the initial characterization to model resources in healthcare processes.

The important characteristics of the existential and availability aspect make the initial characterization of active resources in healthcare simulation modeling:

Existential

- **Identity:** In healthcare processes it is important to identify individual resources. All resources in healthcare have their own characteristics which are relevant for the process. For example, the work times and the activities that the resource can do are important in general healthcare processes.
- **Consumption:** In healthcare processes it is important to model that the active resources can be reused. After an activity the resource becomes available again for a new activity.
- **Make-up:** The composition of resources is important if multiple active resources are involved in an activity. Multiple resources are used in several healthcare activities, like a surgery.

Availability

- **Status:** The status of an active resource is important, to check whether the resource is available to carry out an activity. Active resources have multiple reasons why they are not available for activities. Free, busy, out of work time, illness and vacation are examples of states of an active resource.
- **Schedule:** Work times of resources are important to model the availability of the resource. Due to the limited availability of human resources it is important to know that resources are working on specific days. Especially when multiple

resources are involved in an activity it is important that all resources are available on the same time.

- **Delivery mode:** To choose the simulation type (discrete event simulation or system dynamics) it is important to know whether the service of the active resource is discrete or continuous. This characteristic will help to select an appropriate simulation tool for the simulation study.
- **Exclusivity:** One active resource can be on one place on one time unit. It is important to model that resources can deliver service on one location. However, it is possible that a resource can do an activity in which more patients are involved. An information session is an example that multiple patients are involved in a process of one resource.

4. Implementation

Characteristics of the active resources can be important for the process, but should be possible to model in the simulation tools. Two well-known simulation tools are used to evaluate the modeling of the most important characteristics of active resources in healthcare. Two questions are evaluated:

1. Can the simulation tool model the characteristic?
2. Can the simulation tool model the characteristic in a generic way?

Bosilj, Ceric and HLupic (2007) give four aspects to evaluate the appropriateness of simulation tools. These aspects are:

- Hardware and software considerations
- Modeling capabilities
- Simulation capabilities
- Input/ Output issues

For this research, only the second aspect is important. This aspect evaluates how well and how precise the characteristics of the resource can be modeled in the simulation tool (Bosilj, Ceric and HLupic, 2007). Analyzed is whether the characteristics of the active resources in the tools can be modeled in a desired way such that the properties of the active resources can be changed easily.

According to the developed characterization in the previous chapter, seven important characteristics are identified for healthcare resources. In this chapter the three most interesting characteristics are evaluated. To evaluate all characteristics was not possible in the time span of this project. Identity, status and schedule are chosen as most interesting characteristics for resources in healthcare processes, because these characteristics relates to one specific resource. It is important that these characteristics can be modeled in simulation tools and that these are modeled as generic as possible. The model should not radically changed if a new parameter setting is used. Just slight adaptations should be made to the model. An example implementation will be created for these three characteristics so that this can help modeling of resources in healthcare processes in the future.

Consumption, make-up and exclusivity are not evaluated, because these characteristics of resources are modeled in the structure of the process and are the same for most active resources. In the process resources are selected, and released. If a resource is busy the resource cannot carry out other activities. These characteristics are also discussed indirectly in the chosen characteristics. Delivery mode is not chosen, because this will help to identify the simulation method (discrete event simulation or system dynamics), but has no influence on the process itself. When the simulation method is chosen this characteristic is not important anymore.

ARENA and CPN Tools are used as evaluation tools in this chapter. ARENA is chosen, because the Libra case is modeled in ARENA in the case study of this report. In ARENA modules are predefined which can assist in modeling of the characteristic of active resources and changing of properties of the resources. CPN Tools is chosen, because models of the three healthcare processes are available in CPN Tools due to previous student projects. Further, this tool is known by the researcher and a license is available. Also, CPN Tools starts from zero, so that properties can be modeled in the desired way. A disadvantage is that this will cost more time. This chapter is quite technical and the terms of the simulation tools are used to explain exactly how these characteristics can be modeled.

4.1 Identity

This characteristic can be modeled in both tools reasonable simple. In ARENA the module of resource can be used. In this module individual resources can be modeled with an identical name. Also, some information of this resource can be added, like the capacity (exclusivity or schedule), costs, statesets (status) and failures. This information is predefined and no other information of the therapist can directly related to this resource. Eventually, some variables can be used to store some extra information of the resource. Individual resources can be found in ARENA using the expression builder due to the identical name which is given in the resource module. For example in a process a resource is selected that will carry out the activity by selecting the name of the resource (seize module). During the process the state of the resource changes and the resource is unavailable for other processes a while (delay module). If the process is finished the resources becomes available again for new processes (release module).

In CPN Tools resources can be modeled as tokens. Characteristics of these tokens can be declared using colorsets in the tool. Several information of the resource can be modeled in the declarations of the colorset, like an individual identifier. In the process, tokens can be used if a resource is needed to carry out an activity. Characteristics of the resource can be adapted using declaration in the process. Resources (tokens) can be distinguished in the process using the defined identical identifier.

4.2 Status

Resources in healthcare processes have several states during the process. In ARENA these states can be modeled using the stateset module. All possible states of the resources can be defined. During the process the state can change from one state to another. The state of the resource can always be requested using the expression builder. Also, expressions can be made to regulate what a resource can do or not in which state. For example, if the resource is available the resource can start a process, but in a busy state the resource cannot start a process.

In CPN Tools states are not possible to model. The places in which the tokens are determine the state of the resource. To fire a transition (execute a process) a token is necessary. This is only possible if the correct token is available in the place (and thus state) before the transition. The state of a resource can change when the resource goes to another place. If a resource is busy the token is in another place than when the resource is free.

4.3 Schedule of work times

The work times of the resources have an important role in healthcare models, because the availability determines whether an activity can be carried out or not. A disadvantage in the case study (chapter two) was that the capacity is not equal to this schedule, because some support activities are carried out by the resources which are unexpected and irregular. This makes the modeling of the availability and capacity of the resources a lot harder. The best option is to model also these activities so that the resource is unavailable at these moments for the core activities. In ARENA the schedule module is available. In this schedule the work times of the resources can be defined. This schedule is also easy to change. In figure 31 an example of the implementation of a workday in ARENA can be found.

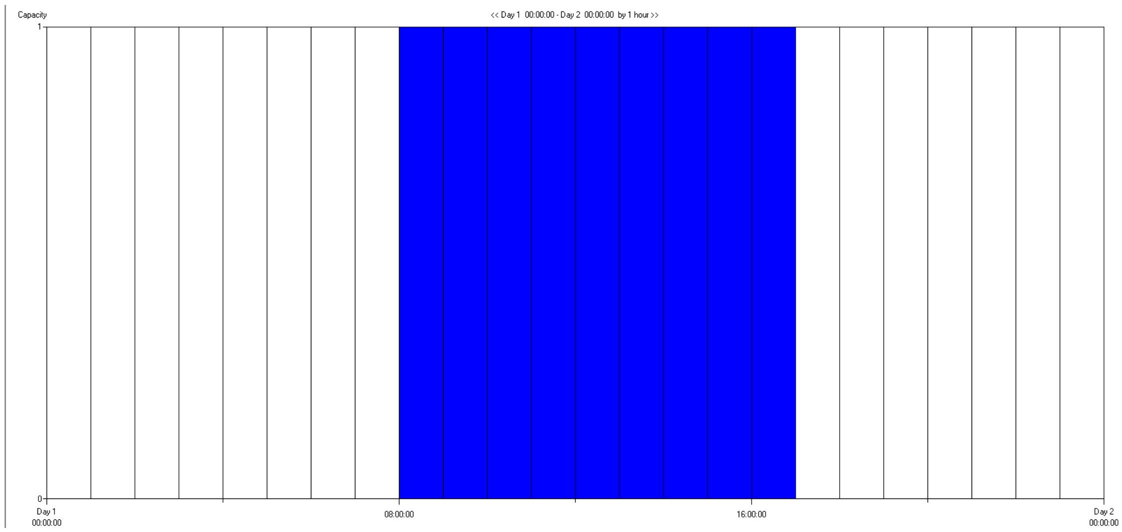

Figure 31: Schedule of work times in ARENA

In CPN Tools the work times are much harder to model. A construction should be made that stored the time of the week. Also, the resource should get the work times in the characteristics. Every time unit, must be checked whether the resource is in work time or not. As an example the implementation in CPN Tools of a workday is described. A therapist work from 8.00h till 17.00h in a day of 24.00 hours. Initially the resource (token) is in a place and cannot do any activity. The resource has two attributes: start time (8) and end time (17). This place can only left when the start time of the resource is reached. The clock goes from 0.00h to 8.00h. Then, the resources should go to another place in which the resource is available for an activity till 17.00h. At that moment the resource goes back to the initial place and cannot carry out an activity any more. Such scheme should be developed for a complete week and will cost relatively much time. However, if finished the work times can easy be changed.

5. Conclusions and future work

In this chapter the overall conclusion of the report is given. Also, some limitations of the project are given and some future research directions are discussed. Finally, a reflection on this master thesis project is given.

5.1 Conclusion

The typology of (Jenkins and Rice, 2007) is used to describe resources in several domains. Therefore, the definitions of this typology are really abstract and some characteristics look therefore similar. After analyzing the three healthcare cases, it seems that some characteristics are case specific (like transportation times in MDL). Differences between core and support process are indicated. However, more healthcare cases should be analyzed to verify whether this indication is true. The abstract definitions and specific characteristics of the processes make it hard to make an initial characterization for the modeling of active resources in healthcare processes. Further, several characteristics of the typology of Jenkins and Rice (2007) are descriptive and important in reality. An example of such characteristic is interaction. This cannot be modeled in discrete event simulation models. Also, specific details of how the resource carries out an activity are not relevant for a simulation model. In words this can described, but a simulation model is a simplification of the real process and such characteristics are not relevant for a simulation model. Nevertheless, the typology of Jenkins and Rice (2007) is used as starting point to design an initial characterization of active resources in healthcare processes.

After the analysis of the most important characteristics in the three healthcare processes it seems that some characteristics of active resources in healthcare are indeed different compared to active resources in manufacturing. As indicated in the case study, the identification of individual resources and the availability of these resources seem also in the analysis very important in healthcare processes. The cause is that humans are more dynamic than machines and that resources in healthcare have their own specific characteristics. However, also some characteristics in healthcare and manufacturing are the same. For example, which resources are used in a process and what will happen with the resource after an activity is important in both sectors.

The framework developed in this research is a first indication of important characteristics in healthcare processes. Just three healthcare processes are analyzed, and the question is if these are representative for the whole healthcare sector. As can be seen in the three cases, there are also specific characteristics of resources important in a specific case and not applicable to the general healthcare processes. More processes should be analyzed to verify whether this initial characterization can be applied to the whole healthcare sector. However, according to this research, the focus in the modeling of active resources in healthcare processes should be on individual resources with an availability scheme.

After it is known which characteristics of resources are important it is important that these characteristics can be modeled in a convenient way in the simulation tools. These should be easy to model and should also be as generic as possible. A library of the characteristics in the simulation tools will be helpful. In ARENA predefined modules are available which assist in the development of the model. In CPN Tools these characteristics should be built complete from zero.

5.2 Limitations

A limitation of this master thesis project is that the typology of Jenkins and Rice (2007) is not validated yet. This typology looks complete. It seems that all characteristics of resources can be described in the characteristics of the typology, but the question is whether this typology is really complete. Also, the descriptive character of the typology is a limitation. Several characteristics that are relevant for real resources are taken into account, while these cannot be modelled in a simulation models.

Another limitation is the analysis of three healthcare cases. Since no literature is available about this topic, all healthcare cases are lumped together. This is maybe not the best option, because in the analysis of the three healthcare case can be seen that several aspects are also case specific and that a distinction can be made between core and support processes.

5.3 Future work

The result of this master thesis project is an initial framework of healthcare characteristics. In the future this framework should be validated to check whether this framework also holds for other healthcare processes and whether this characterization is complete. Also, research can be done on the limitation that no distinction is made within healthcare processes. Maybe it is better to divide healthcare into some areas in which a separate framework can be developed.

Another possibility for future work is to develop a library for the modeling of the characteristics of the healthcare resources. Research can be done how these characteristics can be modeled best in the simulation tools so that the resources contains the desired behavior and that these can be adapted easy (generic).

5.4 Reflection

The identification of the framework for healthcare resource characteristics was a hard task. No concrete information was available in the literature. However, the typology of Jenkins and Rice (2007) was a helpful starting point. This typology was reasonable abstract and quite descriptive. Therefore, it was the question whether this typology was appropriate for this research. Resources in healthcare can be described with this typology, but describing is not the same as modelling. A simulation model is a simplification of the real process, but some characteristics describe the real process in detail. Such detailed information is not necessary in simulation models or cannot be modelled in a simulation model. Also, it seems that not all healthcare processes are similar. Therefore, a general characterization was hard to make. Nevertheless, three healthcare cases are analyzed using this typology to get an initial framework. It is clear that this framework needs to be validated and extended with more healthcare processes before it can be seen as a framework of active resources for all kind of healthcare processes. Afterwards, it was maybe more valuable to start this master thesis project with the characterization of important characteristics of healthcare resources, so that these can be applied to a case study. After the case study the framework should be judged. However, since no concrete information in the literature, a case study was used to get a first indication of important characteristics of resources in healthcare.

The characteristics of the active resources are analyzed in this project. However, the case study was a large part of this study. Other criteria, next to resources, are found in the case study that makes the use of simulation in healthcare models complex. During the case study some remarkable issues are found. The complexity is mainly caused by the different way of approaching healthcare systems and manufacturing systems. In manufacturing products have no fixed throughput time and can wait in a queue till they can start the process. In the case study this seemed a lot more complex, because fixed throughput times are required for Libra and patients are treated according to a treatment scheme. These characteristics make it hard to develop a good simulation model and the question arises whether simulation is the best option to analyze such planning processes.

Also, some design choices of the process resulted in limitations of the model. The determination of the routing of the treatments is a criterion that can improve simulation models in the future. Now, probabilities are used in the model, but according to the case study this method had influence (more than expected) on the results. The average planned capacity needed per week was similar to the capacity available per week, but the utilization was relative low. More treatments can be carried out if the routing of the treatments can be modelled better (for example iteratively). In reality the planning process is also a difficult part for Libra, because gaps are created in the planning schemes of the therapists. Due to these gaps the production was too low given the available capacity. An advice for Libra is to study the possibilities with other planning methods. This can maybe improve these results in the future. An option is to automate this planning process using mathematical methods, like linear programming. Braaksma (n.a) studied such methodology in the rehabilitation care and found some positive results. Further research is needed to identify whether this method also works for Libra. Possibly, a simulation tool can be developed in the future that can make a planning during the simulation. Another limitation of the model was the choice of fixed therapists. This is based on probabilities in the simulation model. This can have effect on the number of treatments missed, because if a therapist has no capacity left this therapist can chosen and another therapist who still has capacity is not chosen. In reality the employee of the planning knows or can see in the schedule of the employee when this resource has capacity left. Especially, these limitations have to be in mind when interpreting the results of the simulation study. Of course also the other limitations and assumptions of the model should be taken into account when interpreting the results.

6. References

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Appendix

Appendix A – Simulation design

A simulation study is used to analyze the effects of some changes in the process (parameters). In this section, a method to perform a simulation study is described. As simulation design in this project is the ten steps of a sound simulation study by (Law, 2007) used. A typical simulation study process is shown in figure 32. The steps of this simulation process are discussed shortly. A more executive explanation can be found in (Law, 2007). Note that a simulation process is not linear, but during a simulation study it is possible that previous steps are redone. The first step is the problem formulation and the study planning. This step describes the objective of the study and the questions that will be considered in the study. Also the performance measures and resources of the study should be considered. The second step is to collect data and to define the conceptual model. In this step information about the as-is situation of the process and information about the parameters of the model are collected. Also the level of detail is determined in this step. The third step is the validation of step two. The simulation will proceed when the stakeholders agree with the model definition and assumptions. Step four is construction of the computer simulation model. More and more characteristics of the process are added to the model till the desired model is reached. Then, this model will be verified before the study can proceed to step five. In step five a pilot run is made which is validated in step six. In step seven the simulation experiments are specified. All scenarios of the simulation study are defined. Also, warm-up and cool-down period, run length and number of replications in the simulation are specified. In step eight the production runs are made to analyze the results in step nine. Finally, in step ten the results are discussed. (Law, 2007)

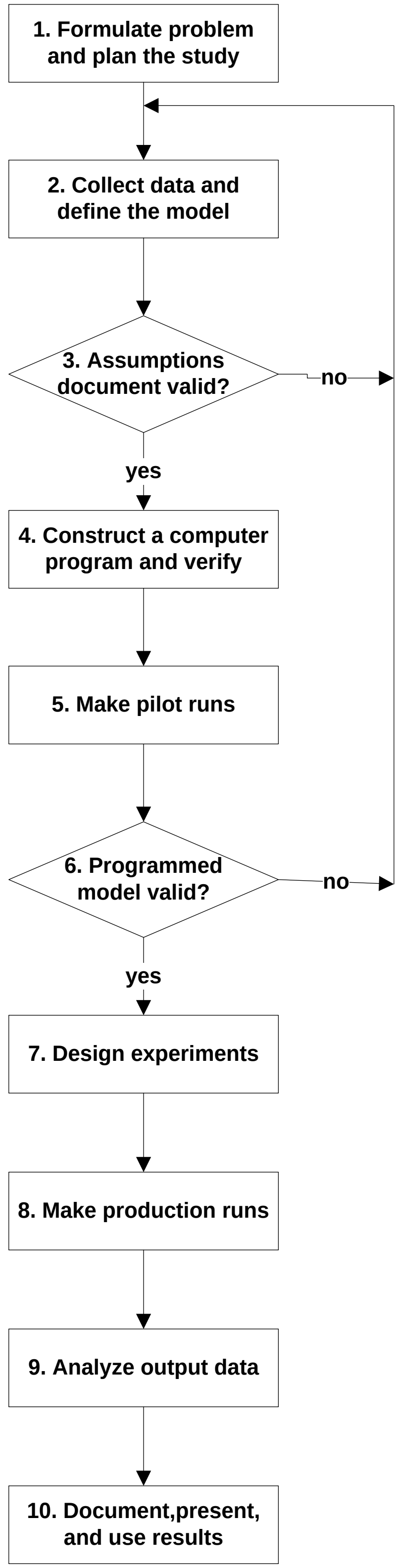

Figure 32: Steps in a sound simulation study (Law, 2007, p.67)

Appendix B – Organizational chart

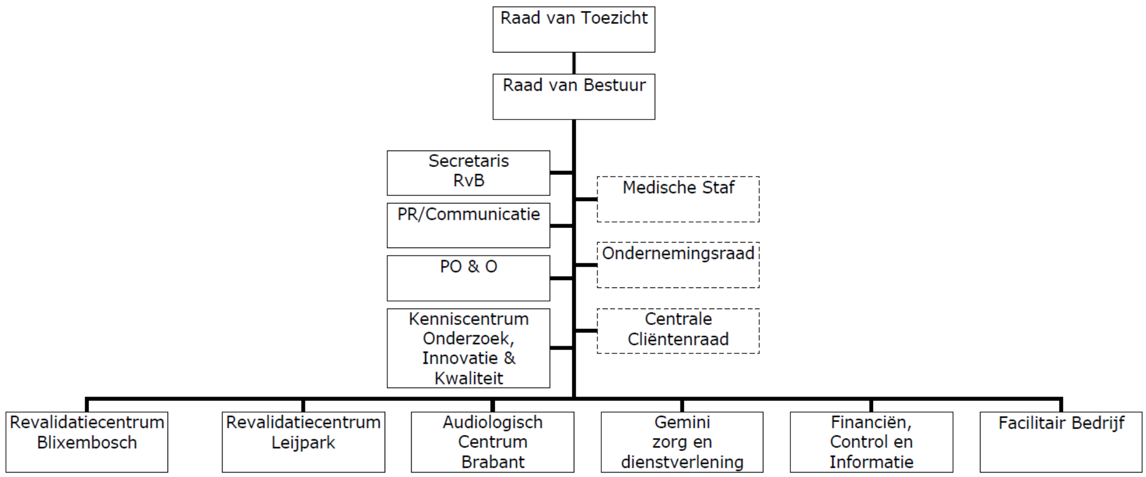

Figure 33: Organizational chart of Libra Zorggroep

Source:http://www.librazorggroep.nl/cms/publish/content/downloaddocument.asp?document_id=8

Appendix C – Calculation of DBC and RBU

	Patiënt gebonden tijd			Overige tijd
	Directe tijd		Indirecte tijd	
	Individuele behandeling	Groepsbehandeling		
DBC	Tijdsduur behandeling* aantal behandelaren	(Aantal behandelaren* tijdsduur behandeling)/ groepsgrootte	Aantal behandelaren* tijdsduur	0
RBU	Tijdsduur behandeling* aantal behandelaren	1.5*((Aantal behandelaren* tijdsduur behandeling)/ groepsgrootte)	0	0

Table 4: Calculation of DBC and RBU level

Appendix D – Simulation tool selection

In this appendix the simulation tool choice is discussed. In the introduction is described why simulation is used to study the consequences of some changes in the process parameters or in the process. A lot of simulation tools are available, but which simulation tool is the most appropriate tool for this process? The research question is about the identification of the most appropriate simulation tool to model the Libra process. In this master thesis project a shortlist of possible simulation tools is made. Two inclusion criteria are used: the tool is known by the researcher and a license is available. Then, this shortlist is analyzed to choose the most appropriate tool. The first research question for this master thesis project is:

> **Research question:** Which simulation tool is the most appropriate tool to model the treatment processes of the patients with chronic pain complaints?

In the literature review of (Sillekens, 2011) the two most used simulation methods are compared. These are discrete-event simulation (DES) and system dynamics (SD). Although the aim of the two methods is the same, both simulation methods are modelling on a different level (Brailsford, 2007). SD is more appropriate for continuous processes and DES is more appropriate for discrete processes. The process of Libra seems discrete. Therapists are treating patients during a time period and are then released. Then, a new patient can be treated. All treatments have their own predefined duration. Now it is known that the process is discrete, a specific DES simulation tools can be chosen. A lot of DES simulation tools are available. A shortlist of DES simulation tools are analyzed to choose the most appropriate tool.

Simulation tools

In this section the shortlist of a number of possible DES simulation tools is discussed. This short list is based on the experiences of the researcher. Only familiar tools for the researcher are included into this shortlist. Also, the availability of a license was important to select the simulation tool. The shortlist is given below inclusive the reason why this tool is included:

- CPN Tools: During the past years some student projects in a simulation course are executed for Libra to give team VI of Libra more insights in their process. The simulation tool that was used during this course was CPN tools.
- Enterprise Dynamics: This tool is used a lot for business modelling (site Enterprise dynamics: http://www.incontrolsim.com/). Possibly this tool can also be used for healthcare modelling.
- ARENA: ARENA is a tool to model and analyze business processes. Predefined modules of this tool will help to develop simulation models in an efficient way.

Evaluation criteria

The simulation tools are studied for the Libra case. Some evaluation criteria are given by Bosilj-Vuksic, Ceric and Hlupic (2007). Their evaluation categories are:

1. Hardware and software configurations
2. Modelling capabilities

3. Simulation capabilities
4. Input/output issues

These categories are split into more concrete evaluation criteria. There are a number of important criteria for Libra. The other criteria will support the researcher in doing a simulation study, but are not that much important for Libra. The most important criteria for Libra are:

i. Software compatibility (category 1): This criterion evaluates whether the tool can interfere with other software programs (Bosilj-Vuksic, Ceric and Hlupic, 2007). In case of Libra it is useful to read data of input parameters from Excel and write output of the model to Excel.
ii. Financial and technical features (category 1): This criterion evaluates the features of the tool related to the costs of the tool to get a license for the organization (Bosilj-Vuksic, Ceric and Hlupic, 2007). In the case of Libra it is important to select a tool that is allowable to use in the study.
iii. General features (category 2): This criteria evaluates the features of the simulation tool. These features are related to the modelling possibilities of the tool (Bosilj-Vuksic, Ceric and Hlupic, 2007). In the Libra case it is important to know which characteristics of the process can be modelled in the tool and which not.
iv. Efficiency (category 3): This criterion evaluates the capability of the tool to model several complex processes and the characteristics of the tool that can help in saving modelling time and improving the quality of the model. This criterion is important in the Libra case to assist in the model development.
v. Input and output capabilities (category 4): This criterion investigates how easy the tool can define input and output for the model (Bosilj-Vuksic, Ceric and Hlupic, 2007). This is important for Libra, because the input and output parameters of the model are specific for the Libra case.

Tool choice

The research question is answered in this section. Also is explained why the other tools are not chosen as simulation tool of this master thesis project.

In Enterprise Dynamics it was difficult to model the treatment programs, because it is not possible to define attributes for the entities (patients). Also, the availability of resources, the assignment of resources to the entities and the assignment of the resources to the entities is not possible. The general features (category 2) of this tool are not in line with the characteristics of the process. Therefore, Enterprise dynamics is removed from the shortlist.

The choice between CPN Tools and ARENA was much harder. Here, the evaluation criteria described in the previous section are used.

i. Software compatibility (category 1): In ARENA it is possible to integrate the models with Excel. In Excel sheets a lot of information about the processes and therapists can be stored. In CPN Tools the integration of Excel is a harder to do.
ii. Financial and technical features (category 1): Both simulation tools are licensed and commercial usage is not allowed. The main goal of this business part is to identify the most important characteristics of resources to model in complex healthcare processes. Models are not delivered to the company, no one is compensated and only some general insights are the results in this report.
iii. General features (category 2): Some main characteristics of the Libra process are identified. The process is analyzed and the most important characteristics of the process are noted, like groups, availability of therapists, capacity of therapists, assignment of fixed therapists and selection of therapists in process. Some small models are developed to see if the characteristics can be modelled in the tools. Therefore, the results are a bit technical and are discussed table 5.

	ARENA	CPN Tools
Group processes	It is possible to group a number of entities before an activity (process). When the activity is finished the entities can be split.	It is possible to do an activity (fire a transition) only with a specified number of entities (tokens). All entities are released separately after the activity.
Availability of therapists	An availability module for resources is available in the program.	To develop an availability scheme in CPN Tools is a hard task and very time consuming to model a correct one.
Capacity of therapists	A variable can be defined for all therapists (and eventually read from an Excel file).	A variable can be defined for all therapists.
Assignment of fixed therapists to patients	In the attributes of the entities can be stored who the fixed therapists of the patient are.	In the entities can be stored who the fixed therapists of the patient are.
Selection of therapists in treatments	In the activity modules can be stored which resource should carry out the process. Only if this resource is available the process can start.	When the resource is selected this must be compared to the fixed therapists of the patient. Only if this resource is available the activity can be carried out.

Table 5: Evaluation of general features of Libra case in ARENA and CPN Tools

iv. Efficiency (category 3): ARENA has predefined modules that cannot be adapted. However, in CPN Tools own constructions can be made with their exact desired behaviour. The modelling of some specific characteristic will cost much time in

CPN Tools. In ARENA this is already available in the library. Therefore, ARENA will save modelling time and improve the quality of the model and thus is more appropriate for this project.

v. Input and output capabilities (category 4): In both simulation tools the input and output (performance indicators) can be specified by the researcher.

ARENA is chosen as most appropriate simulation tool according to previous criteria. Availability of the therapists seemed to be a very important aspect in the Libra process. According to the previous student projects in CPN Tools this aspect was underexposed. Also, the integration with Excel is an advantage of ARENA over CPN Tools. Even the predefined modules of ARENA should probably result in a higher quality model and in lower modelling time in comparison with CPN Tools.

Appendix E – Verification

Verification is checking whether the simulation model works as it should work. This is step four of figure 3. Several analysis techniques can be used to verify the model. However, it can never be verified perfectly (Kleijnen, 1995). Especially in large and complex models this seems a hard task. The methods used in this project are that the model is built in parts and verified separately and experts are asked to check whether the model is in accordance with the reality.

The base simulation model is verified. Syntax errors are identified by ARENA automatically. Errors in the process and in the parameter values should be found manually. To reduce these errors the model is built in steps. More and more detail is added to the model until all desired functionality is in the model. Sub-models are used to keep the overview. The observation program and treatment programs are separate sub-models. Also, the calendar function and the read function of the start weeks are separate parts of the model. Each part is analyzed separately to check whether this works as it should work. Initially, the developer of the model checked whether the model works correctly for one patient. Later, also more patients are sent through the system to verify whether the model is in accordance with the real behavior.

Also, experts are asked to check whether the model works as it should work during a formal meeting and several informal meetings. The experts had the possibility to assess the assumption, model parameters and the modeled process. In practice a lot of exceptions are made which were hard to model. These exception are not formulated and only in the mind the employee of the planning. Therefore, several times the process needed to be changed.

Appendix F – Validation

Validation is checking whether the simulation model is an accurate representation of the reality (Kleijnen, 1995). This is step five and six of figure 3. It seemed very hard to validate this simulation model. A mathematical method is not available. Historical data can be used to validate the model, but not much data is available by Libra. The cause is that treatment programs are introduced in September 2010. Not much specific data is stored in the last years. The problem of Libra is that a lot of specific performance indicators are not known. This is also the reason why Libra wants more insights in the performance of the process.

Also, the compensation system of rehabilitation centers is changed recently (from RBU to DBC). In the current compensation method, the group factor in group treatments is left. Administration time is compensated in the new situation. This change has also caused that historical data is absent.

Nevertheless, some validation is carried out to improve the acceptance of the simulation model. The validation of this model is done in four ways. A simulation of five replications is used to validate the model.

In the first validation method a historical value is compared to calculated expectations and model results. According to the historical data of Libra the level of RBU in 2011 is 9130. Therapists of FT, ET, MW, PSY and BA are included in this value. The physician is calculated separately, but out of the scope in this model. Of course no real data of 2012 is available. Therefore, the planned amount of RBU in 2012 is manually calculated in table 5. Note that this calculation neglects missed treatments.

	Number of starts in 2012	***RBU per program***	***Total RBU planned***
Observation	346	12.5	4325
Program 1	8	227.5	1820
Program 2	7	136.5	955.5
Program 3	7	114	798
Program 4	31	22.5	697.5
Program 5	37	25.5	943.5
Total			9539.5

Table 6: Calculation of planned therapist's capacity in 2012

This planned RBU in 2012 is higher than the real RBU value of 2011. This is possible since in 2012 another planning is used and experts indicated an increase in production for 2012. Also, the missed treatment will decrease the planned RBU level. According to the simulation model the real RBU in 2012 become in the confidence interval of 8719 and 8884. This value is somewhat lower than in 2011, because the body group treatment is not taken into account in 2012, but in the RBU level in 2011 it is. The RBU level of the body group is maximal 250 RBU[1] per year, but this is divided over patients of several

[1] A body group module consists of two treatments per week during five weeks.
One treatment will cost 1.25 hours. Every five weeks two groups are started, approximately 20 per year.
So the amount of RBU is 5*2*1.25=12.5 per body group module.

teams. Also, a larger amount of missed treatments, due to the routing limitation discussed in section 3.3, will decrease the planned RBU level in 2012 more as in reality.

The second validation method is to check the DBC and RBU level per program (inclusive observation) per patient and the level of DBC and RBU in the simulation model. Unfortunately, real data is not available for the DBC or RBU level per program per patient. So, the expected DBC and RBU are manually calculated in table 6 (see appendix W). The calculated values should be considered as upper bound as programs are completely filled, because missed treatment in the simulation run will lower the DBC and RBU level. However, if groups are not complete this will increase the DBC and RBU level. The observation, program IV and program V, this can be seen as upper bound, since these programs are always completely filled (individual). In the group programs this can be no upper bound if the groups are not complete. The group size for program I, II, III is 9, 8, and 6 respectively. According to the simulation results the average group size of the program was 9, 7.8 and 4.8 during the five test runs. Therefore, the DBC and RBU of program I is also an upper bound. In program II and III groups are not complete what can cause a higher DBC and RBU level than calculated under ideal circumstances. Especially this is the case in program III. These results are confirmed by the table.

	DBC per program per patient			***RBU per program per patient***		
	calculated	Simulation LB	Simulation UB	calculated	Simulation LB	Simulation UB
Observation	15.5	14.10	14.24	12.5	11.83	11.94
Program 1	38.06	33.50	34.03	37.78	37.16	37.89
Program 2	31.63	22.66	25.43	29.56	22.17	25.85
Program 3	34.42	28.34	32.28	31.5	30.21	35.57
Program 4	43	36.90	38.64	35	33.10	34.54
Program 5	46.5	40.28	41.63	38	36.40	37.52

Table 7: Average DBC and RBU level per program per patient compared to the simulation results

In the third validation method an expert was asked to validate the results. Initially, the available capacity of the therapists was overestimated. The hours that the employees are available for only the pain patients were not available for Libra. This caused that Libra has to estimate the capacity of the therapists for the pain team. The results of the model were not completely valid, since all therapists had a lot of rest hours. According to the expert, the therapists have (almost) no rest hours in reality. A new estimation of the capacity available was made by the expert to get more acceptable results.

Finally, the model was validated using sensitivity analysis (Kleijnen, 1995). Some sensitivity analysis is performed to see what happens when a small number of patients are in the model and when a large number of patients are in the model. Also, models with high and low capacity of the therapists are run. These results are analyzed by the researcher and the model shows desired behavior.

The total RBU during a year for the body group module is approximately 20*12.5=250.
Note that patients of several teams are involved in this module.

Appendix G – Inter-arrival time of patients

According to the information of Libra, 346 patients can start an observation per year
A year in the model has 52*5*12=3120 hours.
The inter-arrival time is $\frac{3120}{346} = 9.02$ hours.

Appendix H – Distribution of patients over treatment programs

Treatment program	Percentage %
1	18.24
2	20.13
3	11.01
4	10.06
5	9.75

Table 8: Distribution of patients over treatment programs

Appendix I – Work schedules of therapists

	Monday	Tuesday	Wednesday	Thursday	Friday
FT1	08.00-17.00	08.00-16.45	08.00-12.00	08.00-16.45	
FT2	08.00-16.45	08.00-16.45	08.00-16.45	08.00-16.45	
FT3	08.00-15.15	08.00-15.00		08.00-15.30	
FT4	08.00-16.45	08.00-16.45	08.00-16.45	08.00-16.45	08.00-12.15
FT10	08.00-13.30	08.00-15.00	09.00-12.00	08.00-14.45	
ET1	08.00-16.45	08.00-12.30	08.00-14.45	08.00-12.45	08.00-12.30
ET2	07.30-16.30	08.00-14.15		07.30-14.15	
ET3		08.00-16.45	08.00-11.45	09.15-14.15	09.00-13.00
ET4	08.00-16.45	08.00-16.45	08.00-16.45	08.00-16.45	
ET5	08.00-16.45	08.00-16.45	08.00-16.45	08.00-16.45	
MW1	08.00-16.30	08.00-16.30	08.00-16.30	08.00-16.30	
MW2	08.00-16.30	08.00-12.45	08.00-16.00		09.00-12.45
PSY1		08.00-15.15	08.00-17.15	08.00-17.15	08.45-17.15
PSY2	08.00-16.30	08.00-16.45		08.00-17.15	
PSY3	08.00-17.00				09.00-16.00

Table 9: Work schedules of therapists

Appendix J – Capacity of therapists

$$Capacity = \left(\frac{contract\ hours}{36}\right) * factor\ for\ net\ capacity$$

FT	80%
ET	76%
MW	58%
PSY	58%

Table 10: Factor of net capacity (direct and indirect hours)

	Uren/week	Hart/Long	Capaciteit
FT1	27.5	6.45	13.76
FT2	32	2.75	19.13
FT3	17.4	0	11.38
FT4	35	3.25	20.76
FT10	1.75	0	1.75
			66.78
ET1	32	2.75	18.17
ET2	17	0	10.56
ET3	21	0	13.04
ET4	32	3.5	17.70
ET5	2	0	2.00
			61.48
MW1	32	0	15.17
MW2	24	8	7.58
			22.75
PSY1	23.36	0	11.07
PSY2	24	0	11.38
PSY3	14	8	2.84
			25.29

Table 11: Capacity of therapists

Since FT10 and FT5 are hired from other team these hours per week are not adapted any more.

Appendix K – Therapists per program inclusive their capacity

Observatie											
FT	FT1	13.76	FT2	19.13	FT3	11.38	FT4	20.76			65.03
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38	PSY3	2.84					25.29
											172.54
P1											
FT	FT1	13.76	FT2	19.13	FT3	11.38	FT4	20.76	FT10	1.75	66.78
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7	ET5	2	61.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38	PSY3	2.84					25.29
P2											
FT	FT3	11.38									11.38
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17									15.17
PSY	PSY2	11.38									11.38
P3											
FT	FT1	13.76	FT2	19.13	FT4	20.76					53.65
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38	PSY3	2.84					25.29
											161.16
P4											
FT	FT1	13.76	FT3	11.38							25.14
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38	PSY3	2.84					25.29
P5											
FT	FT1	13.76	FT2	19.13	FT4	20.76					53.65
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38							22.45

Table 12: Therapists per program in combination with the capacity to determine the probability to become a fixed therapist

The chance that a therapist is chosen is the capacity of the therapists divided by the total capacity of therapists which can be assigned to the treatment. Not all therapists can be used in every program and treatment. For example, the chance that FT3 is chosen in program 4 for an FT activity is 11.38/25.14*100%=45.27%

Appendix L – Contents of observation and treatment programs

Observation

Week 1 and 2

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
ET ind	2	0.75	ET	100
FT ind	2	0.75	PSY	100
Test*	1	4	-	100
PSY ind*	2	0.75	Test assistant	100
MW ind**	1	1	MW	100

* Only in week one
** Only in week two

Week 3

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Administration FT	1	0.5	FT	100
Administration ET	1	0.5	ET	100
Administration MW	1	0.5	MW	100
Administration PSY	1	0.5	PSY	100

Week 4

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
PBS	1	0.25	FT+ET+MW+PSY	100
Control session	1	0.25	RA	100

Program 1

Week 0

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Introduction	1	1	PSY	100

Week 1 -10

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Zwemmen	2	0.50	2BA	100
ET group*	2	1	2ET	100
PSY group	2	1	PSY	100
Fitness	1	1	FT+BA	100
GA/Lopen	1	1	FT+BA	100

Ontspanning**	1	1.25	FT+BA	100
MW ind***	1	0.75	MW	100
PBS****	1	0.5	FT+ET+MW+PSY	100

* After week 6 one time a week
** FT1, FT3 and FT10 only possible therapists
*** three times in 10 weeks
**** Every two weeks (odd)

Week 11

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Administration ET Group	1	1	2ET	100
Administration PSY group	1	1	PSY	100
Administration Fitness	1	1	FT+BA	100
Administration GA/Lopen	1	1	FT+BA	100
Administration Ontspanning	1	1.25	FT+BA	100
Administration MW ind	1	0.5	MW	100

Week 12

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Control session	1	0.25	RA + PSY	100

Week 22

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Terugkom sessie	1	1	PSY +(FT/ET/MW)	100

Program 2

Week 0

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Introduction	1	1	PSY	100

Week 1 -10

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Lichaamsbewustwording	1	1.25	FT+ET	100

group*				
Mindfullness*	1	1	FT	100
ET group	1	1	2ET	100
ACT cursus	1	1	MW+PSY	100
MW ind**	1	0.75	MW	100
PBS***	1	0.5	FT+ET+MW+PSY	100

* FT1, FT3 and FT10 only possible therapists
** three times in 10 weeks
*** Every two weeks (odd)

Week 11

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Administration Lichaamsbewustwording	1	1	FT+ET	100
Administration mindfullness	1	1	FT	100
Administration ET group	1	1	2ET	100
Administration ACT cursus	1	1	MW+PSY	100
Administration MW ind	1	0.5	MW	100

Week 12

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Control session	1	0.25	RA + PSY	100

Week 22

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Terugkom sessie	1	1	PSY +(FT/ET/MW)	100

Program 3

Week 0

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Introduction	1	1	PSY/MW/FT/ET	100

Week 1 -10

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Conditie training*	2	1	Ft + BA	100
ET group	1	1	2ET	100

Fitness	1	1	FT+BA	100
PSY ind**	1	0.75	PSY	50
MW ind**	1	0.75	MW	50
PBS***	1	0.5	FT+ET+MW+PSY	100

* Not FT3
**One time in two weeks
*** Every two weeks (odd)

Week 11

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Administration ET Group	1	1	2ET	100
Administration Conditie training	1	1	FT + BA	100
Administration Fitness	1	1	FT+BA	100
Administration PSY ind	1	0.5	PSY	50
Administration MW ind	1	0.5	MW	50

Week 12

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Control session	1	0.25	RA	100

Program 4

Week 1 -12

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Lichaamsbewustwording ind*	1	0.75	FT	100
Belastbaarheid	1	0.75	ET	100
PSY ind**	1	0.75	PSY	50
MW ind**	1	0.75	MW	50

* Only FT1, FT3, FT10
**Five times in 12 weeks

Week 13

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Administration	1	0.5	FT	100

lichaamsbewustwording ind				
Administration Belastbaarheid	1	0.5	ET	100
Administration PSY ind	1	0.5	PSY	50
Administration MW ind	1	0.5	MW	50

Week 14

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
PBS	1	0.25	FT+ET+MW+PSY	100
Control session	1	0.25	RA	100

Program 5

Week 1 -12

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Module fysiek*	2	0.5	FT	100
Belastbaarheid	1	0.75	ET	100
PSY ind**	1	0.75	PSY	50
MW ind**	1	0.75	MW	50

* Not FT3
**Five times in 12 weeks

Week 13

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
Administration module fysiek	1	0.5	FT	100
Administration Belastbaarheid	1	0.5	ET	100
Administration PSY ind	1	0.5	PSY	50
Administration MW ind	1	0.5	MW	50

Week 14

Treatment	Number of times a week	Time (hr)	therapist	Chance (%)
PBS	1	0.25	FT+ET+MW+PSY	100
Control session	1	0.25	RA	100

Appendix M – Planning of program starts

JAARPLANNING TEAM VI 2011

weeknummer	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1
	3	10	17	24	31	7	14	21	28	7	14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	5	12	19	26	3	10	17	24	31	7	14	21	28	5	12	19	26	2
	1	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	5	6	6	6	6	7	7	7	7	8	8	8	8	8	9	9	9	9	10	10	10	10	10	11	11	11	11	12	12	12	12	1
Groepsprogramma's																																																					
Hart (Wr/jk/w b/lkl/mb/soo/lz/fco)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Long (w r/jk/mle/lh/soo/lz/fco)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Pijn de baas-1(jko/ag/lkl/soo/svr/maa)		x	x	x	x	x	x	x	l		x	x	x	x	x	x	x		x	x	x	l	x	x	x	x	x							x	x	x	x	x	l	x	x	x		x	x	x	x	x	x	x	l		
Anders denken en voelen-2a(les/mvt/lkl/lm/rbo/agra)		x	x	x	x	x	x	l	x		x	x	x	x	x	x	x		x	x		l	x	x	x	x	x							x	x	x	x	x	l	x	x	x		x	x	x	x	x	x	x	l		
Anders denken en voelen-2b(mvt/jko/lm/agra/les)		x	x	x	l	x	x	x	x		x	x	x	x	x	x	l		x	x	x	x	x	x	x	x	x	x								l	x	x	x	x	x	x		x	x	x	x	l	x	x	x		
Anders doen-3a(les/maa/rb/tv/rbo/soo)	x	x	x	x	x	x	x	x	l	x	x	x	x	x	x	x	x	x	x	l	x	x	x	x	x	x	x	x	x	x	l	x	x	x	x	x	x	x	x	x	x	l	x	x	x	x	x	x	x	x	x	x	
Anders doen-3b(les/mvt/mle/agra/soo/tv)	x	x			l	x	x	x	x	x	x	x	x	x	x	l	x	x	x	x	x	x	x	x	x	x	l	x	x	x	x	x	x	x	x	x	x	l	x	x	x	x	x	x	x	x	x	x	l	x	x	x	

weeknummer	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1
INDIVIDUELE PROGRAMMA'S																																																					
Anders denken en voelen ind.1a (les/mvt/mb/rbo/jko/les)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Anders denken en voelen ind.1b(lkl/agra/mvt/tv)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Anders denken en voelen ind.1c(mb/soo/mvt/tv)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Anders denken en voelen ind.1d(mvt/jko/lm/mb)		x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Anders denken en voelen ind.1e(les/lkl/mvt/agra/tv)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders denken en voelen ind.1f(agra/mvt/lkl/tv)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders doen ind.2a(mvt/jko/mle/rbo)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Anders doen ind.2b(mvt/jko/rbo/mle)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders doen ind.2c(les/mb/soo/mvt/tv)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders doen ind.2d(tv/mvt/mle/agra)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders doen ind.2e(mvt/jko/mle/lm)			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders doen ind.2f(mle/agra/tv/mvt)				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders doen ind.2g(les/rb/rbo/mvt/tv)						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Anders doen ind.2h(lm/rb/mvt/tv)							x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Anders doen ind.2i(rb/mvt/tv/soo)								x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Anders doen ind.2j(les/rbo/mb/jko)										x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Anders doen ind 2k(jko/mvt/mle/soo)											x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		

Table 13: Planning of treatment programs in 2011

According to the scheme above, the start weeks of the program in 2011 are:

- Program I: 9-22-39-51
- Program II:5-8-17-22-36-39-48-51
- Program III:5-9-16-20-27-31-38-42-49
- Program IV:3-6-9-14-14-15-17-20-23-28-28-29-33-35-39-41-44-45-47-49
- Program V:1-3-4-6-7-8-10-11-13-14-15-15-17-18-20-21-22-24-25-27-28-29-31-33-34-36-37-38-40-41-43-44-45-45-47-48-50-51

JAARPLANNING TEAM VI 2012

weeknummer	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1
	2	9	16	23	30	6	13	20	27	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	3	10	17	24	31
	1	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	7	7	8	8	8	8	9	9	9	9	10	10	10	10	10	11	11	11	11	12	12	12	12	12
Groepsprogramma's																																																					
Hart (Wr/jk/w b/rb/mb/soo/lz/fco)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Long (w r/jk/mle/lh/soo/lz/fco)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Pijn de baas-1a		I	x	x	x	x	x		x	x	x	x	x		I	x	x		x	x	x	x	x	x	x	x	X						I	x	x	x	x	x	x	x	x		x	x	I	x	x	x	x	x	x		
Pijn de baas-1b					I	x	x		x	x	x	x	x	x	x	x			I	x	x	x	x	x	x	x							x	x	x	I	x	x	x	x	x		x	x	x	x	x	I	x	x	x		
ACT-2a	I	x	x	x	x	x	x		x	x	x	x	I	x	x	x	x		x	x	x	x	x	x	x							I	x	x	x	x	x	x	x	x	x		x	I	x	x	x	x	x	x	x		
ACT -2b		x	x	x	x	x	x		x	I	x	x	x	x	x	x	x		x	x	x	x	I	x	x	x							x	x	x	x	x	x	x	I	x		x	x	x	x	x	x	x	x	x		
Anders doen-3a	x	x	x	x					I	x	x	x	x	x	x	x	x	x	x	x				I	x	x	x	x	x	x	x	x	x	x			I	x	x	x	x	x	x	x	x	x	x						
Anders doen-3b		I	x	x	x	x	x	x	x	x	x	x			I	x	x	x	x	x	x	x	x	x	x	x						I	x	x	x	x	x	x	x	x	x	x					I	x	x	x	x	x	

weeknummer	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1
INDIVIDUELE PROGRAMMA'S																																																					
Anders denken en voelen ind.1a					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Anders denken en voelen ind.1b							x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Anders denken en voelen ind.1c							x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Anders denken en voelen ind.1d												x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Anders denken en voelen ind.1e	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders denken en voelen ind.1f				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders denken en voelen ind.1g		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders denken en voelen ind.1h	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders doen ind.2a					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Anders doen ind.2b						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders doen ind.2c					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders doen ind.2d					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders doen ind.2e	X	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders doen ind.2f							x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders doen ind.2g												x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders doen ind.2h													x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders doen ind.2i												x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Anders doen ind.2j	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	

Table 14: Planning of treatment programs in 2012

According to the scheme above, the start weeks of the program in 2012 are:

- Program I: 2-5-15-19-33-36-45-48
- Program II:1-10-13-23-32-40-44
- Program III:2-9-15-24-32-37-47
- Program IV:1-1-2-4-5-7-7-12-15-15-16-18-19-21-21-26-31-31-32-34-35-37-37-42-45-45-46-48-49-51-51
- Program V:1-1-5-5-5-6-7-12-12-13-15-15-19-19-19-20-21-26-26-27-29-31-35-35-35-36-37-42-42-43-43-45-49-49-49-50-51

Appendix N – Research questions simulation study

The simulation study is used to get answer on a number of question, so that Libra gets insights in the consequences of some changes in the process (parameters) on some performance indicators, like production results. A sensitivity analysis is carried out for some decision variables in the as-is situation. Also, some more flexible processes are analyzed. More flexible processes can better react on changes in the environment.

The first research question is about the consequences of lower available capacity of therapists. Absence of therapists and vacation of therapists are analyzed. The first research question of this master thesis project is:

> **Research question 1:** What are the consequences on the performance indicators when the capacity of the therapists (decision variable 2) changes during the year?

The second research question is about the consequences when the amount of patients changes in a treatment program. Due to this change the number of programs starts during the year will also change. The second research question of this master thesis project is:

> **Research question 2:** What are the consequences on the performance indicators if the number of patients in a treatment program changed (decision variable 1)? The change in the number of patient in a treatment program changes also the number of programs that will start during the year (decision variable 5).

One way to increase the flexibility of the process is to decrease the number of planned treatments. Administration time is planned in the current situation. More flexible is to do administration tasks in 'own' time. Capacity of the therapists is decreased to compensate the 'own' time. The third research question of this master thesis project is:

> **Research question 3:** What are the consequences on the performance indicators of the system when the administration is not planned anymore?

The last research question describes also a way to increase the flexibility of the process. In the current situation the start weeks of the treatment programs are predefined. The disadvantage is that it is beforehand not known how many patients arrive to the programs. This can result in an inefficient planning using the predefined start weeks. In the new situation the start weeks are not longer predefined. Treatment programs will start when there are enough patients waiting for the program. The last research question of the business part is:

> **Research question 4:** What are the consequences on the performance indicators when the start weeks of the treatment programs are determined dynamically instead of predefined?

Appendix O – Conclusions research questions simulation study

According to the planned capacity in 2012 the disciplines FT and ET have enough capacity available. On average, not all available capacity per week will be used for these disciplines. For MW and PSY the capacity is a problem, since on average too less capacity is available per week. For MW are on average 3 hours per week extra needed and for PSY 1.5 extra hours are needed per week. Using this planning, it is advisable to increase the capacity of the MW and PSY disciplines.

An increase or decrease of the number of patients in a program has effect on the capacity needed per year. The reduction of the number of program III starts saves approximately 114 hours divided over 12 weeks. However, per discipline this change is smaller but not all disciplines are equally involved. The increase of the number of starts of program III cost 114 hours divided over 12 weeks.

Vacation periods have of course effects on the production of the Libra case. Due to vacation periods, fewer treatments are carried out. However, the predefined start dates limited the interpretation of the results. If RCB is closed a couple of weeks, this capacity should be overtaken in the other weeks. Due to the predefined start weeks the vacation periods are again taken into account and thus the vacation period is in this case two times taken into account. Less valuable results are found for this research question.

The deletion of the administration activities in the planning process will not result in better results. This is more or less a surprise. The flexibility of the process is increased and the other treatments have more possibilities in which these treatments can be planned. No improvements are found in the results when the administration is dropped out of the process. Apparently, the planning of the administration activities has less influence on the process than expected.

In the scenarios of the absence of the therapists no strange differences are found. The therapists with the small contracts (FT, ET and PSY) will not influence the process that much. On the other side, this suggests that these therapists are not really needed in the process and that the same results can be reached when these therapists are not used any more. However, the capacity in MW and PSY seemed too low in the base model and this capacity seemed needed to carry out all treatments. In the scenario when a MW therapist is absent the effects are much larger. This is also logical, because the percentage of capacity that is dropped out is much larger. It is recommended that this therapist will be replaced, because otherwise the MW and PSY will get problems.

The predefined start weeks of the programs make the process very static. A change in, for example, the number of arriving patients cannot directly processed by the model. The complete planning should be changed if the deviation over the programs changed. In the current situation, the waiting times are reasonable high. Also, seemed that using the predefined start weeks the groups (especially III) are not completely filled. Less program starts are needed which delivers more capacity for other programs. These are limitations of the current process. A more flexible process is desired. This increased the capacity needed, probably because more programs are finished. Long term results should be analyzed whether this is caused to the timing of the end of a programs or this will be consequently. The capacity of FT, ET, MW and PSY increases with respectively 1.2, 1, 0.7, 0.8 hours per week. The waiting time of most programs (except program III) decreases enormously if program are started when a program is complete. The average waiting time decreases in program I with approximately 13 weeks, in program II with approximately 7 weeks, in program IV with approximately 16 weeks and in program V with approximately 2 weeks. Also, more patients can be treated in this case, using the same capacity. A disadvantage is that the percentage of missed treatments increased slightly, but this can also be caused by the routing and choice of fixed therapists for the patients in the model. In reality more iteration are carried out to make a week planning, but that is not done in this model. The differences in waiting time and number of patients that is finished during the year are promising and it is certainly worth to consider starting the treatment programs if the group is complete instead of making a year planning beforehand. A disadvantage of this method is that vacation periods are neglected. A possible solution is to close RCB a couple of weeks, in which no treatments are carried out. In the other weeks the programs can proceed in the same way.

So, some interesting results are found in the previous section. However, a remark should be made. The determination of the order that the treatments are carried out was hard to model in a realistic way. Now, probabilities are used, but according to the results this method was not optimal. The utilization was too low, given the average planned capacity needed per week and the available capacity per week. More treatments can be carried out if the routing of the treatments can be modelled better. The choice of fixed therapists is also based on probabilities in the simulation model. This can also have effects in the number of treatments missed, because if a therapist has no capacity left this therapist can chosen and another therapist who still has capacity is not chosen. Further, the capacity of the therapists in this model is estimated. If there is a deviation in the real value and estimated value this will have influence on the results. Finally, the rooms are left out of the scope in this model, but are in reality surely an issue according to the experts. Therefore, the assumptions and limitations of the model should be taken into account when interpreting the results.

Appendix P – Parameter settings scenarios

Base model

- Number of patients in a group treatment program

Treatment program I, II and III are group programs. The maximum number of patients in the program is:

  - Program I: 9 patients
  - Program II: 8 patients
  - Program III: 6 patients

- Capacity per week of the therapists

	Uren/week	Hart/Long	Capaciteit
FT1	27.5	6.45	13.76
FT2	32	2.75	19.13
FT3	17.4	0	11.38
FT4	35	3.25	20.76
FT10	1.75	0	1.75
			66.78
ET1	32	2.75	18.17
ET2	17	0	10.56
ET3	21	0	13.04
ET4	32	3.5	17.70
ET5	2	0	2.00
			61.48
MW1	32	0	15.17
MW2	24	8	7.58
			22.75
PSY1	23.36	0	11.07
PSY2	24	0	11.38
PSY3	14	8	2.84
			25.29

- Work schedules of the therapists

	Monday	Tuesday	Wednesday	Thursday	Friday
FT1	08.00-17.00	08.00-16.45	08.00-12.00	08.00-16.45	
FT2	08.00-16.45	08.00-16.45	08.00-16.45	08.00-16.45	
FT3	08.00-15.15	08.00-15.00		08.00-15.30	
FT4	08.00-16.45	08.00-16.45	08.00-16.45	08.00-16.45	08.00-12.15
FT10	08.00-13.30	08.00-15.00	09.00-12.00	08.00-14.45	
ET1	08.00-16.45	08.00-12.30	08.00-14.45	08.00-12.45	08.00-12.30
ET2	07.30-16.30	08.00-14.15		07.30-14.15	
ET3		08.00-16.45	08.00-11.45	09.15-14.15	09.00-13.00
ET4	08.00-16.45	08.00-16.45	08.00-16.45	08.00-16.45	
ET5	08.00-16.45	08.00-16.45	08.00-16.45	08.00-16.45	
MW1	08.00-16.30	08.00-16.30	08.00-16.30	08.00-16.30	
MW2	08.00-16.30	08.00-12.45	08.00-16.00		09.00-12.45

PSY1		08.00-15.15	08.00-17.15	08.00-17.15	08.45-17.15
PSY2	08.00-16.30	08.00-16.45		08.00-17.15	
PSY3	08.00-17.00				09.00-16.00

- Arrival rate of patients

According to the information of Libra, 346 patients can start an observation per year

- Start weeks of programs

According to the scheme above, the start weeks of the program in 2012 are:

Program I: 2-5-15-19-33-36-45-48

Program II: 1-10-13-23-32-40-44

Program III: 2-9-15-24-32-37-47

Program IV: 1-1-2-4-5-7-7-12-15-15-16-18-19-21-21-26-31-31-32-34-35-37-37-42-45-45-46-48-49-51-51

Program V: 1-1-5-5-5-6-7-12-12-13-15-15-19-19-19-20-21-26-26-27-29-31-35-35-35-36-37-42-42-43-43-45-49-49-49-50-51

- Maximal number of observation per week

Maximal seven observations can start per week.

- Amount of treatments in an observation or treatment program

See the content of the treatment programs in appendix G.

Scenario 1a:
In this scenario the maximum number of patients in program III changes from 6 to 4 patients. Since more program start are needed to treat the same amount of patients the new start weeks of program III in 2011 and 2012 are determined. The programs are divided over the year, but are relative random chosen. The new start weeks of program III in 2011 and 2012 are:
2-7-12-17-22-27-32-37-42-47.

Scenario 1b:
In this scenario the maximum number of patients in program III changes from 6 to 8 patients. Since fewer program starts are needed to treat the same amount of patients the new start weeks of program III in 2011 and 2012 are determined. The programs are divided over the year, but are relative random chosen. The new start weeks of program III in 2011 and 2012 are:
2-12-22-32-42.

Scenario 2:
Some vacation weeks are introduced in the planning. When no capacity is available the treatment programs and observations are postponed and no patients arrive to the model. If the capacity of the therapists is reduced the planning normally proceeds.

The vacation weeks in which no capacity is available in 2012 are: 1-28-29-30-52

In week 18 and 42 the capacity of all therapists is reduced with 50%.
In week 9 the capacity of all therapists is reduced with 25%.

Scenario 3:
The administration activities are dropped out of the model. This is done by making a redesign of the process. Further, the capacity of the therapists is adapted to compensate the administration in own time. The new factor for net capacity is decreased with 10%.

Factor for net capacity:

FT	70%
ET	66%
MW	48%
PSY	48%

The new capacity of the therapists per program is:

FT1	12.04
FT2	16.73
FT3	9.95
FT4	18.16
FT10	1.58
	58.47
ET1	15.78
ET2	9.17
ET3	11.33
ET4	15.37
ET5	1.80
	53.45
MW1	12.55
MW2	6.28
	18.83
PSY1	9.16
PSY2	9.42
PSY3	2.35
	20.93

Scenario 4a:

The therapists ET5 is dropped out of the model. This therapist will not be used in the process anymore. The new chances are calculated using the following figure:

Observatie											
FT	FT1	13.76	FT2	19.13	FT3	11.38	FT4	20.76			65.03
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38	PSY3	2.84					25.29
											172.54
P1											
FT	FT1	13.76	FT2	19.13	FT3	11.38	FT4	20.76	FT10	1.75	66.78
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38	PSY3	2.84					25.29
P2											
FT	FT3	11.38									11.38
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17									15.17
PSY	PSY2	11.38									11.38
P3											
FT	FT1	13.76	FT2	19.13	FT4	20.76					53.65
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38	PSY3	2.84					25.29
											161.16
P4											
FT	FT1	13.76	FT3	11.38							25.14
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38	PSY3	2.84					25.29
P5											
FT	FT1	13.76	FT2	19.13	FT4	20.76					53.65
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38							22.45

Scenario 4b:

The therapists FT10 is dropped out of the model. This therapist will not be used in the process anymore. The new chances are calculated using the following figure:

Observatie											
FT	FT1	13.76	FT2	19.13	FT3	11.38	FT4	20.76			65.03
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38	PSY3	2.84					25.29
											172.54
P1											
FT	FT1	13.76	FT2	19.13	FT3	11.38	FT4	20.76			65.03
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7	ET5	2	61.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38	PSY3	2.84					25.29
P2											
FT	FT3	11.38									11.38
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17									15.17
PSY	PSY2	11.38									11.38
P3											
FT	FT1	13.76	FT2	19.13	FT4	20.76					53.65
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38	PSY3	2.84					25.29
											161.16
P4											
FT	FT1	13.76	FT3	11.38							25.14
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38	PSY3	2.84					25.29
P5											
FT	FT1	13.76	FT2	19.13	FT4	20.76					53.65
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38							22.45

Scenario 4c:
Therapist MW1 is dropped of the model. All activities of the MW discipline are carried out by MW 2. The new percentages that the therapists are chosen are calculated using the following table.

Observatie											
FT	FT1	13.76	FT2	19.13	FT3	11.38	FT4	20.76			65.03
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW2	7.58									7.58
PSY	PSY1	11.07	PSY2	11.38	PSY3	2.84					25.29
											157.37
P1											
FT	FT1	13.76	FT2	19.13	FT3	11.38	FT4	20.76	FT10	1.75	66.78
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7	ET5	2	61.47
MW	MW2	7.58									7.58
PSY	PSY1	11.07	PSY2	11.38	PSY3	2.84					25.29
P2											
FT	FT3	11.38									11.38
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW2	7.58									7.58
PSY	PSY2	11.38									11.38
P3											
FT	FT1	13.76	FT2	19.13	FT4	20.76					53.65
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW2	7.58									7.58
PSY	PSY1	11.07	PSY2	11.38	PSY3	2.84					25.29
											145.99
P4											
FT	FT1	13.76	FT3	11.38							25.14
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW2	7.58									7.58
PSY	PSY1	11.07	PSY2	11.38	PSY3	2.84					25.29
P5											
FT	FT1	13.76	FT2	19.13	FT4	20.76					53.65
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW2	7.58									7.58
PSY	PSY1	11.07	PSY2	11.38							22.45

Scenario 4d:
The therapists PSY3 is dropped out of the model. This therapist will not be used in the process anymore. The new chances are calculated using the following figure:

Observatie											
FT	FT1	13.76	FT2	19.13	FT3	11.38	FT4	20.76			65.03
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38							22.45
											169.70
P1											
FT	FT1	13.76	FT2	19.13	FT3	11.38	FT4	20.76	FT10	1.75	66.78
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7	ET5	2	61.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38							22.45
P2											
FT	FT3	11.38									11.38
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17									15.17
PSY	PSY2	11.38									11.38
P3											
FT	FT1	13.76	FT2	19.13	FT4	20.76					53.65
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38							22.45
											158.32
P4											
FT	FT1	13.76	FT3	11.38							25.14
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38							22.45
P5											
FT	FT1	13.76	FT2	19.13	FT4	20.76					53.65
ET	ET1	18.17	ET2	10.56	ET3	13.04	ET4	17.7			59.47
MW	MW1	15.17	MW2	7.58							22.75
PSY	PSY1	11.07	PSY2	11.38							22.45

Scenario 5a:
In this scenario no decision variables are changed. A program start if a complete (maximum number of patients) program can be started instead of the predefined start weeks. This is called a dynamic start.

Scenario 5b:
In this scenario also a dynamic start is used. However, more patients arrive to the system to check whether more patients can be treated using dynamic starts. In the current situation 346 patients arrive per year. Maximal 364 observations can be started (7 per week). Approximately 95% of these possible observations are carried out. One observation per week can be performed in the new situation. This are 416 observations per year. Assumed is that also 95% of the possible observations will proceed. This results in 395.2 patients arriving per year. This corresponds with an inter arrival time of 7.84 hours.

Appendix Q – Simulation parameters

The simulation parameters of the simulation study are discussed in this section. Two types of output data is analysed: on week level and on patient level. First, the run length of replication is discussed. Then the warm-up and cool-down period are determined. Finally, the number of replication runs is given.

4.2.1 Run length of replication

Libra wants to know the results for 2012 using the planning of 2012. Since no patients are in the system a warm-up period is needed. To ensure the warm-up period is long enough the planning of 2011 is added to the model. In 2013 no programs are started and thus the number of patients in the system will decrease. To ensure that all patients will finish, the length of a replication is 150 weeks. Since no steady state is reached for the long term (because the planning of 2013 is not available) every replication is restarted.

4.2.2 Warm-up period and cool-down period

Initially, no patients are in the system and no observations and treatment programs are running. In the beginning too less programs are running and groups are not complete. To prevent biased data, a warm-up period is needed. The warm-up period of the week data is determined using the graphical method of Welch (Law, 2007). The left side of figure 34 shows the result of the Welch method with window of 1. The right side of figure 34 shows the Welch graphical method with window of 10. As can be seen in the figure the model will not reach a completely steady state. The predefined start dates have influence on the level of DBC and RBU per week. In the beginning of year 2 apparently a lot programs are running. Around week 20 the model will not change that much anymore as can be seen in the right side of figure 34.

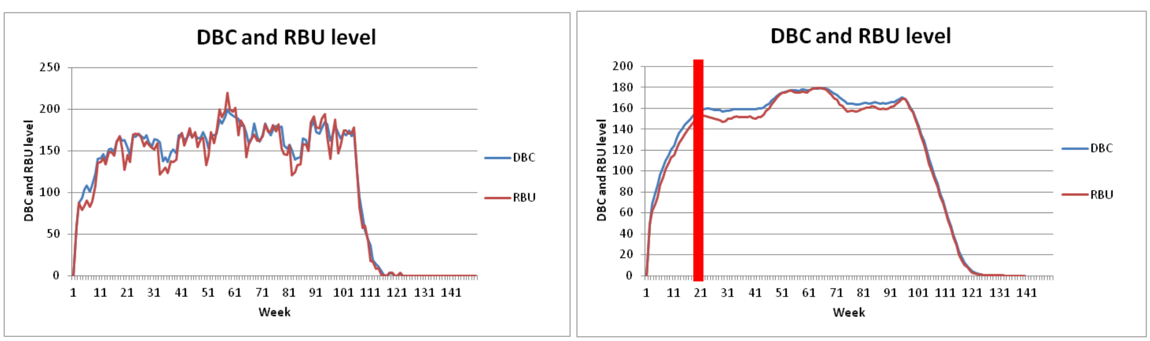

Figure 34: Graphical method of Welch to determine warm-up period (Left: Window=1; Right: Window=10)

The results for 2012 are important for Libra. Therefore, results of patients that will finish in 2012 are included in the results. To get statistical reliable data, patients who start after the warm-up period (20 weeks) should be included. Patients are in the system for while, but due to the variable waiting time between the observation phase and treatment phase is it not known how long these patients are in the system. As warm-up period is chosen for 2011 so that the chance is small that the patient starts in the first 20 weeks of 2011 and finishes in 2012. If there are patients that start in the warm-up period and finish in 2012 this number is small and will not affect the results that much.

In 2013 no new patients are added to the model since no planning for this year is available. Therefore, no new observation and treatment programs are started. The data after 2012 is not relevant anymore and is neglected in the analysis.

4.2.3 Number of replications

According to Metha (2000) a rule of thumb is to use at least 3 to 5 replications. The following equation can be found in Burgout (2004).

$$N(m) = \left(\frac{S(m)t_{m-1,1-\alpha/2}}{X(m)\varepsilon}\right)^2$$

m	= Number of initial replications
$N(m)$	= Number of replications required, using initial m replications
$X(m)$	= Estimation of mean, using initial m replications
$S(m)$	= Estimation of standard deviation, using initial m replications
α	= Level of significance
$\varepsilon = \frac{\lvert X(m)-\mu \rvert}{\lvert \mu \rvert}$	= Allowable percentage of error of X(m)
$t_{m-1,1-\alpha/2}$	= critical value of two-tailed t-distribution

According to five initial replications it seems that eight replications are necessary in for all needed capacity in the disciplines (FT, ET, MW and PSY) and for the DBC and RBU level per program. This amount is larger than the rule of thumb and therefore eight replications are used for the simulation.

	FT	ET	MW	PSY
m	5.00	5.00	5.00	5.00
alfa	0.05	0.05	0.05	0.05
t	2.78	2.78	2.78	2.78
S(m)	5.24	5.82	6.79	2.94
X(m)	52.85	53.44	25.65	26.76
e	0.10	0.11	0.26	0.11
N	7.71	7.71	7.71	7.71

Table 15: Number of replications for needed capacity of the four disciplines

	obs		p1		p2		p3		p4		p5	
	DBC	RBU	DBC	RBU	DBC	RBU	DBC	RBU	DBC	RBU	DBC	RBU
m	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
alfa	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
t	2.78	2.78	2.78	2.78	2.78	2.78	2.78	2.78	2.78	2.78	2.78	2.78
S(m)	1.36	1.23	1.52	1.78	2.75	3.59	8.46	11.07	3.68	3.08	3.63	3.11
X(m)	14.17	11.88	33.77	37.53	23.98	23.93	29.93	32.42	37.77	33.82	40.97	36.98
e	0.10	0.10	0.05	0.05	0.11	0.15	0.28	0.34	0.10	0.09	0.09	0.08
N	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71

Table 16: Number of replications for DBC and RBU per program

Appendix R – Result tables

The tables of the results are given in this section. The bold values of almost all scenarios are significant different from the base model. Only the bold difference of scenario 5b are significant different from scenario 5a.

	FT		ET		MW		PSY		Total	
	LB	**UB**	**LB**	**UB**	**LB**	**UB**	**LB**	**UB**	**LB**	**UB**
Base model	**2712 (52.2)**	**2776 (53.4)**	**2752 (52.9)**	**2799 (53.8)**	**1315 (25.3)**	**1341 (25.8)**	**1374 (26.4)**	**1401 (26.9)**	**8153 (156.8)**	**8317 (159.9)**
Scenario 1a	2779	2846	2823	2872	**1324**	**1348**	**1374**	**1432**	**8300**	**8498**
Scenario 1b	2577	2706	2632	2730	**1299**	**1339**	**1349**	**1402**	**7857**	**8177**
Scenario 2	2418	2507	2456	2524	1181	1226	1212	1251	7267	7508
Scenario 3	2428	2489	2457	2510	1042	1089	1155	1191	7082	7280
Scenario 4a	**2706**	**2739**	**2747**	**2772**	**1320**	**1345**	**1357**	**1393**	**8130**	**8249**
Scenario 4b	**2696**	**2751**	**2741**	**2782**	**1310**	**1360**	**1374**	**1402**	**8121**	**8295**
Scenario 4c	**2688**	**2773**	**2735**	**2798**	**1297**	**1332**	**1356**	**1412**	**8076**	**8315**
Scenario 4d	**2739**	**2780**	**2773**	**2801**	**1312**	**1344**	**1372**	**1406**	**8196**	**8331**
Scenario 5a	**2763**	**2851**	**2782**	**2873**	1347	1385	1413	1444	**8305**	**8553**
Scenario 5b	3162	3238	3190	3261	1528	1593	1569	1640	9449	9733

Table 17: Confidence intervals capacity hours needed per discipline per year (between brackets is the average per week)

	FT		ET		MW		PSY		Total	
	LB	**UB**	**LB**	**UB**	**LB**	**UB**	**LB**	**UB**	**LB**	**UB**
Base model	**2367**	**2465**	**2368**	**2410**	**930**	**962**	**1048**	**1091**	**6713**	**6928**
Scenario 1a	**2445**	**2529**	**2386**	**2460**	**952**	**981**	**1052**	**1080**	**6835**	**7050**
Scenario 1b	**2263**	**2389**	2286	2346	**939**	**974**	**1036**	**1086**	**6525**	**6795**
Scenario 2	2088	2195	2084	2146	831	857	911	957	5914	6154
Scenario 3	2082	2152	2037	2086	719	749	839	880	5677	5867
Scenario 4a	**2357**	**2419**	**2363**	**2407**	**942**	**968**	**1036**	**1088**	**6699**	**6882**
Scenario 4b	**2350**	**2456**	**2347**	**2393**	**933**	**975**	**1038**	**1096**	**6668**	**6920**
Scenario 4c	**2339**	**2417**	**2327**	**2391**	389	390	982	1022	6037	6220
Scenario 4d	**2390**	**2472**	**2357**	**2405**	**930**	**956**	**1022**	**1057**	**6699**	**6890**
Scenario 5a	**2430**	**2495**	**2387**	**2443**	**964**	**995**	**1073**	**1097**	**6853**	**7029**
Scenario 5b	2615	2681	2570	2615	1007	1044	1124	1156	7315	7497

Table 18: Capacity hours used in 2012

	FT		ET		MW		PSY	
	LB	**UB**	**LB**	**UB**	**LB**	**UB**	**LB**	**UB**
Base model	**0.68**	**0.71**	**0.74**	**0.76**	**0.77**	**0.83**	**0.79**	**0.86**
Scenario 1a	**0.71**	**0.73**	**0.74**	**0.77**	**0.79**	**0.84**	**0.79**	**0.85**
Scenario 1b	**0.65**	**0.69**	**0.71**	**0.74**	**0.78**	**0.83**	**0.77**	**0.86**
Scenario 2	0.63	0.66	0.67	0.70	0.72	0.76	0.70	0.78

Scenario 3	**0.69**	**0.71**	**0.73**	**0.76**	**0.72**	**0.78**	**0.77**	**0.85**
Scenario 4a	**0.68**	**0.70**	0.76	0.78	**0.80**	**0.82**	**0.80**	**0.84**
Scenario 4b	**0.70**	**0.73**	**0.73**	**0.75**	**0.79**	**0.82**	**0.80**	**0.84**
Scenario 4c	**0.67**	**0.70**	**0.72**	**0.75**	0.99	0.99	**0.73**	**0.81**
Scenario 4d	**0.69**	**0.71**	**0.73**	**0.76**	**0.78**	**0.82**	0.87	0.94
Scenario 5a	**0.70**	**0.72**	**0.74**	**0.77**	**0.80**	**0.85**	**0.82**	**0.86**
Scenario 5b	0.75	0.77	0.80	0.82	**0.84**	**0.90**	**0.85**	**0.91**

Table 19: Confidence interval of average Utilization per discipline per year

	DBC		RBU	
	LB	**UB**	**LB**	**UB**
Base model	**8814**	**9000**	**8693**	**8857**
Scenario 1a	**9000**	**9168**	**8925**	**9113**
Scenario 1b	8582	8810	**8385**	8618
Scenario 2	7777	8029	**7629**	7901
Scenario 3	7719	7899	**8528**	**8729**
Scenario 4a	**8812**	**8949**	**8702**	**8824**
Scenario 4b	**8803**	**8992**	**8698**	**8871**
Scenario 4c	**8174**	**8293**	**8280**	**8437**
Scenario 4d	**8795**	**8935**	**8643**	**8807**
Scenario 5a	**8924**	**9049**	**8720**	**8874**
Scenario 5b	9626	9748	9336	9525

Table 20: Confidence interval of DBC and RBU per year

% treatment missed	All		All – PBS and control session		FT and ET		MW and PSY		All-Admin, PBS and control session	
	LB	**UB**	**LB**	**UB**	**LB**	**UB**	**LB**	**UB**	**LB**	**UB**
Base model	**10.7**	**11.4**	**5.8**	**6.4**	**2.5**	**3.4**	**12.7**	**14.2**	**6.4**	**7.0**
Scenario 1a	**10.8**	**11.3**	**5.8**	**6.2**	**2.7**	**3.2**	**12.9**	**13.5**	**6.3**	**6.9**
Scenario 1b	**10.4**	**11.0**	**5.7**	**6.3**	**2.6**	**3.0**	**12.4**	**14.3**	**6.2**	**7.0**
Scenario 2	**11.2**	**11.8**	**6.2**	**7.0**	**3.3**	**3.8**	**13.0**	**14.7**	**6.8**	**7.7**
Scenario 3	12.5	13.3	7.2	7.9	3.9	4.9	16.6	17.7	7.2	7.9
Scenario 4a	**10.8**	**11.2**	**5.9**	**6.2**	**2.8**	**3.2**	**12.6**	**14.0**	**6.5**	**6.8**
Scenario 4b	**10.7**	**11.5**	**5.9**	**6.4**	**2.6**	**3.4**	**12.9**	**14.0**	**6.4**	**7.1**
Scenario 4c	20.0	20.6	13.2	13.9	3.5	4.3	35.6	36.2	11.5	12.3
Scenario 4d	**11.1**	**11.8**	**6.0**	**6.6**	**2.6**	**3.5**	**13.4**	**14.2**	**6.5**	**7.3**
Scenario 5a	12.0	12.9	6.9	7.8	**3.2**	**4.7**	14.8	15.8	7.5	8.5
Scenario 5b	16.0	17.1	10.5	11.6	6.8	7.9	18.9	20.8	11.4	12.6

Table 21: % missed treatments per treatment group

Observation	DBC		RBU		Number of patients	
	LB	**UB**	**LB**	**UB**	**LB**	**UB**

Base model	**14.1**	**14.3**	**11.8**	**12.0**	**95.4**	**110.6**
Scenario 1a	**14.1**	**14.2**	**11.8**	**11.9**	**93.0**	**108.0**
Scenario 1b	**14.2**	**14.4**	**11.9**	**12.0**	**109.9**	**122.1**
Scenario 2	**14.0**	**14.2**	**11.7**	**11.9**	**88.5**	**105.3**
Scenario 3	**12.2**	**12.4**	**11.8**	**12.0**	**96.3**	**108.2**
Scenario 4a	**14.1**	**14.3**	**11.8**	**12.0**	**98.7**	**115.0**
Scenario 4b	**14.1**	**14.3**	**11.8**	**12.1**	**96.7**	**117.0**
Scenario 4c	**13.1**	**13.4**	11.4	11.7	**104.1**	**114.9**
Scenario 4d	**14.0**	**14.1**	**11.8**	**11.9**	**103.0**	**119.3**
Scenario 5a	**14.2**	**14.2**	**11.9**	**12.0**	**96.4**	**110.1**
Scenario 5b	13.5	13.7	11.4	11.6	**116.0**	**132.2**

Table 22: Observation results

Program 1	DBC		RBU		Number of patients		Waiting time		Group size
	LB	**UB**	**LB**	**UB**	**LB**	**UB**	**LB**	**UB**	**Average**
Base model	**33.4**	**33.9**	**37.1**	**37.7**	**54.0**	**54.0**	**13.8**	**21.9**	**9.0**
Scenario 1a	**33.8**	**34.6**	**37.5**	**38.6**	**53.5**	**55.3**	**13.9**	**21.6**	**9.0**
Scenario 1b	**33.3**	**35.1**	**36.6**	**39.3**	**50.5**	**54.8**	**12.7**	**22.4**	**8.9**
Scenario 2	**33.1**	**33.8**	**36.8**	**37.6**	**53.6**	**54.2**	**14.8**	**22.9**	**9.0**
Scenario 3	29.1	30.1	**36.2**	**37.5**	**54.0**	**54.0**	**17.4**	**22.2**	**9.0**
Scenario 4a	**33.6**	**34.0**	**37.3**	**37.8**	**54.0**	**54.0**	**15.6**	**22.7**	**9.0**
Scenario 4b	**33.6**	**34.6**	**37.4**	**38.7**	**53.6**	**54.2**	**13.7**	**21.7**	**9.0**
Scenario 4c	31.2	32.5	**35.8**	**37.7**	**51.5**	**55.0**	**14.7**	**21.6**	**9.0**
Scenario 4d	**32.9**	**34.0**	**36.3**	**37.9**	**54.0**	**54.0**	**13.7**	**21.5**	**9.0**
Scenario 5a	**32.7**	**33.8**	**36.6**	**37.8**	**61.8**	**73.2**	4.9	5.6	**9.0**
Scenario 5b	30.8	31.8	34.6	35.6	**65.6**	**85.2**	**4.5**	**5.3**	**9.0**

Table 23: Results of program I

Program 2	DBC		RBU		Number of patients		Waiting time		Group size
	LB	**UB**	**LB**	**UB**	**LB**	**UB**	**LB**	**UB**	**Average**
Base model	**23.1**	**25.2**	**22.8**	**25.5**	**58.7**	**64.6**	**8.9**	**14.4**	**7.8**
Scenario 1a	**23.7**	**24.8**	**23.4**	**25.0**	**61.4**	**64.9**	**8.4**	**14.6**	**7.9**
Scenario 1b	**23.9**	**24.5**	**23.8**	**24.5**	**62.3**	**64.2**	**8.6**	**13.2**	**7.9**
Scenario 2	**23.3**	**25.3**	**23.1**	**25.7**	**57.9**	**64.6**	**9.9**	**15.3**	**7.8**
Scenario 3	21.0	21.4	**23.7**	**24.5**	**62.6**	**64.1**	**7.2**	**14.6**	**7.9**
Scenario 4a	**23.5**	**25.2**	**23.3**	**25.5**	**58.7**	**64.6**	**9.2**	**13.2**	**7.8**
Scenario 4b	**23.7**	**24.8**	**23.6**	**25.1**	**61.9**	**64.9**	**10.3**	**15.1**	**8.0**
Scenario 4c	19.7	21.2	20.1	21.9	**59.2**	**65.3**	**8.3**	**13.9**	**7.9**
Scenario 4d	**23.1**	**23.9**	**22.7**	**23.9**	**59.9**	**72.1**	**8.8**	**12.4**	**8.0**
Scenario 5a	**22.3**	**23.4**	**21.8**	**23.3**	**69.8**	**82.2**	4.3	4.8	**8.0**
Scenario 5b	20.0	20.7	19.1	20.1	**72.7**	**89.3**	**4.2**	**4.7**	**8.0**

Table 24: Results of program II

Program 3	DBC		RBU		Number of patients		Waiting time		Group size
	LB	**UB**	**LB**	**UB**	**LB**	**UB**	**LB**	**UB**	**Average**
Base model	**28.8**	**32.0**	**30.9**	**35.1**	**32.0**	**42.0**	**4.2**	**5.3**	**5.1**
Scenario 1a	**32.8**	**35.3**	**36.1**	**39.5**	**33.1**	**37.9**	**4.1**	**8.1**	**3.8**
Scenario 1b	24.6	26.9	24.9	27.7	**33.1**	**39.4**	**6.1**	**10.7**	**7.4**
Scenario 2	**28.0**	**31.4**	**29.8**	**34.4**	**28.3**	**38.4**	**5.9**	**6.7**	**5.2**
Scenario 3	**24.3**	**30.9**	**29.0**	**38.4**	**30.0**	**43.0**	**4.4**	**5.2**	**4.9**
Scenario 4a	**28.9**	**31.3**	**30.7**	**34.2**	**33.8**	**40.7**	**4.5**	**5.3**	**5.1**
Scenario 4b	**28.1**	**30.7**	**29.8**	**33.5**	**33.9**	**42.6**	**4.3**	**5.7**	**5.3**
Scenario 4c	**26.3**	**28.9**	**28.8**	**32.2**	**35.5**	**42.7**	**4.6**	**6.6**	**5.2**
Scenario 4d	**29.0**	**32.1**	**31.2**	**34.9**	**31.0**	**38.0**	**4.4**	**5.4**	**5.0**
Scenario 5a	26.5	27.2	27.7	28.4	**32.3**	**44.2**	**4.8**	**6.8**	**6.0**
Scenario 5b	24.3	25.8	25.4	27.0	**38.2**	**45.8**	**4.5**	**5.5**	**6.0**

Table 25: Results of program III

Program 4	DBC		RBU		Number of patients		Waiting time	
	LB	**UB**	**LB**	**UB**	**LB**	**UB**	**LB**	**UB**
Base model	**36.9**	**38.2**	**33.1**	**34.1**	**29.0**	**29.0**	**12.3**	**24.1**
Scenario 1a	**37.3**	**37.7**	**33.4**	**33.8**	**29.0**	**29.0**	**18.6**	**28.7**
Scenario 1b	**37.2**	**38.6**	**33.2**	**34.6**	**29.0**	**29.0**	**20.6**	**27.2**
Scenario 2	**36.7**	**37.4**	**32.9**	**33.5**	24.2	25.3	**13.1**	**25.8**
Scenario 3	33.8	34.4	**33.3**	**33.8**	**26.9**	**29.9**	**12.1**	**23.4**
Scenario 4a	**36.9**	**37.9**	**33.0**	**33.9**	**29.0**	**29.0**	**11.5**	**25.2**
Scenario 4b	**36.9**	**37.9**	**33.1**	**33.9**	**29.0**	**29.0**	**14.1**	**25.6**
Scenario 4c	34.8	35.7	32.0	32.7	**29.0**	**29.0**	**13.1**	**23.8**
Scenario 4d	**36.7**	**38.3**	**32.9**	**34.3**	**29.0**	**29.0**	**14.8**	**25.1**
Scenario 5a	**36.6**	**37.7**	**32.9**	**33.9**	**30.1**	**39.9**	1.3	2.2
Scenario 5b	35.0	36.0	31.6	32.4	**37.5**	**47.7**	**1.3**	**3.8**

Table 26: Results of program IV

Program 5	DBC		RBU		Number of patients		Waiting time	
	LB	**UB**	**LB**	**UB**	**LB**	**UB**	**LB**	**UB**
Base model	**40.2**	**41.4**	**36.3**	**37.3**	**31.0**	**36.0**	**2.4**	**5.7**
Scenario 1a	**39.8**	**40.9**	**36.0**	**37.0**	**29.8**	**35.7**	**2.5**	**4.9**
Scenario 1b	**40.4**	**41.2**	**36.6**	**37.1**	**23.7**	**34.3**	**1.8**	**5.1**
Scenario 2	**39.9**	**40.8**	**36.1**	**36.8**	**21.0**	**32.0**	**3.8**	**5.7**
Scenario 3	36.8	37.4	**36.3**	**36.8**	**28.5**	**33.3**	**2.7**	**3.6**
Scenario 4a	**39.8**	**41.2**	**36.0**	**37.2**	**30.1**	**33.2**	**2.1**	**3.8**
Scenario 4b	**40.1**	**40.9**	**36.2**	**36.9**	**29.5**	**34.3**	**1.8**	**4.5**
Scenario 4c	37.7	38.9	34.7	36.0	**28.4**	**35.6**	**3.0**	**5.1**
Scenario 4d	**39.6**	**41.0**	**35.9**	**37.1**	**32.5**	**36.5**	**3.3**	**7.2**
Scenario 5a	**40.1**	**41.0**	**36.3**	**37.0**	**33.2**	**37.3**	**1.4**	**2.1**
Scenario 5b	38.5	39.8	34.9	36.2	**34.0**	**43.8**	**1.6**	**3.2**

Table 27: Results of program V

Appendix S – Result Figures

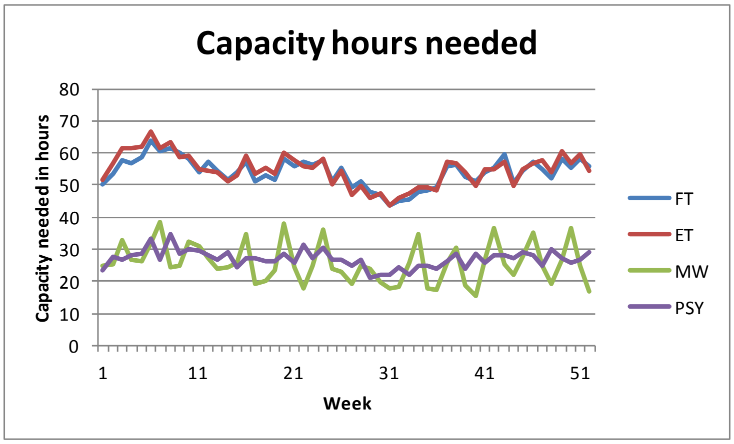

Figure 35: Capacity hours needed per discipline per week – Scenario 1a

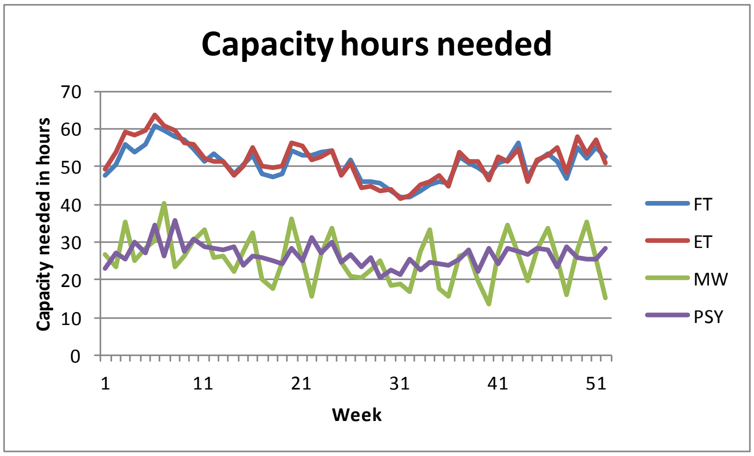

Figure 36: Capacity hours needed per discipline per week – Scenario 1b

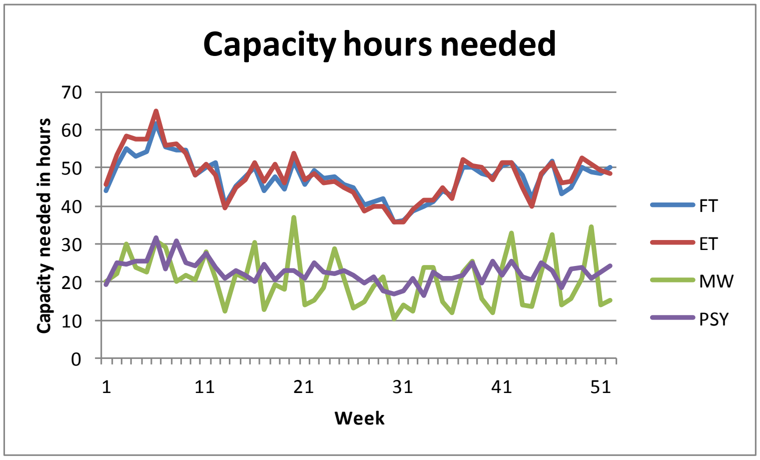

Figure 37: Capacity hours needed per discipline per week – Scenario 3

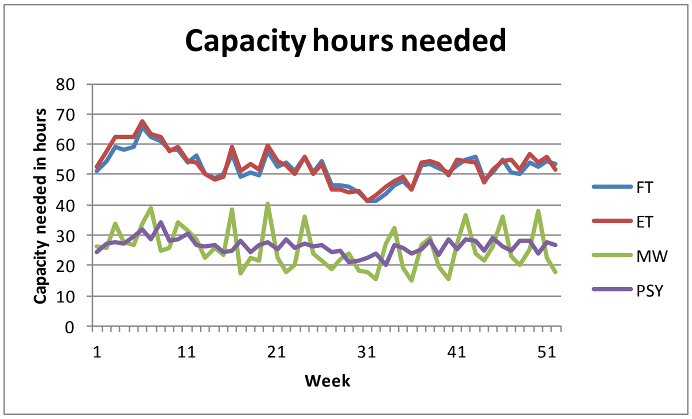

Figure 38: Capacity hours needed per discipline per week – Scenario 4

Appendix T – Typology applied to Libra

The active resources in the case of Libra are the therapists. The treatments are carried out by these resources. Also, the treatments can be seen as resource of the Libra case. Only open treatments should be carried out. Rooms are also a resource of the Libra case. These resources can have an important role in the process. Since these resources are not active these are left out of the scope for this project. For all characteristics of the typology of (Jenkins and Rice, 2007) is discussed whether the characteristic is important in a simulation model.

1. Existential

- **Identity:** For Libra it is important that individual therapist can be identified, since the therapists are fixed during the observation phase and treatment phase. Not all therapists can carry out all treatments of the own discipline or are present every day. Therefore, it is important to know which individual treatment can carry out which treatments and when the treatment is available.
- **Origin:** In the Libra case the resources are humans. This gives the resource a number of characteristics (like birth date, gender etc.). However, since this characteristic cannot modeled, this characteristic is not important.
- **Living:** Implicitly an assumption is made that all active resources in the Libra case are living. Whether the resource in this case is not living the resource cannot carry out treatments and is thus not suitable resource for this process. Of course it is important for the process that resources are living, but because of the implicit assumption this characteristic is not important any more.
- **Consumption:** Therapists are not consumed during an activity. After an activity is carried out, the therapists come available for other activities. Therefore, it is important to model that resources come available after an activity.
- **Make-up:** Resources in the Libra case can be a combination of several individual therapists. During group treatments multiple therapists can be needed. Therefore, it should be modeled that multiple resources are selected to carry out an activity.
- **Traits:** These relative fixed characteristics can help to identify individual therapists, but has no effect on the Libra process.

2. Availability

- **Status:** The status of a resource is very important in the Libra case. Before a treatment can start the relevant therapists should be present but may not busy in another treatment.
- **Location:** In the Libra case the treatments are carried out on one place. Since the travelling time from one place to another is very low, it is assumed this is zero. Therefore, this characteristic is not important in the Libra case.
- **Schedule:** This characteristic is very important for Libra. The work hours of the employees are not completely available for patients. In group treatments, more therapists should be available at the same time. Therefore, it is important to know when the therapists are available to start a treatment.
- **Delivery mode:** The therapists give discrete service in the Libra case. The therapist(s) treat(s) a patient for a specified time. Then the therapists become free and can treat another patient. This is important for the process, because it describes how the treatments are carried out.

- **Failure mode:** A resource in healthcare can fail in the Libra process when the resource becomes ill. Then, some time is required to become healthy. During this time the resource cannot treat employees. This can have impact on the results of the Libra case. Dependent on the desired results this characteristic should be modeled.
- **Selectivity:** Therapists in the Libra case should treat the same patients during the observation and/or treatment phase. The reason is that the therapists know better the history of the patients and how they can proceed the treatments. Therefore, this characteristic is important in the Libra case.
- **Exclusivity:** In the individual treatments a therapists can only treat one patient, but in some treatments of Libra one (or two) therapists should give care to multiple patients. This should be possible in the model.

3. Utility

- **Competencies:** In the Libra case this characteristic is important. Not all therapists can do the same treatment. All have their own work discipline, but also within the work discipline not all therapists do all treatments.
- **Size:** All therapists can deliver one service at one time. Sometimes, a combination of therapists can deliver their service on one time. The therapist(s) can deliver their service to an individual or group. A therapist cannot carry out two treatments at the same time. That is why this characteristic is important for the Libra case.
- **Performance:** The performance of the therapists is not that relevant for the process in the Libra case, because the predefined program determines the amount of the treatment. However, it is important that therapists will reach their work targets.
- **Cognition:** The cognitive abilities of a therapist are not really important in the Libra case. Within Libra is expected that all therapists that have the competency of a treatment is capable to carry out the treatment. This characteristic is hard to model in simulation models, because research is needed to the cognitive abilities of the therapists and which abilities are important for the treatment.

4. Implementation

- **Adaptability:** The way how the therapists treat the patients is not really important in the Libra case. This characteristic can have influence when the programs will change due to new methods. However, because these are provisionally fixed this characteristic is not important for Libra.
- **Activity:** The therapists are seen as active resources in the simulation model. This characteristic is not really important in a simulation model, since no distinction between active and passive resources are made in simulation tools.
- **Interactivity:** Interaction between patient and therapists can help to improve the assignment to or content of the treatments programs. Communication cannot modeled in simulation models.
- **Autonomy:** The predefined treatment program ensures that therapists have less control about the total process. However, therapists have control about their own treatments. Also, this characteristic describes a situation and cannot modeled in simulation models.

- **Coupling:** Therapists are all individual resources. Sometimes a combination of therapists is needed for a group treatment. These resources will not change each other and are thus loosely coupled. In the Libra case only individual therapists should be modeled, and therefore coupling is not important for the Libra case.
- **Isolation:** In reality all therapists knows each other existence. The relationship among the therapists is important for the Libra case, since all therapists have to work with each in a treatment program.
- **Discoverability:** For all patients it is clear that the resources exists and that they will help during the rehabilitation process. However, this is a fact in reality and cannot modeled in simulation models.
- **Composition:** All therapists are built of individual persons. In group treatments the resource can be seen as a collection of individual resources. Therefore, this characteristic is relevant for the Libra case and several resources should be selected when multiple therapists are needed.
- **Centralization:** The therapists in the Libra case work treat the patients at the rehabilitation centre. Since the distance to the several specific locations are very small and there are no transport times this characteristic can be neglected in the Libra case.
- **Mobility:** The therapists can move from one place to another place, but because the distances in the rehabilitation centre are quite low transportation times can be neglected. Therefore, the mobility of the therapists can be neglected in the Libra case.
- **Forgetfulness:** This characteristic is not important for the Libra case. Therapists know what they have to do during a treatment. Therefore, the forgetfulness of the therapists is not needed in a simulation model for Libra.
- **Preemptibility:** Therapists in Libra can be interrupted by a phone call during a treatment. The therapists have to follow the planning and interrupted phone calls will not change this planning. Therefore, this characteristic is not important in the Libra case.
- **Standardization:** All therapists in the Libra case need almost the same properties. Therefore, it is handy that the therapist of the Libra case can be modeled using a standard, but will not affect the process.
- **Risk:** The risk in a rehabilitation centre is relatively low, because therapists will help the patients to improve the lives of the patients. No risky treatments are carried out in the Libra process. That is why the Libra process can neglect the risk for resources.
- **Policy:** Preferences of a therapist are not taken into account since the therapists should help all people. Also, the treatment programs are fixed. However, the working days of the therapists can be changed in consultation with the chief. Further, treatments can be overtaken by other therapists when the fixed therapist is ill. Therefore, this can have impact on the results of the model. Policy is implicitly modeled in the structure of the process.

Appendix U – Typology applied to MDL

The active resources in the case of MDL are the physicians and nurses. These resources are involved in the endoscopy treatments. Other resources that can have a role are rooms or equipment. These are passive resources and therefore not analyzed in this project. For all characteristics of the typology of (Jenkins and Rice, 2007) is discussed whether the characteristic is important in the MDL case.

1. Existential

- **Identity:** It is not important which nurses and physicians are involved in the in the process of MDL. The endoscopy is a onetime process and all physicians and nurses are capable to carry out the MDL process. However, distinction between physicians and nurses is essential. These groups should be identified in the model and therefore is identity important for the MDL case.
- **Origin:** In the MDL case the resources are humans. This gives the resource a number of characteristics (like birth date, gender etc.). There are differences between nurses and physicians, but these resources have the same source. The origin itself is not important for the MDL case.
- **Living:** An implicit assumption is made that the resources in the MDL case are living. Whether the resource in this case is not living the resource cannot involved in the MDL process. Of course it is important for the process that resources are living, but because of the implicit assumption this characteristic is not important any more.
- **Consumption:** Nurses and physicians are not consumed during an activity. After an activity is carried out, the nurses and physicians come available for other activities. Therefore, it is important that the resource comes available again after an activity in the simulation model.
- **Make-up:** In the MDL case combinations of nurses and physician are needed to carry out activities in the process. For the MDL case it is important which resources are grouped to treat the patient.
- **Traits:** These relative fixed characteristics can help to identify individual therapists, but are not really important for the MDL process.

2. Availability

- **Status:** The status of the resource is important in the MDL case. Before a patient can be treated the nurses and physician should be available to carry out the activities.
- **Location:** In the MDL case the nurses and physician carry out the activities at several places, preparation room, endoscopy room and care unit. Since there is travelling time from one place to another, the location characteristic is important in the MDL case.
- **Schedule:** This characteristic is important in the MDL case. The work hours of the nurses and physician determined whether patient can be helped. Enough nurses and physicians should be available to carry out the complete endoscopy process.
- **Delivery mode:** Nurses and physicians give discrete service to the patients. The preparation, treatment and recovery process takes some time. Afterwards the nurses and physicians come free and can help another patient. This is important for the process, because it describes how the treatments are carried out and the resources are available.

- **Failure mode:** A resource in healthcare can fail in the MDL process when the resource becomes ill. Then, some time is required to become healthy. During this time the resource cannot treat patients. If treatment can overtaken this will have no consequences, but if the capacity is too low it has consequences for the performance.
- **Selectivity:** Nurses and physicians in the MDL case should treat the all patients that will come to the endoscopy section. Therefore this aspect is not important in the MDL case.
- **Exclusivity:** Nurses and physicians can deliver their service to maximal one patient at one moment. This should be in the model of the MDL case.

3. Utility

- **Competencies:** In the MDL case it is important to know what activities the resources can carry out. Nurses can do several tasks. The physicians can do the endoscopy procedure. Since there are more types of procedures it is important to know which physician can do which type of procedure.
- **Size:** All nurses and physicians can deliver one service at one time. In some activities the physician in necessary next to some nurses. However, one patient can be helped. In the simulation model should be modeled that (a group of) resources can perform one activity per time unit.
- **Performance:** The performance of the therapists is relevant in the MDL case. The activities are for all patients the same, but some patients are sedated. Then some extra activities are needed. During all activities something can go wrong what leads to lower performance. Therefore, the performance of the resources can influence the results of the MDL case.
- **Cognition:** The cognitive abilities of the nurses and physicians are not really important in the MDL case. The cognitive abilities have leaded the nurses and physicians to the level they are, but will not affect the process of MDL.

4. Implementation

- **Adaptability:** The process of MDL is almost the same for all patients. The difference is the sedation. It is important that physicians and nurses easily can change of procedure type. This characteristic describes how easily the resources can change and cannot modeled in CPN Tools and ARENA. However, can be important in reality.
- **Activity:** The nurses and physicians are seen as active resources in the model. This characteristic is not really important in a simulation model, since no distinction between active and passive resources are made in simulation tools.
- **Interactivity:** Interaction between nurses and physician is important. This will ensure that the physician is on the right time at the right place and prepared the correct patient. Also, during the procedure communication is important to succeed the procedure. However, communication among nurses/physicians is not possible to model.
- **Autonomy:** In the MDL process the physicians and the nurses know what they have to do. The process is fixed for all nurses and physicians. Nurses and physicians control their own activities. This characteristic describes the extent in which resources control their own activities, but that cannot modeled in simulation models.

- **Coupling:** Nurses and physicians are all individual resources. Sometimes a combination of nurses and physicians is needed to carry out the endoscopy procedure. However, a change of a resource should not affect the process. Therefore, this characteristic is not important for the MDL case.
- **Isolation:** In reality all nurses and physicians knows each other existence and have to communicate with each other, but cannot modeled in a simulation model.
- **Discoverability:** For all patients it is clear that the resources exist and that they will help during the MDL process, but this characteristic is not important for the MDL process.
- **Composition:** All nurses or physicians are built of individual persons. In some sub activities a combination of these nurses and/or physicians is needed to carry out an activity. Therefore, this characteristic is relevant for the MDL process.
- **Centralization:** The process of MDL is carried out on several locations. Therefore, resources in this process can be on a different location and will cost time to go to another location. This characteristic is relevant for the MDL process.
- **Mobility:** Nurses and physicians can move. This will result in transportation time in which a resource is gone from place A to place B. This is relevant for the MDL case.
- **Forgetfulness:** This characteristic is not important for the MDL case. Nurses and physicians know what they have to do during a treatment using some preparation time. So, forgetfulness is not relevant in the MDL case.
- **Preemptibility:** In general, resources cannot disturbed when they are carry out a activity. However, in practice some activities (like administration) will be stopped due to a phone call. This characteristic is not relevant for a model of MDL case.
- **Standardization:** Nurses and physicians need almost the same properties. Therefore, it is handy that these are modeled as a standard, but will not affect the process.
- **Risk:** During the preparation and procedure errors can be made. Dependent on the risk percentage of the procedure this will have effect on the MDL process, but cannot modeled in simulation models.
- **Policy:** The policy is an important characteristic in the MDL process. It is important that the hospital has enough nurses and physician available to treat the patients completely on a day. Also the resources have to carry out the activities in the correct order. This characteristic is modeled in the structure of the model.

Appendix V – Typology applied to Feniks

The active resources in the Feniks process are the pharmacy assistants. Also other resources (like medicines) are important for the Feniks process, but are not actively involved in the process. For all characteristics of the typology of (Jenkins and Rice, 2007) is discussed whether the characteristics are important in the Feniks case.

1. Existential

- **Identity:** The procedure of Feniks is carried out by three pharmacy assistants. The pharmacy assistants have their own role, but all should be able to perform all tasks. For the results it is not really important that individual resource can be tracked.
- **Origin:** All resources in the Feniks process are humans. This gives the resource a number of characteristics (like birth date, gender etc.). However, the origin is not important for the Feniks case.
- **Living:** An implicit assumption is made that all active resources in the Feniks case are living. Whether the resource is not living in this case the resource cannot carry out any activity and is thus no resource for this process. Of course it is important for the process that resources are living, but because of the implicit assumption this characteristic is not important any more.
- **Consumption:** The pharmacy assistants are not consumed during an activity. After a medicine is prepared, the assistants proceed with the preparation of the next medicine on the planning. Therefore, it is important that the resources are released after an activity.
- **Make-up:** Resources in the Feniks case are a combination of three individual assistants. Since all assistant are able to carry out all assistants can team up with each other.
- **Traits:** These relative fixed characteristics can help to identify pharmacy assistants, but because the assistants can carry out all activities this characteristic is not important in the Feniks case.

2. Availability

- **Status:** The status of the resource is important in the Feniks case. The assistants can only prepares medicines whether enough assistants are present for the preparation and are not preparing another medicine.
- **Location:** In the Feniks case the medicines are prepared in the hospitals pharmacy. In this place all required devices/material is present. The location does not have a crucial role since the medicines are divided over the wards by a transporter after the medicines are prepared.
- **Schedule:** This characteristic is important for Feniks. The opening time of the hospitals pharmacy is from 6.30h till 22.00h. During this time enough assistants should be present so that during all work times medicines can be prepared.
- **Delivery mode:** The requests arrive continuously during the days. However, the pharmacy checks four times per day the requests and then a planning is made. The delivery mode is important, because it determined how the medicines are prepared.
- **Failure mode:** In the Feniks process, the assistants can become ill. Then, some time is required to become healthy. During this time the resource cannot prepare medicines. But since it does not whether which assistant is used the ill assistant can be overtaken by another assistant. Therefore, this characteristic is less important in the Feniks process.

- **Selectivity:** The assistant has to carry out all requests of medicines. The order can change due to emergency requests, but on the long run all requests must be carried out.
- **Exclusivity:** Assistants can work on one request at one time. Several request are carried out at one time will cause errors. Therefore, it is important to have in the model that the assistants can work on one request at one time.

3. Utility

- **Competencies:** In the Feniks case this characteristic is less important, because pharmacy assistants have to do all three roles in the preparation of the medicines.
- **Size:** Each assistant can work on one request at one time. That is why this characteristic is important for the Feniks case.
- **Performance:** The performance is important in the Feniks case. The aim of using the pharmacy assistant instead of nurses is to reduce the errors in the medication process. The performance of the assistants is thus important in the Feniks case.
- **Cognition:** The cognitive abilities of the assistants are not important. The assistants all have learned to prepare the medication. The cognitive abilities will not have influence on the results of this process that much, but can have a role in the performance.

4. Implementation

- **Adaptability:** Medicines are prepared in special ways. Therefore it is important that the assistants can easily change among the preparation of medicines. This characteristic describes the extent to which resources can switch among the several preparation types, but cannot be modeled in a simulation model.
- **Activity:** The assistants are seen as active resources in the simulation model. This characteristic is not really important in the Feniks case, since no distinction between active and passive resources are made in ARENA and CPN Tools.
- **Interactivity:** Interaction among the pharmacy assistants is important to improve the preparation of the medicines. When an error is made, other assistants should communicate this. Therefore interactivity is important in the Feniks case. The disadvantage is that communication cannot be modeled in ARENA and CPN Tools.
- **Autonomy:** Assistants plan their own requirements, but an emergency case can disturb this planning. Autonomy has a role in the Feniks case, but cannot modeled in CPN Tools and ARENA.
- **Coupling:** Assistants have their own task in the Feniks process. Changes in the resources will not affect the other resources, because all assistant should do every task. Therefore, this characteristic is not relevant in the Feniks case.
- **Isolation:** In reality all therapists knows each other existence. The relationship between the assistants is important, because they have work together to deliver the medicines at the correct moment at the correct place. This characteristic describes the relation among assistants, but cannot modeled in ARENA or CPN Tools.
- **Discoverability:** This characteristic is not relevant for the Feniks case, since the clients (requests for medicines) are not aware of resources.

- **Composition:** Three assistants are involved in the preparation of the medication and have the same aim. Each assistant have their own role. Therefore, this characteristic is important for the Feniks case.
- **Centralization:** The Feniks process is carried out in the hospital's pharmacy. Since one location is available to prepare the medicines this characteristic is not important for the Feniks case.
- **Mobility:** The assistants can move from one place to another place, but because the distances within the pharmacy are quite low, transportation times can be neglected. Therefore, the mobility of the therapists can be neglected in the Feniks case.
- **Forgetfulness:** This characteristic is not important for the Feniks case. Assistants have made a planning of all requirements. If the assistants have finished the medicines the list can be updated and the preparation "forgotten''. Therefore this characteristic is not important for the Feniks case.
- **Preemptibility:** Pharmacy assistants can be disturbed by emergency cases. When a medicine is needed very fast, this should be done before proceeding with their planning. Note that emergency cases are carried out sometimes on the wards. But, because the pharmacy can also get emergency cases this characteristic is important in the Feniks case.
- **Standardization:** All assistants in the Feniks case needs the same properties, because they have to carry out all activities. Therefore, it useful to model all assistants as a standard.
- **Risk:** The risk in a medicine preparation is high, because an error in the medicine preparation can have large consequences for the patients. Therefore, risk is an important characteristic of the Feniks process.
- **Policy:** The policy is an important characteristic in the Feniks process. First, a policy is needed to decide in what order requests are carried out. Emergency request have priority over normal request. Also, batches or due date must be taken into account. This characteristic is modeled in the structure of the model.

Appendix W – Calculation of RBU per program

obs	Number of times	Duration	Number of therapists		DBC	RBU
FT ind	4	0.75	1		3	3
ET ind	4	0.75	1		3	3
MW ind	1	1	1		1	1
PSY ind	2	0.75	1		1.5	1.5
Test	1	4	1		4	4
Admin FT	1	0.5	1		0.5	0
Admin ET	1	0.5	1		0.5	0
Admin MW	1	0.5	1		0.5	0
Admin PSY	1	0.5	1		0.5	0
PBS	1	0.25	4		1	0
Controle	1	0.25	0		0	0
				Totaal	**15.5**	**12.5**

p1	Number of times	Duration	Number of therapists		DBC	RBU
Ind						
MW ind	27	0.75	1		20.25	20.25
Group						
Zwemmen	20	0.5	2		20	30
Ergotherapie	16	1	2		32	48
psychologie	20	1	1		20	30
Fitness	10	1	2		20	30
GA/Lopen	10	1	2		20	30
Ontspanning	10	1.25	2		25	37.5
introductie	1	1	1		1.00	1.50
Admin MW ind	1	0.5	1		4.5	0
Admin ergotherapie	2	2	2		8	0
Admin psychologie	2	2	1		4	0
Admin fitness	1	1	2		2	0
Admin GA Lopen	1	2	2		4	0
Admin ontspanning	1	1.25	2		2.5	0
PBS	5	0.5	7		17.5	0
controle	1	0.25	1		0.25	0.25
terugkomstbijeenkomst	1	1	2		2	2
				Totaal	**203**	**227.5**

p2	Number of times	Duration	Number of therapists		DBC	RBU
Ind						
MW ind	27	0.75	1		20.25	20.25
Group						
Lichaamsbewustwording	10	1.25	2		25	37.5
Ergotherapie	10	1	2		20	30
mindfullness	10	1	1		10	15
ACT cursus	10	1	2		20	30
introductie	1	1	1		1	1.5
Admin MW ind	1	0.5	1		0.5	0
Admin ergotherapie	1	2	2		4	0
Admin ACT cursus	1	2	2		4	0
Admin mindfullness	1	2	1		2	0
Admin lichaamsbewustwording	1	2.5	2		5	0
PBS	5	0.5	6		15	0
controle	1	0.25	1		0.25	0.25
terugkomstbijeenkomst	1	1	2		2	2
				Totaal	**129**	**136.5**

p3	Number of times	Duration	Number of therapists		DBC	RBU
Ind						
MW ind	15	0.75	1		11.25	11.25
PSY ind	15	0.75	1		11.25	11.25
Group						
Conditie training	20	0.5	2		20	30
Ergotherapie	10	1	2		20	30
fitness	10	1	2		20	30
introductie	1	1	1		1	1.5
Admin MW ind	3	0.5	1		1.5	0
Admin PSY ind	3	0.5	1		1.5	0
Admin conditie training	1	2	2		4	0
Admin ergotherapie	1	2	2		4	0
Admin fitness	1	2	2		4	0
PBS	5	0.5	6		15	0
controle	1	0.25	0		0	0
				Totaal	**113.5**	**114**

p4	Number of times	Duration	Number of therapists		DBC	RBU
Ind						
MW ind	3	0.75	1		2.25	2.25
PSY ind	3	0.75	1		2.25	2.25
Lichaamsbewustwording	12	0.75	1		9	9
belastbaarheid	12	0.75	1		9	9
Admin MW ind	3	0.5	1		1.5	0
Admin PSY ind	3	0.5	1		1.5	0
Admin lichaamsbewustwording	1	0.5	1		0.5	0
Admin belastbaarheid	1	0.5	1		0.5	0
PBS	1	0.25	4		1	0
controle	1	0.25	0		0	0
				Totaal	**27.5**	**22.5**

p5	Number of times	Duration	Number of therapists		DBC	RBU
Ind						
MW ind	3	0.75	1		2.25	2.25
PSY ind	3	0.75	1		2.25	2.25
Module fysiek	24	0.5	1		12	12
belastbaarheid	12	0.75	1		9	9
Admin MW ind	0.5	0.5	1		0.25	0
Admin PSY ind	0.5	0.5	1		0.25	0
Admin module fysiek	1	0.5	1		0.5	0
Admin belastbaarheid	1	0.5	1		0.5	0
PBS	1	1	4		4	0
controle	1	0.25	0		0	0
				Totaal	**31**	**25.5**